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# CHAN TECHNOLOGIES INC. / TECHNOLOGIE CHAN INC.

ANTENNA AND MICROWAVE SYSTEMS

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A STUDY TO ESTABLISH AT CRC A LIBRARY OF  
VERIFIABLE ANTENNA DESIGN SOFTWARE FOR  
COMMUNICATIONS SATELLITE SYSTEMS

## FINAL REPORT

PREPARED BY : Chan Technologies Inc.

SUBMITTED TO : Space Electronics Directorate  
Communications Research Centre  
Shirley Bay  
P.O. Box 11490, Station "H"  
Ottawa, Ontario  
K2H 8S2

ATTENTION : Mr. R. Milne

DSS FILE NO. : 12ST.36001-3-4238

SERIAL NO. : OST83-00153

DATE : 7 December, 1984

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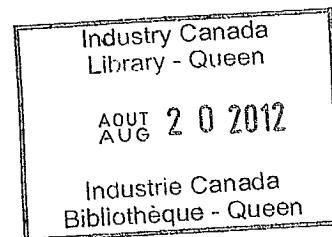
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## ABSTRACT

Four tasks, related to reflector antenna technology, are carried out in the present study. The first task is the implementation of reflector antenna software developed under the Radarsat program on to the CRC CP-6 computer. In all, four programs have been transferred and modified, ready for use. For the second task, the theory behind the analysis of communication satellite type reflector antenna is developed. Associated computer programs are written. They are capable of treating different reflector configurations fed by a variety of horn types. The reflector may be offset in either or both North-South and East-West directions. For central-fed reflector, aperture blockages may be specified. The far-field observation frame is the rectangular elevation-azimuth grid. These programs are fairly efficient in terms of execution times. The third task requires using the implemented programs to generate shaped beams. Two different techniques are investigated. The first involves stepping the reflector surface to generate sector beams. The second makes use of a planar array of horns, disposed about the reflector focal region, to produce DBS beams for Canadian coverage. The last task is on the assessment of the accuracy of the present software and recommendations for future software development.

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1.0 TRANSFER AND IMPLEMENTATION OF ANTENNA DESIGN SOFTWARE  
DEVELOPED UNDER RADARSAT PROGRAM.

The reflector programs, written in FORTRAN and developed under Radarsat Study #17, have been transferred and modified to run on the CRC CP-6 computer. Their implementation has been rather straight forward by and large. Only the input and output statements and the random number generation subroutine need be altered. The names of these programs are: PANRFL\_SIF, FACRFL\_SIF, GENODE1\_SIF, GENODE2\_SIF. They reside under the same account number as the rest of the programs developed for this study.

The first program PANRFL\_SIF analyses a multi-horn array-fed parabolic reflector with rectangular aperture. The reflector surface may be broken up into a number of rectangular parabolic strips. The positions and orientations may be arbitrarily specified by the user or take on random values generated internally. Both uncorrelated errors, such as those arising from alignment or deployment process, and correlated errors, like thermal distortions, may thus be introduced to the panels. Random surface deviations arising from manufacturing errors may also be simulated through the displacements of surface integration points of the diffraction field integral. This program has been used in the design of four shaped beams for Radarsat. Data input to the program is through a data file named PAREFL\_DAT. Far field observation is restricted to elevation and azimuth cuts only. The observation frame has since been enlarged to cover a two dimensional elevation and azimuth grid. Such a modification has been implemented in a separate program named RECRFL\_SIF and the corresponding input data file is

RECRFL\_DAT. The output from either program is directed to the user's terminal. It contains information on the feed - reflector configuration as well as panel and surface distortion statistics, spillover efficiency, co-polar and cross-polar gain patterns.

The second program treats a different kind of surface, one in which the desired shape is approximated by an assemblage of flat triangular elements or facets. The positions of the nodes of these elements are assumed to be known. Since the program deals only with basic elements, there is no restriction on the shape or type of surface that can be analysed. Deviations of nodes from their ideal positions may be specified by the user or generated internally, to simulate mechanical errors. Input data are to be provided in two separate files. The first file, FACRFL\_DAT1, contains data of the horn configuration, feed excitations, reflector integration and far field observation frame. The second file, FACRFL\_DAT2, contain the locations and numbering of the facet nodes forming each triangular element. Output from the program contains statistics of the node displacements, surface error, spillover efficiency and co- and cross-polarized gain patterns.

The last two programs GENODE1-SIF and GENODE2-SIF are explicitly written for the purpose of generating node locations and numbering of triangular elements in the discretization of a parabolic reflector with rectangular aperture. Two different schemes, that give the same performance, are available. The criteria used for determining the nodes' locations is equal or nearly equal chord lengths for the longerons and ribs of the surface forming structure. The facets end up being equilateral triangles. The output will produce file FACRFL\_DAT2 for the reflector

analysis program.

The descriptions, usages, restrictions and listings of the above programs are not included in this report. All these details together with the underlying theory can be found in the Radarsat report on Study #17.

## 2.0 GENERATION OF REFLECTOR ANTENNA DESIGN SOFTWARE

Three reflector antenna analysis programs were developed. The first program, PAREFC\_SIF, employs feeds that can be linearly or circularly or elliptically polarised. The class of feeds that falls into this description includes the single-moded or multi-moded pyramidal and conical horns. The second program, PAREFM\_SIF, allows the user to enter measured data to represent the feed's radiation patterns. The third, PAREFL\_SIF, is strictly for linearly polarised feeds where special loading of the feeds' apertures are used to improve the secondary gain by reducing spill-over loss.

A by-product from the feed model development is a program, HORNPAT\_SIF, to compute E- and H-plane patterns of pyramidal and conical horns. It may be used to view the primary illumination patterns of horns with known physical dimensions.

Among the output from the reflector programs is a co-polarized gain matrix. Gain contour plots may be obtained from this matrix by using program DSCRPLT\_SIF. Plots represented by discrete symbols are produced on a line printer. The resolution is dependent on the printer's characteristics.

The theory behind these programs ~~are~~ <sup>is</sup> given in the sections below. Program usage, description and listing are provided in the appendices. Names of source programs have the suffix SIF while data files have the same name but a different suffix of DAT.

### 2.1 PHYSICAL OPTICS METHOD

The electromagnetic field at any point in a source-free region V is uniquely specified once the fields on the surfaces

bounding this region are known. In the reflector problem, the region is bounded by the sphere at infinity where the field is zero and by a closed surface  $S$  enclosing the reflector and its feed as shown in Figure 2.1. Assuming that there is no contribution from the feed, which is a valid assumption since the back radiation from the reflector,  $S$  may be taken to be the same as the reflector surface. The field at any point  $Q$  within the region  $V$  is then given by the vector Kirchoff diffraction integral in terms of the equivalent sources on the reflector.

$$\bar{E}(Q) = \frac{1}{4\pi} \iint_S \left\{ -\bar{\mathcal{J}}_{sm} \times \nabla \psi - j\omega \mu_0 \psi \bar{\mathcal{J}}_s + \frac{1}{j\omega \epsilon} [\bar{\mathcal{J}}_s \cdot \nabla] \nabla \psi \right\} dS$$

(2.1)

where

$$\psi = \frac{e^{-jk\mathbf{r}}}{\mathbf{r}}$$

If  $S$  is a perfectly conducting surface, then the magnetic current sources,  $\bar{\mathcal{J}}_{sm}$ , vanish, leaving only the electric current sources,  $\bar{\mathcal{J}}_s$ .

$$-\hat{n} \times \bar{E} = \bar{\mathcal{J}}_{sm} = 0 \quad (2.2)$$

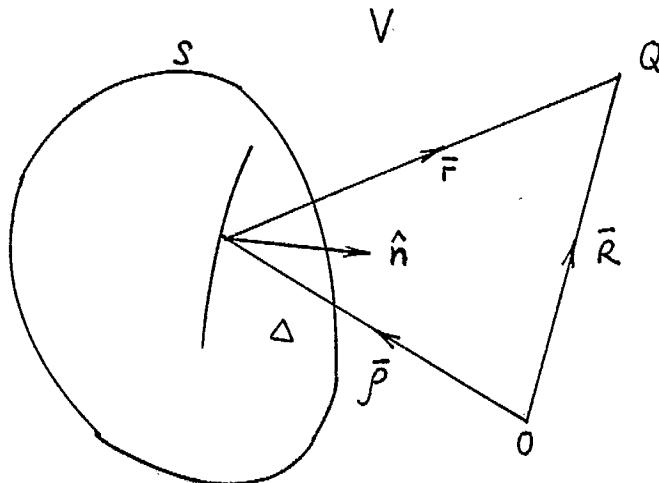


Figure 2.1 Scattering from Antenna Structure.

Substituting (2.2) into (2.1), and performing the vector operations indicated, the following equation results.

$$\bar{E}(Q) = \frac{i}{4\pi} \iint_S \left\{ -j\omega\mu_0 \bar{J}_s + \frac{i}{j\omega\epsilon} [(-k^2 + j3k/r + 3/r^2)(\bar{J}_s \cdot \hat{r})\hat{r} - \bar{J}_s (jk/r + 1/r^2)] \right\} \frac{e^{jkR}}{r} dS$$

(2.3)

However, if one is only interested in the far-field, the above equation can be further reduced to give

$$\bar{E}(Q) = -\frac{j\omega\mu_0}{4\pi} \frac{e^{jkR}}{R} \iint_S \left\{ \bar{J}_s - (\bar{J}_s \cdot \hat{R})\hat{R} \right\} e^{jk\vec{p} \cdot \hat{R}} dS$$

(2.4)

In this expression, there is a radial component which is not only small but also drops out when the above field is resolved into its co-polarized and cross-polarized components because of orthogonality. The final form of the equation that is used to give the radiation from the reflector then becomes

$$\bar{E}(Q) = - \frac{j\omega\mu_0}{4\pi} \frac{\bar{e}^{jkR}}{R} \iint_S \bar{J}_s e^{+jk\bar{p} \cdot \hat{R}} dS \quad (2.5)$$

where  $\bar{p}$  is the vector from 0 to a point on the surface and  $\hat{R}$  is a unit vector in the direction of the far field point.

To obtain the induced currents,  $\bar{J}_s$ , one applies the physical optics principle which states that

$$\bar{J}_s = 0 \quad \text{on the shadow side,}$$

and,

$$\bar{J}_s = 2\hat{n} \times \bar{H}_{inc} \quad \text{on the illuminated side}$$

(2.6)

where  $\hat{n}$  is a unit normal vector to the surface and  $\bar{H}_{inc}$  is the incident magnetic field from the feed. Hence, knowing the radiation from the feed and the reflector configuration, the far-field can be determined.

## 2.2 REFLECTOR MODEL

The geometry of the reflector system is shown in Figure 2.2. A global co-ordinate system, X Y Z, is defined at the

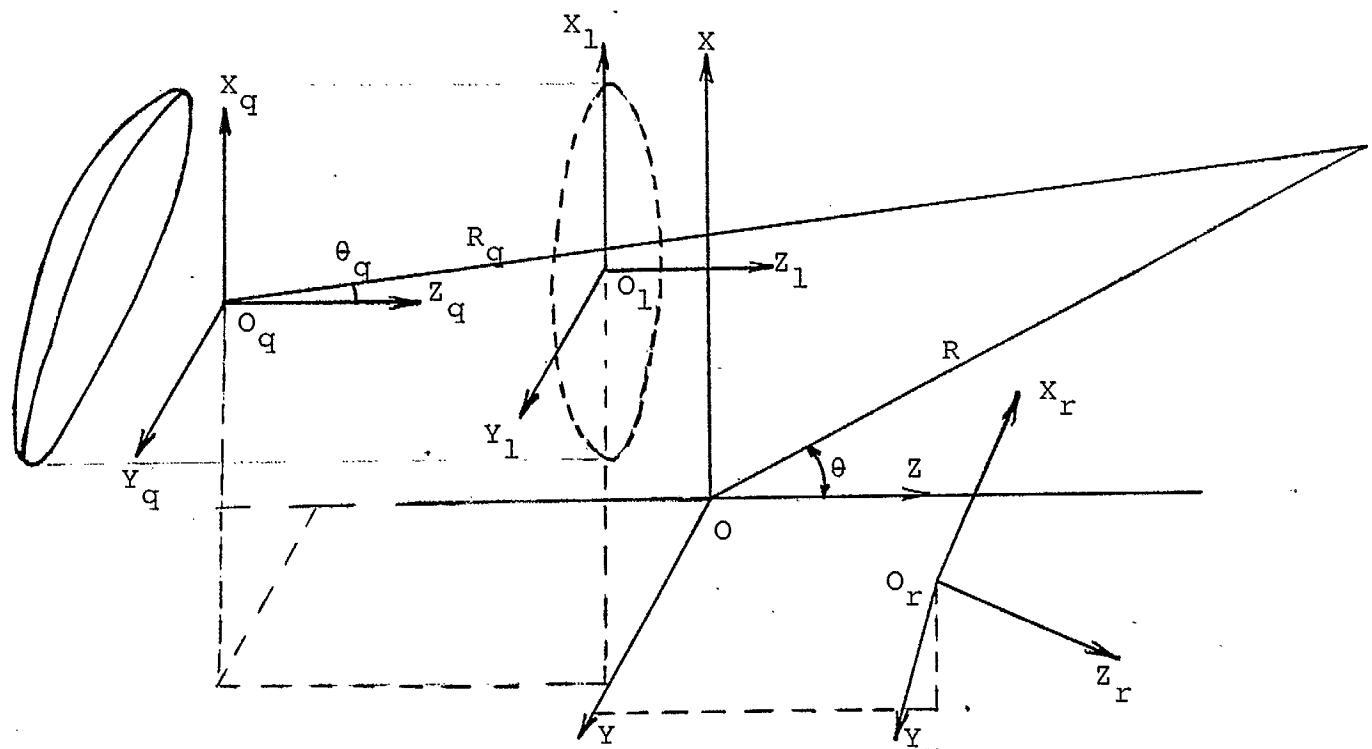


Figure 2.2 Co-ordinate Systems for Reflector Analysis

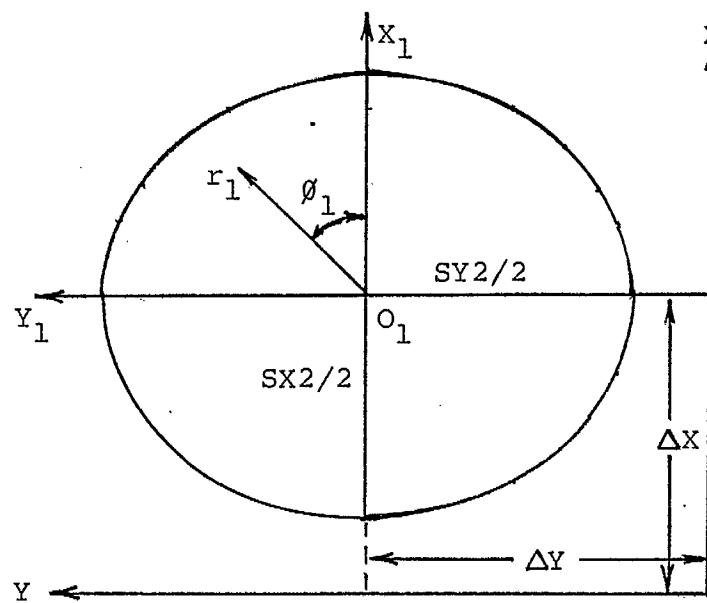


Figure 2.3 Co-ordinate System for Surface Integration

focal point of the reflector,  $0$ . Input quantities such as reflector offsets and feed displacements are referred to this system. Apart from the global system, three other local co-ordinate systems are used. The first,  $x_q y_q z_q$ , is for the far-field observation point. The second,  $x_r y_r z_r$ , is for the feed. The third,  $x_l y_l z_l$ , is for the integration over the reflector surface and is parallel to the global system. The origin  $0_l$  of  $x_l y_l z_l$  is located at the centre of the projected aperture on the focal plane.

The reflector is part of a parent parabola with focal length  $F$ . Its aperture can be offset in the  $X$ - and  $Y$ -directions. These displacements of  $0_l$  from  $0$  are  $\Delta X$  and  $\Delta Y$  as given in Figure 2.3. The shape of the projected aperture is elliptical with principal axes equal to  $SX_2$  and  $SY_2$ . In referring the scattered field to the  $x_q y_q z_q$  observation system, which is parallel to the global system, eqn. (2.5) needs to be augmented by an additional phase term leading to

$$\bar{E}(Q) = - \frac{j\omega u_0}{4\pi} \frac{\bar{e}^{-jkR_f}}{R_f} \bar{e}^{jk\overline{0}_q 0} \cdot \hat{R}_f \iint_s \bar{T}_s e^{jk\bar{p} \cdot \hat{R}} ds \quad (2.7)$$

where  $\overline{0}_q 0$  is the displacement vector of the observation system.

$$\overline{0}_q 0 = x_{dq} \hat{x} + y_{dq} \hat{y} + z_{dq} \hat{z} \quad (2.8)$$

The capability of moving the field reference system is useful if one is interested in removing the far-field phase variation due to parallax error. If such is the case, the origin  $0_q$  should be

Tracking near field

9

located close to the phase centre of the reflector. Let the spherical co-ordinates of the observation point  $Q$  be  $(R_q, \theta_q, \phi_q)$ . Then the phase term, obtained by taking the dot product, becomes

$$\overline{O_q O} \cdot \hat{R}_q = X_{dq} \sin \theta_q \cos \phi_q + Y_{dq} \sin \theta_q \sin \phi_q + Z_{dq} \cos \theta_q \quad (2.9)$$

In order to evaluate the integral, the inward pointing unit surface normal vector  $\hat{n}$  and the elemental surface area,  $d_s$ , are required. If the surface is represented by

$$z_1 = \frac{(x_1 + \Delta x)^2 + (y_1 + \Delta y)^2}{4f} - f \quad (2.10)$$

then, from differential geometry,

$$ds = [1 + (\frac{x_1 + \Delta x}{2f})^2 + (\frac{y_1 + \Delta y}{2f})^2]^{1/2} dx_1 dy_1 \quad (2.11)$$

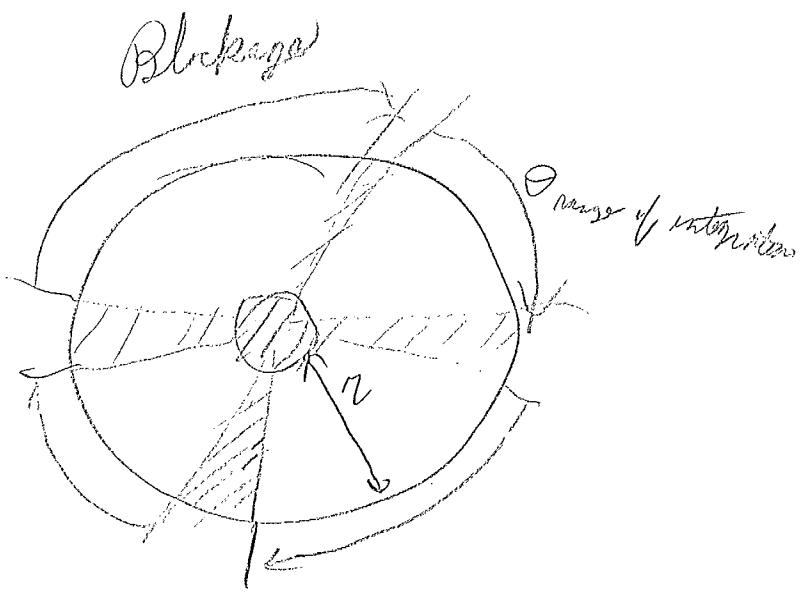
Making a further substitution using the polar co-ordinates of Fig. 2.3,

$$x_1 = r_1 \cos \phi_1$$

$$y_1 = r_1 \sin \phi_1$$

the elemental area becomes

$$ds = \left[ 1 + \left( \frac{r_1 \cos \phi_1 + \Delta x}{2f} \right)^2 + \left( \frac{r_1 \sin \phi_1 + \Delta y}{2f} \right)^2 \right]^{1/2} dx_1 dy_1 \quad (2.12)$$



The unit normal may be written as

$$\hat{n} = \left[ 1 + \left( \frac{r_i \cos \phi_i + \Delta x}{2f} \right)^2 + \left( \frac{r_i \sin \phi_i + \Delta y}{2f} \right)^2 \right]^{-1/2} \cdot [n_x \hat{x} + n_y \hat{y} + \hat{z}]$$

$$n_x = - \left( \frac{r_i \cos \phi_i + \Delta x}{2f} \right)$$

$$n_y = - \left( \frac{r_i \sin \phi_i + \Delta y}{2f} \right)$$
(2.13)

The surface integration is performed in  $(r_1, \phi_1)$  co-ordinates. For zero blockage, the integration limits are

$$\phi_1 = 0 \rightarrow 2\pi$$

$$r_1 = 0 \rightarrow \frac{sx_2 \cdot sy_2}{2[(sx_2 \sin \phi_1)^2 + (sy_2 \cos \phi_1)^2]^{1/2}} \quad (2.14)$$

With spar and central blockages, the limits change to

$$\phi_1 = 0 \rightarrow \phi_{bi}^l, \phi_{bi}^u \rightarrow \phi_{b2}^l, \dots, \phi_{bn}^u \rightarrow 2\pi \quad (2.15)$$

$$r_1 = \frac{bx_2 \cdot by_2}{2\sqrt{(bx_2 \sin \phi_1)^2 + (by_2 \cos \phi_1)^2}} \rightarrow \frac{sx_2 \cdot sy_2}{2\sqrt{(sx_2 \sin \phi_1)^2 + (sy_2 \cos \phi_1)^2}}$$

As defined above, there are  $n$  spar sector blockages where  $\phi$ -limits of the  $i$  th blockage are  $\phi_{bi}^l$  and  $\phi_{bi}^u$ . The central blockage is elliptical with principal axes equal to  $BX_2$  and  $BY_2$ . These limits together with the integration formula used, will determine the locations  $(x_1, y_1, z_1)$  of the integration nodes on the reflector surface. They are converted to global co-ordinates using

$$x = x_1 + \Delta x$$

$$y = y_1 + \Delta y$$

$$z = z_1$$

The phase term in the exponential within the integrand can now be evaluated, giving

$$\bar{p} \cdot \hat{R} = X \sin \theta_q \cos \phi_q + Y \sin \theta_q \sin \phi_q + Z \cos \theta_q \quad (2.16)$$

In the absence of blockages, the program automatically divides the  $\phi_1$ -region into four quadrants. Within each quadrant, the same number of quadrature points are used for the  $\phi_1$ - and  $r_1$ -integrations.

### 2.3 FEED ARRAY DESCRIPTION

The local co-ordinate system for the  $n$ th horn in the feed array is  $(x_{rn}, y_{rn}, z_{rn})$  as shown in Fig. 2.4. This system is translated from the global co-ordinate system by  $(\delta x_{rn}, \delta y_{rn}, \delta z_{rn})$  and then rotated about the translated axes  $x_{tn}$ ,  $y_{tn}$  and  $z_{tn}$  in turn by angles  $\alpha_{rn}$ ,  $\beta_{rn}$  and  $\gamma_{rn}$  respectively. Given a point  $(r_1, \phi_1, z_1)$  on the reflector, its spherical coordinates  $(\rho_{rn}, \theta_{rn}, \phi_{rn})$  in the  $n$ th feed's rotated reference system are needed to find the incident field. They are determined by carrying out the following sequence of transformations.

- (i) Transform from  $(r_1, \phi_1, z_1)$  to  $(X, Y, Z)$

$$x = r_1 \cos \phi_1 + \Delta x \quad (2.17)$$

$$y = r_1 \sin \phi_1 + \Delta y$$

$$z = z_1$$

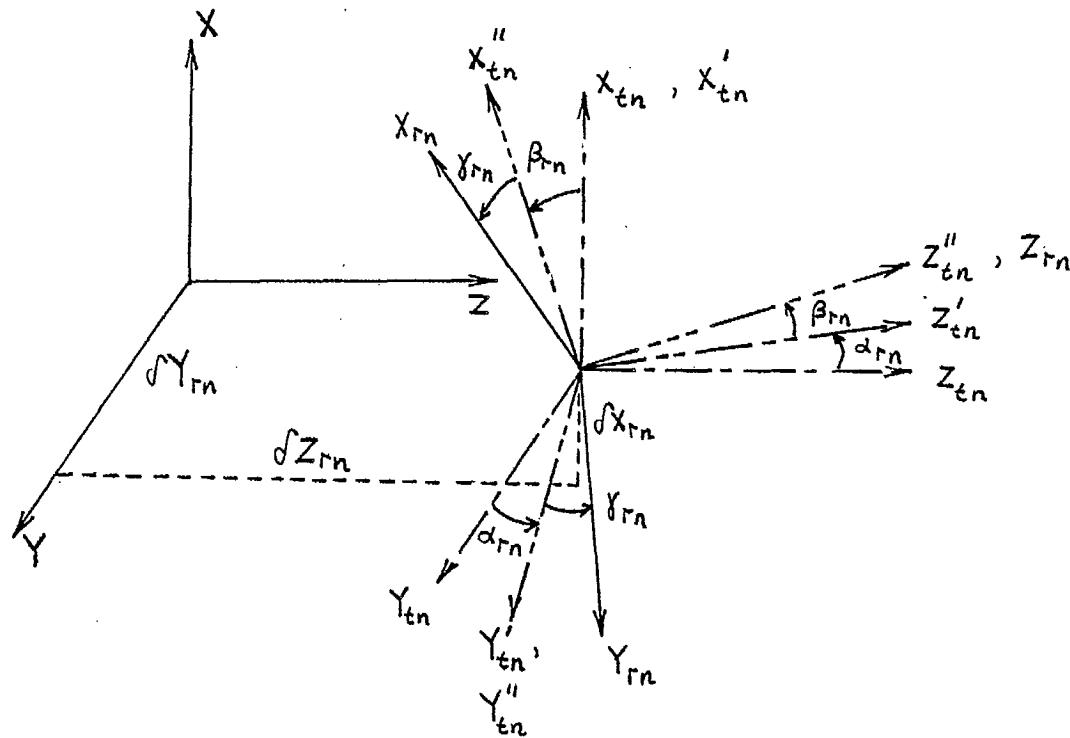


Figure 2.4 Feed Co-ordinate System

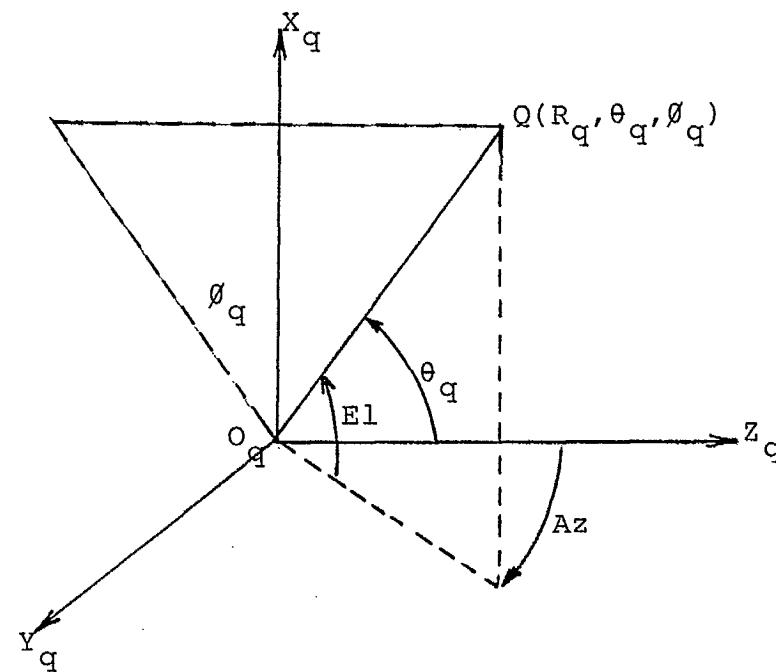


Figure 2.5 Field Observation Co-ordinate System

(ii) Transform from  $(X, Y, Z)$  to  $(\rho_t, \theta_t, \phi_t)$

$$\rho_{rn}^2 = (x - \rho_{X_{rn}})^2 + (y - \rho_{Y_{rn}})^2 + (z - \rho_{Z_{rn}})^2$$

$$\theta_{tn} = \cos^{-1} [(z - \rho_{Z_{rn}})/\rho_{rn}] \quad (2.18)$$

$$\phi_{tn} = \tan^{-1} [(y - \rho_{Y_{rn}})/(x - \rho_{X_{rn}})]$$

(iii) Transform from  $(\rho_t, \theta_t, \phi_t)$  to  $(\rho_r, \theta_r, \phi_r)$

$$\rho_{tn} = \rho_{rn}$$

$$\begin{bmatrix} \sin \theta_{rn} \cos \phi_{rn} \\ \sin \theta_{rn} \sin \phi_{rn} \\ \cos \theta_{rn} \end{bmatrix} = \begin{bmatrix} \cos \beta_{rn} \cos \gamma_{rn} & \sin \alpha_{rn} \sin \beta_{rn} \cos \gamma_{rn} & \sin \alpha_{rn} \sin \beta_{rn} \sin \gamma_{rn} \\ -\cos \beta_{rn} \sin \gamma_{rn} & \cos \alpha_{rn} \cos \gamma_{rn} - \sin \alpha_{rn} \sin \beta_{rn} \sin \gamma_{rn} & \cos \alpha_{rn} \sin \beta_{rn} \sin \gamma_{rn} + \sin \alpha_{rn} \cos \gamma_{rn} \\ \sin \beta_{rn} & -\sin \alpha_{rn} \cos \beta_{rn} & \cos \alpha_{rn} \cos \beta_{rn} \end{bmatrix} \begin{bmatrix} \sin \theta_{tn} \cos \phi_{tn} \\ \sin \theta_{tn} \sin \phi_{tn} \\ \cos \theta_{tn} \end{bmatrix} \quad (2.19)$$

The incident electric field from the  $n$  th horn at this surface point may be represented by

$$\bar{E}_{inc}^n = \frac{-jk\rho_{rn}}{\rho_{rn}} \left\{ F_{1n}(\theta_{rn}, \phi_{rn}) \hat{\theta}_{rn} + F_{2n}(\theta_{rn}, \phi_{rn}) \hat{\phi}_{rn} \right\} \quad (2.20)$$

where  $F_{1n}$  and  $F_{2n}$  are the theta- and phi- components of the electric field. Since the reflector is in the far field of the horn feed, TEM propagation may be assumed. In which case, the electric field may be obtained from eqn. (2.20).

$$\begin{aligned}
 \bar{H}_{\text{inc}}^n &= \left(\frac{\epsilon}{\mu_0}\right)^{1/2} (\hat{p}_{rn} \times \bar{E}_{\text{inc}}^n) \\
 &= \left(\frac{\epsilon}{\mu_0}\right)^{1/2} \frac{-jk p_{rn}}{p_{rn}} [(F_{1n} T_{x\theta n} - F_{2n} T_{x\phi n}) \hat{x} \\
 &\quad + (F_{1n} T_{y\phi n} - F_{2n} T_{y\theta n}) \hat{y} + (F_{1n} T_{z\phi n} - F_{2n} T_{z\theta n}) \hat{z}]
 \end{aligned} \tag{2.21}$$

The transformation functions,  $T$ , convert horn local spherical co-ordinates to the global co-ordinates

$$\begin{bmatrix} T_{x\theta n} \\ T_{y\theta n} \\ T_{z\theta n} \end{bmatrix} = \begin{bmatrix} \cos \beta_{rn} \cos \gamma_{rn} & -\cos \beta_{rn} \sin \gamma_{rn} & -\sin \beta_{rn} \\ \sin \alpha_{rn} \sin \beta_{rn} \cos \gamma_{rn} & \cos \alpha_{rn} \cos \gamma_{rn} & \sin \alpha_{rn} \cos \beta_{rn} \\ \cos \alpha_{rn} \sin \beta_{rn} & -\sin \alpha_{rn} \sin \beta_{rn} \sin \gamma_{rn} & \sin \alpha_{rn} \sin \beta_{rn} \end{bmatrix} \begin{bmatrix} \cos \theta_{rn} \cos \phi_{rn} \\ \cos \theta_{rn} \sin \phi_{rn} \\ \sin \theta_{rn} \end{bmatrix} \tag{2.22}$$

$$\begin{bmatrix} T_{x\phi n} \\ T_{y\phi n} \\ T_{z\phi n} \end{bmatrix} = \begin{bmatrix} -\cos \beta_{rn} \cos \gamma_{rn} & -\cos \beta_{rn} \sin \gamma_{rn} & \sin \phi_{rn} \\ \sin \alpha_{rn} \sin \beta_{rn} \cos \gamma_{rn} & \cos \alpha_{rn} \cos \gamma_{rn} & \cos \phi_{rn} \\ \cos \alpha_{rn} \sin \beta_{rn} & -\sin \alpha_{rn} \sin \beta_{rn} \sin \gamma_{rn} & \end{bmatrix} \begin{bmatrix} \sin \phi_{rn} \\ \cos \phi_{rn} \\ ? \end{bmatrix} \tag{2.23}$$

If all the horns in the arrays are excited simultaneously, the total incident magnetic field is the sum of the component fields given by eqn. (2.21).

#### 2.4 FAR-FIELD GAIN PATTERN COMPUTATION

With the incident magnetic field known, the induced current is derived from eqns. (2.6) and (2.13).

$$\left[ 1 + \left( \frac{x_1 + \Delta x}{2f} \right)^2 + \left( \frac{y_1 + \Delta y}{2f} \right)^2 \right]^{1/2} \bar{J}_s = 2 \left( \frac{\epsilon}{\mu_0} \right)^{1/2} \sum_{n=1}^N \frac{-e^{jk\rho_{rn}}}{\rho_{rn}} \left\{ \begin{aligned} & \hat{x} [n_y (F_{1n} T_{z\phi n} - F_{2n} T_{z\theta n}) - n_z (F_{1n} T_{y\phi n} - F_{2n} T_{y\theta n})] + \\ & \hat{y} [n_z (F_{1n} T_{x\phi n} - F_{2n} T_{x\theta n}) - n_x (F_{1n} T_{z\phi n} - F_{2n} T_{z\theta n})] + \\ & \hat{z} [n_x (F_{1n} T_{y\phi n} - F_{2n} T_{y\theta n}) - n_y (F_{1n} T_{x\phi n} - F_{2n} T_{x\theta n})] \end{aligned} \right\} \\ = 2 \left( \frac{\epsilon}{\mu_0} \right)^{1/2} [ J_{sx} \hat{x} + J_{sy} \hat{y} + J_{sz} \hat{z}] \quad (2.24) \end{math>$$

The feed array has N horns. Substituting eqn. (2.24) into (2.7), the electric field at observation point Q becomes

$$\bar{E}(Q) = -j \frac{\bar{e}^{jkR_f}}{R_f} \exp[-jk(x_{dq} \sin \theta_q \cos \phi_q + Y_{dq} \sin \theta_q \sin \phi_q + Z_{dq} \cos \theta_q)] \cdot \iint_S [J_{sx} \hat{x} + J_{sy} \hat{y} + J_{sz} \hat{z}] \exp[jk(x \sin \theta_q \cos \phi_q + Y \sin \theta_q \sin \phi_q + Z \cos \theta_q)] \cdot r_i dr_i d\phi_i \quad (2.25)$$

Eqn. (2.25) is written in a more concise notation to give

$$\begin{aligned}\bar{E}(\Omega) &= -\frac{j}{\lambda} \frac{\bar{e}^{jkR_q}}{R_q} \bar{E}'(\theta_q, \phi_q) \\ &= -\frac{j}{\lambda} \frac{\bar{e}^{jkR_q}}{R_q} [E'_x \hat{x} + E'_y \hat{y} + E'_z \hat{z}]\end{aligned}\quad (2.26)$$

The next step is to resolve the secondary radiated field into its co- and cross-polarized components. The polarization of the radiation from a Huygen's source is used as the reference.

Let  $v_x$  be the unit vector parallel to the electric field from a Huygen's source whose electric dipole is directed along the X-axis.

Similarly, let  $v_y$  be the unit vector parallel to the electric field from a Huygen's source whose electric dipole is directed along the Y-axis. These two vectors are orthogonal and are used to define the principal polarization directions.

$$\begin{aligned}v_x &= \cos \phi_q \hat{\theta} - \sin \phi_q \hat{\phi} = [1 - \cos^2 \phi_q (1 - \cos \theta_q)] \hat{x} \\ &\quad - \sin \theta_q \cos \phi_q \hat{z} - (1 - \cos \theta_q) \sin \phi_q \cos \phi_q \hat{y}\end{aligned}$$

$$\begin{aligned}\hat{v}_y &= \sin \phi_q \hat{\theta} + \cos \phi_q \hat{\phi} = -(1 - \cos \theta_q) \sin \phi_q \cos \phi_q \hat{x} \\ &\quad + [1 - \sin^2 \phi_q (1 - \cos \theta_q)] \hat{y} - \sin \theta_q \sin \phi_q \hat{z}\end{aligned}$$

(2.27)

If the electric field is linearly polarised, its vertically,  $E'_{vx}$ , and horizontally,  $E'_{vy}$ , polarized components are obtained by the dot products of eqns. (2.26) and (2.27).

$$\begin{aligned}\bar{E}'_{vy} &= \bar{E}' \cdot \hat{v}_y = [-(1 - \cos \theta_q) \sin \phi_q \cos \phi_q] E'_x - \sin \theta_q \sin \phi_q E'_z \\ &\quad + [1 - \sin^2 \phi_q (1 - \cos \theta_q)] E'_y\end{aligned}\tag{2.28}$$

$$\begin{aligned}\bar{E}'_{vx} &= \bar{E}' \cdot \hat{v}_x = [1 - \cos^2 \phi_q (1 - \cos \theta_q)] E'_x - \sin \theta_q \cos \phi_q E'_z \\ &\quad - (1 - \cos \theta_q) \sin \phi_q \cos \phi_q E'_y\end{aligned}$$

If the electric field is circularly polarised, it may be resolved into its right,  $E'_{rcp}$ , and left handed,  $E'_{lcp}$ , components as follows.

$$\begin{aligned}E'_{rcp} &= \bar{E}' \cdot (\hat{v}_x + j\hat{v}_y)/\sqrt{2} \\ &= (E'_{vx} + jE'_{vy})/\sqrt{2}\end{aligned}\tag{2.29}$$

$$\begin{aligned}E'_{lcp} &= \bar{E}' \cdot (\hat{v}_x - j\hat{v}_y)/\sqrt{2} \\ &= (E'_{vx} - jE'_{vy})/\sqrt{2}\end{aligned}$$

The axial ratio of the CP wave is

$$AR = \frac{|E'_{rcp}| + |E'_{lcp}|}{|E'_{rcp}| - |E'_{lcp}|}\tag{2.30}$$

while the tilt angle of the polarization ellipse is given by

$$\psi = [\arg(E'_{rcp}) - \arg(E'_{lcp})]/2\tag{2.31}$$

The tilt angle is the angle between the reference direction and the major axis of the ellipse when viewed in the direction of

propagation. The reference direction for establishing the ellipse orientation is arbitrary but  $\hat{\theta}$  is commonly accepted as the reference.

For horn feeds that are rotated about its own local  $z_r$ -axis by angle  $\gamma$ , the principal polarization vectors must also be rotated by the same amount.

$$\begin{aligned}\hat{v}'_x &= \hat{v}_x \cos \gamma + \hat{v}_y \sin \gamma \\ \hat{v}'_y &= -\hat{v}_x \sin \gamma + \hat{v}_y \cos \gamma\end{aligned}\quad (2.32)$$

The electric field is resolved into these new directions.

The gain of the reflector in any direction  $(\theta_q, \phi_q)$  is defined as

$$G(\theta_q, \phi_q) = 4\pi \frac{P_r(\theta_q, \phi_q)}{P_t} \quad (2.33)$$

where

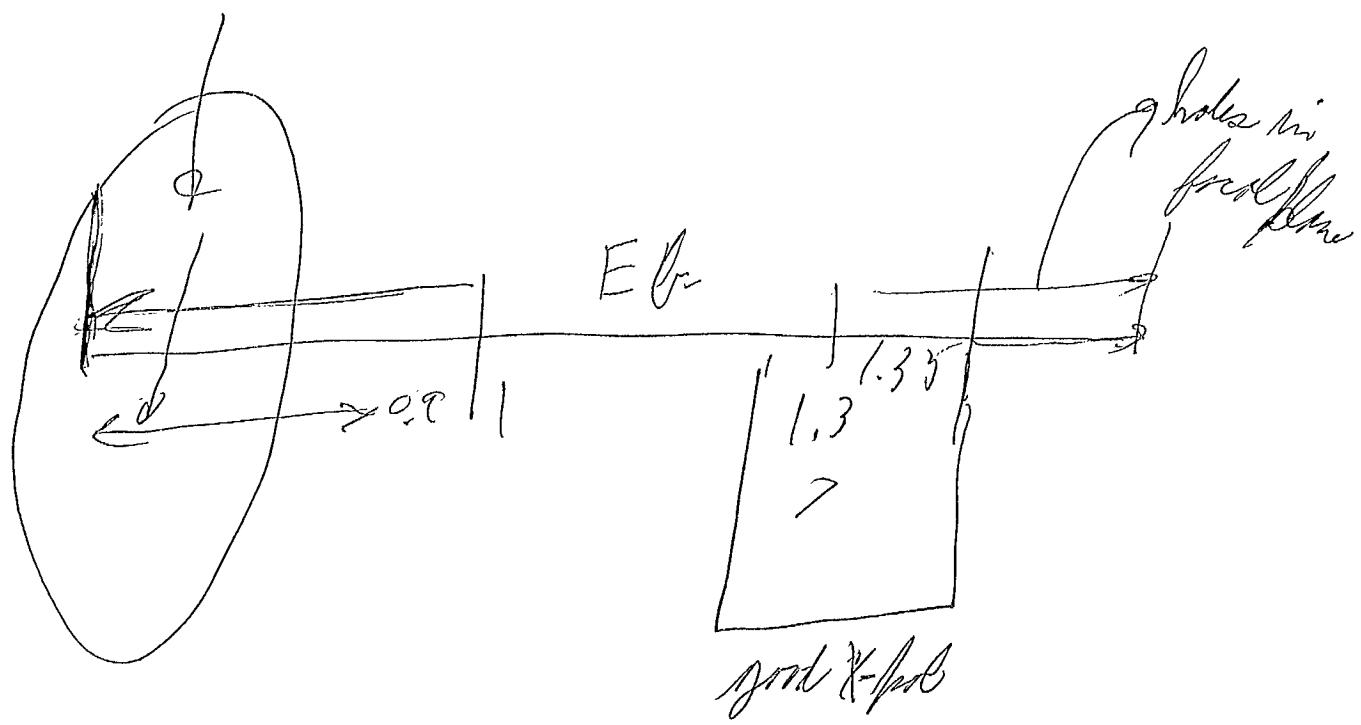
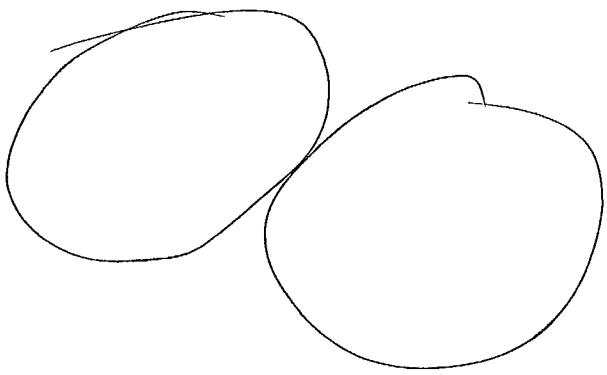
$P_r$  = power radiated per unit solid angle

$$= (\epsilon/\mu_0)^{1/2} R_q^2 | \bar{E} |^2 / 2$$

$P_t$  = total power radiated by the feed.

The gains for the various polarizations may be obtained by substituting the polarized components of  $\bar{E}$ , eqn. (2.26), into (2.33).

$$\begin{aligned}G_x(\theta_q, \phi_q) &= 2\pi (\epsilon/\mu_0)^{1/2} |E'_{vx}|^2 / (P_t \lambda^2) \\ G_y(\theta_q, \phi_q) &= 2\pi (\epsilon/\mu_0)^{1/2} |E'_{vy}|^2 / (P_t \lambda^2)\end{aligned}\quad (2.34)$$



$$G_{rcp}(\theta_q, \phi_q) = 2\pi (\epsilon/\mu_0)^{1/2} |E'_{rcp}|^2 / (P_t \lambda^2)$$

$$G_{lcp}(\theta_q, \phi_q) = 2\pi (\epsilon/\mu_0)^{1/2} |E'_{lcp}|^2 / (P_t \lambda^2)$$

The total power radiated by the feed array may be found by integrating the feed's Poynting vector either over the forward hemisphere or just across the horn apertures. The former procedure is followed in programs PAREFC\_SIF and PAREFM\_SIF while the latter is employed in program PAREFL\_SIF. For the same reflector-horn configuration, gain computed by PAREFC\_SIF differs from that computed by PAREFL\_SIF due to feed power difference. This gain difference ranges from nil for horn sizes  $> 3\lambda$  to 0.25 dB for horn sizes  $< 1\lambda$ . Gain computed by the first procedure is higher than that from the second procedure.

## 2.5 FAR-FIELD OBSERVATION CO-ORDINATE SYSTEM

The field co-ordinate system that is used in the analysis is the spherical system  $(R_q, \theta_q, \phi_q)$ . For some applications, it is preferable to use the elevation and azimuth co-ord. system instead. This system is illustrated in Fig. 2.5. Its relationship to the spherical system is expressed by

$$\theta_q = \cos^{-1} [\cos(EI) \cos(Az)] \quad (2.35)$$

$$\phi_q = \tan^{-1} [\sin(Az) / \tan(EI)]$$

In the programs,  $(EI, Az)$  are used to describe the location of the

far field point but they are converted to  $(\theta_q, \phi_q)$  for the gain calculation.

## 2.6 SPILLOVER CALCULATION

The power captured by the reflector is found by integrating the incident field Poynting vector over its surface. To achieve this, the electric and magnetic fields are written as

$$\begin{aligned}\bar{E}_{\text{inc}} &= \sum_{n=1}^N \frac{-jk\rho_{rn}}{\rho_{rn}} \left[ (F_{2n} T_{x\phi n} + F_{in} T_{x\theta n}) \hat{x} + (F_{2n} T_{y\phi n} + F_{in} T_{y\theta n}) \hat{y} \right. \\ &\quad \left. + (F_{2n} T_{z\phi n} + F_{in} T_{z\theta n}) \hat{z} \right] \\ &= E_{ix} \hat{x} + E_{iy} \hat{y} + E_{iz} \hat{z}\end{aligned}\quad (2.36)$$

$$\begin{aligned}\bar{H}_{\text{inc}} &= \left(\frac{\epsilon}{\mu_0}\right)^{1/2} \sum_{n=1}^N \frac{-jk\rho_{rn}}{\rho_{rn}} \left[ (F_{in} T_{x\phi n} - F_{2n} T_{x\theta n}) \hat{x} + \right. \\ &\quad \left. (F_{in} T_{y\phi n} - F_{2n} T_{y\theta n}) \hat{y} + (F_{in} T_{z\phi n} - F_{2n} T_{z\theta n}) \hat{z} \right] \\ &= \left(\frac{\epsilon}{\mu_0}\right)^{1/2} (H_{ix} \hat{x} + H_{iy} \hat{y} + H_{iz} \hat{z})\end{aligned}\quad (2.37)$$

The power incident on the elemental area  $dS$  is obtained by substituting the above expressions into the following

$$1/2 \operatorname{Re} \left\{ \bar{E}_{\text{inc}} \times \bar{H}_{\text{inc}}^* \right\} \cdot (-\hat{n}) dS$$

The negative sign is used because  $\hat{n}$  is an inward pointing vector.

The total power captured,  $P_c$ , is given by

$$\begin{aligned} P_c = -\frac{1}{2} \left(\frac{\epsilon}{\mu_0}\right)^{1/2} \iint_S & \left[ (E_{iy} H_{iz}^* - E_{iz} H_{iy}^*) n_x + (E_{iz} H_{ix}^* - E_{ix} H_{iz}^*) n_y \right. \\ & \left. + (E_{ix} H_{iy}^* - E_{iy} H_{ix}^*) \right] r_i d\Gamma d\phi, \end{aligned} \quad (2.38)$$

Spillover efficiency is expressed as the ratio of the power captured to the power transmitted.

$$\eta_s = P_c / P_t \quad (2.39)$$

## 2.7 NUMERICAL INTEGRATION

In computing the scattered fields, integrals that need to be evaluated are of the form

$$I = \int_{\phi_L}^{\phi_U} \int_{r_L}^{r_U} f(r, \phi) dr d\phi \quad (2.40)$$

where the two dimensional integration is taken over a rectangular domain. To facilitate its evaluation, the following substitutions are made to normalise the interval of integration,

$$r = (r_u + r_l)/2 + (r_u - r_l) r'/2$$

$$\phi = (\phi_u + \phi_l)/2 + (\phi_u - \phi_l) \phi'/2$$

Number of interpretation points  
depends on size of reflector  
and observation angles

yielding

$$I = \frac{(\phi_u - \phi_l)}{2} \frac{(r_u - r_l)}{2} \int_{-1}^{+1} \int_{-1}^{+1} f(r, \phi) dr' d\phi' \quad (2.41)$$

The resulting integral may now be evaluated using the product Gauss-Legendre formula. Of all the numerical integration schemes, the Gaussian quadratures have the highest degree of precision. For instance, if the integrand can be represented by a polynomial with no higher degree than  $2n-1$ , then the integral can be evaluated with zero error using a  $n$ -point formula. However, if the integrand is of higher degree than  $2n-1$ , the error resulting from using a  $n$ -point formula is minimum with Gaussian quadrature. In the evaluation of eqn. (2.41), a  $J$ -point formula is used for  $r'$  and a  $M$ -point formula for  $\phi'$ , then the equation may be rewritten to give

$$I = \frac{(\phi_u - \phi_l)}{2} \frac{(r_u - r_l)}{2} \sum_{j=1}^J \sum_{m=1}^M w_j w_m f(r'_j, \phi'_m) \quad (2.42)$$

The variables  $r'_j$  and  $\phi'_m$  are the abscissae of the Gaussian formulas while  $w_j$  and  $w_m$  are the corresponding weight functions.

Their values may be found tabulated in various mathematical handbooks. The integration procedure now reduces to a double summation of the integrand evaluated at the specified locations and multiplied by the appropriate weights.

Next, the matter of determining the required number of integration points is presented. Numerical experiments have shown that the required degree of polynomial approximating the integrand is about three times the number of roots the integrand has within the integration interval. So if the integrand displays

$L$  half cycles, there will be  $L+1$  zeroes, thus necessitating a  $3(L+1)$  degree approximating polynomial and a  $[3(L+1) + 1]/2$  - point formula. To apply this, let us assume that the size of the antenna aperture in the direction of integration is 'a', then the radiation from this aperture at angle  $\theta$  measured from broadside, is simply

$$\begin{aligned} E(\theta) &\propto \int_{-a/2}^{+a/2} A(s) e^{jks \sin\theta} ds \\ &\propto \int_{-1}^{+1} A(s') e^{j\frac{kas' \sin\theta}{2}} ds' \end{aligned} \quad (2.43)$$

The aperture illumination function,  $A(s)$ , in most instances is slowly varying. Only the exponential term shows the oscillatory behavior. In this case, there are  $(2a/\lambda) \sin\theta$  half cycles, a number that is dependent on the angle of observation measured from the peak of the beam and the size of the aperture. The number of integration points required is conservatively estimated at

$$N = \text{Integer } [(3a \sin \theta) / \lambda + 1.5] \quad (2.44)$$

The process of selecting the appropriate quadrature formula is automated in the program. A search is made to find the largest angle between the peak of the component beam and the edge of the observation frame. Substitution of this worst case angle into eqn. (2.44) gives the required formula.

E field model  
scramble for E and H from size 1 to 131  
other values → new CAC model based  
on coordinates

## 2.8 MODELING FEED HORN RADIATION PATTERNS

Feed horns for the reflector programs were purposely divided into two groups. The first group consists of linearly polarized horns and is used in program PAREFL\_SIF. The radiation patterns from these horns are computed using the aperture field model and the vector diffraction integral. Both transverse electric and magnetic fields across the aperture are used to compute the radiated fields. With this formulation, known as the Chu model, the co-polarised fields are accurately predicted but not the cross-polarised components. Power flow from the horn is obtained by the integral of Poynting's vector across its aperture. It may be readily evaluated in closed form. Gain computation based on this radiated power from the horn tends to be conservative, erring on the low side. A built-in margin therefore exists with this model.

The second group comprises horns that are suitable for both linear and circular polarizations. Again the aperture field method is used to compute the radiation patterns. However, a choice of two aperture field models is provided, the Chu and the E-field models. The latter model makes use of only the electric field with a conducting plane across the aperture. It provides good prediction for the co-polar patterns and reasonable approximations to the cross-polar patterns of horns with sizes in the range of  $1.0 \sim 1.3 \lambda$ . To compute the power radiated, a different approach is used whereby the Poynting's vector is integrated over the forward hemisphere. Gain computation using this method of computing power from the horn array tends to be slightly optimistic.

The method of computing patterns from horn apertures

is first presented, followed by evaluation of patterns from the two horn groups. Excitation of the orthogonal ports of the horn to produce circular polarization is then discussed.

### 2.8.1 RADIATION FROM HORN APERTURES

To find the radiation from the horn aperture, the vector Huygen's principle is applied by enclosing the horn with a surface that includes the aperture, exterior surface of the horn and the sphere at infinity. There is no contribution from the sphere at infinity. The tangential electric field over the horn surface is zero while the surface tangential magnetic field is neglected. This leaves only the tangential electric and magnetic fields across the horn aperture. One could then postulate that sources across the aperture consist of electric and magnetic currents given by

$$\bar{J}_e = \hat{n} \times \bar{H}_t$$

$$\bar{J}_m = \bar{E}_t \times \hat{n}$$

This model for the horn radiation is the Chu model. For horns whose sizes are in the range of  $1.0 \sim 1.3 \lambda$ , the fields are strong at the periphery and the model gives reasonable agreement with co-polar measured patterns. As the horn aperture increases, the contribution from external currents would become proportionate smaller. The agreement with co-polar measurements becomes better. Also for multimode horns where the fields are zero at the periphery, the Chu model gives good prediction of the patterns. Patterns from the Chu model are obtained from the following equations.

*and multimode horns*

*the Chu model  
calculated for  
 $\lambda/1.31$*

$$E_\theta = \frac{j e^{-jkR}}{2\lambda R} [1 + \alpha \cos \theta] (N_x \cos \phi + N_y \sin \phi) \quad (2.45)$$

$$E_\phi = \frac{-j e^{-jkR}}{2\lambda R} [\cos \theta + \alpha] (N_x \sin \phi - N_y \cos \phi) \quad (2.46)$$

where

$$\bar{N} = \iint_{\text{aper}} \bar{E}_t \exp[jk(x \sin \theta \cos \phi + y \sin \theta \sin \phi)] dx dy$$

$$\bar{E}_t = (1 + r) (\bar{E}_t)_i$$

$$\alpha = \frac{k}{\beta_{mn}} \left( \frac{1-r}{1+r} \right) \quad \text{TM}_{mn} \text{ modes}$$

$$= \frac{\beta_{mn}}{k} \left( \frac{1-r}{1+r} \right) \quad \text{TE}_{mn} \text{ modes}$$

$(\bar{E}_t)_i$  is the incident electric field and  $\beta_{mn}$  is the phase constant for the given mode. The reflection coefficient  $r$  is small and usually set to zero. Very often  $\alpha$  is set to one in arriving at a Huygen's source.

An alternate model may be used for  $1.0 - 1.3 \lambda$  horns. The Huygen's surface is continued through the aperture of the horn to form an infinite electric conducting ground plane. Only the electric field needs to be specified, leading to magnetic currents of

$$\begin{aligned} \bar{J}_m &= 2(\bar{E}_t \times \bar{n}) \quad \text{over aperture} \\ &= 0 \quad \text{elsewhere} \end{aligned}$$

Fairly good agreement with measurements is obtained for both co-polar and cross-polar patterns. Eqns. (2.45) and (2.46) are modified for this E-field model with  $\alpha = 0$  and  $\bar{N}$  replaced by  $2\bar{N}$ , giving

$$E_\theta = \frac{j \exp(-jkR)}{R} (N_x \cos \phi + N_y \sin \phi) \quad (2.47)$$

$$E_\phi = \frac{-j \exp(-jkR)}{R} \cos \theta (N_x \sin \phi - N_y \cos \phi) \quad (2.48)$$

### 2.8.2 FEEDS SUITABLE FOR LINEAR POLARIZATION

In the reflector analysis program PAREFL\_SIF, various types of rectangular horns may be used to feed the reflector. The horn types allowed are tabulated in Table 2.1 together with the assumed aperture distributions. In addition, quadratic phase error may be present at the horn aperture since the feed waveguide size is equal to or smaller than the horn. The expression for this phase error may be obtained as follows:

Consider a principal cut through the horn as shown in Figure 2.6. The flare length of the horn is ' $\lambda$ ' while the aperture dimension is 'd'. Assuming that a spherical wavefront is emanating from the phase centre P, the deviation from the phase front at a point X on the aperture is

$$\phi = \lambda - px = \lambda - \lambda [1 + (x/\lambda)^2 - (0.5 d/\lambda)^2]^{1/2} \quad (2.49)$$

$$\approx - (0.5 x/\lambda)^2 + (0.125 d/\lambda)^2$$

This quadratic phase error is used in the feed modeling.

With the appropriate aperture distribution and phase error, the radiation pattern from the horn is computed using the

Table 2,1 Aperture Distributions for the Various Rectangular Horn Types

<u>Horn Types</u>	<u>E-Plane Distribution</u>	<u>H-Plane Distribution</u>
Pyramidal	Uniform	Cosinusoidal
Dielectric Loaded	Uniform	Uniform
Corrugated	Cosinusoidal	Cosinusoidal
Dielectric Loaded Corrugated	Cosinusoidal	Uniform
Dielectric Loaded Trifurcated	Binomial	Uniform
Trifurcated	Binomial	Cosinusoidal

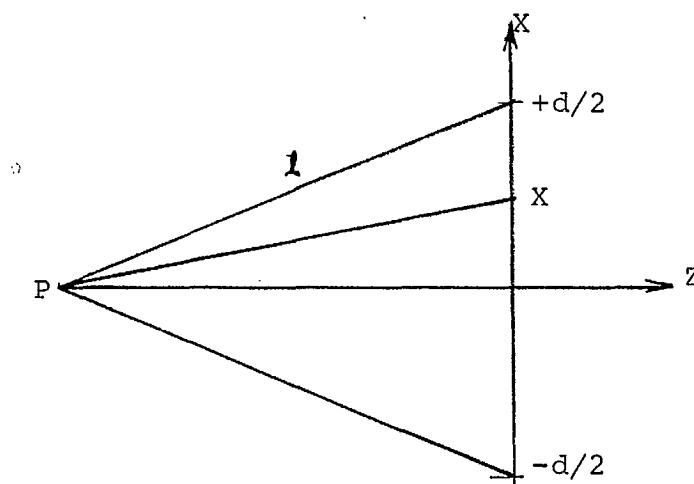


Figure 2.6 Aperture Phase Error.

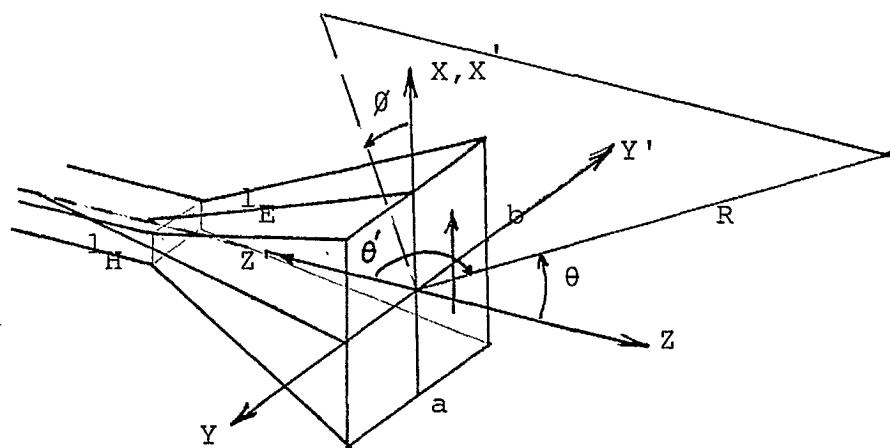


Figure 2.7 Pyramidal Horn.

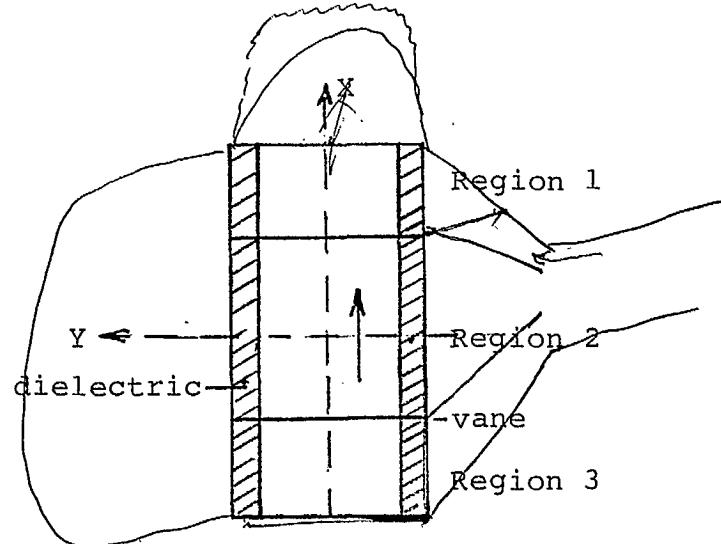


Figure 2.8 Dielectric Loaded Trifurcated Horn.

aperture field method. Horizontal and vertical polarizations may be prescribed for the horn. In the program, the vertical polarization vector is parallel to the X-axis while the horizontal polarization vector is parallel to the Y-axis. Expressions for the radiation patterns of the different types of horns are given below.

#### Vertically Polarized Pyramidal Horn

The fundamental TE<sub>10</sub> mode is assumed to be the only propagating mode. By assuming that the mode propagation constant is equal to that of free space and the reflection coefficient is zero at the horn aperture, the field distribution for the horn of Figure 2.7 may be written as

$$E_x = A \cos\left(\frac{\pi y}{a}\right) \exp[-jk(x^2/2l_E + y^2/2l_H)]$$

$$\exp[jk(\frac{a^2}{8l_H} + \frac{b^2}{8l_E})]$$

$$H_y = E_x/\zeta$$

where

A = amplitude constant (2.50)

$l_E$  = E-plane flare length

$l_H$  = H-plane flare length

a = H-plane dimension

$b$  = E-plane dimension

$\xi$  = free space impedance

From eqns. (2.45) and (2.46), the theta and phi-components of the radiation pattern can be readily shown to be

$$\begin{aligned} E_\theta &= \frac{jk \bar{e}^{jkR}}{4\pi R} [1 + \cos\theta] \cos\phi A e^{+jk\alpha} N_x \\ E_\phi &= \frac{-jk \bar{e}^{jkR}}{4\pi R} [1 + \cos\theta] \sin\phi A e^{+jk\alpha} N_x \\ N_x &= \int_{-a/2}^{+a/2} \int_{-b/2}^{+b/2} \cos\left(\frac{\pi y}{a}\right) e^{-jk\left(\frac{x^2}{2\ell_E} + \frac{y^2}{2\ell_H}\right)} e^{+jk(x\sin\theta\cos\phi + y\sin\theta\sin\phi)} dx dy \\ e^{+jk\alpha'} &= e^{+jk\left(\frac{a^2}{8\ell_H} + \frac{b^2}{8\ell_E}\right)} \end{aligned} \quad (2.51)$$

As can be seen, the polarization vector for the above pattern is

$$\hat{p} = \cos\phi \hat{\theta} - \sin\phi \hat{\phi}$$

which is equal to the Huygen's source. The prediction for the

*Horn antenna*

cross-polarization response, which is zero, is unrealistic and is brought about by assuming the propagation constant is that of free space. Such a situation is realised only when  $a \gg \lambda$  since

$\frac{\beta_{10}}{K} = \frac{\lambda}{\lambda_{g10}} = [1 - (\frac{\lambda}{2a})^2]^{\frac{1}{2}}$ . A more accurate model for the cross-polarization pattern is the electric field model. The present model, however, gives very good co-polarization pattern prediction.

The horn co-ordinate system (XYZ) is rotated about the X-axis by  $180^\circ$  to give ( $X'Y'Z'$ ) as shown in Figure 2.7. The new system is consistent with the reflector co-ordinate system. This co-ordinate transformation is done here to reduce the number of transformations required later. To perform the rotations, the following substitutions are entered into equation (2.51)

$$x = x' \quad y = -y'$$

$$\hat{\theta} = -\hat{\theta}' \quad \hat{\phi} = -\hat{\phi}'$$

$$\sin \theta = \sin \theta' \quad \cos \theta = -\cos \theta'$$

$$\sin \phi = -\sin \phi' \quad \cos \phi = \cos \phi'$$

giving

$$E_{\theta'} = \frac{-jk e^{jkr}}{j4\pi R} [1 - \cos \theta'] \cos \phi' A e^{+jkd'} N_x'$$

$$E_{\phi'} = \frac{-jk e^{jkr}}{j4\pi R} [1 - \cos \theta'] \sin \phi' A e^{+jkd'} N_x'$$

(2.52)

$$N_{x'} = \int \int \cos\left(\frac{\pi y'}{a}\right) \exp\left[-jk\left(\frac{x'^2}{2l_E} + \frac{y'^2}{2l_H}\right)\right] \exp[jk(x'\sin\theta'\cos\phi' + y'\sin\theta'\sin\phi')] dx' dy'$$

apert

To convert the integral  $N_{x'}$  into a form suitable for Gaussian integration, the following further substitutions are made.

$$y' = ya/2 \quad x' = xb/2$$

As a result, the term  $N_{x'}$  in equation (2.52), becomes

$$N_{x'} = \frac{ab}{4} \int_{-1}^{+1} \cos\left(\frac{\pi y}{2}\right) \exp\left[-jk\left(\frac{a^2 y^2}{8l_H}\right)\right] \exp\left[+jk\frac{ay}{2}\sin\theta'\sin\phi'\right] dy \cdot$$

$$\int_{-1}^{+1} \exp\left[-jk\left(\frac{bx^2}{8l_E}\right)\right] \exp\left[jk\left(\frac{bx}{2}\sin\theta\cos\phi\right)\right] dx$$
(2.53)

8-point integration formula is sufficient to evaluate the above integral for horn sizes up to 4 wavelengths.

Normally, the power input to the horn is specified. In order to evaluate the pattern, the amplitude constant A must be known. The power flow across the horn aperture is first obtained by integrating the Poynting's vector and is equal to

the input power,  $P_i$ .

$$P_i = \frac{1}{2} \iint \operatorname{Re} \left\{ \bar{E} \times \bar{H}^* \right\} \cdot \hat{Z} dx dy = \frac{ab}{4\zeta} |A|^2 \quad (2.54)$$

As can be seen, the amplitude  $A$  can now be readily obtained from the input power.

Derivations for the rest of the horn types are similar. Only the aperture field distribution, radiation patterns and power radiated expressions are given.

#### Horizontally Polarized Pyramidal Horn

Aperture field distribution:

$$E_y = A \cos\left(\frac{\pi x}{a}\right) \exp\left[-jk\left(\frac{x^2}{2\ell_H} + \frac{y^2}{2\ell_E}\right)\right] \exp[jk\alpha'] \quad (2.55)$$

$$H_x = -E_y/\zeta$$

Radiation patterns:

$$E_{\theta'} = \frac{jk \bar{e}^{jkR}}{4\pi R} [1 - \cos\theta'] \sin\phi' A e^{jk\alpha'} N_y \quad (2.56)$$

$$E_{\phi'} = \frac{-jk \bar{e}^{jkR}}{4\pi R} [1 - \cos\theta'] \cos\phi' A e^{jk\alpha'} N_y$$

$$N_y = \frac{ab}{4} \int_{-1}^{+1} \cos\left(\frac{\pi x}{2}\right) \exp\left[-jk \frac{a^2 x^2}{8\ell_H}\right] \exp\left[jk \frac{ax}{2} \sin\theta' \cos\phi'\right] dx \cdot \\ \int_{-1}^{+1} \exp\left[-jk \frac{b^2 y^2}{8\ell_E}\right] \exp\left[jk \frac{by}{2} \sin\theta' \sin\phi'\right] dy$$

Power radiated:

$$P_i = \frac{ab}{4\xi} |A|^2 \quad (2.57)$$

### Vertically Polarized Dielectric Loaded Horn

Aperture field distribution:

$$E_x = A \exp \left[ -jk \left( \frac{y^2}{2l_H} + \frac{x^2}{2l_E} \right) \right] \exp [+jk\alpha'] \quad (2.58)$$

$$H_y = \frac{E_x}{\xi}$$

Radiation patterns:

$$E_{\theta'} = -\frac{jk}{4\pi R} e^{jkR} [1 - \cos\theta'] \cos\phi' A e^{+jk\alpha'} N_x \quad (2.59)$$

$$E_{\phi'} = -\frac{jk}{4\pi R} e^{jkR} [1 - \cos\theta'] \sin\phi' A e^{+jk\alpha'} N_x$$

$$N_x = \frac{ab}{4} \int_{-1}^{+1} \exp \left[ -jk \frac{a^2 y^2}{8l_H} \right] \exp \left[ jk \frac{ay}{2} \sin\theta' \sin\phi' \right] dy \\ \int_{-1}^{+1} \exp \left[ -jk \frac{b^2 x^2}{8l_E} \right] \exp \left[ jk \frac{bx}{2} \sin\theta' \cos\phi' \right] dx$$

Power radiated:

$$P_i = \frac{ab}{2\xi} |A|^2 \quad (2.60)$$

### Horizontally Polarized Dielectric Loaded Horn

Aperture field distribution:

$$E_Y = A \exp [-jk(\frac{x^2}{2l_H} + \frac{y^2}{2l_E})] \exp [+jk\alpha'] \quad (2.61)$$

$$H_x = - \frac{E_Y}{\xi}$$

Radiation patterns:

$$E_{\theta'} = \frac{jke^{jkR}}{4\pi R} [1 - \cos\theta'] \sin\phi' A e^{+jk\alpha'} N_y \quad (2.62)$$

$$E_{\phi'} = \frac{-jke^{jkR}}{4\pi R} [1 - \cos\theta'] \cos\phi' A e^{+jk\alpha'} N_y$$

$$N_Y = \frac{ab}{4} \int_{-1}^{+1} \exp \left[ -jk \frac{a^2 x^2}{8l_H} \right] \exp \left[ jk \frac{ax}{2} \sin\theta' \cos\phi' \right] dx \\ \int_{-1}^{+1} \exp \left[ -jk \frac{b^2 y^2}{8l_E} \right] \exp \left[ jk \frac{yb}{2} \sin\theta' \sin\phi' \right] dy$$

Power radiated:

$$P_i = \frac{ab}{2\xi} |A|^2 \quad (2.63)$$

### Vertically Polarized Corrugated Horn

Aperture field distribution:

$$E_x = A \cos\left(\frac{\pi x}{a}\right) \cos\left(\frac{\pi y}{b}\right) \exp\left[-jk\left(\frac{x^2}{2l_H} + \frac{y^2}{2l_E}\right)\right] \cdot \exp[+jk\alpha'] \quad (2.64)$$

$$H_y = E_x / \xi$$

Radiation patterns:

$$E_\theta = \frac{-jk e^{jkR}}{4\pi R} \left[ 1 - \cos\theta' \right] \cos\phi' A e^{+jk\alpha'} N_x \quad (2.65)$$

$$E_\phi = \frac{-jk e^{jkR}}{4\pi R} \left[ 1 - \cos\theta' \right] \sin\phi' A e^{+jk\alpha'} N_x$$

$$N_x = \frac{ab}{4} \int_{-1}^{+1} \cos\left(\frac{\pi y}{2}\right) \exp\left[-jk \frac{a^2 y^2}{8l_H}\right] \exp\left[jk \frac{ay}{2} \sin\theta' \sin\phi'\right] dy \\ \int_{-1}^{+1} \cos\left(\frac{\pi x}{2}\right) \exp\left[-jk \frac{b^2 x^2}{8l_E}\right] \exp\left[jk \frac{bx}{2} \sin\theta' \cos\phi'\right] dx$$

Power radiated:

$$P_i = \frac{ab}{8\zeta} |A|^2 \quad (2.66)$$

### Horizontally Polarized Corrugated Horn

Aperture field distribution:

$$\begin{aligned} E_y &= A \cos\left(\frac{\pi x}{a}\right) \cos\left(\frac{\pi y}{b}\right) \exp\left[-jk\left(\frac{x^2}{2l_H} + \frac{y^2}{2l_E}\right)\right] e_p [+jk\alpha'] \\ H_x &= -\frac{E_y}{\zeta} \end{aligned} \quad (2.67)$$

Radiation patterns:

$$E_\theta = \frac{-jk e^{jkr}}{4\pi R} [1 - \cos\theta'] \sin\phi' A e^{+jk\alpha'} N_y \quad (2.68)$$

$$E_\phi = \frac{-jk e^{jkr}}{4\pi R} [1 - \cos\theta'] \cos\phi' A e^{+jk\alpha'} N_y$$

$$N_y = \frac{ab}{4} \int_{-1}^{+1} \cos\left(\frac{\pi x}{2}\right) \exp\left[-jk \frac{a^2 x^2}{8l_H}\right] \exp\left[jk \frac{ax}{2} \sin\theta' \cos\phi'\right] dx$$

$$\int_{-1}^{+1} \cos\left(\frac{\pi y}{2}\right) \exp\left[-jk \frac{b^2 y^2}{8l_E}\right] \exp\left[jk \frac{yb}{2} \sin\theta' \sin\phi'\right] dy$$

Power radiated:

$$P_i = \frac{ab}{2\xi} |A|^2 \quad (2.69)$$

### Vertically Polarized Dielectric Loaded Corrugated Horn

Aperture field distribution:

$$E_x = A \cos(\pi x/a) \exp[-jk(\frac{x^2}{2l_H} + \frac{y^2}{2l_E})] \exp[jk\alpha'] \quad (2.70)$$

Radiation patterns:

$$E_{\theta'} = \frac{-jk e^{jkR}}{4\pi R} [1 - \cos\theta'] \cos\phi' A e^{jka'} N_x \quad (2.71)$$

$$E_{\phi'} = \frac{-jk e^{jkR}}{4\pi R} [1 - \cos\theta'] \sin\phi' A e^{jka'} N_x$$

$$N_x = \frac{ab}{4} \int_{-1}^{+1} \exp[-jk \frac{a^2 y^2}{8l_H}] \exp[jk \frac{ay}{2} \sin\theta' \sin\phi'] dy .$$

$$\int_{-1}^{+1} (\cos(\frac{\pi x}{2}) \exp[-jk \frac{b^2 x^2}{8l_E}] \exp[jk \frac{bx}{2} \sin\theta' \cos\phi']) dx$$

Power radiated:

$$P_i = \frac{1}{4} \frac{ab}{\xi} |A|^2 \quad (2.72)$$

### Horizontally Polarized Dielectric Loaded Corrugated Horn

Aperture field distribution:

$$E_y = A \cos(\pi y/b) \exp[-jk(\frac{x^2}{2l_H} + \frac{y^2}{2l_E})] \exp[jk\alpha'] \quad (2.73)$$

Radiation pattern :

$$E_{\theta'} = \frac{jk e^{jkr}}{4\pi R} [1 - \cos\theta'] \sin\phi' A e^{jkd'} N_y \quad (2.74)$$

$$E_{\phi'} = \frac{-jk e^{jkr}}{4\pi R} [1 - \cos\theta'] \cos\phi' A e^{jkd'} N_y$$

$$N_y = \frac{ab}{4} \int_{-1}^{+1} \exp\left[-jk \frac{a^2 x^2}{8l_H}\right] \exp\left[jk \frac{ax}{2} \sin\theta' \cos\phi'\right] dx .$$

$$\int_{-1}^{+1} \cos\left(\frac{\pi y}{2d}\right) \exp\left[-jk \frac{b^2 y^2}{8l_E}\right] \exp\left[+jk \frac{by}{2d} \sin\theta' \sin\phi'\right] dy$$

Power radiated:

$$P_i = \frac{1}{4} \frac{ab}{\xi} |A|^2 \quad (2.75)$$

### Vertically Polarized Dielectric Loaded Trifurcated Horn

The trifurcated horn has a non-uniform (binomial) aperture illumination in the E-plane. The amplitude ratio of 1:2:1 is achieved by introducing vanes into the horn which split the energy entering at the horn throat. The aperture area is also divided in a binomial fashion. For a dielectric loaded aperture, as shown in Fig. 2.8, the field distribution becomes

$$\begin{aligned}
 E_x &= A \exp[jk\Delta] & b/2 \geq x \geq b/4 & \text{Region 1} \\
 &= 2A \exp[jk\Delta] & b/4 \geq x \geq -b/4 & \text{Region 2} \\
 &= A \exp[jk\Delta] & -b/4 \geq x \geq -b/2 & \text{Region 3}
 \end{aligned} \tag{2.76}$$

where

$$\Delta = -\frac{x^2}{2l_E} - \frac{y^2}{2l_H} + \frac{a^2}{8l_H} + \frac{b^2}{8l_E}$$

By combining the radiation from the three subapertures, the theta and phi-components of the resultant pattern may be written as follows:

$$E_\theta = \frac{-jk e^{jkr}}{4\pi R} [1 - \cos\theta'] \cos\phi' A e^{+jka'} N_x \tag{2.77}$$

$$E_\phi = \frac{-jk e^{jkr}}{4\pi R} [1 - \cos\theta'] \sin\phi' A e^{+jka'} N_x$$

$$\begin{aligned}
 N_x &= \frac{ab}{16} \left\{ \int_{-1}^{+1} \exp \left[ jk \frac{ay}{2} \sin\theta \sin\phi' \right] \exp \left[ -jk \frac{a^2 y^2}{8\ell_E} \right] dy \right\} \\
 &\quad \int_{-1}^{+1} \exp \left[ -jk \frac{b^2 (3+x)^2}{128\ell_E} \right] \exp \left[ jk \frac{b(3+x)}{8} \sin\theta \cos\phi' \right] dx \\
 &\quad + \int_{-1}^{+1} \exp \left[ jk (x-3) \frac{b}{8} \sin\theta \cos\phi' \right] \exp \left[ -jk \frac{b^2 (x-3)^2}{128\ell_E} \right] dx + \\
 &\quad 4 \int_{-1}^{+1} \exp \left[ -jk \frac{b^2 x^2}{32\ell_E} \right] \exp \left[ jk \frac{bx}{4} \sin\theta \cos\phi' \right] dx \}
 \end{aligned}$$

Power radiated is obtained by summing the power flowing across each subaperture.

$$P_i = \frac{5}{4} \frac{ab}{5} |A|^2 \quad (2.78)$$

### Horizontally Polarized Dielectric Loaded Trifurcated Horn

Aperture field distribution:

$$\begin{aligned}
 E_y &= A \exp [jk\Delta] & b/2 &\geq y &\geq b/4 \\
 &= 2A \exp [jk\Delta] & b/4 &\geq y &\geq -b/4 \\
 &= A \exp [jk\Delta] & -b/4 &\geq y &\geq -b/2
 \end{aligned}$$

(2.79)

### Vertically Polarized Trifurcated Horn

Aperture field distribution:

$$\begin{aligned}
 E_x &= A \cos\left(\frac{\pi y}{a}\right) \exp(jk\Delta) & b/2 \geq x \geq b/4 \\
 &= 2A \cos\left(\frac{\pi y}{a}\right) \exp(jk\Delta) & b/4 \geq x \geq -b/4 \\
 &= A \cos\left(\frac{\pi y}{a}\right) \exp(jk\Delta) & -b/4 \geq x \geq -b/2
 \end{aligned} \tag{2.80}$$

Radiation patterns:

$$E_{\theta'} = \frac{-jk e^{jkr}}{4\pi R} [1 - \cos\theta'] \cos\phi' A e^{jkd'} N_x \tag{2.81}$$

$$E_{\phi'} = \frac{-jk e^{jkr}}{4\pi R} [1 - \cos\theta'] \sin\phi' A e^{jkd'} N_x$$

$$N_x = \frac{ab}{16} \int_{-1}^{+1} \cos\left(\frac{\pi y}{2}\right) \exp\left[-jk \frac{a^2 y^2}{8\ell_H}\right] \exp\left[jk \frac{ay}{2} \sin\theta' \sin\phi'\right] dy$$

$$\left\{ \int_{-1}^{+1} \exp\left[-jk \frac{b^2(3+x)^2}{128\ell_E}\right] \exp\left[jk \frac{b}{8}(3+x) \sin\theta' \cos\phi'\right] dx \right.$$

$$+ \int_{-1}^{+1} \exp\left[jk(x-3)\frac{b}{8} \sin\theta' \cos\phi'\right] \exp\left[-jk \frac{b^2(x-3)^2}{128\ell_E}\right] dx$$

$$\left. + 4 \int_{-1}^{+1} \exp\left[-jk \frac{bx^2}{32\ell_E}\right] \exp\left[jk \frac{bx}{4} \sin\theta' \cos\phi'\right] dx \right\}$$

Power radiated:

$$P_i = \frac{5}{8} \frac{ab}{\xi} |A|^2 \tag{2.82}$$

Radiation patterns:

$$E_{\theta'} = \frac{jk e^{-jkR}}{4\pi R} [1 - \cos\theta'] \sin\phi' A e^{+jka'} N_y \quad (2.83)$$

$$E_{\phi'} = \frac{-jk e^{-jkR}}{4\pi R} [1 - \cos\theta'] \cos\phi' A e^{+jka'} N_y$$

$$N_y = \frac{ab}{16} \int_{-1}^{+1} \exp\left[-jk \frac{a^2 x^2}{8l_H}\right] \exp\left[jk \frac{ax}{2} \sin\theta' \cos\phi'\right] dx \left\{ \begin{aligned} & \int_{-1}^{+1} \exp\left[jk(y-3) \frac{b}{8} \sin\theta' \sin\phi'\right] \exp\left[-jk(y-3) \frac{b^2}{128l_E}\right] dy \\ & + \int_{-1}^{+1} \exp\left[-jk(y+3) \frac{b^2}{128l_E}\right] \exp\left[jk(y+3) \frac{b}{8} \sin\theta' \sin\phi'\right] dy \\ & + 4 \int_{-1}^{+1} \exp\left[jk \frac{by}{4} \sin\theta' \sin\phi'\right] \exp\left[-jk \frac{b^2 y^2}{32l_E}\right] dy \end{aligned} \right\}$$

Power radiated:

$$P_i = \frac{5}{4} \frac{ab}{\xi} |A|^2 \quad (2.84)$$

### Horizontally Polarized Trifurcated Horn

Aperture field distribution:

$$\begin{aligned}
 E_y &= A \cos(\pi x/a) \exp(jk\Delta) & b/2 \geq y \geq b/4 \\
 &= 2A \cos(\pi x/a) \exp(jk\Delta) & b/4 \geq y \geq -b/4 \\
 &= A \cos(\pi x/a) \exp(jk\Delta) & -b/4 \geq y \geq -b/2
 \end{aligned} \tag{2.85}$$

Radiation patterns:

$$E_\theta = \frac{jk \bar{e}^{jkR}}{4\pi R} [1 - \cos\theta'] \sin\phi' A e^{+jk\alpha'} N_y \tag{2.86}$$

$$E_\phi = -\frac{jk \bar{e}^{jkR}}{4\pi R} [1 - \cos\theta'] \cos\phi' A e^{+jk\alpha'} N_y$$

$$\begin{aligned}
 N_y &= \frac{ab}{16} \int_{-1}^{+1} (\cos(\frac{\pi x}{2}) \exp[-jk \frac{a^2 x^2}{8l_E}] \exp[jk \frac{ax}{2} \sin\theta' \cos\phi']) dx \\
 &\quad \left\{ \int_{-1}^{+1} \exp[jk(y-3)\frac{b}{8} \sin\theta' \sin\phi'] \exp[-jk(y-3)\frac{b^2}{128l_E}] dy \right. \\
 &\quad + \int_{-1}^{+1} \exp[-jk(y+3)\frac{b^2}{128l_E}] \exp[jk(y+3)\frac{b}{8} \sin\theta' \sin\phi'] dy \\
 &\quad \left. + 4 \int_{-1}^{+1} \exp[jk \frac{by}{4} \sin\theta' \sin\phi'] \exp[-jk \frac{b^2 y^2}{32l_E}] dy \right\}
 \end{aligned}$$

Power radiated:

$$P_i = \frac{5}{8} \frac{ab}{\xi} |A|^2 \tag{2.87}$$

### 2.8.3 FEEDS SUITABLE FOR LINEAR AND CIRCULAR POLARIZATION

#### CONICAL HORN PATTERNS

The tangential electric fields appearing across the aperture of a conical horn excited with the  $TE_{mn}$  mode may be written as:

$$E_x = A(jk_{mn}/2) [J_{m-1}(k_{mn}\rho) \cdot \sin(m-1)\psi + J_{m+1}(k_{mn}\rho) \cdot \sin(m+1)\psi] e^{-j\bar{\phi}(\rho)}$$

$$E_y = A(jk_{mn}/2) [J_{m-1}(k_{mn}\rho) \cos(m-1)\psi - J_{m+1}(k_{mn}\rho) \cos(m+1)\psi] e^{-j\bar{\phi}(\rho)} \quad (2.88)$$

The characteristic values  $k_{mn}$  satisfy the relationship  $J'_m(k_{mn}a) = 0$ , where  $a$  is the radius of the aperture. The radial and angular variables at the aperture are  $\rho$  and  $\psi$  respectively. Flaring of the horn produces a phase front deviation from planar across the opening by an amount expressed by

$$\exp[-j\bar{\phi}(\rho)] = \exp[-jk(\sqrt{\rho^2 + l_a^2} - l_a)] \quad (2.89)$$

where  $l_a$  is the axial length from the apex to the aperture. The phase is referenced to the horn centre. Eqn. (2.88) is substituted into eqns. (2.45) and (2.46) where the cartesian integration variables are converted into cylindrical ones. Performing the  $\phi$ -integration, the resulting expressions for the  $N$  functions become

$$\begin{aligned}
 N_\theta &= N_x \cos \phi + N_y \sin \phi \\
 &= -(1+r)\pi A k_{mn} j^m \int_0^a e^{j\Phi(\rho)} [-J_{m-1}(k_{mn}\rho) J_{m-1}(k\rho \sin \theta) + \\
 &\quad J_{m+1}(k_{mn}\rho) J_{m+1}(k\rho \sin \theta)] \rho d\rho \sin m\phi \quad (2.90)
 \end{aligned}$$

$$\begin{aligned}
 N_\phi &= N_x \sin \phi - j N_y \cos \phi \\
 &= -(1+r)\pi A k_{mn} j^m \int_0^a e^{j\Phi(\rho)} [J_{m-1}(k_{mn}\rho) J_{m-1}(k\rho \sin \theta) + \\
 &\quad J_{m+1}(k_{mn}\rho) J_{m+1}(k\rho \sin \theta)] \rho d\rho \cos m\phi \quad (2.91)
 \end{aligned}$$

The above integrals can be evaluated analytically provided  $\Phi(\rho)$  is zero. Otherwise, they have to be calculated numerically. The power flow across the circular aperture is calculated by integrating the Poynting vector. For the  $TE_{mn}$  mode, power radiated is found to be

$$P_t = \frac{\pi \beta_{mn}}{2\omega \mu \epsilon_m} (1 - |r|^2) A^2 [(k_{mn}a)^2 - m^2] J_m^2(k_{mn}a) \quad (2.92)$$

$$\begin{aligned}
 \epsilon_m &= 1 \quad \text{for } m = 0 \\
 &= 2 \quad \text{for } m \neq 0
 \end{aligned}$$

$$\beta_{mn}^2 = k^2 - k_{mn}^2 a^2$$

When the horn is excited with  $TM_{mn}$  mode, the aperture distribution takes on the following form

$$E_x = (-j B k_{mn}/2) [J_{m-1}(k_{mn}\rho) \cdot \cos(m-1)\psi - J_{m+1}(k_{mn}\rho) \cdot \cos(m+1)\psi] e^{-j\bar{\phi}(\rho)}$$

$$E_y = (j B k_{mn}/2) [J_{m-1}(k_{mn}\rho) \cdot \sin(m-1)\psi + J_{m+1}(k_{mn}\rho) \cdot \sin(m+1)\psi] e^{-j\bar{\phi}(\rho)} \quad (2.93)$$

The eigenvalue,  $k_{mn}$ , satisfies the relationship  $J_m(k_{mn}a) = 0$ .

Substitution of the above field distributions into the radiation equations result in the  $N$  functions below.

$$\begin{aligned} N_\theta &= N_x \cos \phi + N_y \sin \phi \\ &= (1+\mu) \pi j B k_{mn} j^{(m+1)} \int_0^a e^{-j\bar{\phi}(\rho)} [J_{m-1}(k_{mn}\rho) \cdot \\ &\quad J_{m-1}(k\rho \sin \theta) + J_{m+1}(k_{mn}\rho) \cdot J_{m+1}(k\rho \sin \theta)] \rho d\rho \cos m\phi \end{aligned} \quad (2.94)$$

$$\begin{aligned} N_\phi &= N_x \sin \phi - N_y \cos \phi \\ &= (1+\mu) \pi j B k_{mn} j^{(m+1)} \int_0^a e^{-j\bar{\phi}(\rho)} [J_{m-1}(k_{mn}\rho) \cdot \\ &\quad J_{m-1}(k\rho \sin \theta) - J_{m+1}(k_{mn}\rho) \cdot J_{m+1}(k\rho \sin \theta)] \rho d\rho \sin m\phi \end{aligned} \quad (2.95)$$

Power flow for a  $TM_{mn}$  mode across the circular aperture may be readily obtained as before, resulting in

$$P_t = \frac{\pi w \epsilon}{2 \beta_{mn} \epsilon_m} (1 - |\Gamma|^2) B^2 k_{mn}^2 a^2 J_m'^2(k_{mn} a) \quad (2.96)$$

$$\epsilon_m = 1 \quad , \quad m = 0$$

$$= 2 \quad , \quad m \neq 0$$

The most frequently used modes in a conical horn are the fundamental  $TE_{11}$  mode and the combination of  $TE_{11}$  and  $TM_{11}$  modes. Substituting for  $m = 1$  and  $n = 1$  in eqns. (2.94) and (2.95) gives the radiation from a  $TM_{11}$  mode horn that is X-axis polarized. Similar substitution in eqns. (2.90) and (2.91) results in a  $TE_{11}$  mode pattern that is Y-axis polarized and may be rotated to align with the  $TM_{11}$  mode polarization. These two modes can then be combined to provide Y-axis polarized patterns that have low side-lobes and are defined by

$$E_\theta = A \frac{\pi e^{-jkR}}{2\lambda R} k_{11H} a^2 \left\{ [1 + (\beta_{11H}/k) \cos \theta] N_{\theta H} - [1 + (k/\beta_{11E}) \cos \theta] (B/A) (k_{11E}/k_{11H}) N_{\theta E} \right\} \cos \phi$$

$$E_\phi = -A \frac{\pi e^{-jkR}}{2\lambda R} k_{11H} a^2 \left\{ [\cos \theta + (\beta_{11H}/k)] N_{\phi H} - [\cos \theta + (k/\beta_{11E})] (B/A) (k_{11E}/k_{11H}) N_{\phi E} \right\} \sin \phi \quad (2.98)$$

where

$$N_{\theta H} = - \int_0^1 e^{j\frac{\pi}{4}(\rho'a)} [J_2(k_{11H}\rho'a) J_2(k\rho' \sin\theta) - J_0(k_{11H}\rho'a) \cdot \\ J_0(k\rho' \sin\theta)] \rho' d\rho'$$

$$N_{\phi H} = \int_0^1 e^{j\frac{\pi}{4}(\rho'a)} [J_2(k_{11H}\rho'a) J_2(k\rho' \sin\theta) + J_0(k_{11H}\rho'a) \cdot \\ J_0(k\rho' \sin\theta)] \rho' d\rho'$$

$$N'_{\theta E} = \int_0^1 e^{j\frac{\pi}{4}(\rho'a)} [J_0(k_{11E}\rho'a) J_0(k\rho' \sin\theta) + J_2(k_{11E}\rho'a) \cdot \\ J_2(k\rho' \sin\theta)] \rho' d\rho'$$

$$N'_{\phi E} = \int_0^1 e^{j\frac{\pi}{4}(\rho'a)} [-J_2(k_{11E}\rho'a) J_2(k\rho' \sin\theta) + J_0(k_{11E}\rho'a) \cdot \\ J_0(k\rho' \sin\theta)] \rho' d\rho'$$

$$k_{11H} a = 1.84118 , \quad k_{11E} a = 3.83171 , \quad k = 2\pi/\lambda$$

$$\beta_{11H}^2 = k^2 - k_{11H}^2 , \quad \beta_{11E}^2 = k^2 - k_{11E}^2$$

The ratio  $(B/A)$  determines the amplitude and phase of the  $TM_{11}$  component relative to the principal  $TE_{11}$  mode. The higher order  $TM_{11}$  mode affects the E-plane only and does not modify the H-plane pattern. The high E-plane sidelobes can thus be independently reduced. The mode content should be chosen so as to equalise the E- and H-  
plane beamwidths down to the -10 dB level. By setting the ratio to zero, the dominant mode patterns are obtained. The E-field radiation model could also be derived by putting the propagation constant ratios ( $\beta_{11H}/k$ ) and ( $k/\beta_{11E}$ ) to zero.

### Pyramidal Horn Patterns

To reduce E-plane sidelobes for a pyramidal horn,  
the higher order mode pair  $TE_{12}$  and  $TM_{12}$  is excited. The  
 aperture distribution for the  $TE_{12}$  mode may be written as

$$E_x = \frac{2\pi j w \mu}{k_{12}^2 b} A_H \sin\left(\frac{\pi x}{a}\right) \sin\left(\frac{2\pi y}{b}\right) \quad (2.99)$$

$$E_y = \frac{\pi j w \mu}{k_{12}^2 a} A_H \cos\left(\frac{\pi x}{a}\right) \cos\left(\frac{2\pi y}{b}\right)$$

while the distribution for the  $TM_{12}$  mode may be presented as

$$E_x = -\frac{\pi j \beta_{12}}{k_{12}^2 a} A_E \sin\left(\frac{\pi x}{a}\right) \sin\left(\frac{2\pi y}{b}\right) \quad (2.100)$$

$$E_y = \frac{2\pi j \beta_{12}}{k_{12}^2 b} A_E \cos\left(\frac{\pi x}{a}\right) \cos\left(\frac{2\pi y}{b}\right)$$

These two modes should be combined such that the cross-polarized  $E_x$  component is cancelled. This condition is obtained when

$$\frac{A_E}{A_H} = \frac{2 w \mu a}{b \beta_{12}} \quad (2.101)$$

Adding the two modes produces

$$\begin{aligned} E_Y &= \frac{jw\mu\pi}{k_{12}^2 a} \left[ 1 + \frac{4a^2}{b^2} \right] \cos\left(\frac{\pi x}{a}\right) \cos\left(\frac{2\pi y}{b}\right) \\ &= A_2 \cos\left(\frac{\pi x}{a}\right) \cos\left(\frac{2\pi y}{b}\right) \end{aligned} \quad (2.102)$$

The fundamental mode excitation results in an aperture distribution of

$$E_Y = A \cos\left(\frac{\pi x}{a}\right) \quad (2.103)$$

By exciting all three modes, the aperture distribution becomes

$$E_Y = A \left[ 1 + \alpha_{12} \cos\left(\frac{2\pi y}{b}\right) \right] \cos\left(\frac{\pi x}{a}\right) \quad (2.104)$$

where  $\alpha_{12}$  is the ratio of TE/TM<sub>12</sub> mode pair to TE<sub>10</sub> mode. For similar E- and H-plane patterns,  $\alpha_{12}$  ranges from .50 to .67. The aperture field may be similarly integrated to give the far-field patterns.

Chu Model:

$$E_\theta = \frac{jka b}{16\pi} \frac{e^{-jkR}}{R} A [1 + \cos\theta] \cos\phi N_x \quad (2.105)$$

$$E_\phi = - \frac{jka b}{16\pi} \frac{e^{-jkR}}{R} A [1 + \cos\theta] \sin\phi N_x \quad (2.106)$$

E-Field Model:

$$E_\theta = \frac{j kab}{16\pi} \frac{e^{jkR}}{R} A \cos \phi N_x \quad (2.107)$$

$$E_\phi = - \frac{j kab}{16\pi} \frac{\bar{e}^{jkR}}{R} A \cos \theta \sin \phi N_x \quad (2.108)$$

$$N_x = \int_{-1}^{+1} \cos\left(\frac{\pi x}{2}\right) e^{+jk(a/2)x \sin \theta \cos \phi} \bar{e}^{-j\bar{\Phi}(x)} dx .$$

$$\int_{-1}^{+1} [1 + \alpha_{12} \cos(\pi y)] e^{+jk(b/2)y \sin \theta \sin \phi} \bar{e}^{-j\bar{\Phi}(y)} dy$$

#### 2.8.4 FEED PATTERNS FROM MEASUREMENTS

Most feeds may be adequately represented by its E- and H-plane far-field patterns  $E_\theta(\theta)$  and  $E_\phi(\theta)$ . For example, the X-axis polarised feed pattern may be represented by

$$\bar{E}(\theta, \phi) = E_\theta(\theta) \cos \phi \hat{\theta} - E_\phi(\theta) \sin \phi \hat{\phi} \quad (2.109)$$

Here the  $\phi = 0^\circ$  plane corresponds to the E-plane while the  $\phi = 90^\circ$  plane is the H-plane. Given the angle  $\theta$ , the field at any  $\phi$ -cut can thus be easily found from the azimuthal  $\cos\phi - \sin\phi$  description.

In the program (PAREFM\_SIF), the amplitude and phase of each point defining the principal plane patterns are entered in dB and degrees respectively. The angular points  $\theta_n$ ,  $n=1, 2, \dots, N$  are assumed to be equally spaced. Quadratic interpolation is used to find the field at the in-between points. The field at points outside the range i.e.  $\theta > \theta_N$ , is set to zero.

### 2.8.5 EXCITATION OF FEEDS

Let us assume the feed, with diagonal symmetry, has two orthogonal ports labeled 'X' and 'Y', which are aligned with the respective axes. Exciting port 'X' with voltage excitation coefficient  $C_x$  yields a radiated pattern of

$$\bar{E}_x = C_x A [ E_\theta (\theta) \cos \phi \hat{\theta} - E_\phi (\theta) \sin \phi \hat{\phi} ] \quad (2.110)$$

where  $E_\theta$  and  $E_\phi$  are the E- and H-plane patterns respectively. Exciting port 'Y' with coefficient  $C_y e^{+j\psi}$  gives rise to

$$\bar{E}_y = AC_y e^{+j\psi} [ E_\theta (\theta) \sin \phi \hat{\theta} + E_\phi (\theta) \cos \phi \hat{\phi} ] \quad (2.111)$$

The E- and H-plane patterns of the orthogonal ports are the same since the feed is symmetric. The two ports may be simultaneously excited to produce an elliptically polarized wave,

$$\bar{E} = A (C_x E_\theta \cos \phi + C_y e^{+j\psi} \cdot E_\theta \sin \phi) \hat{\theta} - A (C_x E_\phi \sin \phi - C_y e^{+j\psi} \cdot E_\phi \cos \phi) \hat{\phi} \quad (2.112)$$

Phase reference has been taken with respect to the 'X' port.

For RCP,  $\psi$  is equal to  $-90^\circ$  and  $C_x$  is equal to  $C_y$ . For LCP,  $\psi$  is equal to  $+90^\circ$ . Linear polarization may also be simulated by setting either  $C_x$  or  $C_y$  to zero. Associated with the patterns is the constant  $A$  which is proportional to the amplitude of the horn aperture excitation. It is related to the input power.

The power radiated by the horn is

$$\begin{aligned}
 P_r &= \frac{1}{2} (\epsilon/\mu)^{1/2} \int_0^{2\pi} \int_0^{\pi} |\bar{E}|^2 \sin\theta d\theta d\phi \\
 &= \frac{1}{2} (\epsilon/\mu)^{1/2} \pi |A|^2 (C_x^2 + C_y^2) \int_0^{\pi} [ |E_{\theta}|^2 + |E_{\phi}|^2 ] \sin\theta d\theta
 \end{aligned}$$

(2.113)

Equating the input power  $P_i$ , which is known, to the radiated power, the excitation constant  $A$  is found to be

$$|A|^2 = \frac{P_i}{(C_x^2 + C_y^2) P_h} \quad (2.114)$$

where

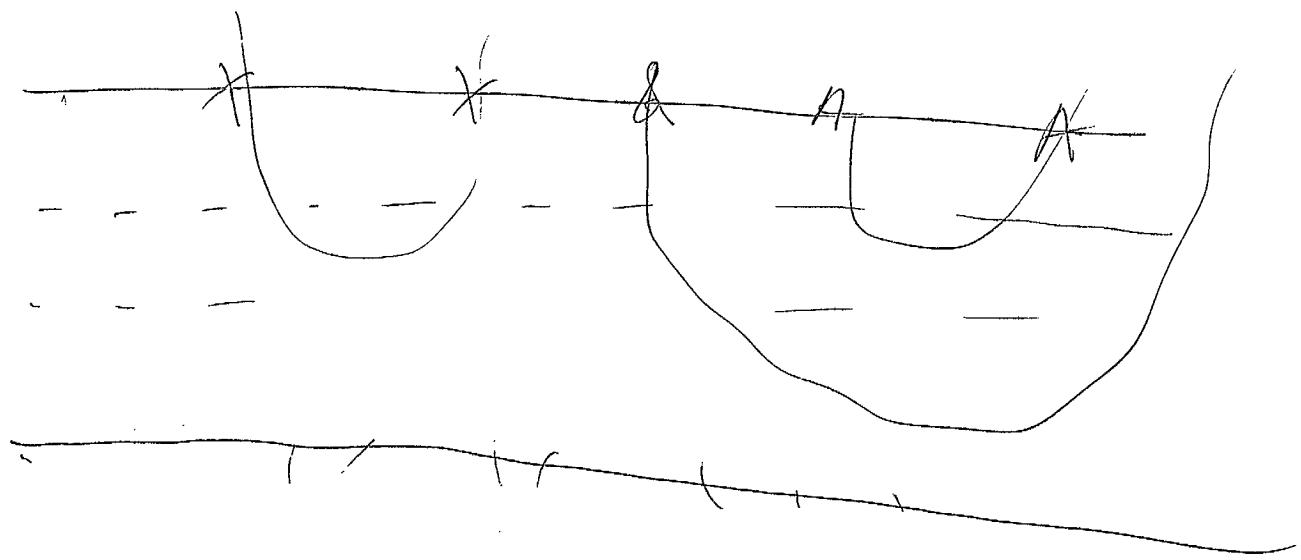
$$P_h = \frac{1}{2} (\epsilon/\mu)^{1/2} \pi \int_0^{\pi} [ |E_{\theta}|^2 + |E_{\phi}|^2 ] \sin\theta d\theta$$

If the feed is not diagonally symmetric such as a pyramidal or elliptical horn, then exciting the 'X' and 'Y' ports will yield an elliptically polarized radiated pattern of

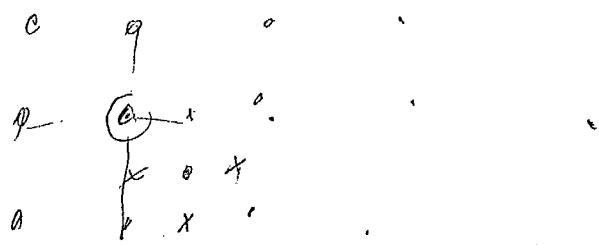
$$\begin{aligned}
 \bar{E} &= \hat{\theta} [ C_x E_{x\theta} \cos\phi + C_y e^{+j\psi} \cdot E_{y\theta} \sin\phi ] - \hat{\phi} [ C_x E_{x\phi} \sin\phi - \\
 &\quad C_y e^{+j\psi} \cdot E_{y\phi} \cos\phi ]
 \end{aligned}$$

Here, the E- and H-plane patterns of the two ports are not the same and must be supplied by the user or calculated separately.

The freedom to choose  $C_x$ ,  $C_y$  and  $\psi$  also allows the user to simulate the effects of non-ideal polarizers on the cross-polarization performance of the secondary beam.



Photograph of sandal



## 2.9 CONTOUR PLOTTING PROGRAM

Output from the reflector analysis program is a gain matrix computed on a rectangular elevation - azimuth grid. The grid is usually coarse to reduce the number of observation points. To get a quick idea of the shape of the secondary beam, gain contour plots over the coverage area on a line printer are desirable.

Program DSCRPLT\_SIF has been developed for this purpose. Its usage and listing are given in Appendix E.

The gain matrix is first expanded on a finer grid using a method of interpolation in which the function and its first derivative are continuous at all points. The gain function in an elevation or azimuth cut is known at a series of given spatial points  $x_1, x_2, x_3 \dots$ . The classical solution is to pass a polynomial through a number of points near the interpolated value of  $x$ . This leads to discontinuity in the curve. Instead, two smoothing polynomials are found over any given interval and a weighted average is taken. The weighting  $w$  is a function of the independent variables and it vanishes with zero slope at the end of the interpolation interval. The idea of this method is illustrated in Figure 2.9.

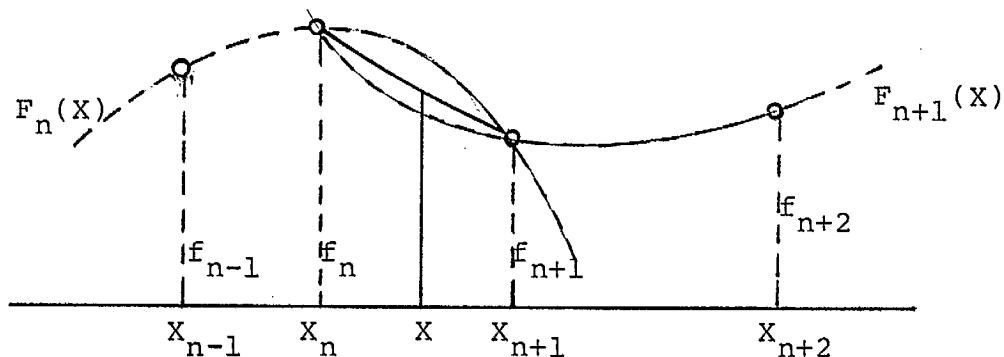


Figure 2.9 Weighted Quadratic Interpolation

In the range  $x_n$  and  $x_{n+1}$ , two second order polynomials may be used, the first,  $F_n$ , fitting exactly  $f_{n-1}$ ,  $f_n$ ,  $f_{n+1}$  and the second,  $F_{n+1}$ , fitting exactly  $f_n$ ,  $f_{n+1}$ ,  $f_{n+2}$ .

The weighted average at  $x$  is then

$$F(x) = WF_n(x) + (1 - W) F_{n+1}(x) \quad (2.115)$$

where  $W$  is a function of  $x$  such that

$$W(x_n) = 1, \quad W(x_{n+1}) = 0, \quad \frac{dW}{dx} \Big|_{x_n} = \frac{dW}{dx} \Big|_{x_{n+1}} = 0$$

(2.116)

The function  $W$ , satisfying the above conditions of eqn. (2.116), takes on the form

$$W = 1 - 3\alpha^2 + 2\alpha^3 \quad (2.117)$$

where

$$\alpha = \frac{x - x_n}{x_{n+1} - x_n}$$

The two interpolation polynomials may be readily written as

$$\begin{aligned} F_n(x) &= f_{n-1} \frac{(x-x_n)(x-x_{n+1})}{(x_{n-1}-x_n)(x_n-x_{n+1})} + f_n \frac{(x-x_{n-1})(x-x_{n+1})}{(x_n-x_{n-1})(x_n-x_{n+1})} + \\ &\quad f_{n+1} \frac{(x-x_{n-1})(x-x_n)}{(x_{n+1}-x_{n-1})(x_{n+1}-x_n)} \quad (2.118) \\ F_{n+1}(x) &= f_n \frac{(x-x_{n+1})(x-x_{n+2})}{(x_n-x_{n+1})(x_n-x_{n+2})} + f_{n+1} \frac{(x-x_n)(x-x_{n+2})}{(x_{n+1}-x_n)(x_{n+1}-x_{n+2})} + f_{n+2} \frac{(x-x_n)(x-x_{n+1})}{(x_{n+2}-x_n)(x_{n+2}-x_{n+1})} \end{aligned}$$

Employing this interpolation technique, the grid interval of the original gain matrix is divided into smaller intervals, i.e. additional rows and columns are added to the matrix.

The line printer is a discrete plotting device. The smallest step across the page is determined by the number of characters per inch (Cpi) setting of the printer. Similarly, the smallest step along the page is fixed by the number of lines per inch (lpi) setting. The printer starts plotting by making the first cut across the page. This cut may be an elevation or azimuth cut, depending on the orientation of the plot and is at one end of the observation frame. A quadratic polynomial is fitted through each group of points in turn and progressively across the cut. The intersections of this curve with the gain contour lines define the locations of the gain contour points, which are then plotted. The relative positions of these points depend on the across page axis scale and the printer Cpi setting specified. The printer then advances to the next cut along the page. The location of this cut is dependent on the along page axis scale and the lpi setting. The gain values for this cut are obtained from the new gain matrix. A similar search across this cut is made to locate the contour points. The whole process is repeated till the printer head has reached the other end of the observation frame. The results of this plotting are gain contours defined by discrete symbols.

Interpolation is only one dimension along the horizontal line  
one line is printed at a time and Interpolation and  
Contour curving points are identified on line by line basis

What about interpolated new lines?

### 3.0 SHAPED BEAM ANTENNA DESIGN STUDY

The computer programs developed in the previous sections were utilised in the design study of shaped beam antennas using two different techniques. The first method makes use of the reflector surface while the second employs multiple feeds to produce the required beam shape.

#### 3.1 SHAPED BEAM FOR RADARSAT APPLICATION

With a reflector antenna, there are two principal methods of generating shaped beams. The most frequently used method is to dispose a linear or planar array of horn feeds in or near the focal plane of a parabolic reflector and then exciting them with the appropriate amplitude and phase. Each feed produces a component beam and these overlapping beams are combined to form a shaped sector beam. In other words, these horn feeds are used to produce a  $\sin X/X$  type illumination across the reflector aperture. Fourier transform of this type of distribution gives the required shaped secondary beam.

Instead of using the feed to produce the required aperture distribution, one could also use the reflector for this purpose. For instance, a simple method of producing a sector beam is to divide the reflector into an inner ring and an outer ring. A cross-section through this reflector will have three parts. The two outer parts have a focal length that is  $\lambda/4$  longer or shorter than the centre part so that illumination of the outer sections of the aperture is 180 deg. out of phase with that of the centre region. However, all sections have the same focal point i.e.

they are confocal. With the horn feed producing a normal primary pattern, stepping of the reflector in such a manner will produce a crude approximation to the  $\sin X/X$  illumination. If this method of generating a scanned sector beam is successful, then a flat lens surface with dipole elements may be used in place of the reflector. The phase shift in this case will be provided by controlling the lengths of the dipoles. This is the main reason for investigating this type of reflector.

To analyse a stepped reflector, the original parabolic reflector program for rectangular apertures may be used after some modifications. Since this program already has the capability of dividing up the aperture into a number of segments, then by adding the option of specifying the focal length for each section, the performance of such composite reflectors can be readily evaluated.

The radiation pattern of the feed horn (E-plane = 12", H-plane = 2.25") used to illuminate the baseline Radarsat reflector ( $X\text{-dim} = 80"$ ,  $Y\text{-dim} = 550"$ ,  $f = 236"$ ) is drawn in Fig. 3.1. Angle subtended by the edge of the reflector is  $\theta = 9.7^\circ$ . The E-plane secondary patterns from the stepped or composite reflector for an on-axis feed are plotted in Fig. 3.2, together with the pattern from a perfect parabolic surface. The percentage referred to in the figures is the percentage of the total aperture that is anti-phased with the centre aperture. The greater the percentage, the wider the beam but also the higher the sidelobe level. This sidelobe level may be reduced at the expense of complexity by using more rings.

When an array of three of these horns is used to illuminate the reflector on-axis, the sector beam produced in the

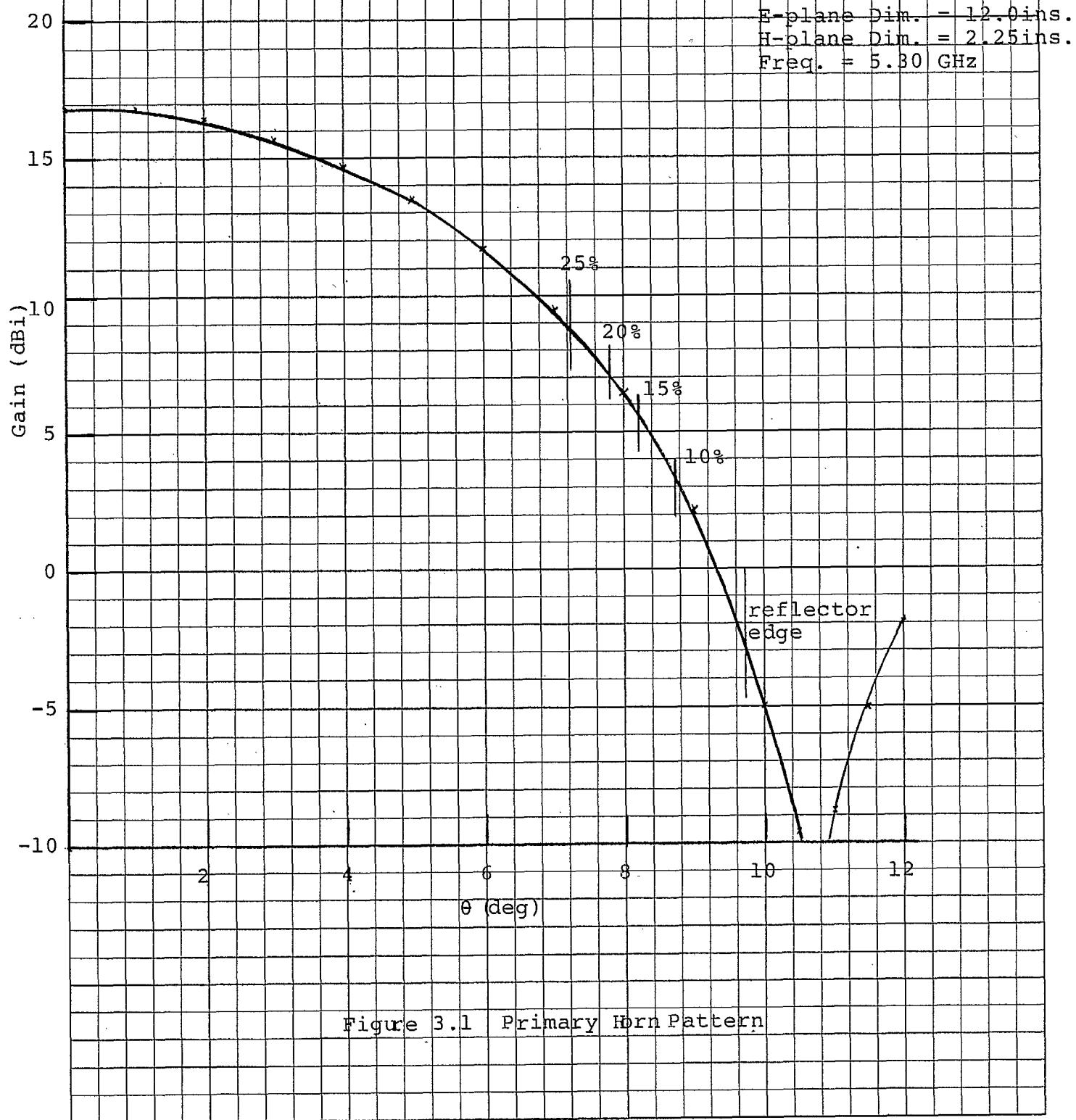
E-plane or elevation plane is shown in Fig. 3.3. The gain at the edge of coverage is approximately the same as that from a perfect parabola. As this array of horns is moved off-axis to provide a scanned beam, the beamwidths of the individual component beams become narrower as depicted in Fig. 3.4. On-axis, the 3-dB shaped beamwidth is  $2.8^\circ$ . At  $10^\circ$  off-axis, the half-power beamwidth has decreased to  $2.5^\circ$ . The beam from the perfect parabola, on the other hand, has widened. Couple this with their higher peak gain, the scanned beam from the perfect parabola has slightly better performance than that from the composite reflector as depicted in Fig. 3.5. The sensitivity of the beamwidth to scanning in the stepped reflector is due to the departure from the anti-phase condition at the aperture. From the above results, it can be seen that there is no particular advantage in using a stepped reflector in situation where the focal length is necessary long.

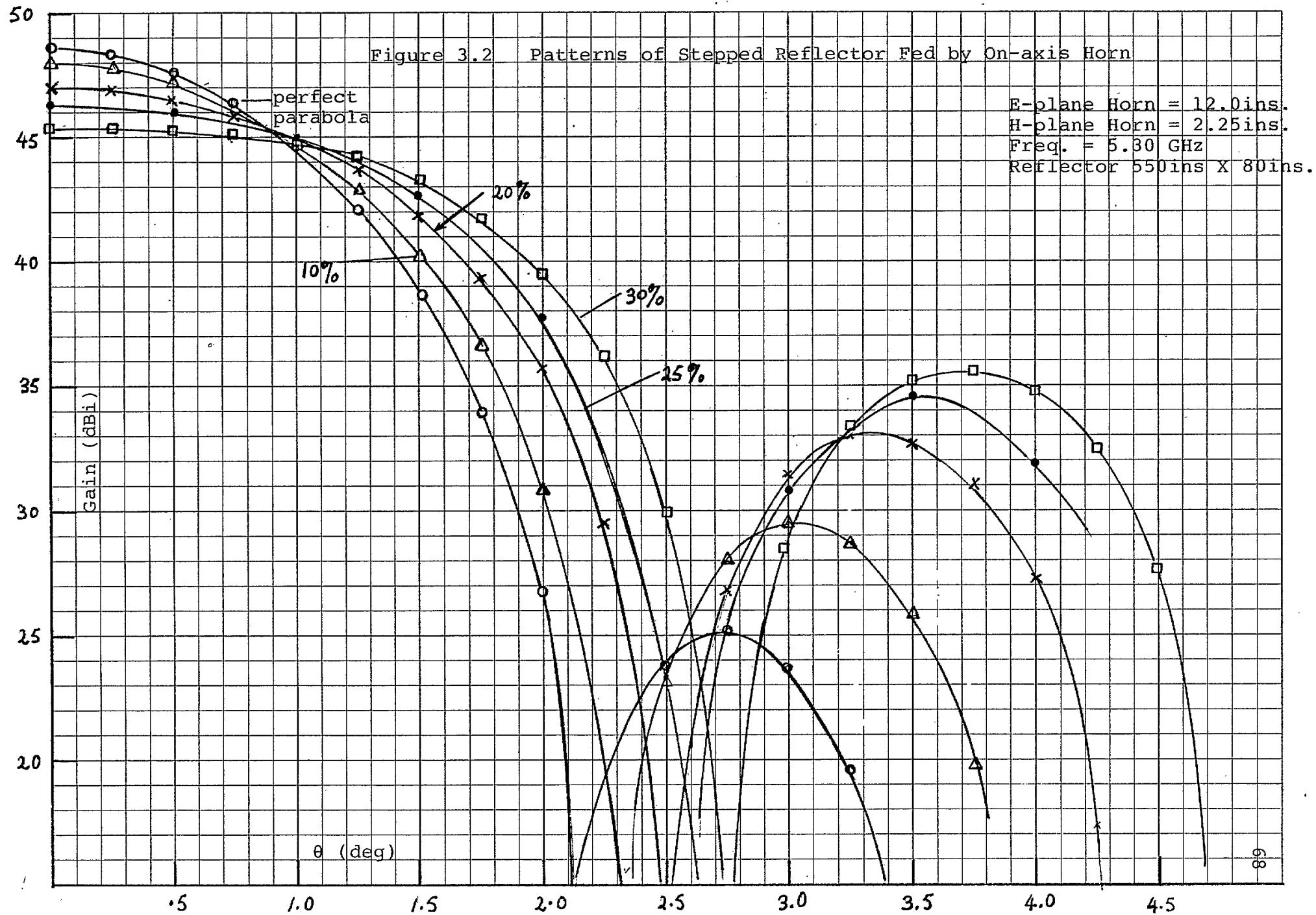
The performance of a centre-fed stepped reflector with a shorter F/D (=1) was next investigated. The reflector has a square aperture of 70" by 70" and a focal length of 70". The frequency of operation is 11.803 GHz. The components beams from this reflector for an on-axis and off-axis feed are shown in Fig. 3.6. The E- and H-plane dimensions of the feed horn are  $1\lambda$  and  $2.25\lambda$  respectively. Three of these horns are combined to give the sector beam of Fig. 3.7. The distance between beams is not large enough to take advantage of the broadened component beams. As the E-plane horn dimension is increased, the higher the edge gain or broader coverage resulting from a stepped reflector is clearly demonstrated in Fig. 3.8 and 3.9. In fact to produce the same coverage from a perfect parabolic reflector, four horns with E-plane dimension of

1.12 ins are needed as shown by the pattern of Fig. 3.10.

This investigation has indicated that for shaped beams with small scan, the shaped reflector does reduce the number of feeds required. But the added complexity of a shaped reflector may off-set this advantage. Since the effect of beam broadening or shaping is dependent on path length constraint, moving the feed off-axis destroyed this condition. The improved performance for an on-axis beam does not carry over to a wide scanned beam. In the case of a reflector with a large F/D, large horns are also required for efficient illumination. To minimise quadratic phase errors across the horn aperture, either a very long horn length or a phase correcting device in the form of a dielectric lens is required. It may be easier to break-up the large horn aperture into an array of smaller horns. One can conclude that for Radarsat purpose, the stepped reflector does not offer better gain performance nor does it lead to any great simplification of the feed network.

The broadened component beam from a shaped reflector is not necessarily a positive feature when it comes to forming a composite beam. This is because the phase is varying across each beam and it is not possible to have all the beams add up in-phase everywhere within the space spanned by these beams. This invariably results in both constructive and destructive interference between the beams leading to observed large ripples and less than expected increase in coverage. In the case of the perfect parabolic reflector, the faster fall-off and lower sidelobes of the component beams cause less interference. Hence a smoother beam results.





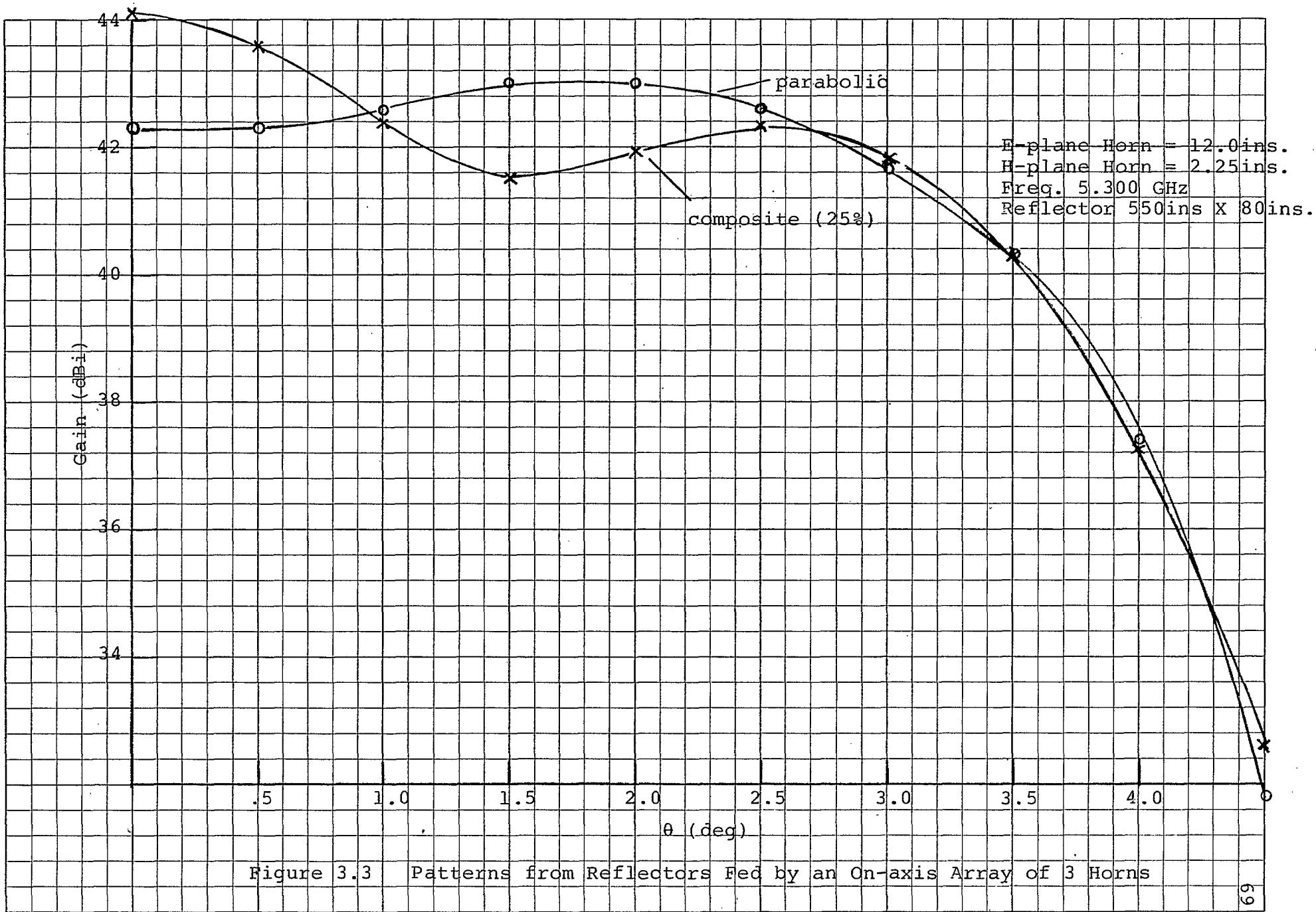
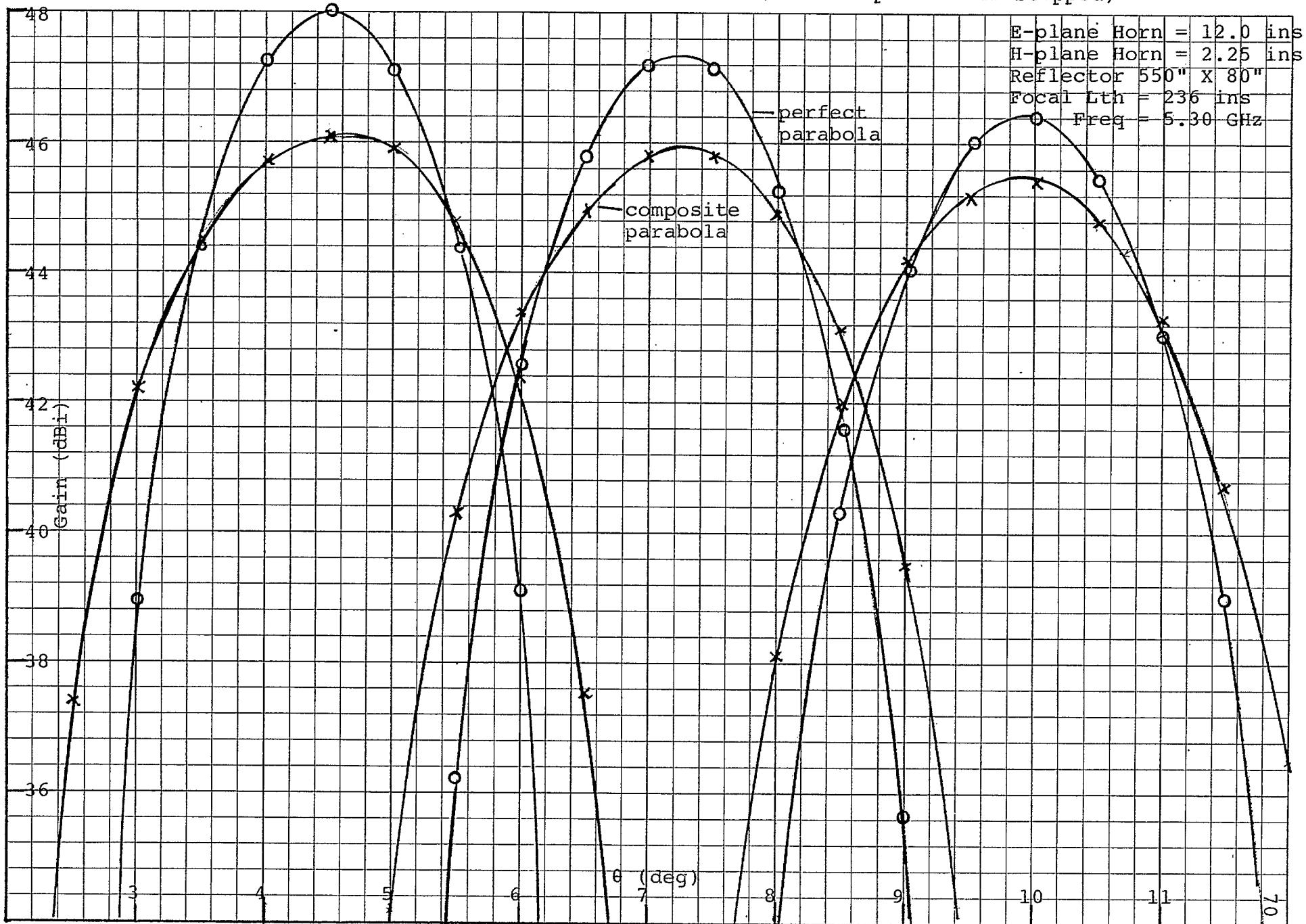


Figure 3.4 Component Beams from Off-Axis Feeds. (25% of aperture is stepped)



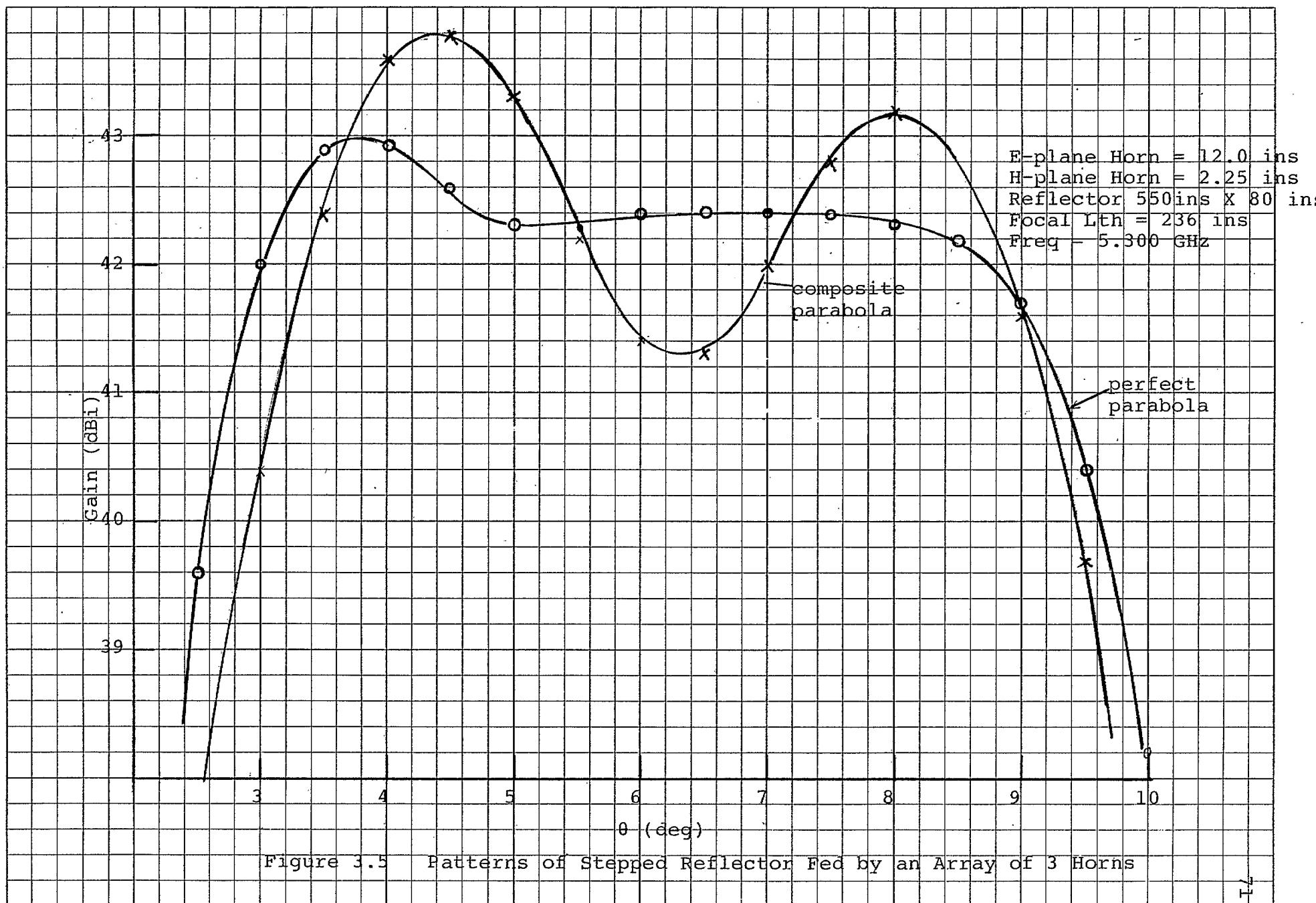


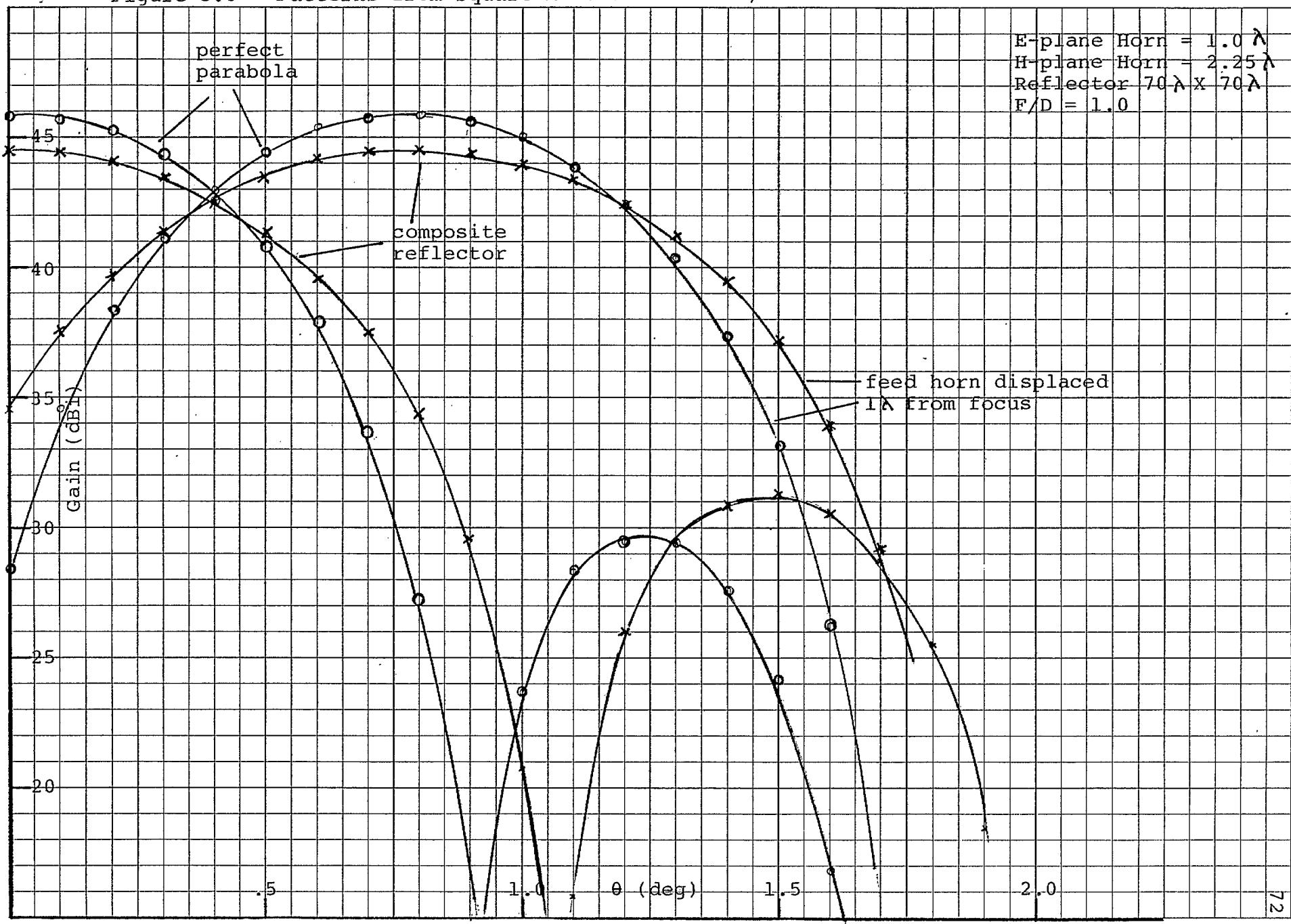
Figure 3.6 Patterns from Square Reflector with  $F/D = 1$ 

Figure 3.7 Secondary Patterns from Square Reflector Fed by an Array of 3 Horns

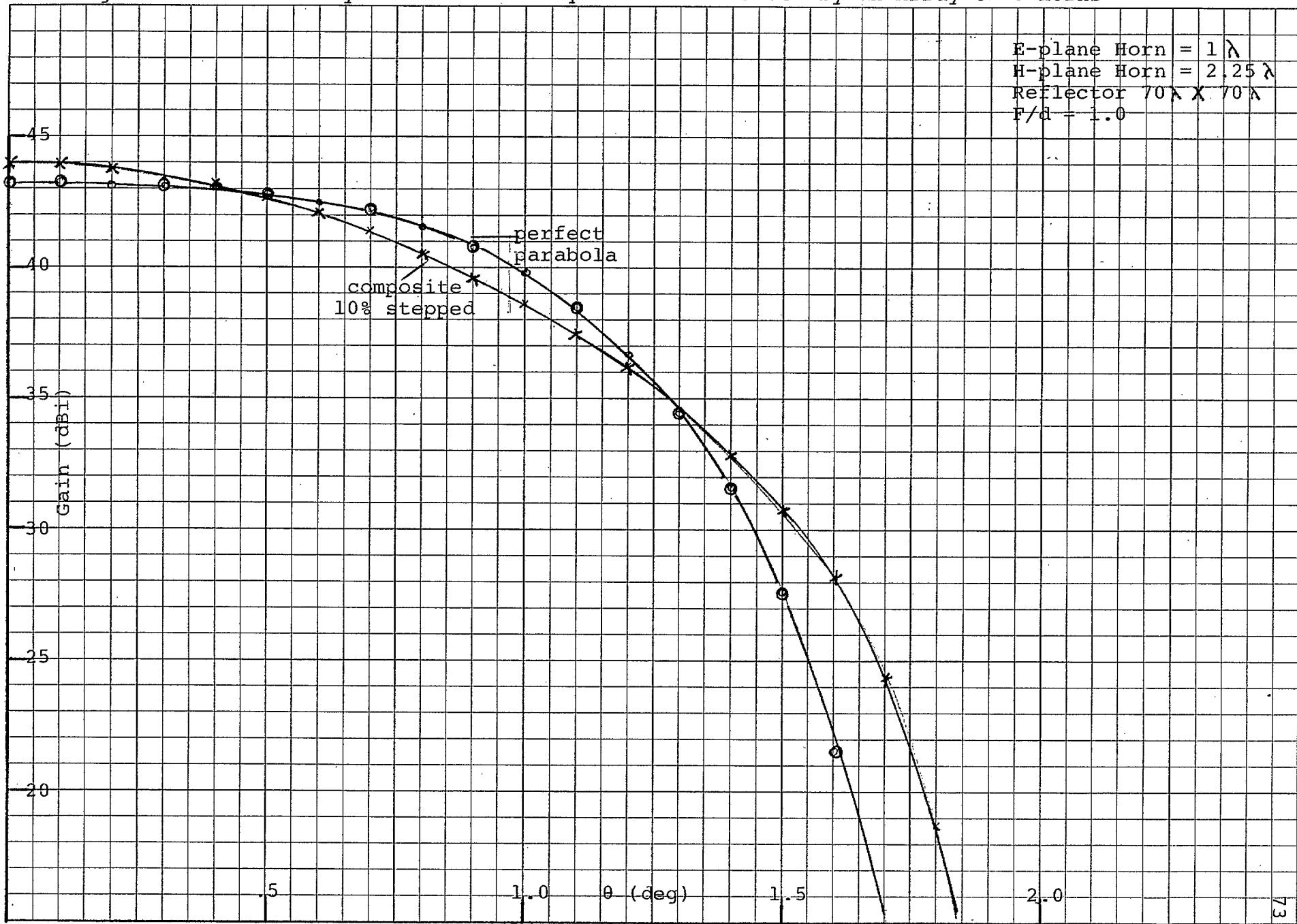


Figure 3.8 Secondary Patterns from Square Reflector Fed by an Array of 3 Horns

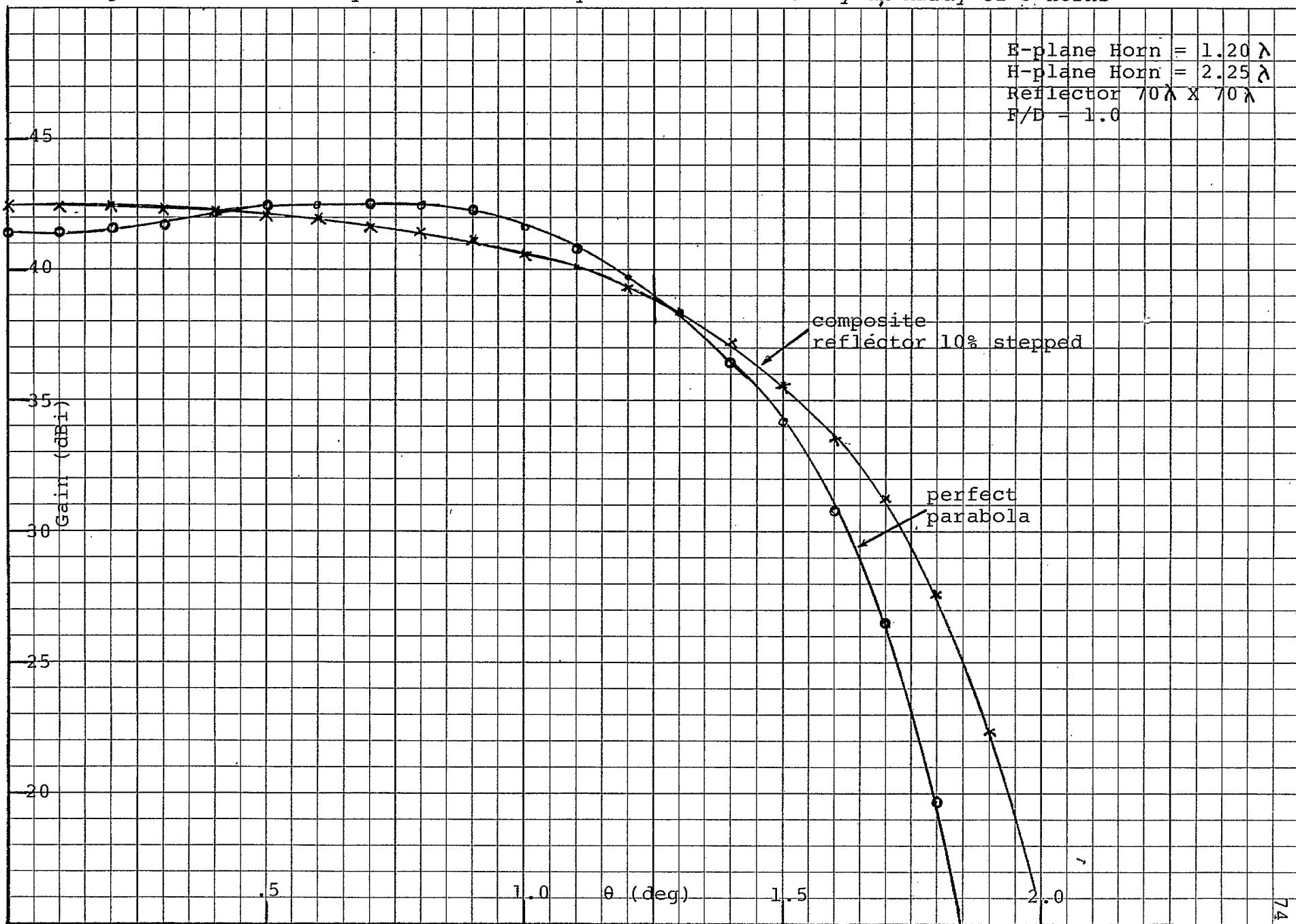
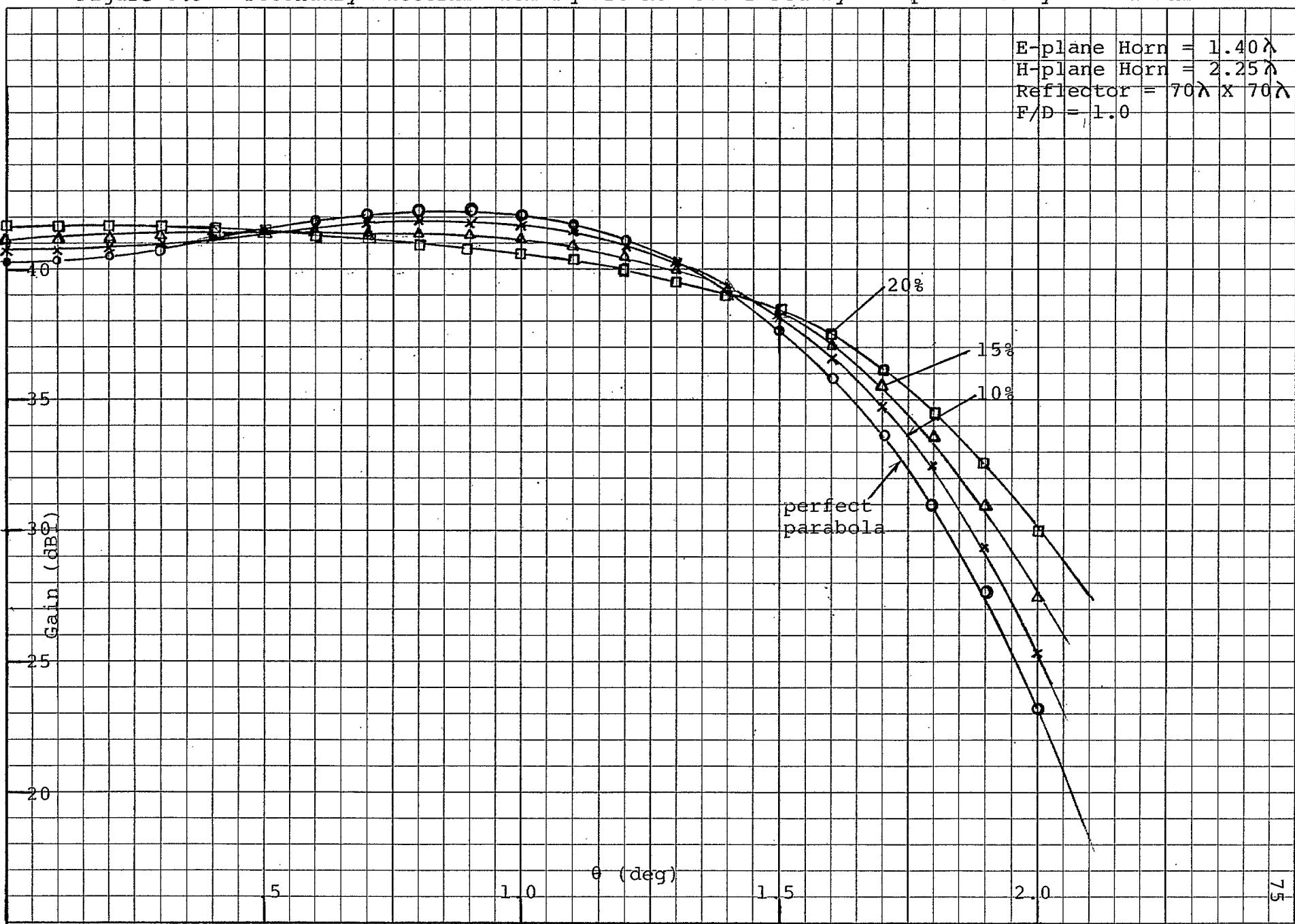
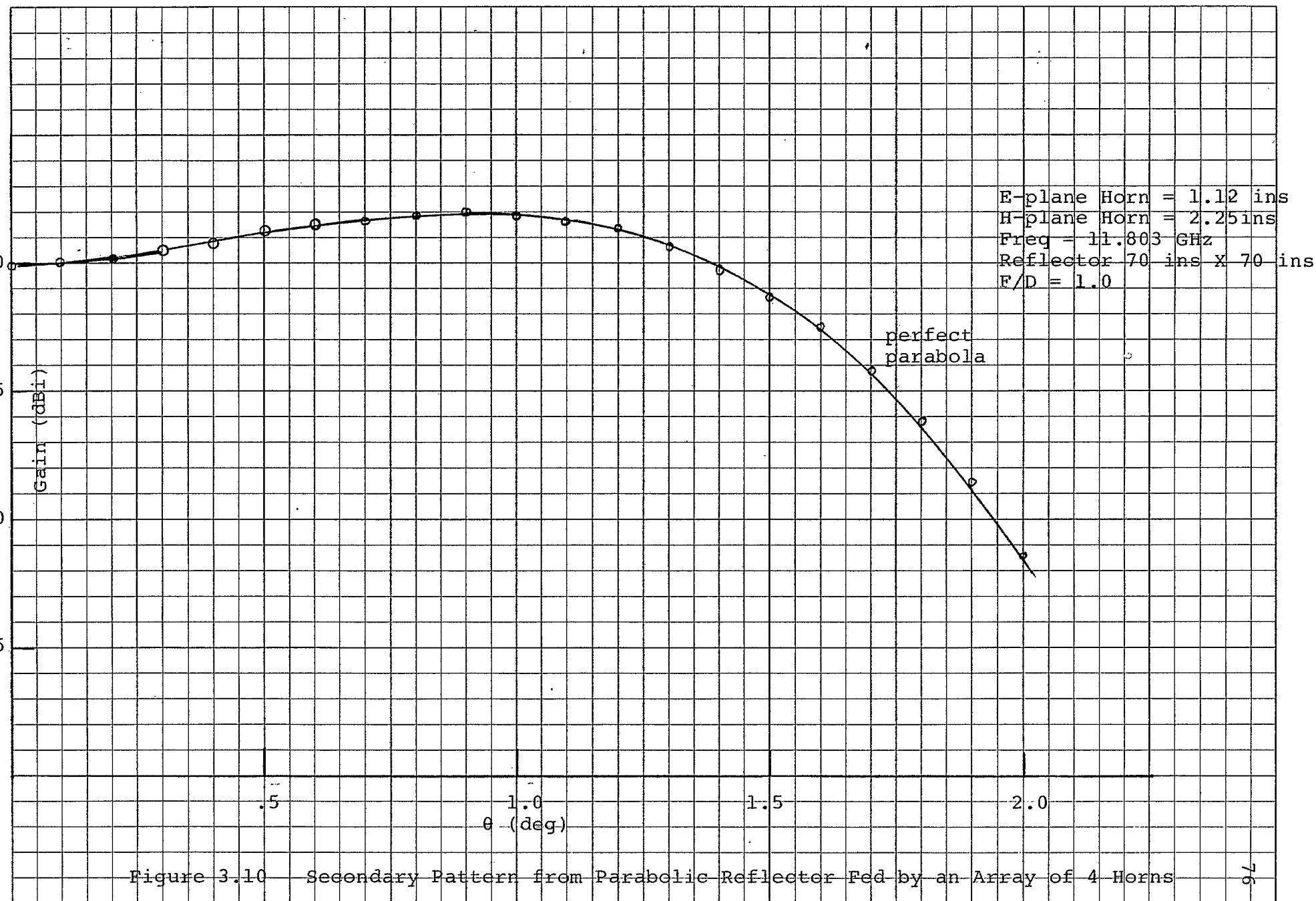


Figure 3.9 Secondary Patterns from Square Reflector Fed by a E-plane Array of 3 Horns





### 3.2 DESIGN OF SHAPED BEAMS FOR CANADIAN BROADCASTING SATELLITE

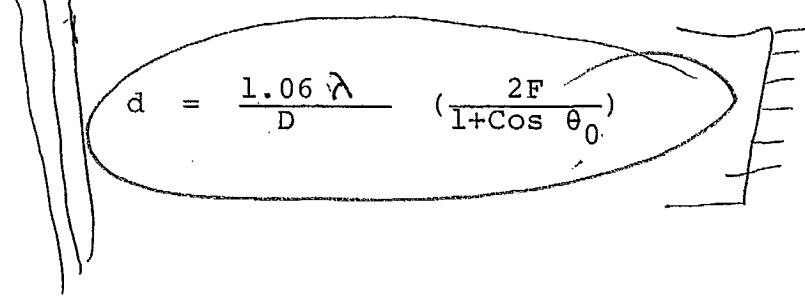
Two of the direct broadcasting satellite (DBS) coverage areas assigned to Canada have the most probability of their coverage beams producing interference into adjacent countries. In other words, there are the worst case beams. CAN101 beam from a satellite located at Long.  $138^{\circ}$  W covers British Columbia and Alberta. It has the potential of its illumination over USSR exceeding the permitted level. Similarly, CAN504 beam from Long.  $91^{\circ}$  W, which covers the Atlantic provinces, might over illuminate Iceland. The goal here is to design the two shape beams with minimum interference into adjacent areas.

The first step in any communication or broadcasting satellite antenna design is to plot the coverage areas as seen by the satellite. These maps are drawn in Figures 3.11 and 3.12. The triangles in the plots define the service areas. The stars and circles are representative points in Regions 1 and 2 respectively at which the eirp must not exceed a given level. Those points that are close to the service coverage are potential problem areas.

Next, the size of the reflector, its focal length and locations of the horns must be determined. A large reflector is required to ensure that the sidelobes decay at a fast rate. At the same time, too large a reflector would require too many component beams. By considering the extent of the coverages, component beams with 0.55° half-power beamwidths are found to provide the required beam shape as shown by the beam layout in Figures 3.13 and 3.14. The beams are arranged in a triangular lattice. This component beam size dictates a 106 ins diameter reflector ( $112\lambda$ ) at 12.45GHz). For circular polarization application, it is

~~L'eg  
Troll will mit  
Ophelia~~

advisable to use the multimode conical (Potter) horn as feed to minimise cross-polarization due to mutual coupling. The minimum horn aperture size that one could use without getting too dispersive for the  $TM_{11}$  mode is approximately  $1.30 \lambda$  (1.24 ins) diameter. The remaining parameters, focal length  $F$  and feed tilt angle,  $\theta_0$  can be obtained from the approximate equation



(3.1)

where

$$d = \frac{1.06 \lambda}{D} \left( \frac{2F}{1 + \cos \theta_0} \right)$$

$D$  = projected offset reflector diameter

$F$  = focal length of paraboloid

$\theta_0$  = feed tilt angle

$\lambda$  = free space wavelength.

This relation is for horn spacing where there is a small cancellation of the secondary pattern sidelobes between adjacent horns. For the design here,  $F$  is chosen to be 124 ins. where  $\theta_0$  becomes  $26.6^\circ$ . The proposed reflector configuration is shown in Figure 3.15.

Horn locations for CAN101 beam are tabulated in Table 3.1 together with the power excitations. All phases have been set to zero. This is not optimum but close enough for our purpose. The resultant contours over the service area and regions 1 and 2 are drawn in Figures 3.16 and 3.17. The gain and eirp at the various designated locations are tabulated in Tables 3.2 and 3.3. As can be seen, the minimum eirp at the service area is easily met.

Feed network loss is calculated to be 0.7 dB in Table 3.4. Gain margins attained could be equalised among the service areas.

EIRP at points outside are below the maximum specified with a comfortable if not substantial margin. It is found that sidelobes are low and decay rapidly when using a large offset reflector.

The locations and excitations of horns for the CAN504 beam are tabulated in Table 3.5. The phases of all horns except one are set to zero. Horn #24 is phased so as to produce a null over Iceland. This can be seen in Figure 3.18 where contours over the service and surrounding areas are depicted. Contours over adjacent regions 1 and 2 are drawn in Figure 3.19. The required eirp over the service points can be easily met while the radiated power in the interference regions is well below the maximum permitted except over Iceland where the margin is reduced to about 4.0 dB. The net eirp at the various reference points are tabulated in Tables 3.6 and 3.7.

These two worst case examples have shown that it is feasible to design shaped DBS beams with low inter-regional interference by using an array-fed offset reflector.

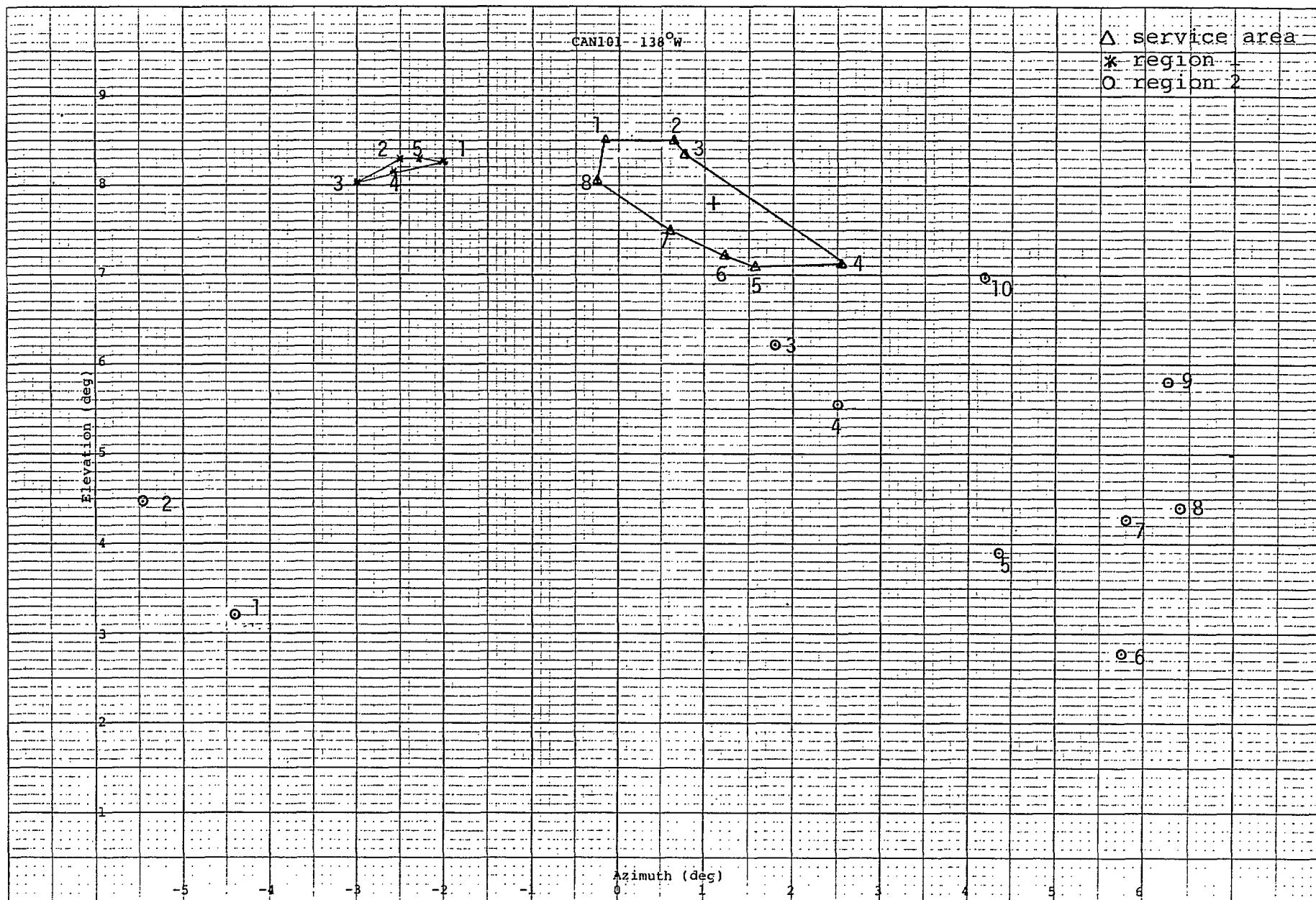
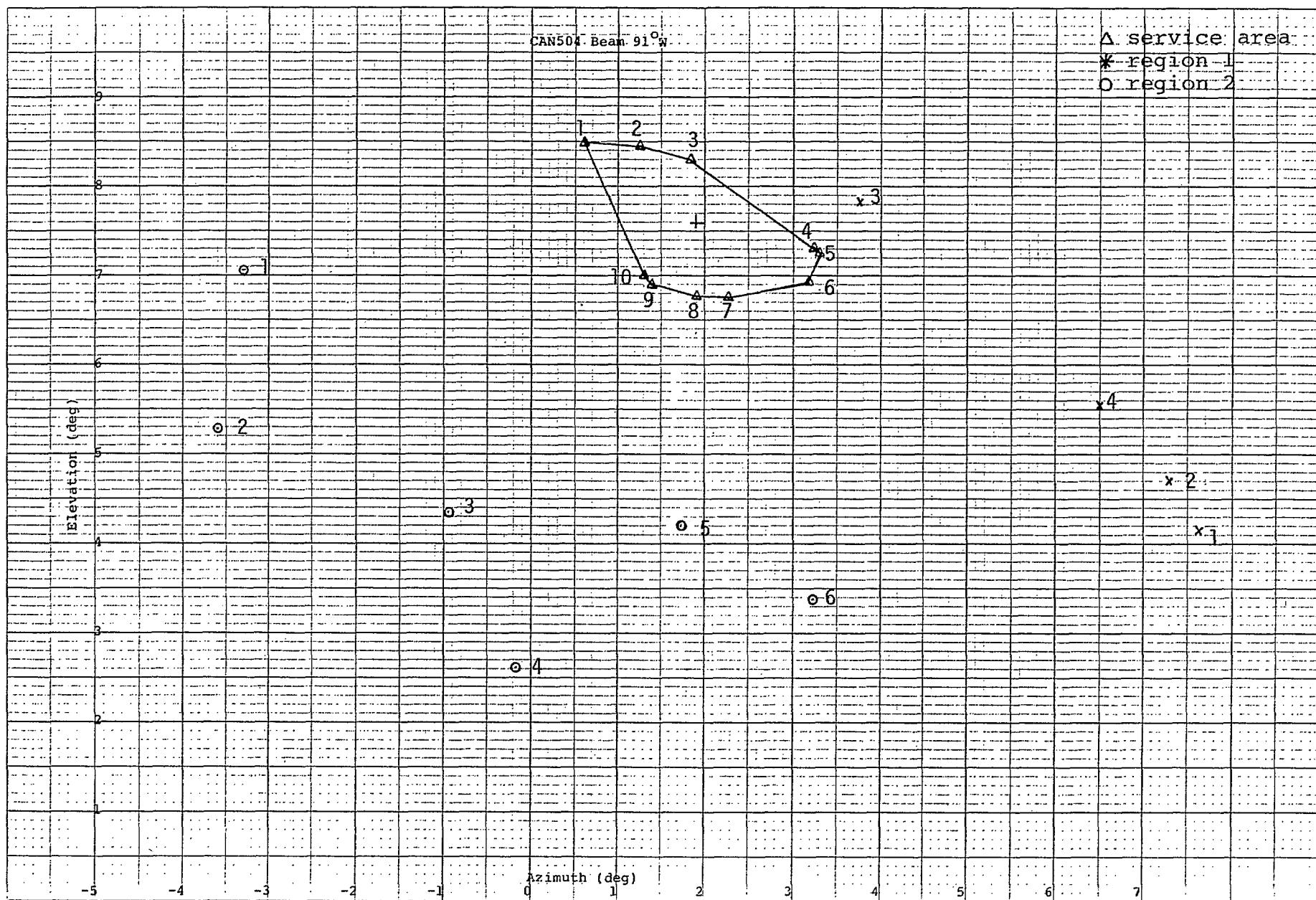


Figure 3.11 Coverage Areas of CAN101 Beam from Long. 138°W

Figure 3.12 Coverage Areas of CAN504 Beam from Long.  $91^{\circ}$ W

CAN101 138°W

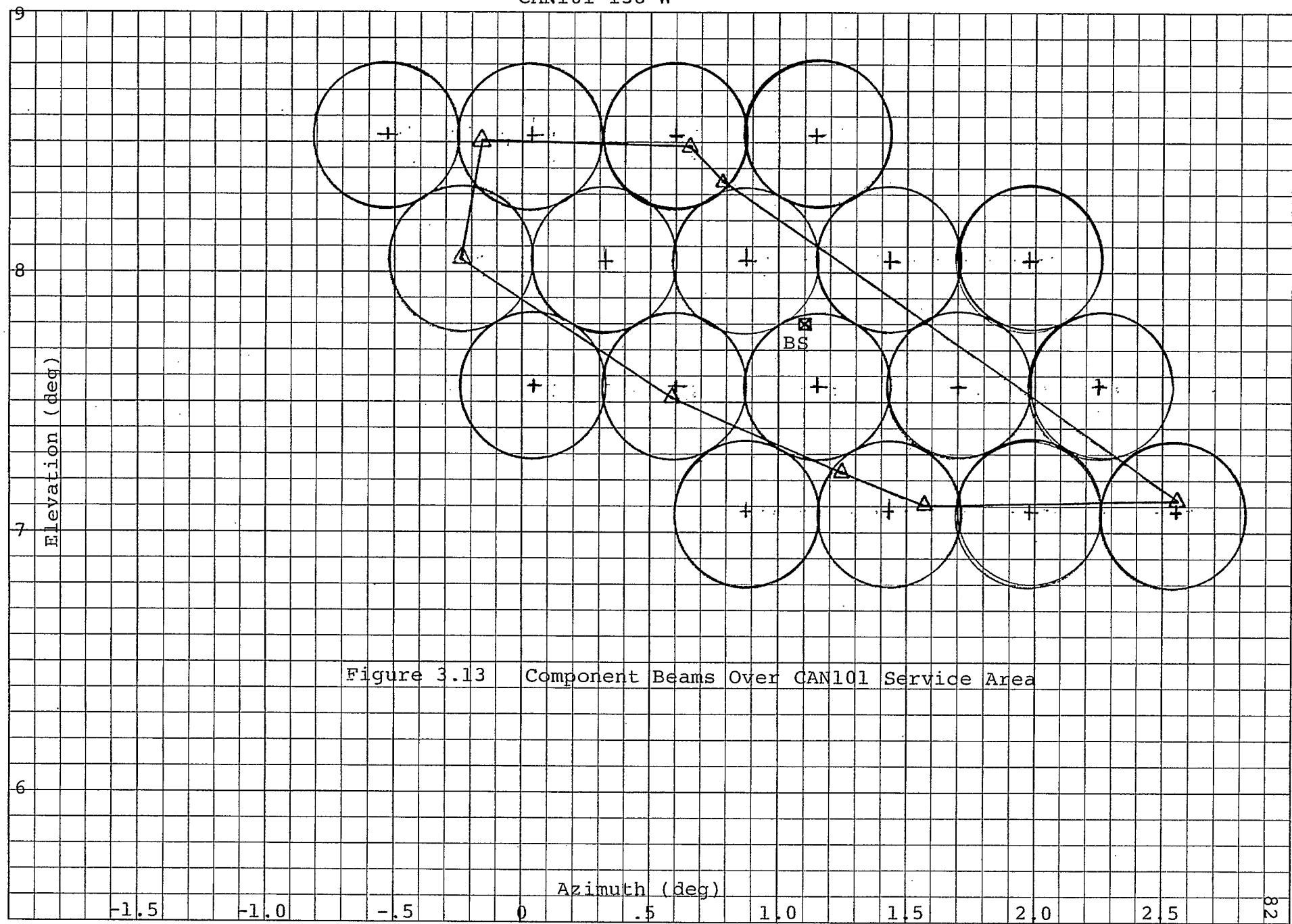
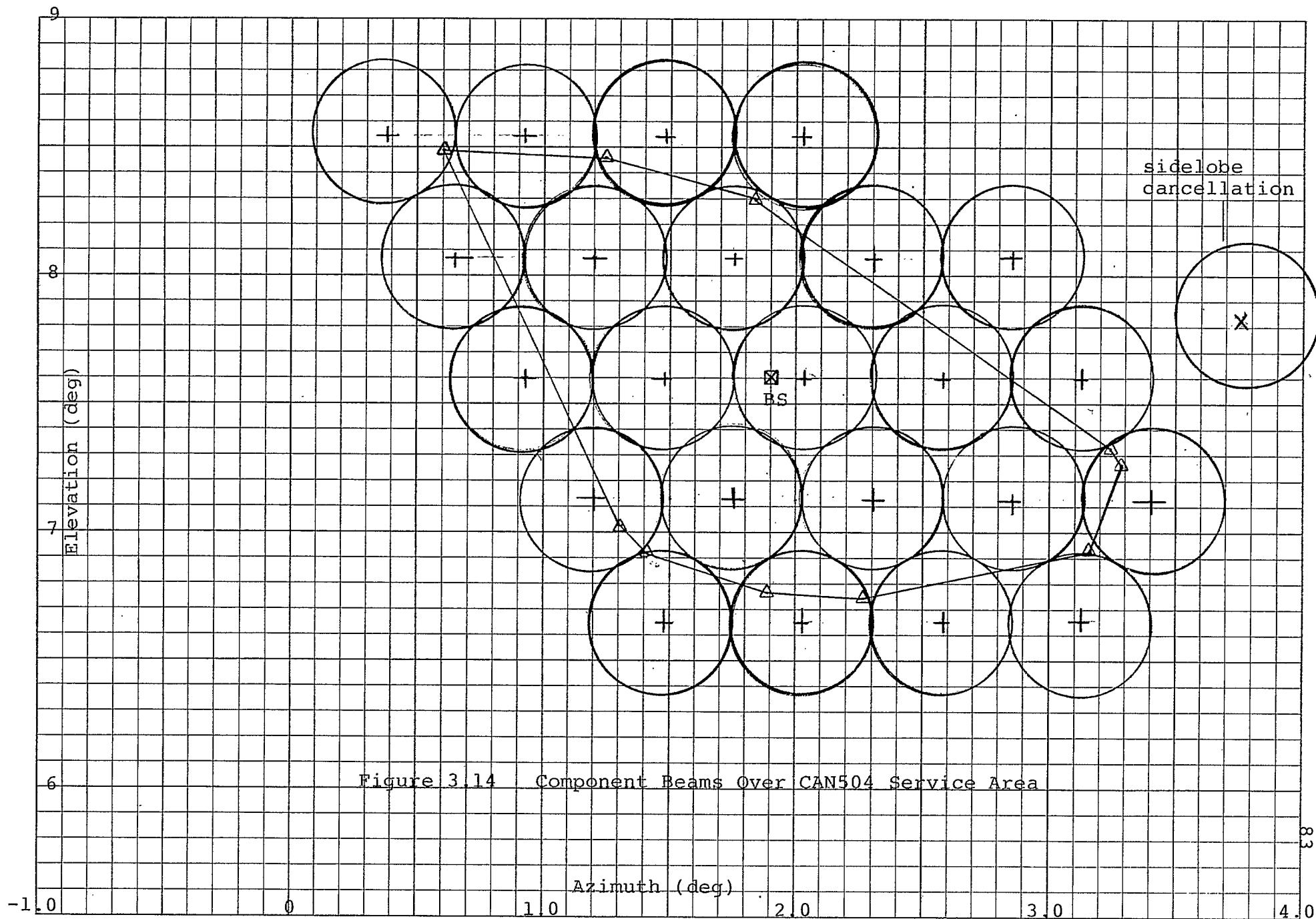


Figure 3.13 Component Beams Over CAN101 Service Area

CAN504 Beam  $91^{\circ}\text{W}$



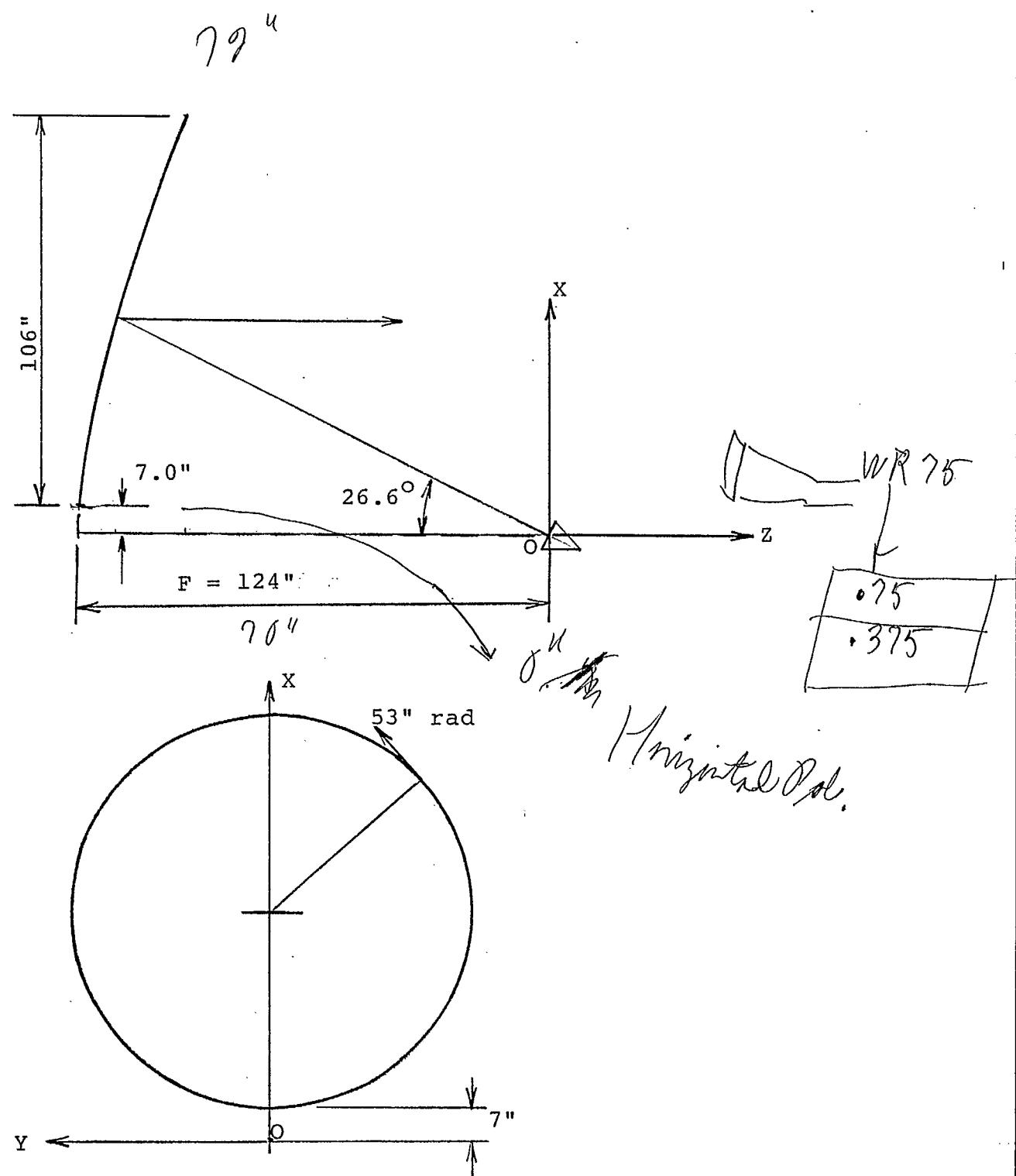


Figure 3.15 DBS Reflector Configuration

DBS BEAM CANADA 101 (POTTER FEED HORNS )  
 START AND STOP VALUES OF SCAN RANGE (DEG) AND NUMBER OF COMPUTED POINTS  
 AZS = -1.75    AZE = 1.75    NAZ = 15  
 ELS = -1.00    ELE = 1.00    NEL = 9

GAIN MATRIX (DB)

	-1.75	-1.50	-1.25	-1.00	-0.75	-0.50	-0.25	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75
-1.75	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
-1.50	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
-1.25	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
-1.00	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
-0.75	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
-0.50	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
-0.25	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
0.00	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
0.25	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
0.50	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
0.75	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
1.00	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
1.25	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
1.50	41.00	40.00	39.00	38.00	37.00	35.00	32.00								
1.75	41.00	40.00	39.00	38.00	37.00	35.00	32.00								

AZIMUTH AXIS SCALE = .50000 DEG/INCH

ELEVATION AXIS SCALE = .50000 DEG/INCH

BORESIGHT    AZ = .00    EL = .00 DEG

CONTOUR SYMBOLS AND CORRESPONDING DB VALUES

SYMBOL	+	-	*	\$	@	§	+
DB VALUE	41.00	40.00	39.00	38.00	37.00	35.00	32.00

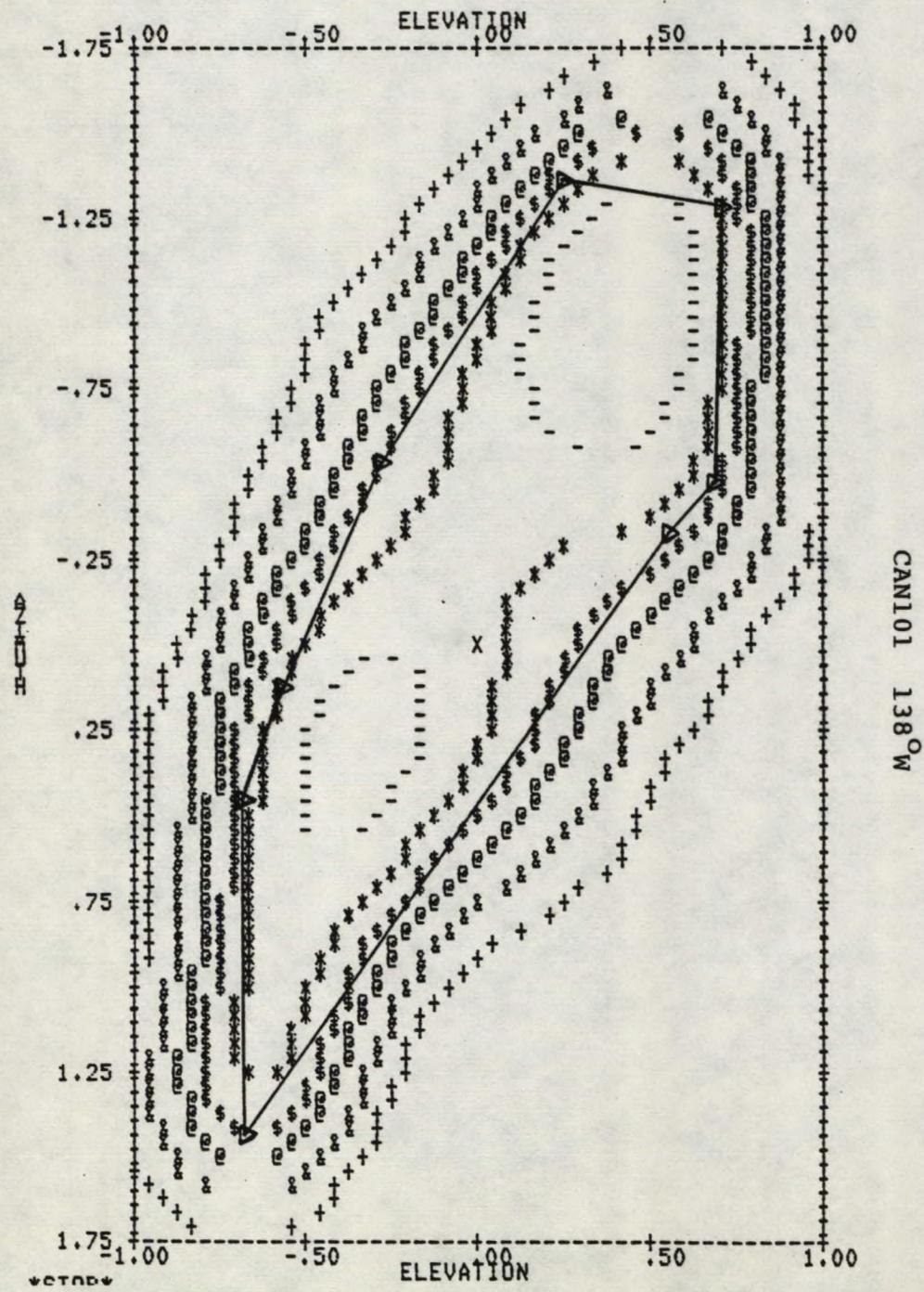


Figure 3.16 Gain Contours Over CAN101 Service Area

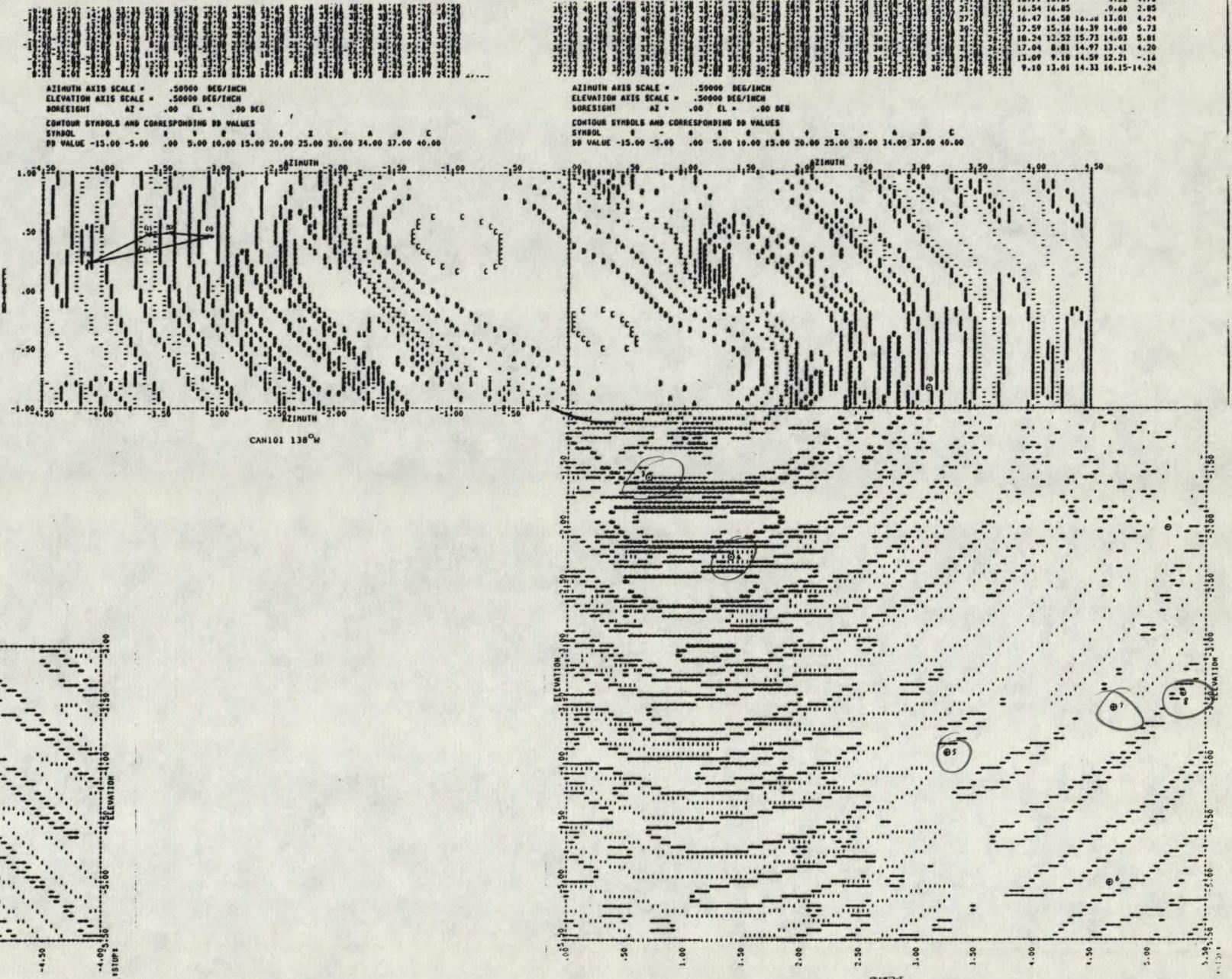
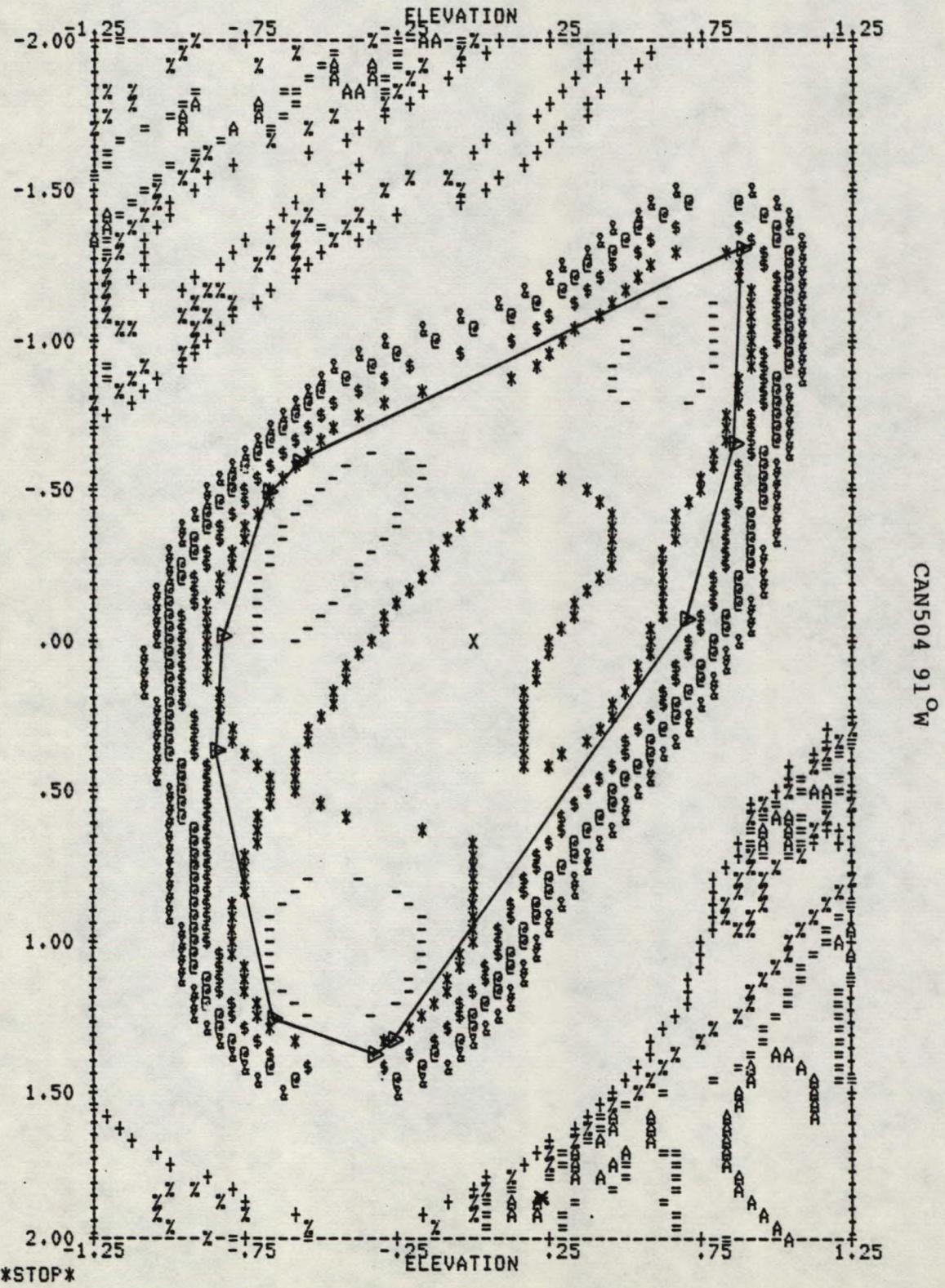


Figure 3.17 Extended Coverage of CAN101 Beam

Figure 3.18 Gain Contours Over CAN504 Service Area



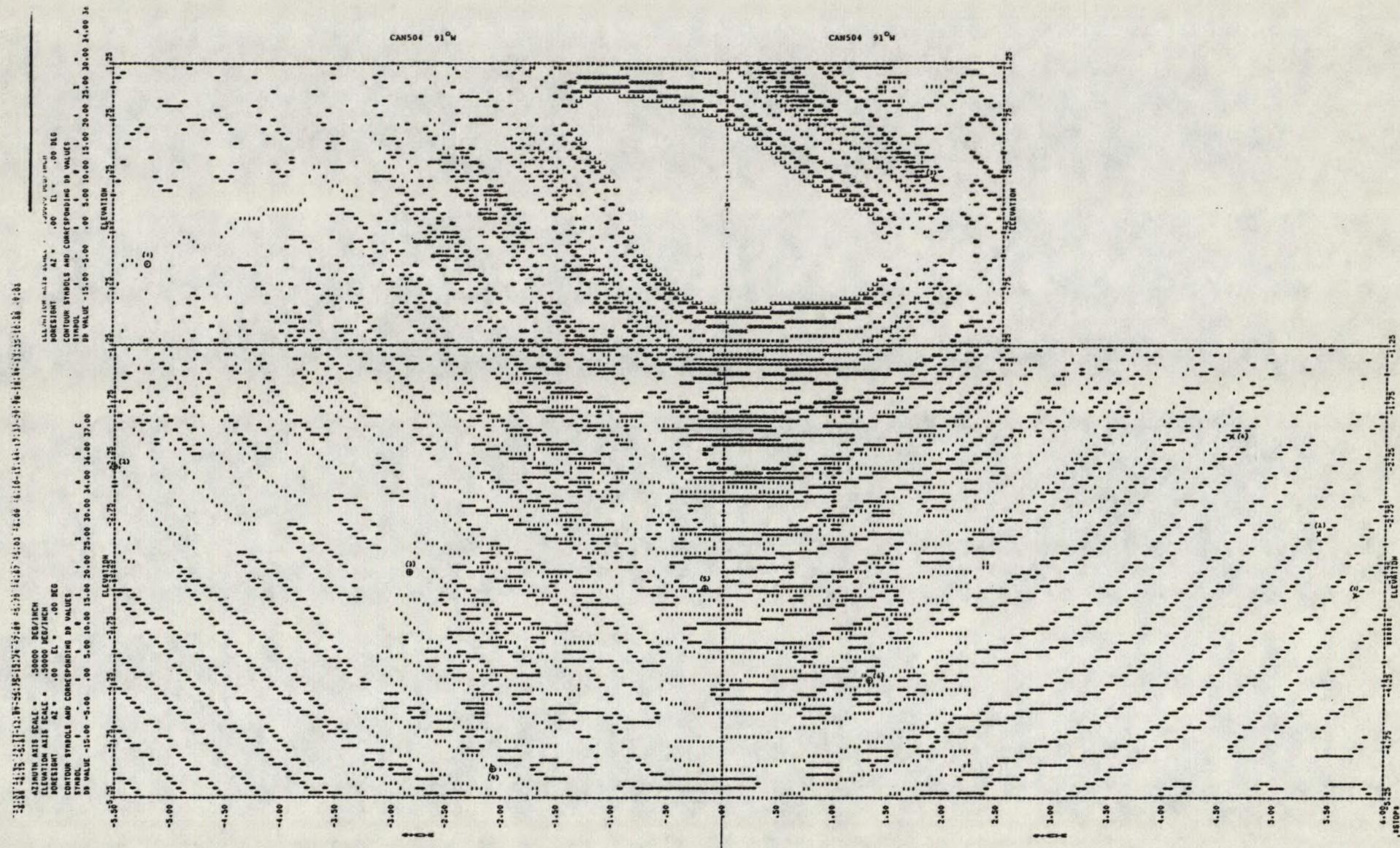


Figure 3.19 Extended Coverage of CAN504 Beam

Table 3.1 Horn Locations and Excitations for CAN101 Beam

Horn #	X(ins)	Y(ins)	Power	Phase
1	1.610	.500	.015	0.0
2	1.610	-.740	.080	
3	1.610	-1.980	.060	
4	1.610	-3.300	.110	
5	0.530	2.360	.0250	
6	0.530	1.120	.110	
7	0.530	-.120	.050	
8	0.530	-1.360	.070	
9	0.530	-2.600	.010	
10	-0.550	2.980	.090	
11	-0.550	1.740	.045	
12	-0.550	0.500	.055	
13	-0.550	-.740	.060	
14	-0.550	-1.980	.010	
15	-1.630	3.600	.040	
16	-1.630	2.360	.070	
17	-1.630	1.120	.090	
18	-1.630	-0.120	.0100	0.0

Horn Aperture = 1.240 ins dia.

Input Waveguide = 0.700 ins dia.

Horn Length = 5.00 ins

Table 3.2 Service Requirements and EIRP for CAN101 Beam from 138°W

Point	Computed Gain(dBi)	Net Gain (dBi)	EIRP <sup>1</sup> (dBw)	Spec. Min (dBw)	Margin <sup>2</sup>
1	39.0	38.3	57.5	55.8	1.7
2	38.2	37.5	56.7	55.8	0.9
3	38.3	37.6	56.8	56.1	0.7
4	38.0	37.3	56.5	55.9	0.6
5	38.3	37.6	56.8	56.2	0.6
6	39.0	38.3	57.5	56.2	1.3
7	38.0	37.3	56.5	56.2	0.3
8	38.3	37.6	56.8	56.2	0.6

0.7 dB less feed network

!!!

- Note: (1) It is assumed here that 84 watts (19.2 dBw) are available at the antenna port interface.
- (2) The gain can be equalised to give an overall margin of 0.7 dB everywhere.

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Table 3.3 Inter-Regional Requirements and EIRP for CAN101 BeamRegion 1 Requirements

Point	Computed Gain (dBi)	Net Gain (dBi)	EIRP (dBW)	Max. Spec. (dBW)	Margin (dB)
1	-2.0	-2.7	16.5	37.2	20.7
2	-6.0	-6.7	12.5	37.5	25.0
3	-15.0	-15.7	3.6	28.7	25.2
4	-2.0	-2.7	16.5	37.8	21.3
5	+5.0	+4.3	23.5	31.2	7.7

0

Region 2 Requirements

Point	Computed Gain (dBi)	Net Gain (dBi)	EIRP (dBW)	Max. Spec. (dBW)	Margin (dB)
1	-10.0	-10.7	8.5	24.0	15.5
2	-9.0	-9.7	9.5	23.5	14.0
3	+18.0	+17.3	36.5	48.4	11.9
4	-5.0	-5.7	13.5	34.3	20.8
5	-11.0	-11.7	7.5	30.5	23.0
6	-12.0	-12.7	6.5	28.6	22.1
7	-10.0	-10.7	8.5	31.6	23.1
8	-15.0	-15.7	3.5	32.2	28.7
9	-3.0	-3.7	15.5	33.8	18.3
10	-1.0	-1.7	17.5	49.2	31.7

Table 3.4 DBS Feed Network Insertion Loss

	dB	
5 levels of couplers	0.25	—
1 polariser	0.05	—
7½ ft. wg (WR75)	0.30	—
0.012 ins rms surface error	0.11	—
	—	—
	0.71	—
	—	—

Table 3.5 Horn Locations and Excitations for CAN504 Beam

Horn #	X(ins)	Y(ins)	Power	Phase
1	2.160	0.960	.027	0.0
2	2.160	-.280	.053	
3	2.160	-1.520	.038	
4	2.160	-2.760	.030	
5	1.080	1.580	.060	
6	1.080	0.340	.050	
7	1.080	-.900	.048	
8	1.080	-2.140	.055	
9	1.080	-3.380	.054	
10	0.000	2.200	.053	
11	0.000	0.960	.049	
12	0.000	-.280	.050	
13	0.000	-1.520	.048	
14	0.000	-2.760	.049	
15	-1.080	2.820	.041	
16	-1.080	1.580	.047	
17	-1.080	0.340	.051	
18	-1.080	-.900	.041	
19	-1.080	-2.140	.0092	
20	-2.160	3.440	.039	
21	-2.160	2.200	.049	
22	-2.160	0.960	.044	
23	-2.160	-.280	.014	0.0
24	-0.540	-4.300	.008	49.00

*produce the null*

Horn Aperture = 1.240 ins diameter

Input Waveguide = 0.700 ins diameter

Horn Length = 5.000 ins

Table 3.6 Service Requirements and EIRP for CAN504 Beam from 91°W

Point	Computed Gain (dBi)	Net Gain(dBi)	EIRP <sup>(1)</sup> (dBW)	Min. Spec. (dBW)	Margin <sup>(2)</sup> (dB)
1	37.5	36.8	57.0	55.8	1.2
2	37.6	36.9	57.0	55.8	1.2
3	37.3	36.6	56.8	55.8	1.0
4	38.0	37.3	57.5	55.9	1.6
5	37.6	36.9	57.1	56.0	1.1
6	38.3	37.6	57.8	56.7	1.1
7	37.6	36.9	57.1	57.0	0.1
8	38.2	37.5	57.7	57.3	0.4
9	38.0	37.3	57.5	57.1	0.4
10	38.0	37.3	57.5	56.2	1.3

Note: (1) In computing EIRP, it is assumed that 105 Watts (20.2 dBW) are available at the input to the antenna interface.

(2) The gain margin could be equalised to give an overall system margin of 0.7 dB.

Table 3.7 Inter-Regional Requirements and EIRP for CAN504 BeamRegion 1 Requirements

Point	Computed Gain (dBi)	Net Gain (dBi)	EIRP (dBW)	Max. Spec. (dBw)	Margin
1	-15.0	-15.7	4.50	31	26.5
2	-15.0	-15.7	4.50	31.2	26.7
3	1.0	+ 0.3	20.5	24.5	4.0
4	-15.0	-15.7	4.5	34.9	30.4

Region 2 Requirements

Point	Computed Gain (dBi)	Net Gain (dBi)	EIRP (dBW)	Max. Spec. (dBW)	Margin
1	-5.0	-5.7	14.5	32.5	18.0
2	-5.0	-5.7	14.5	29.1	14.6
3	-7.0	-7.7	12.5	29.8	17.3
4	-5.0	-5.7	14.5	27.8	13.3
5	0.0	- .7	19.5	33.0	13.5
6	-3.0	-3.7	16.5	32.0	15.5

GTP

faster combustion of fuel  
includes run effect = edge reflection

## 4.0 PRESENT AND FUTURE SATELLITE ANTENNA DESIGN SOFTWARE

### 4.1 SURVEY OF REFLECTOR ANTENNA DESIGN SOFTWARE FOR SATELLITE SYSTEMS.

Most antenna design software used in industry are proprietary and do not appear in the open literature. A survey turns up three references on general reflector software which are written for government agencies.

The first is a numerical code on reflector antenna written by Rudduck and Lee of Ohio State University for the U.S. Navy department. This code was created as part of a larger effort to develop computer models for simulating antennas at UHF and higher frequencies in a complex ship. The theoretical approach for computing the fields of the reflector is based on a combination of aperture integration (AI) and geometrical theory of diffraction (GTD) techniques. The reflector could have a general rim shape but it must be a parabola. AI is used to compute the main beam and near-in sidelobes while GTD is used to compute wide-angle sidelobes and the backlobes. Feed pattern description is either through measured data or  $\cos^N \theta$  type mathematical model. However, the feed must be located at the focus and have a constant phase pattern. It is possible to include the effects of scattering from struts.

The second computer program was written by TICRA for ESA and goes under the name of GRASP. Both GTD and physical optics techniques are used to compute radiated fields from reflector surfaces which are either perfect or distorted. Dual reflector systems may be analysed. Feed and strut blockages could also be specified by ignoring shadowed areas. Either internal mathematical

To QB/B

models or measured values may be employed to describe the feed patterns. The system may be linearly or circularly polarized. The good features offered by this program are the ability to analyse dual reflector systems and the use of GTD for sidelobe computations. The bad features are the use of only a single feed at a time to illuminate the reflector and the choice of integration scheme for the reflector surface which is inefficient. Basically, the surface is divided into a large number of patches by a rectangular grid in  $\theta$  and  $\phi$ . Such a scheme may facilitate analysis of distorted surfaces, but increases the computation times for perfect surfaces. In other words, this program would not be ideal for analysing shaped beam DBS antennas.

Single feed  
Only  
Worm  
may have  
it

The third reflector program was developed by Kauffman, Croswell and Jowers for NASA. This program makes use of AI technique in which the aperture is first divided into a rectangular grid. By means of geometric optics, the intersection points of the reflected rays from the feed with the aperture plane are determined. The field values at these points are then interpolated to find the aperture distribution at the grid points which are subsequently ~~summing~~ <sup>using</sup> integrated to give the far field pattern. Feed pattern description which must be linearly polarised, is entered into the program by the user. Provisions were not made to model the feed internally nor is the possibility of taking aperture blockages into account. Because of the rather inefficient method of integration, the NASA program is slower which is borne out by the computer times quoted.

*Not suitable*

#### 4.2 PRESENT SOFTWARE ACCURACY

Accuracy of most of the reflector programs in use to-day are limited by their modeling of feed radiation patterns. If only a single horn feed or measured feed pattern is used to illuminate the reflector, then the predicted pattern agrees very well with measurements as shown in Figures 4.1 to 4.4. These measurements were taken on the Anik-C reflector which has a projected diameter of 72 ins and a focal length of 70 ins. It was fed by a single horn 8 ins long with E- and H-plane aperture dimensions of 1.60 and 2.2 ins respectively. Predicted and measured on-axis gains agree within  $\pm 0.2$  dB and there is almost exact agreement for the main beam. For sidelobes between the -20 to -30 dB level, agreement is within the range of  $\pm 1$  dB while for sidelobes between -30 and -40 dB, the agreement is poorer between the bounds of  $\pm 3$  dB. The same ranges of accuracy also go for the X-polar patterns. Such good agreement is possible because the primary pattern is known fairly well.

Anik C

However, when an array of feeds is used to produce a shaped beam, the co-polar agreement over the coverage area is about  $\pm .5$  dB for simple beams with six or less component beams. For more complex shaped beams, the agreement between measured and predicted falls to  $\pm 1$  dB at certain worst case locations constituting about 5% of the coverage area. The gain over the remainder of the area is still predictable to  $\pm .5$  dB. The increased discrepancy is caused by the inability of the simple model to predict feed pattern in an array environment where mutual coupling plays an

important role.. This is especially manifested by the x-polar pattern where 10 dB or more deviation from prediction is not uncommon. However, this is at measured x-polar isolation level of less than -30 dB.

Figure 4.1

E-Plane Patterns of ANIK-C HP Reflector at 11.70 GHz.

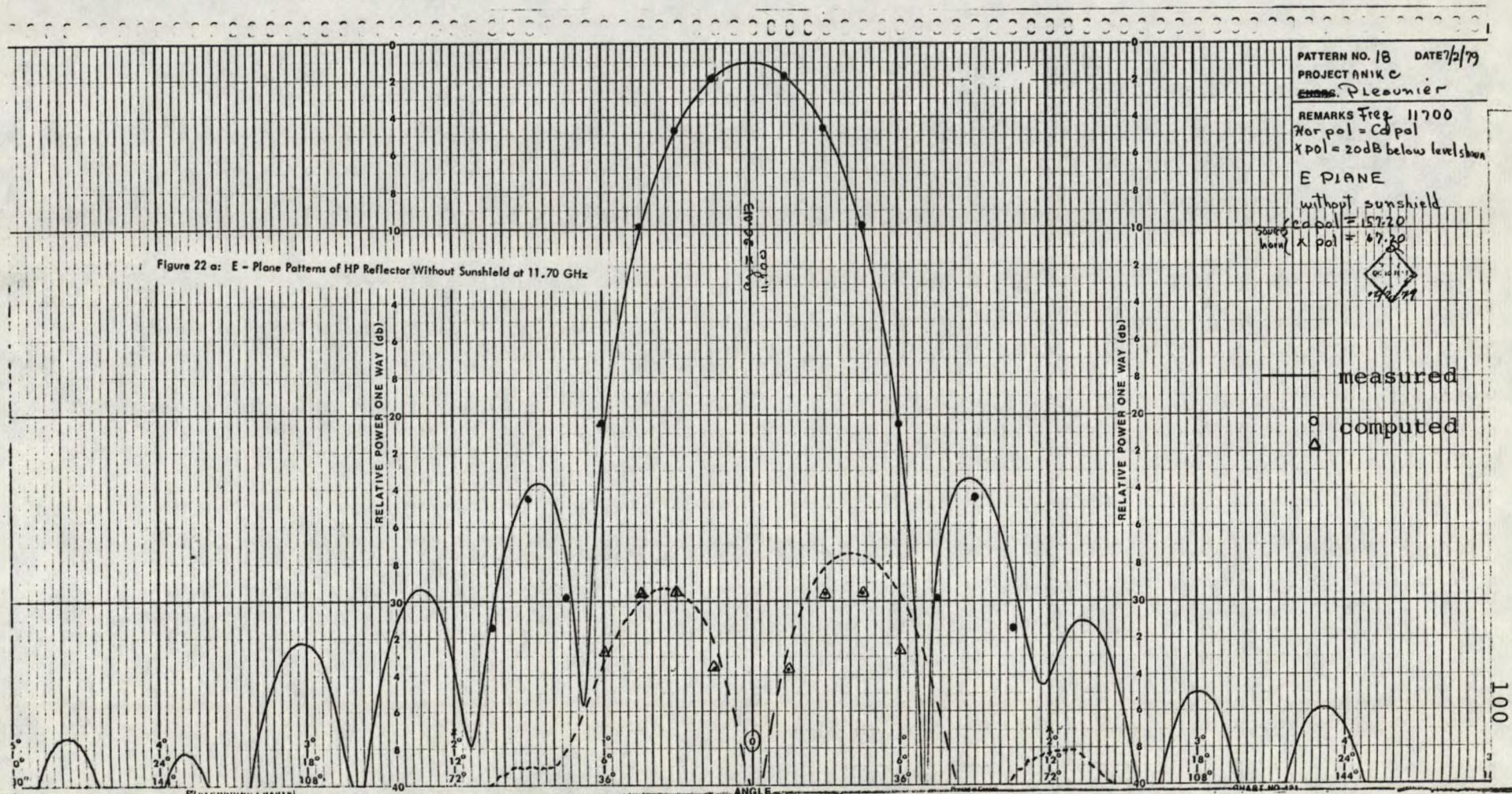


Figure 4.2

E-Plane Patterns of ANIK-C HP Reflector at 11.95 GHz.

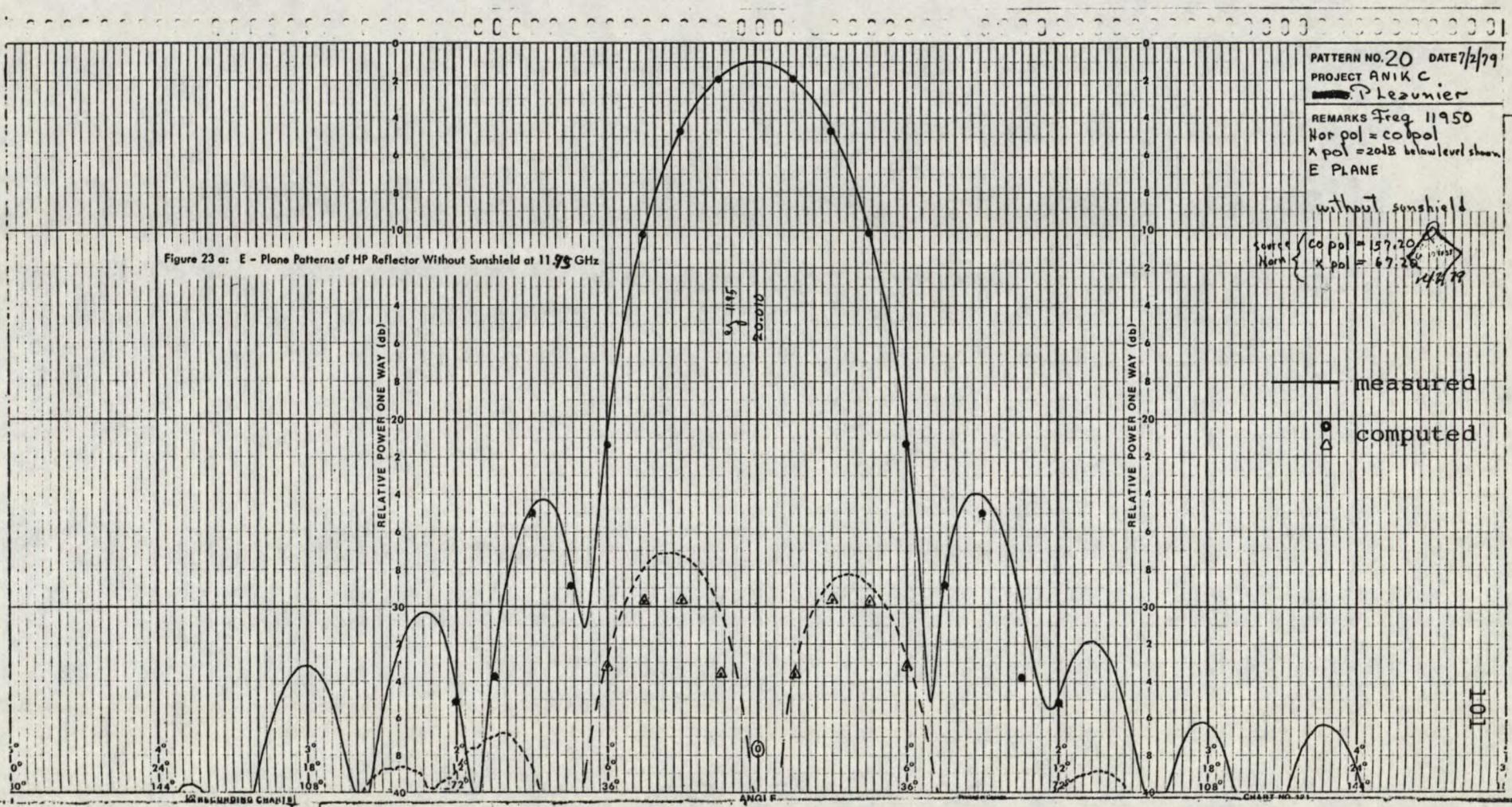


Figure 4.3 E-Plane Patterns of ANIK-C HP Reflector at 14.00 GHz.

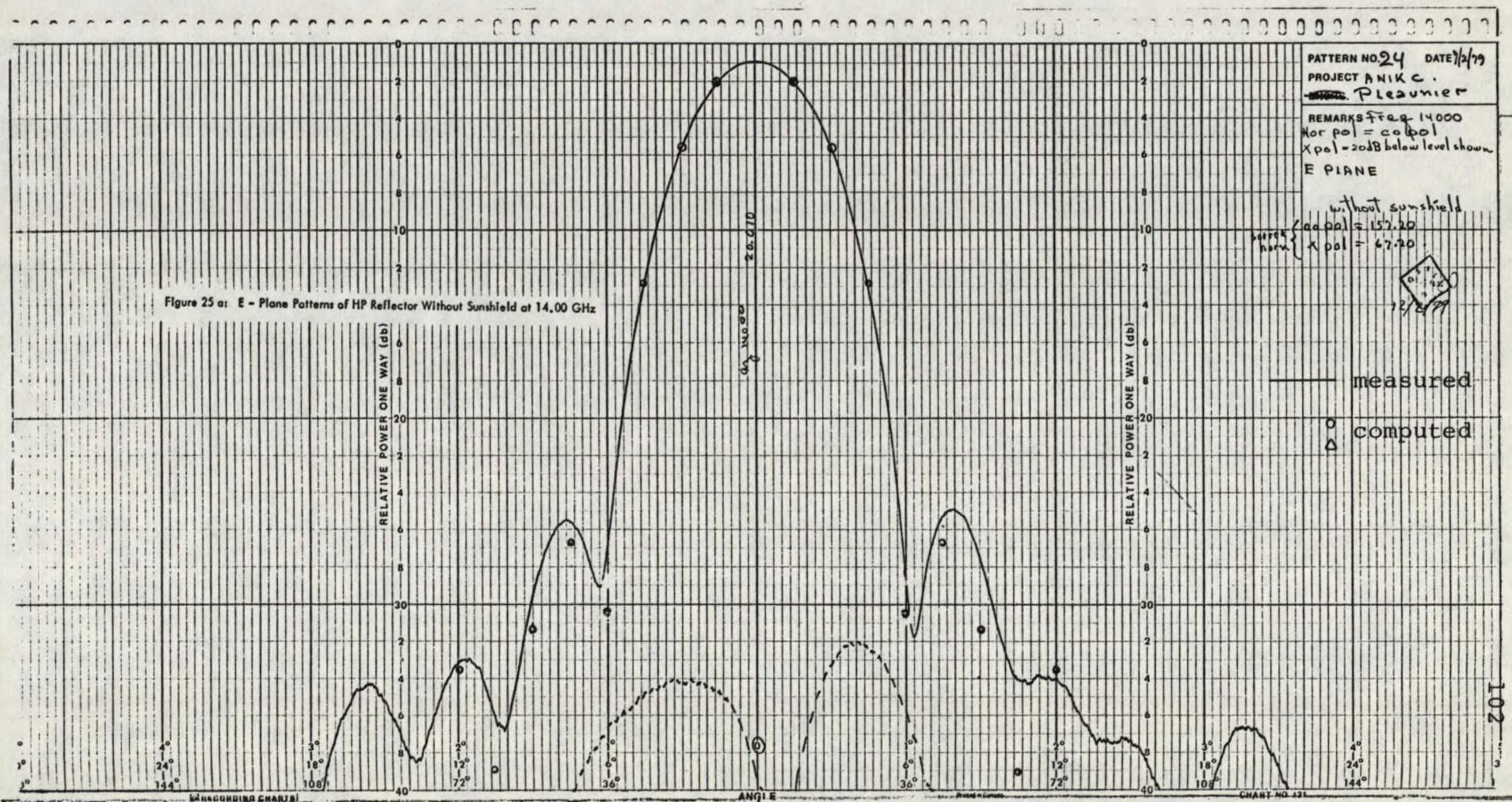
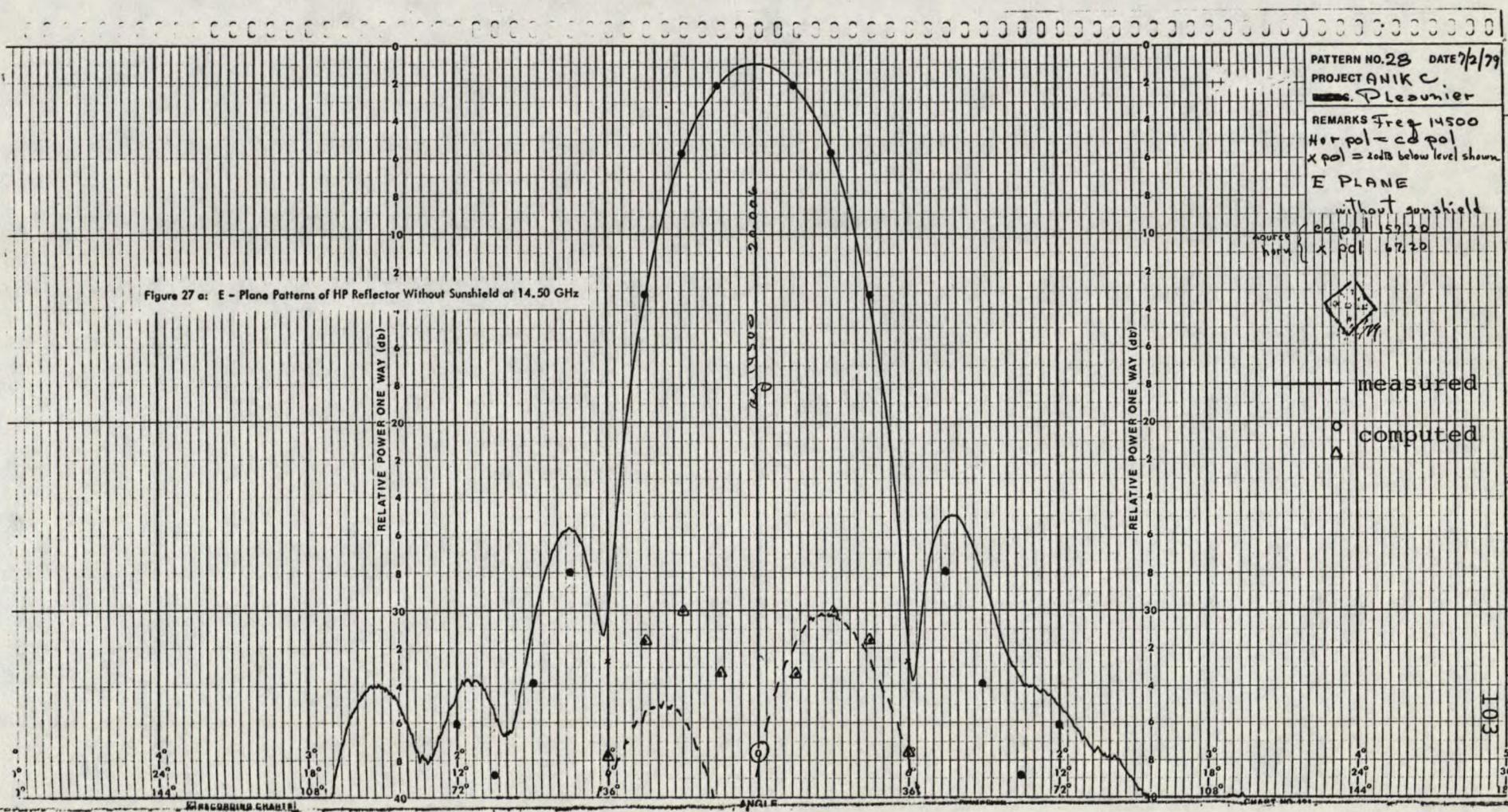


Figure 4.4 E-Plane Patterns of ANIK-C HP Reflector at 14.50 GHz.



Canonical interpolation?

#### 4.3 ANTENNA DESIGN SOFTWARE REQUIREMENTS FOR FUTURE SATELLITES

The following is a list of suggested software for future development together with a short description and justification for their adoption. Only software related to satellite antenna systems have been proposed.

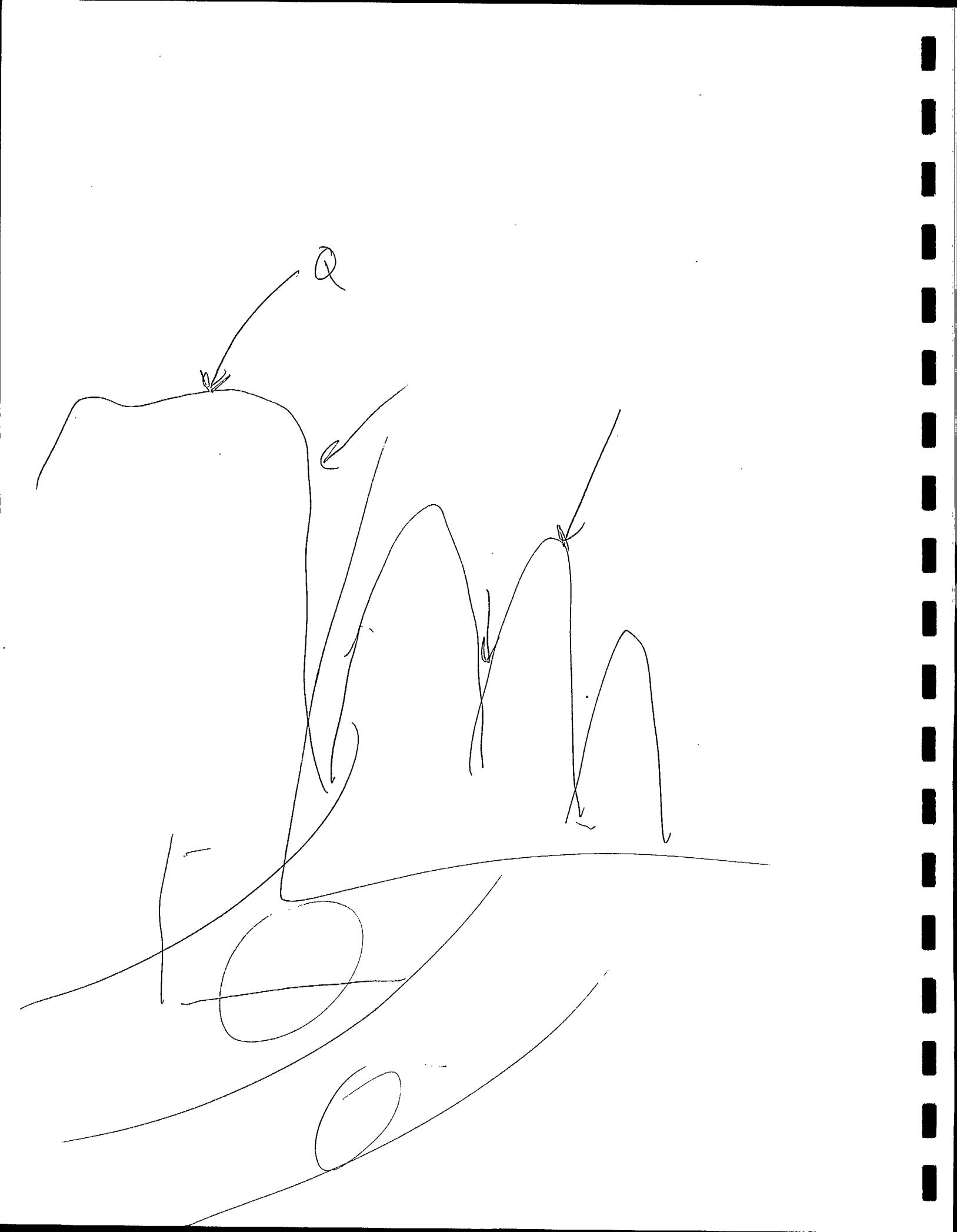
##### (a) GTD Capability for Single Reflector Program

The present reflector analysis program should be enhanced with GTD capability. This is needed to improve the prediction of wide angle sidelobes especially for DBS applications where interference into adjacent regions must be controlled. Stringent sidelobe isolation requirements are also found in multiple beams communication satellite systems employing TDMA concepts. In this scenario, high spacial isolation has to be maintained between closely spaced beams. Hence, accurate field computation is needed in both the near-in and far-out regions. To do this, the physical optics field is extended to include the edge diffracted fields through the addition of a fringe current component. The field radiated by this fringe current is derived from the canonical problem of a half-plane illuminated by a plane wave.

6/1  
OK

##### (b) Fast Computation of Radiation Patterns of Large Antennas

At least four to five points per lobe must be computed in order to reconstruct the sidelobe contours in conjunction with quadratic interpolation. This amount of work could be reduced considerably by resorting to sampling theory to reconstruct the complete radiation pattern. Using the existing or extended program as suggested in (a), the radiated field is first computed in



prescribed sampled space directions ( $u, v$ ), amounting roughly to one direction per lobe. Then the far field at any given point is found from the following double summation.

$$\bar{E}(\theta, \phi) = \sum_n \sum_m \bar{E}(\theta_{nm}, \phi_{nm}) \frac{\sin(u-n\pi)}{(u-n\pi)} \frac{\sin(v-m\pi)}{(v-m\pi)} \text{Cardinal function}$$

*Based on sampling theorem*

where  $\theta_{nm}$  and  $\phi_{nm}$  are the prescribed directions. The savings in computation times is obvious. This feature is ~~is~~ readily incorporated into the existing program.

### (c) Optimization of Feed Excitations for Reflector Antenna

When the number of feeds used in illuminating the reflector is more than a handful, the process of determining their appropriate excitations manually is long and tedious. This type of computation is best done on the computer with an optimization routine. One starts by defining the locations of a number of points surrounding the coverage area and also areas where the radiated fields are required to be low. Then the fields at these points are computed using the existing program with one feed at a time, all other feeds are not excited. The co-polar gains and phases are stored. Next, a gradient optimization routine is used to find the best excitations.

The objective function to be minimised here is the summation of the deviation of the gain at each point from the desired raised to the  $p$  th power.  $P$  is an even number. This is the least  $p$  th method. Since the objective function is not a unimodal function, a number of different starting points should be used to ensure that the best possible solution is arrived at.

*for 566 lines*      *being developed*      *more for manufacturers*  
*+ Inf. will have it end of March*

(d) Dual Reflector Antenna Analysis Software

Dual offset-fed reflector antennas can provide low sidelobes, folded optics and good beam scanning. They should be investigated for future satellite applications especially at the higher frequency bands. Again a combination of physical optics and geometrical theory of diffraction may be used to accurately predict the radiation patterns. The program should be general so that both numerically and analytically defined sub and main reflector surfaces may be analysed. The locations and orientations of the feed elements must also be completely unrestricted. With this software, one can then obtain a better understanding of the antenna overall performance.

(e) Advanced Feed System Analysis Software

At present the prediction of co-polar patterns from an array-fed reflector is fair while the agreement between computed and measured cross-polar patterns are poor. This is a result of neglecting the effects of mutual coupling in the feed array, internal scattering in the feed network and interaction between the feed array and the feed network. Further, 1979 WARC has allocated additional bandwidth to the fixed satellite services at 4 and 6 GHz. These wider bandwidths impact the design of feed network and feed radiators. Ultimately, the goal is to develop a quantitative prediction capability to assess the effects of mutual coupling, bandwidth, mismatches and excitation errors on the overall feed network. Two software packages are envisaged here, one is for the network and the other is for the horn array. The mutual interaction

between network and array can be dealt with by feeding the output of one as input to the other since S-parameters will be used for characterisation. The embedded patterns of the horn feeds in an array environment including the effects of feed network can then be obtained and may be input to the reflector analysis program. The co- and x-polar patterns can now be accurately predicted. The network program could also be used to determine feed network and components specification and assist in the analysis and development <sup>manufacture</sup> of new components. For instance, this software could be used to modify amplitude and phase at the excitation ports by either adding more components or modifying current components. This type of interactive design is easily done at the terminal rather than on the bench with substantial savings in costs. Further, this program allows a final check on the performance of the eventual feed network layout before it is built.

#### (f) Multi-Beam Phased Array Antenna Design

Phased array antennas, utilised either in a direct radiator configuration or as feed system for a near-field dual-offset reflector system, potentially offer an attractive alternative in the 11/14 and higher frequency bands to the use of conventional single offset reflector technology. In a multi-beam, frequency reuse environment, the full complement of radiators can be used to form each beam providing enhanced beam shaping capabilities. To do this, a multi-input port and multi-output port beam forming network (BFN) is required to feed the radiators. Such BFN may take the form of a Blass matrix, Butler matrix or Rotman lens. Clearly

then, software is required for beam shaping where the independent variables are the amplitude and phase excitations as well as the spatial distribution characteristics of the elements. With the excitations known, further software is required to synthesise the BFN network chosen. If the network is implemented in a lossy format, transmit/receive modules may be incorporated to form an active array.

(g) Design of a Multi-mode Horn Feed

For applications in circularly polarised, frequency reuse reflector antenna systems, there is a need for software to design a multi-mode circular horn feed. Given the band of operation, input and output apertures, the program should produce the number and degrees of flares together with the lengths of the sections needed for good input match and low cross-polarization performance.

*Earth  
Station*

APPENDIX AA.1-Description of Computer Program PAREFC\_SIF

IDENTIFICATION: PAREFC\_SIF

PURPOSE:

The program calculates the field radiated by a parabolic reflector antenna with projected elliptical aperture using the method of physical optics (surface currents). Various feed models, single or dual-mode pyramidal or conical horns, may be used to illuminate the reflector. Either linearly or circularly polarized secondary beam may be specified.

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DESCRIPTION:

The geometry of a general reflector antenna system is shown in Figure Al. A global co-ordinate system, XYZ, is defined at the focal point, 0, of the reflector. All input quantities are referred to this co-ordinate system. Besides this global system, three other local co-ordinate systems are also used. The first,  $x_1y_1z_1$ , is for the inte-

gration of currents over the reflector surface and has its origin located at the centre of the projected aperture in the focal plane. The second,  $X_r Y_r Z_r$ , is used to describe the feed while the third,  $X_q Y_q Z_q$ , is the far field observation co-ordinate system.

The reflector is a parabola with focal length  $F$  and its projected aperture can be off-set in the X- and Y-direction. The offset distances of the centre of the projected aperture from the focal axis are  $\Delta X$  and  $\Delta Y$  as shown in Figure A2. The projected aperture is assumed to be elliptical with major X- and Y-axes equal to  $SX2$  and  $SY2$  respectively.

There are two ways of specifying the position and orientation of the feed in the program. The most frequently used approach, especially when a horn array is involved, is to position first the horn feeds on the X-Y plane (focal plane). The entire horn array is then rotated about the global X- and Y-axes as shown in Figure A3. The rotation,  $\alpha$ , about the X-axis is carried out first, followed by rotation,  $\beta$ , about the rotated Y-axis. If required, one can further rotate each feed about its own local  $Z_r$ -axis by  $\gamma$ . Hence if this approach is selected, the X-, Y- and z- displacements

B.W.H.

ments given by ( $\delta x_r$ ,  $\delta y_r$ ,  $\delta z_r = 0$ ) on the focal plane have to be specified together with the rotations. This ensures that the apertures of the feeds lie on the same plane without any obscuration.

The other approach is to position and orientate each feed individually. The feed is first translated from the global system by ( $\delta x_r$ ,  $\delta y_r$ ,  $\delta z_r$ ) and then rotated about the translated  $x_t$ -,  $y_t$ - and  $z_t$ - axes in turn by  $\alpha_r$ ,  $\beta_r$ , and  $\gamma_r$  respectively as shown in Figure A1.

This method allows for complete freedom in locating the feed.

The far-field observation system may be displaced from the global system by ( $x_{dq}$ ,  $y_{dq}$ ,  $z_{dq}$ ) when one is interested in phase parallax correction.

If one is only interested in co- and cross- polarized gain, the displacement may be set to zero. Location of the far-field point is defined by its elevation and azimuth co-ordinates as shown in Figure A4. Elevation angle is positive when measured upwards from the  $y_q$ - $z_q$  plane while the azimuth angle in the  $y_q$ - $z_q$  plane is positive when measured from the  $z_q$ -axis towards the  $y_q$ -axis.

Far-field computations are carried out as follows.

A suitable Gaussian integration formula is first obtained by taking into account the reflector size in wavelength, furthest observation angle and extreme feed position. This formula determines the locations ( $r_1$ ,  $\phi_1$ ) of the surface integration points. At each point, the incident fields from the feeds are found, summed and stored. Next, the field at each of the observation point is obtained by adding the contribution from all the integration points. Knowing the field intensity and the total power radiated by the feeds, the co- and cross-polarized gain may be calculated for the observation point.

The built-in feed models are:

- conical horn excited in the fundamental  $TE_{11}$  mode.
- conical horn excited with  $TE_{11}$  and  $TM_{11}$  modes.
- pyramidal horn excited in the fundamental  $TE_{10}$  mode.
- pyramidal horn excited with  $TE_{10}$  and  $TE/TM_{12}$  modes

These horns may be excited either with linear polarization or circular polarization. To visualise the excitation arrangement, consider the feed of Figure A5, which has a  $X_r$ -axis and a  $Y_r$ -axis directed probe. For VP, only the  $X_r$ -probe is

excited. Similarly, for HP, only the  $Y_r$ -probe is excited. To produce a RHCP (LHCP) secondary beam, the excitation of the  $X_r$ -probe is  $C_x \angle 0^\circ$  and the excitation of the  $Y_r$ -probe is  $C_y \angle 90^\circ + \psi$  ( $C_y \angle -90^\circ + \psi$ ). For perfect CP,  $C_x = C_y = 1.0$  and  $\psi = 0^\circ$ . To simulate realistic condition, the amplitude imbalance ratio,  $C_y/C_x$ , and the departure from phase quadrature,  $\psi$ , may be specified.

## REMARKS:

The dimensions of the horns are checked to ensure that the fundamental and/or higher order modes could propagate. Execution is terminated if the modes are below cut-off. Program does not check for overlapping of feeds. User must ensure that this does not occur.

The output gain matrices are with respect to an elevation-azimuth co-ordinate system whose boresight axis is parallel to the RF-axis of the reflector. This means that the user has to position the gain contours over the coverage area to obtain the best possible boresight direction.

In order to speed up the computation of the feed illumination, two computations saving features are incorporated. The first involves a search through the list of entered horns and separates them into different groups. Within each group, the horns have the same dimensions. Hence patterns need to

OK

OK

OK

be computed only for one horn from each group.

The second time saving feature is obtained by computing only the E-plane and H-plane patterns of the designated horn at 46 points equally spaced between  $\theta = 0^\circ$  and  $90^\circ$ . Any in-between points within a phi-plane are obtained by quadratic interpolation while points between phi-planes are found by  $\cos \phi - \sin \phi$  interpolation.

USAGE ( INPUT ):

The input data required by the program are to be supplied in a file named PAREFC\_DAT. Data may be written in free format and follow the sequence laid out below. Data input is list directed.

IHEAD(I)- Header describing the particular run. Maximum of 60 characters. Limitation due to array size.

FREQ- Frequency in GHz.

NHORN- Number of horns in feed array. See Restriction.

ITYPE- Type of built-in feed. All horns must either be pyramidal or conical. A mixture is not allowed.  
= 0, pyramidal horn.  
= 1, conical horn.

AM- Amplitude ratio of the higher order mode relative to the fundamental mode.  
= 0.0, for basic mode operation.  
= 0.100 ~ 0.125, for small dual mode conical horns.  
= 0.670, for small multi-mode pyramidal horns.  
These are only suggested values for mode content and are found to equalise the beamwidths down to the -10 dB point.

PM- Relative phase in radians of the higher order mode.  
= 0.0, normally.

B(I)- E-plane horn aperture dimension in inches. Pyramidal horn option only. An entry must be provided for each feed. B(I) should not exceed  $7.5 \lambda$ .

A(I)- H-plane horn aperture dimension in inches.  
Pyramidal horn option only. An entry must be provided for each feed.  $A(I) \leq 7.5\lambda$ .

WGB(I)- E-plane dimension of input rectangular waveguide in inches. Pyramidal horn option only. An entry must be provided for each feed.  $WGB(I) \leq B(I)$

WGA(I)- H-plane dimension of input rectangular waveguide in inches. Pyramidal horn option only. An entry must be provided for each feed.  $WGA(I) \leq A(I)$ .

AR(I)- Radius of circular horn aperture in inches.  
Conical horn option only. An entry must be provided for each feed.  $AR(I) \leq 8\lambda$ .

WGR(I)- Radius of input waveguide in inches. Conical horn option only. An entry must be provided for each feed.  $WGR(I) \leq AR(I)$ .

HRNLTH(I)- Horn length between input guide and aperture in inches. An entry must be provided by each feed.

MODH- Choice of aperture field model for horn pattern.  
= 0, Electric field model. Good approximation to measured results for horn sizes between  $0.95\lambda$  and  $1.30\lambda$ .  
= 1, Chu model. Conservative model that can be used for all horn sizes.

OPTH- Option for specifying feed positions and rotations.  
= 0, Collective movement and rotation of feed array.  
= 1, Individual movement and rotation of feed horn.

DX(I), Displacements of component feeds in inches from focal point. A set of values must be provided for each feed.

DY(I),

XZ(I) -

ALPHA(I), - Rotations about X-, Y- and Z- axes in degrees.

BETA(I) , See text for definition. If the option of

GAMMA(I) collective movement is chosen, only one set of values need be provided. Otherwise, a set must be provided for each feed.

IPOLA - Polarization of secondary beam.

= 1, Vertical polarization. (VP).

= 2, Horizontal polarization. (HP).

= 3, Right hand circular polarization. (RHCP).

= 4, Left hand circular polarization. (LHCP).

CXY(I) - Amplitude imbalance of  $Y_r$ -port relative to  $X_r$ -port. CP only. An entry must be provided for each feed.

PSI(I) - Departure from phase quadrature of the  $Y_r$ -port in degrees. CP only. An entry must be provided for each feed.

HPWR(I) - Power input to each feed in watts.

HPHASE(I) - Relative phase excitation of each feed in degrees.

F - Focal length of parabolic reflector in inches.

SX2 - X-dimension of elliptical reflector aperture in inches.

SY2 - Y-dimension of elliptical reflector aperture in inches.

DELTAX - X-offset of aperture centre in inches.

DELTAY - Y-offset of aperture centre in inches.

OPTB - Option for specifying limits of integration.  
This feature may be used to simulate aperture  
blockage.  
= 0, Limits are generated by program. No  
blockage is assumed.  
= 1, Limits are specified by user.

NREG - Number of regions of  $\phi_1$  - integration. In the  
program this number is set equal to 4.

PHL(I), Lower and upper limits of  $\phi_1$  - integration for  
PHU(I) - the I th region in radians.

BX2, BY2 - X- and Y-dimension of central elliptical blockage  
in inches.

OPTQ - Option of specifying number of integration points.  
= 0, Determined by program.  
= 1, Specified by user.

NQR - No. of integration points in the radial-direction  
 $(r_1)$ . Choose from: 3,4,6,8,10,12,14,16,20,24,28,34,40

NQP - No. of integration points in the phi-direction  
 $(\phi_1)$ . Choose from: 3,4,6,8,10,12,14,16,20,24,28,34,40

AZS - Start of azimuth cut in degrees.

AZE - End of azimuth cut in degrees.

NAZ - Number of azimuth points. See Restriction.

ELS - Start of elevation cut in degrees.

ELE - End of elevation cut in degrees.

NEL - Number of elevation points. See Restriction.

XDQ, YDQ,- X-, Y- and Z- translation of field co-ordinate system from global system in inches.

ZDQ -

PVR - Angular rotation about Z-axis of field polarization vector in degrees. It is used to rotate the linear polarization vector in cases where minimising rain attenuation is important. For CP application, it has the effect of rotating the polarization ellipse. In most situations, it is set equal to GAMMA.

In the above input list, all variables beginning with the letter I through N as well as OPTH, OPTB and OPTQ, are integer variables. The flow chart for the data input section is shown in Figure A6.

OUTPUT:

All input data are printed out for the purpose of verification and run identification. The spillover efficiency of the reflector is printed out next, followed by the co-polar component gain, cross-polar component gain, and co-polar component phase. The gain, expressed in dBi and the phase in degrees are presented in a tabular form. A column corresponds to an elevation cut while a row gives the azimuth cut. In addition to this output which is directed to file PAREFC\_DUM ,

the co-polar gain matrix together with the header and angular information on the observation frame (AZS, AZE, NAZ, ELS, ELE, NEL) are written into a file named GNMAT. This gain file can be assessed later for contour plotting purposes.

CODING INFORMATION:

Program is written in FORTRAN 77 for use on the CRC Honeywell CP-6 computer system.

Restriction:

The restriction on the antenna configuration that can be analysed is solely due to array dimensions. In order to minimise the demand on computer resources, the arrays have been dimensioned to cover many of the cases usually encountered. In certain situations such as DBS application where the number of feeds required or the number of integration points needed or the field of view exceeded those envisaged, the pertinent arrays must be changed according to the following prescription.

To Increase the Number of Horn Feeds

The program has been set to allow a maximum of 50 feeds. To increase the number of feeds, the following changes have to be made.

MAIN PROGRAM: (i) Change the dimensions of the following arrays to the value of NHORN -

A, B, WGA, WGB, AR, WGR, HRNLTH, DX, DY, DZ,  
GAMMA, BETA, ALPHA, HPWR, HPHASE, AN, CXY,  
PSI, PWRL, W11, W12, W13, W21, W22, W23, W31,  
W32, W33, CX, CY, IND, IGP.

(ii) Change the value of MAXHRN in the data statement to the value of NHORN.

**SUBROUTINE SOURCE:**

Change the dimensions of the following arrays to NHORN - AN, HPHASE, CX, CY, PSI, IGP.

To Increase the Number of Horn Groups

Eventhough the number of horn feeds is set by MAXHRN, the number of different horn sizes within the array must not be more than MAXHGP which, at present, has a value of 10.

MAIN PROGRAM: Change the value of MAXHGP in the data statement to reflect the new value.

SUBROUTINE PAT: Change the second dimensions of arrays EPA, EPP, HPA and HPP to MAXHGP.

SUBROUTINE PYRHRN: Change the second dimensions of arrays EPA, EPP, HPA, HPP to MAXHGP.

SUBROUTINE CONHRN: Change the second dimensions of arrays EPA, EPP, HPA, HPP to MAXHGP.

SUBROUTINE PTNORM: Change the second dimensions of arrays EPA, EPP, HPA, HPP to MAXHGP.

To Increase Array Sizes to Accomodate Larger Number of Integ. Points.

The maximum number of integration points allowable in the radial or phi-direction is given by the variable MAXQ. MAXQ is set equal to the larger of the two numbers, NQR and NQP, which determines the dimension requirement. At present, the value of MAXQ is 28.

MAIN PROGRAM: (i) Change the value of MAXQ in the data statement to reflect the new value.  
(ii) Change the first dimensions of arrays RDL and RDU to the value of MAXQ.  
(iii) Change the dimensions of the following arrays to  $4 * \text{MAXQ} * \text{MAXQ}$  -  
XG, YG, ZG, RJX, RJY, RJZ.

SUBROUTINE FIELD: (i) Change the dimensions of the following arrays to  $4 * \text{MAXQ} * \text{MAXQ}$  -  
 $X, Y, Z, RJX, RYJ, RJZ.$

To Increase Frame of Observation

The field of observation is defined by a rectangular grid of elevation and azimuth cuts. The number of grid points in the elevation direction is given by NEL and its maximum is set by MAXEL. Similarly, the number of grid points in the azimuth direction is given by NAZ and its maximum is set by MAXAZ. At present the values of MAXEL and MAXAZ are 49 and 49 respectively.

MAIN PROGRAM: (i) Change the values of MAXEL and MAXAZ in the data statement.  
(ii) Change the dimension of array EL and AZ to MAXEL and MAXAZ respectively.  
(iii) Change the dimensions of arrays CGN, CPH and XGN to the value given by MAXEL \* MAXAZ.

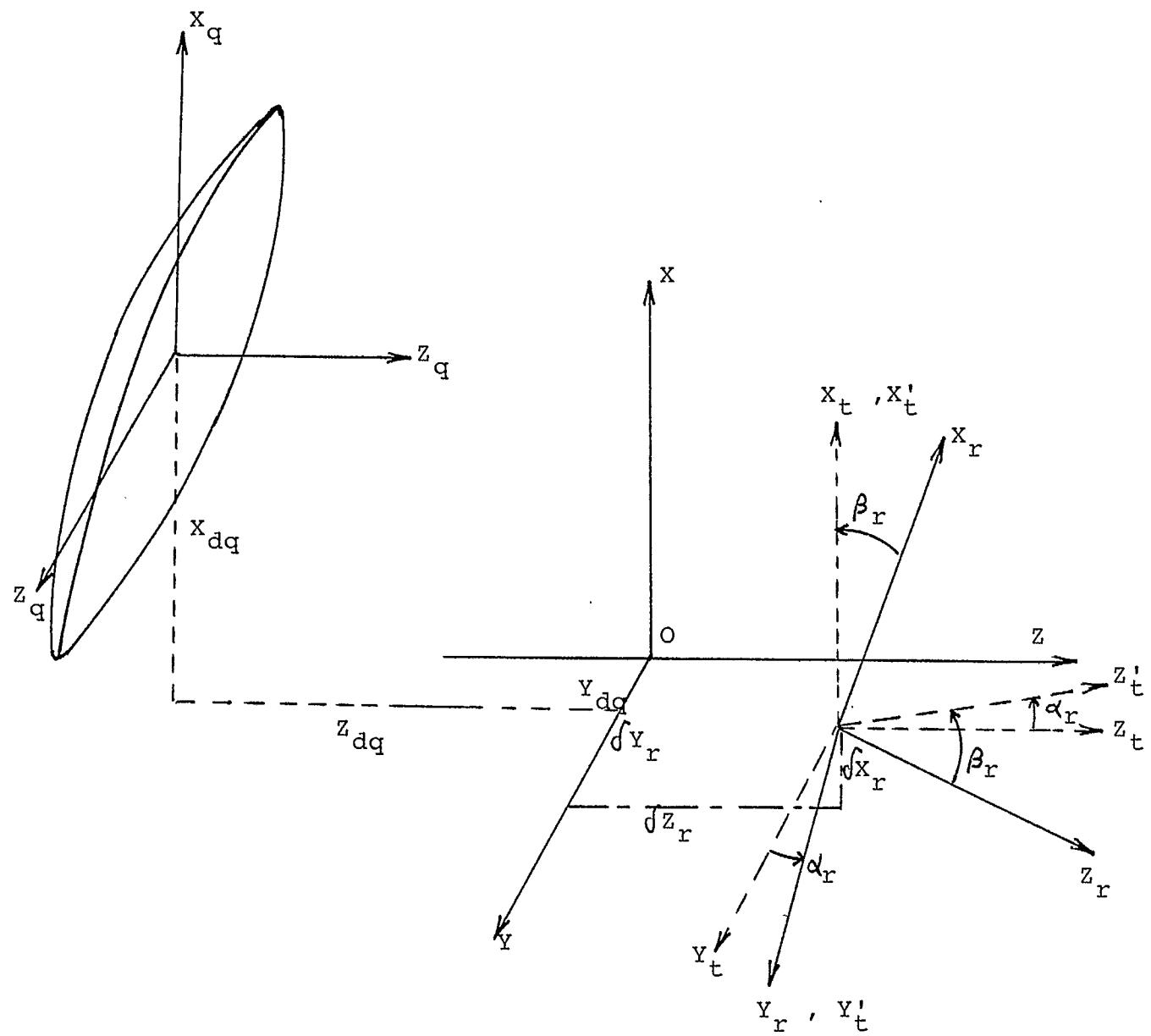


Figure A1. Geometry of Reflector Antenna System.

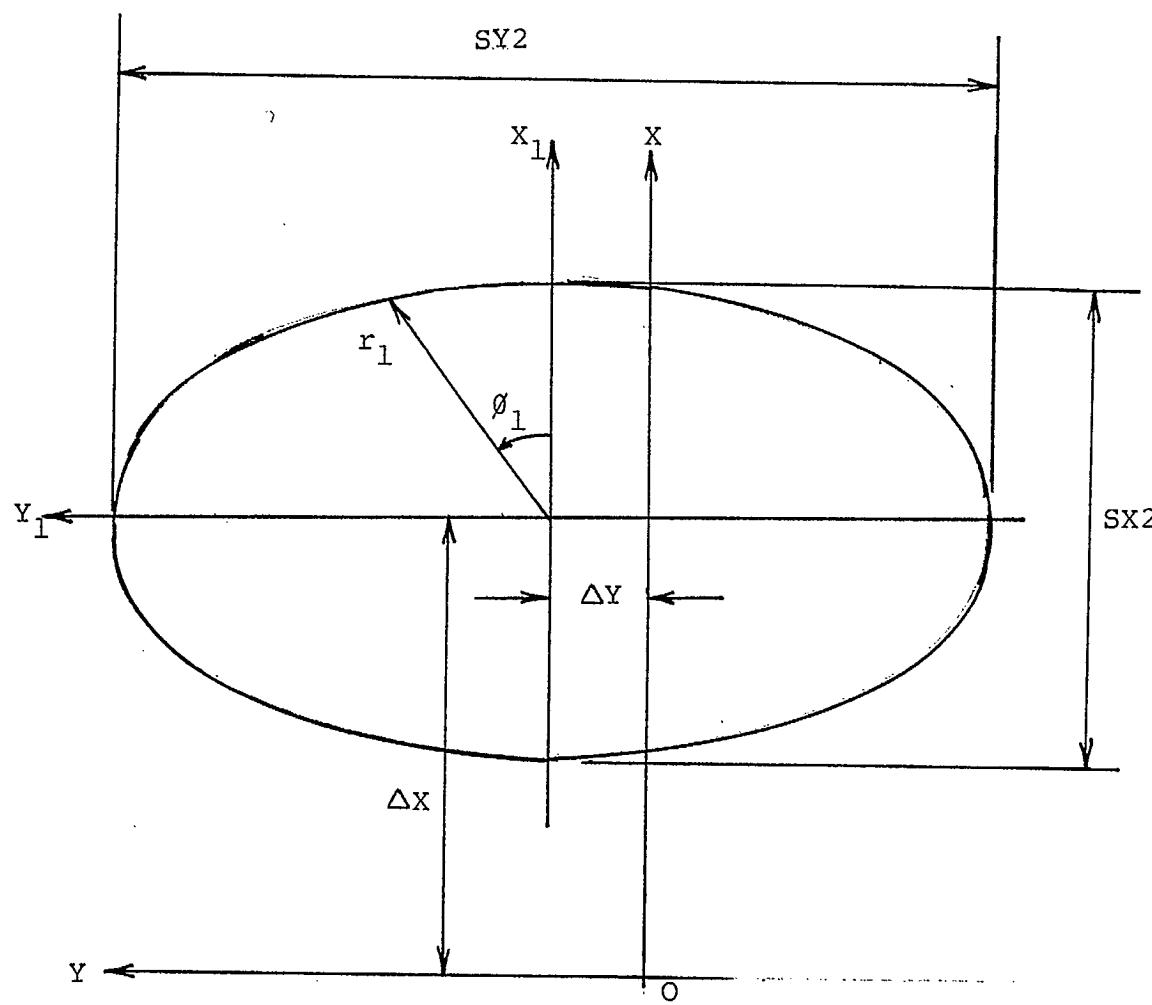


Figure A2. Projected Aperture in the Focal Plane.

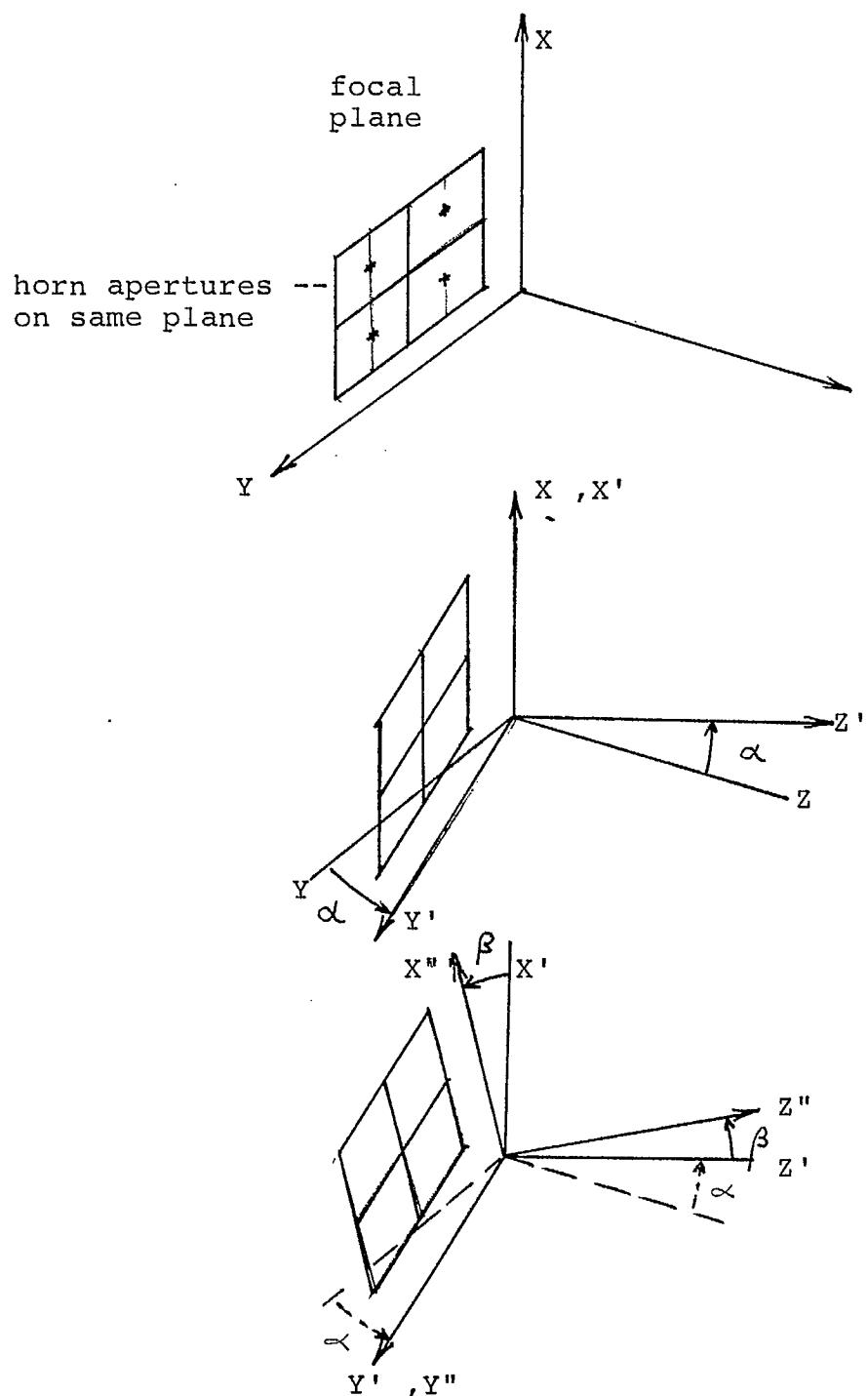


Figure A3. Collective Translation and Rotation of Feed Array.

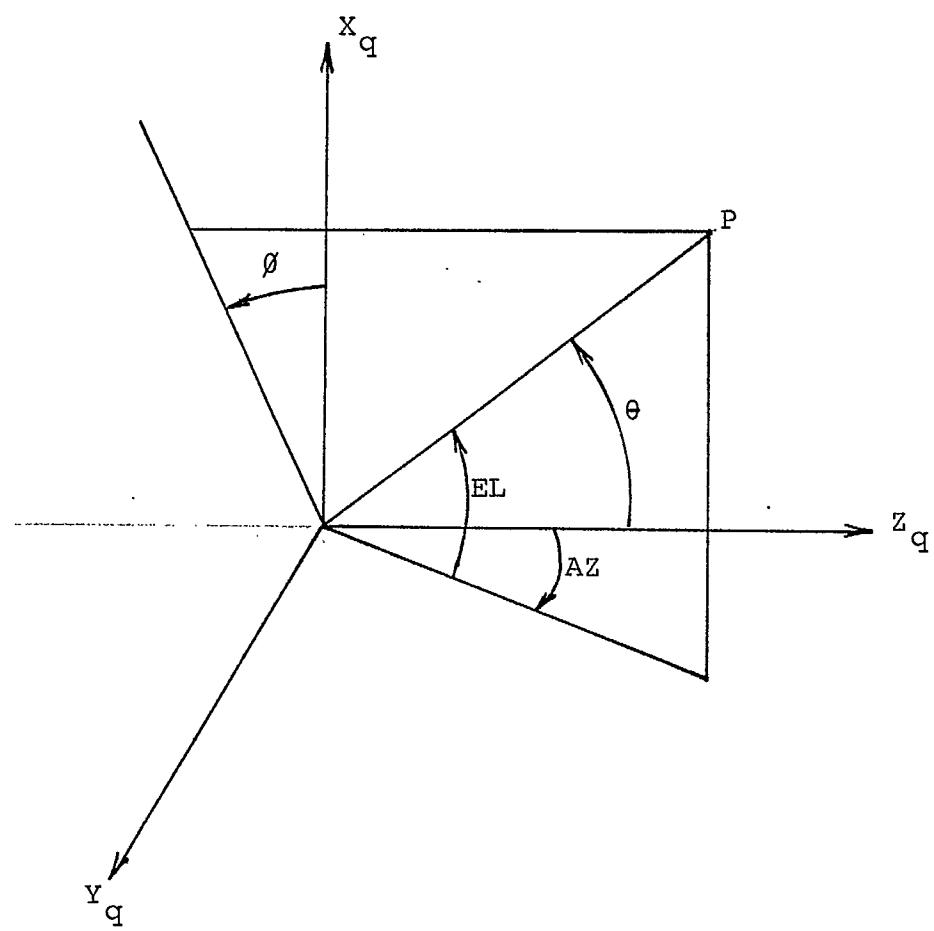


Figure A4. Elevation and Azimuth Co-ordinates of Observation Point.

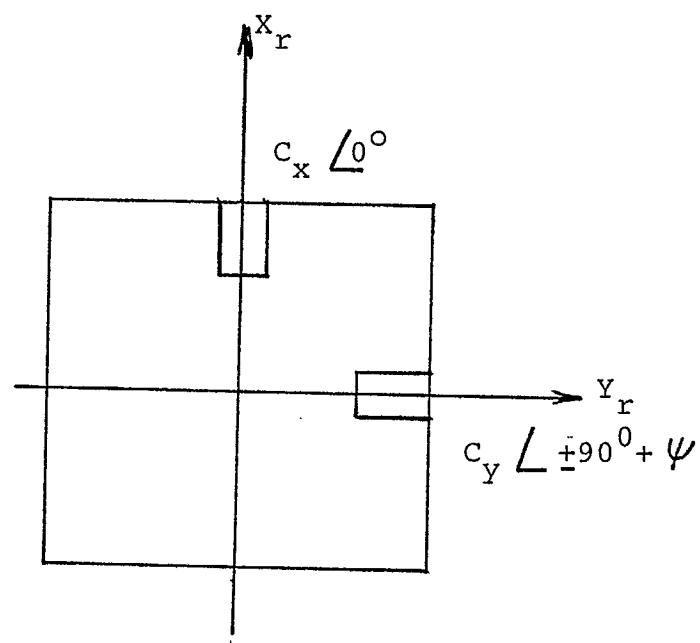
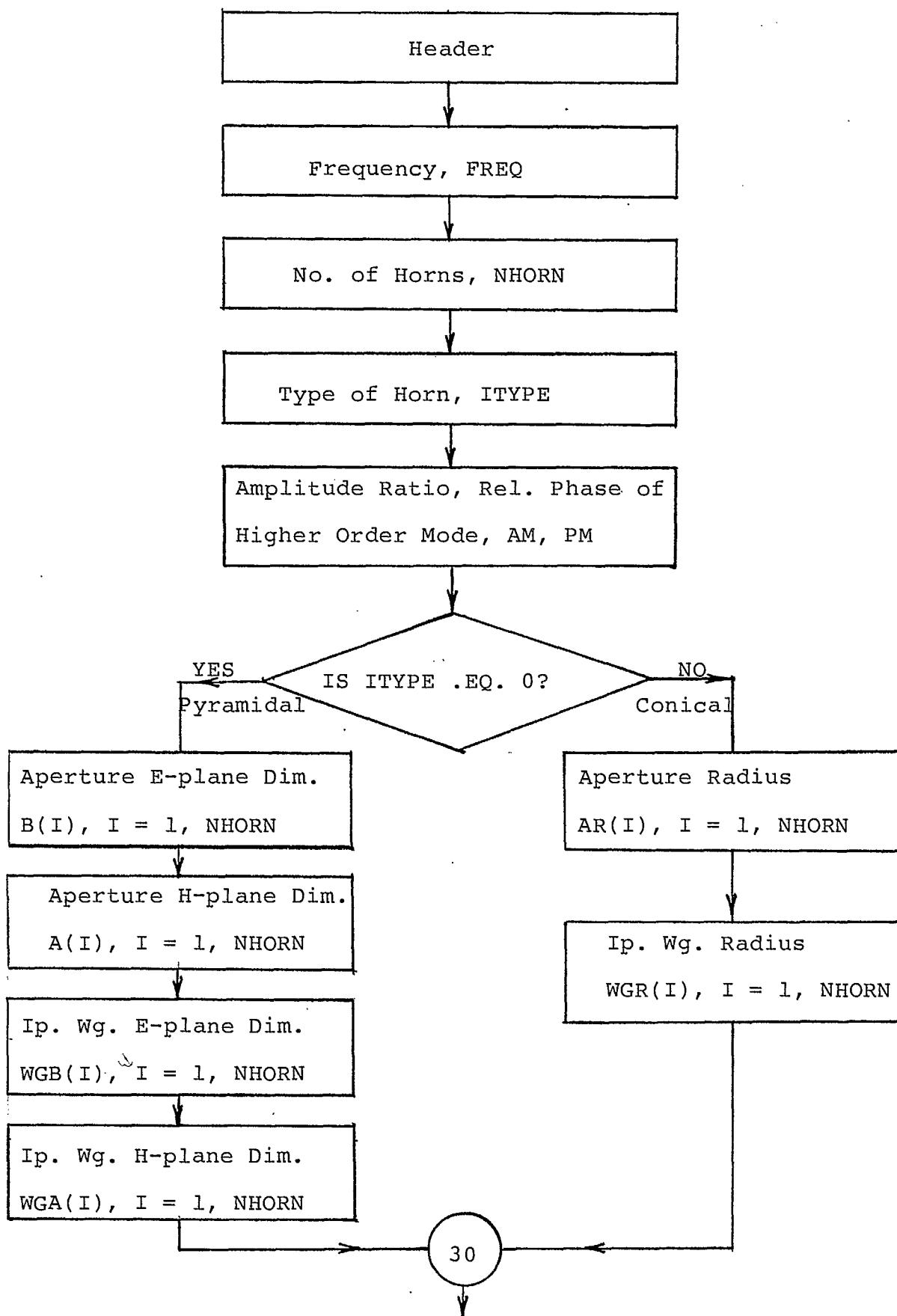
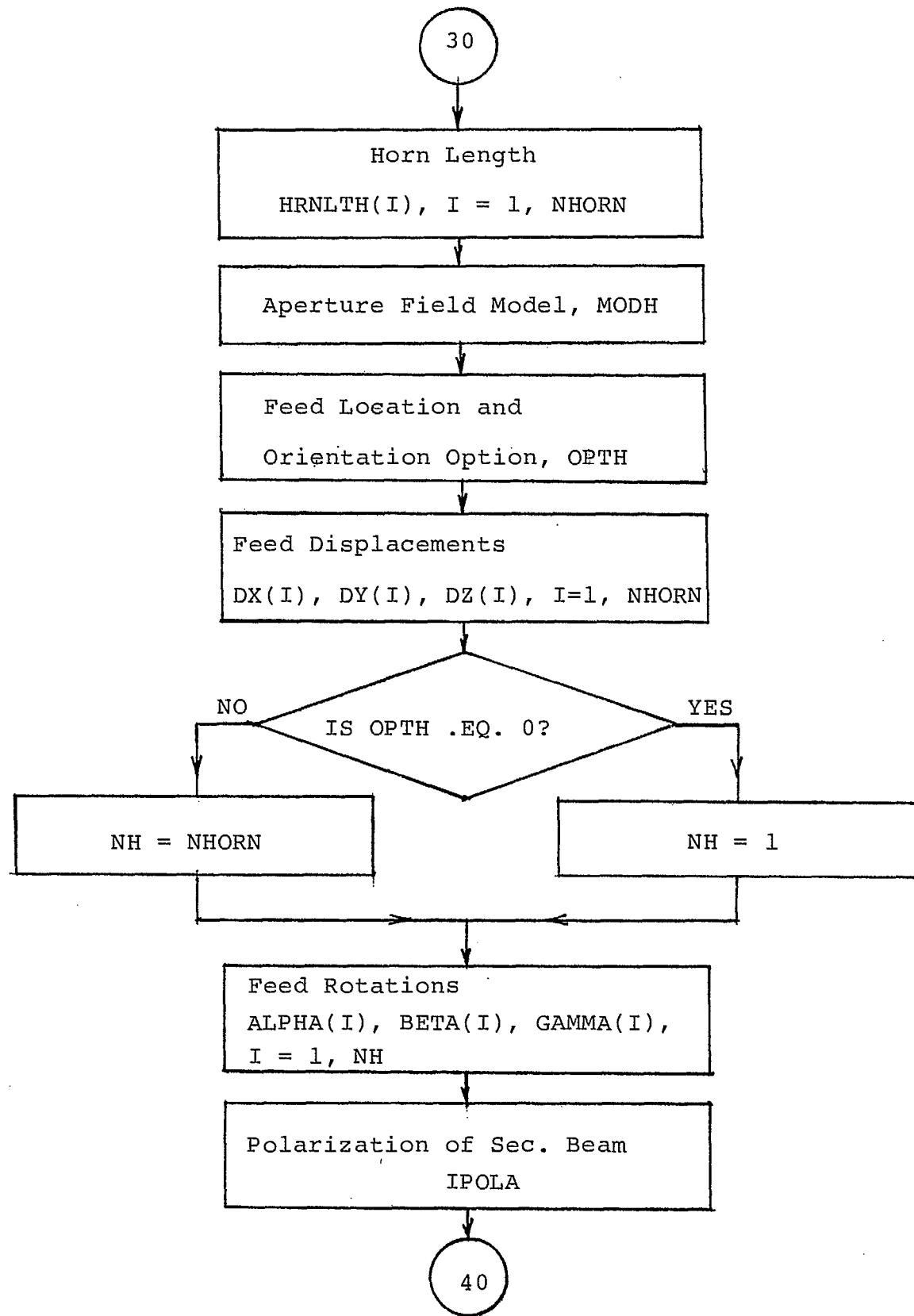
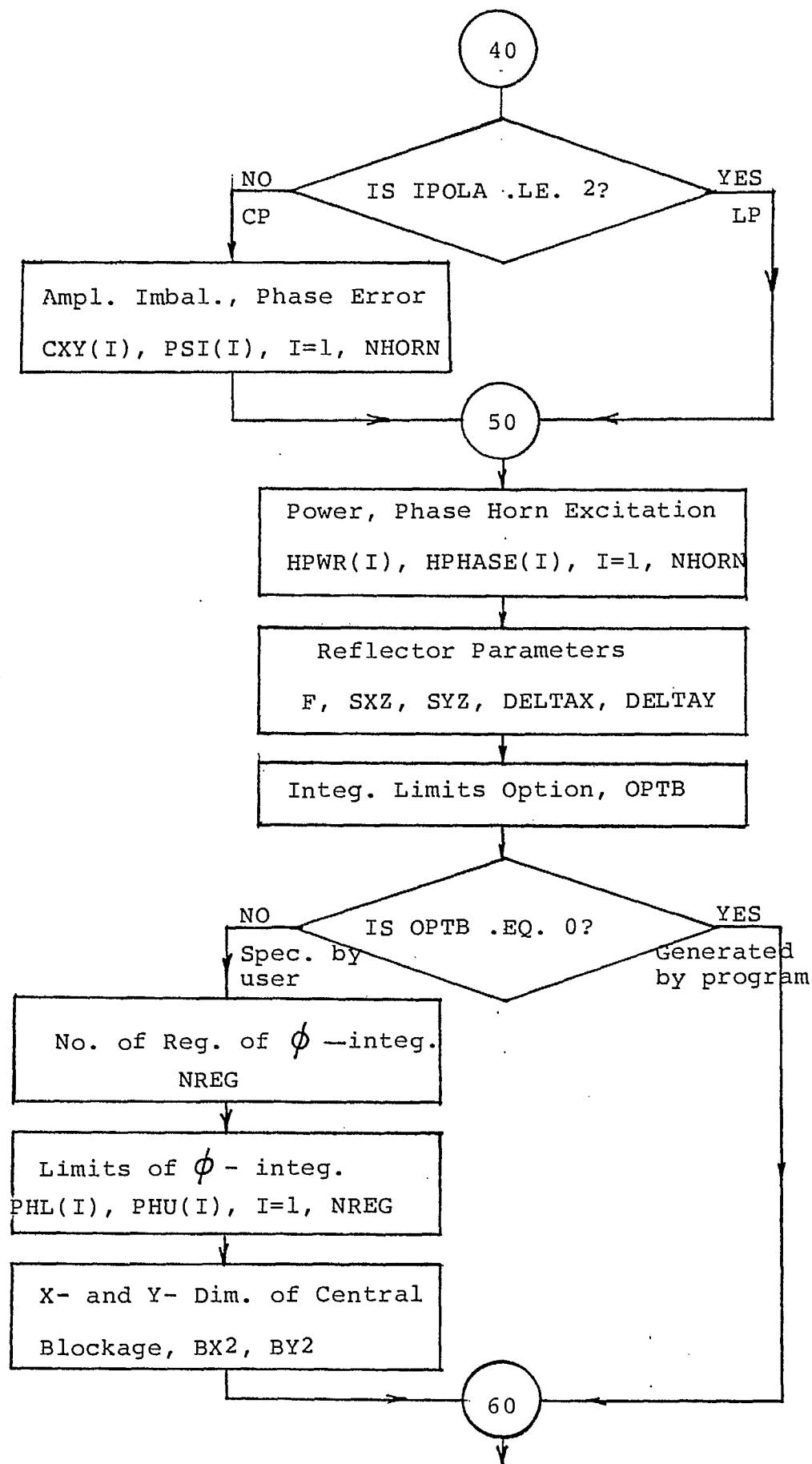


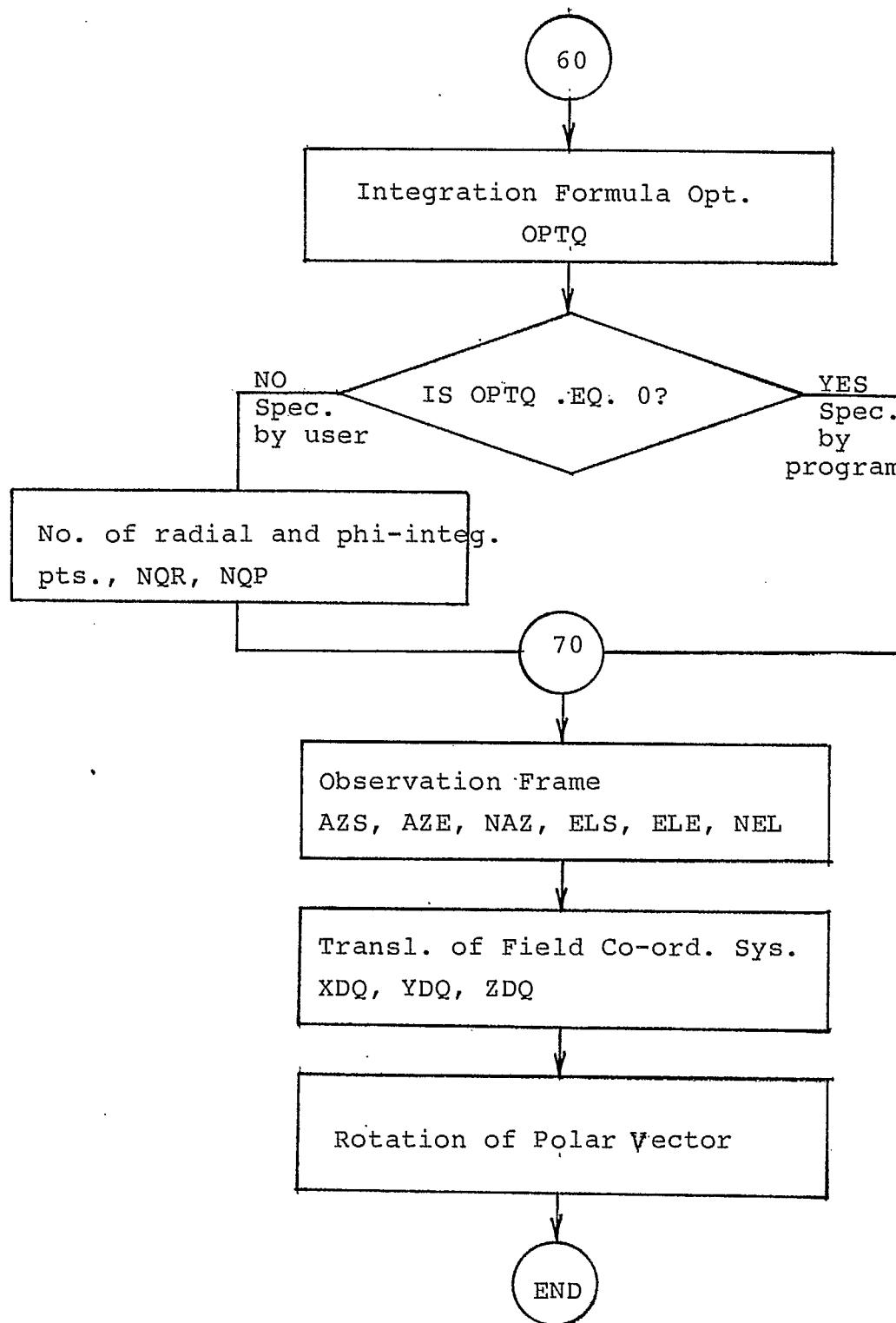
Figure A5. Excitation of Horn Feed.

Figure A6. Flow Chart of Input Data File.









## A.2 PROGRAM LISTING

```

1.000      PROGRAM PAREFC
2.000 *
3.000 * PHYSICAL OPTICS ANALYSIS OF A PARABOLIC REFLECTOR FED BY A
4.000 * MULTI-HORN ARRAY.
5.000 * THE REFLECTOR HAS AN ELLIPTICAL APERTURE AND IS OFF-SET IN THE
6.000 * X- AND Y- DIRECTION. FAR FIELD CO-POLARISED AND CROSS-POLARISED
7.000 * GAIN MATRICES ARE COMPUTED OVER A RECTANGULAR ELEVATION - AZIMUTH
8.000 * GRID.
9.000 * MAIN FEATURES OF THE PROGRAM ARE THE FOLLOWING -
10.000 * MULTIPLE HORN CAPABILITY.
11.000 * CHOICE OF HORN TYPE , CONICAL OR PYRAMIDAL.
12.000 * HORNS MAY BE EXCITED WITH A COMBINATION OF BASIC AND HIGHER ORDER
13.000 * MODES. PYRAMIDAL HORN MAY CONTAIN TE10 AND TE/TM12 MODES.
14.000 * CONICAL HORN MAY CONTAIN TE11 AND TM11 MODES.
15.000 * CHOICE OF HORN APERTURE FIELD MODEL.
16.000 * MODELING OF APERTURE BLOCKAGE BY FEED AND STRUTS.
17.000 * AUTOMATIC SELECTION OF INTEGRATION LIMITS AND FORMULAS.
18.000 * CHOICE OF CIRCULAR OR ROTATABLE LINEAR POLARISATION.
19.000 * FOR CIRCULAR POL. ,ABILITY TO SPECIFY AMPL. AND PHASE IMBALANCE
20.000 * IN THE EXCITATION OF THE ORTHOGONAL PORTS.
21.000 *
22.000 * WRITTEN BY CHAN TECHNOLOGIES INC.
23.000 * REVISION 0 , MAY 1984.
24.000 *
25.000   CHARACTER*4 IHEAD(15)
26.000   DIMENSION A(50),B(50),WGA(50),WGB(50),AR(50),WGR(50),HRNLTH(50)
27.000   DIMENSION DX(50),DY(50),DZ(50),GAMMA(50),BETA(50),ALPHA(50)
28.000   DIMENSION HPWR(50),HPHASE(50),AN(50),CX(50),PSI(50),PWR1(50)
29.000   DIMENSION W11(50),W12(50),W13(50),W21(50),W22(50),W23(50)
30.000   DIMENSION W31(50),W32(50),W33(50),CX(50),CY(50)
31.000   DIMENSION PHL(4),PHU(4),RDL(28,4),RDU(28,4)
32.000   DIMENSION XG(3136),YG(3136),ZG(3136)
33.000   DIMENSION CGN(2401),CPH(2401),XGN(2401),EL(49),AZ(49),TETA(46)
34.000   COMPLEX EX,EY,EZ,EXPN,ETHETA,EPHI,FTX,FTY,FTZ,HX,HY,HZ
35.000   COMPLEX RJX(3136),RJY(3136),RJZ(3136)
36.000   INTEGER OPTB,OPTH,OPTQ,IND(50),IGF(50)
37.000   COMMON/VAL1/PI,RAD,RK,ZETA
38.000   COMMON/VAL2/AN,HPHASE,CX,CY,PSI,IPOLA,IGP
39.000   COMMON/BLOCK/QX(219),QW(219)
40.000   COMMON/CURENT/RJX,RJY,RJZ,XG,YG,ZG
41.000   COMMON/VAL3/NREG,NQR,NQP,PT,XDQ,YDQ,ZDQ,CPVR,SPVR
42.000   COMMON/PATPAR/NPP,PAI,TETA
43.000   DATA PI,RAD,ZETA/3.14159265,57.2957795,376.99111/
44.000 *
45.000 * THE FOLLOWING ARE PRESET LIMITS DUE TO ARRAY DIMENSIONS.
46.000 * MAXQ - MAX. NO. OF INTEGRATION PTS. PERMITTED
47.000 * MAXHRN - MAX. NO. OF HORNS PERMITTED
48.000 * MAXHGP - MAX. NO. OF HORN GROUPS PERMITTED
49.000 * MAXEL - MAX. NO. OF EL GRID PTS.
50.000 * MAXAZ - MAX. NO. OF AZ GRID PTS. PERMITTED
51.000 *
52.000   DATA MAXQ,MAXHRN,MAXHGP,MAXEL,MAXAZ/28,50,10,49,49/

```

```
53.000 *
54.000 * START OF DATA INPUT
55.000 *
56.000 * INPUT DATA ARE READ FROM FILE PAREFC_DAT
57.000     OPEN(UNIT=5,NAME='PAREFC_DAT',STATUS='OLD',USAGE='INPUT')
58.000 * OUTPUT DATA ARE WRITTEN INTO FILE PAREFC_DUM
59.000     OPEN(UNIT=6,NAME='PAREFC_DUM',STATUS='OLD',USAGE='OUTPUT')
60.000 *
61.000 * IHEAD - HEADING FOR COMPUTER RUN. MAX. OF 60 CHARACTERS.
62.000 *
63.000     READ(5,10) (IHEAD(I),I=1,15)
64.000 10    FORMAT(15A4)
65.000 *
66.000 * DATA DESCRIBING HORN ARRAY
67.000 *
68.000 * FREQ - FREQUENCY IN GHZ
69.000 *
70.000     READ(5,*) FREQ
71.000 *
72.000 * NHORN - NO. OF HORNS.
73.000 *
74.000     READ(5,*) NHORN
75.000     IF (NHORN.LE.MAXHRN) GO TO 14
76.000     WRITE(6,12) MAXHRN
77.000 12    FORMAT(1X,'EXECUTION TERMINATED. NO. OF HORNS EXCEEDED MAX. OF'
78.000      +,I3)
79.000     STOP
80.000 14    CONTINUE
81.000 *
82.000 * ITYPE - TYPE OF HORN
83.000     = 0, PYRAMIDAL
84.000     = 1, CONICAL
85.000 *
86.000 * IT IS ASSUMED THAT ALL HORNS IN THE ARRAY ARE OF THE SAME TYPE.
87.000 *
88.000     READ(5,*) ITYPE
89.000 *
90.000 * SPEC. OF HIGHER ORDER MODE CONTENT OF HORN.
91.000 * FOR CONICAL HORN, THE HIGHER ORDER MODE IS TM11.
92.000 * FOR PYRAMIDAL HORN, THE HIGHER ORDER MODE PAIR IS THE TE/TM12.
93.000 * AM = AMPLITUDE RATIO OF THE HIGHER ORDER MODE.
94.000 * PM = REL. PHASE (RAD) OF THE HIGHER ORDER MODE.
95.000 *
96.000     READ(5,*) AM , PM
97.000     IF (ITYPE.EQ.1) GO TO 20
98.000 *
99.000 * IF CIRCULAR POLARIZATION IS SPEC. BOTH E- AND H-PLANE DIM. OF THE
100.000 * PYRAMIDAL HORN MUST BE THE SAME I.E. SQUARE HORN ONLY.
101.000 * B - E-PLANE DIMENSION OF HORN APERTURE IN INS.
102.000 *
103.000     READ(5,*) (B(I),I=1,NHORN)
104.000 *
105.000 * A - H-PLANE DIM. OF HORN APERTURE IN INS.
106.000 *
107.000     READ(5,*) (A(I),I=1,NHORN)
108.000 *
```

```
109.000 * WGB - E-PLANE DIM. OF INPUT WAVEGUIDE IN INS.  
110.000 *  
111.000      READ(5,*) (WGB(I),I=1,NHORN)  
112.000 *  
113.000 * WGA - H-PLANE DIM. OF INPUT WAVEGUIDE IN INS.  
114.000 *  
115.000      READ(5,*) (WGA(I),I=1,NHORN)  
116.000      GO TO 30  
117.000 *  
118.000 * AR - CIRCULAR HORN APERTURE RADIUS IN INS.  
119.000 *  
120.000 20    READ(5,*) (AR(I),I=1,NHORN)  
121.000 *  
122.000 * WGR - INPUT WAVEGUIDE RADIUS IN INS.  
123.000 *  
124.000      READ(5,*) (WGR(I),I=1,NHORN)  
125.000 *  
126.000 * HRNLTH - HORN LENGTH IN INS.  
127.000 *  
128.000 30    READ(5,*) (HRNLTH(I),I=1,NHORN)  
129.000 *  
130.000 * MODH - CHOICE OF APERTURE FIELD MODEL  
131.000 *      = 0 , ELECTRIC FIELD MODEL  
132.000 *      = 1 , CHU MODEL  
133.000 *  
134.000      READ(5,*) MODH  
135.000 *  
136.000 * OPTH - OPTION FOR SPECIFYING FEED POSITIONS AND ROTATIONS.  
137.000 *      = 0, FEED POSITIONS ARE SPECIFIED BEFORE ROTATION.THE WHOLE  
138.000 *          FEED ARRAY IS ROTATED ABOUT THE GLOBAL X-AXIS BY ANGLE  
139.000 *          ALPHA FOLLOWED BY ROTATION ABOUT THE NEW Y-AXIS BY ANGLE  
140.000 *          BETA.FINALLY EACH FEED IS ROTATED ABOUT ITS OWN LOCAL Z-  
141.000 *          AXIS BY ANGLE GAMMA.THIS OPTION ALLOWS FOR THE COLLECTIVE  
142.000 *          MOVEMENT OF THE ARRAY.ONLY THREE VALUES NEED TO BE SPECI-  
143.000 *          FIED FOR THE ROTATIONS.  
144.000 *      = 1, FEED DISPLACEMENTS SPECIFIED ARE THE FINAL POSITIONS.THE  
145.000 *          ROTATIONS TO FOLLOW ARE ABOUT THE INDIVIDUAL FEED LOCAL  
146.000 *          X,Y AND Z-AXES.THIS OPTION ALLOWS FOR INDEPENDENT ROTATION  
147.000 *          AND POSITIONING OF THE FEEDS.THREE ROTATION ANGLES MUST BE  
148.000 *          ENTERED FOR EACH FEED.  
149.000 *  
150.000      READ(5,*) OPTH  
151.000 *  
152.000 * DISPLACEMENTS OF COMPONENT FEEDS IN INCHES FROM FOCAL POINT  
153.000 *  
154.000      READ(5,*) (DX(I),DY(I),DZ(I),I=1,NHORN)  
155.000 *  
156.000 * ALPHA - ROTATION ABOUT EITHER THE GLOBAL OR LOCAL X-AXIS IN DEG.  
157.000 * BETA - ROTATION ABOUT EITHER THE GLOBAL OR LOCAL Y-AXIS IN DEG.  
158.000 * GAMMA - ROTATION ABOUT LOCAL Z-AXIS IN DEG.  
159.000 *  
160.000      NH = 1  
161.000      IF (OPTH.NE.0) NH = NHORN  
162.000      READ(5,*) (ALPHA(I),BETA(I),GAMMA(I),I=1,NH)  
163.000 *  
164.000 * IPOLA - POLARISATION OF SECONDARY BEAM FROM REFLECTOR SYSTEM.
```

```
165.000 *      - VP=1 , HP=2 , RHCP=3 , LHCP=4
166.000 *
167.000      READ(5,*) IPOLA
168.000      IF (IPOLA.LE.2) GO TO 50
169.000 *
170.000 * FOR NON-IDEAL CP FEEDS, AN IMBALANCE EXISTS IN THE AMPLITUDE
171.000 * EXCITATIONS OF THE ORTHOGONAL PORTS AS WELL AS DEVIATION FROM THE
172.000 * PHASE QUADRATURE CONDITION. PORT 1 IS ASSOCIATED WITH THE X-PORT
173.000 * AND PORT 2 WITH THE Y-PORT.
174.000 *
175.000 * CXY(I) = AMPLITUDE IMBALANCE OF Y-PORT RELATIVE TO X-PORT.
176.000 * PSI(I) = DEPARTURE FROM PHASE QUADRATURE IN DEG OF THE Y-PORT.
177.000 *
178.000      READ(5,*) (CXY(I),I=1,NHORN)
179.000      READ(5,*) (PSI(I),I=1,NHORN)
180.000 *
181.000 * HPWR - POWER INPUT TO EACH FEED IN WATTS.
182.000 * HPHASE - RELATIVE PHASE EXCITATION OF EACH FEED IN DEG.
183.000 *
184.000 50    READ(5,*) (HPWR(I),HPHASE(I),I=1,NHORN)
185.000 *
186.000 * DATA DESCRIBING PARABOLIC REFLECTOR CONFIGURATION.
187.000 *
188.000 * F - FOCAL LENGTH OF PARABOLIC REFLECTOR IN INCHES.
189.000 * SX2 - X-DIMENSION OF ELLIPTICAL REFLECTOR APERTURE IN INCHES
190.000 * SY2 - Y-DIMENSION OF ELLIPTICAL REFLECTOR APERTURE IN INCHES
191.000 * DELTAX - X-OFFSET OF APERTURE CENTRE IN INCHES
192.000 * DELTAY - Y-OFFSET OF APERTURE CENTRE IN INCHES.
193.000 *
194.000      READ(5,*) F, SX2, SY2, DELTAX, DELTAY
195.000 *
196.000 * OPTB - OPTION FOR SPECIFYING LIMITS OF INTEGRATION TO SIMULATE BLOCKAGE,
197.000 *      = 0, LIMITS ARE GENERATED BY PROGRAM FROM INPUT REFLECTOR
198.000 *      DATA. NO APERTURE BLOCKAGE IS ASSUMED.
199.000 *      = 1, LIMITS ARE DERIVED BY THE USER AND READ INTO THE PROGRAM,
200.000 *
201.000      READ(5,*) OPTB
202.000      IF (OPTB.EQ.0) GO TO 60
203.000 *
204.000 * NREG - NUMBER OF REGIONS OF PHI-INTEGRATION.
205.000 *
206.000      READ(5,*) NREG
207.000 *
208.000 * PHL(I) - LOWER LIMIT OF PHI-INTEG FOR THE I TH REGION IN RADIANS.
209.000 * PHU(I) - UPPER LIMIT OF PHI-INTEG FOR THE I TH REGION IN RADIANS.
210.000 *
211.000      READ(5,*) (PHL(I),PHU(I),I=1,NREG)
212.000 *
213.000 * BX2 - X-AXIS DIMENSION OF CENTRAL ELLIPTICAL BLOCKAGE IN INS.
214.000 * BY2 - Y-AXIS DIMENSION OF CENTRAL ELLIPTICAL BLOCKAGE IN INS.
215.000 *
216.000      READ(5,*) BX2, BY2
217.000 *
218.000 * OPTQ - OPTION FOR SPECIFYING NO. OF INTEGRATION POINTS,
219.000 *      = 0, NO. OF INTEGRATION POINTS IS DETERMINED BY PROGRAM.
220.000 *      = 1, SPECIFIED BY USER.
```

```
221.000 *
222.000 60 READ(5,*) OPTQ
223.000 IF (OPTQ.EQ.0) GO TO 70
224.000 *
225.000 * DATA FOR SURFACE INTEGRATION,
226.000 * NQR - NO. OF INTEGRATION POINTS IN THE RADIAL-DIRECTION,
227.000 * NQP - NO. OF INTEGRATION POINTS IN THE PHI-DIRECTION,
228.000 * CHOOSE FROM THE FOLLOWING LIST - 3,4,6,8,10,12,14,16,20,24,28,34,40 PTS
229.000 *
230.000 READ(5,*) NQR,NQP
231.000 *
232.000 * DETERMINE LOCATION OF THESE INTEGRATION FORMULAS,
233.000 *
234.000 CALL APQUAD(NQR,I,LQR)
235.000 NQR = I
236.000 CALL APQUAD(NQP,I,LQP)
237.000 NQP = I
238.000 *
239.000 * READ IN DATA FOR FAR FIELD OBSERVATION
240.000 *
241.000 * ELS - START OF ELEV CUT IN DEG
242.000 * ELE - END OF ELEV CUT IN DEG
243.000 * NEL - NO. OF ELEVATION GRID POINTS. (NO. OF AZ CUTS)
244.000 * AZS - START OF AZIMUTH CUT IN DEG
245.000 * AZE - END OF AZIMUTH CUT IN DEG
246.000 * NAZ - NO. OF AZIMUTH GRID POINTS. (NO. OF ELEV CUTS)
247.000 *
248.000 70 READ(5,*) AZS,AZE,NAZ,ELS,ELE,NEL
249.000 IF (NEL.LE.MAXEL) GO TO 74
250.000 WRITE(6,72) MAXEL
251.000 72 FORMAT(1X,'EXECUTION TERMINATED. NO. OF ELEV PTS EXCEEDED MAX. OF'
252.000 +,I3)
253.000 STOP
254.000 74 IF (NAZ.LE.MAXAZ) GO TO 78
255.000 WRITE(6,76) MAXAZ
256.000 76 FORMAT(1X,'EXECUTION TERMINATED. NO. OF AZ PTS EXCEEDED MAX. OF'
257.000 +,I3)
258.000 STOP
259.000 78 CONTINUE
260.000 *
261.000 * XDQ - X-TRANSLATION OF FIELD CO-ORDINATE SYSTEM FROM GLOBAL SYSTEM.(INS)
262.000 * YDQ - Y-TRANSLATION OF FIELD CO-ORDINATE SYSTEM FROM GLOBAL SYSTEM.(INS)
263.000 * ZDQ - Z-TRANSLATION OF FIELD CO-ORDINATE SYSTEM FROM GLOBAL SYSTEM.(INS)
264.000 *
265.000 READ(5,*) XDQ,YDQ,ZDQ
266.000 *
267.000 * PVR - ANGULAR ROTATION OF FIELD POLARISATION VECTOR IN DEGREES.
268.000 *
269.000 READ(5,*) PVR
270.000 *
271.000 * DATA INPUT COMPLETED
272.000 *
273.000 80 FORMAT(12I5)
274.000 90 FORMAT(12F10.4)
275.000 95 FORMAT(1X,15A4)
276.000 WRITE(6,95) (IHEAD(I),I=1,15)
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277.000      WRITE(6,100)
278.000 100  FORMAT(1X,'FREQUENCY IN GHZ')
279.000      WRITE(6,90) FREQ
280.000      WRITE(6,110)
281.000 110  FORMAT(1X,'NO OF FEED HORNS')
282.000      WRITE(6,80) NHORN
283.000      WRITE(6,115)
284.000 115  FORMAT(1X,'HORN TYPE - 0=PYRAMIDAL , 1=CONICAL')
285.000      WRITE(6,80) ITYPE
286.000      WRITE(6,120)
287.000 120  FORMAT(1X,'AMPL. AND PHASE (RAD) OF HIGHER ORDER MODE')
288.000      WRITE(6,90) AM , PM
289.000      IF (ITYPE.EQ.1) GO TO 145
290.000      WRITE(6,125)
291.000 125  FORMAT(1X,'E-PLANE DIM. OF HORN APERTURE IN INS.')
292.000      WRITE(6,90) (B(I),I=1,NHORN)
293.000      WRITE(6,130)
294.000 130  FORMAT(1X,'H-PLANE DIM. OF HORN APERTURE IN INS.')
295.000      WRITE(6,90) (A(I),I=1,NHORN)
296.000      WRITE(6,135)
297.000 135  FORMAT(1X,'E-PLANE DIM. OF INPUT WAVEGUIDE IN INS.')
298.000      WRITE(6,90) (WGB(I),I=1,NHORN)
299.000      WRITE(6,140)
300.000 140  FORMAT(1X,'H-PLANE DIM. OF INPUT WAVEGUIDE IN INS.')
301.000      WRITE(6,90) (WGA(I),I=1,NHORN)
302.000      GO TO 160
303.000 145  WRITE(6,150)
304.000 150  FORMAT(1X,'          RADIUS OF HORN APERTURE IN INS.')
305.000      WRITE(6,90) (AR(I),I=1,NHORN)
306.000      WRITE(6,155)
307.000 155  FORMAT(1X,'RADIUS OF INPUT WAVEGUIDE IN INS.')
308.000      WRITE(6,90) (WGR(I),I=1,NHORN)
309.000 160  WRITE(6,165)
310.000 165  FORMAT(1X,'HORN LENGTH IN INS')
311.000      WRITE(6,90) (HRNLTH(I),I=1,NHORN)
312.000      WRITE(6,170)
313.000 170  FORMAT(1X,'HORN APERTURE FIELD MODEL - 0=E-FIELD , 1=CHU')
314.000      WRITE(6,80) MODH
315.000      IF (OPTH.EQ.1) THEN
316.000          WRITE(6,175)
317.000 175  FORMAT(1X,'OPT. CHOSEN - INDIVIDUAL DISPLACEMENT AND ROTATION',
318.000      +' OF HORNS')
319.000      ELSE
320.000          WRITE(6,180)
321.000 180  FORMAT(1X,'OPT. CHOSEN - COLLECTIVE MOVEMENT AND ROTATION OF',
322.000      +' HORN ARRAY')
323.000      END IF
324.000      WRITE(6,80) OPTH
325.000      WRITE(6,185)
326.000 185  FORMAT(1X,'DISPLACEMENTS OF FEEDS IN INS.')
327.000      WRITE(6,90) (DX(I),DY(I),DZ(I),I=1,NHORN)
328.000      WRITE(6,190)
329.000 190  FORMAT(1X,'ROT. OF FEEDS ABOUT X-,Y-,AND Z-AXIS IN DEG.')
330.000      WRITE(6,90) (ALPHA(I),BETA(I),GAMMA(I),I=1,NH)
331.000      WRITE(6,195)
332.000 195  FORMAT(1X,'POLAR. OF SECON. BEAM - VP=1,HP=2,RHCP=3,LHCP=4')
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333.000      WRITE(6,80) IPOLA
334.000      IF (IPOLA,LE,2) GO TO 210
335.000      WRITE(6,200)
336.000 200  FORMAT(1X,'AMPL IMBALANCE OF Y-PORT REL. TO X-PORT')
337.000      WRITE(6,90) (CXY(I),I=1,NHORN)
338.000      WRITE(6,205)
339.000 205  FORMAT(1X,'PHASE DEPARTURE OF Y-PORT FROM QUADRATURE IN DEG.')
340.000      WRITE(6,90) (PSI(I),I=1,NHORN)
341.000 210  WRITE(6,215)
342.000 215  FORMAT(1X,'POWER(W) AND PHASE(DEG) OF FEED EXCITATIONS')
343.000      WRITE(6,90) (HPWR(I),HPHASE(I),I=1,NHORN)
344.000      WRITE(6,220)
345.000 220  FORMAT(1X,'FOC LTH.,APER. X-DIM,Y-DIM AND X-, Y-OFFSET IN INS.')
346.000      WRITE(6,90) F,SX2,SY2,DELTAX,DELTAY
347.000      IF (OPTB,LE,0) GO TO 260
348.000      WRITE(6,230)
349.000 230  FORMAT(1X,'NO. OF REGIONS OF PHI-INTEG = ',I2)
350.000      WRITE(6,80) NREG
351.000      WRITE(6,240)
352.000 240  FORMAT(1X,'LOWER AND UPPER LIMITS OF PHI-INTEG IN RADIANS')
353.000      WRITE(6,90) (PHL(I),PHU(I),I=1,NREG)
354.000      WRITE(6,250)
355.000 250  FORMAT(1X,'X-AND Y-DIM. OF CENTRAL ELLIPTICAL BLOCKAGE IN INS')
356.000      WRITE(6,90) BX2,BY2
357.000 260  IF (OPTQ,LE,0) GO TO 275
358.000      WRITE(6,270)
359.000 270  FORMAT(1X,'INTEG. PTS. SPEC. BY USER FOR RADIAL AND PHI-VAR.')
360.000      WRITE(6,80) NQR, NQP
361.000 275  WRITE(6,280)
362.000 280  FORMAT(1X,'START,STOP AND NO. OF PTS. FOR AZ,EL SCAN')
363.000      WRITE(6,290) AZS,AZE,NAZ,ELS,ELE,NEL
364.000 290  FORMAT(2(2F10.5,I5))
365.000      WRITE(6,300)
366.000 300  FORMAT(1X,'X-,Y-,Z-TRANSLATION OF FIELD CO-ORD. SYSTEM IN INS')
367.000      WRITE(6,90) XDQ , YDQ , ZDQ
368.000      WRITE(6,310)
369.000 310  FORMAT(1X,'ROTATION OF FIELD POLARISATION VECTOR IN DEGREES')
370.000      WRITE(6,90) PVR
371.000 *
372.000 * COMPUTE WAVELENGTH
373.000 *
374.000      WAVE = 29.97925/(2.54*FREQ)
375.000      RK = 2.0*PI/WAVE
376.000      IF (OPTH,NE,0) GO TO 325
377.000 *
378.000 * COMPUTE FINAL LOCATIONS OF HURNS AFTER COLLECTIVE ALPHA AND BETA ROTATIONS.
379.000 *
380.000      SA = SIN(ALPHA(1)/RAD)
381.000      CA = COS(ALPHA(1)/RAD)
382.000      SB = SIN(BETA(1)/RAD)
383.000      CB = COS(BETA(1)/RAD)
384.000      SG = SIN(GAMMA(1)/RAD)
385.000      CG = COS(GAMMA(1)/RAD)
386.000      DO 315 I = 1,NHORN
387.000      ARG1 = DX(I)
388.000      ARG2 = DY(I)
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389.000      ARG3 = DZ(I)
390.000      DX(I) = ARG1*CB + ARG3*SB
391.000      DY(I) = ARG1*SA*SB + ARG2*CA - ARG3*SA*CB
392.000      DZ(I) = -ARG1*SB*CA + ARG2*SA + ARG3*CA*CB
393.000 315  CONTINUE
394.000 *
395.000 * COMPUTE TRANSFORMATION FUNCTIONS OF COLLECTIVE HORN ROTATIONS
396.000 *
397.000      W11(1) = CB*CG
398.000      W12(1) = SA*SB*CG + CA*SG
399.000      W13(1) = -CA*SB*CG + SA*SG
400.000      W21(1) = -CB*SG
401.000      W22(1) = -SA*SB*SG + CA*CG
402.000      W23(1) = CA*SB*SG + SA*CG
403.000      W31(1) = SB
404.000      W32(1) = -SA*CB
405.000      W33(1) = CA*CB
406.000      IF (NHORN.EQ.1) GO TO 335
407.000      DO 320 I = 2,NHORN
408.000      W11(I) = W11(1)
409.000      W12(I) = W12(1)
410.000      W13(I) = W13(1)
411.000      W21(I) = W21(1)
412.000      W22(I) = W22(1)
413.000      W23(I) = W23(1)
414.000      W31(I) = W31(1)
415.000      W32(I) = W32(1)
416.000      W33(I) = W33(1)
417.000 320  CONTINUE
418.000      GO TO 335
419.000 *
420.000 * COMPUTE TRANSFORMATION FUNCTIONS OF INDIVIDUAL HORN ROTATIONS.
421.000 *
422.000 325  DO 330 I = 1,NHORN
423.000      SB = SIN(BETA(I)/RAD)
424.000      CB = COS(BETA(I)/RAD)
425.000      SA = SIN(ALPHA(I)/RAD)
426.000      CA = COS(ALPHA(I)/RAD)
427.000      SG = SIN(GAMMA(I)/RAD)
428.000      CG = COS(GAMMA(I)/RAD)
429.000      W11(I) = CB*CG
430.000      W12(I) = SA*SB*CG + CA*SG
431.000      W13(I) = -CA*SB*CG + SA*SG
432.000      W21(I) = -CB*SG
433.000      W22(I) = -SA*SB*SG + CA*CG
434.000      W23(I) = CA*SB*SG + SA*CG
435.000      W31(I) = SB
436.000      W32(I) = -SA*CB
437.000      W33(I) = CA*CB
438.000 330  CONTINUE
439.000 *
440.000 * CONVERT DEGREES INTO RADIANS AND DB INTO VOLTAGE.
441.000 *
442.000 335  DO 340 I = 1,NHORN
443.000      HPHASE(I) = HPHASE(I)/RAD
444.000 340  CONTINUE

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445.000 \*

446.000 \* SORT HORNS INTO DIFFERENT GROUPS ACCORDING TO SIZES

447.000 \*

448.000 \* NGP = TOTAL NO. OF GROUPS

449.000 \* IND(N) = INDEX OF HORN THAT IS REPRESENTATIVE OF THE N TH GROUP.

450.000 \* IGP(I) = INDEX OF GROUP TO WHICH THE I TH HORN BELONGS.

451.000 \*

452.000       IND(1) = 1

453.000       IGP(1) = 1

454.000       NGP = 1

455.000       IF (NHORN,EQ.1) GO TO 354

456.000       DO 352 I = 2,NHORN

457.000       IF (ITYPE,EQ.1) GO TO 344

458.000 \* RECTANGULAR APERTURE

459.000       DO 342 J = 1,NGP

460.000       IF (ABS(A(I) - A(IND(J))),LT.0.001,AND,ABS(B(I)-B(IND(J))),LT.  
461.000       +0.001) GO TO 350

462.000 342   CONTINUE

463.000       GO TO 348

464.000 \* CIRCULAR APERTURE

465.000 344   DO 346 J = 1,NGP

466.000       IF (ABS(AR(I) - AR(IND(J))),LT.0.001) GO TO 350

467.000 346   CONTINUE

468.000 348   NGP = NGP + 1

469.000       IND(NGP) = I

470.000       IGP(I) = NGP

471.000       GO TO 352

472.000 350   IGP(I) = J

473.000 352   CONTINUE

474.000 \*

475.000 \* MAXIMUM ALLOWABLE NUMBER OF DIFFERENT HORN GROUPS IS DEFINED BY MAXHGP.

476.000       IF (NGP,LE.,MAXHGP) GO TO 354

477.000       WRITE(6,353) NGP, MAXHGP

478.000 353   FORMAT(1X,'EXECUTION TERMINATED. NO. OF HORN GROUPS IS ',I2,  
479.000       +', MAXIMUM ALLOWABLE IS ',I2)

480.000       STOP

481.000 \*

482.000 \* COMPUTE E- AND H-PLANE PATTERNS OF EACH HORN GROUP

483.000 \*

484.000 \* NPP = NO. OF OBSERVATION POINTS SPANNING 0 TO 90 DEG.

485.000 \*       THIS HAS BEEN ARBITRARILY SET TO 46.

486.000 \* PAI = EQUAL SPACING OF OBSERVATION POINTS.

487.000 \*

488.000 354   CONTINUE

489.000       NPP = 46

490.000       PAI = 1.570/(NPP - 1)

491.000       DO 356 I = 1,NPP

492.000       TETA(I) = PAI\*(I-1)

493.000 356   CONTINUE

494.000       IF (ITYPE,EQ.1) GO TO 360

495.000       DO 358 J = 1,NGP

496.000       I = IND(J)

497.000       CALL PYRHRN(A(I),B(I),WGA(I),WGB(I),HRNLTH(I),AM,PM,MODH,RK,J)

498.000 358   CONTINUE

499.000       GO TO 365

500.000 360   DO 362 J = 1,NGP

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501.000      I = IND(J)
502.000      CALL CONHRN(AR(I),WGR(I),HRNLTH(I),AM,PM,MODH,RK,J)
503.000 362  CONTINUE
504.000 *
505.000 * SPECIFY EXCITATIONS OF ORTHOGONAL PORTS OF EACH HORN.
506.000 *
507.000 365  DO 390 I = 1,NHORN
508.000      GO TO (370,375,380,385), IPOLA
509.000 *
510.000 * VERTICAL POLARIZATION
511.000 *
512.000 370  CX(I) = 1.0
513.000      CY(I) = 0.0
514.000      PSI(I) = 0.0
515.000      GO TO 390
516.000 *
517.000 * HORIZONTAL POLARIZATION
518.000 *
519.000 375  CX(I) = 0.0
520.000      CY(I) = 1.0
521.000      PSI(I) = 0.0
522.000      GO TO 390
523.000 *
524.000 * RIGHT HANDED CIRCULAR POLARIZATION
525.000 *
526.000 380  CX(I) = 1.0
527.000      CY(I) = CXY(I)*CX(I)
528.000      PSI(I) = PSI(I)/RAD + 1.5707963
529.000      GO TO 390
530.000 *
531.000 * LEFT HANDED CIRCULAR POLARIZATION
532.000 *
533.000 385  CX(I) = 1.0
534.000      CY(I) = CXY(I)*CX(I)
535.000      PSI(I) = PSI(I)/RAD - 1.5707963
536.000 390  CONTINUE
537.000 *
538.000 * COMPUTE VOLTAGE NORMALISATION CONSTANT , AN , FOR EACH FEED.
539.000 *
540.000      DO 395 J = 1,NGP
541.000      CALL PWRFED(J,PWR1(J))
542.000 395  CONTINUE
543.000      DO 400 I = 1,NHORN
544.000      AN(I) = (CX(I)*CX(I) + CY(I)*CY(I))*PWR1(IGP(I))
545.000 400  CONTINUE
546.000      DO 415 J = 1,NHORN
547.000      AN(J) = SQRT(HFWR(J)/AN(J))
548.000 415  CONTINUE
549.000 *
550.000 * TAKE SINE AND COSINE OF FIELD VECTOR ROTATION ANGLE.
551.000 *
552.000      CPVR = COS(PVR/RAD)
553.000      SPVR = SIN(PVR/RAD)
554.000      IF (OPTB.GT.0) GO TO 425
555.000 *
556.000 * INTERNAL DEFAULT INTEGRATION LIMITS.
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557.000 \* APERTURE IS DIVIDED INTO FOUR REGIONS FOR PHI-INTEG.  
558.000 \* LIMITS OF THESE REGIONS ARE SET BELOW.  
559.000 \*  
560.000 NREG = 4  
561.000 PHL(1) = 0.0  
562.000 PHU(1) = 1.570796327  
563.000 DO 420 I = 2,NREG  
564.000 PHL(I) = PHL(I-1) + 1.570796327  
565.000 PHU(I) = PHU(I-1) + 1.570796327  
566.000 420 CONTINUE  
567.000 \*  
568.000 \* THERE IS NO CENTRAL BLOCKAGE.  
569.000 \*  
570.000 BX2 = 0.0  
571.000 BY2 = 0.0  
572.000 425 IF (OPTQ.GT.0) GO TO 455  
573.000 \*  
574.000 \* SELECTION OF THE APPROPRIATE QUADRATURE FORMULA  
575.000 \*  
576.000 XMAX = -99999.0  
577.000 XMIN = +99999.0  
578.000 YMAX = -99999.0  
579.000 YMINT = +99999.0  
580.000 DO 430 I = 1,NHORN  
581.000 IF (DX(I).GT.XMAX) XMAX = DX(I)  
582.000 IF (DX(I).LT.XMIN) XMIN = DX(I)  
583.000 IF (DY(I).GT.YMAX) YMAX = DY(I)  
584.000 IF (DY(I).LT.YMIN) YMIN = DY(I)  
585.000 430 CONTINUE  
586.000 \* FIND THE LARGEST ANGLE BETWEEN COMPONENT BEAMS AND FIELD  
587.000 \* OBSERVATION POINTS.  
588.000 ARG1 = ABS(ELE/RAD + ATAN(XMAX/F))  
589.000 ARG2 = ABS(ATAN(XMIN/F) + ELS/RAD)  
590.000 ARG3 = ABS(AZE/RAD + ATAN(YMAX/F))  
591.000 ARG4 = ABS(ATAN(YMIN/F) + AZS/RAD)  
592.000 ARG1 = AMAX1(ARG1,ARG2)  
593.000 ARG3 = AMAX1(ARG3,ARG4)  
594.000 NQR = (SIN(ARG1)\*SX2/WAVE + 1.0)\*1.50  
595.000 NQP = (SIN(ARG3)\*SY2/WAVE + 1.0)\*1.50  
596.000 NQR = MAX0(NQR,NQP)  
597.000 \*  
598.000 CALL APQUAD(NQR,NQP,LQP)  
599.000 NQR = NQP  
600.000 LQR = LQP  
601.000 WRITE(6,450)  
602.000 450 FORMAT(1X,'NO. OF INTEG. PTS. SELECTED FOR RADIAL AND PHI-VAR.')  
603.000 WRITE(6,80) NQR,NQP  
604.000 455 IF (NQR.LE.MAXQ.AND.NQP.LE.MAXQ) GO TO 459  
605.000 WRITE(6,457) NQR,NQP  
606.000 457 FORMAT(1X,'EXECUTION TERMINATED. INCREASE ARRAYS SIZE TO',  
607.000 +' ACCOMMODATE FOLLOWING RADIAL AND PHI INTEG. PTS.-',2I3)  
608.000 STOP  
609.000 459 CONTINUE  
610.000 \*  
611.000 \* COMPUTE SEMI-AXES DIMENSIONS FOR REFLECTOR AND BLOCKAGE APERTURES.  
612.000 \*

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613.000      SX2 = SX2*0.50
614.000      SY2 = SY2*0.50
615.000      BX2 = BX2*0.50
616.000      BY2 = BY2*0.50
617.000 *
618.000 * INITIALISE CURRENT MATRIX RJX,RJY,RJZ
619.000 *
620.000      KOUNT = 0
621.000      DO 470 L = 1,NREG
622.000      DO 465 J = 1,NQR
623.000      DO 460 I = 1,NQP
624.000      KOUNT = KOUNT + 1
625.000      RJX(KOUNT) = (0.0,0.0)
626.000      RJY(KOUNT) = (0.0,0.0)
627.000      RJZ(KOUNT) = (0.0,0.0)
628.000 460  CONTINUE
629.000 465  CONTINUE
630.000 470  CONTINUE
631.000 *
632.000 * COMPUTE CURRENT MATRIX
633.000 * AT THE SAME TIME COMPUTE POWER INTERCEPTED BY REFL
634.000 *
635.000      PWR = 0.0
636.000 *
637.000 * L = INDEX FOR REGION OF PHI- INTEGRATION.
638.000 *
639.000      KOUNT = 0
640.000      DO 520 L = 1,NREG
641.000 *
642.000 * I = INDEX FOR PHI-INTEG
643.000 *
644.000      DO 510 I = 1,NQP
645.000      PHII = (PHL(L)+PHU(L))*0.50+(PHU(L)-PHL(L))*0.50*QX(I+LQP)
646.000      CPI = COS(PHII)
647.000      SPI = SIN(PHII)
648.000 *
649.000 * FIND THE LIMITS OF RADIAL-INTEGRATION GIVEN PHII
650.000 *
651.000      CALL RADLIM(CPI,SPI,SX2,SY2,BX2,BY2,RDL(I,L),RDU(I,L))
652.000      FAC = (PHU(L)-PHL(L))*(RDU(I,L)-RDL(I,L))*0.25
653.000 *
654.000 * J = INDEX FOR RHO-INTEG.
655.000 *
656.000      DO 500 J = 1,NQR
657.000      RDJ = (RDL(I,L)+RDU(I,L))*0.50+(RDU(I,L)-RDL(I,L))*0.50*
658.000      + QX(J+LQR)
659.000      KOUNT = KOUNT + 1
660.000 *
661.000 * STORE REFLECTOR SURFACE POINTS
662.000 *
663.000      XG(KOUNT) = RDJ*CPI + DELTAX
664.000      YG(KOUNT) = RDJ*SPI + DELTAY
665.000      ZG(KOUNT) = (XG(KOUNT)**2 + YG(KOUNT)**2)*0.25/F - F
666.000 *
667.000 * COMPUTE COMPONENTS OF SURFACE NORMAL
668.000 *
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669.000      RNX = -XG(KOUNT)*0.50/F
670.000      RNY = -YG(KOUNT)*0.50/F
671.000 *
672.000 * K = INDEX FOR FEED HORN
673.000      EX = (0.0,0.0)
674.000      EY = (0.0,0.0)
675.000      EZ = (0.0,0.0)
676.000      HX = (0.0,0.0)
677.000      HY = (0.0,0.0)
678.000      HZ = (0.0,0.0)
679.000      DO 490 K = 1,NHORN
680.000 * THE FOLLOWING TRANSFORMATIONS CONVERT SURFACE POINT
681.000 * COORDINATES TO HORN COORDINATES.
682.000 * TRANSFORM (RHO,THETA,PHI) TO (RHOT,THETAT,PHIT)
683.000      RHOT = SQRT((XG(KOUNT) - DX(K))**2 + (YG(KOUNT) - DY(K))**2
684.000      + +(ZG(KOUNT) - DZ(K))**2)
685.000      CTT = (ZG(KOUNT)-DZ(K))/RHOT
686.000      STT = ACOS(CTT)
687.000      STT = SIN(STT)
688.000      SPT = ATAN2((YG(KOUNT)-DY(K)),(XG(KOUNT)-DX(K)))
689.000      CPT = COS(SPT)
690.000      SPT = SIN(SPT)
691.000 *
692.000 * TRANSFORM (RHOT,THETAT,PHIT) TO (RHOR,THETAR,PHIR)
693.000      STSP = STT*SPT
694.000      STCP = STT*CPT
695.000      CTR = STCP*W31(K) + STSP*W32(K) + CTT*W33(K)
696.000      THETAR = ACOS(CTR)
697.000      STR = SIN(THETAR)
698.000      SPR = STCP*W21(K) + W22(K)*STSP + W23(K)*CTT
699.000      CPR = STCP*W11(K) + STSP*W12(K) + CTT*W13(K)
700.000      SPR = ATAN2(SPR,CPR)
701.000      CPR = COS(SPR)
702.000      SPR = SIN(SPR)
703.000      CTCP = CTR*CPR
704.000      CTSP = CTR*SPR
705.000 *
706.000      TXT = CTCP*W11(K) + CTSP*W21(K) - STR*W31(K)
707.000      TYT = CTCP*W12(K) - STR*W32(K) + CTSP*W22(K)
708.000      TZT = CTCP*W13(K) + CTSP*W23(K) - STR*W33(K)
709.000      TXP = -SPR*W11(K) + CPR*W21(K)
710.000      TYP = -SPR*W12(K) + CPR*W22(K)
711.000      TZP = -SPR*W13(K) + CPR*W23(K)
712.000 *
713.000      PT = RK*RHOT
714.000      EXPN = CMPLX(COS(PT),-SIN(PT))/RHOT
715.000 * COMPUTE FEED ARRAY FIELDS AT (RHOR,THETAR,PHIR)
716.000      CALL SOURCE(THETAR,SPR,CPR,EETHETA,EPHI,K)
717.000      EETHETA = EETHETA*EXPN
718.000      EPHI = EPHI*EXPN
719.000      FTX = EETHETA*TXP - EPHI*TXT
720.000      FTY = EETHETA*TYP - EPHI*TYT
721.000      FTZ = EETHETA*TZP - EPHI*TZT
722.000      RJX(KOUNT) = RJX(KOUNT) + FTZ*RNY - FTY
723.000      RJP(KOUNT) = RJP(KOUNT) + FTX - FTZ*RNX
724.000      RJZ(KOUNT) = RJZ(KOUNT) + FTY*RNX - FTX*RNY

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725.000 *
726.000 * COMPUTE COMBINED FEED PATTERN FOR SPILL-OVER CALCULATION
727.000 *
728.000     EX = EX + ETHETA*TXT + EPHI*TXP
729.000     EY = EY + ETHETA*TYT + EPHI*TYP
730.000     EZ = EZ + ETHETA*TZT + EPHI*TZP
731.000     HX = HX + FTX
732.000     HY = HY + FTY
733.000     HZ = HZ + FTZ
734.000 490  CONTINUE
735.000     FACW = FAC*RDJ*QW(I+LQP)*QW(J+LQR)
736.000     RJX(KOUNT) = RJX(KOUNT)*FACW
737.000     RJJ(KOUNT) = RJJ(KOUNT)*FACW
738.000     RJZ(KOUNT) = RJZ(KOUNT)*FACW
739.000     PWR = PWR - (REAL(EY*CONJG(HZ)) - EZ*CONJG(HY))*RNX +
740.000     +           REAL(EZ*CONJG(HX)) - EX*CONJG(HZ))*RNY +
741.000     +           REAL(EX*CONJG(HY)) - EY*CONJG(HX)))*FACW
742.000 500  CONTINUE
743.000 510  CONTINUE
744.000 520  CONTINUE
745.000 * COMPUTATION OF CURRENT MATRIX COMPLETED
746.000 *
747.000 * COMPUTE SPILL-OVER EFFICIENCY - ETAS
748.000 * PWR = POWER CAPTURED BY REFLECTOR
749.000 *
750.000     PWR = PWR*0.50/ZETA
751.000 * PT = TOTAL POWER RADIATED
752.000     PT = 0.0
753.000     DO 530 K = 1,NHORN
754.000 530  PT = PT + HPWR(K)
755.000     ETAS = PWR/PT
756.000     WRITE(6,540) ETAS
757.000 540  FORMAT(//,1X,'SPILL-OVER EFFICIENCY =',F7.3,/)
758.000     PT = PT*60.0*WAVE*WAVE
759.000 *
760.000 * COMPUTE GAIN AND PHASE OF CO-POLAR AND X-POLAR COMPONENTS
761.000 *
762.000     ELIN = ELE - ELS
763.000     IF (NEL.GT.1) ELIN = ELIN/FLOAT(NEL - 1)
764.000     AZIN = AZE - AZS
765.000     IF (NAZ.GT.1) AZIN = AZIN/FLOAT(NAZ - 1)
766.000     DO 550 I = 1,NEL
767.000 550  EL(I) = ELE - ELIN*(I-1)
768.000     DO 560 I = 1,NAZ
769.000 560  AZ(I) = AZS + AZIN*(I-1)
770.000     KOUNT = 0
771.000     DO 580 I = 1,NEL
772.000     DO 570 J = 1,NAZ
773.000     KOUNT = KOUNT + 1
774.000     CALL CONV(EL(I),AZ(J),STQ,CTQ,SPQ,CPQ)
775.000     CALL FIELD(STQ,CTQ,SPQ,CPQ,IPOLA,CGNO,XGNO,CPHO)
776.000     CGN(KOUNT) = CGNO
777.000     XGN(KOUNT) = XGNO
778.000     CPH(KOUNT) = CPHO
779.000 570  CONTINUE
780.000 580  CONTINUE

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781.000 * OUTPUT FAR FIELD OBSERVATION CUTS.  
782.000 *  
783.000      WRITE(6,710)  
784.000 710  FORMAT(////,50X,'CO-POLAR GAIN IN DB')  
785.000      WRITE(6,720)  
786.000 720  FORMAT(48X,23(1H-))  
787.000      WRITE(6,730) (AZ(I),I=1,NAZ)  
788.000 730  FORMAT(//,1X,' ELEV *',50X,'AZIMUTH (DEG)',/,1X,' (DEG) *',  
789.000 +20F6.2)  
790.000      WRITE(6,735)  
791.000 735  FORMAT(1X,65(2H *))  
792.000      DO 740 I = 1,NEL  
793.000      KOUNT = (I-1)*NAZ + 1  
794.000      KOUNT1 = KOUNT + NAZ - 1  
795.000 740  WRITE(6,750) EL(I),(CGN(J),J=KOUNT,KOUNT1)  
796.000 750  FORMAT(/,8X,1H*,/,1X,F7.3,1H*,20F6.2,/,8X,1H*)  
797.000      WRITE(6,760)  
798.000 760  FORMAT(////,50X,'X-POLAR GAIN IN DB')  
799.000      WRITE(6,720)  
800.000      WRITE(6,730) (AZ(I),I=1,NAZ)  
801.000      WRITE(6,735)  
802.000      DO 770 I = 1,NEL  
803.000      KOUNT = (I-1)*NAZ + 1  
804.000      KOUNT1 = KOUNT + NAZ - 1  
805.000 770  WRITE(6,765) EL(I),(XGN(J),J=KOUNT,KOUNT1)  
806.000 765  FORMAT(/,8X,1H*,/,1X,F7.3,1H*,20F6.1,/,8X,1H*)  
807.000      WRITE(6,775)  
808.000 775  FORMAT(////,49X,'CO-POLAR PHASE IN DEG')  
809.000      WRITE(6,720)  
810.000      WRITE(6,730) (AZ(I),I=1,NAZ)  
811.000      WRITE(6,735)  
812.000      DO 780 I = 1,NEL  
813.000      KOUNT = (I-1)*NAZ + 1  
814.000      KOUNT1 = KOUNT + NAZ - 1  
815.000 780  WRITE(6,765) EL(I),(CPH(J),J=KOUNT,KOUNT1)  
816.000      OPEN(7,FILE='GNMAT',STATUS='OLD',USAGE='OUTPUT')  
817.000      WRITE(7,10) (IHEAD(I),I=1,15)  
818.000      WRITE(7,290) AZS,AZE,NAZ,ELS,ELE,NEL  
819.000      DO 790 I = 1,NEL  
820.000      KOUNT = (I-1)*NAZ + 1  
821.000      KOUNT1 = KOUNT + NAZ - 1  
822.000 790  WRITE(7,800) (CGN(J),J=KOUNT,KOUNT1)  
823.000 800  FORMAT(10F8.2)  
824.000      STOP  
825.000      END  
826.000      SUBROUTINE RADLIM(CP,SP,A1,B1,A2,B2,RL,RU)  
827.000 *  
828.000 * COMPUTES LOWER AND UPPER LIMITS OF RADIAL VAR. INTEG. FOR A GIVEN  
829.000 * PHI.  
830.000 *  
831.000      RU = A1*B1/SQRT(A1*A1*SP*SP + B1*B1*CP*CP)  
832.000      RL = 0.0  
833.000      IF (A2.LT.1.0E-04,.OR.B2.LT.1.0E-04) RETURN  
834.000      RL = A2*B2/SQRT(A2*A2*SP*SP + B2*B2*CP*CP)  
835.000      RETURN  
836.000      END
```

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837.000      SUBROUTINE SOURCE(THETAR,SP,CP,ETHETA,EPHI,K)
838.000 *
839.000 * COMPUTES ETHETA AND EPHI COMPONENTS OF FEED HORN
840.000 *
841.000      COMPLEX ETHETA,EPHI,CONSTX,CONSTY,EXT,EXP
842.000      COMMON/VAL2/AN(50),HPHASE(50),CX(50),CY(50),PSI(50),IFOLA,IGP(50)
843.000 *
844.000      CONSTX = AN(K)*CMPLX(COS(HPHASE(K)),SIN(HPHASE(K)))
845.000      CONSTY = CONSTX*CY(K)*CMPLX(COS(PSI(K)),SIN(PSI(K)))
846.000      CONSTX = CONSTX*CX(K)
847.000      THETA = 3.14159265 - THETAR
848.000      KK = IGP(K)
849.000      CALL PAT(THETA,ETHA,ETHP,EPHA,EPHP,KK)
850.000      EXT = ETHA*CMPLX(COS(ETHP),SIN(ETHP))
851.000      EXP = EPHA*CMPLX(COS(EPHP),SIN(EPHP))
852.000      ETHETA = -CONSTX*EXT*CP + CONSTY*EXT*SP
853.000      EPHI = -CONSTY*EXP*CP - CONSTX*EXP*SP
854.000      RETURN
855.000      END
856.000      SUBROUTINE PAT(THETA,ETHA,ETHP,EPHA,EPHP,J)
857.000 *
858.000 * INTERPOLATES INPUT PATTERN DATA.
859.000 *
860.000      COMMON/PATERN/EPA(46,10),EPP(46,10),HPA(46,10),HPP(46,10)
861.000      COMMON/PATPAR/NPP,PAI,TETA(46)
862.000 *
863.000 * STATEMENT FUNCTION DEFINING SECOND ORDER LAGRANGIAN INTERPOLATION,
864.000 *
865.000      FX(X1,X2,X3,Y1,Y2,Y3,X) = Y1*(X-X2)*(X-X3)/((X1-X2)*(X1-X3))
866.000      + + Y2*(X-X1)*(X-X3)/((X2-X1)*(X2-X3)) +
867.000      + Y3*(X-X1)*(X-X2)/((X3-X1)*(X3-X2))
868.000 *
869.000      X = THETA
870.000      N = X/PAI
871.000      N1 = N + 1
872.000      IF (N1.EQ.(NPP-1)) N1 = N1 - 1
873.000      IF (N1.GE.NPP) GO TO 10
874.000      X1 = (N1 - 1)*PAI
875.000      X2 = N1*PAI
876.000      X3 = (N1 + 1)*PAI
877.000      N2 = N1 + 1
878.000      N3 = N1 + 2
879.000      Y1 = EPA(N1,J)
880.000      Y2 = EPA(N2,J)
881.000      Y3 = EPA(N3,J)
882.000      ETHA = FX(X1,X2,X3,Y1,Y2,Y3,X)
883.000      Y1 = EPP(N1,J)
884.000      Y2 = EPP(N2,J)
885.000      Y3 = EPP(N3,J)
886.000      ETHP = FX(X1,X2,X3,Y1,Y2,Y3,X)
887.000      Y1 = HPA(N1,J)
888.000      Y2 = HPA(N2,J)
889.000      Y3 = HPA(N3,J)
890.000      EPHA = FX(X1,X2,X3,Y1,Y2,Y3,X)
891.000      Y1 = HPP(N1,J)
892.000      Y2 = HPP(N2,J)
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893.000      Y3 = HPP(N3,J)
894.000      EPHP = FX(X1,X2,X3,Y1,Y2,Y3,X)
895.000      RETURN
896.000 10   WRITE(6,20)
897.000 20   FORMAT(1X,'PATTERN INTERPOLATION IS OUT OF RANGE OF DATA')
898.000      STOP
899.000      END
900.000      SUBROUTINE PWRFED(K,PWR)
901.000 *
902.000 * INTEGRATES POYNTING'S VECTOR TO OBTAIN POWER RADIATED BY THE K TH
903.000 * HORN.
904.000 *
905.000      DIMENSION THL(2),THU(2),POW(2)
906.000      COMMON/VAL1/PI,RAD,RK,ZETA
907.000      COMMON/PATPAR/NPP,PAI,TETA(46)
908.000      COMMON/BLOCK/QX(219),QW(219)
909.000 *
910.000 * RANGE OF THETA-INTEGRATION IS DIVIDED INTO TWO REGIONS, 20-PT
911.000 * GAUSS-LEGENDRE FORMULA IS USED FOR EACH REGION.
912.000 *
913.000 * LOC = LOCATION OF FORMULA
914.000 *
915.000      LOC = 73
916.000      TINC = (NPP - 1)*PAI*0.50
917.000      PWR = 0.0
918.000      DO 20 N = 1,2
919.000      POW(N) = 0.0
920.000      THL(N) = (N-1)*TINC
921.000      THU(N) = THL(N) + TINC
922.000      DO 10 I = 1,20
923.000      THETA = (THL(N) + THU(N))*0.50 + (THU(N) - THL(N))*0.50*QX(I+LOC)
924.000      CALL PAT(THETA,ETHA,ETHP,EPHA,EPHP,K)
925.000      POW(N) = POW(N) + (ETHA**2 + EPHA**2)*SIN(THETA)*QW(I+LOC)
926.000 10   CONTINUE
927.000      PWR = POW(N)*(THU(N) - THL(N)) + PWR
928.000 20   CONTINUE
929.000      PWR = PWR*0.25*PI/ZETA
930.000      RETURN
931.000      END
932.000      SUBROUTINE CONV(EL,AZ,ST,CT,SP,CP)
933.000 *
934.000 * CONVERTS (EL,AZ) TO (THETA,PHI) CO-ORD.
935.000 *
936.000 * ST = SIN(THETA)
937.000 * CT = COS(THETA)
938.000 * SP = SIN(PHI)
939.000 * CP = COS(PHI)
940.000 *
941.000      COMMON/VAL1/PI,RAD,RK,ZETA
942.000 *
943.000      CT = COS(EL/RAD)*COS(AZ/RAD)
944.000      ST = SQRT(1.0 - CT*CT)
945.000      IF (ABS(EL).LT.1.0E-07) GO TO 10
946.000      SP = COS(EL/RAD)*SIN(AZ/RAD)/ST
947.000      CP = SIN(EL/RAD)/ST
948.000      RETURN
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949.000 10 IF(AZ) 20,30,40
950.000 20 SP = -1.0
951.000 CP = 0.0
952.000 RETURN
953.000 30 SP = 0.0
954.000 CP = 1.0
955.000 RETURN
956.000 40 SP = 1.0
957.000 CP = 0.0
958.000 RETURN
959.000 END
960.000 SUBROUTINE FIELD(STQ,CTQ,SPQ,CPQ,IPOLA,CGN,XGN,CPH)
961.000 *
962.000 * COMPUTE FIELD COMPONENTS OF REFLECTOR AT (THETAQ,PHIQ)
963.000 *
964.000 DIMENSION X(3136),Y(3136),Z(3136)
965.000 COMPLEX FTX,FTY,FTZ,RJX(3136),RJY(3136),RJZ(3136)
966.000 COMPLEX EXPN,POL1,POL2,COPOL,XPOL
967.000 COMMON/CURENT/RJX,RJY,RJZ,X,Y,Z
968.000 COMMON/VAL3/NREG,NQR,NQP,PT,XDQ,YDQ,ZDQ,CPVR,SPVR
969.000 COMMON/VAL1/PI,RAD,RK,ZETA
970.000 *
971.000 * SUM UP CONTRIBUTIONS FROM ALL PANEL CURRENTS.
972.000 *
973.000 FTX = (0.0,0.0)
974.000 FTY = (0.0,0.0)
975.000 FTZ = (0.0,0.0)
976.000 STCP = STQ*CPQ
977.000 STSP = STQ*SPQ
978.000 KOUNT = 0
979.000 DO 30 L = 1,NREG
980.000 DO 20 J = 1,NQP
981.000 DO 10 I = 1,NQR
982.000 KOUNT = KOUNT + 1
983.000 ARG = (X(KOUNT)*STCP + Y(KOUNT)*STSP + Z(KOUNT)*CTQ)*RK
984.000 EXPN = CMPLX(COS(ARG),SIN(ARG))
985.000 FTX = FTX + RJX(KOUNT)*EXPN
986.000 FTY = FTY + RJY(KOUNT)*EXPN
987.000 FTZ = FTZ + RJZ(KOUNT)*EXPN
988.000 10 CONTINUE
989.000 20 CONTINUE
990.000 30 CONTINUE
991.000 POL1 = (1.0 - (1.0 - CTQ)*CPQ*CPQ)*FTX - (1.0 - CTQ)*SPQ*CPQ*FTY
992.000 + - STCP*FTZ
993.000 POL2 = -(1.0 - CTQ)*SPQ*CPQ*FTX + (1.0 - SPQ*SPQ*(1.0 - CTQ))*FTY
994.000 + - STSP*FTZ
995.000 *
996.000 * SHIFT REFERENCE TO FIELD CO-ORDINATE SYSTEM
997.000 *
998.000 ARG = (STCP*XDQ + STSP*YDQ + CTQ*ZDQ)*RK
999.000 EXPN = CMPLX(COS(ARG),-SIN(ARG))
1000.000 FTX = (POL1*CPVR + POL2*SPVR)*EXPN
1001.000 FTY = (POL2*CPVR - POL1*SPVR)*EXPN
1002.000 GO TO (40,50,60,70), IPOLA
1003.000 40 COPOL = FTX
1004.000 XPOL = FTY
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1005.000      GO TO 80
1006.000 50   COPOL = FTY
1007.000      XPOL = FTX
1008.000      GO TO 80
1009.000 60   COPOL = 0.70710678*(FTX + CMPLX(0.0,1.0)*FTY)
1010.000      XPOL = 0.70710678*(FTX - CMPLX(0.0,1.0)*FTY)
1011.000      GO TO 80
1012.000 70   COPOL = 0.70710678*(FTX - CMPLX(0.0,1.0)*FTY)
1013.000      XPOL = 0.70710678*(FTX + CMPLX(0.0,1.0)*FTY)
1014.000 80   CGN = 10.0*ALOG10(CABS(COPOL)**2/PT)
1015.000      XGN = 10.0*ALOG10(CABS(XPOL)**2/PT)
1016.000      CPH = ATAN2(AIMAG(COPOL),REAL(COPOL))*RAD
1017.000      RETURN
1018.000      END
1019.000      SUBROUTINE PYRHRN(A,B,WGA,WGB,HRNLTH,AM,PM,MODH,RK,IG)
1020.000 *
1021.000 * COMPUTES PATTERNS OF SINGLE MODE OR MULTIMODE PYRAMIDAL HORNS.
1022.000 *
1023.000      DIMENSION EPA(46,10),EPP(46,10),HPA(46,10),HPP(46,10),THETA(46)
1024.000      COMPLEX HAR(24),EAR(24),A12,HSUM,ESUM,CSUM,EF
1025.000      COMMON/PATTERN/EPA,EPP,HPA,HPP
1026.000      COMMON/PATPAR/NPT,PAI,THETA
1027.000      COMMON/BLOCK/QX(219),QW(219)
1028.000 *
1029.000 * TE10 MODE CUT-OFF CHECK
1030.000 *
1031.000      IF (RK.LE.(3.14159/A)) GO TO 90
1032.000      IF (AM.LT.1.0E-02) GO TO 5
1033.000 *
1034.000 * TE/TM21 MODE CUT-OFF CHECK
1035.000 *
1036.000      IF (RK.LE.(6.28318*SQRT(1.0 + (.50*A/B)**2)/A)) GO TO 100
1037.000 *
1038.000 * COMPUTE HORN AXIAL LENGTHS
1039.000 *
1040.000 5    ALE = 999.0
1041.000      ALH = 999.0
1042.000      IF (B.GT.WGB) ALE = HRNLTH*B/(B - WGB)
1043.000      IF (A.GT.WGA) ALH = HRNLTH*A/(A - WGA)
1044.000 *
1045.000 * COMPUTE MODE COEFFICIENTS
1046.000 *
1047.000      A12 = AM*CMPLX(COS(PM),SIN(PM))
1048.000 *
1049.000 * SELECTION OF APPROPRIATE QUADRATURE FORMULA
1050.000 * ARRAYS HAR AND EAR ARE DIMENSIONED TO ACCOMODATE HORN SIZES LESS
1051.000 * THAN OR EQUAL TO 7.5 WAVELENGTHS.
1052.000 *
1053.000      ARG = AMAX1(A,B)
1054.000      IQ = RK*ARG/3.141592 + 1.0
1055.000      IQ = (IQ+1)*1.40
1056.000      IF (IQ.GT.24) GO TO 70
1057.000      CALL APQUAD(IQ,NQ,LOC)
1058.000 *
1059.000 * COMPUTE INTEGRAL INVARIANT WITH OBSERVATION ANGLE
1060.000 *
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1061.000      HSUM = (0,0,0,0)
1062.000      ESUM = (0,0,0,0)
1063.000      DO 10 I = 1,NQ
1064.000      ARG = RK*((QX(I+LOC)*A*0.50)**2)*0.50/ALH
1065.000      HAR(I) = COS(1.5707963*QX(I+LOC))*CMPLX(COS(ARG),-SIN(ARG))*  
+QW(I+LOC)
1066.000      HSUM = HSUM + HAR(I)
1067.000      ARG = RK*((QX(I+LOC)*B*0.50)**2)*0.50/ALE
1068.000      EAR(I) = (1.0 + A12*COS(3.1415926*QX(I+LOC)))*  
+CMPLX(COS(ARG),-SIN(ARG))*QW(I+LOC)
1069.000      ESUM = ESUM + EAR(I)
1070.000      CONTINUE
1071.000      10
1072.000      10
1073.000      *
1074.000      * COMPUTE E-PLANE PATTERN
1075.000      *
1076.000      DO 40 I = 1,NPT
1077.000      ST = RK*B*0.50*SIN(THETA(I))
1078.000      CSUM = (0,0,0,0)
1079.000      DO 30 J = 1,NQ
1080.000      ARG = ST*QX(J+LOC)
1081.000      CSUM = CSUM + EAR(J)*CMPLX(COS(ARG),SIN(ARG))
1082.000      30
1083.000      CONTINUE
1084.000      EF = HSUM*CSUM
1085.000      IF (MODH.EQ.1) EF = EF*(1.0 + COS(THETA(I)))
1086.000      EPA(I,IG) = CABS(EF)
1087.000      EPP(I,IG) = ATAN2(AIMAG(EF),REAL(EF))
1088.000      40
1089.000      CONTINUE
1090.000      *
1091.000      1088
1092.000      * COMPUTE H-PLANE PATTERN
1093.000      *
1094.000      DO 60 I = 1,NPT
1095.000      ST = RK*A*0.50*SIN(THETA(I))
1096.000      CSUM = (0,0,0,0)
1097.000      60
1098.000      DO 50 J = 1,NQ
1099.000      ARG = ST*QX(J+LOC)
1100.000      CSUM = CSUM + HAR(J)*CMPLX(COS(ARG),SIN(ARG))
1101.000      50
1102.000      CONTINUE
1103.000      CSUM = CSUM*ESUM
1104.000      IF (MODH.EQ.1) EF = EF + CSUM
1105.000      EPA(I,IG) = CABS(EF)
1106.000      EPP(I,IG) = ATAN2(AIMAG(EF),REAL(EF))
1107.000      60
1108.000      CONTINUE
1109.000      *
1110.000      1104
1111.000      NORMALISE PATTERNS
1112.000      *
1113.000      CALL PTNORM(IG,NPT)
1114.000      RETURN
1115.000      *
1116.000      ERROR DIAGNOSTICS
1117.000      WRITE(6,80)
1118.000      1115
1119.000      FORMAT(1X,'HORN APER. DIM. IS TOO LARGE. EXECUTION TERMINATED.')
1120.000      STOP
1121.000      1116
1122.000      WRITE(6,95)
1123.000      1121
1124.000      FORMAT(1X,'PYRAMIDAL HORN DIM. IS BELOW TE10 MODE CUT-OFF.')
1125.000      1122
1126.000      +' EXECUTION IS TERMINATED.'
1127.000      STOP
1128.000      1126
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1117.000 100  WRITE(6,105)
1118.000 105  FORMAT(1X,'MULTI MODE PYRAMIDAL RN DIM. IS BELOW TE/TM21',
1119.000      +'MODE CUT-OFF. STOP.')
1120.000      STOP
1121.000      END
1122.000      SUBROUTINE CONHRN(AR,WGR,HRNLTH,AM,PM,MODH,RK,IG)
1123.000 *
1124.000 * COMPUTES PATTERNS OF CONICAL HORNS.
1125.000 * E- AND H-PLANE NORM. AMP. ARE STORED IN ARRAYS EPA AND HPA RESP.
1126.000 * E- AND H-PLANE NORM. PHASES ARE STORED IN ARRAYS EPP AND HPP RESP.
1127.000 *
1128.000      DIMENSION EPA(46,10),EPP(46,10),HPA(46,10),HPP(46,10),THETA(46)
1129.000      COMPLEX HJ0(14),HJ2(14),EJ0(14),EJ2(14),ESUMT,ESUMP,HSUMT,
1130.000      +HSUMP,B11,EF
1131.000      COMMON/BLOCK/QX(219),QW(219)
1132.000      COMMON/PATERN/EPA,EPP,HPA,HPP
1133.000      COMMON/PATPAR/NPT,PAI,THETA
1134.000 *
1135.000 * TE11 MODE CUT-OFF CHECK
1136.000 *
1137.000      IF (RK.LE.1.84118/AR) GO TO 80
1138.000      IF (AM.LT.1.0E-02) GO TO 5
1139.000 *
1140.000 * TM11 MODE CUT-OFF CHECK
1141.000 *
1142.000      IF (RK.LE.3.83171/AR) GO TO 90
1143.000 *
1144.000 * COMPUTE AXIAL LENGTH
1145.000 *
1146.000 5     AL = 999.0
1147.000      IF (AR.GT.WGR) AL = HRNLTH*AR/(AR - WGR)
1148.000 *
1149.000 * COMPUTE MODE COEFFICIENT
1150.000 *
1151.000      B11 = 2.08116*AM*CMPLX(COS(PM),SIN(PM))
1152.000 *
1153.000 * SELECTION OF APPROPRIATE QUADRATURE FORMULA
1154.000 * ARRAYS HJ0,HJ2,EJ0 AND EJ2 ARE DIMENSIONED TO ACCOMODATE HORN.
1155.000 * DIAMETERS LESS THAN 8 WAVELENGTHS.
1156.000 *
1157.000      IQ = RK*AR/3.141592 + 1.0
1158.000      IQ = (IQ+1)*1.40
1159.000      IF (IQ.GT.14) GO TO 50
1160.000      CALL APQUAD(IQ,NQ,LOC)
1161.000 *
1162.000 * COMPUTE INTEGRAND INVARIANT WITH OBSERVATION POINTS.
1163.000 *
1164.000      DO 10 I = 1,NQ
1165.000      RHO = 0.50*(1.0 + QX(I+LOC))
1166.000      ARG1 = RK*RHO*RHO*AR*AR*0.50/AL
1167.000      ARG2 = 1.84118*RHO
1168.000      CALL BESSEL(ARG2,BJ0,BJ2)
1169.000      ESUMT = CMPLX(COS(ARG1),-SIN(ARG1))
1170.000      HJ2(I) = BJ2*RHO*ESUMT*QW(I+LOC)
1171.000      HJ0(I) = BJ0*ESUMT*QW(I+LOC)*RHO
1172.000      IF (MODE.EQ.1) GO TO 10
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1173.000      ARG2 = 3.83171*RHO
1174.000      CALL BESEL(ARG2,BJ0,BJ2)
1175.000      EJ0(I) = BJ0*ESUMT*QW(I+LOC)*RHO
1176.000      EJ2(I) = BJ2*ESUMT*QW(I+LOC)*RHO
1177.000 10    CONTINUE
1178.000 *
1179.000 * COMPUTES E- AND H-PLANE PATTERNS
1180.000 *
1181.000      DO 40 I = 1,NPT
1182.000      ST = RK*AR*SIN(THETA(I))
1183.000      HSUMT = (0.0,0.0)
1184.000      HSUMP = (0.0,0.0)
1185.000      ESUMT = (0.0,0.0)
1186.000      ESUMP = (0.0,0.0)
1187.000      DO 20 J = 1,NQ
1188.000      ARG = ST*0.50*(1.0 + QX(J+LOC))
1189.000      CALL BESEL(ARG,BJ0,BJ2)
1190.000      HSUMP = HSUMP - HJ2(J)*BJ2 - HJ0(J)*BJ0
1191.000      HSUMT = HSUMT + HJ2(J)*BJ2 - HJ0(J)*BJ0
1192.000      IF (AM,LT,1.0E-02) GO TO 20
1193.000      ESUMP = ESUMP - EJ2(J)*BJ2 + EJ0(J)*BJ0
1194.000      ESUMT = ESUMT + EJ0(J)*BJ0 + EJ2(J)*BJ2
1195.000 20    CONTINUE
1196.000      BKH = 0.0
1197.000      BKE = 0.0
1198.000      IF (MODH.EQ.0) GO TO 30
1199.000      BKH = SQRT(RK**2 - (1.84118/AR)**2)/RK
1200.000      IF (AM,LT,1.0E-02) GO TO 30
1201.000      BKE = RK/SQRT(RK**2 - (3.83171/AR)**2)
1202.000 30    CT = COS(THETA(I))
1203.000      EF = (1.0 + BKH*CT)*HSUMT - (1.0+BKE*CT)*B11*ESUMT
1204.000      EPA(I,IG) = CABS(EF)
1205.000      EPP(I,IG) = ATAN2(AIMAG(EF),REAL(EF))
1206.000      EF = (CT + BKH)*HSUMP - (CT+BKE)*B11*ESUMP
1207.000      HPA(I,IG) = CABS(EF)
1208.000      HPP(I,IG) = ATAN2(AIMAG(EF),REAL(EF))
1209.000 40    CONTINUE
1210.000 *
1211.000 * NORMALISE PATTERNS
1212.000 *
1213.000      CALL PTNORM(IG,NPT)
1214.000      RETURN
1215.000 * ERROR DIAGNOSTICS
1216.000 50    WRITE(6,60)
1217.000 60    FORMAT(1X,'CONICAL HORN APER. RAD. IS TOO LARGE. EXECUTION TERM.')
1218.000      STOP
1219.000 80    WRITE(6,85)
1220.000 85    FORMAT(1X,'CONICAL HORN DIM. IS BELOW TE11 MODE CUT-OFF.','
1221.000      +' EXECUTION IS TERMINATED.')
1222.000      STOP
1223.000 90    WRITE(6,95)
1224.000 95    FORMAT(1X,'DUAL MODE CONICAL HORN DIM. IS BELOW TM11 MODE ','
1225.000      +'CUT-OFF. STOP.')
1226.000      STOP
1227.000      END
1228.000      SUBROUTINE PTNORM(IG,NPT)

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1229.000 *
1230.000 * NORMALISES AMPLITUDE AND PHASE PATTERNS.
1231.000 *
1232.000     DIMENSION EPA(46,10),EPP(46,10),HPA(46,10),HPP(46,10)
1233.000     COMMON/PATTERN/EPA,EPP,HPA,HPP
1234.000 *
1235.000     ANORM = EPA(1,IG)
1236.000     PNORM = EPP(1,IG)
1237.000     EPA(1,IG) = EPA(1,IG)/ANORM
1238.000     EPP(1,IG) = EPP(1,IG) - PNORM
1239.000     HPA(1,IG) = HPA(1,IG)/ANORM
1240.000     HPP(1,IG) = HPP(1,IG) - PNORM
1241.000     IF (NPT.EQ.1) RETURN
1242.000     DO 10 I = 2,NPT
1243.000     EPA(I,IG) = EPA(I,IG)/ANORM
1244.000     HPA(I,IG) = HPA(I,IG)/ANORM
1245.000     EPP(I,IG) = EPP(I,IG) - PNORM
1246.000     PDIF = EPP(I,IG) - EPP(I-1,IG)
1247.000     IF (PDIF.GE.3.141592) EPP(I,IG) = EPP(I,IG) - 6.283185
1248.000     IF (PDIF.LE.-3.141592) EPP(I,IG) = EPP(I,IG) + 6.283185
1249.000     HPP(I,IG) = HPP(I,IG) - PNORM
1250.000     PDIF = HPP(I,IG) - HPP(I-1,IG)
1251.000     IF (PDIF.GE.3.141592) HPP(I,IG) = HPP(I,IG) - 6.283185
1252.000     IF (PDIF.LE.-3.141592) HPP(I,IG) = HPP(I,IG) + 6.283185
1253.000 10    CONTINUE
1254.000     RETURN
1255.000     END
1256.000     SUBROUTINE BESSEL(ARG,BJ0,BJ2)
1257.000 *
1258.000 * COMPUTES BESSEL FUNCTION OF THE FIRST KIND , ZERO(BJ0) AND
1259.000 * SECOND(BJ2) ORDER. ARG IS THE INPUT ARGUMENT.
1260.000 *
1261.000     IF (ARG.GE.3.0) GO TO 10
1262.000 *
1263.000 * 0 < ARG < 3
1264.000 *
1265.000     X2 = (ARG/3.0)**2
1266.000     X4 = X2*X2
1267.000     X6 = X4*X2
1268.000     X8 = X6*X2
1269.000     X10 = X8*X2
1270.000     X12 = X10*X2
1271.000     BJ0 = 1.0 - 2.2499997*X2 + 1.2656208*X4 - .3163866*X6
1272.000     + + .0444479*X8 - .0039444*X10 + .0002100*X12
1273.000     BJ2 = 0.5 - .56249995*X2 + .21093573*X4 - .03954289*X6
1274.000     + + .00443319*X8 - .00031761*X10 + .00001109*X12
1275.000     BJ2 = 2.0*BJ2 - BJ0
1276.000     RETURN
1277.000 *
1278.000 * ARG > 3
1279.000 *
1280.000 10    X = 3.0/ARG
1281.000     X2 = X**X
1282.000     X3 = X2**X
1283.000     X4 = X3**X
1284.000     X5 = X4**X
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1285.000      X6 = X5*X
1286.000      THETA = ARG - .78539816 - .04166397*X - .00003954*X2
1287.000      + + .00262573*X3 - .00054125*X4 - .00029333*X5 + .00013558*X6
1288.000      F = .79788456 - .00000077*X - .00552740*X2 - .00009512*X3
1289.000      + + .00137237*X4 - .00072805*X5 + .00014476*X6
1290.000      BJO = F*COS(THETA)/SQRT(ARG)
1291.000      THETA = ARG - 2.35619449 + .12499612*X + .0000565*X2
1292.000      + - .00637879*X3 + .00074348*X4 + .00079824*X5 - .00029166*X6
1293.000      BJ2 = F*COS(THETA)/(ARG*SQRT(ARG))
1294.000      BJ2 = 2.0*BJ2 - BJO
1295.000      RETURN
1296.000      END
1297.000      SUBROUTINE APQUAD(IQ,NQ,LOC)
1298.000 *
1299.000 * FINDS THE NEAREST QUAD. FORMULA TO THAT REQUIRED,
1300.000 * THE AVAILABLE FORMULAS ARE STORED IN ASCENDING ORDER IN ARRAY
1301.000 * IQF. NQF IS THE NUMBER OF FORMULAS STORED IN THE BLOCK DATA.
1302.000 * BOTH IQF AND NQF ARE DEFINED IN THE DATA STATEMENT BELOW.
1303.000 * IQ = IQ POINT FORM. REQ.
1304.000 * NQ = NEAREST AVAIL. IS NQ POINT FORM.
1305.000 * LOC = LOCATION OF FORM.
1306.000 *
1307.000      INTEGER IQF(13)
1308.000      DATA NQF,IQF/13,3,4,6,8,10,12,14,16,20,24,28,34,40/
1309.000 *
1310.000      DO 10 I = 1,NQF
1311.000      IF (IQ.LE.IQF(I)) GO TO 30
1312.000 10    CONTINUE
1313.000      WRITE(6,20)
1314.000 20    FORMAT(1X,'QUADRATURE FORMULA REQUIRED IS LARGER THAN THAT ',
1315.000      +'AVAILABLE IN THE BLOCK DATA. SEE DOCUMENTATION. EXECUTION',
1316.000      +'TERMINATED')
1317.000      STOP
1318.000 30    NQ = IQF(I)
1319.000      CALL QRLOC(NQ,LOC)
1320.000      RETURN
1321.000      END
1322.000      SUBROUTINE QRLOC(NQ,LOC)
1323.000 *
1324.000 * PURPOSE - DETERMINE LOCATION OF INTEGRATION FORMULA IN BLOCK DATA
1325.000 * BLOCK DATA IS ASSUMED TO CONTAIN THE FOLLOWING FORMULAE,
1326.000 * 3,4,6,8,10,12,14,16,20,24,28,34,40 PTS.
1327.000 *
1328.000      IF_(NQ = 34) 10,170,180
1329.000 10    IF_(NQ = 24) 20,150,160
1330.000 20    IF_(NQ = 16) 30,130,140
1331.000 30    IF_(NQ = 12) 40,110,120
1332.000 40    IF_(NQ = 8) 50,90,100
1333.000 50    IF_(NQ = 4) 60,70,80
1334.000 60    LOC = 0
1335.000      RETURN
1336.000 70    LOC = 3
1337.000      RETURN
1338.000 80    LOC = 7
1339.000      RETURN
1340.000 90    LOC = 13

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1341.000 RETURN  
1342.000 100 LOC = 21  
1343.000 RETURN  
1344.000 110 LOC = 31  
1345.000 RETURN  
1346.000 120 LOC = 43  
1347.000 RETURN  
1348.000 130 LOC = 57  
1349.000 RETURN  
1350.000 140 LOC = 73  
1351.000 RETURN  
1352.000 150 LOC = 93  
1353.000 RETURN  
1354.000 160 LOC = 117  
1355.000 RETURN  
1356.000 170 LOC = 145  
1357.000 RETURN  
1358.000 180 LOC = 179  
1359.000 RETURN  
1360.000 END  
1361.000 BLOCK DATA  
1362.000 COMMON/BLOCK/QX(219),QW(219)  
1363.000 \* 3 PTS  
1364.000 DATA (QX(I),I=1,3)/-.774596669241,0.00000000,+.774596669241/  
1365.000 DATA (QW(I),I=1,3)/.555555555555,,888888888888,,555555555555/  
1366.000 \* 4 PTS  
1367.000 DATA (QX(I),I=4,7)/-.861136311594,-.3399810435848,.3399810435848,  
1368.000 +.861136311594/  
1369.000 DATA (QW(I),I=4,7)/.347854845137,,652145154862,,652145154862,  
1370.000 +.347854845137/  
1371.000 \* 6 PTS.  
1372.000 DATA (QX(I),I=8,13)/.93246951420315,,66120938646626,  
1373.000 +.23861918608319,  
1374.000 +-23861918608319,-.66120938646626,-.93246951420315/  
1375.000 DATA (QW(I),I=8,13)/.17132449237917,,36076157304814,  
1376.000 +.46791393457269,  
1377.000 +.46791393457269,,36076157304814,.17132449237917/  
1378.000 \* 8 PTS.  
1379.000 DATA (QX(I),I=14,21)/-.9602898564,-.7966664774,-.5255324099,  
1380.000 +-1834346424,,1834346424,.5255324099,.7966664774,.9602898564/  
1381.000 DATA (QW(I),I=14,21)/.1012285362,.2223810344,.3137066458,  
1382.000 +.3626837833,.3626837833,.3137066458,.2223810344,.1012285362/  
1383.000 \* 10 PTS.  
1384.000 DATA (QX(I),I=22,31)/-.9739065285,-.8650633666,-.6794095682,  
1385.000 +-4333953941,-.1488743389,  
1386.000 +.1488743389,,4333953941,.6794095682,.8650633666,.9739065285/  
1387.000 DATA (QW(I),I=22,31)/.0666713443,.1494513491,.2190863625,  
1388.000 +.2692667193,.2955242247,  
1389.000 +.2955242247,.2692667193,.2190863625,.1494513491,.0666713443/  
1390.000 \* 12 PTS.  
1391.000 DATA (QX(I),I=32,43)/-.981560634246,-.90411725637,-.769902674194,  
1392.000 +-587317954286,-.367831498998,-.125233408511,.125233408511,  
1393.000 +.367831498998,.587317954286,.769902674194,.904117256370,  
1394.000 +.981560634246/  
1395.000 DATA (QW(I),I=32,43)/.047175336386,.106939325995,.160078328543,  
1396.000 +.203167426723,.233492536538,.249147045813,.249147045813,

1397.000 +.233492536538,.203167426723,.160078328543,.106939325995,  
 1398.000 +.047175336386/  
 1399.000 \* 14 PTS.  
 1400.000 DATA (QX(I),I=44,57)/-.986283808696,-.928434883663,-.82720131507,  
 1401.000 +-,.687292904811,-.515248636358,-.319112368927,-.108054948707,  
 1402.000 +.108054948707,.319112368927,.515248636358,.687292904811,  
 1403.000 +.827201315069,.928434883663,.986283808696/  
 1404.000 DATA (QW(I),I=44,57)/.035119460331,.080158087159,.121518570687,  
 1405.000 +.157203167158,.185538397477,.205198463721,.215263853463,  
 1406.000 +.215263853463,.205198463721,.185538397477,.157203167158,  
 1407.000 +.121518570687,.080158087159,.035119460331/  
 1408.000 \* 16 PTS.  
 1409.000 DATA (QX(I),I=58,73)/-.989400934991,-.944575023073,-.865631202388,  
 1410.000 +-,.755404408355,-.617876244403,-.458016777657,-.281603550779,  
 1411.000 +-,.095012509837,.095012509837,.281603550779,.458016777657,  
 1412.000 +.617876244403,.755404408355,.865631202387,.944575023073,  
 1413.000 +.989400934992/  
 1414.000 DATA (QW(I),I=58,73)/.027152459412,.062253523938,.095158511682,  
 1415.000 +.124628971255,.149595988816,.169156519395,.182603415045,  
 1416.000 +.189450610455,.189450610455,.182603415045,.169156519395,  
 1417.000 +.149595988816,.124628971255,.095158511682,.062253523938,  
 1418.000 +.0271524594117/  
 1419.000 \* 20 PTS.  
 1420.000 DATA (QX(I),I=74,93)/-.9931285991,-.9639719272,-.9122344282,  
 1421.000 +-,.8391169718,  
 1422.000 +-,.7463319064,-.6360536807,-.5108670019,-.3737060887,-.2277858511,  
 1423.000 +-,.07652652113,.07652652113,.2277858511,.3737060887,.5108670019,  
 1424.000 +.6360536807,  
 1425.000 +.7463319064,.8391169718,.9122344282,.9639719272,.9931285991/  
 1426.000 DATA (QW(I),I=74,93)/.01761400713,.04060142980,.06267204833,  
 1427.000 +.08327674157,  
 1428.000 +.1019301198,.1181945319,.1316886384,.1420961093,.1491729864,  
 1429.000 +.1527533871,  
 1430.000 +.1527533871,.1491729864,.1420961093,.1316886384,.1181945319,  
 1431.000 +.1019301198,  
 1432.000 +.08327674157,.06267204833,.04060142980,.01761400713/  
 1433.000 \* 24 PTS.  
 1434.000 DATA (QX(I),I=94,117)/-.9951872199,-.9747285559,-.9382745520,  
 1435.000 +-,.8864155270,-.8200019859,-.7401241915,-.6480936519,  
 1436.000 +-,.5454214713,-.4337935076,-.3150426796,-.1911188674,  
 1437.000 +-,.06405689286,.06405689286,.1911188674,.3150426796,.4337935076,  
 1438.000 +.5454214713,.6480936519,.7401241915,.8200019859,.8864155270,  
 1439.000 +.9382745520,.9747285559,.9951872199/  
 1440.000 DATA (QW(I),I=94,117)/.01234122979,.02853138862,.04427743881,  
 1441.000 +.05929858491,.07334648141,.08619016153,.09761865210,.1074442701,  
 1442.000 +.1155056680,.1216704729,.1258374563,.1279381953,.1279381953,  
 1443.000 +.1258374563,.1216704729,.1155056680,.1074442701,.0976186521,  
 1444.000 +.08619016153,.07334648141,.05929858491,.04427743881,  
 1445.000 +.02853138862,.01234122979/  
 1446.000 \* 28 PTS.  
 1447.000 DATA (QX(I),I=118,145)/-.9964424975,-.9813031653,-.9542592806,  
 1448.000 +-,.9156330263,-.8658925225,-.8056413709,-.7356108780,  
 1449.000 +-,.6566510940,-.5697204718,-.4758742249,-.3762515160,  
 1450.000 +-,.2720616276,-.1645692821,-.05507928988,.05507928988,  
 1451.000 +.1645692821,.2720616276,.3762515160,.4758742249,.5697204718,  
 1452.000 +.6566510940,.7356108780,.8056413709,.8658925225,.9156330263,

1453.000 +.9542592806,.9813031653,.9964424975/  
1454.000 DATA (QW(I),I=118,145)/.009124282593,.02113211259,.03290142778,  
1455.000 +.04427293475,.05510734567,.06527292396,.07464621423,  
1456.000 +.08311341722,.09057174439,.09693065799,.1021129675,.1060557659,  
1457.000 +.1087111922,.1100470130,.1100470130,.1087111922,.1060557659,  
1458.000 +.1021129675,.09693065799,.09057174439,.08311341722,.07464621423,  
1459.000 +.06527292396,.05510734567,.04427293475,.03290142778,  
1460.000 +.02113211259,.009124282593/  
1461.000 \* 34 PTS.  
1462.000 DATA (QX(I),I=146,179)/-.9975717537,-.9872278164,-.9687082625,  
1463.000 +-,.9421623974,-.9078096777,-.8659346383,-.8168842279,  
1464.000 +-,.7610648766,-.6989391132,-.6310217270,-.5578755006,  
1465.000 +-,.4801065451,-.3983592777,-.3133110813,-.2256666916,  
1466.000 +-,.1361523572,-.04550982195,.04550982195,.1361523572,  
1467.000 +.2256666916,.3133110813,.3983592777,.4801065451,.5578755006,  
1468.000 +.6310217270,.6989391132,.7610648766,.8168842279,.8659346383,  
1469.000 +.9078096777,.9421623974,.9687082625,.9872278164,.9975717537/  
1470.000 DATA (QW(I),I=146,179)/.006229140555,.01445016274,.02256372198,  
1471.000 +.03049138063,.03816659379,.04552561152,.05250741457,.05905413582,  
1472.000 +.06511152155,.07062937581,.07556198466,.07986844433,.08351309969,  
1473.000 +.08646573974,.08870189783,.09020304437,.09095674033,.09095674033,  
1474.000 +.09020304437,.08870189783,.08646573974,.08351309969,.07986844433,  
1475.000 +.07556197466,.07062937581,.06511152155,.05905413582,.05250741457,  
1476.000 +.04552561152,.03816659379,.03049138063,.02256372198,.01445016274,  
1477.000 +.006229140555/  
1478.000 \* 40 PTS.  
1479.000 DATA (QX(I),I=180,219)/-.9982377097,-.9907262386,-.9772599499,  
1480.000 +-,.9579168192,-.9328128082,-.9020988069,-.8659595032,-.8246122308,  
1481.000 +-,.7783056514,-.7273182551,-.6719566846,-.6125538896,-.549467125,  
1482.000 +-,.4830758016,-.4137792043,-.3419940908,-.268152185,-.1926975807,  
1483.000 +-,.1160840706,-.0387724175,.0387724175,.1160840706,.1926975807,  
1484.000 +.268152185,.3419940908,.4137792043,.4830758016,.549467125,  
1485.000 +.6125538896,.6719566846,.7273182551,.7783056514,.8246122308,  
1486.000 +.8659595032,.9020988069,.9328128082,.9579168192,.9772599499,  
1487.000 +.9907262386,.9982377097/  
1488.000 DATA (QW(I),I=180,219)/.00452127709,.0104982845,.0164210583,  
1489.000 +.0222458491,.0279370069,.0334601952,.0387821679,.0438709081,  
1490.000 +.0486958076,.0532278469,.0574397690,.0613062424,.0648040134,  
1491.000 +.0679120458,.0706116473,.0728865823,.0747231690,.0761103619,  
1492.000 +.0770398181,.0775059479,.0775059479,.0770398181,.0761103619,  
1493.000 +.0747231690,.0728865823,.0706116473,.0679120458,.0648040134,  
1494.000 +.0613062424,.0574397690,.0532278469,.0486958076,.0438709081,  
1495.000 +.0387821679,.0334601952,.0279370069,.0222458491,.0164210583,  
1496.000 +.0104982845,.00452127709/  
1497.000 END

### A.3 EXAMPLE OF INPUT DATA FILE PAREFC.DAT

A.4 SAMPLE OUTPUT

1.000 DBS BEAM CANADA 504 (POTTER FEED HORNS )  
 2.000 FREQUENCY IN GHZ  
 3.000 12.4500  
 4.000 NO OF FEED HORNS  
 5.000 24  
 6.000 HORN TYPE - 0=PYRAMIDAL , 1=CONICAL  
 7.000 1  
 8.000 AMPL. AND PHASE (RAD) OF HIGHER ORDER MODE  
 9.000 .1000 .0000  
 10.000 APERTURE RADIUS OF HORN APERTURE IN INS.  
 11.000 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200  
 12.000 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200 .6200  
 13.000 RADIUS OF INPUT WAVEGUIDE IN INS.  
 14.000 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500  
 15.000 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500 .3500  
 16.000 HORN LENGTH IN INS  
 17.000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000  
 18.000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000 5.0000  
 19.000 HORN APERTURE FIELD MODEL - 0=E-FIELD , 1=CHU  
 20.000 0  
 21.000 OPT. CHOSEN - COLLECTIVE MOVEMENT AND ROTATION OF HORN ARRAY  
 22.000 0  
 23.000 DISPLACEMENTS OF FEEDS IN INS.  
 24.000 2.1600 .7600 .0000 2.1600 -.2800 .0000 2.1600 -1.5200 .0000 2.1600 -2.7600 .0000  
 25.000 1.0800 1.5800 .0000 1.0800 .3400 .0000 1.0800 -.9000 .0000 1.0800 -2.1400 .0000  
 26.000 1.0800 -3.3800 .0000 .0000 2.2000 .0000 .0000 .9600 .0000 .0000 -.2800 .0000  
 27.000 .0000 -1.5200 .0000 .0000 -2.7600 .0000 -1.0800 2.8200 .0000 -1.0800 1.5800 .0000  
 28.000 -1.0800 .3400 .0000 -1.0800 -.9000 .0000 -1.0800 -2.1400 .0000 -2.1600 3.4400 .0000  
 29.000 -2.1600 2.2000 .0000 -2.1600 .9600 .0000 -2.1600 -.2800 .0000 -.5400 -4.3000 .0000  
 30.000 ROT. OF FEEDS ABOUT X-,Y-,AND Z-AXIS IN DEG.  
 31.000 .0000 -26.6000 .0000  
 32.000 POLAR. OF SECND. BEAM - VP=1,HP=2,RHCP=3,LHCP=4  
 33.000 3  
 34.000 AMPL IMBALANCE OF Y-PORT REL. TO X-PORT  
 35.000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000  
 36.000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000  
 37.000 PHASE DEPARTURE OF Y-PORT FROM QUADRATURE IN DEG.  
 38.000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000  
 39.000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000  
 40.000 POWER(W) AND PHASE(DEG) OF FEED EXCITATIONS  
 41.000 .0270 .0000 .0530 .0000 .0380 .0000 .0300 .0000 .0600 .0000 .0500 .0000  
 42.000 .0480 .0000 .0550 .0000 .0540 .0000 .0530 .0000 .0490 .0000 .0500 .0000  
 43.000 .0480 .0000 .0490 .0000 .0410 .0000 .0470 .0000 .0510 .0000 .0410 .0000  
 44.000 .0092 .0000 .0390 .0000 .0490 .0000 .0440 .0000 .0140 .0000 .0008 49.0000  
 45.000 FOC LTH.,APER. X-DIM,Y-DIM AND X-, Y-OFFSET IN INS.  
 46.000 124.0000 106.0000 106.0000 60.0000 .0000  
 47.000 START,STOP AND NO. OF PTS. FOR AZ,EL SCAN  
 48.000 -1.50000 1.50000 13 -1.00000 1.00000 9  
 49.000 X-,Y-,Z-TRANSLATION OF FIELD CO-ORD. SYSTEM IN INS  
 50.000 .0000 .0000 .0000  
 51.000 ROTATION OF FIELD POLARISATION VECTOR IN DEGREES  
 52.000 .0000



## CD-POLAR PHASE IN DEG

	ELEV *	AZIMUTH (DEG)												
	(DEG)	-1.50	-1.25	-1.00	-.75	-.50	-.25	.00	.25	.50	.75	1.00	1.25	1.50
144,000	*													
145,000	(DEG)	* -1.50	-1.25	-1.00	-.75	-.50	-.25	.00	.25	.50	.75	1.00	1.25	1.50
146,000	*	***	***	***	***	***	***	***	***	***	***	***	***	***
147,000	*													
148,000	*													
149,000	1.000*	169.9	171.1	174.5	177.8	177.7	174.9	173.5	175.3	178.8	23.7	47.6	88.7	-177.7
150,000														
151,000	*													
152,000	.750*	74.3	72.9	74.5	77.4	78.8	77.7	76.8	78.1	80.2	75.2	43.6	10.0	-41.6
153,000														
154,000	*													
155,000	.500*	-21.6	-25.3	-24.7	-22.1	-19.8	-20.1	-21.2	-20.7	-19.2	-19.1	-23.1	-29.9	-39.5
156,000														
157,000	*													
158,000	.250*	-113.1	-121.5	-122.0	-120.0	-117.5	-117.0	-118.3	-118.4	-116.9	-115.8	-116.3	-117.5	-118.1
159,000														
160,000	*													
161,000	.000*	-179.3	144.8	142.3	143.0	144.9	146.1	145.8	145.9	146.8	147.1	146.3	145.3	144.5

162.000  
163.000 \*  
164.000 -.250\*-174.6 51.6 46.7 46.0 46.7 47.8 48.7 49.4 49.5 48.4 46.9 46.3 46.0  
165.000  
166.000 \*  
167.000 -.500\* 122.6 -38.0 -48.5 -50.8 -51.3 -51.2 -50.7 -50.1 -50.5 -51.9 -52.8 -52.4 -51.2  
168.000  
169.000 \*  
170.000 -.750\* 34.5 13.7-139.9-146.2-148.4-149.3-149.6-149.7-150.4-151.5-151.2-149.1-145.5  
171.000  
172.000 \*  
173.000 -1.000\* -54.6 -66.4-155.6 122.3 116.8 114.7 113.8 113.4 112.4 111.7 113.2 117.8 126.5  
\*

APPENDIX BB.1 Description of Computer Program PAREFM\_SIF

IDENTIFICATION: PAREFM\_SIF

PURPOSE: The program calculates the field radiated by a parabolic reflector antenna with projected elliptical aperture using the method of physical optics. The radiation patterns of the feeds are provided by the user. Either linearly or circularly polarized patterns may be specified.

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DESCRIPTION: The geometry of the general reflector antenna system is the same as that treated by program PAREFC\_SIF. The co-ordinate systems used are the same. The only difference here is that the primary radiation patterns of the feeds are provided by the user. This capability allows the user to enter either measured amplitude and phase patterns of feeds or computed patterns of specialised feeds predicted by different programs.

It is visualised that each feed has two orthogonal input ports, Port 1 and Port 2. In LP systems only one port, Port 1, is used. In this case,

Port 1 is the co-polarized port and may be designated as either the X-port (parallel to the local X-axis) for vertical polarization or the Y-port (parallel to the local Y-axis) for horizontal polarization. In CP systems both ports are used. If the feed has principal and diagonal plane symmetry, only the E- and H-plane patterns for Port 1 are required. If the feed does not have diagonal planes symmetry, such as a rectangular horn, and is used in a CP system, then E- and H-plane patterns for both Port 1 and Port 2 must be entered. Feed patterns are thus assumed to possess at least a  $\text{Sin } \phi - \text{Cos } \phi$  symmetry i.e. symmetric about the principal planes. Patterns are to be provided at equally spaced intervals starting from the broadside direction with  $\theta = 0$  deg. Quadratic interpolation is used to find the fields for the in-between points.

USAGE (INPUT):

Input data required by the program are to be supplied in a file named PAREFM\_DAT. Data is read in free format and must follow the sequence laid out below. Data input is list directed.

- IHEAD(I)
- Header describing the particular run. Maximum of 60 characters. Limitation due to array dimension.
- FREQ
- Frequency in GHz.
- NHORN
- Number of feeds in array. Maximum determined by array dimensions. See Restriction.

- OPTH
  - Option for specifying feed positions and rotations.  
See description for program PAREFC\_SIF.
  - = 0, Collective movement and rotation of feed array.
  - = 1, Individual movement and rotation of feed element.
- DX (I)      }  
DY (I)      }  
DZ (I)      }
  - Displacements of component feeds in inches from focal point. A set of values must be provided for each feed.
- ALPHA (I)    }  
BETA (I)     }  
GAMMA (I)    }
  - Rotations about the X-, Y- and Z- axis in degrees.
  - If option of collective movement is chosen, only one set of values need be provided. Otherwise, a set must be provided for each feed.
- IPOLA
  - Polarization of secondary beam.
  - = 1, Vertical polarization (VP).
  - = 2, Horizontal polarization (HP).
  - = 3, Right hand circular polarization (RHCP).
  - = 4, Left hand circular polarization (LHCP).
- ISYMM
  - Parameter to indicate if feed has diagonal plane symmetry in addition to principal plane symmetry.
  - = 0, YES.
  - = 1, NO.
- NPP
  - Number of equally spaced points per principal plane describing pattern. See Restriction.
- PAI
  - Angular increment of pattern points in degrees.
- ISAME
  - Parameter to indicate whether all the feed patterns are the same.

= 0, Identical.

= 1, Not identical.

EPA (I,J,K) } - E-plane amplitude (dB) and phase (deg) patterns  
EPP (I,J,K) } of Port 1. In LP system, this port corresponds  
to the co-polarized port. In CP system, this  
port corresponds to the X-port. NPP pairs of  
values are to be provided.

HPA (I,J,K) } - H-plane amplitude (dB) and phase (deg) patterns  
HPP (I,J,K) } of Port 1. Above comments apply. HPP pairs of  
values are to be provided.

If all the feeds are not the same , ISAME = 1,  
then the above information must be provided for  
each feed i.e. 2\*NPP pairs of values per feed.

If for CP system, the feeds do not possess diagonal  
symmetry, the above data must be provided for the  
second port.

I is the index for the pattern points.

J is the index for the feeds.

K is the index for the orthogonal ports.

CXY (I) - Amplitude imbalance of Y-port relative to X-port  
CP only. An entry must be provided for each feed.

PSI (I) - Departure from phase quadrature of the Y-port  
relative to the X-port in degrees. CP only.  
An entry must be provided for each feed.

HPWR (I) - Power input to each feed in watts.

HPHASE(I) - Relative phase excitation of each feed in deg.

F - Focal length of parabolic reflector in ins.

SX2 - X-dimension of elliptical reflector aperture in ins.

SY2 - Y-dimension of elliptical reflector aperture in ins.

DELTAX - X-offset of aperture centre in inches.

DELTAY - Y-offset of aperture centre in inches.

OPTB - Option for specifying limits of integration.  
This feature may be used to simulate aperture blockage.  
= 0, Limits are generated by program. No blockage is assumed.  
= 1, Limits are specified by user.

NREG - Number of regions of  $\phi_1$  - integration. In the program this number is set equal to 4.

PHL(I), Lower and upper limits of  $\phi_1$  - integration for

PHU(I) - the I th region in radians.

BX2, BY2 - X- and Y-dimension of central elliptical blockage in inches.

OPTQ - Option of specifying number of integration points.  
= 0, Determined by program.  
= 1, Specified by user.

NQR - No. of integration points in the radial-direction ( $r_1$ ). Choose from: 3,4,6,8,10,12,14,16,20,24,28,34,40

NQP - No. of integration points in the phi-direction ( $\phi_1$ ). Choose from: 3,4,6,8,10,12,14,16,20,24,28,34,40

AZS - Start of azimuth cut in degrees.

AZE - End of azimuth cut in degrees.

NAZ - Number of azimuth points. See Restriction.

ELS - Start of elevation cut in degrees.

ELE - End of elevation cut in degrees.

NEL - Number of elevation points. See Restriction.

XDQ, YDQ,- X-, Y- and Z- translation of field co-ordinate system from global system in inches.

ZDQ -

PVR - Angular rotation about Z-axis of field polarization vector in degrees. It is used to rotate the linear polarization vector in cases where minimising rain attenuation is important. For CP application, it has the effect of rotating the polarization ellipse. In most situations, it is set equal to GAMMA.

In the above input list, all variables beginning with the letter I through N as well as OPTH, OPTB and OPTQ, are integer variables. The flow chart for the data input section is shown in Figure B1.

#### OUTPUT:

All input data are printed out for the purpose of verification and run identification. The spillover efficiency of the reflector is printed out next, followed by the co-polar component gain, cross-polar component gain, and co-polar component phase. The gain, expressed in dBi and the phase in degrees are presented in a tabular form. A column corresponds to an elevation cut while a row gives the azimuth cut.

In addition to the above output to the line printer,

the co-polar gain matrix together with the header and angular information on the observation frame (AZS, AZE, NAZ, ELS, ELE, NEL) are written into a file named GNMAT. This gain file can be assessed later for contour plotting purposes.

CODING INFORMATION:

Program is written in FORTRAN 77 for use on the CRC Honeywell CP-6 computer system.

RESTRICTIONS:

The restrictions on the antenna configuration that can be analysed is solely due to array dimensions. In order to minimise the demand on computer resources, the arrays have been dimensioned to cover many of the cases usually encountered. In certain situations such as DBS applications where the number of feeds required or the number of integration points needed or the field of view exceeded those envisaged, etc., the pertinent arrays must be changed according to the following prescriptions. The preset limits of these arrays are defined in the DATA statement at the beginning of the main program.

To Increase the Number of Feeds (NHORN)

The program has been set to allow a maximum of 30 feeds. If NHORN exceeds this number, the following changes are necessary.

## MAIN PROGRAM:

- (i) Change the dimensions of the following arrays to the value of NHORN -  
DX, DY, DZ, GAMMA, BETA, ALPHA, HPWR, HPHASE, AN,  
CXY, PSI, W11, W12, W13, W21, W22, W23, W31, W32,  
W33, CX, CY,
- (ii) If all the component feeds are the same, the second dimension (J) of the following three dimensional arrays can be set to unity -  
EPA(I,J,K), EPP(I,J,K), HPA(I,J,K), HPP(I,J,K)

If the feeds are not identical, then the second dimensions of the above arrays must be set equal to the value of NHORN.

- (iii) Change the value of MAXHRN in the data statement to the value of NHORN.

SUBROUTINE SOURCE:

Change the dimensions of the following arrays to the value of NHORN - AN, HPHASE, CX, CY, PSI.

SUBROUTINE PAT:

Same as step (ii) under MAIN PROGRAM.

To Increase the Number of Points Describing Feed Pattern (NPP)

The program has been set to allow a maximum (MAXNPP) of 46 points to describe a principal plane of a feed pattern. If NPP exceeds this value, then incorporate the following changes.

MAIN PROGRAM:

- (i) Change the first dimension of the following arrays to the value of NPP - EPA, EPP, HPA, HPP.
- (ii) Change the value of MAXNPP in the data statement to the value of NPP.

**SUBROUTINE PAT:**

- (i) Change the first dimension of the following arrays in the common statement to the value of NPP - EPA, EPP, HPA, HPP.

To Increase Array Sizes to Accommodate Larger Number of Integration Points.

---

The maximum number of integration points allowable in the radial (NQR) or phi-direction (NQP) is given by the variable MAXQ. At present, the value of MAXQ is 24. With the available quadrature formulas contained in the BLOCK DATA, MAXQ may be set to a maximum value of 40. If NQR or NQP exceeds MAXQ, make the following changes.

**MAIN PROGRAM:**

- (i) Change the value of MAXQ in the data statement to NQR or NQP, whichever is larger.
- (ii) Change the first dimensions of arrays RDL and RDU to the value of MAXQ.
- (iii) Alter the dimensions of the following arrays to  
 $4 * \text{MAXQ} * \text{MAXQ}$  -  
XG, YG, ZG, RJX, RJY, RJZ

**SUBROUTINE FIELD:**

- (i) Alter the dimensions of the following arrays to  
 $4 * \text{MAXQ} * \text{MAXQ}$  -  
X, Y, Z, RJX, RJY, RJZ.

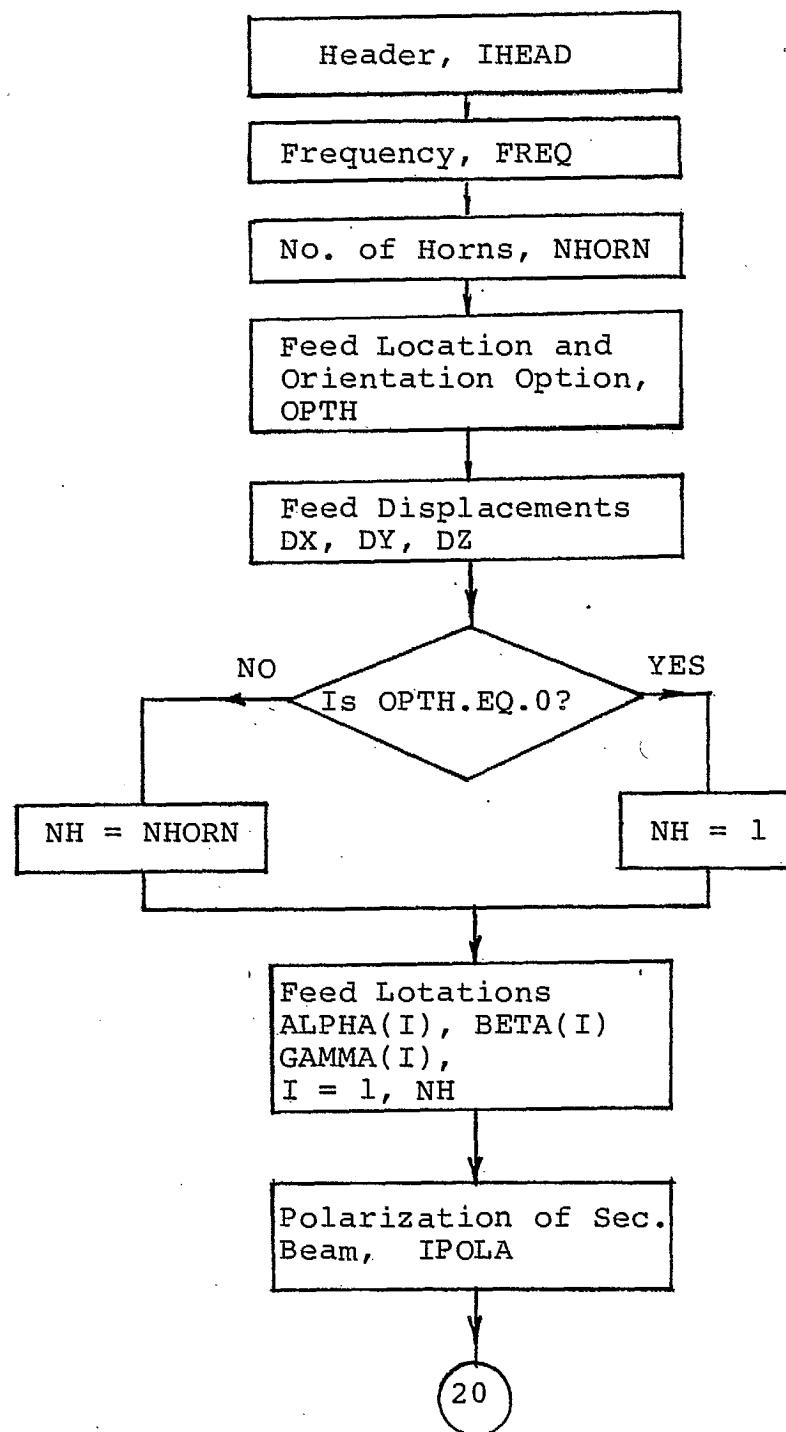
To Increase Frame of Observation

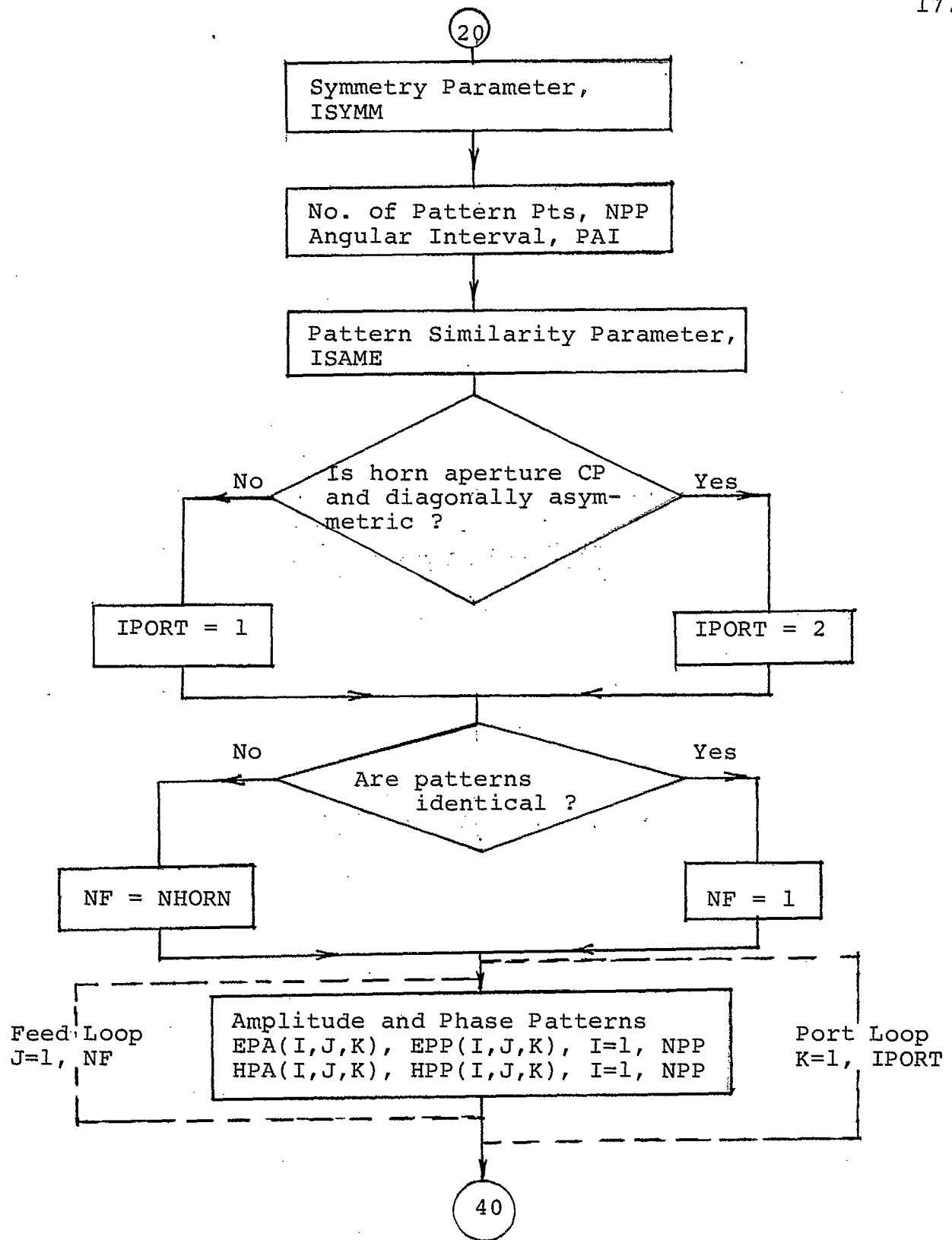
The field of observation is defined by a rectangular grid of elevation and azimuth cuts. The number of grid points in the elevation direction is given by NEL and its maximum is set by MAXEL. Similarly, the number of grid points in the azimuth direction is given by NAZ and its maximum is set by MAXAZ. At present, the values of MAXEL and MAXAZ are equal to 41.

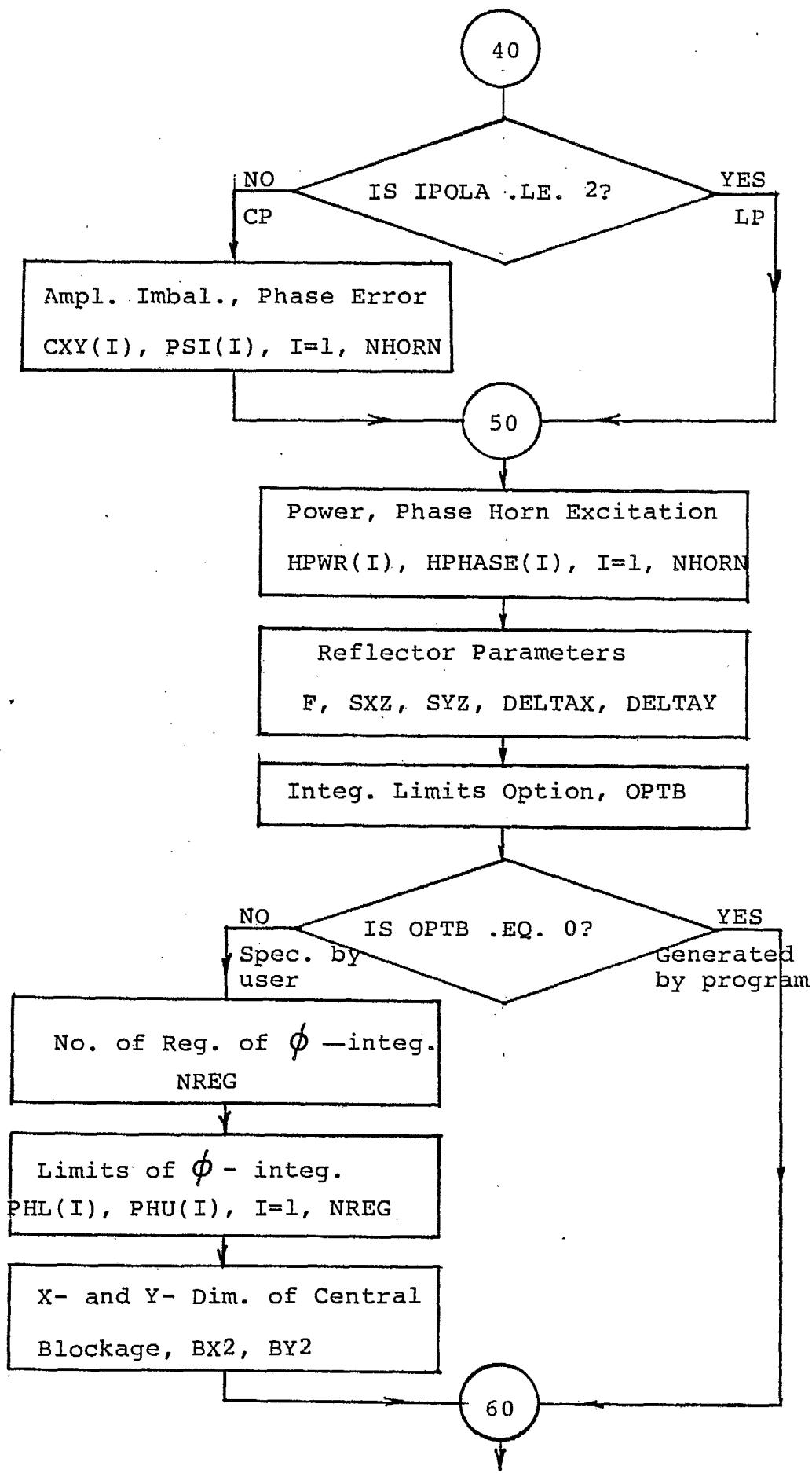
## MAIN PROGRAM:

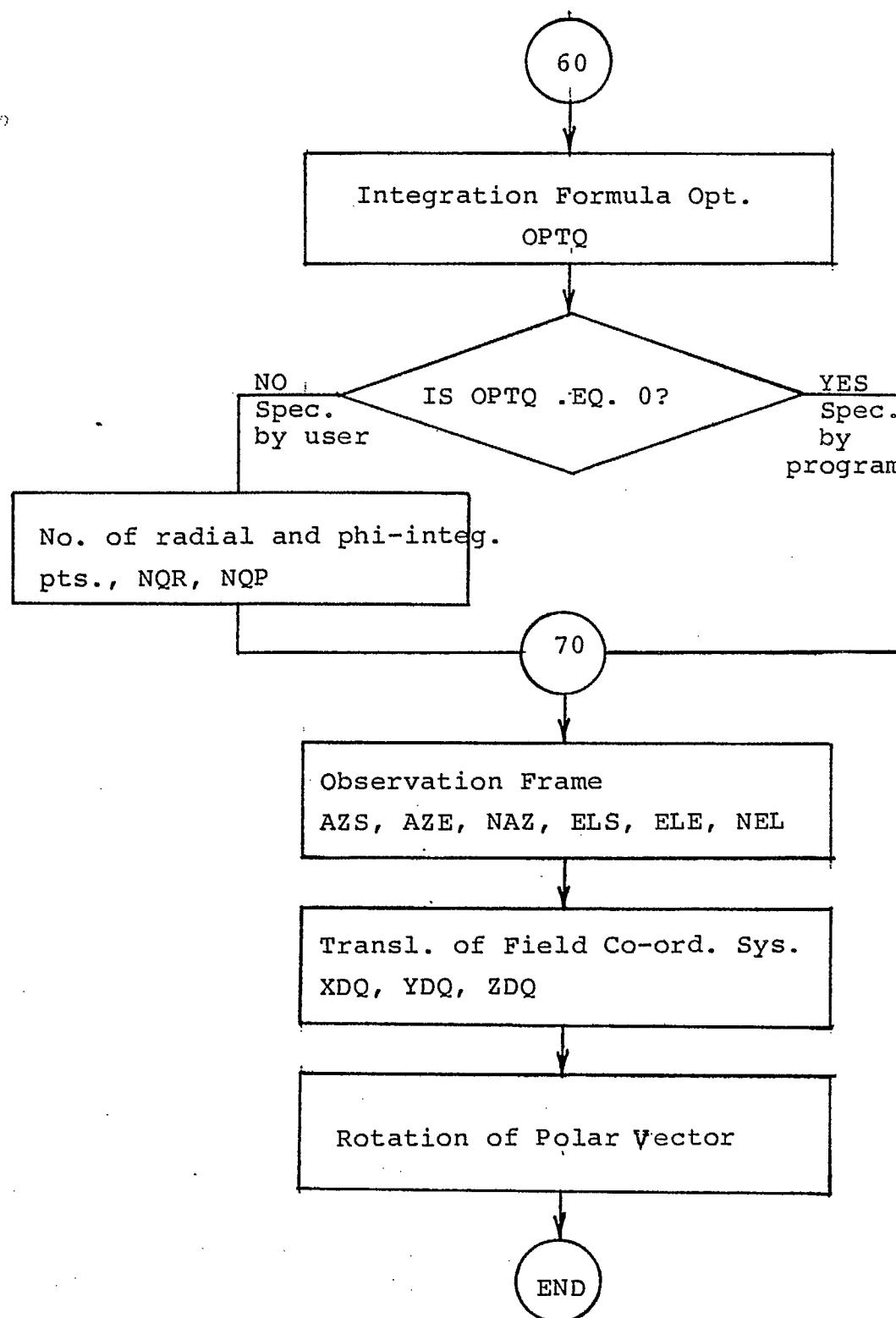
- (i) Change the values of MAXEL and MAXAZ in the data statement to NEL and NAZ respectively.
- (ii) Alter the dimensions of arrays EL and AZ to MAXEL and MAXAZ respectively.
- (iii) Alter the dimensions of arrays CGN, CPH, and XGN to the product MAXEL \*MAXAZ.

Figure B.1 Flow Chart of Input Data File for PAREFM.DAT









B.2 PROGRAM LISTING

```

1.000      PROGRAM PAREFM
2.000 *
3.000 * PHYSICAL OPTICS ANALYSIS OF A PARABOLIC REFLECTOR FED BY A
4.000 * MULTI-FEED ARRAY.
5.000 * THE REFLECTOR HAS AN ELLIPTICAL APERTURE AND IS OFF-SET IN THE
6.000 * X- AND Y- DIRECTION. FAR FIELD CO-POLARISED AND CROSS-POLARISED
7.000 * GAIN MATRICES ARE COMPUTED OVER A RECTANGULAR ELEVATION - AZIMUTH
8.000 * GRID.
9.000 * MAIN FEATURES OF THE PROGRAM ARE THE FOLLOWING -
10.000 * MULTIPLE FEED CAPABILITY.
11.000 * USER SUPPLIED MEASURED OR COMPUTED FEED PATTERN DATA.
12.000 * PATTERNS CAN EITHER BE FROM FEEDS WITH PRINCIPAL PLANES SYMMETRY
13.000 * OR FROM FEEDS WITH BOTH PRINCIPAL AND DIAGONAL PLANES SYMMETRY.
14.000 * MODELING OF APERTURE BLOCKAGE BY FEED AND STRUTS.
15.000 * AUTOMATIC SELECTION OF INTEGRATION LIMITS AND FORMULAS.
16.000 * CHOICE OF CIRCULAR OR ROTATABLE LINEAR POLARISATION.
17.000 * FOR CIRCULAR POL., ABILITY TO SPECIFY AMPL. AND PHASE IMBALANCE
18.000 * IN THE EXCITATION OF THE ORTHOGONAL PORTS.
19.000 *
20.000 * WRITTEN BY K. K. CHAN , CHAN TECHNOLOGIES INC. , MARCH 1984
21.000 *
22.000      CHARACTER*4 IHEAD(15)
23.000      DIMENSION DX(30),DY(30),DZ(30),GAMMA(30),BETA(30),ALPHA(30)
24.000      DIMENSION EPA(46,30,2),EPP(46,30,2),HPA(46,30,2),HPP(46,30,2)
25.000      DIMENSION HPWR(30),HPHASE(30),AN(30),CX(30),PSI(30)
26.000      DIMENSION W11(30),W12(30),W13(30),W21(30),W22(30),W23(30)
27.000      DIMENSION W31(30),W32(30),W33(30),CX(30),CY(30)
28.000      DIMENSION PHL(4),PHU(4),RDL(24,4),RDU(24,4)
29.000      DIMENSION XG(2304),YG(2304),ZG(2304)
30.000      DIMENSION CGN(1681),CPH(1681),XGN(1681),EL(41),AZ(41)
31.000      COMPLEX EX,EY,EZ,EXPX,ETHETA,EPHI,FTX,FTY,FTZ,HX,HY,HZ
32.000      COMPLEX RJX(2304),RJY(2304),RJZ(2304)
33.000      INTEGER OPTB,OPTH,OPTQ,NQ(13)
34.000      COMMON/VAL1/PI,RAD,RK,ZETA
35.000      COMMON/VAL2/AN,HPHASE,CX,CY,PSI,IPOLA,ISYMM,ISAME
36.000      COMMON/BLOCK/QX(219),QW(219)
37.000      COMMON/CURRENT/RJX,RJY,RJZ,XG,YG,ZG
38.000      COMMON/VAL3/NREG,NQR,NQP,PT,XDQ,YDQ,ZDQ,CPVR,SPVR
39.000      COMMON/PATERN/EPA,EPP,HPA,HPP,NPP,PAI
40.000      DATA PI,RAD,ZETA/3.14159265,57.2957795,376.99111/
41.000 * NQF - NO. OF QUADRATURE FORMULAS AVAILABLE IN THE BLOCK DATA,
42.000 * NQ - NO. OF POINTS IN THE QUADRATURE FORMULAS,
43.000      DATA NQF,NQ/13,3,4,6,8,10,12,14,16,20,24,28,34,40/
44.000 *
45.000 * FOLLOWING ARE PRESET LIMITS DUE TO ARRAY DIMENSIONS
46.000 * MAXQ - MAX. NO. OF INTEGRATION PTS.
47.000 * MAXHRN - MAX. NO. OF FEEDS.
48.000 * MAXNPP - MAX. NO. OF PATTERN PTS.
49.000 * MAXEL - MAX. NO. OF EL GRID PTS.
50.000 * MAXAZ - MAX. NO. OF AZ GRID PTS.
51.000 *
52.000      DATA MAXQ,MAXHRN,MAXNPP,MAXEL,MAXAZ/24,30,46,41,41/

```

```
53.000 *
54.000 * START OF DATA INPUT
55.000 *
56.000      OPEN(UNIT=5,NAME='PAREFM.DAT',STATUS='OLD',USAGE='INPUT')
57.000 *
58.000 * IHEAD - HEADING FOR COMPUTER RUN. MAX. OF 60 CHARACTERS.
59.000 *
60.000      READ(5,10) (IHEAD(I),I=1,15)
61.000 10    FORMAT(15A4)
62.000 *
63.000 * DATA DESCRIBING FEED ARRAY
64.000 *
65.000 * FREQ - FREQUENCY IN GHZ
66.000 *
67.000      READ(5,*) FREQ
68.000 *
69.000 * NHORN - NO. OF FEEDS.
70.000 *
71.000      READ(5,*) NHORN
72.000 *
73.000      IF (NHORN.LE.MAXHRN) GO TO 14
74.000      PRINT 12 , MAXHRN
75.000 12    FORMAT(1X,'STOP. NO. OF FEEDS EXCEEDED LIMIT OF ',I2)
76.000      STOP
77.000 14    CONTINUE
78.000 *
79.000 * OPTH - OPTION FOR SPECIFYING FEED POSITIONS AND ROTATIONS,
80.000 *      = 0, FEED POSITIONS ARE SPECIFIED BEFORE ROTATION. THE WHOLE
81.000 *          FEED ARRAY IS ROTATED ABOUT THE GLOBAL X-AXIS BY ANGLE
82.000 *          ALPHA FOLLOWED BY ROTATION ABOUT THE NEW Y-AXIS BY ANGLE
83.000 *          BETA. FINALLY EACH FEED IS ROTATED ABOUT ITS OWN LOCAL Z-
84.000 *          AXIS BY ANGLE GAMMA. THIS OPTION ALLOWS FOR THE COLLECTIVE
85.000 *          MOVEMENT OF THE ARRAY. ONLY THREE VALUES NEED TO BE SPECI-
86.000 *          FIED FOR THE ROTATIONS.
87.000 *      = 1, FEED DISPLACEMENTS SPECIFIED ARE THE FINAL POSITIONS. THE
88.000 *          ROTATIONS TO FOLLOW ARE ABOUT THE INDIVIDUAL FEED LOCAL
89.000 *          X, Y AND Z-AXES. THIS OPTION ALLOWS FOR INDEPENDENT ROTATION
90.000 *          AND POSITIONING OF THE FEEDS. THREE ROTATION ANGLES MUST BE
91.000 *          ENTERED FOR EACH FEED.
92.000 *
93.000      READ(5,*) OPTH
94.000 *
95.000 * DISPLACEMENTS OF COMPONENT FEEDS IN INCHES FROM FOCAL POINT
96.000 *
97.000      READ(5,*) (DX(I),DY(I),DZ(I),I=1,NHORN)
98.000 *
99.000 * ALPHA - ROTATION ABOUT EITHER THE GLOBAL OR LOCAL X-AXIS IN DEG.
100.000 * BETA - ROTATION ABOUT EITHER THE GLOBAL OR LOCAL Y-AXIS IN DEG.
101.000 * GAMMA - ROTATION ABOUT LOCAL Z-AXIS IN DEG.
102.000 *
103.000      NH = 1
104.000      IF (OPTH.NE.0) NH = NHORN
105.000      READ(5,*) (ALPHA(I),BETA(I),GAMMA(I),I=1,NH)
106.000 *
107.000 * IPOLA - POLARISATION OF SECONDARY BEAM FROM REFLECTOR SYSTEM,
108.000 *      - VP=1 , HP=2 , RHCP=3 , LHCP=4
```

109.000 \*  
110.000 READ(5,\*) IPOLA  
111.000 \*  
112.000 \* DATA DESCRIBING FEED PATTERNS.  
113.000 \*  
114.000 \* FEED PATTERNS ARE ASSUMED TO POSSESS AT LEAST SIN(PHI)-COS(PHI) AZ  
115.000 \* SYMMETRY I.E. FEEDS ARE SYMMETRIC ABOUT THE PRINCIPAL PLANES. ONLY  
116.000 \* THE E- AND H-PLANE PATTERNS NEED TO BE READ IN AT EquALLY SPACED  
117.000 \* POINTS STARTING WITH THETA=0.0 DEG. A COARSE SPACING MAY BE  
118.000 \* SUFFICIENT SINCE QUADRATIC INTERPOLATION IS USED TO FIND THE FIELDS  
119.000 \* FOR THE IN-BETWEEN POINTS.  
120.000 \*  
121.000 \*  
122.000 \* ISYMM - PARAMETER TO INDICATE WHETHER FEED HAS DIAGONAL PLANE SYMMETRY  
123.000 \* = 0 , FEED POSSESSES DIAGONAL PLANES SYMMETRY.  
124.000 \* = 1 , FEED HAS NO DIAGONAL PLANES SYMMETRY.  
125.000 \*  
126.000 READ(5,\*) ISYMM  
127.000 \*  
128.000 \* NPP = NUMBER OF EquALLY SPACED PATTERN POINTS.  
129.000 \* PAI = ANGULAR INCREMENT OF OBSERVATION POINTS IN DEGREES.  
130.000 \*  
131.000 READ(5,\*) NPP,PAI  
132.000 \*  
133.000 IF (NPP,LE,MAXNPP) GO TO 18  
134.000 PRINT 16 , MAXNPP  
135.000 16 FORMAT(1X,'STOP. NO. OF FEED PATTERN PTS. EXCEEDED LIMIT OF',  
136.000 + I3)  
137.000 STOP  
138.000 18 CONTINUE  
139.000 \*  
140.000 \* ISAME - PARAMETER TO INDICATE WHETHER ALL THE FEED PATTERNS ARE THE  
141.000 \* SAME.  
142.000 \* = 0 , FEED PATTERNS ARE IDENTICAL. ONLY ONE SET OF FEED  
143.000 \* PATTERNS NEED TO BE SUPPLIED.  
144.000 \* = 1 , FEED PATTERNS ARE NOT IDENTICAL. NHORN SETS OF PATTERN  
145.000 \* NEED TO BE SUPPLIED.  
146.000 \*  
147.000 READ(5,\*) ISAME  
148.000 \*  
149.000 \* IT IS VISUALISED THAT EACH FEED HAS TWO INPUT PORTS, PORT 1 AND  
150.000 \* PORT 2. IN LP SYSTEMS ONLY ONE PORT(PORT 1) IS USED. PORT 1 IS  
151.000 \* THE CO-POLARISED PORT EITHER THE X- OR THE Y-PORT. IN CP SYSTEMS BOTH  
152.000 \* PORTS ARE USED. IF THE FEED HAS PRINCIPAL AND DIAGONAL PLANES SYMMETRY  
153.000 \* ONLY THE E- AND H-PLANE PATTERNS FOR PORT 1 ARE REQUIRED. IF THE FEED  
154.000 \* DOES NOT HAVE DIAGONAL PLANES SYMMETRY AND IS USED IN A CP SYSTEM,  
155.000 \* THEN E- AND H-PLANE PATTERNS FOR BOTH PORT 1 AND PORT 2 MUST BE  
156.000 \* ENTERED.  
157.000 \*  
158.000 \* EPA(I,J,K) = E-PLANE AMPL(DB) PATTERN FOR PORT K OF THE J TH FEED  
159.000 \* AT THE I TH OBSERVATION POINT.  
160.000 \* EPP(I,J,K) = E-PLANE PHASE(DEG) PATTERN FOR PORT K OF THE J TH FEED  
161.000 \* AT THE I TH OBSERVATION POINT.  
162.000 \* HPA(I,J,K) = H-PLANE AMPL(DB) PATTERN FOR PORT K OF THE J TH FEED  
163.000 \* AT THE I TH OBSERVATION POINT.  
164.000 \* HPP(I,J,K) = H-PLANE PHASE(DEG) PATTERN FOR PORT K OF THE J TH FEED

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165.000 * AT THE I TH OBSERVATION POINT.  
166.000 *  
167.000 IPORT = 1  
168.000 IF (IPOLA.GE.3.AND.ISYMM.NE.0) IPORT = 2  
169.000 NF = 1  
170.000 IF (ISAME.NE.0) NF = NHORN  
171.000 DO 30 K = 1,IPORT  
172.000 DO 20 J = 1,NF  
173.000 READ(5,*) (EPA(I,J,K),EPP(I,J,K),I=1,NPP)  
174.000 READ(5,*) (HPA(I,J,K),HPP(I,J,K),I=1,NPP)  
175.000 20 CONTINUE  
176.000 30 CONTINUE  
177.000 IF (IPOLA.LE.2) GO TO 50  
178.000 *  
179.000 * FOR NON-IDEAL CP FEEDS, AN IMBALANCE EXISTS IN THE AMPLITUDE  
180.000 * EXCITATIONS OF THE ORTHOGONAL PORTS AS WELL AS DEVIATION FROM THE  
181.000 * PHASE QUADRATURE CONDITION. PORT 1 IS ASSOCIATED WITH THE X-PORT  
182.000 * AND PORT 2 WITH THE Y-PORT.  
183.000 *  
184.000 * CXY(I) = AMPLITUDE IMBALANCE OF Y-PORT RELATIVE TO X-PORT,  
185.000 * PSI(I) = DEPARTURE FROM PHASE QUADRATURE IN DEG OF THE Y-PORT.  
186.000 *  
187.000 READ(5,*) (CXY(I),I=1,NHORN)  
188.000 READ(5,*) (PSI(I),I=1,NHORN)  
189.000 *  
190.000 * HPWR - POWER INPUT TO EACH FEED IN WATTS,  
191.000 * HPHASE - RELATIVE PHASE EXCITATION OF EACH FEED IN DEG,  
192.000 *  
193.000 50 READ(5,*) (HPWR(I),HPHASE(I),I=1,NHORN)  
194.000 *  
195.000 * DATA DESCRIBING PARABOLIC REFLECTOR CONFIGURATION.  
196.000 *  
197.000 * F - FOCAL LENGTH OF PARABOLIC REFLECTOR IN INCHES.  
198.000 * SX2 - X-DIMENSION OF ELLIPTICAL REFLECTOR APERTURE IN INCHES  
199.000 * SY2 - Y-DIMENSION OF ELLIPTICAL REFLECTOR APERTURE IN INCHES  
200.000 * DELTAX - X-OFFSET OF APERTURE CENTRE IN INCHES  
201.000 * DELTAY - Y-OFFSET OF APERTURE CENTRE IN INCHES.  
202.000 *  
203.000 READ(5,*) F, SX2, SY2, DELTAX, DELTAY  
204.000 *  
205.000 * OPTB - OPTION FOR SPECIFYING LIMITS OF INTEGRATION TO SIMULATE BLOCKAGE.  
206.000 * = 0, LIMITS ARE GENERATED BY PROGRAM FROM INPUT REFLECTOR  
207.000 * DATA, NO APERTURE BLOCKAGE IS ASSUMED.  
208.000 * = 1, LIMITS ARE DERIVED BY THE USER AND READ INTO THE PROGRAM.  
209.000 *  
210.000 READ(5,*) OPTB  
211.000 IF (OPTB.EQ.0) GO TO 60  
212.000 *  
213.000 * NREG - NUMBER OF REGIONS OF PHI-INTEGRATION.  
214.000 *  
215.000 READ(5,*) NREG  
216.000 *  
217.000 * PHL(I) - LOWER LIMIT OF PHI-INTEG FOR THE I TH REGION IN RADIANS.  
218.000 * PHU(I) - UPPER LIMIT OF PHI-INTEG FOR THE I TH REGION IN RADIANS.  
219.000 *  
220.000 READ(5,*) (PHL(I),PHU(I),I=1,NREG)
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221.000 *
222.000 * BX2 - X-AXIS DIMENSION OF CENTRAL ELLIPTICAL BLOCKAGE IN INS.
223.000 * BY2 - Y-AXIS DIMENSION OF CENTRAL ELLIPTICAL BLOCKAGE IN INS.
224.000 *
225.000      READ(5,*) BX2, BY2
226.000 *
227.000 * OPTQ - OPTION FOR SPECIFYING NO. OF INTEGRATION POINTS.
228.000 *      = 0, NO. OF INTEGRATION POINTS IS DETERMINED BY PROGRAM.
229.000 *      = 1, SPECIFIED BY USER.
230.000 *
231.000 60    READ(5,*) OPTQ
232.000      IF (OPTQ.EQ.0) GO TO 70
233.000 *
234.000 * DATA FOR SURFACE INTEGRATION.
235.000 * NQR - NO OF INTEGRATION POINTS IN THE RADIAL-DIRECTION.
236.000 * NQP - NO OF INTEGRATION POINTS IN THE PHI-DIRECTION.
237.000 * CHOOSE FROM THE FOLLOWING LIST - 3,4,6,8,10,12,14,16,20,24,28,34,40 PTS
238.000 *
239.000      READ(5,*) NQR,NQP
240.000 *
241.000 * READ IN DATA FOR FAR FIELD OBSERVATION
242.000 *
243.000 * ELS - START OF ELEV CUT IN DEG
244.000 * ELE - END OF ELEV CUT IN DEG
245.000 * NEL - NO. OF ELEV POINTS
246.000 * AZS - START OF AZIMUTH CUT IN DEG
247.000 * AZE - END OF AZIMUTH CUT IN DEG
248.000 * NAZ - NO. OF AZIM POINTS
249.000 *
250.000 70    READ(5,*) AZS,AZE,NAZ,ELS,ELE,NEL
251.000 *
252.000      IF (NEL.LE.MAXEL) GO TO 74
253.000      PRINT 72 , MAXEL
254.000 72    FORMAT(1X,'STOP. NO. OF EL GRID PTS. EXCEEDED MAX. OF ',I2)
255.000      STOP
256.000 74    IF (NAZ.LE.MAXAZ) GO TO 78
257.000      PRINT 76 , MAXAZ
258.000 76    FORMAT(1X,'STOP. NO. OF AZ GRID PTS. EXCEEDED MAX. OF ',I2)
259.000      STOP
260.000 78    CONTINUE
261.000 *
262.000 * XDQ - X-TRANSLATION OF FIELD CO-ORDINATE SYSTEM FROM GLOBAL SYSTEM.(INS)
263.000 * YDQ - Y-TRANSLATION OF FIELD CO-ORDINATE SYSTEM FROM GLOBAL SYSTEM.(INS)
264.000 * ZDQ - Z-TRANSLATION OF FIELD CO-ORDINATE SYSTEM FROM GLOBAL SYSTEM.(INS)
265.000 *
266.000      READ(5,*) XDQ,YDQ,ZDQ
267.000 *
268.000 * PVR - ANGULAR ROTATION OF FIELD POLARISATION VECTOR IN DEGREES.
269.000 *
270.000      READ(5,*) PVR
271.000 *
272.000 * DATA INPUT COMPLETED
273.000 *
274.000 80    FORMAT(12I5)
275.000 90    FORMAT(12F10.4)
276.000 95    FORMAT(1X,15A4)
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277.000 PRINT 95 , (IHEAD(I),I=1,15)
278.000 PRINT 100
279.000 100 FORMAT(1X,'FREQUENCY IN GHZ')
280.000 PRINT 90,FREQ
281.000 PRINT 110
282.000 110 FORMAT(1X,'NO OF FEED RADIATORS')
283.000 PRINT 80,NHORN
284.000 IF (OPTH,EQ.1) THEN
285.000 PRINT 120
286.000 120 FORMAT(1X,'OPT. CHOSEN - INDIVIDUAL DISPLACEMENT AND ROTATION',
287.000 +' OF FEEDS')
288.000 ELSE
289.000 PRINT 125
290.000 125 FORMAT(1X,'OPT. CHOSEN - COLLECTIVE MOVEMENT AND ROTATION OF',
291.000 +' FEED ARRAY')
292.000 END IF
293.000 PRINT 80, OPTH
294.000 PRINT 130
295.000 130 FORMAT(1X,'DISPLACEMENTS OF FEEDS IN INS.')
296.000 PRINT 90,(DX(I),DY(I),DZ(I),I=1,NHORN)
297.000 PRINT 140
298.000 140 FORMAT(1X,'ROT. OF FEEDS ABOUT X-,Y-,AND Z-AXIS IN DEG.')
299.000 PRINT 90,(ALPHA(I),BETA(I),GAMMA(I),I=1,NH)
300.000 PRINT 145
301.000 145 FORMAT(1X,'POLAR. OF SECON. BEAM - VP=1,HP=2,RHCP=3,LHCP=4')
302.000 PRINT 80,IPOLA
303.000 PRINT 150
304.000 150 FORMAT(1X,'FEED SYMMETRY - PRINCIPAL + DIAG. PLANES = 0',
305.000 +' , PRINCIPAL PLANES ONLY = 1')
306.000 PRINT 80 , ISYMM
307.000 PRINT 155
308.000 155 FORMAT(1X,'NO. OF PTS. DESCRIPT. PATTERNS AND ANGULAR INCREMENT',
309.000 +' OF POINTS')
310.000 PRINT 160, NPP,PAI
311.000 160 FORMAT(I5,F7.2)
312.000 DO 175 J = 1,NF
313.000 PRINT 165 , J
314.000 165 FORMAT(1X,'PORT 1 E-PLANE AMPL(DB) AND PHASE(DEG) PATTERNS',
315.000 +' FOR FEED NO. ',I2)
316.000 PRINT 90 , (EPA(I,J,1),EPP(I,J,1),I=1,NPP)
317.000 PRINT 170 , J
318.000 170 FORMAT(1X,'PORT 1 H-PLANE AMPL(DB) AND PHASE(DEG) PATTERNS',
319.000 +' FOR FEED NO. ',I2)
320.000 PRINT 90 , (HPA(I,J,1),HPP(I,J,1),I=1,NPP)
321.000 175 CONTINUE
322.000 IF (IPOLA.LE.2) GO TO 210
323.000 IF (ISYMM.EQ.0) GO TO 195
324.000 DO 190 J = 1,NF
325.000 PRINT 180 , J
326.000 180 FORMAT(1X,'PORT 2 E-PLANE AMPL(DB) AND PHASE(DEG) PATTERNS',
327.000 +' FOR FEED NO. ',I2)
328.000 PRINT 90 , (EPA(I,J,2),EPP(I,J,2),I=1,NPP)
329.000 PRINT 185 , J
330.000 185 FORMAT(1X,'PORT 2 H-PLANE AMPL(DB) AND PHASE(DEG) PATTERNS',
331.000 +' FOR FEED NO. ',I2)
332.000 PRINT 90 , (HPA(I,J,2),HPP(I,J,2),I=1,NPP)
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333.000 190 CONTINUE
334.000 195 PRINT 200
335.000 200 FORMAT(1X,'AMPL IMBALANCE OF Y-PORT REL. TO X-PORT')
336.000 PRINT 90 , (CXY(I),I=1,NHORN)
337.000 PRINT 205
338.000 205 FORMAT(1X,'PHASE DEPARTURE OF Y-PORT FROM QUADRATURE IN DEG.')
339.000 PRINT 90 , (PSI(I),I=1,NHORN)
340.000 210 PRINT 215
341.000 215 FORMAT(1X,'POWER(W) AND PHASE(DEG) OF FEED EXCITATIONS')
342.000 PRINT 90 , (HPWR(I),HPHASE(I),I=1,NHORN)
343.000 PRINT 220
344.000 220 FORMAT(1X,'FOC LTH.,APER. X-DIM,Y-DIM AND X-, Y-OFFSET IN INS.')
345.000 PRINT 90 , F,SX2,SY2,DELTAX,DELTAY
346.000 IF (OPTB.LE.0) GO TO 260
347.000 PRINT 230
348.000 230 FORMAT(1X,'NO. OF REGIONS OF PHI-INTEG = ',I2)
349.000 PRINT 80 , NREG
350.000 PRINT 240
351.000 240 FORMAT(1X,'LOWER AND UPPER LIMITS OF PHI-INTEG IN RADIANS')
352.000 PRINT 90 , (PHL(I),PHU(I),I=1,NREG)
353.000 PRINT 250
354.000 250 FORMAT(1X,'X-AND Y-DIM. OF CENTRAL ELLIPTICAL BLOCKAGE IN INS')
355.000 PRINT 90 , BX2,BY2
356.000 260 IF (OPTQ.LE.0) GO TO 275
357.000 PRINT 270
358.000 270 FORMAT(1X,'INTEG. PTS. SPEC. BY USER FOR RADIAL AND PHI-VAR,',
359.000 +/-,1X,'MUST BE MEMBERS OF FOLLOWING SET -3,4,6,8,10,12,14,16,',
360.000 '+20,24,28,34,40')
361.000 PRINT 80 , NQR, NQP
362.000 275 PRINT 280
363.000 280 FORMAT(1X,'START,STOP AND NO. OF PTS. FOR AZ,EL SCAN')
364.000 PRINT 290 , AZS,AZE,NAZ,ELS,ELE,NEL
365.000 290 FORMAT(2(2F10.5,I5))
366.000 PRINT 300
367.000 300 FORMAT(1X,'X-,Y-,Z-TRANSLATION OF FIELD CO-ORD. SYSTEM IN INS')
368.000 PRINT 90 , XDQ , YDQ , ZDQ
369.000 PRINT 310
370.000 310 FORMAT(1X,'ROTATION OF FIELD POLARISATION VECTOR IN DEGREES')
371.000 PRINT 90 , PVR
372.000 *
373.000 * COMPUTE WAVELENGTH
374.000 *
375.000 WAVE = 29.97925/(2.54*FREQ)
376.000 RK = 2.0*PI/WAVE
377.000 IF (OPTH.NE.0) GO TO 325
378.000 *
379.000 * COMPUTE FINAL LOCATIONS OF HURNS AFTER COLLECTIVE ALPHA AND BETA ROTATIONS
380.000 *
381.000 SA = SIN(ALPHA(1)/RAD)
382.000 CA = COS(ALPHA(1)/RAD)
383.000 SB = SIN(BETA(1)/RAD)
384.000 CB = COS(BETA(1)/RAD)
385.000 SG = SIN(GAMMA(1)/RAD)
386.000 CG = COS(GAMMA(1)/RAD)
387.000 DO 315 I = 1,NHORN
388.000 ARB1 = DX(I)
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389.000      ARG2 = DY(I)
390.000      ARG3 = DZ(I)
391.000      DX(I) = ARG1*CB + ARG3*SB
392.000      DY(I) = ARG1*SA*SB + ARG2*CA - ARG3*SA*CB
393.000      DZ(I) = -ARG1*SB*CA + ARG2*SA + ARG3*CA*CB
394.000 315   CONTINUE
395.000 *
396.000 * COMPUTE TRANSFORMATION FUNCTIONS OF COLLECTIVE HORN ROTATIONS
397.000 *
398.000      W11(1) = CB*CG
399.000      W12(1) = SA*SB*CG + CA*SG
400.000      W13(1) = -CA*SB*CG + SA*SG
401.000      W21(1) = -CB*SG
402.000      W22(1) = -SA*SB*SG + CA*CG
403.000      W23(1) = CA*SB*SG + SA*CG
404.000      W31(1) = SB
405.000      W32(1) = -SA*CB
406.000      W33(1) = CA*CB
407.000      IF (NHORN,EQ,1) GO TO 335
408.000      DO 320 I = 2,NHORN
409.000      W11(I) = W11(1)
410.000      W12(I) = W12(1)
411.000      W13(I) = W13(1)
412.000      W21(I) = W21(1)
413.000      W22(I) = W22(1)
414.000      W23(I) = W23(1)
415.000      W31(I) = W31(1)
416.000      W32(I) = W32(1)
417.000      W33(I) = W33(1)
418.000 320   CONTINUE
419.000      GO TO 335
420.000 *
421.000 * COMPUTE TRANSFORMATION FUNCTIONS OF INDIVIDUAL HORN ROTATIONS.
422.000 *
423.000 325   DO 330 I = 1,NHORN
424.000      SB = SIN(BETA(I)/RAD)
425.000      CB = COS(BETA(I)/RAD)
426.000      SA = SIN(ALPHA(I)/RAD)
427.000      CA = COS(ALPHA(I)/RAD)
428.000      SG = SIN(GAMMA(I)/RAD)
429.000      CG = COS(GAMMA(I)/RAD)
430.000      W11(I) = CB*CG
431.000      W12(I) = SA*SB*CG + CA*SG
432.000      W13(I) = -CA*SB*CG + SA*SG
433.000      W21(I) = -CB*SG
434.000      W22(I) = -SA*SB*SG + CA*CG
435.000      W23(I) = CA*SB*SG + SA*CG
436.000      W31(I) = SB
437.000      W32(I) = -SA*CB
438.000      W33(I) = CA*CB
439.000 330   CONTINUE
440.000 *
441.000 * CONVERT DEGREES INTO RADIANS AND DB INTO VOLTAGE.
442.000 *
443.000 335   DO 340 I = 1,NHORN
444.000      HPHASE(I) = HPHASE(I)/RAD
```

445.000 340 CONTINUE  
446.000 \*  
447.000 PAI = PAI/RAD  
448.000 \*  
449.000 DO 350 J = 1,NF  
450.000 DO 345 I = 1,NPP  
451.000 EPA(I,J,1) = 10.0\*\*(EPA(I,J,1)/20.0)  
452.000 HPA(I,J,1) = 10.0\*\*((HPA(I,J,1)/20.0))  
453.000 EPP(I,J,1) = EPP(I,J,1)/RAD  
454.000 HPP(I,J,1) = HPP(I,J,1)/RAD  
455.000 345 CONTINUE  
456.000 350 CONTINUE  
457.000 IF (IPOLA.LE.2..OR.ISYMM.EQ.0) GO TO 365  
458.000 DO 360 J = 1,NF  
459.000 DO 355 I = 1,NPP  
460.000 EPA(I,J,2) = 10.0\*\*((EPA(I,J,2)/20.0))  
461.000 HPA(I,J,2) = 10.0\*\*((HPA(I,J,2)/20.0))  
462.000 EPP(I,J,2) = EPP(I,J,2)/RAD  
463.000 HPP(I,J,2) = HPP(I,J,2)/RAD  
464.000 355 CONTINUE  
465.000 360 CONTINUE  
466.000 \*  
467.000 \* SPECIFY EXCITATIONS OF ORTHOGONAL PORTS.  
468.000 \*  
469.000 365 DO 390 I = 1,NHORN  
470.000 GO TO (370,375,380,385), IPOLA  
471.000 \*  
472.000 \* VERTICAL POLARIZATION  
473.000 \*  
474.000 370 CX(I) = 1.0  
475.000 CY(I) = 0.0  
476.000 PSI(I) = 0.0  
477.000 GO TO 390  
478.000 \*  
479.000 \* HORIZONTAL POLARIZATION  
480.000 \*  
481.000 375 CX(I) = 0.0  
482.000 CY(I) = 1.0  
483.000 PSI(I) = 0.0  
484.000 GO TO 390  
485.000 \*  
486.000 \* RIGHT HANDED CIRCULAR POLARIZATION  
487.000 \*  
488.000 380 CX(I) = 1.0  
489.000 CY(I) = CXY(I)\*CX(I)  
490.000 PSI(I) = PSI(I)/RAD + 1.5707963  
491.000 GO TO 390  
492.000 \*  
493.000 \* LEFT HANDED CIRCULAR POLARIZATION  
494.000 \*  
495.000 385 CX(I) = 1.0  
496.000 CY(I) = CXY(I)\*CX(I)  
497.000 PSI(I) = PSI(I)/RAD - 1.5707963  
498.000 390 CONTINUE  
499.000 \*  
500.000 \* COMPUTE VOLTAGE NORMALISATION CONSTANT , AN , FOR EACH FEED.

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501.000 *
502.000      DO 400 J = 1,NF
503.000      CALL PWRFED(J,1,PWR1,NPP,PAI)
504.000      IF (IPOLA.LE.2.OR.ISYMM.EQ.0) GO TO 395
505.000      CALL PWRFED(J,2,PWR2,NPP,PAI)
506.000      AN(J) = CX(J)*CX(J)*PWR1 + CY(J)*CY(J)*PWR2
507.000      GO TO 400
508.000 395  AN(J) = (CX(J)*CX(J) + CY(J)*CY(J))*PWR1
509.000 400  CONTINUE
510.000      IF (ISAME.EQ.1.OR.NHORN.EQ.1) GO TO 410
511.000      DO 405 J = 2,NHORN
512.000      AN(J) = AN(1)
513.000 405  CONTINUE
514.000 410  DO 415 J = 1,NHORN
515.000      AN(J) = SQRT(HPWR(J)/AN(J))
516.000 415  CONTINUE
517.000 *
518.000 * TAKE SINE AND COSINE OF FIELD VECTOR ROTATION ANGLE.
519.000 *
520.000      CPVR = COS(PVR/RAD)
521.000      SPVR = SIN(PVR/RAD)
522.000      IF (OPTB.GT.0) GO TO 425
523.000 *
524.000 * INTERNAL DEFAULT INTEGRATION LIMITS.
525.000 * APERTURE IS DIVIDED INTO FOUR REGIONS FOR PHI-INTEG.
526.000 * LIMITS OF THESE REGIONS ARE SET BELOW.
527.000 *
528.000      NREG = 4
529.000      PHL(1) = 0.0
530.000      PHU(1) = 1.570796327
531.000      DO 420 I = 2,NREG
532.000      PHL(I) = PHL(I-1) + 1.570796327
533.000      PHU(I) = PHU(I-1) + 1.570796327
534.000 420  CONTINUE
535.000 *
536.000 * THERE IS NO CENTRAL BLOCKAGE.
537.000 *
538.000      BX2 = 0.0
539.000      BY2 = 0.0
540.000 425  IF (OPTQ.GT.0) GO TO 455
541.000 *
542.000 * SELECTION OF THE APPROPRIATE QUADRATURE FORMULA
543.000 *
544.000      XMAX = -99999.0
545.000      XMIN = +99999.0
546.000      YMAX = -99999.0
547.000      YMIN = +99999.0
548.000      DO 430 I = 1,NHORN
549.000      IF (DX(I).GT.XMAX) XMAX = DX(I)
550.000      IF (DX(I).LT.XMIN) XMIN = DX(I)
551.000      IF (DY(I).GT.YMAX) YMAX = DY(I)
552.000      IF (DY(I).LT.YMIN) YMIN = DY(I)
553.000 430  CONTINUE
554.000 * FIND THE LARGEST ANGLE BETWEEN COMPONENT BEAMS AND FIELD
555.000 * OBSERVATION POINTS.
556.000      ARG1 = ABS(ELE/RAD + ATAN(XMAX/F))
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557.000      ARG2 = ABS(ATAN(XMIN/F) + ELS/RAD)
558.000      ARG3 = ABS(AZE/RAD + ATAN(YMAX/F))
559.000      ARG4 = ABS(ATAN(YMIN/F) + AZS/RAD)
560.000      ARG1 = AMAX1(ARG1,ARG2)
561.000      ARG3 = AMAX1(ARG3,ARG4)
562.000      NQR = (SIN(ARG1)*SX2/WAVE + 1.0)*1.50
563.000      NQP = (SIN(ARG3)*SY2/WAVE + 1.0)*1.50
564.000      NQR = MAX0(NQR,NQP)
565.000 *
566.000 * SEARCH FOR THE CLOSEST AVAILABLE QUADRATURE FORMULA
567.000 * THE AVAILABLE FORMULAS ARE STORED IN ASCENDING ORDER IN ARRAY NQ,
568.000 * NQF IS THE NUMBER OF FORMULAS. BOTH NQ AND NQF ARE DEFINED IN DATA
569.000 * STATEMENT ABOVE.
570.000 *
571.000      DO 435 I = 1,NQF
572.000      IF (NQR.LE.NQ(I)) GO TO 445
573.000 435    CONTINUE
574.000      PRINT 440
575.000 440    FORMAT(1X,'QUADRATURE FORMULA REQUIRED IS LARGER THAN AVAILABLE'
576.000      +' IN THE PROGRAM. EXECUTION IS TERMINATED')
577.000      STOP
578.000 445    NQR = NQ(I)
579.000      NQP = NQR
580.000      PRINT 450
581.000 450    FORMAT(1X,'INTEG. PTS. SELECTED FOR RADIAL AND PHI-VAR.')
582.000      PRINT 80 , NQR,NQP
583.000 *
584.000 455    IF (NQR.LE.MAXQ.AND.NQP.LE.MAXQ) GO TO 458
585.000      PRINT 457 , NQR,NQP
586.000 457    FORMAT(1X,'STOP. INCREASE ARRAYS DIMENSIONS TO ACCOMODATE',
587.000      +' FOLLOWING NQR AND NQP PTS. RESP. - ',2I3)
588.000      STOP
589.000 *
590.000 * DETERMINE LOCATION OF QUADRATURE FORMULA
591.000 *
592.000 458    CALL QRLOC(NQR,LQR)
593.000    CALL QRLOC(NQP,LQP)
594.000 *
595.000 * COMPUTE SEMI-AXES DIMENSIONS FOR REFLECTOR AND BLOCKAGE APERTURES.
596.000 *
597.000      SX2 = SX2*0.50
598.000      SY2 = SY2*0.50
599.000      BX2 = BX2*0.50
600.000      BY2 = BY2*0.50
601.000 *
602.000 * INITIALISE CURRENT MATRIX RJX,RJY,RJZ
603.000 *
604.000      KOUNT = 0
605.000      DO 470 L = 1,NREG
606.000      DO 465 J = 1,NQR
607.000      DO 460 I = 1,NQP
608.000      KOUNT = KOUNT + 1
609.000      RJX(KOUNT) = (0.0,0.0)
610.000      RJY(KOUNT) = (0.0,0.0)
611.000      RJZ(KOUNT) = (0.0,0.0)
612.000 460    CONTINUE

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613.000 465    CONTINUE
614.000 470    CONTINUE
615.000 *
616.000 * COMPUTE CURRENT MATRIX
617.000 * AT THE SAME TIME COMPUTE POWER INTERCEPTED BY REFL
618.000 *
619.000      PWR = 0.0
620.000 *
621.000 * L = INDEX FOR REGION OF PHI- INTEGRATION.
622.000 *
623.000      KOUNT = 0
624.000      DO 520 L = 1,NREG
625.000 *
626.000 * I = INDEX FOR PHI-INTEG
627.000 *
628.000      DO 510 I = 1,NQP
629.000      PHII = (PHL(L)+PHU(L))*0.50+(PHU(L)-PHL(L))*0.50*QX(I+LQP)
630.000      CPI = COS(PHII)
631.000      SPI = SIN(PHII)
632.000 *
633.000 * FIND THE LIMITS OF RADIAL-INTEGRATION GIVEN PHII
634.000 *
635.000      CALL RADLIM(CPI,SPI,SX2,SY2,BX2,BY2,RDL(I,L),RDU(I,L))
636.000      FAC = (PHU(L)-PHL(L))*(RDU(I,L)-RDL(I,L))*0.25
637.000 *
638.000 * J = INDEX FOR RHO-INTEG.
639.000 *
640.000      DO 500 J = 1,NQR
641.000      RDJ = (RDL(I,L)+RDU(I,L))*0.50+(RDU(I,L)-RDL(I,L))*0.50*
642.000      + QX(J+LQR)
643.000      KOUNT = KOUNT + 1
644.000 *
645.000 * STORE REFLECTOR SURFACE POINTS
646.000 *
647.000      XG(KOUNT) = RDJ*CPI + DELTAX
648.000      YG(KOUNT) = RDJ*SPI + DELTAY
649.000      ZG(KOUNT) = (XG(KOUNT)**2 + YG(KOUNT)**2)*0.25/F - F
650.000 *
651.000 * COMPUTE COMPONENTS OF SURFACE NORMAL
652.000 *
653.000      RNX = -XG(KOUNT)*0.50/F
654.000      RNY = -YG(KOUNT)*0.50/F
655.000 *
656.000 * K = INDEX FOR FEED HORN
657.000      EX = (0.0,0.0)
658.000      EY = (0.0,0.0)
659.000      EZ = (0.0,0.0)
660.000      HX = (0.0,0.0)
661.000      HY = (0.0,0.0)
662.000      HZ = (0.0,0.0)
663.000      DO 490 K = 1,NHORN
664.000 * THE FOLLOWING TRANSFORMATIONS CONVERT SURFACE POINT
665.000 * COORDINATES TO HORN COORDINATES.
666.000 * TRANSFORM (RHO,THETA,PHI) TO (RHOT,THETAT,PHIT)
667.000      RHOT = SQRT((XG(KOUNT) - DX(K))**2 + (YG(KOUNT) - DY(K))**2
668.000      + (ZG(KOUNT) - DZ(K))**2)
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669.000     CTT = (ZG(KOUNT)-DZ(K))/RHOT
670.000     STT = ACOS(CTT)
671.000     STT = SIN(STT)
672.000     SPT = ATAN2((YG(KOUNT)-DY(K)),(XG(KOUNT)-DX(K)))
673.000     CPT = COS(SPT)
674.000     SPT = SIN(SPT)
675.000 *
676.000 * TRANSFORM (RHOT,THETAT,PHIT) TO (RHOR,THETAR,PHIR)
677.000     STSP = STT*SPT
678.000     STCP = STT*CPT
679.000     CTR = STCP*W31(K) + STSP*W32(K) + CTT*W33(K)
680.000     THETAR = ACOS(CTR)
681.000     STR = SIN(THETAR)
682.000     SPR = STCP*W21(K) + W22(K)*STSP + W23(K)*CTT
683.000     CPR = STCP*W11(K) + STSP*W12(K) + CTT*W13(K)
684.000     SPR = ATAN2(SPR,CPR)
685.000     CPR = COS(SPR)
686.000     SPR = SIN(SPR)
687.000     CTCP = CTR*CPR
688.000     CTSP = CTR*SFR
689.000 *
690.000     TXT = CTCP*W11(K) + CTSP*W21(K) - STR*W31(K)
691.000     TYT = CTCP*W12(K) - STR*W32(K) + CTSP*W22(K)
692.000     TZT = CTCP*W13(K) + CTSP*W23(K) - STR*W33(K)
693.000     TXP = -SPR*W11(K) + CPR*W21(K)
694.000     TYP = -SPR*W12(K) + CPR*W22(K)
695.000     TZP = -SPR*W13(K) + CPR*W23(K)
696.000 *
697.000     PT = RK*RHOT
698.000     EXPN = CMPLX(COS(PT),-SIN(PT))/RHOT
699.000 * COMPUTE FEED ARRAY FIELDS AT (RHOR,THETAR,PHIR)
700.000     CALL SOURCE(THETAR,SPR,CPR,EETHETA,EPHI,K)
701.000     EETHETA = EETHETA*EXPN
702.000     EPHI = EPHI*EXPN
703.000     FTX = EETHETA*TXP - EPHI*TXT
704.000     FTY = EETHETA*TYP - EPHI*TYT
705.000     FTZ = EETHETA*TZP - EPHI*TZT
706.000     RJX(KOUNT) = RJX(KOUNT) + FTZ*RNY - FTY
707.000     RJP(KOUNT) = RJP(KOUNT) + FTX - FTZ*RNX
708.000     RJZ(KOUNT) = RJZ(KOUNT) + FTY*RNX - FTX*RNY
709.000 *
710.000 * COMPUTE COMBINED FEED PATTERN FOR SPILL-OVER CALCULATION
711.000 *
712.000     EX = EX + EETHETA*TXT + EPHI*TXP
713.000     EY = EY + EETHETA*TYT + EPHI*TYP
714.000     EZ = EZ + EETHETA*TZT + EPHI*TZP
715.000     HX = HX + FTX
716.000     HY = HY + FTY
717.000     HZ = HZ + FTZ
718.000 490  CONTINUE
719.000     FACW = FAC*RDJ*QW(I+LQP)*QW(J+LQR)
720.000     RJX(KOUNT) = RJX(KOUNT)*FACW
721.000     RJP(KOUNT) = RJP(KOUNT)*FACW
722.000     RJZ(KOUNT) = RJZ(KOUNT)*FACW
723.000     PWR = PWR - (REAL(EY*CONJG(HZ)) - EZ*CONJG(HY))*RNX +
724.000     +           REAL(EZ*CONJG(HX)) - EX*CONJG(HZ))*RNY +

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725.000      +      REAL(EX*CONJG(HY) - EY*CONJG(HX)))*FACW
726.000 500  CONTINUE
727.000 510  CONTINUE
728.000 520  CONTINUE
729.000 * COMPUTATION OF CURRENT MATRIX COMPLETED
730.000 *
731.000 * COMPUTE SPILL-OVER EFFICIENCY - ETAS
732.000 * PWR = POWER CAPTURED BY REFLECTOR
733.000 *
734.000      PWR = PWR*0.50/ZETA
735.000 * PT = TOTAL POWER RADIATED
736.000      PT = 0.0
737.000      DO 530 K = 1,NHORN
738.000 530  PT = PT + HPWR(K)
739.000      ETAS = PWR/PT
740.000      PRINT 540 , ETAS
741.000 540  FORMAT(///,1X,'SPILL-OVER EFFICIENCY =',F7.3,/)
742.000      PT = PT*60.0*WAVE*WAVE
743.000 *
744.000 * COMPUTE GAIN AND PHASE OF CO-POLAR AND X-POLAR COMPONENTS
745.000 *
746.000      ELIN = ELE - ELS
747.000      IF (NEL.GT.1) ELIN = ELIN/FLOAT(NEL - 1)
748.000      AZIN = AZE - AZS
749.000      IF (NAZ.GT.1) AZIN = AZIN/FLOAT(NAZ - 1)
750.000      DO 550 I = 1,NEL
751.000 550  EL(I) = ELE - ELIN*(I-1)
752.000      DO 560 I = 1,NAZ
753.000 560  AZ(I) = AZS + AZIN*(I-1)
754.000      KOUNT = 0
755.000      DO 580 I = 1,NEL
756.000      DO 570 J = 1,NAZ
757.000      KOUNT = KOUNT + 1
758.000      CALL CONV(EL(I),AZ(J),STQ,CTQ,SPQ,CPQ)
759.000      CALL FIELD(STQ,CTQ,SPQ,CPQ,IPOLA,CGNO,XGNO,CPHO)
760.000      CGN(KOUNT) = CGNO
761.000      XGN(KOUNT) = XGNO
762.000      CPH(KOUNT) = CPHO
763.000 570  CONTINUE
764.000 580  CONTINUE
765.000 * OUTPUT FAR FIELD OBSERVATION CUTS.
766.000 *
767.000      PRINT 710
768.000 710  FORMAT(////,50X,'CO-POLAR GAIN IN DB')
769.000      PRINT 720
770.000 720  FORMAT(48X,23(1H-))
771.000      PRINT 730 , (AZ(I),I=1,NAZ)
772.000 730  FORMAT(//,1X,' ELEV *',50X,'AZIMUTH (DEG)',/,1X,'(DEG) *',20F6.2)
773.000      PRINT 735
774.000 735  FORMAT(1X,65(2H *))
775.000      DO 740 I = 1,NEL
776.000      KOUNT = (I-1)*NAZ + 1
777.000      KOUNT1 = KOUNT + NAZ - 1
778.000 740  PRINT 750 , EL(I),(CGN(J),J=KOUNT,KOUNT1)
779.000 750  FORMAT(//,7X,1H*,/,1X,F6.2,1H*,20F6.2,/,7X,1H*)
780.000      PRINT 760
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781.000 760 FORMAT(////,50X,'X-POLAR GAIN IN DB')
782.000 PRINT 720
783.000 PRINT 730 , (AZ(I),I=1,NAZ)
784.000 PRINT 735
785.000 DO 770 I = 1,NEL
786.000 KOUNT = (I-1)*NAZ + 1
787.000 KOUNT1 = KOUNT + NAZ - 1
788.000 770 PRINT 765 , EL(I),(XGN(J),J=KOUNT,KOUNT1)
789.000 765 FORMAT(//,7X,1H*,/,1X,F6.2,1H*,20F6.1//,7X,1H*)
790.000 PRINT 775
791.000 775 FORMAT(////,49X,'CO-POLAR PHASE IN DEG')
792.000 PRINT 720
793.000 PRINT 730 , (AZ(I),I=1,NAZ)
794.000 PRINT 735
795.000 DO 780 I = 1,NEL
796.000 KOUNT = (I-1)*NAZ + 1
797.000 KOUNT1 = KOUNT + NAZ - 1
798.000 780 PRINT 765 , EL(I),(CPH(J),J=KOUNT,KOUNT1)
799.000 * OPEN(7,FILE='GNMAT',STATUS='OLD',USAGE='OUTPUT')
800.000 * WRITE(7,10) (IHEAD(I),I=1,15)
801.000 * WRITE(7,290) AZS,AZE,NAZ,ELS,ELE,NEL
802.000 * DO 790 I = 1,NEL
803.000 * KOUNT = (I-1)*NAZ + 1
804.000 * KOUNT1= KOUNT + NAZ - 1
805.000 *790 WRITE(7,800) (CGN(J),J=KOUNT,KOUNT1)
806.000 *800 FORMAT(11F7.2)
807.000 STOP
808.000 END
809.000 SUBROUTINE RADLIM(CP,SP,A1,B1,A2,B2,RL,RU)
810.000 *
811.000 * COMPUTES LOWER AND UPPER LIMITS OF RADIAL VAR. INTEG. FOR A GIVEN
812.000 * PHI.
813.000 *
814.000 RU = A1*B1/SQRT(A1*A1*SP*SP + B1*B1*CP*CP)
815.000 RL = 0.0
816.000 IF (A2.LT.1.0E-04.OR.B2.LT.1.0E-04) RETURN
817.000 RL = A2*B2/SQRT(A2*A2*SP*SP + B2*B2*CP*CP)
818.000 RETURN
819.000 END
820.000 SUBROUTINE SOURCE(THETAR,SP,CP,ETHETA,EPHI,K)
821.000 *
822.000 * COMPUTES ETHETA AND EPHI COMPONENTS OF FEED RADIATOR
823.000 *
824.000 COMPLEX ETHETA,EPHI,CONSTX,CONSTY,EXT,EXP,EYT,EYP
825.000 COMMON/VAL2/AN(30),HPHASE(30),CX(30),CY(30),PSI(30),IPOLA,ISYMM
826.000 + ,ISAME
827.000 *
828.000 CONSTX = AN(K)*CMPLX(COS(HPHASE(K)),SIN(HPHASE(K)))
829.000 CONSTY = CONSTX*CY(K)*CMPLX(COS(PSI(K)),SIN(PSI(K)))
830.000 CONSTX = CONSTX*CX(K)
831.000 THETA = 3.14159265 - THETAR
832.000 KK = 1
833.000 IF (ISAME.NE.0) KK = K
834.000 IF (IPOLA.LE.2.OR.ISYMM.EQ.0) GO TO 10
835.000 *
836.000 * FEED IS CIRCULARLY POLARISED AND IS SYMMETRIC ABOUT THE PRINCIPAL

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837.000 * PLANES AND NOT ABOUT THE DIAGONAL PLANES.
838.000 *
839.000     CALL PAT(THETA,ETHA,ETHP,EPHA,EPHP,KK,1)
840.000     EXT = ETHA*CMPLX(COS(ETHP),SIN(ETHP))
841.000     EXP = EPHA*CMPLX(COS(EPHP),SIN(EPHP))
842.000     CALL PAT(THETA,ETHA,ETHP,EPHA,EPHP,KK,2)
843.000     EYT = ETHA*CMPLX(COS(ETHP),SIN(ETHP))
844.000     EYP = EPHA*CMPLX(COS(EPHP),SIN(EPHP))
845.000     ETHETA = -CONSTX*EXT*CP + CONSTY*EYT*SP
846.000     EPHI = -CONSTY*EYP*CP - CONSTX*EXP*SP
847.000     RETURN
848.000 *
849.000 * FEED HAS SYMMETRY ABOUT PRINCIPAL AND DIAGONAL PLANES
850.000 *
851.000 10    CALL PAT(THETA,ETHA,ETHP,EPHA,EPHP,KK,1)
852.000     EXT = ETHA*CMPLX(COS(ETHP),SIN(ETHP))
853.000     EXP = EPHA*CMPLX(COS(EPHP),SIN(EPHP))
854.000     ETHETA = -CONSTX*EXT*CP + CONSTY*EXT*SP
855.000     EPHI = -CONSTY*EXP*CP - CONSTX*EXP*SP
856.000     RETURN
857.000     END
858.000     SUBROUTINE PAT(THETA,ETHA,ETHP,EPHA,EPHP,J,IPORT)
859.000 *
860.000 * INTERPOLATES INPUT PATTERN DATA.
861.000 *
862.000     COMMON/PATERN/EPA(46,30,2),EPP(46,30,2),HPA(46,30,2),HPP(46,30,2)
863.000     + ,NPP,PAI
864.000 *
865.000 * STATEMENT FUNCTION DEFINING SECOND ORDER LAGRANGIAN INTERPOLATION.
866.000 *
867.000     FX(X1,X2,X3,Y1,Y2,Y3,X) = Y1*(X-X2)*(X-X3)/((X1-X2)*(X1-X3))
868.000     + Y2*(X-X1)*(X-X3)/((X2-X1)*(X2-X3)) +
869.000     + Y3*(X-X1)*(X-X2)/((X3-X1)*(X3-X2))
870.000 *
871.000     X = THETA
872.000     N = X/PAI
873.000     N1 = N + 1
874.000     IF (N1.EQ.(NPP-1)) N1 = N1 - 1
875.000     IF (N1.GE.NPP) GO TO 10
876.000     X1 = (N1 - 1)*PAI
877.000     X2 = N1*PAI
878.000     X3 = (N1 + 1)*PAI
879.000     N2 = N1 + 1
880.000     N3 = N1 + 2
881.000     Y1 = EPA(N1,J,IPORT)
882.000     Y2 = EPA(N2,J,IPORT)
883.000     Y3 = EPA(N3,J,IPORT)
884.000     ETHA = FX(X1,X2,X3,Y1,Y2,Y3,X)
885.000     Y1 = EPP(N1,J,IPORT)
886.000     Y2 = EPP(N2,J,IPORT)
887.000     Y3 = EPP(N3,J,IPORT)
888.000     ETPH = FX(X1,X2,X3,Y1,Y2,Y3,X)
889.000     Y1 = HPA(N1,J,IPORT)
890.000     Y2 = HPA(N2,J,IPORT)
891.000     Y3 = HPA(N3,J,IPORT)
892.000     EPHA = FX(X1,X2,X3,Y1,Y2,Y3,X)

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893.000      Y1 = HPP(N1,J,IPORT)
894.000      Y2 = HPP(N2,J,IPORT)
895.000      Y3 = HPP(N3,J,IPORT)
896.000      EPHP = FX(X1,X2,X3,Y1,Y2,Y3,X)
897.000      RETURN
898.000 10   PRINT 20
899.000 20   FORMAT(1X,'PATTERN INTERPOLATION IS OUT OF RANGE OF DATA')
900.000      STOP
901.000      END
902.000      SUBROUTINE PWRFED(K,IP,PWR,NPP,PAI)
903.000 *
904.000 * INTEGRATES POYNTING'S VECTOR TO OBTAIN POWER RADIATED BY THE K TH
905.000 * FEED AT PORT IP.
906.000 *
907.000      DIMENSION THL(2),THU(2),POW(2)
908.000      COMMON/VAL1/PI,RAD,RK,ZETA
909.000      COMMON/BLOCK/QX(219),QW(219)
910.000 *
911.000 * RANGE OF THETA-INTEGRATION IS DIVIDED INTO TWO REGIONS. 20-PT
912.000 * GAUSS-LEGENDRE FORMULA IS USED FOR EACH REGION.
913.000 *
914.000 * LOC = LOCATION OF FORMULA
915.000 *
916.000      LOC = 73
917.000      TINC = (NPP - 1)*PAI*0.50
918.000      PWR = 0.0
919.000      DO 20 N = 1,2
920.000      POW(N) = 0.0
921.000      THL(N) = (N-1)*TINC
922.000      THU(N) = THL(N) + TINC
923.000      DO 10 I = 1,20
924.000      THETA = (THL(N) + THU(N))*0.50 + (THU(N) - THL(N))*0.50*QX(I+LOC)
925.000      CALL PAT(THETA,ETHA,ETHP,EPHA,EPHP,K,IP)
926.000      POW(N) = POW(N) + (ETHA**2 + EPHA**2)*SIN(THETA)*QW(I+LOC)
927.000 10   CONTINUE
928.000      PWR = POW(N)*(THU(N) - THL(N)) + PWR
929.000 20   CONTINUE
930.000      PWR = PWR*0.25*PI/ZETA
931.000      RETURN
932.000      END
933.000      SUBROUTINE CONV(EL,AZ,ST,CT,SP,CP)
934.000 *
935.000 * CONVERTS (EL,AZ) TO (THETA,PHI) CO-ORD.
936.000 *
937.000 * ST = SIN(THETA)
938.000 * CT = COS(THETA)
939.000 * SP = SIN(PHI)
940.000 * CP = COS(PHI)
941.000 *
942.000      COMMON/VAL1/PI,RAD,RK,ZETA
943.000 *
944.000      CT = COS(EL/RAD)*COS(AZ/RAD)
945.000      ST = SQRT(1.0 - CT*CT)
946.000      IF (ABS(EL).LT.1.0E-07) GO TO 10
947.000      SP = COS(EL/RAD)*SIN(AZ/RAD)/ST
948.000      CP = SIN(EL/RAD)/ST
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949.000      RETURN
950.000 10   IF(AZ) 20,30,40
951.000 20   SP = -1.0
952.000      CP = 0.0
953.000      RETURN
954.000 30   SP = 0.0
955.000      CP = 1.0
956.000      RETURN
957.000 40   SP = 1.0
958.000      CP = 0.0
959.000      RETURN
960.000      END
961.000      SUBROUTINE FIELD(STQ,CTQ,SPQ,CPQ,IPOLA,CGN,XGN,CPH)
962.000 *
963.000 * COMPUTE FIELD COMPONENTS OF REFLECTOR AT (THETAQ,PHIQ)
964.000 *
965.000      DIMENSION X(2304),Y(2304),Z(2304)
966.000      COMPLEX FTX,FTY,FTZ,RJX(2304),RJY(2304),RJZ(2304)
967.000      COMPLEX EXPN,POL1,POL2,COPOL,XPOL
968.000      COMMON/CURRENT/RJX,RJY,RJZ,X,Y,Z
969.000      COMMON/VAL3/NREG,NQR,NQP,PT,XDQ,YDQ,ZDQ,CPVR,SPVR
970.000      COMMON/VAL1/PI,RAD,RK,ZETA
971.000 *
972.000 * SUM UP CONTRIBUTIONS FROM ALL PANEL CURRENTS.
973.000 *
974.000      FTX = (0.0,0.0)
975.000      FTY = (0.0,0.0)
976.000      FTZ = (0.0,0.0)
977.000      STCP = STQ*CPQ
978.000      STSP = STQ*SPQ
979.000      KOUNT = 0
980.000      DO 30 L = 1,NREG
981.000      DO 20 J = 1,NQP
982.000      DO 10 I = 1,NQR
983.000      KOUNT = KOUNT + 1
984.000      ARG = (X(KOUNT)*STCP + Y(KOUNT)*STSP + Z(KOUNT)*CTQ)*RK
985.000      EXPN = CMPLX(COS(ARG),SIN(ARG))
986.000      FTX = FTX + RJX(KOUNT)*EXPN
987.000      FTY = FTY + RJY(KOUNT)*EXPN
988.000      FTZ = FTZ + RJZ(KOUNT)*EXPN
989.000 10    CONTINUE
990.000 20    CONTINUE
991.000 30    CONTINUE
992.000      POL1 = (1.0 - (1.0 - CTQ)*CPQ*CPQ)*FTX - (1.0 - CTQ)*SPQ*CPQ*FTY
993.000      + - STCP*FTZ
994.000      POL2 = -(1.0 - CTQ)*SPQ*CPQ*FTX + (1.0 - SPQ*SPQ*(1.0 - CTQ))*FTY
995.000      + - STSP*FTZ
996.000 *
997.000 * SHIFT REFERENCE TO FIELD CO-ORDINATE SYSTEM
998.000 *
999.000      ARG = (STCP*XDQ + STSP*YDQ + CTQ*ZDQ)*RK
1000.000     EXPN = CMPLX(COS(ARG),-SIN(ARG))
1001.000     FTX = (POL1*CPVR + POL2*SPVR)*EXPN
1002.000     FTY = (POL2*CPVR - POL1*SPVR)*EXPN
1003.000     GO TO (40,50,60,70), IPOLA
1004.000 40    COPOL = FTX

```

1005.000 XPOL = FTY  
1006.000 GO TO 80  
1007.000 50 COPOL = FTY  
1008.000 XPOL = FTX  
1009.000 GO TO 80  
1010.000 60 COPOL = 0.70710678\*(FTX + CMPLX(0.0,1.0)\*FTY)  
1011.000 XPOL = 0.70710678\*(FTX - CMPLX(0.0,1.0)\*FTY)  
1012.000 GO TO 80  
1013.000 70 COPOL = 0.70710678\*(FTX - CMPLX(0.0,1.0)\*FTY)  
1014.000 XPOL = 0.70710678\*(FTX + CMPLX(0.0,1.0)\*FTY)  
1015.000 80 CGN = 10.0\*ALOG10(CABS(COPOL)\*\*2/PT)  
1016.000 XGN = 10.0\*ALOG10(CABS(XPOL)\*\*2/PT)  
1017.000 CPH = ATAN2(AIMAG(COPOL),REAL(COPOL))\*RAD  
1018.000 RETURN  
1019.000 END  
1020.000 SUBROUTINE QRLOC(NQ,LOC)  
1021.000 \*  
1022.000 \* PURPOSE - DETERMINE LOCATION OF INTEGRATION FORMULA IN BLOCK DATA  
1023.000 \* BLOCK DATA IS ASSUMED TO CONTAIN THE FOLLOWING FORMULAE.  
1024.000 \* 3,4,6,8,10,14,16,20,24,28,34,40 PTS.  
1025.000 \*  
1026.000 IF (NQ = 34) 10,170,180  
1027.000 10 IF (NQ = 24) 20,150,160  
1028.000 20 IF (NQ = 16) 30,130,140  
1029.000 30 IF (NQ = 12) 40,110,120  
1030.000 40 IF (NQ = 8) 50,90,100  
1031.000 50 IF (NQ = 4) 60,70,80  
1032.000 60 LOC = 0  
1033.000 RETURN  
1034.000 70 LOC = 3  
1035.000 RETURN  
1036.000 80 LOC = 7  
1037.000 RETURN  
1038.000 90 LOC = 13  
1039.000 RETURN  
1040.000 100 LOC = 21  
1041.000 RETURN  
1042.000 110 LOC = 31  
1043.000 RETURN  
1044.000 120 LOC = 43  
1045.000 RETURN  
1046.000 130 LOC = 57  
1047.000 RETURN  
1048.000 140 LOC = 73  
1049.000 RETURN  
1050.000 150 LOC = 93  
1051.000 RETURN  
1052.000 160 LOC = 117  
1053.000 RETURN  
1054.000 170 LOC = 145  
1055.000 RETURN  
1056.000 180 LOC = 179  
1057.000 RETURN  
1058.000 END  
1059.000 BLOCK DATA  
1060.000 COMMON/BLOCK/QX(219),QW(219)

1061.000 \* 3 PTS.  
 1062.000 DATA (QX(I),I=1,3)/-,774596669241,0.0000000,+.774596669241/  
 1063.000 DATA (QW(I),I=1,3)/,.5555555555,,888888888888,,555555555555/  
 1064.000 \* 4 PTS.  
 1065.000 DATA (QX(I),I=4,7)/-,861136311594,-,3399810435848,.3399810435848,  
 1066.000 +.861136311594/  
 1067.000 DATA (QW(I),I=4,7)/.347854845137,.652145154862,.652145154862,  
 1068.000 +.347854845137/  
 1069.000 \* 6 PTS.  
 1070.000 DATA (QX(I),I=8,13)/.93246951420315,.66120938646626,  
 1071.000 +.23861918608319,  
 1072.000 +-,.23861918608319,-.66120938646626,-.93246951420315/  
 1073.000 DATA (QW(I),I=8,13)/.17132449237917,.36076157304814,  
 1074.000 +.46791393457269,  
 1075.000 +.46791393457269,.36076157304814,.17132449237917/  
 1076.000 \* 8 PTS.  
 1077.000 DATA (QX(I),I=14,21)/-,9602898564,-,7966664774,-,5255324099,  
 1078.000 +-,.1834346424,.1834346424,.5255324099,.7966664774,.9602898564/  
 1079.000 DATA (QW(I),I=14,21)/.1012285362,.2223810344,.3137066458,  
 1080.000 +.3626837833,.3626837833,.3137066458,.2223810344,.1012285362/  
 1081.000 \* 10 PTS.  
 1082.000 DATA (QX(I),I=22,31)/-,9739065285,-.8650633666,-.6794095682,  
 1083.000 +-,.4333953941,-.1488743389,  
 1084.000 +.1488743389,.4333953941,.6794095682,.8650633666,.9739065285/  
 1085.000 DATA (QW(I),I=22,31)/.0666713443,.1494513491,.2190863625,  
 1086.000 +.2692667193,.2955242247,  
 1087.000 +.2955242247,.2692667193,.2190863625,.1494513491,.0666713443/  
 1088.000 \* 12 PTS.  
 1089.000 DATA (QX(I),I=32,43)/-,981560634246,-.90411725637,-.769902674194,  
 1090.000 +-,.587317954286,-.367831498998,-.125233408511,.125233408511,  
 1091.000 +.367831498998,.587317954286,.769902674194,.904117256370,  
 1092.000 +.981560634246/  
 1093.000 DATA (QW(I),I=32,43)/.047175336386,.106939325995,.160078328543,  
 1094.000 +.203167426723,.233492536538,.249147045813,.249147045813,  
 1095.000 +.233492536538,.203167426723,.160078328543,.106939325995,  
 1096.000 +.047175336386/  
 1097.000 \* 14 PTS.  
 1098.000 DATA (QX(I),I=44,57)/-,986283808696,-.928434883663,-.82720131507,  
 1099.000 +-,.687292904811,-.515248636358,-.319112368927,-.108054948707,  
 1100.000 +.108054948707,.319112368927,.515248636358,.687292904811,  
 1101.000 +.827201315069,.928434883663,.986283808696/  
 1102.000 DATA (QW(I),I=44,57)/.035119460331,.080158087159,.121518570687,  
 1103.000 +.157203167158,.185538397477,.205198463721,.215263853463,  
 1104.000 +.215263853463,.205198463721,.185538397477,.157203167158,  
 1105.000 +.121518570687,.080158087159,.035119460331/  
 1106.000 \* 16 PTS.  
 1107.000 DATA (QX(I),I=58,73)/-,989400934991,-.944575023073,-.865631202388,  
 1108.000 +-,.755404408355,-.617876244403,-.458016777657,-.281603550779,  
 1109.000 +-,.095012509837,.095012509837,.281603550779,.458016777657,  
 1110.000 +.617876244403,.755404408355,.865631202387,.944575023073,  
 1111.000 +.989400934992/  
 1112.000 DATA (QW(I),I=58,73)/.027152459412,.062253523938,.095158511682,  
 1113.000 +.124628971255,.149595988816,.169156519395,.182603415045,  
 1114.000 +.189450610455,.189450610455,.182603415045,.169156519395,  
 1115.000 +.149595988816,.124628971255,.095158511682,.062253523938,  
 1116.000 +.0271524594117/

1117.000 \* 20 PTS.

1118.000 DATA (QX(I),I=74,93)/-.9931285991,-.9639719272,-.9122344282,  
 1119.000 +-,.8391169718,  
 1120.000 +-,.7463319064,-.6360536807,-.5108670019,-.3737060887,-.2277958511,  
 1121.000 +-,.07652652113,.07652652113,.2277858511,.3737060887,.5108670019,  
 1122.000 +-,.6360536807,  
 1123.000 +-,.7463319064,.8391169718,.9122344282,.9639719272,.9931285991/  
 1124.000 DATA (QW(I),I=74,93)/.01761400713,.04060142980,.06267204833,  
 1125.000 +-,.08327674157,  
 1126.000 +-,.1019301198,.1181945319,.1316886384,.1420961093,.1491729864,  
 1127.000 +-,.1527533871,  
 1128.000 +-,.1527533871,.1491729864,.1420961093,.1316886384,.1181945319,  
 1129.000 +-,.1019301198,  
 1130.000 +-,.08327674157,.06267204833,.04060142980,.01761400713/

1131.000 \* 24 PTS.

1132.000 DATA (QX(I),I=94,117)/-.9951872199,-.9747285559,-.9382745520,  
 1133.000 +-,.8864155270,-.8200019859,-.7401241915,-.6480936519,  
 1134.000 +-,.5454214713,-.4337935076,-.3150426796,-.1911188674,  
 1135.000 +-,.06405689286,.06405689286,.1911188674,.3150426796,.4337935076,  
 1136.000 +-,.5454214713,.6480936519,.7401241915,.8200019859,.8864155270,  
 1137.000 +-,.9382745520,.9747285559,.9951872199/  
 1138.000 DATA (QW(I),I=94,117)/.01234122979,.02853138862,.04427743881,  
 1139.000 +-,.05929858491,.07334648141,.08619016153,.09761865210,.1074442701,  
 1140.000 +-,.1155056680,.1216704729,.1258374563,.1279381953,.1279381953,  
 1141.000 +-,.1258374563,.1216704729,.1155056680,.1074442701,.0976186521,  
 1142.000 +-,.08619016153,.07334648141,.05929858491,.04427743881,  
 1143.000 +-,.02853138862,.01234122979/

1144.000 \* 28 PTS.

1145.000 DATA (QX(I),I=118,145)/-.9964424975,-.9813031653,-.9542592806,  
 1146.000 +-,.9156330263,-.8658925225,-.8056413709,-.7356108780,  
 1147.000 +-,.6566510940,-.5697204718,-.4758742249,-.3762515160,  
 1148.000 +-,.2720616276,-.1645692821,-.05507928988,.05507928988,  
 1149.000 +-,.1445692821,.2720616276,.3762515160,.4758742249,.5697204718,  
 1150.000 +-,.6566510940,.7356108780,.8056413709,.8658925225,.9156330263,  
 1151.000 +-,.9542592806,.9813031653,.9964424975/  
 1152.000 DATA (QW(I),I=118,145)/.009124282593,.02113211259,.03290142778,  
 1153.000 +-,.04427293475,.05510734567,.06527292396,.07464621423,  
 1154.000 +-,.08311341722,.09057174439,.09693065799,.1021129675,.1060557659,  
 1155.000 +-,.1087111922,.1100470130,.1100470130,.1087111922,.1060557659,  
 1156.000 +-,.1021129675,.09693065799,.09057174439,.08311341722,.07464621423,  
 1157.000 +-,.06527292396,.05510734567,.04427293475,.03290142778,  
 1158.000 +-,.02113211259,.009124282593/

1159.000 \* 34 PTS.

1160.000 DATA (QX(I),I=146,179)/-.9975717537,-.9872278164,-.9687082625,  
 1161.000 +-,.9421623974,-.9078096777,-.8659346383,-.8168842279,  
 1162.000 +-,.7610648766,-.6989391132,-.6310217270,-.5578755006,  
 1163.000 +-,.4801065451,-.3983592777,-.3133110813,-.2256666916,  
 1164.000 +-,.1361523572,-.04550982195,.04550982195,.1361523572,  
 1165.000 +-,.2256666916,.3133110813,.3983592777,.4801065451,.5578755006,  
 1166.000 +-,.6310217270,.6989391132,.7610648766,.8168842279,.8659346383,  
 1167.000 +-,.9078096777,.9421623974,.9687082625,.9872278164,.9975717537/  
 1168.000 DATA (QW(I),I=146,179)/.006229140555,.01445016274,.02256372198,  
 1169.000 +-,.03049138063,.03816659379,.04552561152,.05250741457,.05905413582,  
 1170.000 +-,.06511152155,.07062937581,.07556198466,.07986844433,.08351309969,  
 1171.000 +-,.08646573974,.08870189783,.09020304437,.09095674033,.09095674033,  
 1172.000 +-,.09020304437,.08870189783,.08646573974,.08351309969,.07986844433,

1173.000       +.07556197466,.07062937581,.06511152155,.05905413582,.05250741457,  
1174.000       +.04552561152,.03816659379,.03049138063,.02256372198,.01445016274,  
1175.000       +.006229140555/  
1176.000 \* 40 PTS.  
1177.000       DATA (QX(I),I=180,219)/-.9982377097,-.9907262386,-.9772599499,  
1178.000       +-,9579168192,-,9328128082,-,9020988069,-,8659595032,-,8246122308,  
1179.000       +-,7783056514,-,7273182551,-,6719566846,-,6125538896,-,549467125,  
1180.000       +-,4830758016,-,4137792043,-,3419940908,-,268152185,-,1926975807,  
1181.000       +-,1160840706,-,0387724175,.0387724175,.1160840706,.1926975807,  
1182.000       +,268152185,.3419940908,.4137792043,.4830758016,.549467125,  
1183.000       +,6125538896,.6719566846,.7273182551,.7783056514,.8246122308,  
1184.000       +,8659595032,.9020988069,.9328128082,.9579168192,.9772599499,  
1185.000       +,9907262386,.9982377097/  
1186.000       DATA (QW(I),I=180,219)/.00452127709,.0104982845,.0164210583,  
1187.000       +.0222458491,.0279370069,.0334601952,.0387821679,.0438709081,  
1188.000       +.0486958076,.0532278469,.0574397690,.0613062424,.0648040134,  
1189.000       +.0679120458,.0706116473,.0728865823,.0747231690,.0761103619,  
1190.000       +.0770398181,.0775059479,.0775059479,.0770398181,.0761103619,  
1191.000       +.0747231690,.0728865823,.0706116473,.0679120458,.0648040134,  
1192.000       +.0613062424,.0574397690,.0532278469,.0486958076,.0438709081,  
1193.000       +.0387821679,.0334601952,.0279370069,.0222458491,.0164210583,  
1194.000       +.0104982845,.00452127709/  
1195.000       END  
\* EOF hit after 1195.000  
\*

B.3 EXAMPLE OF INPUT DATA FILE PAREFM.DAT

1.000 ARABSAT , RECEIVE BEAM  
2.000 6.175  
3.000 6  
4.000 0  
5.000 1.970 -2.036 0.0 .840 -.10 0.0 -.175 -2.698 0.0 -1.357 -.780 0.0  
6.000 -1.180 1.453 0.0 .220 3.250 0.0  
7.000 0.0 -48.0 0.0  
8.000 4  
9.000 0  
10.000 29.4.0  
11.000 0  
12.000 0.0 0.0 -.07 0.0 -.27 0.0 -.550 0.0 -.95 0.0 -1.55 0.0 -2.20 0.0  
13.000 -3.0 0.0 -3.9 0.0 -5.3 0.0 -6.6 0.0 -8.0 0.0 -9.75 0.0 -11.75 0.0  
14.000 -13.7 0.0 -15.3 0.0 -17.1 0.0 -18.8 0.0 -20.5 0.0 -21.8 0.0 -23.1 0.0  
15.000 -24.2 0.0 -25.2 0.0 -26.0 0.0 -26.6 0.0 -27.4 0.0 -27.8 0.0 -28.2 0.0  
16.000 -28.6 0.0  
17.000 0.0 0.0 -.06 0.0 -.24 0.0 -.46 0.0 -.88 0.0 -1.45 0.0 -2.1 0.0  
18.000 -2.8 0.0 -3.7 0.0 -4.9 0.0 -6.0 0.0 -7.3 0.0 -8.4 0.0 -9.7 0.0  
19.000 -11.0 0.0 -12.25 0.0 -13.75 0.0 -15.4 0.0 -16.8 0.0 -18.2 0.0 -19.8 0.0  
20.000 -21.3 0.0 -24.0 0.0 -25.4 0.0 -27.0 0.0 -29.0 0.0 -31.5 0.0 -33.5 0.0  
21.000 -35.5 0.0  
22.000 1.0 1.0 1.0 1.0 1.0 1.0  
23.000 0.0 0.0 0.0 0.0 0.0 0.0  
24.000 .13 -20.0 .18 -10.0 .20 0.0 .16 0.0 .17 60.0 .16 80.0  
25.000 27.0 40.0 35.0 25.5 0.0  
26.000 0  
27.000 0  
28.000 -6.0 +6.0 13 -4.0 3.0 8  
29.000 0.0 0.0 0.0  
30.000 0.0

B.4 SAMPLE OUTPUT

ARABSAT , RECEIVE BEAM

FREQUENCY IN GHZ

6.1750

NO OF FEED RADIATORS

6

OPT. CHOSEN - COLLECTIVE MOVEMENT AND ROTATION OF FEED ARRAY

0

DISPLACEMENTS OF FEEDS IN INS.

1.9700	-2.0360	.0000	.8400	-.1000	.0000	-.1750	-2.6980	.0000	-1.3570	-.7800	.0000
-1.1800	1.4530	.0000	.2200	3.2500	.0000						

ROT. OF FEEDS ABOUT X-,Y-,AND Z-AXIS IN DEG.

.0000 -48.0000 .0000

POLAR. OF SECON. BEAM - VP=1,HP=2,RHCP=3,LHCP=4

4

FEED SYMMETRY - PRINCIPAL + DIAG. PLANES = 0 , PRINCIPAL PLANES ONLY = 1

0

NO. OF PTS. DESCRIPT. PATTERNS AND ANGULAR INCREMENT OF POINTS

29 4.00

PORT 1 E-PLANE AMPL(DB) AND PHASE(DEG) PATTERNS FOR FEED NO. 1

.0000	.0000	-.0700	.0000	-.2700	.0000	-.5500	.0000	-.9500	.0000	-1.5500	.0000
-2.2000	.0000	-3.0000	.0000	-3.9000	.0000	-5.3000	.0000	-6.6000	.0000	-8.0000	.0000
-9.7500	.0000	-11.7500	.0000	-13.7000	.0000	-15.3000	.0000	-17.1000	.0000	-18.8000	.0000
-20.5000	.0000	-21.8000	.0000	-23.1000	.0000	-24.2000	.0000	-25.2000	.0000	-26.0000	.0000
-26.6000	.0000	-27.4000	.0000	-27.8000	.0000	-28.2000	.0000	-28.6000	.0000		

PORT 1 H-PLANE AMPL(DB) AND PHASE(DEG) PATTERNS FOR FEED NO. 1

.0000	.0000	-.0600	.0000	-.2400	.0000	-.4600	.0000	-.8800	.0000	-1.4500	.0000
-2.1000	.0000	-2.8000	.0000	-3.7000	.0000	-4.9000	.0000	-6.0000	.0000	-7.3000	.0000
-8.4000	.0000	-9.7000	.0000	-11.0000	.0000	-12.2500	.0000	-13.7500	.0000	-15.4000	.0000
-16.8000	.0000	-18.2000	.0000	-19.8000	.0000	-21.3000	.0000	-24.0000	.0000	-25.4000	.0000
-27.0000	.0000	-29.0000	.0000	-31.5000	.0000	-33.5000	.0000	-35.5000	.0000		

AMPL IMBALANCE OF Y-PORT REL. TO X-PORT

1.0000 1.0000 1.0000 1.0000 1.0000

PHASE DEPARTURE OF Y-PORT FROM QUADRATURE IN DEG.

.0000 .0000 .0000 .0000 .0000

POWER(W) AND PHASE(DEG) OF FEED EXCITATIONS

.1300 -20.0000 .1800 -10.0000 .2000 .0000 .1600 .0000 .1700 60.0000 .1600 80.0000

FOC LTH.,APER, X-DIM,Y-DIM AND X-, Y-OFFSET IN INS.

27.0000 40.0000 35.0000 25.5000 .0000

START,STOP AND NO. OF PTS. FOR AZ,EL SCAN

-6.00000 6.00000 13 -4.00000 3.00000 8

X-,Y-,Z-TRANSLATION OF FIELD CO-ORD. SYSTEM IN INS

.0000 .0000 .0000

ROTATION OF FIELD POLARISATION VECTOR IN DEGREES

.0000

INTEG. PTS. SELECTED FOR RADIAL AND PHI-VAR.

8 8

SPILL-OVER EFFICIENCY = .646

## CO-POLAR GAIN IN DE

ELEVEN \*

AZIMUTH (DEG)

(DEG) \* -6,00 -5,00 -4,00 -3,00 -2,00 -1,00 ,00 1,00 2,00 3,00 4,00 5,00 6,00

本

3,00\* 12,14 17,44 21,00 22,78 23,31 23,19 23,07 23,17 23,08 22,37 20,74 18,07 14,38

4

2.00\* 19.08 22.73 24.84 25.65 25.52 25.08 25.08 25.55 25.88 25.58 24.42 22.28 19.09

三

1.00\* 22.77 25.25 26.39 26.41 25.68 25.09 25.53 26.60 27.36 27.36 26.45 24.51 21.44

2

.00\* 23.87 25.54 25.88 25.09 23.79 23.57 25.06 26.80 27.89 28.07 27.23 25.27 22.00

2

-1.00\* 22.67 23.70 23.20 21.49 20.16 21.70 24.41 26.53 27.73 27.95 27.08 24.94 21.21

-2.000\* 19.01 19.35 17.80 15.38 16.69 20.40 23.42 25.58 26.85 27.10 26.18 23.83 19.53

本

-3.00\* 12.28 11.27 7.58 8.30 13.81 17.75 20.86 23.33 24.91 25.38 24.55 22.14 17.45

2

-4.00\* 3.78 -1.89 -9.12 1.68 5.93 10.21 15.09 18.98 21.44 22.46 21.99 19.74 14.97

X-POLAR GAIN IN DI

ELEV. \*

AZIMUTH (DEG)

(DEG) \* -6.00 -5.00 -4.00 -3.00 -2.00 -1.00 .00 1.00 2.00 3.00 4.00 5.00 6.00

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3.00\* -21.3 -20.6 -22.6 -27.1 -32.1 -27.3 -22.4 -20.3 -20.5 -23.5 -29.9 -31.7 -28.6

三

2.00% -15.7 -16.6 -20.2 -26.3 -37.2 -31.8 -23.2 -20.4 -21.1 -25.3 -35.7 -34.2 -29.1

\*  
 1.00\* -14.5 -16.5 -20.3 -23.2 -26.4 -38.8 -26.6 -23.0 -24.1 -27.8 -30.5 -35.8 -34.5  
 \*  
 .00\* -17.4 -20.1 -21.3 -21.1 -24.0 -35.7 -31.9 -29.6 -29.5 -25.1 -24.3 -28.9 -39.3  
 \*  
 -1.00\* -23.4 -21.6 -19.6 -20.8 -26.8 -32.0 -28.2 -34.6 -29.9 -24.0 -24.3 -30.1 -32.1  
 \*  
 -2.00\* -20.0 -17.7 -17.8 -21.3 -33.5 -30.5 -27.1 -28.4 -25.9 -25.2 -29.7 -31.0 -26.5  
 \*  
 -3.00\* -19.0 -17.8 -18.8 -22.9 -32.1 -37.2 -30.7 -25.6 -24.2 -27.9 -29.5 -23.3 -22.6  
 \*  
 -4.00\* -21.7 -21.8 -24.0 -28.6 -35.9 -32.6 -24.4 -21.2 -21.8 -25.1 -22.7 -20.2 -21.6

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#### CO-POLAR PHASE IN DEG

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ELEV *	AZIMUTH (DEG)												
(DEG)	-6.00	-5.00	-4.00	-3.00	-2.00	-1.00	.00	1.00	2.00	3.00	4.00	5.00	6.00
*	*	*	*	*	*	*	*	*	*	*	*	*	*
3.00*	165.2	142.1	139.0	143.4	152.8	166.7	177.1	163.1	154.1	149.4	146.6	142.8	133.6
*	*	*	*	*	*	*	*	*	*	*	*	*	*
2.00*	138.9	144.7	143.5	137.8	127.5	112.3	95.0	81.4	73.7	70.4	69.1	67.7	64.2
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1.00*	64.6	65.2	62.2	55.5	43.5	25.3	6.4	-5.9	-11.3	-12.8	-12.6	-12.3	-12.8
*	*	*	*	*	*	*	*	*	*	*	*	*	*
.00*	-13.2	-15.8	-20.8	-29.8	-46.4	-70.1	-88.8	-97.1	-99.0	-98.2	-96.5	-94.8	-93.2
*	*	*	*	*	*	*	*	*	*	*	*	*	*
-1.00*	-90.4	-96.5	-104.9	-119.9	-147.6	-175.3	173.1	171.4	173.2	175.9	178.5	179.1	-176.6
*	*	*	*	*	*	*	*	*	*	*	*	*	*
-2.00*	-164.0	-175.1	169.4	138.3	97.4	81.1	80.3	84.1	88.2	91.5	93.9	95.7	97.5
*	*	*	*	*	*	*	*	*	*	*	*	*	*
-3.00*	133.7	113.9	79.4	13.2	-10.4	-9.5	-2.4	4.1	8.1	10.2	11.1	11.5	11.3
*	*	*	*	*	*	*	*	*	*	*	*	*	*
-4.00*	109.7	101.3	-153.7	-121.6	-105.2	-82.8	-69.6	-65.8	-66.0	-67.3	-68.5	-69.2	-69.9
*STOP*													

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APPENDIX CC.1 Description of Computer Program PAREFL\_SIF

IDENTIFICATION: PAREFL\_SIF

PURPOSE:

The program calculates the field radiated by a parabolic reflector antenna with projected elliptical aperture using the method of physical optics. Only linearly polarised feeds are permitted. A choice of pyramidal horns or a variety of specialised horns is available.

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Kirkland, Quebec,  
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Tel: (514) 697 -6419

DESCRIPTION:

The geometry of the reflector system analysed here is the same as that treated by program PAREFC\_SIF. Only linearly polarized feeds may be specified. There is a choice between ordinary pyramidal, E-plane dielectric loaded, E-plane corrugated, dielectric loaded plus corrugated, dielectric loaded trifurcated, and trifurcated only horns. These horns are not suitable for circular polarization. Aperture loading is used either to increase aperture efficiency in a particular plane or reduce side-lobes. Computed gains using linearly polarised rectangular pyramidal

feed horns from this program differ slightly from the results calculated by PAREFC\_SIF. This difference ranges from nil for large horns  $> 3.0 \lambda$  to  $\sim .25$  dB for small horns  $< 1 \lambda$ . It is due to the two different methods of calculating power radiated by the horns. Further, the Chu model is used to calculate the horn patterns. Mixture of horn types is permitted.

USAGE (INPUT):

Input data required by the program are to be provided in a file named PAREFL\_DAT. Data may be written in free format and must follow the sequence as given in the program listing. Input variables are defined in the input section of the listing. Additional comments on the same variables as used in programs PAREFC\_SIF and PAREFM\_SIF can be found in their respective usage sections of Appendix A and B.

OUTPUT: Same as for PAREFC\_SIF.

CODING INFORMATION: Honeywell CP-6 FORTRAN 77.

RESTRICTIONS:

The restriction on the antenna configuration that may be analysed is solely due to array dimensions. In order to minimise the demand on computer resources, the arrays have been dimensioned to cover many of the cases usually encountered. In situations where the number of feeds required or the number of integration points needed or the field of view exceeded those envisaged, the relevant arrays must be changed according to the following prescriptions.

To Increase the Number of Horn Feeds

The program has been set to allow a maximum of 25 feeds. To increase the allowable number, dimension changes to affected arrays have to be made.

MAIN PROGRAM:

- (i) Change the declarations of the following arrays to the value of NHORN - A, B, WGA, WGB, HRNLTH, DX, DY, DZ, GAMMA, BETA, ALPHA, ITYPE, HPWR, HPHASE, HMAG, HFL, EFL, W11, W12, W13, W21, W22, W23, W31, W32, W33.
- (ii) Change the value of MAXHRN in the data statement to the value of NHORN.

SUBROUTINE RECAP:

- (i) Change the dimensions of the following arrays to the value of NHORN -  
A, B, HMAG, HPHASE, HLT, ELT, ITYPE, LQH, NQH.
- (ii) Change the second dimensions of the following arrays to the value of NHORN - HAP, EAP, AP1, AP2, AP3, AP4. The last four arrays, AP1, AP2, AP3, and AP4, need be modified only if there are more than 25 dielectric loaded trifurcated or trifurcated only horns. The first two arrays, HAP and EAP, need be modified only if there are more than 25 of the rest of the horn types.

SUBROUTINE APINT:      Same as for SUBROUTINE RECAP.

To Increase Array Sizes to Accommodate Larger Number of Integration Pts.

The maximum number of integration points allowable in the radial or phi-direction is given by MAXQ. At present the value of MAXQ. is 24.

MAIN PROGRAM:

- (i)      Change the value of MAXQ in the data statement to reflect the new value.
- (ii)     Change the first dimension of arrays RDL and RDU to the value of MAXQ.
- (iii)    Change the dimensions of the following arrays to  $4 * \text{MAXQ} * \text{MAXQ}$  -  
XG, YG, ZG, RJX, RJY, RJZ.

SUBROUTINE FIELD:

- (i)      Change the dimensions of the following arrays to  $4 * \text{MAXQ} * \text{MAXQ}$  -  
X, Y, Z, RJX, RJY, RJZ.

To Increase Frame of Observation

The field of observation is defined by a rectangular grid of elevation and azimuth cuts. The number of grid points in the elevation direction is given by NEL and its maximum is set by MAXEL. Similarly, the number of grid points in the azimuth direction is given by NAZ and its maximum is set by MAXAZ.

At present, the values of MAXEL and MAXAZ are 41 and 41.

MAIN PROGRAM:

- (i) Change the values of MAXEL and MAXAZ in the data statement.
- (ii) Change the dimensions of arrays EL and AZ to MAXEL and MAXAZ respectively.
- (iii) Change the dimensions of arrays CGN, CPH and XGN to the value given by MAXEL\*MAXAZ.

## C.2 PROGRAM LISTING

```

1.000      PROGRAM PAREFL
2.000 *
3.000 * PHYSICAL OPTICS ANALYSIS OF A SOLID REFLECTOR FED BY A MULTIHORN ARRAY.
4.000 * THE REFLECTOR HAS AN ELLIPTICAL APERTURE AND IS OFF-SET IN THE
5.000 * X- AND Y- DIRECTION. FAR FIELD CO-POLARISED AND CROSS-POLARISED
6.000 * GAIN MATRICES ARE COMPUTED OVER A RECTANGULAR ELEVATION - AZIMUTH
7.000 * GRID.
8.000 * MAIN FEATURES OF THE PROGRAM ARE THE FOLLOWING -
9.000 * MULTIPLE FEED HORN CAPABILITY.
10.000 * MODELING OF FEED HORN WITH QUADRATIC APERTURE PHASE ERROR.
11.000 * CHOICE OF DIFFERENT HORN TYPES.
12.000 * X- AND Y- OFFSET OF REFLECTOR.
13.000 * MODELING OF APERTURE BLOCKAGE BY FEED AND STRUTS.
14.000 * AUTOMATIC SELECTION OF INTEGRATION LIMITS AND FORMULAS.
15.000 * ROTATABLE LINEAR POLARISATION.
16.000 *
17.000 * WRITTEN BY K. K. CHAN , CHAN TECHNOLOGIES INC. , FEB 1984
18.000 *
19.000      CHARACTER*4 IHEAD(15)
20.000      DIMENSION A(25),B(25),HRNLTH(25),WGB(25),WGA(25),ALPHA(25)
21.000      DIMENSION DX(25),DY(25),DZ(25),GAMMA(25),BETA(25),ITYPE(25)
22.000      DIMENSION HPWR(25),HPHASE(25),HMAG(25),HFL(25),EFL(25)
23.000      DIMENSION W11(25),W12(25),W13(25),W21(25),W22(25),W23(25)
24.000      DIMENSION W31(25),W32(25),W33(25)
25.000      DIMENSION PHL(4),PHU(4),RDL(24,4),RDU(24,4)
26.000      DIMENSION XG(2304),YG(2304),ZG(2304)
27.000      DIMENSION CGN(1681),CPH(1681),XGN(1681),EL(41),AZ(41)
28.000      COMPLEX EX,EY,EZ,EXPX,ETHETA,EPHI,FTX,FTY,FTZ,HX,HY,HZ
29.000      COMPLEX RJX(2304),RJY(2304),RJZ(2304)
30.000      INTEGER OPTB,OPTH,OPTQ
31.000      COMMON/VAL1/WAVE,PI,RAD,RK
32.000      COMMON/VAL2/A,B,HMAG,HPHASE,HFL,EFL,ITYPE,IPOLA
33.000      COMMON/BLOCK/QX(219),QW(219)
34.000      COMMON/CURENT/RJX,RJY,RJZ,XG,YG,ZG
35.000      COMMON/VAL3/NREG,NQR,NQP,PT,XDQ,YDQ,ZDQ,CPVR,BPVR
36.000      DATA PI,RAD,ZETA/3.14159265,57.2957795,376.99111/
37.000 *
38.000 * THE FOLLOWING ARE PRESET LIMITS CONSISTENT WITH PRESENT ARRAY
39.000 * DIMENSIONING.
40.000 *
41.000 * MAXQ - MAX. NO. OF INTEGRATION PTS. PERMITTED.
42.000 * MAXHRN - MAX. NO. OF HORNS PERMITTED.
43.000 * MAXEL - MAX. NO. OF EL GRID PTS.
44.000 * MAXAZ - MAX. NO. OF AZ GRID PTS.
45.000 *
46.000      DATA MAXQ,MAXHRN,MAXEL,MAXAZ/24,25,41,41/
47.000 *
48.000 * START OF DATA INPUT
49.000 *
50.000      OPEN(UNIT=5,NAME='PAREFL.DAT',STATUS='OLD',USAGE='INPUT')
51.000 *
52.000 * IHEAD - HEADING FOR COMPUTER RUN. MAX. OF 60 CHARACTERS.
53.000 *

```

```
54.000      READ(5,10) (IHEAD(I),I=1,15)
55.000 10   FORMAT(15A4)
56.000 *
57.000 * DATA DESCRIBING FEED HORNS
58.000 *
59.000 * FREQ - FREQUENCY IN GHZ
60.000 *
61.000      READ(5,*) FREQ
62.000 *
63.000 * NHORN - NO. OF FEED HORNS.
64.000 *
65.000      READ(5,*) NHORN
66.000      IF (NHORN.LE.MAXHRN) GO TO 14
67.000      PRINT 12 , MAXHRN
68.000 12   FORMAT(1X,'STOP. NO. OF HORNS EXCEEDED LIMIT OF ',I2)
69.000      STOP
70.000 14   CONTINUE
71.000 *
72.000 * B - E-PLANE DIMENSION OF HORN APERTURES IN INCHES
73.000 *
74.000      READ(5,*) (B(I),I=1,NHORN)
75.000 *
76.000 * A - H-PLANE DIMENSION OF APERTURES IN INCHES
77.000 *
78.000      READ(5,*) (A(I),I=1,NHORN)
79.000 *
80.000 * WGB - E-PLANE DIMENSION OF INPUT FEED GUIDE IN INCHES
81.000 *
82.000      READ(5,*) (WGB(I),I=1,NHORN)
83.000 *
84.000 * WGA - H-PLANE DIMENSION OF INPUT FEED GUIDE IN INCHES
85.000 *
86.000      READ(5,*) (WGA(I),I=1,NHORN)
87.000 *
88.000 * HRNLTH - AXIAL HORN LENGTH IN INCHES
89.000 *
90.000      READ(5,*) (HRNLTH(I),I=1,NHORN)
91.000 *
92.000 * OPTH - OPTION IN SPECIFYING HORN POSITIONS AND ROTATIONS.
93.000 *      = 0, HORN POSITIONS ARE SPECIFIED BEFORE ROTATION. THE WHOLE
94.000 *      FEED ARRAY IS ROTATED ABOUT THE GLOBAL X-AXIS BY ANGLE
95.000 *      ALPHA FOLLOWED BY ROTATION ABOUT THE NEW Y-AXIS BY ANGLE
96.000 *      BETA. FINALLY EACH HORN IS ROTATED ABOUT ITS OWN LOCAL Z-
97.000 *      AXIS BY ANGLE GAMMA. THIS OPTION ALLOWS FOR THE COLLECTIVE
98.000 *      MOVEMENT OF THE ARRAY. ONLY THREE VALUES NEED TO BE SPECI-
99.000 *      FIED FOR THE ROTATIONS.
100.000 *     = 1, HORN DISPLACEMENTS SPECIFIED ARE THE FINAL POSITIONS. THE
101.000 *     ROTATIONS TO FOLLOW ARE ABOUT THE INDIVIDUAL HORN LOCAL
102.000 *     X, Y AND Z-AXES. THIS OPTION ALLOWS FOR INDEPENDENT ROTATION
103.000 *     AND POSITIONING OF THE HORNS. THREE ROTATION ANGLES MUST BE
104.000 *     ENTERED FOR EACH FORN.
105.000 *
106.000      READ(5,*) OPTH
107.000 *
108.000 * DISPLACEMENTS OF FEED HORN IN INCHES FROM FOCAL POINT
```

```
109.000 *
110.000      READ(5,*) (DX(I),DY(I),DZ(I),I=1,NHORN)
111.000 *
112.000 * ALPHA - ROTATION ABOUT EITHER THE GLOBAL OR LOCAL X-AXIS IN DEG.
113.000 * BETA - ROTATION ABOUT EITHER THE GLOBAL OR LOCAL Y-AXIS IN DEG.
114.000 * GAMMA - ROTATION ABOUT LOCAL Z-AXIS IN DEG.
115.000 *
116.000      NH = 1
117.000      IF (OPTH.GT.0) NH = NHORN
118.000      READ(5,*) (ALPHA(I),BETA(I),GAMMA(I),I=1,NH)
119.000 *
120.000 * IPOLA - POLARISATION OF FEED HORN AND REFLECTOR SYSTEM. VP=1 , HP=2
121.000 *
122.000      READ(5,*) IPOLA
123.000 *
124.000 * ITYPE - TYPE OF HORN , 0=ORD. PYRAMIDAL , 1=DIEL , 2=CORRUG ,
125.000 *           3=BOTH(1+2) , 4=DIEL TRIF , 5=TRIF ONLY
126.000 *
127.000      READ(5,*) (ITYPE(I),I=1,NHORN)
128.000 *
129.000 * HPWR - RELATIVE POWER EXCITATION OF EACH HORN IN WATTS.
130.000 * HPHASE - RELATIVE PHASE EXCITATION OF EACH HORN IN DEG.
131.000 *
132.000      READ(5,*) (HPWR(I),HPHASE(I),I=1,NHORN)
133.000 *
134.000 * DATA DESCRIBING PARABOLIC REFLECTOR CONFIGURATION.
135.000 *
136.000 * F - FOCAL LENGTH OF PARABOLIC REFLECTOR IN INCHES.
137.000 * SX2 - X-DIMENSION OF ELLIPTICAL REFLECTOR APERTURE IN INCHES
138.000 * SY2 - Y-DIMENSION OF ELLIPTICAL REFLECTOR APERTURE IN INCHES
139.000 * DELTAX - X-OFFSET OF APERTURE CENTRE IN INCHES
140.000 * DELTAY - Y-OFFSET OF APERTURE CENTRE IN INCHES,
141.000 *
142.000      READ(5,*) F, SX2, SY2, DELTAX, DELTAY
143.000 *
144.000 * OPTB - OPTION FOR SPECIFYING LIMITS OF INTEGRATION TO SIMULATE BLOCKAGE.
145.000 *           = 0, LIMITS ARE GENERATED BY PROGRAM FROM INPUT REFLECTOR
146.000 *           DATA. NO APERTURE BLOCKAGE IS ASSUMED.
147.000 *           = 1, LIMITS ARE DERIVED BY THE USER AND READ INTO THE PROGRAM.
148.000 *
149.000      READ(5,*) OPTB
150.000      IF (OPTB.LE.0) GO TO 50
151.000 *
152.000 * NREG - NUMBER OF REGIONS OF PHI-INTEGRATION.
153.000 *
154.000      READ(5,*) NREG
155.000 *
156.000 * PHL(I) - LOWER LIMIT OF PHI-INTEG FOR THE I TH REGION IN RADIANS.
157.000 * PHU(I) - UPPER LIMIT OF PHI-INTEG FOR THE I TH REGION IN RADIANS.
158.000 *
159.000      READ(5,*) (PHL(I),PHU(I),I=1,NREG)
160.000 *
161.000 * BX2 - X-AXIS DIMENSION OF CENTRAL ELLIPTICAL BLOCKAGE IN INS.
162.000 * BY2 - Y-AXIS DIMENSION OF CENTRAL ELLIPTICAL BLOCKAGE IN INS.
163.000 *
```

```
164.000      READ(5,*) BX2, BY2
165.000 *
166.000 * OPTQ - OPTION FOR SPECIFYING NO. OF INTEGRATION POINTS.
167.000 *      = 0, NO. OF INTEGRATION POINTS IS DETERMINED BY PROGRAM.
168.000 *      = 1, SPECIFIED BY USER.
169.000 *
170.000 50    READ(5,*) OPTQ
171.000      IF (OPTQ.LE.0) GO TO 60
172.000 *
173.000 * DATA FOR SURFACE INTEGRATION.
174.000 * NQR - NO OF INTEGRATION POINTS IN THE RADIAL-DIRECTION.
175.000 * NQP - NO OF INTEGRATION POINTS IN THE PHI-DIRECTION.
176.000 * CHOOSE FROM THIS LIST - 3,4,6,8,10,12,14,16,20,24,28,34,40 PTS
177.000 *
178.000      READ(5,*) NQR,NQP
179.000 *
180.000 * CHECK AND DETERMINE LOCATION OF THESE FORMULAS
181.000 *
182.000      CALL APQUAD(NQR,I,LQR)
183.000      NQR = I
184.000      CALL APQUAD(NQP,I,LQP)
185.000      NQP = I
186.000 *
187.000 * READ IN DATA FOR FAR FIELD OBSERVATION
188.000 *
189.000 * ELS - START OF ELEV CUT IN DEG
190.000 * ELE - END OF ELEV CUT IN DEG
191.000 * NEL - NO. OF ELEV POINTS
192.000 * AZS - START OF AZIMUTH CUT IN DEG
193.000 * AZE - END OF AZIMUTH CUT IN DEG
194.000 * NAZ - NO. OF AZIM POINTS
195.000 *
196.000 60    READ(5,*) AZS,AZE,NAZ,ELS,ELE,NEL
197.000      IF (NEL.LE.MAXEL) GO TO 74
198.000      PRINT 72 , MAXEL
199.000 72    FORMAT(1X,'STOP. NO. OF EL GRID PTS. EXCEEDED MAX. OF ',I2)
200.000      STOP
201.000 74    IF (NAZ.LE.MAXAZ) GO TO 78
202.000      PRINT 76 , MAXAZ
203.000 76    FORMAT(1X,'STOP. NO. OF AZ GRID PTS. EXCEEDED MAX. OF ',I2)
204.000      STOP
205.000 78    CONTINUE
206.000 *
207.000 * XDQ - X-TRANSLATION OF FIELD CO-ORDINATE SYSTEM FROM GLOBAL SYSTEM.(INS)
208.000 * YDQ - Y-TRANSLATION OF FIELD CO-ORDINATE SYSTEM FROM GLOBAL SYSTEM.(INS)
209.000 * ZDQ - Z-TRANSLATION OF FIELD CO-ORDINATE SYSTEM FROM GLOBAL SYSTEM.(INS)
210.000 *
211.000      READ(5,*) XDQ,YDQ,ZDQ
212.000 *
213.000 * PVR - ANGULAR ROTATION OF FIELD POLARISATION VECTOR IN DEGREES.
214.000 *
215.000      READ(5,*) PVR
216.000 *
217.000 * DATA INPUT COMPLETED
218.000 *
```

```
219.000 80 FORMAT(12I5)
220.000 90 FORMAT(12F10.4)
221.000 95 FORMAT(1X,15A4)
222.000 PRINT 95 , (IHEAD(I),I=1,15)
223.000 PRINT 100
224.000 100 FORMAT(1X,'FREQUENCY IN GHZ')
225.000 PRINT 90,FREQ
226.000 PRINT 110
227.000 110 FORMAT(1X,'NO OF HORNS')
228.000 PRINT 80,NHORN
229.000 PRINT 120
230.000 120 FORMAT(1X,'E-PLANE HORN APERTURE DIM - B IN INS.')
231.000 PRINT 90,(B(I),I=1,NHORN)
232.000 PRINT 130
233.000 130 FORMAT(1X,'H-PLANE HORN APERTURE DIM - A IN INS.')
234.000 PRINT 90,(A(I),I=1,NHORN)
235.000 PRINT 140
236.000 140 FORMAT(1X,'INPUT WAVEGUIDE DIMENSION B(E-PLANE) IN INS.')
237.000 PRINT 90,(WGB(I),I=1,NHORN)
238.000 PRINT 150
239.000 150 FORMAT(1X,'INPUT WAVEGUIDE DIMENSION A(H-PLANE) IN INS.')
240.000 PRINT 90,(WGA(I),I=1,NHORN)
241.000 PRINT 155
242.000 155 FORMAT(1X,'AXIAL HORN LENGTH IN INS.')
243.000 PRINT 90,(HRNLTH(I),I=1,NHORN)
244.000 IF (OPTH.EQ.1) THEN
245.000 PRINT 160
246.000 160 FORMAT(1X,'OPT. CHOSEN - INDIVIDUAL DISPLACEMENT AND ROTATION',
247.000 +' OF HORNS')
248.000 ELSE
249.000 PRINT 165
250.000 165 FORMAT(1X,'OPT. CHOSEN - COLLECTIVE MOVEMENT AND ROTATION OF',
251.000 +' HORN ARRAY')
252.000 END IF
253.000 PRINT 80, OPTH
254.000 PRINT 170
255.000 170 FORMAT(1X,'DISPLACEMENT OF HORNS IN INS.')
256.000 PRINT 90,(DX(I),DY(I),DZ(I),I=1,NHORN)
257.000 PRINT 180
258.000 180 FORMAT(1X,'ROT. OF HORNS ABOUT X-,Y-,AND Z-AXIS IN DEG.')
259.000 PRINT 90,(ALPHA(I),BETA(I),GAMMA(I),I=1,NH)
260.000 PRINT 190
261.000 190 FORMAT(1X,'POLAR. OF ANTENNA SYS. - VP(X-AXIS)=1,HP(Y-AXIS)=2')
262.000 PRINT 80,IPOLA
263.000 PRINT 200
264.000 200 FORMAT(1X,'HORN TYPE,0=DRD,1=DIEL,2=CORR,3=BOTH(1+2),4=DIEL TRIF'
265.000 +'5=TRIF')
266.000 PRINT 80, (ITYPE(I),I=1,NHORN)
267.000 PRINT 210
268.000 210 FORMAT(1X,'REL. POWER(W) AND PHASE(DEG) OF HORN EXCITATIONS')
269.000 PRINT 90, (HPWR(I),HPHASE(I),I=1,NHORN)
270.000 PRINT 220
271.000 220 FORMAT(1X,'FOC LTH.,APER, X-DIM,Y-DIM AND X-OFFSET IN INS.')
272.000 PRINT 90 , F,SX2,SY2,DELTAX,DELTAY
273.000 IF (OPTB.LE.0) GO TO 260
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```
274.000 PRINT 230
275.000 230 FORMAT(1X,'NO. OF REGIONS OF PHI-INTEG = ',I2)
276.000 PRINT 80 , NREG
277.000 PRINT 240
278.000 240 FORMAT(1X,'LOWER AND UPPER LIMITS OF PHI-INTEG IN RADIANS')
279.000 PRINT 90 , (PHL(I),PHU(I),I=1,NREG)
280.000 PRINT 250
281.000 250 FORMAT(1X,'X-AND Y-DIM. OF CENTRAL ELLIPTICAL BLOCKAGE IN INS')
282.000 PRINT 90, BX2,BY2
283.000 260 IF (OPTQ.LE.0) GO TO 275
284.000 PRINT 270
285.000 270 FORMAT(1X,'INTEG. PTS. SPEC. BY USER FOR RADIAL AND PHI-VAR.',  
286.000 +'1X,'MUST BE A MEMBER OF THIS SET - 3,4,6,8,10,12,14,16,20,',  
287.000 +'24,28,34,40')
288.000 PRINT 80 , NQR, NQP
289.000 275 PRINT 280
290.000 280 FORMAT(1X,'START,STOP AND NO. OF PTS. FOR AZ,EL SCAN')
291.000 PRINT 290, AZS,AZE,NAZ,ELS,ELE,NEL
292.000 290 FORMAT(2(2F10.5,IS))
293.000 PRINT 300
294.000 300 FORMAT(1X,'X-,Y-,Z-TRANSLATION OF FIELD CO-ORD. SYSTEM IN INS')
295.000 PRINT 90 , XDQ , YDQ , ZDQ
296.000 PRINT 310
297.000 310 FORMAT(1X,'ROTATION OF FIELD POLARISATION VECTOR IN DEGREES')
298.000 PRINT 90, PVR
299.000 *
300.000 * COMPUTE WAVELENGTH
301.000 *
302.000 WAVE = 29.97925/(2.54*FREQ)
303.000 RK = 2.0*PI/WAVE
304.000 *
305.000 * COMPUTE FLARE LENGTHS OF HORNS
306.000 *
307.000 DO 340 I = 1,NHORN
308.000 IF (B(I).GT.WGB(I)) GO TO 320
309.000 EFL(I) = 999.0
310.000 GO TO 330
311.000 320 EFL(I) = 0.50*B(I)*SQRT(1.0+(2.0*HRNLTH(I)/(B(I)-WGB(I)))**2)
312.000 330 IF (A(I).GT.WGA(I)) GO TO 340
313.000 HFL(I) = 999.0
314.000 GO TO 350
315.000 340 HFL(I) = 0.50*A(I)*SQRT(1.0+(2.0*HRNLTH(I)/(A(I)-WGA(I)))**2)
316.000 350 CONTINUE
317.000 IF (OPTH.GT.0) GO TO 365
318.000 *
319.000 * COMPUTE FINAL LOCATIONS OF HORNS AFTER COLLECTIVE ALPHA AND BETA ROTATIONS.
320.000 *
321.000 SA = SIN(ALPHA(1)/RAD)
322.000 CA = COS(ALPHA(1)/RAD)
323.000 SB = SIN(BETA(1)/RAD)
324.000 CB = COS(BETA(1)/RAD)
325.000 SG = SIN(GAMMA(1)/RAD)
326.000 CG = COS(GAMMA(1)/RAD)
327.000 DO 355 I = 1,NHORN
328.000 ARG1 = DX(I)
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329.000 ARG2 = DY(I)  
330.000 ARG3 = DZ(I)  
331.000 DX(I) = ARG1\*CB + ARG3\*SB  
332.000 DY(I) = ARG1\*SA\*SB + ARG2\*CA - ARG3\*SA\*CB  
333.000 DZ(I) = -ARG1\*SB\*CA + ARG2\*SA + ARG3\*CA\*CB  
334.000 355 CONTINUE  
335.000 \*  
336.000 \* COMPUTE TRANSFORMATION FUNCTIONS OF COLLECTIVE HORN ROTATIONS  
337.000 \*  
338.000 W11(1) = CB\*CG  
339.000 W12(1) = SA\*SB\*CG + CA\*SG  
340.000 W13(1) = -CA\*SB\*CG + SA\*SG  
341.000 W21(1) = -CB\*SG  
342.000 W22(1) = -SA\*SB\*SG + CA\*CG  
343.000 W23(1) = CA\*SB\*SG + SA\*CG  
344.000 W31(1) = SB  
345.000 W32(1) = -SA\*CB  
346.000 W33(1) = CA\*CB  
347.000 IF (NHORN.EQ.1) GO TO 375  
348.000 DO 360 I = 2,NHORN  
349.000 W11(I) = W11(1)  
350.000 W12(I) = W12(1)  
351.000 W13(I) = W13(1)  
352.000 W21(I) = W21(1)  
353.000 W22(I) = W22(1)  
354.000 W23(I) = W23(1)  
355.000 W31(I) = W31(1)  
356.000 W32(I) = W32(1)  
357.000 W33(I) = W33(1)  
358.000 360 CONTINUE  
359.000 GO TO 375  
360.000 \*  
361.000 \* COMPUTE TRANSFORMATION FUNCTIONS OF INDIVIDUAL HORN ROTATIONS.  
362.000 \*  
363.000 365 DO 370 I = 1,NHORN  
364.000 SB = SIN(BETA(I)/RAD)  
365.000 CB = COS(BETA(I)/RAD)  
366.000 SA = SIN(ALPHA(I)/RAD)  
367.000 CA = COS(ALPHA(I)/RAD)  
368.000 SG = SIN(GAMMA(I)/RAD)  
369.000 CG = COS(GAMMA(I)/RAD)  
370.000 W11(I) = CB\*CG  
371.000 W12(I) = SA\*SB\*CG + CA\*SG  
372.000 W13(I) = -CA\*SB\*CG + SA\*SG  
373.000 W21(I) = -CB\*SG  
374.000 W22(I) = -SA\*SB\*SG + CA\*CG  
375.000 W23(I) = CA\*SB\*SG + SA\*CG  
376.000 W31(I) = SB  
377.000 W32(I) = -SA\*CB  
378.000 W33(I) = CA\*CB  
379.000 370 CONTINUE  
380.000 \*  
381.000 \* CONVERT DEGREES INTO RADIANS  
382.000 \*  
383.000 375 DO 380 I = 1,NHORN

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384.000      HPHASE(I) = HPHASE(I)/RAD
385.000 380    CONTINUE
386.000 *
387.000 * TAKE SINE AND COSINE OF FIELD VECTOR ROTATION ANGLE,
388.000 *
389.000      CPVR = COS(PVR/RAD)
390.000      SPVR = SIN(PVR/RAD)
391.000 *
392.000 * COMPUTE HORN APERTURE EXCITATION
393.000 *
394.000      DO 390 I = 1,NHORN
395.000      HMAG(I) = SQRT(4.0*HPWR(I)*ZETA/(A(I)*B(I)))
396.000      IF (ITYPE(I).EQ.1) HMAG(I) = HMAG(I)/1.4142
397.000      IF (ITYPE(I).EQ.2) HMAG(I) = HMAG(I)*1.4142
398.000      IF (ITYPE(I).EQ.4) HMAG(I) = HMAG(I)/2.236068
399.000      IF (ITYPE(I).EQ.5) HMAG(I) = HMAG(I)/1.581139
400.000 390    CONTINUE
401.000      IF (OPTB.GT.0) GO TO 405
402.000 *
403.000 * INTERNAL DEFAULT INTEGRATION LIMITW.
404.000 * APERTURE IS DIVIDED INTO FOUR REGIONS FOR PHI-INTEG.
405.000 * LIMITS OF THESE REGIONS ARE SET BELOW.
406.000 *
407.000      NREG = 4
408.000      PHL(1) = 0.0
409.000      PHU(1) = 1.570796327
410.000      DO 400 I = 2,NREG
411.000      PHL(I) = PHL(I-1) + 1.570796327
412.000      PHU(I) = PHU(I-1) + 1.570796327
413.000 400    CONTINUE
414.000 *
415.000 * THERE IS NO CENTRAL BLOCKAGE.
416.000 *
417.000      BX2 = 0.0
418.000      BY2 = 0.0
419.000 405    IF (OPTQ.GT.0) GO TO 430
420.000 *
421.000 * SELECTION OF THE APPROPRIATE QUADRATURE FORMULA
422.000 *
423.000      XMAX = -99999.0
424.000      XMIN = +99999.0
425.000      YMAX = -99999.0
426.000      YMIN = +99999.0
427.000      DO 410 I = 1,NHORN
428.000      IF (DX(I).GT.XMAX) XMAX = DX(I)
429.000      IF (DX(I).LT.XMIN) XMIN = DX(I)
430.000      IF (DY(I).GT.YMAX) YMAX = DY(I)
431.000      IF (DY(I).LT.YMIN) YMIN = DY(I)
432.000 410    CONTINUE
433.000      ARG1 = ABS(ELE/RAD + ATAN(XMAX/F))
434.000      ARG2 = ABS(ATAN(XMIN/F) + ELS/RAD)
435.000      ARG3 = ABS(AZE/RAD + ATAN(YMAX/F))
436.000      ARG4 = ABS(ATAN(YMIN/F) + AZS/RAD)
437.000      ARG1 = AMAX1(ARG1,ARG2)
438.000      ARG3 = AMAX1(ARG3,ARG4)
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439.000      NQR = (SIN(ARG1)*SX2/WAVE + 1.0)*1.50
440.000      NQP = (SIN(ARG3)*SY2/WAVE + 1.0)*1.50
441.000      NQR = MAX0(NQR,NQP)
442.000 *
443.000 * SEARCH FOR THE CLOSEST AVAILABLE QUADRATURE FORMULA.
444.000 *
445.000      CALL APQUAD(NQR,NQP,LQP)
446.000      NQR = NQP
447.000      LQR = LQP
448.000      PRINT 427
449.000 427  FORMAT(1X,'INTEG. PTS. SELECTED FOR RADIAL AND PHI-VAR.')
450.000      PRINT 80 , NQR,NQP
451.000 430  IF (NQR.LE.MAXQ.AND.NQP.LE.MAXQ) GO TO 440
452.000      PRINT 435 , NQR,NQP
453.000 435  FORMAT(1X,'STOP. CAHNGE MAXQ. INCREASE ARRAYS DIMENSIONS TO',
454.000      +' ACCOMMODATE FOLLOWING RADIAL AND PHI-INTEG PTS. - ',2I3)
455.000      STOP
456.000 440  CONTINUE
457.000 *
458.000 * COMPUTE SEMI-AXES DIMENSIONS FOR REFLECTOR AND BLOCKAGE APERTURES.
459.000 *
460.000      SX2 = SX2*0.50
461.000      SY2 = SY2*0.50
462.000      BX2 = BX2*0.50
463.000      BY2 = BY2*0.50
464.000 *
465.000 * INITIALISE CURRENT MATRIX RJX,RJY,RJZ
466.000 *
467.000      KOUNT = 0
468.000      DO 480 L = 1,NREG
469.000      DO 470 J = 1,NQR
470.000      DO 460 I = 1,NQP
471.000      KOUNT = KOUNT + 1
472.000      RJX(KOUNT) = (0.0,0.0)
473.000      RJY(KOUNT) = (0.0,0.0)
474.000      RJZ(KOUNT) = (0.0,0.0)
475.000 460  CONTINUE
476.000 470  CONTINUE
477.000 480  CONTINUE
478.000 *
479.000 * EVALUATE INTEGRAND REQ. FOR CALCULATING HORN RADIATION PATTERNS.
480.000 *
481.000      CALL APINT(NHORN)
482.000 *
483.000 * COMPUTE CURRENT MATRIX
484.000 * AT THE SAME TIME COMPUTE POWER INTERCEPTED BY REFL
485.000 *
486.000      PWR = 0.0
487.000 *
488.000 * L = INDEX FOR REGION OF PHI- INTEGRATION.
489.000 *
490.000      KOUNT = 0
491.000      DO 520 L = 1,NREG
492.000 *
493.000 * I = INDEX FOR PHI-INTEG
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494.000 *
495.000      DO 510 I = 1,NQP
496.000      PHII = (PHL(L)+PHU(L))*0.50+(PHU(L)-PHL(L))*0.50*QX(I+LQP)
497.000      CPI = COS(PHII)
498.000      SPI = SIN(PHII)
499.000 *
500.000 * FIND THE LIMITS OF RADIAL-INTEGRATION GIVEN PHII
501.000 *
502.000      CALL RADLIM(CPI,SPI,SX2,SY2,BX2,BY2,RDL(I,L),RDU(I,L))
503.000      FAC = (PHU(L)-PHL(L))*(RDU(I,L)-RDL(I,L))*0.25
504.000 *
505.000 * J = INDEX FOR RHO-INTEG.
506.000 *
507.000      DO 500 J = 1,NQR
508.000      RDJ = (RDL(I,L)+RDU(I,L))*0.50+(RDU(I,L)-RDL(I,L))*0.50*
509.000      + QX(J+LQR)
510.000      KOUNT = KOUNT + 1
511.000 *
512.000 * STORE REFLECTOR SURFACE POINTS
513.000 *
514.000      XG(KOUNT) = RDJ*CPI + DELTAX
515.000      YG(KOUNT) = RDJ*SPI + DELTAY
516.000      ZG(KOUNT) = (XG(KOUNT)**2 + YG(KOUNT)**2)*0.25/F - F
517.000 *
518.000 * COMPUTE COMPONENTS OF SURFACE NORMAL
519.000 *
520.000      RNX = -XG(KOUNT)*0.50/F
521.000      RNY = -YG(KOUNT)*0.50/F
522.000 *
523.000 * K = INDEX FOR FEED HORN
524.000      EX = (0.0,0.0)
525.000      EY = (0.0,0.0)
526.000      EZ = (0.0,0.0)
527.000      HX = (0.0,0.0)
528.000      HY = (0.0,0.0)
529.000      HZ = (0.0,0.0)
530.000      DO 490 K = 1,NHORN
531.000 * THE FOLLOWING TRANSFORMATIONS CONVERT SURFACE POINT
532.000 * COORDINATES TO HORN COORDINATES.
533.000 * TRANSFORM (RHO,THETA,PHI) TO (RHOT,THETAT,PHIT)
534.000      RHOT = SQRT((XG(KOUNT) - DX(K))**2 + (YG(KOUNT) - DY(K))**2
535.000      + + (ZG(KOUNT) - DZ(K))**2)
536.000      CTT = (ZG(KOUNT)-DZ(K))/RHOT
537.000      STT = ACOS(CTT)
538.000      STT = SIN(STT)
539.000      SPT = ATAN2((YG(KOUNT)-DY(K)),(XG(KOUNT)-DX(K)))
540.000      CPT = COS(SPT)
541.000      SPT = SIN(SPT)
542.000 *
543.000 * TRANSFORM (RHOT,THETAT,PHIT) TO (RHOR,THETAR,PHIR)
544.000      STSP = STT*SPT
545.000      STCP = STT*CPT
546.000      CTR = STCP*W31(K) + STSP*W32(K) + CTT*W33(K)
547.000      STR = ACOS(CTR)
548.000      STR = SIN(STR)
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549.000      SPR = STCP*W21(K) + W22(K)*STSP + W23(K)*CTT
550.000      CPR = STCP*W11(K) + STSP*W12(K) + CTT*W13(K)
551.000      SPR = ATAN2(SPR,CPR)
552.000      CPR = COS(SPR)
553.000      SPR = SIN(SPR)
554.000      CTCP = CTR*CPR
555.000      CTSP = CTR*SPR
556.000 *
557.000      TXT = CTCP*W11(K) + CTSP*W21(K) - STR*W31(K)
558.000      TYT = CTCP*W12(K) - STR*W32(K) + CTSP*W22(K)
559.000      TZT = CTCP*W13(K) + CTSP*W23(K) - STR*W33(K)
560.000      TXP = -SPR*W11(K) + CPR*W21(K)
561.000      TYP = -SPR*W12(K) + CPR*W22(K)
562.000      TZP = -SPR*W13(K) + CPR*W23(K)
563.000 *
564.000      PT = RK*RHOT
565.000      EXPN = CMPLX(COS(PT),-SIN(PT))/RHOT
566.000 * COMPUTE FEED ARRAY FIELDS AT (RHOT,THETAR,PHIR)
567.000      CALL RECAP(STR,CTR,SPR,CPR,EHTHETA,EPHI,K)
568.000      EHTHETA = EHTHETA*EXPN
569.000      EPHI = EPHI*EXPN
570.000      FTX = EHTHETA*TXP - EPHI*TXT
571.000      FTY = EHTHETA*TYP - EPHI*TYT
572.000      FTZ = EHTHETA*TZP - EPHI*TZT
573.000      RJX(KOUNT) = RJX(KOUNT) + FTZ*RNY - FTY
574.000      RJY(KOUNT) = RJY(KOUNT) + FTX - FTZ*RNX
575.000      RJZ(KOUNT) = RJZ(KOUNT) + FTY*RNX - FTX*RNY
576.000 *
577.000 * COMPUTE COMBINED FEED PATTERN FOR SPILL-OVER CALCULATION
578.000 *
579.000      EX = EX + EHTHETA*TXT + EPHI*TXP
580.000      EY = EY + EHTHETA*TYT + EPHI*TYP
581.000      EZ = EZ + EHTHETA*TZT + EPHI*TZP
582.000      HX = HX + FTX
583.000      HY = HY + FTY
584.000      HZ = HZ + FTZ
585.000 490  CONTINUE
586.000      FACW = FAC*RDJ*QW(I+LQP)*QW(J+LQR)
587.000      RJX(KOUNT) = RJX(KOUNT)*FACW
588.000      RJY(KOUNT) = RJY(KOUNT)*FACW
589.000      RJZ(KOUNT) = RJZ(KOUNT)*FACW
590.000      PWR = PWR - (REAL(EY*CONJG(HZ)) - EZ*CONJG(HY))*RNX +
591.000      +           REAL(EZ*CONJG(HX)) - EX*CONJG(HZ))*RNY +
592.000      +           REAL(EX*CONJG(HY)) - EY*CONJG(HX))*FACW
593.000 500  CONTINUE
594.000 510  CONTINUE
595.000 520  CONTINUE
596.000 * COMPUTATION OF CURRENT MATRIX COMPLETED
597.000 *
598.000 * COMPUTE SPILL-OVER EFFICIENCY - ETAS
599.000 * PWR = POWER CAPTURED BY REFLECTOR
600.000 *
601.000      PWR = PWR*0.50/ZETA
602.000 * PT = TOTAL POWER RADIATED
603.000      PT = 0.0

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604.000      DO 530 K = 1,NHORN
605.000 530    PT = PT + HPWR(K)
606.000      ETAS = PWR/PT
607.000      PRINT 540 , ETAS
608.000 540    FORMAT(///,1X,'SPILL-OVER EFFICIENCY =',F7.3,/)
609.000      PT = PT*60.0*WAVE*WAVE
610.000 *
611.000 * COMPUTE GAIN AND PHASE OF CO-POLAR AND X-POLAR COMPONENTS
612.000 *
613.000      ELIN = ELE - ELS
614.000      IF (NEL.GT.1) ELIN = ELIN/FLOAT(NEL - 1)
615.000      AZIN = AZE - AZS
616.000      IF (NAZ.GT.1) AZIN = AZIN/FLOAT(NAZ - 1)
617.000      DO 550 I = 1,NEL
618.000 550    EL(I) = ELE - ELIN*(I-1)
619.000      DO 560 I = 1,NAZ
620.000 560    AZ(I) = AZS + AZIN*(I-1)
621.000      KOUNT = 0
622.000      DO 580 I = 1,NEL
623.000      DO 570 J = 1,NAZ
624.000      KOUNT = KOUNT + 1
625.000      CALL CONV(EL(I),AZ(J),STQ,CTQ,SPQ,CPQ)
626.000      CALL FIELD(STQ,CTQ,SPQ,CPQ,IPOLA,CGN0,XGN0,CPH0)
627.000      CGN(KOUNT) = CGN0
628.000      XGN(KOUNT) = XGN0
629.000      CPH(KOUNT) = CPH0
630.000 570    CONTINUE
631.000 580    CONTINUE
632.000 * OUTPUT FAR FIELD OBSERVATION CUTS.
633.000 *
634.000      PRINT 710
635.000 710    FORMAT(///,50X,'CO-POLAR GAIN IN DB')
636.000      PRINT 720
637.000 720    FORMAT(4BX,23(1H-))
638.000      PRINT 730 , (AZ(I),I=1,NAZ)
639.000 730    FORMAT(//,1X,' ELEV *',50X,'AZIMUTH (DEG)',//,1X,'(DEG) *',20F6.2)
640.000      PRINT 735
641.000 735    FORMAT(1X,65(2H *))
642.000      DO 740 I = 1,NEL
643.000      KOUNT = (I-1)*NAZ + 1
644.000      KOUNT1 = KOUNT + NAZ - 1
645.000 740    PRINT 750 , EL(I),(CGN(J),J=KOUNT,KOUNT1)
646.000 750    FORMAT(/,7X,1H*,/,1X,F6.2,1H*,20F6.2,/,7X,1H*)
647.000      PRINT 760
648.000 760    FORMAT(///,50X,'X-POLAR GAIN IN DB')
649.000      PRINT 720
650.000      PRINT 730 , (AZ(I),I=1,NAZ)
651.000      PRINT 735
652.000      DO 770 I = 1,NEL
653.000      KOUNT = (I-1)*NAZ + 1
654.000      KOUNT1 = KOUNT + NAZ - 1
655.000 770    PRINT 765 , EL(I),(XGN(J),J=KOUNT,KOUNT1)
656.000 765    FORMAT(/,7X,1H*,/,1X,F6.2,1H*,20F6.1,/,7X,1H*)
657.000      PRINT 775
658.000 775    FORMAT(///,49X,'CO-POLAR PHASE IN DEG')
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659.000      PRINT 720
660.000      PRINT 730 , (AZ(I),I=1,NAZ)
661.000      PRINT 735
662.000      DO 780 I = 1,NEL
663.000      KOUNT = (I-1)*NAZ + 1
664.000      KOUNT1 = KOUNT + NAZ - 1
665.000 780  PRINT 765 , EL(I),(CPH(J),J=KOUNT,KOUNT1)
666.000      OPEN(7,FILE='GNMAT',STATUS='OLD',USAGE='OUTPUT')
667.000      WRITE(7,10) (IHEAD(I),I=1,15)
668.000      WRITE(7,290) AZS,AZE,NAZ,ELS,ELE,NEL
669.000      DO 790 I = 1,NEL
670.000      KOUNT = (I-1)*NAZ + 1
671.000      KOUNT1= KOUNT + NAZ - 1
672.000 790  WRITE(7,800) (CGN(J),J=KOUNT,KOUNT1)
673.000 800  FORMAT(11F7.2)
674.000      STOP
675.000      END
676.000      SUBROUTINE RADLIM(CP,SP,A1,B1,A2,B2,RL,RU)
677.000 *
678.000 * COMPUTES LOWER AND UPPER LIMITS OF RADIAL VAR. INTEG. FOR A GIVEN
679.000 * PHI.
680.000 *
681.000      RU = A1*B1/SQRT(A1*A1*SP*SP + B1*B1*CP*CP)
682.000      RL = 0.0
683.000      IF (A2.LT.1.0E-04.OR.B2.LT.1.0E-04) RETURN
684.000      RL = A2*B2/SQRT(A2*A2*SP*SP + B2*B2*CP*CP)
685.000      RETURN
686.000      END
687.000      SUBROUTINE RECAP(ST,CT,SP,CP,ETHETA,EPHI,K)
688.000 *
689.000 * COMPUTE ETHETA AND EPHI COMPN. OF X- OR Y-POL REC. APER,
690.000 *
691.000      DIMENSION A(25),B(25),HMAG(25),HPHASE(25),HLT(25),ELT(25)
692.000      DIMENSION ITYPE(25),LQH(25),NQH(25)
693.000      COMPLEX ETHETA,EPHI,HAP(14,25),EAP(14,25)
694.000      COMPLEX AP1(14,25),AP2(14,25),AP3(14,25),AP4(14,25)
695.000      COMMON /HEAP/ HAP,EAP,AP1,AP2,AP3,AP4,LQH,NQH
696.000      COMMON/BLOCK/QX(219),QW(219)
697.000      COMMON/VAL1/WAVE,PI,RAD,RK
698.000      COMMON/VAL2/A,B,HMAG,HPHASE,HLT,ELT,ITYPE,IPOL
699.000 *
700.000      LC = LQH(K)
701.000 *
702.000      IF(IPOL.EQ.1) GO TO 90
703.000 * Y-AXIS POL. APERTURE. PHASE ERROR INCLU.
704.000 *
705.000      IF (ITYPE(K).LT.4) GO TO 60
706.000 * TRIFURCATED OR DIELECTRIC LOADED TRIFURCATED HORNS
707.000      RB = RK*B(K)*ST*SP*0.125
708.000      RA = RK*A(K)*ST*CP*0.50
709.000      ETHETA = (0.0,0.0)
710.000      DO 10 I = 1,NQH(K)
711.000      X = RB*(3.0+QX(I+LC))
712.000 10    ETHETA = ETHETA + CMPLX(COS(X),SIN(X))*AP2(I,K)
713.000      DO 20 I = 1,NQH(K)

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714.000      X = RB*(QX(I+LC) -3.0)
715.000 20   ETHETA = ETHETA + CMPLX(COS(X),SIN(X))*AP3(I,K)
716.000      DO 30 I = 1,NQH(K)
717.000      X = RB*QX(I+LC)*2.0
718.000 30   ETHETA = ETHETA + CMPLX(COS(X),SIN(X))*AP4(I,K)
719.000      EPHI = (0.0,0.0)
720.000      DO 40 I = 1,NQH(K)
721.000      X = RA*QX(I+LC)
722.000 40   EPHI = EPHI + CMPLX(COS(X),SIN(X))*AP1(I,K)
723.000      ETHETA = (1.0 - CT)*ETHETA*EPHI
724.000      EPHI = ETHETA*CP
725.000      ETHETA = -ETHETA*SP
726.000      RETURN
727.000 * PYRAMIDAL HORNS
728.000 60   ETHETA = (0.0,0.0)
729.000      DO 70 I = 1,NQH(K)
730.000      X = A(K)*PI*QX(I+LC)*ST*CP/WAVE
731.000 70   ETHETA = ETHETA + CMPLX(COS(X),SIN(X))*HAP(I,K)
732.000      EPHI = (0.0,0.0)
733.000      DO 80 I = 1,NQH(K)
734.000      X = B(K)*PI*QX(I+LC)*ST*SP/WAVE
735.000 80   EPHI = EPHI + CMPLX(COS(X),SIN(X))*EAP(I,K)
736.000      ETHETA = (1.0-CT)*ETHETA*EPHI
737.000      EPHI = ETHETA*CP
738.000      ETHETA = -ETHETA*SP
739.000      RETURN
740.000 * X-AXIS POL. APERTURE, PHASE ERROR INCLU.
741.000 *
742.000 90   IF (ITYPE(K).LT.4) GO TO 170
743.000 * TRIFURCATED OR DIELECTRIC LOADED TRIFURCATED HORNS
744.000      ETHETA = (0.0,0.0)
745.000      DO 130 I = 1,NQH(K)
746.000      X = PI*B(K)*(3.0+QX(I+LC))*ST*CP*0.250/WAVE
747.000 130   ETHETA = ETHETA + CMPLX(COS(X),SIN(X))*AP2(I,K)
748.000      DO 140 I = 1,NQH(K)
749.000      X = PI*B(K)*(QX(I+LC) - 3.0)*ST*CP*0.250/WAVE
750.000 140   ETHETA = ETHETA + CMPLX(COS(X),SIN(X))*AP3(I,K)
751.000      DO 150 I = 1,NQH(K)
752.000      X = PI*B(K)*QX(I+LC)*ST*CP*0.50/WAVE
753.000 150   ETHETA = ETHETA + CMPLX(COS(X),SIN(X))*AP4(I,K)
754.000      EPHI = (0.0,0.0)
755.000      DO 160 I=1,NQH(K)
756.000      X = PI*A(K)*QX(I+LC)*ST*SP/WAVE
757.000 160   EPHI = EPHI + CMPLX(COS(X),SIN(X))*AP1(I,K)
758.000      ETHETA = (1.0 -CT)*ETHETA*EPHI
759.000      EPHI = ETHETA*SP
760.000      ETHETA = ETHETA*CP
761.000      RETURN
762.000 * PYRAMIDAL HORNS
763.000 170   ETHETA = (0.0,0.0)
764.000      DO 180 I = 1,NQH(K)
765.000      X = PI*A(K)*QX(I+LC)*ST*SP/WAVE
766.000 180   ETHETA = ETHETA + CMPLX(COS(X),SIN(X))*HAP(I,K)
767.000      EPHI = (0.0,0.0)
768.000      DO 190 I = 1,NQH(K)
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769.000      X = PI*B(K)*QX(I+LC)*ST*CP/WAVE
770.000 190  EPHI = EPHI + CMPLX(COS(X),SIN(X))*EAP(I,K)
771.000      ETHETA = (1.0 - CT)*ETHETA*EPHI
772.000      EPHI = ETHETA*SP
773.000      ETHETA = ETHETA*CP
774.000      RETURN
775.000      END
776.000      SUBROUTINE APINT(NHORN)
777.000 *
778.000 * COMPUTE PART OF INTEGRAND WHICH IS DIRECTION INDEPENDENT FOR ROUTINE RECAP
779.000 *
780.000      DIMENSION A(25),B(25),HLT(25),ELT(25),HMAG(25),HPHASE(25),
781.000      + ITYPE(25),NQH(25),LQH(25)
782.000      COMPLEX CONST,EAP(14,25),HAP(14,25)
783.000      COMPLEX AP1(14,25),AP2(14,25),AP3(14,25),AP4(14,25)
784.000      COMMON /HEAP/ HAP,EAP,AP1,AP2,AP3,AP4,LQH,NQH
785.000      COMMON/VAL1/WAVE,PI,RAD,RK
786.000      COMMON/VAL2/A,B,HMAG,HPHASE,HLT,ELT,ITYPE,IPOL
787.000      COMMON/BLOCK/QX(219),QW(219)
788.000 *
789.000 * TE10 MODE CUT-OFF CHECK
790.000 *
791.000      DO 10 I = 1,NHORN
792.000      IF (RK.LE.(PI/A(I))) GO TO 90
793.000 10    CONTINUE
794.000 *
795.000 * SELECT APPROPRIATE QUADRATURE FORMULAS FOR HORN PATTERNS.
796.000 * ARRAYS HAVE BEEN DIMENSIONED TO ACCOMODATE HORN SIZES LESS THAN
797.000 * OR EQUAL TO 4.5 WAVELENGTHS.
798.000 *
799.000      DO 20 I = 1,NHORN
800.000      BB = B(I)
801.000      IF (ITYPE(I).GE.4) BB = 0.50*BB
802.000      ARG = AMAX1(A(I),BB)
803.000      IQ = 2.0*ARG/WAVE + 1.0
804.000      IQ = (IQ + 1)*1.30
805.000      IF (IQ.GT.14) GO TO 70
806.000      CALL APQUAD(IQ,NQH(I),LQH(I))
807.000 20    CONTINUE
808.000 *
809.000      DO 60 I = 1,NHORN
810.000      CONST = HMAG(I)*CMPLX(COS(HPHASE(I)),SIN(HPHASE(I)))*A(I)*B(I)
811.000      + *0.125/WAVE
812.000      ARG = (A(I)**2/HLT(I) + B(I)**2/ELT(I))*RK*0.125
813.000      CONST = CONST*CMPLX(COS(ARG),SIN(ARG))
814.000      KP = ITYPE(I)
815.000      LC = LQH(I)
816.000      IF(KP,GE.4) GO TO 40
817.000      DO 30 J = 1,NQH(I)
818.000      ARG = PI*A(I)*A(I)*QX(J+LC)*QX(J+LC)/(4.0*HLT(I)*WAVE)
819.000      HAP(J,I) = COS(PI*QX(J+LC)*.5)*CMPLX(COS(ARG),-SIN(ARG))*QW(J+LC)
820.000      IF (KP.EQ.3) HAP(J,I)=HAP(J,I)*CONST/COS(.5*QX(J+LC)*PI)
821.000      IF (KP.EQ.1) HAP(J,I)=HAP(J,I)/COS(.5*QX(J+LC)*PI)
822.000      ARG = PI*B(I)*B(I)*QX(J+LC)*QX(J+LC)/(4.0*ELT(I)*WAVE)
823.000      EAP(J,I) = CMPLX(COS(ARG),-SIN(ARG))*CONST*QW(J+LC)

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824.000      IF (KP,EQ,3) EAP(J,I)=EAP(J,I)*COS(.5*QX(J+LC)*PI)/CONST
825.000      IF (KP,EQ,2) EAP(J,I)=EAP(J,I)*COS(.5*QX(J+LC)*PI)
826.000 30    CONTINUE
827.000      GO TO 60
828.000 40    CONST = CONST*0.250
829.000      DO 50 J = 1,NQH(I)
830.000      ARG = PI*A(I)*A(I)*QX(J+LC)*QX(J+LC)/(4.0*HLT(I)*WAVE)
831.000      AP1(J,I) = CONST*CMPLX(COS(ARG),-SIN(ARG))*QW(J+LC)
832.000      IF (KP,EQ,5) AP1(J,I)=AP1(J,I)*COS(0.5*QX(J+LC)*PI)
833.000      ARG = PI*B(I)*B(I)*((3.0+QX(J+LC))**2)/(64.0*ELT(I)*WAVE)
834.000      AP2(J,I) = CMPLX(COS(ARG),-SIN(ARG))*QW(J+LC)
835.000      ARG = PI*B(I)*B(I)*((QX(J+LC)-3.0)**2)/(64.0*ELT(I)*WAVE)
836.000      AP3(J,I) = CMPLX(COS(ARG),-SIN(ARG))*QW(J+LC)
837.000      ARG = PI*B(I)*B(I)*QX(J+LC)*QX(J+LC)/(16.0*ELT(I)*WAVE)
838.000      AP4(J,I) = CMPLX(COS(ARG),-SIN(ARG))*QW(J+LC)*4.0
839.000 50    CONTINUE
840.000 60    CONTINUE
841.000      RETURN
842.000 * ERROR DIAGNOSTICS
843.000 70    PRINT 80 , I
844.000 80    FORMAT(1X,'HORN NO. ',I2,' IS TOO LARGE. STOP.')
845.000      STOP
846.000 90    PRINT 100, I
847.000 100   FORMAT(1X,'HORN NO. ',I2,' IS BELOW CUT-OFF. STOP.')
848.000      STOP
849.000      END
850.000      SUBROUTINE CONV(EL,AZ,ST,CT,SP,CP)
851.000 *
852.000 * CONVERTS (EL,AZ) TO (THETA,PHI) CO-ORD.
853.000 *
854.000 * ST = SIN(THETA)
855.000 * CT = COS(THETA)
856.000 * SP = SIN(PHI)
857.000 * CP = COS(PHI)
858.000 *
859.000      RAD = 57.29577951
860.000      CT = COS(EL/RAD)*COS(AZ/RAD)
861.000      ST = SQRT(1.0 - CT*CT)
862.000      IF (ABS(EL).LT.1.0E-07) GO TO 10
863.000      SP = COS(EL/RAD)*SIN(AZ/RAD)/ST
864.000      CP = SIN(EL/RAD)/ST
865.000      RETURN
866.000 10    IF(AZ) 20,30,40
867.000 20    SP = -1.0
868.000      CP = 0.0
869.000      RETURN
870.000 30    SP = 0.0
871.000      CP = 1.0
872.000      RETURN
873.000 40    SP = 1.0
874.000      CP = 0.0
875.000      RETURN
876.000      END
877.000      SUBROUTINE FIELD(STQ,CTQ,SPQ,CPQ,IPOLA,CGN,XGN,CPH)
878.000 *
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879.000 * COMPUTE FIELD COMPONENTS OF REFLECTOR AT (THETAQ,PHIQ)
880.000 *
881.000      DIMENSION X(2304),Y(2304),Z(2304)
882.000      COMPLEX FTX,FTY,FTZ,RJX(2304),RJY(2304),RJZ(2304)
883.000      COMPLEX EXPN,POL1,POL2,COPOL,XPOL
884.000      COMMON/CURRENT/RJX,RJY,RJZ,X,Y,Z
885.000      COMMON/VAL3/NREG,NQR,NQP,PT,XDQ,YDQ,ZDQ,CPVR,SPVR
886.000      COMMON/VAL1/WAVE,PI,RAD,RK
887.000 *
888.000 * SUM UP CONTRIBUTIONS FROM ALL PANEL CURRENTS.
889.000 *
890.000      FTX = (0.0,0.0)
891.000      FTY = (0.0,0.0)
892.000      FTZ = (0.0,0.0)
893.000      STCP = STQ*CPQ
894.000      STSP = STQ*SPQ
895.000      KOUNT = 0
896.000      DO 30 L = 1,NREG
897.000      DO 20 J = 1,NQP
898.000      DO 10 I = 1,NQR
899.000      KOUNT = KOUNT + 1
900.000      ARG = (X(KOUNT)*STCP + Y(KOUNT)*STSP + Z(KOUNT)*CTQ)*RK
901.000      EXPN = CMPLX(COS(ARG),SIN(ARG))
902.000      FTX = FTX + RJX(KOUNT)*EXPN
903.000      FTY = FTY + RJY(KOUNT)*EXPN
904.000      FTZ = FTZ + RJZ(KOUNT)*EXPN
905.000 10    CONTINUE
906.000 20    CONTINUE
907.000 30    CONTINUE
908.000      POL1 = (1.0 - (1.0 - CTQ)*CPQ*CPQ)*FTX - (1.0 - CTQ)*SPQ*CPQ*FTY
909.000      + - STCP*FTZ
910.000      POL2 = -(1.0 - CTQ)*SPQ*CPQ*FTX + (1.0 - SPQ*SPQ*(1.0 - CTQ))*FTY
911.000      + - STSP*FTZ
912.000 *
913.000 * SHIFT REFERENCE TO FIELD CO-ORDINATE SYSTEM
914.000 *
915.000      ARG = (STCP*XQ + STSP*YQ + CTQ*ZQ)*RK
916.000      EXPN = CMPLX(COS(ARG),-SIN(ARG))
917.000      POL1 = POL1*EXPN
918.000      POL2 = POL2*EXPN
919.000      IF (IPOLA,EQ,2) GO TO 40
920.000      COPOL = POL1*CPVR + POL2*SPVR
921.000      XPOL = POL2*CPVR - POL1*SPVR
922.000      GO TO 50
923.000 40    COPOL = POL2*CPVR - POL1*SPVR
924.000      XPOL = POL1*CPVR + POL2*SPVR
925.000 50    CGN = 10.0*ALOG10(CABS(COPOL)**2/PT)
926.000      XGN = 10.0*ALOG10(CABS(XPOL)**2/PT)
927.000      CPH = ATAN2(AIMAG(COPOL),REAL(COPOL))*RAD
928.000      RETURN
929.000      END
930.000      SUBROUTINE APQUAD(IQ,NQ,LOC)
931.000 *
932.000 * FINDS THE NEAREST QUAD. FORMULA TO THAT REQUIRED.
933.000 * THE AVAILABLE FORMULAS ARE STORED IN ASCENDING ORDER IN ARRAY

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934.000 \* IQF, NQF IS THE NUMBER OF FORMULAS STORED IN THE BLOCK DATA.  
935.000 \* BOTH IQF AND NQF ARE DEFINED IN THE DATA STATEMENT BELOW.  
936.000 \* IQ = IQ POINT FORM, REQ.  
937.000 \* NQ = NEAREST AVAIL. IS NQ POINT FORM.  
938.000 \* LOC = LOCATION OF FORM.  
939.000 \*  
940.000        INTEGER IQF(13)  
941.000        DATA NQF,IQF/13,3,4,6,8,10,12,14,16,20,24,28,34,40/  
942.000 \*  
943.000        DO 10 I = 1,NQF  
944.000        IF (IQ.LE.IQF(I)) GO TO 30  
945.000 10      CONTINUE  
946.000        PRINT 20  
947.000 20      FORMAT(1X,'QUADRATURE FORMULA REQUIRED IS LARGER THAN THAT ',  
948.000        +'AVAILABLE IN THE BLOCK DATA. SEE DOCUMENTATION, EXECUTION',  
949.000        +' TERMINATED')  
950.000        STOP  
951.000 30      NQ = IQF(I)  
952.000        CALL QRLOC(NQ,LOC)  
953.000        RETURN  
954.000        END  
955.000        SUBROUTINE QRLOC(NQ,LOC)  
956.000 \*  
957.000 \* PURPOSE - DETERMINE LOCATION OF INTEGRATION FORMULA IN BLOCK DATA  
958.000 \* BLOCK DATA IS ASSUMED TO CONTAIN THE FOLLOWING FORMULAE.  
959.000 \* 3,4,6,8,10,12,14,16,20,24,28,34,40 PTS.  
960.000 \*  
961.000        IF (NQ = 34) 10,170,180  
962.000 10      IF (NQ = 24) 20,150,160  
963.000 20      IF (NQ = 16) 30,130,140  
964.000 30      IF (NQ = 12) 40,110,120  
965.000 40      IF (NQ = 8) 50,90,100  
966.000 50      IF (NQ = 4) 60,70,80  
967.000 60      LOC = 0  
968.000        RETURN  
969.000 70      LOC = 3  
970.000        RETURN  
971.000 80      LOC = 7  
972.000        RETURN  
973.000 90      LOC = 13  
974.000        RETURN  
975.000 100     LOC = 21  
976.000        RETURN  
977.000 110     LOC = 31  
978.000        RETURN  
979.000 120     LOC = 43  
980.000        RETURN  
981.000 130     LOC = 57  
982.000        RETURN  
983.000 140     LOC = 73  
984.000        RETURN  
985.000 150     LOC = 93  
986.000        RETURN  
987.000 160     LOC = 117  
988.000        RETURN

989.000 170 LOC = 145  
990.000 RETURN  
991.000 180 LOC = 179  
992.000 RETURN  
993.000 END  
994.000 BLOCK DATA  
995.000 COMMON/BLOCK/QX(219),QW(219)  
996.000 \* 3 PTS  
997.000 DATA (QX(I),I=1,3)/-.774596669241,0.00000000,+.774596669241/  
998.000 DATA (QW(I),I=1,3)/.5555555555,.888888888888,.555555555555/  
999.000 \* 4 PTS  
1000.000 DATA (QX(I),I=4,7)/-.861136311594,-.3399810435848,.3399810435848,  
1001.000 +.861136311594/  
1002.000 DATA (QW(I),I=4,7)/.347854845137,.652145154862,.652145154862,  
1003.000 +.347854845137/  
1004.000 \* 6 PTS.  
1005.000 DATA (QX(I),I=8,13)/.93246951420315,.66120938646626,  
1006.000 +.23861918608319,  
1007.000 +-23861918608319,-.66120938646626,-.93246951420315/  
1008.000 DATA (QW(I),I=8,13)/.17132449237917,.36076157304814,  
1009.000 +.46791393457269,  
1010.000 +.46791393457269,.36076157304814,.17132449237917/  
1011.000 \* 8 PTS.  
1012.000 DATA (QX(I),I=14,21)/-.9602898564,-.7966664774,-.5255324099,  
1013.000 +-.1834346424,.1834346424,.5255324099,.7966664774,.9602898564/  
1014.000 DATA (QW(I),I=14,21)/.1012285362,.2223810344,.3137066458,  
1015.000 +.3626837833,.3626837833,.3137066458,.2223810344,.1012285362/  
1016.000 \* 10 PTS.  
1017.000 DATA (QX(I),I=22,31)/-.9739065285,-.8650633666,-.6794095682,  
1018.000 +-.4333953941,-.1488743389,  
1019.000 +.1488743389,.4333953941,.6794095682,.8650633666,.9739065285/  
1020.000 DATA (QW(I),I=22,31)/.0666713443,.1494513491,.2190863625,  
1021.000 +.2692667193,.2955242247,  
1022.000 +.2955242247,.2692667193,.2190863625,.1494513491,.0666713443/  
1023.000 \* 12 PTS.  
1024.000 DATA (QX(I),I=32,43)/-.981560634246,-.90411725637,-.769902674194,  
1025.000 +-.587317954286,-.367831498998,-.125233408511,.125233408511,  
1026.000 +.367831498998,.587317954286,.769902674194,.904117256370,  
1027.000 +.981560634246/  
1028.000 DATA (QW(I),I=32,43)/.047175336386,.106939325995,.160078328543,  
1029.000 +.203167426723,.233492536538,.249147045813,.249147045813,  
1030.000 +.233492536538,.203167426723,.160078328543,.106939325995,  
1031.000 +.047175336386/  
1032.000 \* 14 PTS.  
1033.000 DATA (QX(I),I=44,57)/-.986283808696,-.928434883663,-.82720131507,  
1034.000 +-.687292904811,-.515248636358,-.319112368927,-.108054948707,  
1035.000 +.108054948707,.319112368927,.515248636358,.687292904811,  
1036.000 +.827201315069,.928434883663,.986283808696/  
1037.000 DATA (QW(I),I=44,57)/.035119460331,.080158087159,.121518570687,  
1038.000 +.157203167158,.185538397477,.205198463721,.215263853463,  
1039.000 +.215263853463,.205198463721,.185538397477,.157203167158,  
1040.000 +.121518570687,.080158087159,.035119460331/  
1041.000 \* 16 PTS.  
1042.000 DATA (QX(I),I=58,73)/-.989400934991,-.944575023073,-.865631202388,  
1043.000 +-755404408355,-.617876244403,-.458016777657,-.281603550779,

1044.000      +-,.095012509837,,.095012509837,,.281603550779,,.458016777657,  
 1045.000      +-,.617876244403,,.755404408355,,.865631202387,,.944575023073,  
 1046.000      +-,.989400934992/  
 1047.000      DATA (QW(I),I=58,73)/-.027152459412,,.062253523938,,.095158511682,  
 1048.000      +-,.124628971255,,.149595988816,,.169156519395,,.182603415045,  
 1049.000      +-,.189450610455,,.189450610455,,.182603415045,,.169156519395,  
 1050.000      +-,.149595988816,,.124628971255,,.095158511682,,.062253523938,  
 1051.000      +-,.0271524594117/  
 1052.000 \* 20 PTS.  
 1053.000      DATA (QX(I),I=74,93)/-.9931285991,-.9639719272,-.9122344282,  
 1054.000      +-,.8391169718,  
 1055.000      +-,.7463319064,-.6360536807,-.5108670019,-.3737060887,-.2277858511,  
 1056.000      +-,.07652652113,,.07652652113,,.2277858511,,.3737060887,,.5108670019,  
 1057.000      +-,.6360536807,  
 1058.000      +-,.7463319064,,.8391169718,,.9122344282,,.9639719272,,.9931285991/  
 1059.000      DATA (QW(I),I=74,93)/-.01761400713,,.04060142980,,.06267204833,  
 1060.000      +-,.08327674157,  
 1061.000      +-,.1019301198,,.1181945319,,.1316886384,,.1420961093,,.1491729864,  
 1062.000      +-,.1527533871,  
 1063.000      +-,.1527533871,,.1491729864,,.1420961093,,.1316886384,,.1181945319,  
 1064.000      +-,.1019301198,  
 1065.000      +-,.08327674157,,.06267204833,,.04060142980,,.01761400713/  
 1066.000 \* 24 PTS.  
 1067.000      DATA (QX(I),I=94,117)/-.9951872199,-.9747285559,-.9382745520,  
 1068.000      +-,.8864155270,-.8200019859,-.7401241915,-.6480936519,  
 1069.000      +-,.5454214713,-.4337935076,-.3150426796,-.1911188674,  
 1070.000      +-,.06405689286,,.06405689286,,.1911188674,,.3150426796,,.4337935076,  
 1071.000      +-,.5454214713,,.6480936519,,.7401241915,,.8200019859,,.8864155270,  
 1072.000      +-,.9382745520,,.9747285559,,.9951872199/  
 1073.000      DATA (QW(I),I=94,117)/.01234122979,,.02853138862,,.04427743881,  
 1074.000      +-,.05929858491,,.07334648141,,.08619016153,,.09761865210,,.1074442701,  
 1075.000      +-,.1155056680,,.1216704729,,.1258374563,,.1279381953,,.1279381953,  
 1076.000      +-,.1258374563,,.1216704729,,.1155056680,,.1074442701,,.0976186521,  
 1077.000      +-,.08619016153,,.07334648141,,.05929858491,,.04427743881,  
 1078.000      +-,.02853138862,,.01234122979/  
 1079.000 \* 28 PTS.  
 1080.000      DATA (QX(I),I=118,145)/-.9964424975,-.9813031653,-.9542592806,  
 1081.000      +-,.9156330263,-.8658925225,-.8056413709,-.7356108780,  
 1082.000      +-,.6566510940,-.5697204718,-.4758742249,-.3762515160,  
 1083.000      +-,.2720616276,-.1645692821,-.05507928988,,.05507928988,  
 1084.000      +-,.1645692821,,.2720616276,,.3762515160,,.4758742249,,.5697204718,  
 1085.000      +-,.6566510940,,.7356108780,,.8056413709,,.8658925225,,.9156330263,  
 1086.000      +-,.9542592806,,.9813031653,,.9964424975/  
 1087.000      DATA (QW(I),I=118,145)/.009124282593,,.02113211259,,.03290142778,  
 1088.000      +-,.04427293475,,.05510734567,,.06527292396,,.07464621423,  
 1089.000      +-,.08311341722,,.09057174439,,.09693065799,,.1021129675,,.1060557659,  
 1090.000      +-,.1087111922,,.1100470130,,.1100470130,,.1087111922,,.1060557659,  
 1091.000      +-,.1021129675,,.09693065799,,.09057174439,,.08311341722,,.07464621423,  
 1092.000      +-,.06527292396,,.05510734567,,.04427293475,,.03290142778,  
 1093.000      +-,.02113211259,,.009124282593/  
 1094.000 \* 34 PTS.  
 1095.000      DATA (QX(I),I=146,179)/-.9975717537,-.9872278164,-.9687082625,  
 1096.000      +-,.9421623974,-.9078096777,-.8659346383,-.8168842279,  
 1097.000      +-,.7610648766,-.6989391132,-.6310217270,-.5578755006,  
 1098.000      +-,.4801065451,-.3983592777,-.3133110813,-.2256666916,

1099.000 +- .1361523572, -.04550982195, .04550982195, .1361523572,  
1100.000 +- .2256666916, .3133110813, .3983592777, .4801065451, .5578755006,  
1101.000 +- .6310217270, .6989391132, .7610648766, .8168842279, .8659346383,  
1102.000 +- .9078096777, .9421623974, .9687092625, .9872278164, .9975717537/  
1103.000 DATA (QW(I), I=146,179)/.006229140555, .01445016274, .02256372198,  
1104.000 +- .03049138063, .03816659379, .04552561152, .05250741457, .05905413582,  
1105.000 +- .06511152155, .07062937581, .07556198466, .07986844433, .08351309969,  
1106.000 +- .08646573974, .08870189783, .09020304437, .09095674033, .09095674033,  
1107.000 +- .09020304437, .08870189783, .08646573974, .08351309969, .07986844433,  
1108.000 +- .07556197466, .07062937581, .06511152155, .05905413582, .05250741457,  
1109.000 +- .04552561152, .03816659379, .03049138063, .02256372198, .01445016274,  
1110.000 +- .006229140555/  
1111.000 \* 40 PTS.  
1112.000 DATA (QX(I), I=180,219)/-.9982377097, -.9907262386, -.9772599499,  
1113.000 +- .9579168192, -.9328128082, -.9020988069, -.8659595032, -.8246122308,  
1114.000 +- .7783056514, -.7273182551, -.6719566846, -.6125538896, -.549467125,  
1115.000 +- .4830758016, -.4137792043, -.3419940908, -.268152185, -.1926975807,  
1116.000 +- .1160840706, -.0387724175, .0387724175, .1160840706, .1926975807,  
1117.000 +- .268152185, .3419940908, .4137792043, .4830758016, .549467125,  
1118.000 +- .6125538896, .6719566846, .7273182551, .7783056514, .8246122308,  
1119.000 +- .8659595032, .9020988069, .9328128082, .9579168192, .9772599499,  
1120.000 +- .9907262386, .9982377097/  
1121.000 DATA (QW(I), I=180,219)/.00452127709, .0104982845, .0164210583,  
1122.000 +- .0222458491, .0279370069, .0334601952, .0387821679, .0438709081,  
1123.000 +- .0486958076, .0532278469, .0574397690, .0613062424, .0648040134,  
1124.000 +- .0679120458, .0706116473, .0728865823, .0747231690, .0761103619,  
1125.000 +- .0770398181, .0775059479, .0775059479, .0770398181, .0761103619,  
1126.000 +- .0747231690, .0728865823, .0706116473, .0679120458, .0648040134,  
1127.000 +- .0613062424, .0574397690, .0532278469, .0486958076, .0438709081,  
1128.000 +- .0387821679, .0334601952, .0279370069, .0222458491, .0164210583,  
1129.000 +- .0104982845, .00452127709/  
1130.000 END  
\*

C.3 EXAMPLE OF INPUT DATA FILE PAREFL.DAT

```
ANIK-C HP REFLECTOR
11.950
1
1.60
2.20
.375
.750
8.0
0
0.0 0.0 0.0
0.0 -28.80 0.0
2
0
1.0 0.0
70.0 72.0 72.0 36.0 0.0
0
1
8 8
0.0 2.0 9 0.0 2.0 9
0.0 0.0 0.0
0.0
!
```

C.4 SAMPLE OUTPUT

ANIK-C HF REFLECTOR  
FREQUENCY IN GHZ

11.9500

NO OF HURNS

1

E-PLANE HORN APERTURE DIM - B IN INS.

1.6000

H-PLANE HORN APERTURE DIM - A IN INS.

2.2000

INPUT WAVEGUIDE DIMENSION B(E-PLANE) IN INS.

.3750

INPUT WAVEGUIDE DIMENSION A(H-PLANE) IN INS.

.7500

AXIAL HORN LENGTH IN INS.

8.0000

OPT. CHOSEN - COLLECTIVE MOVEMENT AND ROTATION OF HORN ARRAY

0

DISPLACEMENT OF HORNS IN INS.

.0000 .0000 .0000

ROT. OF HORNS ABOUT X-,Y-,AND Z-AXIS IN DEG.

.0000 -28.8000 .0000

POLAR. OF ANTENNA SYS. - VP(X-AXIS)=1,HP(Y-AXIS)=2

2

HORN TYPE,0=ORD,1=DIEL,2=CORR,3=BOTH(1+2),4=DIEL TRIF,5=TRIF

0

REL. POWER(W) AND PHASE(DEG) OF HORN EXCITATIONS

1.0000 .0000

FOC LTH.,APER. X-DIM,Y-DIM AND X-OFFSET IN INS.

70.0000 72.0000 72.0000 36.0000 .0000

INTEG. PTS. SPEC. BY USER FOR RADIAL AND PHI-VAR.

MUST BE A MEMBER OF THIS SET - 3,4,6,8,10,12,14,16,20,24,28,34,40

8 8

START,STOP AND NO. OF PTS. FOR AZ,EL SCAN

.00000 2.00000 9 .00000 2.00000 9

X-,Y-,Z-TRANSLATION OF FIELD CO-ORD. SYSTEM IN INS

.0000 .0000 .0000

ROTATION OF FIELD POLARISATION VECTOR IN DEGREES

.0000

SPILL-OVER EFFICIENCY = .821

CO-POLAR GAIN IN DB

ELEV \*

AZIMUTH (DEG)

X-POLAR GAIN IN DB

ELEV *	AZIMUTH (DEG)									
(DEG) *	.00	.25	.50	.75	1.00	1.25	1.50	1.75	2.00	
*	*	*	*	*	*	*	*	*	*	
*	2.00*	-105.2	-19.7	-16.5	-20.1	-22.5	-11.3	-7.5	-7.6	-12.9
*	1.75*	-103.9	-13.6	-8.5	-7.1	-9.3	-21.8	-11.9	-6.4	-6.7
*	1.50*	-110.7	-16.9	-9.2	-4.8	-3.2	-5.3	-16.3	-10.6	-5.3
*	1.25*	-106.1	-11.0	-11.1	-13.6	-4.0	-1.4	-4.1	-20.8	-7.5
*	1.00*	-102.0	.8	3.7	.9	-11.8	-2.6	-.4	-5.5	-16.3

*	.75*	-108.9	6.9	10.5	9.5	3.6	-12.3	.1	-1.0	-14.4
*	.50*	-96.5	10.6	14.5	14.0	9.9	-2.2	-1.6	1.0	-6.4
*	.25*	-96.7	12.6	16.6	16.4	12.8	3.6	-4.6	1.6	-3.6
*	.00*	-92.8	13.2	17.2	17.1	13.7	5.1	-6.4	1.7	-2.8

### CO-POLAR PHASE IN DEG

APPENDIX DD.1 Description of Computer Program HORNPAT\_SIF

IDENTIFICATION: HORNPAT\_SIF

PURPOSE: The program computes E- and H-plane patterns of single mode or multimode pyramidal and conical horns.

AUTHOR: K. K. Chan,  
Chan Technologies Inc.,  
26 Calais Circle,  
Kirkland, Quebec,  
H9H 3V3.

Tel: (514) 697-6419.

DESCRIPTION: The radiation patterns of the following horn models are computed by the program:

- Single mode conical horn excited in the fundamental  $TE_{11}$  mode.
- dual mode conical horn excited with  $TE_{11}$  and  $TM_{11}$  modes.
- single mode pyramidal horn excited in the fundamental  $TE_{10}$  mode.
- multimode pyramidal horn excited with  $TE_{10}$  and  $TE/TM_{12}$  mode pair.

This program allows the user to view the patterns of horns whose dimensions are known. One can also observe the effects on patterns by changing the amplitude ratio and phase of modes in a multimode horn.

USAGE (INPUT):

The input data required are to be supplied in a file named HORNPAT\_DAT. Data may be written in free format and follow the sequence laid out below. Data input is list directed.

IHEAD (I)	-	Title of run. Maximum of 60 characters.
ITYPE	-	Type of horn.
	=	0, pyramidal horn.
	=	1, conical horn.
AM	-	Amplitude ratio of the higher order mode relative to the fundamental mode.
	=	0.0, for fundamental mode operation.
	=	0.10 - 0.125, for small dual mode conical horn.
	=	0.670 for small multimode pyramidal horns.

These are only suggested values for mode content. For a given horn, a value should be found that will equalise the beamwidths down to -10 dB point.

PM	-	Relative phase in radians of the higher order mode.
	=	0.0 (small horn feeds).
B	-	E-plane horn aperture dimension in inches. (pyramidal horn only) $B \leq 8 \lambda$
A	-	H-plane horn aperture dimension in inches. (pyramidal horn only) $A \leq 8 \lambda$
WGB	-	Input waveguide E-plane dimension in inches. (pyramidal horn only) $WGB \leq B$ .

WGA - Input waveguide H-plane dimension in inches.  
(pyramidal horn only) WGA  $\leq A$ .  
AR - Circular horn aperture radius in inches.  
(conical horn only) AR  $\leq 8 \lambda$   
WGR - Input circular waveguide radius in inches.  
(conical horn only) WGR  $\leq AR$ .  
HRNLTH - Horn length in inches.  
MODH - Choice of aperture field model.  
= 0, electric field model.  
= 1, Chu model.  
FREQ - Frequency in GHz.  
NPT - No. of observation points between 0 and 90 deg.

OUTPUT: All input data are printed out for verification and run identification. This is followed by the normalised E- and H-plane amplitude and phase patterns between the angular range of  $0^\circ$  and  $90^\circ$ .

CODING INFORMATION: Program is written in FORTRAN 77 for use on the CRC Honeywell CP-6 computer.

RESTRICTIONS: The number of observation points between  $0^\circ$  and  $90^\circ$  is restricted to 91 equally spaced points, i.e. at  $1^\circ$  interval. To increase this number to NPT, make the following changes.

MAIN PROGRAM: Change the dimensions of arrays EPA, EPP, HPA, HPP and THETA to NPT.

SUBROUTINE PYRHRN: Change the dimensions of arrays EPA, EPP,  
HPA, HPP and THETA to NPT.

SUBROUTINE CONHRN: Change the dimensions of arrays EPA, EPP,  
HPA, HPP and THETA to NPT.

SUBROUTINE PTNORM: Change the dimensions of arrays EPA, EPP,  
HPA, HPP.

D.2 PROGRAM LISTING

```
1.000      PROGRAM HORNPAT
2.000 *
3.000 * PROGRAM COMPUTES E- AND H-PLANE PATTERNS OF SINGLE MODE AND
4.000 * MULTIMODE PYRAMIDAL AND CONICAL HORNS.
5.000 * SINGLE MODE PYRAMIDAL HORN CONTAINS TE10 MODE.
6.000 * MULTIMODE PYRAMIDAL HORN CONTAINS TE10 , TE12 AND TM12 MODES.
7.000 * SINGLE MODE CONICAL HORN CONTAINS TE11 MODE.
8.000 * MULTIMODE CONICAL HORN CONTAINS TE11 AND TM11 MODES.
9.000 * WRITTEN BY CHAN TECHNOLOGIES INC. , APRIL 1984.
10.000 *
11.000      DIMENSION EPA(91),EPP(91),HPA(91),HPP(91),THETA(91),IHEAD(15)
12.000      COMMON/PATTERN/EPA,EPP,HPA,HPP,NPT,THETA
13.000 *
14.000      OPEN(UNIT=5,NAME='HORNPAT.DAT',STATUS='OLD',USAGE='INPUT')
15.000 *
16.000 * IHEAD = HEADING. MAX. 60 CHARACTERS.
17.000 *
18.000      READ(5,10) (IHEAD(I),I=1,15)
19.000 10    FORMAT(15A4)
20.000 *
21.000 * ITYPE = TYPE OF HORN
22.000 *      = 0 , PYRAMIDAL HORN
23.000 *      = 1 , CONICAL HORN
24.000 *
25.000      READ(5,*) ITYPE
26.000 *
27.000 * SPEC. OF HIGHER ORDER MODE CONTENT IN ADDITION TO THE BASIC MODE.
28.000 * FOR CONICAL HORN, THE HIGHER ORDER MODE IS TM11.
29.000 * FOR PYRAMIDAL HORN, THE HIGHER ORDER MODE PAIR IS TE/TM12.
30.000 * AM = AMPLITUDE RATIO OF HIGHER ORDER MODE.
31.000 * PM = REL. PHASE OF HIGHER ORDER MODE IN RADIANS.
32.000 *
33.000      READ(5,*) AM , PM
34.000 * MODE = 1 , SINGLE MODE (FUNDAMENTAL)
35.000 *      = 2 , MULTIMODE (FUNDAMENTAL + HIGHER ORDER)
36.000 *
37.000      MODE = 1
38.000      IF (AM.GT.1.0E-02) MODE = 2
39.000 *
40.000      IF (ITYPE.EQ.1) GO TO 20
41.000 *
42.000 * A = H-PLANE HORN APERTURE DIMENSION IN INCHES.
43.000 * B = E-PLANE HORN APERTURE DIMENSION IN INCHES.
44.000 *
45.000      READ(5,*) B,A
46.000 *
47.000 * WGA = INPUT WAVEGUIDE H-PLANE DIMENSION IN INCHES.
48.000 * WGB = INPUT WAVEGUIDE E-PLANE DIMENSION IN INCHES.
49.000 *
50.000      READ(5,*) WGB,WGA
51.000      GO TO 30
52.000 *
53.000 * AR = CIRCULAR HORN APERTURE RADIUS IN INCHES.
```

```
54.000 * WGR = INPUT CIRCULAR WAVEGUIDE RADIUS IN INCHES.  
55.000 *  
56.000 20 READ(5,*) AR,WGR  
57.000 *  
58.000 * HRNLTH = HORN LENGTH IN INCHES.  
59.000 *  
60.000 30 READ(5,*) HRNLTH  
61.000 *  
62.000 * MODH = APERTURE FIELD MODEL  
63.000 *      = 0 , ELECTRIC FIELD MODEL  
64.000 *      = 1 , CHU MODEL  
65.000 *  
66.000 READ(5,*) MODH  
67.000 *  
68.000 * FREQ = FREQUENCY IN GHZ  
69.000 *  
70.000 READ(5,*) FREQ  
71.000 *  
72.000 * NPT = NO. OF OBSERVATION POINTS BETWEEN 0 AND 90 DEG.  
73.000 *  
74.000 READ(5,*) NPT  
75.000 *  
76.000 * END OF INPUT DATA  
77.000 *  
78.000 PRINT 10 , (IHEAD(I),I=1,15)  
79.000 PRINT 40  
80.000 40 FORMAT(1X,'HORN TYPE - 0=PYRAMIDAL , 1=CONICAL')  
81.000 PRINT 50 , ITYPE  
82.000 50 FORMAT(1X,I2)  
83.000 PRINT 60  
84.000 60 FORMAT(1X,'AMPLITUDE AND PHASE (RAD) OF HIGHER ORDER MODE')  
85.000 PRINT 70 , AM , PM  
86.000 70 FORMAT(1X,2F7.3)  
87.000 IF (ITYPE.EQ.1) GO TO 100  
88.000 PRINT 80  
89.000 80 FORMAT(1X,'E- AND H-PLANE RECT. APER. DIM. IN INS.')  
90.000 PRINT 70 , A,B  
91.000 PRINT 90  
92.000 90 FORMAT(1X,'E- AND H-PLANE INPUT WG. DIM. IN INS.')  
93.000 PRINT 70 , WGA,WGB  
94.000 GO TO 120  
95.000 100 PRINT 110  
96.000 110 FORMAT(1X,'CIR. HORN APER. AND INPUT WG. RADII IN INS.')  
97.000 PRINT 70 , AR,WGR  
98.000 120 PRINT 130  
99.000 130 FORMAT(1X,'HORN LENGTH IN INS.')  
100.000 PRINT 70 , HRNLTH  
101.000 PRINT 140  
102.000 140 FORMAT(1X,'HORN APETURE FIELD MODEL - =0,E-FIELD ; =1,CHU')  
103.000 PRINT 50 , MODH  
104.000 PRINT 150  
105.000 150 FORMAT(1X,'FREQUENCY IN GHZ')  
106.000 PRINT 70 , FREQ  
107.000 PRINT 155  
108.000 155 FORMAT(1X,'NO. OF FIELD OBSERVATION POINTS FROM 0 TO 90 DEG.')
```

```
109.000      PRINT 50 , NPT
110.000 *
111.000 * COMPUTE OBSERVATION POINTS
112.000 *
113.000      TINC = 1.5707963/(NPT - 1)
114.000      DO 165 I = 1,NPT
115.000      THETA(I) = TINC*(I-1)
116.000 165  CONTINUE
117.000      RK = 0.532344*FREQ
118.000      IF (ITYPE.EQ.1) GO TO 170
119.000      CALL PYRHRN(A,B,WGA,WGB,HRNLTH,AM,PM,MODH,RK)
120.000      GO TO 180
121.000 170  CALL CONHRN(AR,WGR,HRNLTH,MODE,AM,PM,MODH,RK)
122.000 *
123.000 * CONVERT AMPLITUDE INTO DB AND PHASE INTO DEG.
124.000 *
125.000 180  DO 190 I = 1,NPT
126.000      HPA(I) = 20.0*ALOG10(HPA(I))
127.000      EPA(I) = 20.0*ALOG10(EPA(I))
128.000      HPP(I) = HPP(I)*57.295779
129.000      EPP(I) = EPP(I)*57.295779
130.000      THETA(I) = THETA(I)*57.295779
131.000 190  CONTINUE
132.000      PRINT 200
133.000 200  FORMAT(//,18X,'E-PLANE PATTERN',11X,'H-PLANE PATTERN')
134.000      PRINT 210
135.000 210  FORMAT(18X,15(1H-),11X,15(1H-))
136.000      PRINT 220
137.000 220  FORMAT(1X,'THETA(DEG)',4X,'AMPL(DB)',4X,'PHASE(DEG)',4X,
+ 'AMPL(DB)',4X,'PHASE(DEG)')
138.000      PRINT 230
139.000      PRINT 230
140.000 230  FORMAT(1X,65(1H-))
141.000      DO 240 I = 1,NPT
142.000      PRINT 250 , THETA(I),EPA(I),EPP(I),HPA(I),HPP(I)
143.000 240  CONTINUE
144.000 250  FORMAT(4X,F5.2,1X,4(6X,F7.2))
145.000      STOP
146.000      END
147.000      SUBROUTINE PYRHRN(A,B,WGA,WGB,HRNLTH,AM,PM,MODH,RK)
148.000 *
149.000 * COMPUTES PATTERNS OF SINGLE MODE OR MULTIMODE PYRAMIDAL HORNS
150.000 *
151.000      DIMENSION EPA(91),EPP(91),HPA(91),HPP(91),THETA(91)
152.000      COMPLEX HAR(25),EAR(25),A12,HSUM,ESUM,CSUM,EF
153.000      COMMON/PATERN/EPA,EPP,HPA,HPP,NPT,THETA
154.000      COMMON/BLOCK/QX(118),QW(118)
155.000 *
156.000 * COMPUTE HORN AXIAL LENGTHS
157.000 *
158.000      ALE = 999.0
159.000      ALH = 999.0
160.000      IF (B.GT.WGB) ALE = HRNLTH*B/(B - WGB)
161.000      IF (A.GT.WGA) ALH = HRNLTH*A/(A - WGA)
162.000 *
163.000 * COMPUTE MODE COEFFICIENTS
```

```
164.000 *
165.000      A12 = AM*CMPLX(COS(PM),SIN(PM))
166.000 *
167.000 * SELECTION OF APPROPRIATE QUADRATURE FORMULA
168.000 *
169.000      ARG = AMAX1(A,B)
170.000      IQ = RK*ARG/3.141592 + 1.0
171.000      IQ = (IQ+1)*1.40
172.000      CALL APQUAD(IQ,NQ,LOC)
173.000      PRINT 1 , NQ , LOC
174.000 1    FORMAT(1X,'QUADRATURE FORMULA = ',I3,5X,'LOCATION = ',I3)
175.000 *
176.000 * COMPUTE INTEGRAL INVARIANT WITH OBSERVATION ANGLE
177.000 *
178.000      HSUM = (0.0,0.0)
179.000      ESUM = (0.0,0.0)
180.000      DO 10 I = 1,NQ
181.000      ARG = RK*((QX(I+LOC)*A*0.50)**2)*0.50/ALH
182.000      HAR(I) = COS(1.5707963*QX(I+LOC))*CMPLX(COS(ARG),-SIN(ARG))*+
183.000      +QW(I+LOC)
184.000      HSUM = HSUM + HAR(I)
185.000      ARG = RK*((QX(I+LOC)*B*0.50)**2)*0.50/ALE
186.000      EAR(I) = (1.0 + A12*COS(3.1415926*QX(I+LOC)))*
187.000      +CMPLX(COS(ARG),-SIN(ARG))*QW(I+LOC)
188.000      ESUM = ESUM + EAR(I)
189.000 10   CONTINUE
190.000 *
191.000 * COMPUTE E-PLANE PATTERN
192.000 *
193.000      DO 40 I = 1,NPT
194.000      ST = RK*B*0.50*SIN(THETA(I))
195.000      CSUM = (0.0,0.0)
196.000      DO 30 J = 1,NQ
197.000      ARG = ST*QX(J+LOC)
198.000      CSUM = CSUM + EAR(J)*CMPLX(COS(ARG),SIN(ARG))
199.000 30   CONTINUE
200.000      EF = HSUM*CSUM
201.000      IF (MODH.EQ.1) EF = EF*(1.0 + COS(THETA(I)))
202.000      EPA(I) = CABS(EF)
203.000      EPP(I) = ATAN2(AIMAG(EF),REAL(EF))
204.000 40   CONTINUE
205.000 *
206.000 * COMPUTE H-PLANE PATTERN
207.000 *
208.000      DO 60 I = 1,NPT
209.000      ST = RK*A*0.50*SIN(THETA(I))
210.000      CSUM = (0.0,0.0)
211.000      DO 50 J = 1,NQ
212.000      ARG = ST*QX(J+LOC)
213.000      CSUM = CSUM + HAR(J)*CMPLX(COS(ARG),SIN(ARG))
214.000 50   CONTINUE
215.000      CSUM = CSUM*ESUM
216.000      EF = COS(THETA(I))*CSUM
217.000      IF (MODH.EQ.1) EF = EF + CSUM
218.000      HPA(I) = CABS(EF)
```

```

219.000      HPP(I) = ATAN2(AIMAG(EF),REAL(EF))
220.000 60    CONTINUE
221.000 *
222.000 * NORMALISE PATTERNS
223.000 *
224.000      CALL PTNORM(EPA,EPP,HPA,HPP,NPT)
225.000      RETURN
226.000      END
227.000      SUBROUTINE CONHRN(AR,WGR,HRNLTH,MODE,AM,PM,MODH,RK)
228.000 *
229.000 * COMPUTES PATTERNS OF CONICAL HORNS.
230.000 * E- AND H-PLANE NORM. AMP. ARE STORED IN ARRAYS EPA AND HPA RESP.
231.000 * E- AND H-PLANE NORM. PHASES ARE STORED IN ARRAYS EPP AND HPP RESP.
232.000 *
233.000      DIMENSION EPA(91),EPP(91),HPA(91),HPP(91),THETA(91)
234.000      COMPLEX HJ0(25),HJ2(25),EJ0(25),EJ2(25),ESUMT,ESUMP,HSUMT,
235.000      +HSUMP,B11,EF
236.000      COMMON/BLOCK/QX(118),QW(118)
237.000      COMMON/PATTERN/EPA,EPP,HPA,HPP,NPT,THETA,NQ,LOC
238.000 *
239.000 * COMPUTE AXIAL LENGTH
240.000 *
241.000      AL = 999.0
242.000      IF (AR.GT.WGR) AL = HRNLTH*AR/(AR - WGR)
243.000 *
244.000 * COMPUTE MODE COEFFICIENT
245.000 *
246.000      B11 = 2.08116*AM*CMPLX(COS(PM),SIN(PM))
247.000 *
248.000 * SELECTION OF APPROPRIATE QUADRATURE FORMULA
249.000 *
250.000      IQ = RK*AR/3.141592 + 1.0
251.000      IQ = (IQ+1)*1.40
252.000      CALL APQUAD(IQ,NQ,LOC)
253.000      PRINT 1,NQ,LOC
254.000 1      FORMAT(1X,'QUADRATURE FORMULA = ',I3,5X,'LOCATION = ',I3)
255.000 *
256.000 * COMPUTE INTEGRAND INVARIANT WITH OBSERVATION POINTS.
257.000 *
258.000      DO 10 I = 1,NQ
259.000      RHO = 0.50*(1.0 + QX(I+LOC))
260.000      ARG1 = RK*RHO*RHO*AR*AR*0.50/AL
261.000      ARG2 = 1.84118*RHO
262.000      CALL BESEL(ARG2,BJ0,BJ2)
263.000      ESUMT = CMPLX(COS(ARG1),-SIN(ARG1))
264.000      HJ2(I) = BJ2*RHO*ESUMT*QW(I+LOC)
265.000      HJ0(I) = BJ0*ESUMT*QW(I+LOC)*RHO
266.000      IF (MODE.EQ.1) GO TO 10
267.000      ARG2 = 3.83171*RHO
268.000      CALL BESEL(ARG2,BJ0,BJ2)
269.000      EJ0(I) = BJ0*ESUMT*QW(I+LOC)*RHO
270.000      EJ2(I) = BJ2*ESUMT*QW(I+LOC)*RHO
271.000 10    CONTINUE
272.000 *
273.000 * COMPUTES E- AND H-PLANE PATTERNS

```

```
274.000 *
275.000      DO 40 I = 1,NPT
276.000      ST = RK*AR*SIN(THETA(I))
277.000      HSUMT = (0.0,0.0)
278.000      HSUMP = (0.0,0.0)
279.000      ESUMT = (0.0,0.0)
280.000      ESUMP = (0.0,0.0)
281.000      DO 20 J = 1,NQ
282.000      ARG = ST*0.50*(1.0 + QX(J+LOC))
283.000      CALL BESEL(ARG,BJ0,BJ2)
284.000      HSUMP = HSUMP - HJ2(J)*BJ2 - HJ0(J)*BJ0
285.000      HSUMT = HSUMT + HJ2(J)*BJ2 - HJ0(J)*BJ0
286.000      IF (MODE.EQ.1) GO TO 20
287.000      ESUMP = ESUMP - EJ2(J)*BJ2 + EJ0(J)*BJ0
288.000      ESUMT = ESUMT + EJ0(J)*BJ0 + EJ2(J)*BJ2
289.000 20    CONTINUE
290.000      BKH = 0.0
291.000      BKE = 0.0
292.000      IF (MODH.EQ.0) GO TO 30
293.000      BKH = SQRT(RK**2 - (1.84118/AR)**2)/RK
294.000      IF (MODE.EQ.1) GO TO 30
295.000      BKE = RK/SQRT(RK**2 - (3.83171/AR)**2)
296.000 30    CT = COS(THETA(I))
297.000      EF = (1.0 + BKH*CT)*HSUMT - (1.0+BKE*CT)*B11*ESUMT
298.000      EPA(I) = CABS(EF)
299.000      EPP(I) = ATAN2(AIMAG(EF),REAL(EF))
300.000      EF = (CT + BKH)*HSUMP - (CT+BKE)*B11*ESUMP
301.000      HPA(I) = CABS(EF)
302.000      HPP(I) = ATAN2(AIMAG(EF),REAL(EF))
303.000 40    CONTINUE
304.000 *
305.000 * NORMALISE PATTERNS
306.000 *
307.000      CALL PTNORM(EPA,EPP,HPA,HPP,NPT)
308.000      RETURN
309.000      END
310.000      SUBROUTINE PTNORM(EPA,EPP,HPA,HPP,NPT)
311.000 *
312.000 * NORMALISES AMPLITUDE AND PHASE PATTERNS.
313.000 *
314.000      DIMENSION EPA(91),EPP(91),HPA(91),HPP(91)
315.000 *
316.000      ANORM = EPA(1)
317.000      PNORM = EPP(1)
318.000      EPA(1) = EPA(1)/ANORM
319.000      EPP(1) = EPP(1) - PNORM
320.000      HPA(1) = HPA(1)/ANORM
321.000      HPP(1) = HPP(1) - PNORM
322.000      IF (NPT.EQ.1) RETURN
323.000      DO 10 I = 2,NPT
324.000      EPA(I) = EPA(I)/ANORM
325.000      HPA(I) = HPA(I)/ANORM
326.000      EPP(I) = EPP(I) - PNORM
327.000      PDIF = EPP(I) - EPP(I-1)
328.000      IF (PDIF.GE.3.141592) EPP(I) = EPP(I) - 6.283185
```

```

329.000      IF (PDIF.LE.-3.141592) EPP(I) = EPP(I) + 6.283185
330.000      HPP(I) = HPP(I) - PNORM
331.000      PDIF = HPP(I) - HPP(I-1)
332.000      IF (PDIF.GE.3.141592) HPP(I) = HPP(I) -6.283185
333.000      IF (PDIF.LE.-3.141592) HPP(I) = HPP(I) + 6.283185
334.000 10    CONTINUE
335.000      RETURN
336.000      END
337.000      SUBROUTINE BESEL(ARG,BJ0,BJ2)
338.000 *
339.000 * COMPUTES BESEL FUNCTION OF THE FIRST KIND , ZERO(BJ0) AND
340.000 * SECOND(BJ2) ORDER. ARG IS THE INPUT ARGUMENT.
341.000 *
342.000      IF (ARG.GE.3.0) GO TO 10
343.000 *
344.000 * 0 < ARG < 3
345.000 *
346.000      X2 = (ARG/3.0)**2
347.000      X4 = X2*X2
348.000      X6 = X4*X2
349.000      X8 = X6*X2
350.000      X10 = X8*X2
351.000      X12 = X10*X2
352.000      BJ0 = 1.0 - 2.2499997*X2 + 1.2656208*X4 - .3163866*X6
353.000      + + .0444479*X8 - .0039444*X10 + .0002100*X12
354.000      BJ2 = 0.5 - .56249985*X2 + .21093573*X4 - .03954289*X6
355.000      + + .00443319*X8 - .00031761*X10 + .00001109*X12
356.000      BJ2 = 2.0*BJ2 - BJ0
357.000      RETURN
358.000 *
359.000 * ARG > 3
360.000 *
361.000 10    X = 3.0/ARG
362.000      X2 = X**X
363.000      X3 = X2*X
364.000      X4 = X3*X
365.000      X5 = X4*X
366.000      X6 = X5*X
367.000      THETA = ARG - .78539816 - .04166397*X - .00003954*X2
368.000      + + .00262573*X3 - .00054125*X4 - .00029333*X5 + .00013558*X6
369.000      F = .79788456 - .00000077*X - .00552740*X2 - .00009512*X3
370.000      + + .00137237*X4 - .00072805*X5 + .00014476*X6
371.000      BJ0 = F*COS(THETA)/SQRT(ARG)
372.000      THETA = ARG - 2.35619449 + .12499612*X + .0000565*X2
373.000      + - .00637879*X3 + .00074348*X4 + .00079824*X5 - .00029166*X6
374.000      BJ2 = F*COS(THETA)/(ARG*SQRT(ARG))
375.000      BJ2 = 2.0*BJ2 - BJ0
376.000      RETURN
377.000      END
378.000      SUBROUTINE APQUAD(IQ,NQ,LOC)
379.000 *
380.000 * MATCHES THE NEAREST QUAD. FORMULA TO THAT REQUIRED.
381.000 * IQ = IQ POINT FORM. REQ.
382.000 * NQ = NEAREST AVAIL. IS NQ POINT FORM.
383.000 * LOC = LOCATION OF FORM.

```

```
384.000 *
385.000      INTEGER IQF(10)
386.000      DATA NQF,IQF/10,3,4,6,8,10,12,14,16,20,25/
387.000 *
388.000      DO 10 I = 1,NQF
389.000      IF (IQ.LE.IQF(I)) GO TO 30
390.000 10    CONTINUE
391.000      PRINT 20
392.000 20    FORMAT(1X,'HORN IS TOO LARGE. QUAD. FORM. REQ. IS LARGER THAN',
393.000      +' AVAIL. IN PROG. EXECUTION TERMINATED.')
394.000      STOP
395.000 30    NQ = IQF(I)
396.000      CALL QRLOC(NQ,LOC)
397.000      RETURN
398.000      END
399.000      SUBROUTINE QRLOC(NQ,LOC)
400.000 *
401.000 * PURPOSE - DETERMINE LOCATION OF INTEGRATION FORMULA IN BLOCK DATA
402.000 * BLOCK DATA IS ASSUMED TO CONTAIN THE FOLLOWING FORMULAE.
403.000 * 3,4,6,8,10,14,16,20,25 PTS,
404.000 *
405.000      IF (NQ = 25) 20,150,160
406.000 20    IF (NQ = 16) 30,130,140
407.000 30    IF (NQ = 12) 40,110,120
408.000 40    IF (NQ = 8) 50,90,100
409.000 50    IF (NQ = 4) 60,70,80
410.000 60    LOC = 0
411.000      RETURN
412.000 70    LOC = 3
413.000      RETURN
414.000 80    LOC = 7
415.000      RETURN
416.000 90    LOC = 13
417.000      RETURN
418.000 100   LOC = 21
419.000      RETURN
420.000 110   LOC = 31
421.000      RETURN
422.000 120   LOC = 43
423.000      RETURN
424.000 130   LOC = 57
425.000      RETURN
426.000 140   LOC = 73
427.000      RETURN
428.000 150   LOC = 93
429.000      RETURN
430.000 160   LOC = 118
431.000      RETURN
432.000      END
433.000      BLOCK DATA
434.000      COMMON/BLOCK/QX(118),QW(118)
435.000 * 3 PTS
436.000      DATA (QX(I),I=1,3)/-.774596669241,0.00000000,+.774596669241/
437.000      DATA (QW(I),I=1,3)/.5555555555,.888888888888,.5555555555555555/
438.000 * 4 PTS
```

439.000 DATA (QX(I),I=4,7)/-.861136311594,-.3399810435848,.3399810435848,  
440.000 +.861136311594/  
441.000 DATA (QW(I),I=4,7)/.347854845137,.652145154862,.652145154862,  
442.000 +.347854845137/  
443.000 \* 6 PTS.  
444.000 DATA (QX(I),I=8,13)/.93246951420315,.66120938646626,  
445.000 +.23861918608319,  
446.000 +- .23861918608319,-.66120938646626,-.93246951420315/  
447.000 DATA (QW(I),I=8,13)/.17132449237917,.36076157304814,  
448.000 +.46791393457269,  
449.000 +.46791393457269,.36076157304814,.17132449237917/  
450.000 \* 8 PTS.  
451.000 DATA (QX(I),I=14,21)/-.9602898564,-.7966664774,-.5255324099,  
452.000 +- .1834346424,.1834346424,.5255324099,.7966664774,.9602898564/  
453.000 DATA (QW(I),I=14,21)/.1012285362,.2223810344,.3137066458,  
454.000 +.3626837833,.3626837833,.3137066458,.2223810344,.1012285362/  
455.000 \* 10 PTS.  
456.000 DATA (QX(I),I=22,31)/-.9739065285,-.8650633666,-.6794095682,  
457.000 +- .4333953941,-.1488743389,  
458.000 +.1488743389,.4333953941,.6794095682,.8650633666,.9739065285/  
459.000 DATA (QW(I),I=22,31)/.0666713443,.1494513491,.2190863625,  
460.000 +.2692667193,.2955242247,  
461.000 +.2955242247,.2692667193,.2190863625,.1494513491,.0666713443/  
462.000 \* 12 PTS.  
463.000 DATA (QX(I),I=32,43)/-.981560634246,-.90411725637,-.769902674194,  
464.000 +- .587317954286,-.367831498998,-.125233408511,.125233408511,  
465.000 +.367831498998,.587317954286,.769902674194,.904117256370,  
466.000 +.981560634246/  
467.000 DATA (QW(I),I=32,43)/.047175336386,.106939325995,.160078328543,  
468.000 +.203167426723,.233492536538,.249147045813,.249147045813,  
469.000 +.233492536538,.203167426723,.160078328543,.106939325995,  
470.000 +.047175336386/  
471.000 \* 14 PTS.  
472.000 DATA (QX(I),I=44,57)/-.986283808696,-.928434883663,-.82720131507,  
473.000 +- .687292904811,-.515248636358,-.319112368927,-.108054948707,  
474.000 +.108054948707,.319112368927,.515248636358,.687292904811,  
475.000 +.827201315069,.928434883663,.986283808696/  
476.000 DATA (QW(I),I=44,57)/.035119460331,.080158087159,.121518570687,  
477.000 +.157203167158,.185538397477,.205198463721,.215263853463,  
478.000 +.215263853463,.205198463721,.185538397477,.157203167158,  
479.000 +.121518570687,.080158087159,.035119460331/  
480.000 \* 16 PTS.  
481.000 DATA (QX(I),I=58,73)/-.989400934991,-.944575023073,-.865631202388,  
482.000 +- .755404408355,-.617876244403,-.458016777657,-.281603550779,  
483.000 +- .095012509837,.095012509837,.281603550779,.458016777657,  
484.000 +.617876244403,.755404408355,.865631202387,.944575023073,  
485.000 +.989400934992/  
486.000 DATA (QW(I),I=58,73)/.027152459412,.062253523938,.095158511682,  
487.000 +.124628971255,.149595988816,.169156519395,.182603415045,  
488.000 +.189450610455,.189450610455,.182603415045,.169156519395,  
489.000 +.149595988816,.124628971255,.095158511682,.062253523938,  
490.000 +.0271524594117/  
491.000 \* 20 PTS.  
492.000 DATA (QX(I),I=74,93)/-.9931285991,-.9639719272,-.9122344282,  
493.000 +- .8391169718,

494.000       +-,7463319064,-,6360536807,-,5108670019,-,3737060887,-,2277858511,  
495.000       +-,07652652113,,07652652113,,2277858511,,3737060887,,5108670019,  
496.000       +.6360536807,  
497.000       +.7463319064,,8391169718,,9122344282,,9639719272,,9931285991/  
498.000       DATA (QW(I),I=74,93)/.01761400713,.04060142980,.06267204833,  
499.000       +.08327674157,  
500.000       +.1019301198,,1181945319,,1316886384,,1420961093,,1491729864,  
501.000       +.1527533871,  
502.000       +.1527533871,,1491729864,,1420961093,,1316886384,,1181945319,  
503.000       +.1019301198,  
504.000       +.08327674157,.06267204833,.04060142980,.01761400713/  
505.000 \* 25 PTS.  
506.000       DATA (QX(I),I=94,118)/~,9955569697905,-,97666392145952,  
507.000       +-,94297457122897,  
508.000       +-,89499199787827,-,83344262876083,-,75925926303735,  
509.000       +-,67356636847347,  
510.000       +-,57766293024122,-,47300273144571,-,36117230580939,  
511.000       +-,24386688372099,  
512.000       +-,12286469261071,,00000000000000,,12286469261071,  
513.000       +,24386688372099,  
514.000       +.36117230580939,.47300273144571,.57766293024122,  
515.000       +.67356636847347,  
516.000       +.75925926303735,.83344262876083,.89499199787827,  
517.000       +.94297457122897,  
518.000       +.97666392145952,.9955569697905/  
519.000       DATA (QW(I),I=94,118)/.01139379850102,.026354986615032,  
520.000       +.04093915670130,  
521.000       +.054904695975835,.06803833381235,.0801407003350,  
522.000       +.09102826198296,  
523.000       +.10053594906705,.108519624474263,.114858259145711,  
524.000       +.119455763535784,  
525.000       +.12224244299031,.123176053726715,.12224244299031,.119455763535784,  
526.000       +.114858259145711,.108519624474263,.10053594906705,  
527.000       +.09102826198296,  
528.000       +.080140700335,.06803833381235,.05490469597583,  
529.000       +.0409391567013,  
530.000       +.026354986615032,.01139379850102/  
531.000       END  
\*

D.3 EXAMPLE OF INPUT FILE HORNPAT.DAT

DUAL MODE CIRCULAR HORN

1  
.100 0.0  
.620 .350  
5.0  
0  
12.45  
46

D.4 SAMPLE OUTPUT

UAL MODE CIRCULAR HORN

HORN TYPE - 0=PYRAMIDAL , 1=CONICAL

1

AMPLITUDE AND PHASE (RAD) OF HIGHER ORDER MODE

.100 .000

CIR. HORN APER. AND INPUT WG. RADII IN INS.

.620 .350

HORN LENGTH IN INS.

.5.000

HORN APETURE FIELD MODEL = =0,E-FIELD ; =1,CHU

0

FREQUENCY IN GHZ

12.450

NO. OF FIELD OBSERVATION POINTS FROM 0 TO 90 DEG.

46

QUADRATURE FORMULA = 4 LOCATION = 3

THETA(DEG)	E-PLANE PATTERN		H-PLANE PATTERN	
	AMPL(DB)	PHASE(DEG)	AMPL(DB)	PHASE(DEG)
.00	.00	.00	.00	.00
2.00	-.02	.00	-.02	.00
4.00	-.08	.01	-.08	.01
6.00	-.17	.03	-.18	.01
8.00	-.31	.05	-.31	.03
10.00	-.48	.08	-.49	.04
12.00	-.69	.11	-.70	.06
14.00	-.93	.15	-.96	.08
16.00	-1.21	.20	-1.25	.11
18.00	-1.53	.26	-1.57	.14
20.00	-1.89	.33	-1.94	.17
22.00	-2.28	.40	-2.34	.20
24.00	-2.71	.48	-2.78	.24
26.00	-3.17	.57	-3.26	.29
28.00	-3.66	.68	-3.77	.34
30.00	-4.19	.79	-4.31	.39
32.00	-4.75	.92	-4.89	.45
34.00	-5.35	1.06	-5.50	.51
36.00	-5.97	1.21	-6.15	.57
38.00	-6.62	1.38	-6.83	.64
40.00	-7.30	1.57	-7.54	.72
42.00	-8.01	1.78	-8.28	.80
44.00	-8.75	2.01	-9.05	.88
46.00	-9.51	2.26	-9.86	.97
48.00	-10.30	2.54	-10.69	1.07
50.00	-11.11	2.85	-11.55	1.16
52.00	-11.92	3.18	-12.45	1.27
54.00	-12.76	3.56	-13.37	1.38
56.00	-13.63	3.98	-14.31	1.49
58.00	-14.51	4.44	-15.29	1.61

60.00	-15.39	4.95	-16.30	1.73
62.00	-16.29	5.51	-17.34	1.85
64.00	-17.18	6.12	-18.41	1.97
66.00	-18.08	6.79	-19.52	2.10
68.00	-18.96	7.52	-20.68	2.22
70.00	-19.83	8.30	-21.89	2.34
72.00	-20.66	9.13	-23.16	2.46
74.00	-21.47	10.00	-24.52	2.57
76.00	-22.22	10.89	-25.98	2.68
78.00	-22.92	11.77	-27.59	2.77
80.00	-23.53	12.62	-29.40	2.86
82.00	-24.07	13.40	-31.54	2.93
84.00	-24.50	14.06	-34.19	2.99
86.00	-24.81	14.58	-37.82	3.03
88.00	-25.00	14.90	-43.91	3.06
90.00	-25.07	15.01	-149.01	3.07

\*STOP\*

APPENDIX EE.1 Description of Computer Program DSCRPLT\_SIF

IDENTIFICATION: DSCRPLTFSIF

PURPOSE: The program obtains the specified gain contours from an input gain matrix and plots them on a line printer using discrete symbols. The gain matrix is on a rectangular grid.

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DESCRIPTION: The program reads in the gain matrix and augments it with additional rows and columns through an interpolation method in which the curve and its derivative are continuous. The scale or angular interval per inch defined by the user for the axis that is along the paper is divided into a number of subintervals that is equal to the number of lines per inch (Lpi). The number of lpi is printer dependent. The larger the number, the finer is the contour map. Along each line which is either on azimuth cut or an elevation cut, depending on the map orientation, the gain is known at a number of equally spaced points from inter-

polation. The gain curve is approximated locally by a quadratic equation. The intercepts of this curve with the specified gain levels locate the contour points that are to be plotted. The resolution crosswise is determined by the number of characters per inch setting of the printer. By searching along each line for the contour points and plotting them when found, a contour map is created.

USAGE ( INPUT ):

Two input files are required. The first is named DSCRPLT\_DAT and the data required are listed below.

AZSCALE	-	Azimuth scale in degrees per inch.
ELSCALE	-	Elevation scale in degrees per inch.
KPI	-	Characters per inch, 10 or 12.
LPI	-	Lines per inch, 6, 8, or 12.
IAXIS	-	Plot orientation parameter
	=	0, Azimuth axis is along paper and elevation axis is across paper.
	=	1, Elevation axis is along paper and azimuth axis is across paper.
NCONT	-	Number of contours. Maximum is 18.
CONT(K)	-	Contour levels in dB.
AZB	-	Azimuth co-ordinate of boresight.
ELB	-	Elevation co-ordinate of boresight.

The following are data to be provided in a second file named GNMAT. These data are usually generated by the reflector analysis programs.

IHEAD(N)	-	Header of run.
AZS	-	Azimuth start angle in degrees of coverage.
AZE	-	Azimuth stop angle in degrees of coverage.
NAZ	-	Number of azimuth points.
ELS	-	Elevation start angle in degrees of coverage.
ELE	-	Elevation stop angle in degrees of coverage.
NEL	-	Number of elevation points.
GN(I,J)	-	Gain matrix entered row wise corresponding to an azimuth cut.

OUTPUT: All input data are printed out for reference, followed by a plot of the gain contours.

CODING INFORMATION:

Program is written in FORTRAN 77 for use on the CRC Honeywell CP-6 computer.

RESTRICTIONS: There is a restriction on the size of the gain matrix. With the present array dimensions, the maximum gain matrix size is 49 by 49. To increase the matrix size that can be treated, the dimensions of ZO and GN must be changed in the main program as well as in the subroutine MATINT.

First and second dimension of ZO = Larger of the two integers NEL and NAZ.

First dimension of GN = NEL + (NEL - 1) NAR

Second dimension of GN = NAZ + (NAZ - 1) NAC

NAR = No. of additional rows to be added  
per interval.

NAC = No. of additional columns to be added  
per interval.

NAL and NAC are defined in the DATA statement located at the beginning of the main program. They have been set to unity. As a result, the dimension of GN is 97 by 97.

E.2 PROGRAM LISTING

```

1.000      PROGRAM DSCRPLT
2.000 *
3.000 * PROGRAM PLOTS SPECIFIED GAIN CONTOURS FROM A GAIN MATRIX ON A LINE
4.000 * PRINTER. MATRIX MUST BE ON A REGULAR RECTANGULAR GRID.
5.000 * PLOTS ARE MADE UP OF DISCRETE SYMBOLS.
6.000 *
7.000 * WRITTEN BY K. K. CHAN , CHAN TECHNOLOGIES INC., FEB 1984.
8.000 *
9.000      DIMENSION Z0(49,49),GN(97,97),CONT(18)
10.000     DIMENSION XLABEL(75),YLABEL(13),ROOT(2),LINE(121)
11.000     INTEGER IHEAD(70),SYMB(18)
12.000     DIMENSION LAZ(9),LEL(9),LXL(9),LYL(9)
13.000 * SYMB = SYMBOLS FOR CONTOURS
14.000     DATA (SYMB(K),K=1,18)/1H#,1H-,1H*,1H$,1H@,1H&,1H+,1H%,
15.000     +1H=,1HA,1HB,1HC,1HD,1HE,1HF,1HG,1HH,1HI/
16.000     DATA (LAZ(N),N=1,9)/1H ,1HA,1HZ,1HI,1HM,1HU,1HT,1HH,1H /
17.000     DATA (LEL(N),N=1,9)/1HE,1HL,1HE,1HV,1HA,1HT,1HI,1HO,1HN/
18.000 * NAR = NO. OF ADDITIONAL ROWS GAIN MATRIX TO BE INCREASED BY.
19.000 * NAC = NO. OF ADDITIONAL COLS GAIN MATRIX TO BE INCREASED BY.
20.000     DATA NAR,NAC/1,1/
21.000 *
22.000 * FIRST INPUT DATA FILE
23.000     OPEN(1,FILE='DSCRPLT_DAT',STATUS='OLD',USAGE='INPUT')
24.000 * AZSCALE = AZIMUTH SCALE IN DEG PER INCH
25.000 * ELSCALE = ELEVATION SCALE IN DEG PER INCH
26.000 * N.B. SCALE FOR THE HORIZONTAL AXIS SHOULD BE CHOSEN SUCH THAT THE
27.000 * RESULTANT ACROSS PAGE PLOT SIZE TIMES NO. OF CHARAC. PER INS. DO
28.000 * NOT EXCEED 121. E.G. WITH 12 CPI , MAX. ACROSS PAGE PLOT SIZE IS
29.000 * 10 INS. THERE IS NO RESTRICTION TO ALONG PAGE (TOP TO BOTTOM) PLOT
30.000 * SIZE.
31.000     READ(1,*) AZSCALE,ELSCALE
32.000 * KPI = CHARACTERS PER INCH , 10 OR 12
33.000 * LPI = LINES PER INCH , 6 , 8 OR 12
34.000 * N.B. PRINTER SETTINGS MUST BE COMPATIBLE WITH KPI AND LPI SPECIFIED.
35.000     READ(1,*) KPI,LPI
36.000 * IAXIS = PARAMETER WHICH DETERMINES ORIENTATION OF PLOT
37.000 * IAXIS = 0 , AZ-AXIS IS ALONG PAPER AND EL-AXIS IS ACROSS PAPER
38.000 * IAXIS = 1 , EL-AXIS IS ALONG PAPER AND AZ-AXIS IS ACROSS PAPER
39.000     READ(1,*) IAXIS
40.000 * NCONT = NUMBER OF CONTOURS. MAX. 18
41.000     READ(1,*) NCONT
42.000 * CONT = CONTOUR LEVELS IN DB
43.000     READ(1,*) (CONT(K),K=1,NCONT)
44.000 * AZB = AZIMUTH CO-ORD OF BORESIGHT
45.000 * ELB = ELEVATION CO-ORD OF BORESIGHT
46.000     READ(1,*) AZB,ELB
47.000 * SECOND INPUT DATA FILE.
48.000     OPEN(2,FILE='GNMAT',STATUS='OLD',USAGE='INPUT')
49.000 * IHEAD = HEADER OF RUN
50.000     READ(2,1) (IHEAD(N),N=1,70)
51.000 1     FORMAT(70A1)
52.000 * AZS = AZIMUTH START ANGLE IN DEG.
53.000 * AZE = AZIMUTH STOP ANGLE IN DEG.

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54.000 * NAZ = NO. OF AZIMUTH PTS. (NO. OF EL CUTS)
55.000 * ELS = ELEVATION START ANGLE IN DEG.
56.000 * ELE = ELEVATION STOP ANGLE IN DEG.
57.000 * NEL = NO. OF ELEVATION PTS. (NO. OF AZ CUTS)
58.000      READ(2,*) AZS,AZE,NAZ,ELS,ELE,NEL
59.000      DO 10 I = 1,NEL
60.000      READ(2,*) (GN(I,J),J=1,NAZ)
61.000 10    CONTINUE
62.000      PRINT 15,(IHEAD(N),N=1,70)
63.000 15    FORMAT(//,20X,70A1)
64.000      PRINT 20
65.000 20    FORMAT(/,10X,'START AND STOP VALUES OF SCAN RANGE (DEG)',/
66.000      +' AND NUMBER OF COMPUTED POINTS',/)
67.000      PRINT 25, AZS,AZE,NAZ,ELS,ELE,NEL
68.000 25    FORMAT(10X,'AZS = ',F6.2,3X,'AZE = ',F6.2,3X,'NAZ = ',I2,/,10X,
69.000      +'ELS = ',F6.2,3X,'ELE = ',F6.2,3X,'NEL = ',I2,/)
70.000      PRINT 30
71.000 30    FORMAT(10X,'GAIN MATRIX (DB)',/)
72.000      DO 40 I = 1,NEL
73.000      PRINT 35, (GN(I,J),J=1,NAZ)
74.000 35    FORMAT(5X,21F6.2)
75.000 40    CONTINUE
76.000      PRINT 45, AZSCALE, ELScale
77.000 45    FORMAT(//,10X,'AZIMUTH AXIS SCALE = ',F10.5,' DEG/INCH',10X,
78.000      +//,10X,'ELEVATION AXIS SCALE = ',F8.5,' DEG/INCH')
79.000      PRINT 50, AZB, ELB
80.000 50    FORMAT(/,10X,'BORESIGHT',7X,'AZ = ',F6.2,3X,'EL = ',F6.2,
81.000      +' DEG')
82.000      PRINT 55
83.000 55    FORMAT(//,10X,'CONTOUR SYMBOLS AND CORRESPONDING',
84.000      +' DB VALUES', /)
85.000      PRINT 60, (SYMB(K) ,K=1,NCONT)
86.000 60    FORMAT(10X,'SYMBOL ',18(4X,A1,1X))
87.000      PRINT 65, (CONT(K),K=1,NCONT)
88.000 65    FORMAT(/,10X,'DB VALUE ',18F6.2)
89.000      IF (IAXIS.GT.0) GO TO 85
90.000      IF (KPI*(ELE-ELS)/ELSCALE.GT.121) GO TO 85
91.000      XSCALE = AZSCALE
92.000      YSCALE = ELScale
93.000      XS = AZS
94.000      XE = AZE
95.000      NX = NAZ
96.000      YS = ELS
97.000      YE = ELE
98.000      NY = NEL
99.000      XB = AZB
100.000     YB = ELB
101.000     DO 75 I = 1,NY
102.000     DO 70 J = 1,NX
103.000     ZO(I,J) = GN(I,J)
104.000 70    CONTINUE
105.000 75    CONTINUE
106.000     DO 80 N = 1,9
107.000     LXL(N) = LAZ(N)
108.000     LYL(N) = LEL(N)

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```
109.000 80    CONTINUE
110.000      GO TO 105
111.000 85    IF (KPI*(AZE-AZS)/AZSCALE.GT.121) GO TO 260
112.000      XSCALE = ELSCALE
113.000      YSCALE = AZSCALE
114.000      XS = ELE
115.000      XE = ELS
116.000      NX = NEL
117.000      YS = AZS
118.000      YE = AZE
119.000      NY = NAZ
120.000      XB = ELB
121.000      YB = AZB
122.000      DO 95 I=1,NY
123.000      DO 90 J = 1,NX
124.000      ZO(I,J) = GN(J,NY+1-I)
125.000 90    CONTINUE
126.000 95    CONTINUE
127.000      DO 100 N= 1,9
128.000      LXL(N) = LEL(N)
129.000      LYL(N) = LAZ(N)
130.000 100   CONTINUE
131.000 *
132.000 * ENLARGE GAIN MATRIX TO A FINER GRID
133.000 * ADDITIONAL ROWS (NAR) AND COLUMNS (NAC) ARE ADDED PER GRID INTERV.
134.000 *
135.000 105   CALL MATINT(ZO,NY,NX,NAR,NAC,GN)
136.000      DELTAX = ABS(XE-XS)/(NX-1)
137.000      DELTAY = (YE - YS)/(NY-1)
138.000      DX = XSCALE/LPI
139.000      NLINES = ABS(XE-XS)/DX + 1.5
140.000      IF(NLINES.LT.LPI+1) GO TO 240
141.000      DY = YSCALE/KPI
142.000      NCHAR = (YE - YS) / DY + 1.5
143.000      IF(NCHAR .LT. KPI + 1) GO TO 250
144.000      IMAX = NY - 2
145.000      JMAX = NX - 2
146.000     LBLX = ABS(XE - XS) / XSCALE + 1.5
147.000      DO 110 LBL=1,LBLX
148.000      XLABEL(LBL) = XS + (LBL - 1) * XSCALE
149.000      IF (IAxis.GT.0) XLABEL(LBL) = XS - (LBL-1)*XSCALE
150.000 110   CONTINUE
151.000     LBLY = (YE - YS) / YSCALE + 1.5
152.000      DO 115 LBL=1,LBLY
153.000      YLABEL(LBL) = YS + (LBL - 1) * YSCALE
154.000 115   CONTINUE
155.000      N1 = (NCHAR - 1) / 2 - 4
156.000      N2 = N1 + 1
157.000      N9 = N1 + 9
158.000      DO 120 N=1,N1
159.000      LINE(N) = 1H
160.000 120   CONTINUE
161.000      DO 125 N=N2, N9
162.000      M = N - N1
163.000      LINE(N) = LYL(M)
```

```

164.000 125  CONTINUE
165.000  LINE(NCHAR) = 1H
166.000  PRINT 130
167.000 130  FORMAT(//)
168.000  PRINT 135, (LINE(N), N=1, N9)
169.000 135  FORMAT(8X,12I1A1)
170.000  IF(KPI .EQ. 10) PRINT 137, (YLABEL(LBL), LBL=1, LBLY)
171.000  IF(KPI .EQ. 12) PRINT 139, (YLABEL(LBL), LBL=1, LBLY)
172.000 137  FORMAT(2X,13(4X,F6.2))
173.000 139  FORMAT(11(6X,F6.2))
174.000  DO 140 N=1,NCHAR
175.000  LINE(N) = 1H-
176.000  IF(((N-1)/KPI) * KPI .EQ. (N-1)) LINE(N) = 1H+
177.000 140  CONTINUE
178.000  DO 225 L=1, NLines
179.000  X = (L - 1) * DX
180.000  LBL = X / XSCALE + 1.5
181.000  J = X / DELTAX + 1
182.000  IF(J .GT. JMAX) J = JMAX
183.000  INT = J - 1
184.000  XP = X/DELTAX - INT
185.000  X = XS + X
186.000  RANGE = 1.0
187.000 *
188.000 * LOCATE CONTOUR POINTS BY FINDING INTERCEPTS OF QUADRATIC
189.000 * GAIN CURVE WITH CONTOUR LEVEL.
190.000 *
191.000  DO 180 I = 1, IMAX
192.000  F1 = (XP - 1.0)*(XP - 2.0)
193.000  F2 = XP*(2.0 - XP)
194.000  F3 = XP*(XP - 1.0)
195.000  FX1 = 0.25*F1*GN(I,J) + 0.5*F2*GN(I,J+1) + 0.25*F3*GN(I,J+2)
196.000  FX2 = 0.5*F1*GN(I+1,J) + F2*GN(I+1,J+1) + 0.5*F3*GN(I+1,J+2)
197.000  FX3 = 0.25*F1*GN(I+2,J)+0.5*F2*GN(I+2,J+1)+0.25*F3*GN(I+2,J+2)
198.000  A = FX1 - FX2 + FX3
199.000  B = -3.0*FX1 + 2.0*FX2 - FX3
200.000  C = 2.0*FX1
201.000  D = C
202.000  DO 175 K = 1, NCONT
203.000  C = D - CONT(K)
204.000  IF (ABS(A).LT.1E-10) GO TO 155
205.000  FACT = B**2 - 4.0*A*C
206.000  IF(FACT) 175,145,150
207.000 * ROOTS ARE EQUAL
208.000 145  ROOT(1) = - 0.5*B/A
209.000  ROOT(2) = ROOT(1)
210.000  GO TO 165
211.000 * ROOTS ARE REAL AND UNEQUAL
212.000 150  ROOT(1) = 0.5*(-B + SQRT(FACT))/A
213.000  ROOT(2) = 0.5*(-B - SQRT(FACT))/A
214.000  GO TO 165
215.000 155  IF(ABS(B).LT.1E-10) GO TO 160
216.000 * INTERSECTION OF A STRAIGHT LINE WITH CONTOUR LEVEL
217.000  ROOT(1) = -C/B
218.000  ROOT(2) = ROOT(1)

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```
219.000 GO TO 165
220.000 160 IF(ABS(C),GT,0.0001) GO TO 175
221.000 ROOT(1) = 0.0
222.000 ROOT(2) = 0.0
223.000 165 IF(I,EQ,IMAX) RANGE = 2.0
224.000 DO 170 II = 1, 2
225.000 IF(ROOT(II),LT,0.0 .OR. ROOT(II),GT,RANGE) GO TO 170
226.000 Y = YE - (I-1)*DELTAY - ROOT(II)*DELTAY
227.000 NDY = (Y - YS)/DY + 1.5
228.000 LINE(NDY) = SYMB(K)
229.000 170 CONTINUE
230.000 175 CONTINUE
231.000 180 CONTINUE
232.000 IF(ABS(X - XB) ,GE, DX/3.0) GO TO 185
233.000 NDY = (YB - YS)/DY + 1.5
234.000 LINE(NDY) = 1HX
235.000 185 LX = 1H
236.000 NL = (NLINES - 1)/2 - 4
237.000 IF(L,LE,NL .OR. L,GT,(NL+9)) GO TO 190
238.000 LX = LX(L - NL)
239.000 190 IF(L,EQ,1 .OR. ((L-1)/LPI)*LPI,EQ,(L-1)) GO TO 200
240.000 PRINT 195, LX, (LINE(N),N=1,NCHAR)
241.000 195 FORMAT(1X,1A1,7X,121A1)
242.000 GO TO 210
243.000 200 LINE(1) = 1H+
244.000 LINE(NCHAR) = 1H+
245.000 PRINT 205, LX,XLABELLBL,(LINE(N),N=1,NCHAR)
246.000 205 FORMAT(1X,1A1,F6.2,1X,121A1)
247.000 210 DO 215 N = 1,NCHAR
248.000 LINE(N) = 1H
249.000 215 CONTINUE
250.000 LINE(1) = 1HI
251.000 LINE(NCHAR) = 1HI
252.000 IF (L,NE,NLINES-1) GO TO 225
253.000 DO 220 N = 1,NCHAR
254.000 LINE(N) = 1H-
255.000 IF (((N-1)/KPI)*KPI,EQ,(N-1)) LINE(N) = 1H+
256.000 220 CONTINUE
257.000 225 CONTINUE
258.000 IF (KPI,EQ,10) PRINT 137,(YLABELLBL),LBL=1,LBLY)
259.000 IF(KPI,EQ,12) PRINT 139,(YLABELLBL),LBL=1,LBLY)
260.000 DO 230 N = 1,N1
261.000 LINE(N) = 1H
262.000 230 CONTINUE
263.000 DO 235 N = N2 , N9
264.000 M = N - N1
265.000 LINE(N) = LY(M)
266.000 235 CONTINUE
267.000 LINE(NCHAR) = 1H
268.000 PRINT 135, (LINE(N), N=1,NCHAR)
269.000 STOP
270.000 240 PRINT 245
271.000 245 FORMAT(///,10X,'X-AXIS SCALE TOO LARGE')
272.000 STOP
273.000 250 PRINT 255
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274.000 255 FORMAT(///,10X,'Y-AXIS SCALE TOO LARGE')
275.000 STOP
276.000 260 PRINT 265
277.000 265 FORMAT(///,10X,'AXIS SCALES TOO SMALL')
278.000 STOP
279.000 END
280.000 SUBROUTINE MATINT(ZO,NRO,NCO,NAR,NAC,ZN)
281.000 * THIS ROUTINE ENLARGES THE INPUT MATRIX THROUGH THE ADDITION OF
282.000 * INTERPOLATED VALUES
283.000 * ZO = INPUT GAIN MATRIX
284.000 * ZN = AUGMENTED OUTPUT GAIN MATRIX
285.000 DIMENSION ZO(49,49),ZN(97,97)
286.000 *
287.000 * INTERPOLATE ACROSS EACH COLUMN OF THE OLD MATRIX
288.000 *
289.000 NAR1 = NAR + 1
290.000 NR2 = NRO - 2
291.000 NR1 = NRO - 1
292.000 NAC1 = NAC + 1
293.000 NC2 = NCO - 2
294.000 NC1 = NCO - 1
295.000 DELX = 1.0/FLOAT(NAR1)
296.000 DO 80 J = 1,NCO
297.000 JJ = 1 + (J-1)*NAC1
298.000 KOUNT = 1
299.000 *
300.000 * INTERPOLATE ACROSS THE FIRST INTERVAL OF THE J TH COLUMN.
301.000 *
302.000 Z1 = ZO(1,J)
303.000 Z2 = ZO(2,J)
304.000 Z3 = ZO(3,J)
305.000 ZN(KOUNT,JJ) = Z1
306.000 IF (NAR1.EQ.1) GO TO 20
307.000 DO 10 L = 2,NAR1
308.000 KOUNT = KOUNT + 1
309.000 X = (L-1)*DELX
310.000 ZN(KOUNT,JJ) = FUNCX(0.0,1.0,2.0,Z1,Z2,Z3,X)
311.000 10 CONTINUE
312.000 *
313.000 * INTERPOLATE FROM THE SECOND TO THE LAST BUT ONE INTERVAL
314.000 * FOR THE J TH COLUMN.
315.000 *
316.000 20 IF (NR2.EQ.1) GO TO 50
317.000 DO 40 K = 2, NR2
318.000 Z1 = ZO(K-1,J)
319.000 Z2 = ZO(K,J)
320.000 Z3 = ZO(K+1,J)
321.000 Z4 = ZO(K+2,J)
322.000 KOUNT = KOUNT + 1
323.000 ZN(KOUNT,JJ) = Z2
324.000 IF (NAR1.EQ.1) GO TO 40
325.000 DO 30 L=2,NAR1
326.000 KOUNT = KOUNT + 1
327.000 X = 1.0 + (L-1)*DELX
328.000 FN = FUNCX(0.0,1.0,2.0,Z1,Z2,Z3,X)
```

```
329.000      FN1 = FUNCX(1.0,2.0,3.0,Z2,Z3,Z4,X)
330.000      ALPHA = X - 1.0
331.000      W = 1.0 - 3.0*ALPHA**2 + 2.0*ALPHA**3
332.000      ZN(KOUNT,JJ) = W*FN + (1.0-W)*FN1
333.000 30   CONTINUE
334.000 40   CONTINUE
335.000 *
336.000 * INTERPOLATE ACROSS THE LAST INTERVAL FOR THE J TH COLUMN
337.000 *
338.000 50   Z1 = Z0(NR1-1,J)
339.000      Z2 = Z0(NR1,J)
340.000      Z3 = Z0(NR1+1,J)
341.000      KOUNT = KOUNT + 1
342.000      ZN(KOUNT,JJ) = Z2
343.000      IF(NAR1.EQ.1) GO TO 70
344.000      DO 60 L = 2,NAR1
345.000      KOUNT = KOUNT + 1
346.000      X = 1.0 + (L-1)*DELX
347.000      ZN(KOUNT,JJ) = FUNCX(0.0,1.0,2.0,Z1,Z2,Z3,X)
348.000 60   CONTINUE
349.000 70   KOUNT = KOUNT + 1
350.000      ZN(KOUNT,JJ) = Z3
351.000 80   CONTINUE
352.000      NRN = KOUNT
353.000 *
354.000 * UPDATE NO. OF ROWS
355.000 *
356.000      NRO = NRN
357.000 *
358.000 * INTERPOLATE ACROSS EACH ROW OF THE AUGMENTED MATRIX
359.000 *
360.000      IF (NAC1.EQ.1) RETURN
361.000      DELX = 1.0/FLOAT(NAC1)
362.000      DO 140 I = 1,NRN
363.000 *
364.000 * INTERPOLATE ACROSS THE FIRST INTERVAL OF THE I TH ROW
365.000 *
366.000      KOUNT = 1
367.000      JJ1 = 1
368.000      JJ2 = JJ1 + NAC1
369.000      JJ3 = JJ1 + 2*NAC1
370.000      Z1 = ZN(I,JJ1)
371.000      Z2 = ZN(I,JJ2)
372.000      Z3 = ZN(I,JJ3)
373.000      DO 90 L = 2,NAC1
374.000      KOUNT = KOUNT + 1
375.000      X = (L-1)*DELX
376.000      ZN(I,KOUNT) = FUNCX(0.0,1.0,2.0,Z1,Z2,Z3,X)
377.000 90   CONTINUE
378.000 *
379.000 * INTERPOLATE FROM THE SECOND TO THE LAST BUT ONE INTERVAL FOR
380.000 * THE I TH ROW.
381.000 *
382.000      IF (NC2.EQ.1) GO TO 120
383.000      DO 110 K = 2,NC2
```

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384.000      JJ1 = 1 + (K-2)*NAC1
385.000      JJ2 = JJ1 + NAC1
386.000      JJ3 = JJ1 + 2*NAC1
387.000      JJ4 = JJ1 + 3*NAC1
388.000      Z1 = ZN(I,JJ1)
389.000      Z2 = ZN(I,JJ2)
390.000      Z3 = ZN(I,JJ3)
391.000      Z4 = ZN(I,JJ4)
392.000      KOUNT = KOUNT + 1
393.000      DO 100 L = 2,NAC1
394.000      KOUNT = KOUNT + 1
395.000      X = 1.0 + (L-1)*DELX
396.000      FN = FUNCX(0.0,1.0,2.0,Z1,Z2,Z3,X)
397.000      FN1 = FUNCX(1.0,2.0,3.0,Z2,Z3,Z4,X)
398.000      ALPHA = X - 1.0
399.000      W = 1.0 - 3.0*ALPHA**2 + 2.0*ALPHA**3
400.000      ZN(I,KOUNT) = W*FN + (1.0-W)*FN1
401.000 100  CONTINUE
402.000 110  CONTINUE
403.000 *
404.000 * INTERPOLATE ACROSS THE LAST INTERVAL FOR THE I TH ROW.
405.000 *
406.000 120  JJ1 = 1 + (NC1 - 2)*NAC1
407.000      JJ2 = JJ1 + NAC1
408.000      JJ3 = JJ1 + 2*NAC1
409.000      Z1 = ZN(I,JJ1)
410.000      Z2 = ZN(I,JJ2)
411.000      Z3 = ZN(I,JJ3)
412.000      KOUNT = KOUNT + 1
413.000      DO 130 L = 2,NAC1
414.000      KOUNT = KOUNT + 1
415.000      X = 1.0 + (L-1)*DELX
416.000      ZN(I,KOUNT) = FUNCX(0.0,1.0,2.0,Z1,Z2,Z3,X)
417.000 130  CONTINUE
418.000      KOUNT = KOUNT + 1
419.000 140  CONTINUE
420.000 * UPDATE NO. OF COLUMNS
421.000      NCO = KOUNT
422.000      RETURN
423.000      END
424.000      FUNCTION FUNCX(T1,T2,T3,V1,V2,V3,T)
425.000      FUNCX = V1*(T-T2)*(T-T3)/((T1-T2)*(T1-T3)) +
426.000      + V2*(T-T1)*(T-T3)/((T2-T1)*(T2-T3)) + V3*(T-T1)*(T-T2)/
427.000      + ((T3-T1)*(T3-T2))
428.000      RETURN
429.000      END
*
```

E.3 EXAMPLE OF INPUT FILE DSCRPLT.DAT AND GNMAT

265

DSCRPLT.DAT

.50 .50  
12 12  
0  
3  
41.0 40.0 39.0 38.0 37.0 35.0 32.0 28.0  
0.0 0.0  
!

GNMAT

DBS BEAM CANADA 101 (POTTER FEED HORNS )  
-1.75000 1.75000 15 -1.00000 1.00000 9  
26.08 30.36 31.46 31.41 31.73 31.95 30.30 24.20 -.70 18.23  
16.35 9.11 .85 1.04 .19  
31.60 36.50 38.29 38.48 38.16 37.53 35.94 32.52 26.83 19.72  
15.85 15.13 11.85 10.18 11.24  
32.47 38.12 40.42 40.85 40.39 39.52 38.21 36.30 33.92 31.19  
27.65 21.89 11.51 -6.33 10.04  
28.95 36.25 39.46 40.49 40.35 39.70 38.89 38.12 37.22 35.54  
31.95 24.10 5.14 17.97 13.94  
19.89 30.87 36.02 38.37 39.20 39.28 39.22 39.29 39.16 38.08  
35.25 29.76 18.75 11.48 17.49  
15.31 20.97 30.24 34.86 37.19 38.35 39.14 ~ 39.90 40.28 39.79  
38.26 35.90 32.90 28.64 21.28  
12.30 10.61 20.62 28.87 33.05 35.52 37.42 39.01 39.93 40.00  
39.56 39.09 38.28 35.93 30.20  
-23.40 10.77 9.31 13.71 22.60 27.98 32.27 35.41 37.05 37.48  
37.67 38.30 38.55 36.87 31.51  
6.01 1.71 13.12 16.38 16.65 8.73 18.99 27.33 30.10 30.11  
30.03 31.82 33.43 32.39 26.63

DBS BEAM CANADA 101 (POTTER FEED HORNS )  
START AND STOP VALUES OF SCAN RANGE (DEG) AND NUMBER OF COMPUTED POINTS  
.AZS = -1.75 AZE = -1.75 NAZ = 15  
.ELS = -1.00 ELE = 1.00 NEL = 9

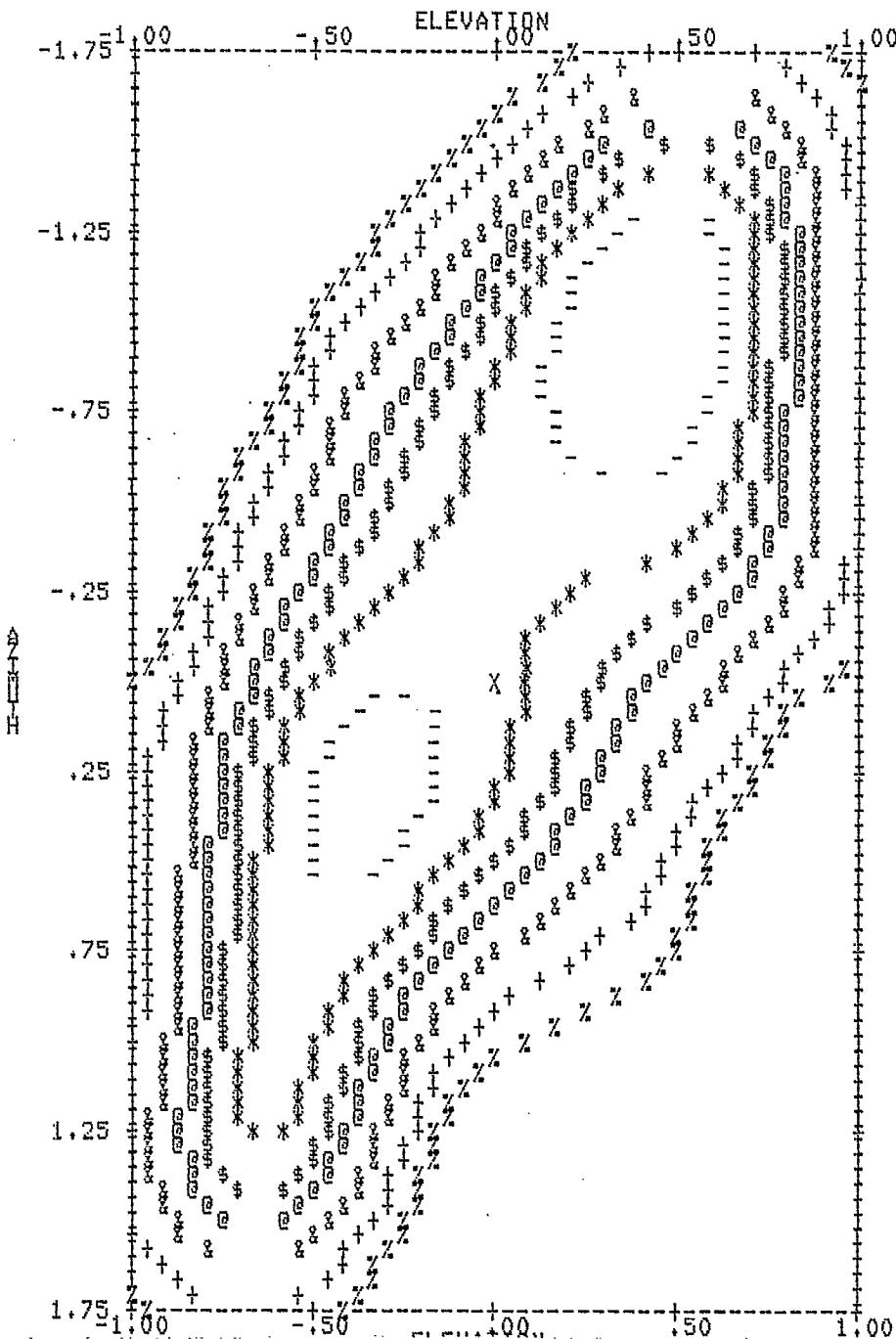
### GAIN MATRIX (DR)

לעומת הכתובים במקרא, שפה זו לא הייתה בשימושם של יהודים נוראים, וסביר להניח, אף לא היהודים הנוראים נטשו אותה.

AZIMUTH AXIS SCALE = .50000 DEG/INCH  
ELEVATION AXIS SCALE = .50000 DEG/INCH  
BORESIGHT AZ = .00 EL = .00 DEG

## CONTOUR SYMBOLS AND CORRESPONDING DB VALUES

SYMBOL	*	-	*	\$	@	%	+	%
DB VALUE	41.00	40.00	39.00	38.00	37.00	35.00	32.00	28.00



LKC  
TK7871.6 .S93 1984  
A study to establish at CRC  
a library of verifiable  
antenna design software for  
communications satellite  
systems : final rep

