FINAL REPORT

on

Synthesis of Multiple Shaped Beam Antenna Patterns

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1. Introduction

This report presents the results of a one year research study on the problem of antenna synthesis. The original goal as outlined in the proposal [1] was to develop analytical and numerical techniques which would aid in the design of multiple shaped beam antennas. During the course of the research it was decided to expand the scope of the project to include virtually any pattern type in combination with many antenna types. This, it is hoped, will increase the number of specific antenna design problems to which this method may be applied.

1.1 The Need for New Approaches

Multiple shaped beam antennas are required for synchronous orbit satellites involving advanced multi-function communications. Anticipated applications include transfer of information for biomedicine, law enforcement, adult education, etc. The satellite should be capable of point-to-point communication between any two points within the continental United States. This will be achieved using multiple satellite antenna beams and a series of ground terminals. The antenna main beams must be shaped to give appropriate illumination of the ground stations. Also, the side lobe levels must be low to minimize interference between adjacent beams. These pattern requirements are quite severe and it is a difficult procedure to find an antenna which meets the pattern specifications and is suitable for a spacecraft environment. The classical approach to determining which antenna system is most suitable is one of repeated analysis. That is, combining and modifying "off-the-shelf" antennas in many ways until an acceptable radiation pattern is obtained. The antenna system may still not be practical because of large size, narrow bandwidth, etc. When this approach is used for many different
antenna systems the "paper study" stage becomes very costly. In addition, when new antenna pattern specifications are introduced another costly "paper study" is required.

To further illustrate the magnitude of the problem, a table of some of the variables that the antenna designer works with is given below.

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There is, of course, a large number of possible combinations of pattern variables and antenna variables. In addition, there are almost endless numbers of possibilities within each category and also other possible categories. The pattern variable categories for this research project are multiple shaped main beams with complex side lobe structure.

1.2 A Practical Approach to Antenna Synthesis

The synthesis problem may be formulated as follows: Given a desired antenna pattern (which may have multiple shaped beams plus controlled side lobe structure), we wish to find antenna structures which will approximate the desired pattern within acceptable limits subject to realizability criteria.
is broadly defined as the ability of the antenna to meet the system specifications of which it is a part. Specifications are often given on the following items:

a. Ability to form the necessary number of main beams.
b. Isolation levels between beams.
c. Polarization control.
d. Power handling capability.
e. Center frequency of operation.
f. Bandwidth
g. Efficiency
h. Size
i. Weight
j. Reliability
k. Pattern control (scanning and beam reshaping for changing user needs).

For satellite systems the specifications on the above items are frequently very demanding. Thus, the antenna designer lists all possible antenna systems which are capable of meeting the specifications. This is indeed the way one must face the problem. The next step is one of determining the design details of how one excites the antenna system in order to obtain an acceptable approximation to the desired pattern. This is classically done by cut-and-try analysis. Many excitations are studied on paper or in the lab until the pattern is found or the money runs out. It is proposed here that a true synthesis (as contrasted to cut-and-try analysis) approach be explored. In other words, given the antenna type to be used (as determined from the realizability criteria) and the desired antenna pattern, determine an excitation which approximates the pattern within acceptable limits. This is done for each candidate antenna type. A general synthesis procedure capable of handling many antenna types would allow the designer to synthesize a pattern once for each antenna type instead of using a lengthy and costly cut-and-try analysis for each one. The
The final stage is then one of determining which antenna type does the best job of meeting pattern and system specifications.

The antenna design problem is then described in three stages:

1. Listing the antenna types which possibly can meet system specifications.
2. Determining the excitation of each antenna type required to meet the pattern requirements.
3. Singling out the one "best" antenna system.

The first two stages are frequently blended together, but ideally they should be distinct in order to avoid missing some candidate antenna types. The first and last stages are dependent upon the antenna designer's experience and judgment. The second stage is dependent upon an accurate mathematical antenna model (experimental design is ruled out for cost reasons) and available design techniques. This project provides a general synthesis technique as a design tool, thus eliminating the cut-and-try analysis approach. Its success in terms of practical application hinges on the availability of an accurate antenna model. In other words, once an excitation is determined by the synthesis method for a given antenna type and given pattern, how does one translate this into hardware? As will be explained later in this report there are several points in the synthesis method where hardware constraints can be inserted into the solution.

1.3 Scope of the Research

This report presents the results of research into the problem of finding an excitation of a given antenna such that the desired radiation pattern is approximated to within acceptable limits. This is to be done in such a fashion that boundary conditions involving hardware limitations may be inserted into the problem. The intended application is synthesis of multiple shaped beam
antennas. Since this is perhaps the most difficult synthesis problem an antenna engineer is likely to encounter, the approach taken was to include as a by-product capability for synthesizing simplier patterns. The synthesis technique has been almost totally computerized. The computer program and its use are described in detail elsewhere in this report.

The class of antennas which may be synthesized with the computer program are those which may be represented as planar (continuous or discrete) current distributions. The technique is not limited in this sense and could indeed be extended to include, for example, the synthesis of conformal arrays or current distributions on the surface of reflectors. The antenna types which the program is set up to synthesize are the following:

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Pattern specifications can be virtually anything—any number of main beams, any main beam shape, or any side lobe structure. Many examples are included in this report for illustration.
2. Mathematical Modeling of Antennas

An antenna can be synthesized by totally theoretical means only if an accurate mathematical model is available initially. It is the purpose of this chapter to summarize how one can approximately represent an antenna.

2.1 Equivalent Currents

It is often convenient to use equivalent currents to obtain the radiation fields from an antenna. Suppose the source antenna is entirely enclosed by a closed surface S. Let \( \mathbf{E}_1 \) and \( \mathbf{H}_1 \) be the values of the electric and magnetic field intensities on the surface S. The fields exterior to S can be found by using the equivalent electric and magnetic surface current sources:

\[
\mathbf{J}_S = \hat{n} \times \mathbf{H}_1 \quad (2-1)
\]

\[
\mathbf{J}_{MS} = -\hat{n} \times \mathbf{E}_1 \quad (2-2)
\]

where \( \hat{n} \) is the outward normal to S. The actual sources are replaced by these equivalent sources acting in free space. The equivalent sources produce exactly the same fields external to S as the original sources. The fields internal to S produced by currents given by (2-1) and (2-2) are zero. The fields exterior to S may be found using equivalent sources \( \mathbf{J}_S \) and \( \mathbf{J}_{MS} \) in one of the following ways:

1) Use \( \mathbf{J}_S \) and \( \mathbf{J}_{MS} \) over S

2) Use \( \mathbf{J}_S \) over S with S a perfectly magnetic conducting surface

3) Use \( \mathbf{J}_{MS} \) over S with S a perfectly conducting surface

Any one of these three equivalent source configurations can be used. The
first has the disadvantage of having two sources. The second and third configurations require that calculations must be made for the source in the presence of a conductor.

If the equivalent surface \( S \) is now a plane surface (closed at infinity such that actual sources are inside), calculations are simplified. Let \( S \) be the \( z = 0 \) plane and suppose the actual sources are on the left \( (z < 0) \). The surface normal is then \( \hat{n} = \hat{z} \). The simplification arises from the fact that in methods 2) and 3) the theory of images may now be employed to replace a current (electric or magnetic) immediately in front of a conductor (magnetic or electric) by a current of double its value acting in free space. Of course, image theory gives us the correct answer only for \( z > 0 \).

Using only currents acting in free space we may now use potential integral formulations to calculate the radiation. The electric and magnetic vector potentials for far field calculations are [2]

\[
\begin{align*}
\vec{A}(r) &= \mu_0 \frac{e^{-jkr}}{4\pi r} \iint \vec{J}_S(r') \, e^{jk\hat{r}' \cdot \hat{r}'} \, dx'dy' \\
\vec{A}_M(r) &= \varepsilon_0 \frac{e^{-jkr}}{4\pi r} \iint \vec{J}_{MS}(r') \, e^{jk\hat{r}' \cdot \hat{r}'} \, dx'dy'
\end{align*}
\]

where \( \hat{\vec{r}'} = x'\hat{x} + y'\hat{y} \) and the coordinate system is shown below.
The currents are doubled for cases 2) and 3).

2.2 Representing Antennas as Finite Apertures

An exact solution for \( z > 0 \) is obtained if the actual fields over the whole \( z = 0 \) plane is used in (2-1) and (2-2). Also, all three formulations of Section 2.1 give the same result. In many cases the fields \( E_a \) and \( H_a \) over a specific aperture in the \( z = 0 \) plane are known or can be approximated well. The fields in the \( z = 0 \) plane and outside of the aperture are assumed to be zero. This is an assumption but is usually a necessary one to obtain a solution. Examples of antennas for which this aperture concept is useful are the horn, lens, and reflector antennas. The three equivalent current formulations now provide approximate solutions which in general do not agree with each other [2]. However, the main features of the radiation pattern are usually unaffected by these approximations.

The approximate equivalent currents over the aperture are

\[
\begin{align*}
\vec{J}_S &= \hat{z} \times \vec{H}_a \\
\vec{J}_{MS} &= -\hat{z} \times \vec{E}_a
\end{align*}
\]

The expressions for the fields in the far-field region of the aperture are

\[
\begin{align*}
E_\theta &= -j\omega A_\theta - j\eta_0 A_M \phi \\
E_\phi &= -j\omega A_\phi + j\eta_0 A_M \theta
\end{align*}
\]

where \( \eta_0 = \sqrt{\mu_0 / \varepsilon_0} \) and the magnetic fields are found using the plane wave relation

\[
\vec{H} = r \times \vec{E} / \eta_0
\]
As an example suppose we use only a magnetic current and the aperture electric field is \( y \)-directed. Then

\[
\mathbf{J}_M = \mathbf{J}_{Mx} \hat{x} = z \times E_y \hat{y} = E_y \hat{x}
\]

(2-10)

and

\[
A_{Mx} = \frac{\varepsilon_0}{4\pi r} e^{-jkr} \int \int_{\text{aperture}} 2 E_y e^{j\mathbf{k} \cdot \mathbf{r}'} \, dx'dy'
\]

(2-11)

where the factor of 2 is necessary from image theory. Now

\[
A_{M\theta} = \cos \theta \cos \phi A_{Mx}
\]

(2-12)

\[
A_{M\phi} = -\sin \phi A_{Mx}
\]

(2-13)

So

\[
E_\theta = -j\omega_0 A_{M\phi} = -j\omega_0 \sin \phi A_{Mx}
\]

(2-14)

\[
E_\phi = +j\omega_0 A_{M\theta} = j\omega_0 \cos \theta \cos \phi A_{Mx}
\]

(2-15)

And

\[
A_{Mx} = \frac{\varepsilon_0}{2\pi r} e^{-jkr} \int \int_{\text{aperture}} E_y e^{jk(x' \sin \theta \cos \phi + y' \sin \theta \sin \phi)} \, dx'dy'
\]

(2-16)

So

\[
E_\theta = \frac{jke^{-jkr}}{2\pi r} \sin \phi F_y
\]

(2-17)

\[
E_\phi = \frac{jke^{-jkr}}{2\pi r} \cos \theta \cos \phi F_y
\]

(2-18)

where

\[
F_y = \int \int_{\text{aperture}} E_y e^{jk(x' \sin \theta \cos \phi + y' \sin \theta \sin \phi)} \, dx'dy'
\]

(2-19)
If there is an $x$-directed component of the aperture electric field the far-field expressions become

\[
E_\theta = \frac{jke^{-jkr}}{2\pi r} (F_y \sin \phi + F_x \cos \phi) \tag{2-20}
\]
\[
E_\phi = \frac{jke^{-jkr}}{2\pi r} \cos \theta (F_y \cos \phi - F_x \sin \phi) \tag{2-21}
\]

If an equivalent electric current is used instead of a magnetic current, equations are obtained which are duals of those above:

\[
E_\theta = \frac{jk\eta_0 e^{-jkr}}{2\pi r} \cos \theta (F_y \cos \phi - F_x \sin \phi) \tag{2-22}
\]
\[
E_\phi = \frac{jk\eta_0 e^{-jkr}}{2\pi r} (F_y \sin \phi + F_x \cos \phi) \tag{2-23}
\]

where

\[
\vec{F} = \int \int H_a (x', y') e^{jk(x' \sin \theta \cos \phi + y' \sin \theta \sin \phi)} \, dx' \, dy' \tag{2-24}
\]

If both electric and magnetic current sources are used a combination of the preceding results is obtained [2]. This approach is not used very often because a knowledge of both aperture fields is required and the resulting number of calculations required.

These solutions are exact if a complete knowledge of the fields over the entire aperture plane is available. This is usually never possible. In fact, some assumption about the aperture fields is made in addition to the assumption that the fields are zero outside the aperture. If the aperture is connected to an infinite plane perfect conductor the formulation using magnetic current only is exact within the limits of a knowledge of the tangential electric field over the aperture. This is true because the tangential electric field is zero over the perfect conductor and thus the equivalent magnetic current is also.
As a first approximation to the aperture fields frequently the so-called physical optics approximation is used. It assumes that the aperture fields are those incident upon it from the actual source. For example, the physical-optics fields in the aperture (or mouth) of a horn antenna are those of the waveguide feed [4].

Frequently aperture antennas are not used, but rather one wishes to relate directly to a source current. In this case $\mathbf{J}_S$ is an actual current and its Fourier transform $\mathbf{A}$ in (2-3) is used in the far-field expression (2-7). So quantitatively there is little difference from actual and equivalent current problems. The actual currents may be used in array antenna solutions.

If a current distribution can be expressed as follows

$$\mathbf{J}_S = \hat{x} J_{Sx} (x') J_{Sx} (y') + \hat{y} J_{Sy} (x') J_{Sy} (y')$$  \hspace{1cm} (2-25)

it is referred to as being separable. In this case the two-dimensional Fourier transform, see (2-19) separates into two one-dimensional transforms. Thus each transform is that corresponding to a line source and the total pattern is the product of the patterns of two line sources. Most practical rectangular sources have separable distributions [3]. Thus, the aperture fields $\mathbf{E}_a$ and $\mathbf{H}_a$ are usually separate and render the two-dimensional integrals of (2-19) and (2-24) a product of one-dimensional integrals.

2.3 Vector Radiation Fields

In the radiation field (or far-field) the waves are locally plane and may be completely described by $\theta$ and $\phi$ components (for an antenna at the origin of a spherical coordinate system). There are also two field components in the aperture which give rise to the radiation fields. It is convenient
to describe the radiation fields in spherical coordinates and the aperture fields in Cartesian coordinates. This complicates the relationship between aperture and radiation fields. It is the purpose of this section to discuss this point.

If one uses the aperture electric field formulation the radiation fields are found from (2-20) and (2-21), which are rewritten below as

\[ \mathbf{E} = \mathbf{E}(r) \begin{bmatrix} \cos \phi F_x + \sin \phi F_y \end{bmatrix} \] (2-26)

\[ \mathbf{E} = \mathbf{E}(r) \begin{bmatrix} -\cos \theta \sin \phi F_x + \cos \theta \cos \phi F_y \end{bmatrix} \] (2-27)

where

\[ \mathbf{E}(r) = \frac{jke^{-jkr}}{2\pi r} \] (2-28)

This can be cast in a matrix form

\[
\begin{bmatrix}
\mathbf{E}_\theta (\theta, \phi) \\
\mathbf{E}_\phi (\theta, \phi)
\end{bmatrix} =
\begin{bmatrix}
G_{\theta x} & G_{\theta y} \\
G_{\phi x} & G_{\phi y}
\end{bmatrix}
\begin{bmatrix}
F_x \\
F_y
\end{bmatrix}
\] (2-29)

where

\[
\mathbf{E}_\theta (\theta, \phi) = \frac{E_\theta}{E(r)}
\] (2-30)

\[
\mathbf{E}_\phi (\theta, \phi) = \frac{E_\phi}{E(r)}
\]

and

\[
G_{\theta x} = \cos \phi \\
G_{\theta y} = \sin \phi \\
G_{\phi x} = -\cos \theta \sin \phi \\
G_{\phi y} = \cos \theta \cos \phi
\] (2-31)

In still more compact form (2-29) becomes

\[ \mathbf{E} = [\mathbf{G}][\mathbf{F}] \] (2-32)
This formulation is particularly convenient for synthesis problems. If a certain desired electric field behavior \([E]\) is known, then the corresponding desired \([F]\) is found from the solution of (2-32):

\[
[F] = [G]^{-1}[E] \tag{2-33}
\]

The determinant of \([G]\) is \(\cos \theta\). The inverse of \([G]\) then exists except for \(\theta = \pi/2\). This is equivalent to radiation in the plane of the source and can be avoided. \(F_x\) and \(F_y\) are related to the corresponding aperture field components \(E_{ax}\) and \(E_{ay}\) by Fourier transforms

\[
F_x(\theta, \phi) = \int \int E_{ax}(x', y') e^{j k(x' \sin \theta \cos \phi + y' \sin \theta \sin \phi)} dx' dy', \tag{2-34}
\]

\[
F_y(\theta, \phi) = \int \int E_{ay}(x', y') e^{j k(x' \sin \theta \cos \phi + y' \sin \theta \sin \phi)} dx' dy', \tag{2-35}
\]

from (2-19). The synthesis problem for vector fields is thus reduced to synthesizing \(F_x\) and \(F_y\) using (2-34) and (2-35). Since \(F_x\) depends only on \(E_{ax}\) and \(F_y\) depends only on \(E_{ay}\), the vector problem reduces to two scalar problems.

If the aperture fields used are magnetic fields (or electric currents) the electric fields in (2-34) and (2-35) are replaced by magnetic fields (or electric surface currents). Then \([G]\) becomes

\[
[G] = \begin{bmatrix}
\cos \theta \cos \phi & -\cos \theta \sin \phi \\
-\sin \phi & -\cos \phi
\end{bmatrix} \tag{2-36}
\]

from (2-22) and (2-23).

The element pattern matrix \([G]\) may also be used to absorb element patterns of array antennas. Suppose that the principle of pattern multiplication can be used. Then
\[ F_x = \int \int x (x', y') \, e^{jk\alpha} \, dx'dy' \]  

(2-37)

where we let

\[ \alpha = x' \sin \theta \cos \phi + y' \sin \theta \sin \phi \]  

(2-38)

becomes

\[ F_x = G_x \sum_{m=1}^{P} I_{xm} e^{jk\alpha_m} = G_x \, F_{arx} \]  

(2-39)

where

\[ \alpha_m = x'_m \sin \theta \cos \phi + y'_m \sin \theta \sin \phi \]  

(2-40)

and \((x'_m, y'_m)\) are the element phase center locations. Similarly

\[ F_y = G_y \sum_{m=1}^{P} I_{ym} e^{jk\alpha_m} = G_y \, F_{ary} \]  

(2-41)

These element factors may be combined into \([G]\) giving

\[
[G_{ar}] = \begin{bmatrix}
\cos \theta \cos \phi & -\cos \theta \sin \phi \\
-\sin \phi & -\cos \phi
\end{bmatrix} \]  

(2-42)

The antenna equation (2-32) for the array problem becomes

\[ [E] = [G_{ar}] \, [F_{ar}] \]  

(2-43)

where the \([F_{ar}]\) entries are the array factors

\[ F_{arx} = \sum_{m=1}^{P} I_{xm} e^{jk\alpha_m} \]

\[ F_{ary} = \sum_{m=1}^{P} I_{ym} e^{jk\alpha_m} \]  

(2-44)

**Example** - A linear array of parallel short dipoles along the x-axis.

Since the current is y-directed we have

\[ F_x = 0 \]  

(2-45)

\[ F_y = G_y \, F_{ary} \]  

(2-46)
The short dipole pattern is

\[ G_y = \sin \beta \]  \hspace{1cm} (2-47)

where \( \beta \) is the spherical polar angle from the y-axis. But \( \cos \beta = \sin \theta \sin \phi \)
so

\[ G_y = \sqrt{1 - (\sin \theta \sin \phi)^2} \]  \hspace{1cm} (2-48)

Now

\[ F_{ary} = \sum_{j}^{jk} \alpha_{m} e^{i ym} \]  \hspace{1cm} (2-49)

where

\[ \alpha_{m} = x_{m}' \sin \theta \cos \phi \]  \hspace{1cm} (2-50)

since \( y_{m}' = 0 \).

### 2.4 Antenna Hardware Parameter Control

A mathematical model of an antenna is useful in design work when the parameter being varied in the model can be translated into hardware. In the synthesis problem we end up with an aperture distribution which will produce the desired radiation pattern. Suppose a circular aperture distribution has been synthesized. Then one must find, for example, a feed system for a reflector antenna which will produce the required field distribution over the aperture. Thus synthesis techniques are useful for a particular antenna only if its excitation is controllable in a known way. If hardware parameters (such as feed antenna size and position) are mathematical related to the aperture excitation, they may also be included in the antenna mathematical...
model. The synthesis procedure then goes from pattern specification to hardware parameter output. Indeed, not many antennas are suited to this at this point in time. However, the synthesis technique presented in this report is capable accommodating several hardware limitations a priori.

Array antennas appear to be the most readily adaptable to synthesis. After specifying the desired radiation pattern, element positions, and element pattern, one obtains the required terminal currents from the synthesis technique. For a few antenna arrays the mutual coupling (or impedance) matrix is available. The required terminal voltages for each element may then be found as follows:

\[
[V] = [Z][I]
\]

(2-51)

where

\[
[V] = \begin{bmatrix}
V_1 \\
V_2 \\
\vdots 
\end{bmatrix} = \text{terminal voltage matrix (computed from (2-51))}
\]

\[
[I] = \begin{bmatrix}
I_1 \\
I_2 \\
\vdots 
\end{bmatrix} = \text{terminal current matrix (found by synthesis)}
\]

\[
[Z] = \begin{bmatrix}
Z_{11} & Z_{12} & \cdots \\
Z_{21} & \cdots & \\
\vdots & \vdots & \ddots
\end{bmatrix} = \text{mutual impedance matrix (known from calculations or experiment)}
\]
3. The Iterative Sampling Method for Planar Sources

3.1 History of the Iterative Sampling Method

The iterative sampling method has been used previously for shaping the main beam [5,6] and controlling the side lobes [5,7,8,9] of line sources and uniformly spaced linear arrays. In this section the theory is extended to include any type of planar source. The method is applied to patterns which have multiple main beams that are shaped and also have controlled side lobe levels.

Many methods are available for synthesis of radiation patterns using one-dimensional sources. Although proponents of most of these methods usually claim that it is a simple matter to extend their method to two dimensions, it is, in fact, rarely simple [10]. This is supported by the fact that it is almost never done. The iterative sampling, on the other hand, has been extended to two dimensions.

The iterative sampling method allows one to suppress side lobes to very low levels over certain regions while relaxing the side lobe requirements for other regions. When applied to the multiple-beam problem for time-zone coverage, beam cutoff and low side lobes would be specified for Canadian coverage, while side lobe specifications above the horizon would be relaxed.

Using this iterative technique the designer has the option of examining the metamorphosis of pattern change (and corresponding source change) as it approaches the desired form. Thus many patterns and their corresponding source currents may be examined. The pattern which approximates the desired pattern to just within the specifications will have the least complicated
source current distribution. The iterative sampling method provides such a design.

Another interesting feature of this design approach is the possibility of using a measured pattern from an existing (or prototype) antenna system as a starting point. Then calculations can be made to reveal what changes in the source are required to make specified corrections in the pattern.

3.2 Pattern Evaluation - What is an Acceptable Pattern?

Patterns can be evaluated using one or more of several criteria. Examples are side lobe level, beam width, rate of cut-off from main beam, mean squared error (between actual and desired pattern), etc. Different synthesis methods provide patterns which perform well with respect to one of these criteria. For complex patterns involving multiple beams, shaped beams, and/or varying side lobe structure, the criteria mentioned above are inadequate. The most flexible means of pattern evaluation is that using upper and lower bounds. In other words, one specifies at any or all points of the radiation pattern how much the synthesized pattern can rise above and/or fall below the desired pattern. Thus, the designer specifies a desired pattern plus an upper and lower tolerance.

The tolerance method of evaluating a synthesized pattern allows one to shape a main beam to within a fraction of a dB of the desired pattern. At the same time the side lobe region can have an upper tolerance of say 1 dB over critical portions and several dB over other regions; the lower tolerance is usually unspecified in the side lobe region because side lobes can fall anywhere below the desired level and be acceptable. It has been shown that
this means of pattern specification together with the iterative sampling method will yield synthesized patterns which include essentially all of the classical patterns which optimize only one parameter (such as side lobe level, main beam cut-off, etc.). [6]

3.3 The Integral Equation

The $\theta$ and $\phi$ components of the electric field are desired to be of a certain relative level as a function of $\theta$ and $\phi$. The desired $E_\theta(\theta,\phi)$ and $E_\phi(\theta,\phi)$ are converted into desired $F_x(\theta,\phi)$ and $F_y(\theta,\phi)$ using (2-33). The synthesis problem is to find the aperture fields $E_{ax}(x',y')$ and $E_{ay}(x',y')$ which produce sufficiently accurate approximations to the desired $F_x(\theta,\phi)$ and $F_y(\theta,\phi)$, respectively. This amounts to solving the integral equations (2-34) and (2-35). Since these two equations are identical in form we will drop subscripts which refer to polarization, while remembering that two polarizations (alone or together) are possible. The integral equation which we wish to solve is then

$$F(u,v) = \int \int_{\text{aperture}} E_a(x',y') e^{jk(x'u + y'v)} \, dx'dy'$$

(3-1)

where

$$u = \sin \theta \cos \phi$$

(3-2)

$$v = \sin \theta \sin \phi.$$ 

(3-3)

$E_a$ and $F$ may correspond to either component ($x$ or $y$) of the aperture field. Define normalized coordinate variables

$$s = x'/\lambda$$

(3-4)

$$t = y'/\lambda$$

and source function
\[ f(s,t) = \begin{cases} \lambda^2 F_a(x',y') & \text{over the aperture} \\ 0 & \text{elsewhere} \end{cases} \quad (3-5) \]

Substituting (3-4) and (3-5) into (3-1) gives

\[ F(u,v) = \int \int f(s,t) e^{j2\pi(su + tv)} \, dsdt \quad (3-6) \]

This integral extends over the whole st-plane and is recognized as a two-dimensional Fourier transform. The analysis problem is straightforward.

Given an aperture distribution \( f \) we can calculate \( F \) from (3-6) by integration.

The synthesis problem, however, is very difficult. Suppose we are given a desired pattern \( F_d(u,v) \), which can be found from a desired electric field using (2-33). We wish to find an \( f \) (which is aperture-limited) giving an \( F \) which approximates \( F_d \) in some specified manner.

### 3.4 Mathematical Development of the Method

The iterative sampling method will be employed to find an aperture distribution which gives a pattern that approximates the desired pattern within acceptable limits as specified by upper and lower tolerances. The iterative procedure begins with an original pattern \( F^{(o)}(u,v) \) and its corresponding source distribution \( f^{(o)}(s,t) \). The source is initially of a certain type, e.g. line source, rectangular aperture, linear array, etc. It also has fixed dimensions in terms of a wavelength. These initial parameters are determined by the designer as discussed in Chapter 1. The original excitation \( f^{(o)}(s,t) \) of the antenna is one which gives a rough approximation \( F^{(o)}(u,v) \) to the desired pattern \( F_d(u,v) \). It can be found from any classical synthesis method, such as the Woodward-Lawson sampling method, or it can be an experimentally obtained pattern.
A series of corrections is added to the original pattern giving

\[ F(K)(u,v) = F(0)(u,v) + \sum_{i=1}^{K} \Delta F^{(i)}(u,v) \]  \hspace{1cm} (3-7)

\( K \) is the number of iterations and \( \Delta F^{(i)} \) is the \( i \)th iteration correction to the pattern. In general, each iteration is composed of a weighted sum of corrections as

\[ \Delta F^{(i)}(u,v) = \sum_{n} a^{(i)}_{n} G(u-u_{n}^{(i)}, v-v_{n}^{(i)}) \]  \hspace{1cm} (3-8)

where \( G(u-u_{n}^{(i)}, v-v_{n}^{(i)}) \) is a correction pattern centered at \( (u_{n}^{(i)}, v_{n}^{(i)}) \) and having a value of unity there. The \( \{a^{(i)}_{n}\} \) are weighting coefficients determined such that the current pattern is forced to equal the desired pattern at the correction point as follows

\[ a^{(i)}_{n} = F_{d}(u_{n}^{(i)}, v_{n}^{(i)}) - F^{(i-1)}(u_{n}^{(i)}, v_{n}^{(i)}) \]  \hspace{1cm} (3-9)

In other words, at the point \( (u_{n}^{(i)}, v_{n}^{(i)}) \) the amount \( a^{(i)}_{n} \) is added to the \( (i-1) \)th iteration pattern to obtain the desired pattern value at that point. If several corrections are applied in a given iteration of (3-8) the pattern will equal the desired pattern at the sample points only if the samples are uncorrelated. However, if the sample points are relatively far apart the correlation between samples can be very low. For a given iteration there are usually only a few corrections, frequently positioned to maintain symmetry. Thus if one abandons the idea that samples must be completely uncorrelated and replaces it with the concept that they should not be strongly correlated, the method is much more powerful and flexible. Also since the type of correction function is not based upon satisfying the property of being uncorrelated, the designer can choose one that is convenient.
For a given iteration then we have forced the pattern to be very close
(exactly equal if only one correction is used) to the desired pattern at the
sample points. The entire pattern is then recomputed and new corrections are
evaluated using (3-9). It has been found that the position of the samples
\((u_n^{(i)}, v_n^{(i)})\) which is most suitable is the location where the \((i-1)^{th}\) iteration
pattern exceeds the tolerance by the greatest amount. Using this scheme the
number of samples is determined by the symmetry of the problem (if there is
no symmetry only one correction is applied per iteration). In this fashion
the largest corrections are applied first and the process tends toward con-
vergence. If the desired pattern specifications are too severe the iteration
procedure will converge to a certain point and then oscillate. This is not
a limitation of the method. It is rather a fundamental limitation. If a well-
behaved correction pattern \(G\) (examples are given in the next section) is used,
superdirective patterns will never be synthesized. Superdirective patterns
are to be avoided because of the accompanying complications of the source
distribution. For example, a small aperture is not capable of producing pat-
terns with an extremely sharp cut-off from the main beam unless superdirective
conditions are allowed. Using well-behaved correction functions the iterative
sampling method will not converge to a sharp cut-off desired pattern with tight
tolerances. In cases where the desired result has not been obtained one can
either use the final pattern as an approximation or start the iteration process
over again using a relaxed version of the pattern specifications.

Corresponding to each correction pattern there is a current correction
\(g^{(i)}_n\) \((s,t)\) related to it as follows:

\[
G(u-u_n^{(i)}, v-v_n^{(i)}) = \int \int \limits_{\text{aperture}} g^{(i)}_n(s,t) e^{j(2\pi su + 2\pi tv)} \, ds \, dt \quad (3-10)
\]
The source distribution corresponding to the pattern of (3-7) is

\[ f^{(K)}(s,t) = f^{(o)}(s,t) + \sum_{i=1}^{K} \Delta f^{(i)}(s,t) \]  

(3-11)

where

\[ \Delta f^{(i)}(s,t) = \sum a^{(i)}_n g^{(i)}_n(s,t) \]  

(3-12)

The pattern \( F^{(K)}(u,v) \) and source \( f^{(K)}(s,t) \) are a Fourier transform pair, see (3-6). However, the only transform that has to be calculated is (3-10); all other patterns and sources are found by summing up the elementary pattern and source corrections, \( G \) and \( g \). This simplifies the required calculations greatly.

If the source is a planar array of isotropic point sources, we have

\[ f^{(K)}(s,t) = \sum \sum I^{(K)}_{lm} \delta(s-s_{lm}, t-t_{lm}) \]  

(3-13)

where \( \delta \) is the dirac delta function and \( I^{(K)}_{lm} \) are the currents for the \( lm \) element of the array. If the array elements are not isotropic the actual pattern is the array-element pattern times \( F(u,v) \) as discussed in Section 2.3. Let

\[ g^{(i)}_n(s,t) = \sum \sum g^{(i)}_{lm} \delta(s-s_{lm}, t-t_{lm}) \]  

(3-14)

for arrays. Then (3-10) becomes

\[ G(u-u_n(i), v-v_n(i)) = \sum \sum g^{(i)}_{n\lambda m} e^{j2\pi(s_{\lambda u} + t_{\lambda v})} \]  

(3-15)

For arrays substitute (3-14) into (3-12) giving

\[ \Delta f^{(i)}(s,t) = \sum a^{(i)}_n \sum \sum I^{(i)}_{lm} \delta(s-s_{lm}, t-t_{lm}) \]  

(3-16)

and let

\[ \Delta f^{(i)}(s,t) = \sum \sum \Delta I^{(i)}_{\lambda m} \delta(s-s_{\lambda}, t-t_{\lambda}) \]  

(3-17)

So
\[ \Delta I_{\lambda \mu}^{(1)} = \sum_{n} a_n^{(1)} \xi_{n \lambda \mu}^{(1)} \]  \hspace{1cm} (3-18)

and

\[ I_{\lambda \mu}^{(K)} = I_{\lambda \mu}^{(o)} + \sum_{i=1}^{K} \Delta I_{\lambda \mu}^{(i)} \]  \hspace{1cm} (3-19)

### 3.5 Common Antenna Types

In this section several common source types will be discussed. Correction functions \( G \) and \( g \) are also suggested. There are many possible functions, that one may use, including those obtained experimentally. Presented here are those functions which have been found to be applicable to many synthesis problems, are easily handled in the computer program, and which do not give superdirective patterns. The only Fourier Transform which must be performed in this method that of (3-10). Since the synthesis problem as formulated here is linear we can use the elementary functions as expansion functions to determine complex pattern and source functions (see (3-8) and (3-7), and (3-12) and (3-11)).

#### 3.5.1 Line Sources

The simplest line source is the uniformly illuminated one. A linear phase taper across the source is included to position the pattern maximum at, say, \( v_n^{(1)} \). The source correction function is

\[ g_n^{(i)}(t) = \begin{cases} 
\frac{L_y}{\lambda} \exp(-j2\pi v_n^{(1)} t) & |t| \leq \frac{L_y}{\lambda}/2 \\
0 & \text{elsewhere} 
\end{cases} \]  \hspace{1cm} (3-20)

where the line source has been positioned on the y-axis and is of length \( L_y/\lambda \) wavelengths. The corresponding correction pattern is

\[ G(v=v_n^{(1)}) = \frac{\sin[L_y(v-v_n^{(1)})\pi]}{L_y(v-v_n^{(1)})\pi} \]  \hspace{1cm} (3-21)

This is the so-called \( \sin x/x \) pattern.
An excitation which gives no edge illumination is the triangular line source. Its pattern has lower side lobes but larger beam width than the uniform line source pattern. The excitation function is
\[ g_n(i) (t) = \begin{cases} 
\frac{L_y}{L_y}^{-1} \left(1 - 2 \frac{|t|}{L_y}\right) \exp \left(-j2\pi v_n i t\right) & |t| \leq L_y/2 \\
0 & \text{elsewhere}
\end{cases} \] (3-22)

The corresponding pattern found from (3-10) is
\[ G(v-v_n(i)) = \left[\frac{\sin \left[\frac{L_y}{L_y} (v-v_n(i)) \pi/2\right]}{L_y (v-v_n(i)) \pi/2}\right]^2 \] (3-23)

3.5.2 Linear Array

The uniformly illuminated, linear phase, equally spaced linear array has currents
\[ g_{nm}(i) = \frac{i}{p} \exp \left(-j2\pi v_n t_m\right) \] (3-24)
where \(t_m\) are the positions of the elements and equal \(m d_y\) and \(p\) is the total number of elements. The corresponding pattern is
\[ G(u-u_n(i)) = \frac{\sin \left[\frac{P(v-v_n(i)) \pi d_y}{L_y}\right]}{P \sin \left[\left(v-v_n(i) \pi d_y\right]\right]} \] (3-25)

3.5.3 Rectangular Aperture

The uniformly illuminated, linear phase, rectangular aperture has excitation function
\[ g_n(i) (s,t) = \begin{cases} 
\frac{L_x}{L_x}^{-1} \frac{L_y}{L_y}^{-1} \exp \left(-j2\pi (u_n(i)s + v_n(t))\right) & |s| \leq L_x/2, |t| \leq L_y/2 \\
0 & \text{elsewhere}
\end{cases} \] (3-26)

The pattern is
\[ G(u-u_n(i), v-v_n(i)) = \frac{\sin \left[\frac{L_x}{L_x} (u-u_n(i)) \pi\right]}{L_x (u-u_n(i)) \pi} \frac{\sin \left[\frac{L_y}{L_y} (v-v_n(i)) \pi\right]}{L_y (v-v_n(i)) \pi} \] (3-27)
3.5.4 Rectangular Array

Consider a planar array which has equally spaced elements in the two principal directions. There are \( P_x \) and \( P_y \) numbers of elements along the \( x \) and \( y \) directions and interelement spacings of \( d_{x\lambda} \) and \( d_{y\lambda} \) wavelengths in the \( x \) and \( y \) directions. The element currents are

\[
E_{n_{x}m_{y}}(i) = \frac{1}{P_x P_y} \exp \left[ -j2\pi \left( u_n(i) \frac{d_x}{\lambda} + v_n(i) \frac{d_y}{\lambda} \right) \right]
\]

(3-28)

The pattern is

\[
G(u-u_n(i), v-v_n(i)) = \frac{\sin [P_x(u-u_n(i))\pi d_{x\lambda}]}{P_x \sin [(u-u_n(i))\pi d_{x\lambda}]} \cdot \frac{\sin [P_y(v-v_n(i))\pi d_{y\lambda}]}{P_y \sin [(v-v_n(i))\pi d_{y\lambda}]} \]

(3-29)

3.5.5 Circular Aperture

Consider a uniform amplitude, linear phase, circular source a radius \( a_\lambda \) wavelengths. The source function is

\[
g_n(i)(s, t) = \frac{1}{\pi a_\lambda^2} \exp \left[ -j2\pi (u_n(1) s + v_n(1) t) \right] \quad \sqrt{s^2 + t^2} \leq a_\lambda
\]

(3-30)

The pattern for this source is, of course, found from (3-10). Since the details of this calculation have not been located in the literature, its details will be included here. First, it is more convenient to use cylindrical rather than rectangular coordinates to describe the source. Then we can write (3-30) as

\[
g_n(i) (\rho', \phi') = \frac{1}{\pi a_\lambda^2} \exp \left[ -j2\pi \rho'(\cos \phi' u_n(1) + \sin \phi' v_n(1)) \right] \quad \rho' \leq a_\lambda
\]

(3-31)

The integral (3-10) over the source (3-31) is
\[ G(u-n(i), v-n(i)) = \int_0^{2\pi} \int_0^{\pi/2} \frac{1}{\pi a_\lambda} \left[ \exp \left\{ j 2\pi p' \left[ (u-n(i)) \cos \phi' + (v-n(i)) \sin \phi' \right] \right\} \right] \rho'_\lambda \, dp' \, d\phi' \]
\[ \quad = \frac{1}{\pi a_\lambda^2} \int_0^{2\pi} \int_0^{\pi/2} \exp \left[ j 2\pi p' \cos (a - \phi') \right] \rho'_\lambda \, dp' \, d\phi' \quad (3-33) \]

where
\[ C = \left[ (u-n(i))^2 + (v-n(i))^2 \right]^{1/2} \quad (3-34) \]
\[ \alpha = \tan^{-1} \frac{u-n(i)}{v-n(i)} \quad (3-35) \]

Now (3-33) is easily integrated as
\[ G(u-n(i), v-n(i)) = \frac{2\pi}{\pi a_\lambda^2} \int_0^{\pi} J_0(2\pi p' C) \rho'_\lambda \, dp' \quad (3-37) \]
\[ = \frac{J_1(2\pi a_\lambda C)}{2\pi a_\lambda C} \quad (3-38) \]

If \( u_n(i) = v_n(i) = 0 \) we have
\[ G_n(u,v) = \frac{J_1(2\pi a_\lambda \sin \theta)}{2\pi a_\lambda \sin \theta} \quad (3-39) \]

which is the pattern of a uniform amplitude, zero phase, circular source. [4]

Also note that when \( u = u_n(i) \) and \( v = v_n(i) \), \( C = 0 \) and (3-38) becomes unity.

Thus \( (u_n(i), v_n(i)) \) is the pattern maximum.

### 3.5.6 Arbitrary Planar Array

There is a large class of antenna arrays which are not included in the previously mentioned linear and rectangular arrays. For example, the so-called
triangular array whose elements are spaced such that the fundamental lattice shape is a triangle. [11] This array provides a pattern similar to an equal size rectangular array but uses fewer elements. Also nonuniformly spaced arrays have applications. If the correction source is that of a uniform amplitude, linear phase array the pattern from (3-15) is

\[ G (u-u_n, v-v_n) = \frac{1}{M} \sum_{m=0}^{M} \exp \{ j2\pi [s_m(u-u_n) + t_m(v-v_n)] \} \] (3-40)

There are M elements located at positions \((s_m, t_m)\) in the s,t plane.

### 3.6 Calculation of Directivity

The radiation pattern has been described for convenience in terms of the variables \(u\) and \(v\) instead of \(\theta\) and \(\phi\). This section discusses a few problems encountered when one wishes to calculate the directivity. The difference in the directivity between the original pattern and the final pattern (after iteration process is completed) is the gain loss. This number is usually small and may be positive or negative.

A derivation of the directivity expression using \(u\) and \(v\) coordinates has not been located in the literature, so its details are included here. The directivity is calculated as follows

\[ D = \frac{4\pi}{\Omega_A} \] (3-41)

The beam solid angle \(\Omega_A\) is given by

\[ \Omega_A = \int_0^{2\pi} \int_0^{\pi} |F(\theta, \phi)|^2 \sin \theta \ d\theta \ d\phi \] (3-42)

where \(|F(\theta, \phi)|\) is the field pattern normalized such that its maximum value is 1.0 and

\[ d\Omega = \sin \theta \ d\theta \ d\phi \] (3-43)
It is frequently convenient to transform from the $\theta, \phi$ space to the $u,v$ plane using

\begin{align*}
   u &= \sin \theta \cos \phi \\
   v &= \sin \theta \sin \phi
\end{align*}

(3-44)

We are collapsing the spherical surface described by $\theta, \phi$ onto a planar surface through its equator giving a circular disk. There is an ambiguity here because points on the upper hemisphere ($\theta > \pi/2$) project onto the top of the $u,v$ disk and points on the lower hemisphere map onto the bottom of the $u,v$ disk. If we confine ourselves to only the upper hemisphere the transformation is one-to-one. In effect we modify (3-42) as

\begin{equation}
   \Omega_A = \int_0^{\pi/2} \int_0^{2\pi} |F(\theta,\phi)| \, du \, dv \, d\Omega
\end{equation}

(3-45)

This is assumed to contain most of the radiation. Back lobes are ignored if the antenna is in free space. If the antenna is backed by an infinite ground plane there are no back lobes and the formulation is exact (if $F(\theta,\phi)$ is exact).

The problem is to evaluate $\Omega_A$ using $F(u,v)$. This may be done in two ways. First, consider the projection of $d\Omega$ onto the $u,v$ plane; it is

\begin{equation}
   du \, dv = \cos \theta \, d\Omega
\end{equation}

(3-46)

so

\begin{equation}
   d\Omega = \frac{du \, dv}{\cos \theta}
\end{equation}

(3-47)

But from (3-44)

\begin{equation}
   \cos \theta = \sqrt{1 - u^2 - v^2}
\end{equation}

(3-48)
so

$$d\Omega = \frac{du \, dv}{\sqrt{1 - u^2 - v^2}}$$  \hspace{1cm} (3-49)

Thus (3-45) becomes

$$\Omega_A = \int \int_{u^2 + v^2 \leq 1} |F(u,v)|^2 \frac{du \, dv}{\sqrt{1 - u^2 - v^2}}$$  \hspace{1cm} (3-50)

This result could also be obtained by a formal mathematical transformation of (3-45) as follows

$$\Omega_A = \int \int_{u^2 + v^2 \leq 1} |F(u,v)|^2 \sin \theta \, J \, du \, dv$$  \hspace{1cm} (3-51)

where $J$ is the Jacobian given by

$$J = \frac{\partial (\theta, \phi)}{\partial (u,v)} = \frac{1}{\frac{\partial (u,v)}{\partial (\theta, \phi)}}$$  \hspace{1cm} (3-52)

and

$$\frac{\partial (u,v)}{\partial (\theta, \phi)} = \begin{vmatrix} \frac{\partial u}{\partial \theta} & \frac{\partial u}{\partial \phi} \\ \frac{\partial v}{\partial \theta} & \frac{\partial v}{\partial \phi} \end{vmatrix} = \begin{vmatrix} \cos \theta \cos \phi - \sin \theta \sin \phi \\ \cos \theta \sin \phi \sin \theta \cos \phi \end{vmatrix} = \cos \theta \sin \theta$$  \hspace{1cm} (3-53)

So

$$\sin \theta \, J \, du \, dv = \sin \theta \frac{du \, dv}{\cos \theta \sin \theta} = \frac{du \, dv}{\sqrt{1 - u^2 - v^2}}$$  \hspace{1cm} (3-54)

using (3-48). Substituting (3-54) into (3-51) gives the previous result (3-50).
Example: An isotropic antenna

\[ F(\theta, \phi) = \begin{cases} 
1.0 & 0 \leq \theta \leq \pi/2 \\
0 & \theta > \pi/2 
\end{cases} \]

Using (3-45)

\[ \Omega_A = \int_0^{\pi/2} d\phi \int_0^{\pi/2} \sin \theta d\theta = 2\pi \]

Then (3-41) gives the directivity as \( D = 2 \). Also

\[ F(u, v) = 1.0 \quad u^2 + v^2 \leq 1 \]

Using (3-50)

\[ \Omega_A = \int \int \frac{1}{\sqrt{1 - (u^2 + v^2)}} \, du \, dv \]

Let \( r^2 = u^2 + v^2 \) then

\[ \Omega_A = \int_0^{2\pi} \int_0^1 r \, dr \, d\alpha \]

\[ = \int_0^{2\pi} \frac{1}{2} \left( \frac{1}{(-r^{2})} \right) \, d\alpha \]

\[ = \int_0^{2\pi} \frac{1}{2} \left( \frac{-dX}{2} \right) = 2\pi \]

where \( X = 1 - r^2 \). Again \( D = 2 \). The directivity for an isotropic antenna is 2 because one hemisphere has been neglected. We could define \( D \) as \( 2\pi/\Omega_A \) and obtain unity directivity for this isotropic antenna.
4. Examples of Computer Antenna Synthesis

The theory of chapter 3 has been computer programmed as the ANTSYN program and is discussed in detail in chapter 6. After an antenna synthesis problem has been solved using ANTSYN the results can be displayed using the ANTDATA program presented in chapter 7. The reader who intends on using these programs is referred to the appendices. In this chapter the results of several examples using the computer programs are presented. The examples given are only a small fraction of the number of antenna and pattern types which the method can handle. The important point to observe is that a wide variety of antenna shapes and pattern shapes can be synthesized using a single computer technique.

4.1 Common Antenna Types

In this section several simple antenna configurations are obtained from the computer programs. They are the patterns of the six correction functions discussed in section 3.5 and used in Subprogram PAT of the ANTSYN and ANTDATA programs. These patterns are examined for two reasons. First it serves as a program check. Many parameters are known about these patterns and can be compared to those obtained from the computer generated patterns to determine accuracy levels. Second, pattern plots of the correction functions provide a reference for visualizing synthesis capability of complex pattern shapes.

The first example is that of a uniform amplitude, uniform phase, line source. The length was chosen to be ten wavelengths. All of these patterns will change with changing antenna size, however the beam widths change in almost an inverse linear way with aperture size.
The side lobe levels do not depend on aperture size. In Fig. 4.1 is shown the pattern for this line source. (Aperture amplitude and phase distributions will be presented only when they are nonuniform.) This is the typical $\sin x/x$ pattern. The linear array version of this pattern is shown in Fig. 4.2 — that of a 21 element, half-wavelength spaced, uniform amplitude, uniform phase, linear array.

A line source with a triangular amplitude taper and uniform phase is shown in Fig. 4.3. Its pattern is plotted in Fig. 4.4. Note its increased beam width and reduced side lobes relative to the uniform amplitude line source.

Next consider a rectangular aperture. For variety choose a size of $10\lambda$ by $20\lambda$. When excited with uniform amplitude and phase it has a pattern given by (3-27). The principal plane patterns are shown in Figs. 4.5 and 4.6. They are identical to patterns from line sources of the same length, e.g. Figs. 4.1 and 4.5 are the same. In Fig. 4.7 is shown a contour map of the pattern, which includes the visible region of the $uv$-plane. The contour levels are 0, -5, -10, ..., -40 dB. The contour levels may be distinguished by examining the profiles. Also the -35 and -40 dB contours are plotted as dashed (looking almost dotted) lines. The square region shown was divided into a grid of 151 by 151 points for plotting this figure. An excellent way to present two dimensional patterns is through the use of Fig. 4.8 which gives a three dimensional effect and provides a good feel for the pattern throughout the visible region.

The patterns of a uniformly excited rectangular array have been omitted because of their similarity to the continuous aperture patterns for element spacings of a half wavelength or less.
Figure 4.1 Pattern of a uniform amplitude, uniform phase, ten wavelength line source.

Figure 4.2 Pattern of a uniform amplitude, uniform phase, half-wavelength spaced, 21 element, linear array.
Figure 4.3 Amplitude distribution of a triangular amplitude, ten wavelength line source.

Figure 4.4 Pattern of a triangular amplitude, uniform phase, ten wavelength line source.
Figure 4.5 Profile along u-axis of the pattern from a uniform amplitude, uniform phase, 10 by 20 wavelength rectangular aperture.

Figure 4.6 Profile along v-axis of the pattern from a uniform amplitude, uniform phase, 10 by 20 wavelength rectangular aperture.
Figure 4.7 Contour map of the pattern from a uniform amplitude, uniform phase, 10 by 20 wavelength rectangular aperture.
Figure 4.8  Radiation pattern of a uniform amplitude, uniform phase, 10 by 20 wavelength rectangular aperture.
Synthesis capability is provided for circular aperture by inclusion of an elementary pattern from such an aperture which is uniformly excited in amplitude. Figs. 4.9 and 4.10 show u and v axis profiles of the pattern from a uniform amplitude, uniform phase, five wavelength radius circular aperture. These plots are, of course, identical. A contour map of this pattern in the \(uv\)-plane for the whole visible region is shown in Fig. 4.11. The three dimensional view of the pattern is shown in Fig. 4.12.

The parameters of beam width, side lobe level and directivity have been calculated from theory and also obtained from this computer technique. They are all presented in Table 4.1 for the elementary patterns. In all cases except one the agreement is excellent. The directivity of a triangular line source is off by 8%. The reason for this is not known.

4.2 Linear Antenna Synthesis

In this section linear antennas are used to synthesize complex pattern shapes. Consider first a ten wavelength line source. Let the desired pattern and the upper and lower bounds be

<table>
<thead>
<tr>
<th>(v)</th>
<th>(F_d(v))</th>
<th>(F_u(v))</th>
<th>(F_L(v))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(</td>
<td>v</td>
<td>\leq 0.2)</td>
<td>0. dB</td>
</tr>
<tr>
<td>(0.4 \leq</td>
<td>v</td>
<td>\leq 1.0)</td>
<td>(-\infty)</td>
</tr>
</tbody>
</table>

The desired pattern is then a square beam with no side lobes but -40 dB side lobes will be tolerated. The original pattern is a Woodward-Lawson pattern with sample points at \(v = -0.2, -0.1, 0., 0.1, 0.2\) and sample values of 1.0 at these points. This original pattern has excursions +0.86 and -0.25 dB over the main beam and a side lobe level of -20 dB in the specified
Figure 4.9 Profile along u-axis of the pattern from a uniform amplitude, uniform phase, 10 wavelength diameter circular aperture.

Figure 4.10 Profile along v-axis of the pattern from a uniform amplitude, uniform phase, 10 wavelength diameter circular aperture.
Figure 4.11 Contour map of the pattern from a uniform amplitude, uniform phase 10 wavelength diameter circular aperture.
Figure 4.12 Radiation pattern of a uniform amplitude, uniform phase 10 wavelength diameter circular aperture.
<table>
<thead>
<tr>
<th>Antenna Type - TYPE</th>
<th>Source Dimensions (λ)</th>
<th>Beam Width</th>
<th>Side Lobe Level (dB)</th>
<th>Directivity (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Theory</td>
<td>Computer</td>
<td>Theory</td>
</tr>
<tr>
<td>Uniform line</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>source - 1</td>
<td>Lyλ = 10</td>
<td>0.0886</td>
<td>0.0886</td>
<td>-13.3</td>
</tr>
<tr>
<td>Uniform linear</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>array - 2</td>
<td>Py = 21 d = 0.5</td>
<td>0.0886</td>
<td>0.0886</td>
<td>-13.3</td>
</tr>
<tr>
<td>Triangular line</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>source - 3</td>
<td>Lyλ = 10</td>
<td>0.128</td>
<td>0.128</td>
<td>-26.6</td>
</tr>
<tr>
<td>Uniform</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rectangular</td>
<td>Lxλ = 10</td>
<td>0.0886</td>
<td>0.0886</td>
<td>-13.3</td>
</tr>
<tr>
<td>aperture - 4</td>
<td>Lyλ = 20</td>
<td>0.0443</td>
<td>0.0443</td>
<td>-13.3</td>
</tr>
<tr>
<td>Uniform</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rectangular</td>
<td>Px = 21 d = 0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>array - 5</td>
<td>Py = 41 d = 0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniform</td>
<td>circular</td>
<td>aλ = 5</td>
<td>0.102</td>
<td>-17.6</td>
</tr>
<tr>
<td>aperture - 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
side lobe region. The final pattern (which met the specifications) was obtained after 69 iterations. It deviated + 0.44 and - 0.42 dB over the main beam region and had a peak side lobe of - 40.79 dB in the specified side lobe region. The pattern is plotted in Fig. 4.13. The corresponding current distribution is given in Fig. 4.14.

The same pattern was synthesized using triangular amplitude source correction coefficients (see Figs. 4.3 and 4.4). This allows for comparison of different correction functions. The original pattern was formed using corrections located at \( v = -0.2, 0.0, 0.2 \) and of amplitude 1.0. The final pattern was obtained after only 30 iterations as compared to 69 for uniform amplitude source correction functions. The pattern deviations about the desired level of 0 dB over the specified main beam region were + 0.30 and - 0.11 dB. The peak side lobe over the specified side lobe region was - 41.68 dB. Thus the synthesized pattern was obtained with fewer iterations and was more comfortably within the tolerances than the pattern synthesized using uniform amplitude source correction coefficients. The pattern for this case is shown in Fig. 4.15. Its corresponding current distribution is plotted in Fig. 4.16. Note that the current is zero at the edges. This is because the source correction function of Fig. 4.3 is zero at the aperture edges. Zero edge illumination may be desirable in some situations.

Occasionally it is desirable to use linear arrays which are not equally spaced. The ITYPE = 7 of the ANTSYN program provides for general array synthesis. This example follows that of [14] which employs a different synthesis technique. The desired pattern is a square beam with upper and lower bounds as follows.
Figure 4.13  Square main beam pattern synthesized using a 10 wavelength line source with uniform amplitude source correction functions.

Figure 4.14  Current amplitude distribution required to produce pattern of Fig. 4.13.
Figure 4.15 Square main beam pattern synthesized using a 10 wavelength line source with triangular amplitude source correction coefficients.

Figure 4.16 Current amplitude distribution required to produce pattern of Fig. 4.15.
<table>
<thead>
<tr>
<th>v</th>
<th>F_d(v)</th>
<th>F_u(v)</th>
<th>F_L(v)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>v</td>
<td>≤ 0.26</td>
<td>0. dB</td>
</tr>
<tr>
<td>0.44 &lt;</td>
<td>v</td>
<td>≤ 1.0</td>
<td>- 20.</td>
</tr>
</tbody>
</table>

The element positions used as input to the program were found from [14] and are \( t_m = 0., \pm 0.496, \pm 0.983, \pm 1.926, \pm 2.372, \pm 3.188, \pm 3.545 \). The original pattern for this 13 element array was formed using the same Woodward-Lawson specifications as the first example of this section. The original pattern has an excursion of 4.51 dB above the desired level of 0. dB over the main (square) beam region and none below. The side lobe level is - 9.2 dB. Thus, in this case, the original pattern is quite far from desired performance. The final pattern obtained from ANTSYN took 15 iterations to meet the specifications. In fact, all side lobes were below - 22. dB. The pattern is shown in Fig. 4.17. This compares to a side lobe level of - 18.6 dB from [14]. The element currents for the two methods are similar.

4.3 Rectangular Antenna Synthesis

The multibeam capability of this technique is displayed with the synthesis of a pattern with pencil beams positioned at (0.5, 0.5), (0.5, -0.5), (-0.5, -0.5), and (0.5, 0.5). The side lobe upper limit was specified to be -25dB in the visible region outside the main beams, i.e. (for example, the beam centered at (0.5, 0.5) was specified for \( 0.38 < u < 0.64 \) and \( 0.38 < u < 0.64 \)).

The other beams were specified in a symmetric fashion. The region outside of these main beam regions had an upper limit of -25dB and no lower limit.

The antenna is a 10 by 10 wavelength square aperture. The original pattern was a Woodward-Lawson pattern with a correction coefficient of 1.0 and correction locations at each of the four main beam locations given above. The final pattern was obtained after 21 iterations. Profiles through the centers of the main beams (along u for v=0.5 and along v for u=0.5) are shown in
Figure 4.17 Square main beam pattern synthesized using a 13 element, 7 wavelength, nonuniformly spaced linear array.
Figures 4.18 and 4.19. The visible region includes abscissa values between -0.866 and 0.866. Thus, the high side lobes on each end of the profiles are outside the visible region. The contour map of the region $|u|$ and $|v| < 1.0$ is plotted in Figure 4.20. The visible region is a circle inscribed in the square shown. The three dimensional view is given in Figure 4.21.

In the next example a rectangular beam is synthesized using a 10 by 20 wavelength rectangular array. There are 20 elements spaced 0.5 wavelength in the s-direction and 40 elements spaced 0.5 wavelength in the t-direction. The pattern specifications are:

<table>
<thead>
<tr>
<th>$u$, $v$</th>
<th>$F_d(u,v)$</th>
<th>$F_{ll}(u,v)$</th>
<th>$F_l(u,v)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>u</td>
<td>&lt; 0.2,</td>
<td>u</td>
</tr>
<tr>
<td>$0.36 &lt;</td>
<td>u</td>
<td>&lt; 0.50$</td>
<td>unspecified</td>
</tr>
<tr>
<td>$0.12 &lt;</td>
<td>v</td>
<td>&lt; 0.50$</td>
<td>-20.0</td>
</tr>
</tbody>
</table>

The pattern is unspecified at all other points of the uv-plane. The gap in specifications between the main beam and side lobe regions allows the main beam to roll off. The elementary correction functions used (see 4.1) will give side lobes below -20.0 dB outside the side lobe region specified. The original pattern is that of a Woodward-Lawson pattern with 1.0 correction coefficients at 15 sample points which are all possible combinations of -0.2, -0.1, 0.0, 0.1, and 0.2 in u and -0.05, 0.0, and 0.05 in v. The ANTSYN computer program converged to a final pattern which met specifications after 62 iterations. The principal plane patterns are shown in Figures 4.22 and 4.23. The contour map is plotted in Figure 4.24. The contours run from 0.0 to -40.0 dB in 5.0 dB steps and the -35.0 and -40.0 dB contours are dotted. The three-dimensional view is shown in Figure 4.25.
Figure 4.18 A multiple beam radiation pattern profile in the $u$-direction for $v = 0.5$ synthesized using a 10 by 10 wavelength aperture antenna. The visible region is for $|u| \leq 0.866$.

Figure 4.19 A multiple beam radiation pattern profile in the $v$-direction for $u = 0.5$ synthesized using a 10 by 10 wavelength aperture. The visible region is for $|v| \leq 0.866$. 
Figure 4.20 Contour map of a multiple beam, low side lobe pattern synthesized from a 10 by 10 wavelength aperture.
Figure 4.21 Multiple beam, low side lobe pattern synthesized from a 10 by 10 wavelength aperture.
Figure 4.22 Profile along u-axis of a rectangular main beam, low side lobe pattern synthesized from a 20 element, 0.5 wavelength spaced by 40 element, 0.5 wavelength spaced rectangular array.

Figure 4.23 Profile along v-axis of a rectangular main beam, low side lobe pattern synthesized from a 20 element, 0.5 wavelength spaced by 40 element, 0.5 wavelength spaced rectangular array.
Figure 4.24 Contour map of a rectangular beam, low side lobe pattern synthesized from a 20 element, 0.5 wavelength spaced by 40 element, 0.5 wavelength spaced rectangular array.
Figure 4.25 Rectangular beam, low side lobe pattern synthesized from a 20 element, 0.5 wavelength spaced by 40 element, 0.5 wavelength spaced rectangular array.
Tighter tolerances are easily achieved. This example is a rectangular beam with the following specifications:

<table>
<thead>
<tr>
<th>(u, v)</th>
<th>F_d(u, v)</th>
<th>F_H(u, v)</th>
<th>F_L(u, v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.2 &lt; u &lt; 0.2</td>
<td>0 dB</td>
<td>0.5 dB</td>
<td>-0.5 dB</td>
</tr>
<tr>
<td>-0.05 &lt; v &lt; 0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.34 &lt; u &lt; 0.50</td>
<td></td>
<td>-∞</td>
<td>-25</td>
</tr>
<tr>
<td>0.12 &lt; v &lt; 0.50</td>
<td></td>
<td></td>
<td>unspecified</td>
</tr>
</tbody>
</table>

The pattern is unspecified at all other points in the uv-plane. The antenna used is again 10 by 20 wavelengths, but this time it is a continuous rectangular aperture. The original pattern is a Woodward-Lawson pattern with sample points and sample values as given in Section 8.1. The ANTSYN program was run and its output is shown in Section 8.2. Coincidentally, the number of iterations required to meet specifications, 62, was identical to the previous example which had weaker specifications. The plots of the final results were obtained using the ANTDATA, whose input for this example is discussed in Section 8.3. The principal plane profiles are shown in Figures 4.26 and 4.27. Note that the main beam ripple is less than +0.5 dB and the side lobes are below -25 dB. The contour map of the pattern is shown in Figure 4.28. In this case the lowest contour shown is -30 dB. The contour interval is still 5.0 dB and the maximum contour level is 0 dB. The three-dimensional plot is shown in Figure 4.29. The floor of this plot is -35 dB, i.e. values -35 dB below the main beam are suppressed.
Figure 4.26 Profile along u-axis of a rectangular main beam, low side lobe pattern synthesized from a 10 by 20 wavelength rectangular aperture.

Figure 4.27 Profile along v-axis of a rectangular main beam, low side lobe pattern synthesized from a 10 by 20 wavelength rectangular aperture.
Figure 4.28 Contour map of a rectangular main beam, low side lobe pattern synthesized from a 10 by 20 wavelength rectangular aperture.
Figure 4.29 Rectangular main beam, low side lobe pattern synthesized from a 10 by 20 wavelength rectangular aperture.
5. Conclusions

In this report we have presented a rather detailed discussion of a general technique for antenna synthesis. This general approach was adopted to allow for synthesizing perhaps the most difficult type of radiation pattern -- that of multiple shaped main beams with side lobe control. The intended application for this particular pattern is for domestic satellite antenna systems. Included are specific models for several common antenna types plus capability for synthesizing special antennas. This was done so that a paper feasibility study can be carried out for many antenna types. After such a study, there remain many engineering decisions concerning realizability (see Chapter 1) for each candidate antenna.

The examples given in Chapter 4 illustrate some of the antenna types and pattern shapes which can be handled with this method. There appears to be no limit to the variety of antennas and patterns one can use. The convergence of the iterative sampling method is not guaranteed. This is due to the simple correction functions we use. However, this selection ensures that no superdirective patterns will be synthesized. If a very narrow beam correction pattern were used, the convergence rate would increase due to increased resolution of the correction patterns. When convergence to the desired pattern is not obtained, one can relax the specifications (usually by widening the region of no-specification between the main beam and side lobe regions).

The synthesis capability can be expanded by increasing the capability of the computer programs given in the appendices. For extremely large antennas the pattern digitizing should be increased. It is now a 51 by 51
grid for one quadrant (for quadrilateral symmetry). This grid should be increased in size for antennas of, say, many tens of wavelengths in size.

The program could be made more efficient by making an array for the correction functions (e.g. PAT, SOURCE), to avoid repeated computations. This would allow one to easily put in an experimental correction function also.

The synthesis of circular apertures is currently rather slow. This is because of the Bessel function calculations which are required. Perhaps a special purpose \( J_1(x) \) routine could be written to avoid the general purpose IBM SSP routine.

The ANTDATA program requires a large amount of time to plot two and three dimensional plots. An ideal solution to this would be to replace the CALCOMP plotter with a video real time display for previewing the results. A hard copy attachment to the video terminal would also be very useful. Interactive computer graphics could be explored too.
References


6. Appendix: The ANTSYN Computer Program

6.1 Introduction

The ANTSYN computer program synthesizes finite planar antennas. It is based on the theory detailed in Chapter 3. On a large scale it can be considered to consist of four major functional blocks. The main program provides control of what operations are to be performed. The subroutines comprise the remaining blocks which function as input, computation, and output. The program as presented in this report is designed to handle antennas of most shapes and sizes. However, if an unusual antenna shape or one with certain limitations arising from hardware considerations is encountered, the modular subroutine structure allows the designer to change only selected subroutines to accommodate his particular problem.

This computer program has evolved over a period of six years and had been tested thoroughly. Because it is designed for wide application, it is, however, large and complex. Thus, if the potential user intends to make any subroutine changes he should have a good grasp of the FORTRAN IV language.

The patterns and source distributions are digitized and set up as two dimensional arrays. The pattern arrays FDES, FU, FL, AND F are specified in the U and V directions at MMAX and NMAX points beginning at STARTU and STARTV and incremented in intervals of DELTAU and DELTAV. The current arrays CURR and CURI are specified in the S and T directions at MCUR and NCUR points beginning at INITLS and INITLT and incremented in intervals of DELTAS and DELTAT.
6.2 Program Organization

A block diagram of the program with all of its subroutines is shown in Fig. 6.1. As mentioned in the previous section, the main program provides control over the subroutines which fall into three categories: input, computation, and output. The organization was selected to offer maximum flexibility. The program is intended to be very general, and it does provide for synthesis of many antenna types. However, if special antenna types are to be synthesized, the subroutines SPECPT and SPSOR can be used. Also, if the original pattern, correction pattern, or source correction are experimental, the subroutines ORGPAT, PAT, and SOURCE may be replaced with a data file of some sort.

The subroutines such as ANTSYN, SEARCH, UPDATE, CHECK, and CURREN have been developed from a considerable amount of effort and should not be changed unless one thoroughly understands the details of the entire program. The other subroutines have been written with the possibility of change in mind.

The arrays F, FDES, FU, FL, CURR, and CURI are presently dimensioned at (51, 51). The arrays US, VS, and CORCOF are dimensioned at 500. The storage used on the Virginia Tech IBM System 370/155 computer is about 200 K. Of course, any example run with the present program with dimension requirements less than those in the present program will be run by the program. If larger dimensioning is necessary the appropriate dimension statements in the program must be changed and storage allocation increased commensurately.
Figure 6.1 Block diagram of ANTSYN program
6.3 User's Guide to ANTSYN

In this section a summary of the steps one must follow when using ANTSYN is presented. The steps are listed in Table 6.1 in order. The device refers to how the step is accomplished in the program. The location refers to where in the program the step is performed. The availability is either standard or special. Standard is the way it is listed in the statement listing of Section 6.6. Special means it is to be provided by the user with the device indicated. The steps will be discussed here. Further details can be found in the variable definitions and subroutine descriptions in the following sections.

**Step 1.** This step is entirely optional and is included to show how one can use data storage (on-line disk in this case). The variables NUMPAT, NUMTRK, NUMSKP and IPASS are read off of the storage unit. NUMPAT is the pattern number assigned to the previous job. The program adds one to NUMPAT to form the current job pattern number. NUMTRK is the track number on disk where the previous job data was stored. NUMSKP is an array whose subscripts correspond to disk storage track numbers. If this number is 0 or 1 there is not data stored on that track. This information is used in step 10 to write onto disk.

**Step 2.** The pattern parameters are read in from cards under

NAMELIST/PARAM/IDISK, ISYMM, ITRMAX, DELTAU, DELTAV, STARTU, STARTV, MMAX, NMAX, MCENT, NCENT

All of these variables are to be provided on cards following the FORTRAN Namelist format.

**Step 3.** Next the switches for control of the print out are read in from cards under

NAMELIST/IPRINT/FDESPT, FDESPR, FDESCN, FDBPT, FDBCN, FDBPR, FORGPT, FORGCN, FORGPR, ICURPT, ICURCN, ICURPR, FCURPT, FCURCN, FCURPR, DIRECT

Only those print outs desired need to have the appropriate switch variable provided on input of this Namelist, because default for all print outs is none.
<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Device</th>
<th>Location</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Job assignment</td>
<td>Auxiliary storage</td>
<td>MAIN</td>
<td>Standard</td>
</tr>
<tr>
<td>2.</td>
<td>Pattern parameters</td>
<td>Cards; use Namelist PARAM</td>
<td>MAIN</td>
<td>Standard</td>
</tr>
<tr>
<td>3.</td>
<td>Output print control</td>
<td>Cards; use Namelist IPRINT</td>
<td>MAIN</td>
<td>Standard</td>
</tr>
<tr>
<td>4.</td>
<td>Antenna parameters</td>
<td>Cards; use Namelist PATIN</td>
<td>INPUT</td>
<td>Standard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If ITYPE &gt;7 also use subroutine SINPUT</td>
<td>SINPUT</td>
<td>Special</td>
</tr>
<tr>
<td>5.</td>
<td>Desired pattern</td>
<td>Program statements to load FDES, FU and FL</td>
<td>DESPAT</td>
<td>Special</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or Program statements to load FDES, FU, and FL</td>
<td>DESPAT</td>
<td>Special</td>
</tr>
<tr>
<td>6.</td>
<td>Original pattern and original source</td>
<td>Cards; read NORG, US, VS, CORG to generate original state using Woodward-Lawson method</td>
<td>ORGPAT</td>
<td>Standard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or Cards or program statements; if Woodward-Lawson is not used, load F, CURR, and CURI, set NORG=0</td>
<td>ORGPAT</td>
<td>Special</td>
</tr>
<tr>
<td>7.</td>
<td>Special correction pattern function</td>
<td>Program statements to generate values of PAT, ITYPE &gt;7</td>
<td>SPECPT</td>
<td>Special</td>
</tr>
<tr>
<td>8.</td>
<td>Special correction source function</td>
<td>Program statements to generate companion to special pattern, ITYPE &gt;7</td>
<td>SPSOR</td>
<td>Special</td>
</tr>
<tr>
<td>9.</td>
<td>Special location</td>
<td>Program statements to generate source coordinates given source array subscripts, use when ITYPE &gt;7</td>
<td>SPLOC</td>
<td>Special</td>
</tr>
<tr>
<td>10.</td>
<td>Job storage</td>
<td>Programming to write job data onto storage unit</td>
<td>MAIN</td>
<td>Standard</td>
</tr>
</tbody>
</table>
Step 4. This step provides input concerning the particular antenna to be used. It is read in on cards under

NAMELIST/PATIN/LX, LY, PX, PY, DISX, DISY, INITLS, DELTAS, FINALS, INITLS, DELTAT, FINALT, NEIMT, ARAD, ITYPE, MCUR, NCUR

See write up on Subroutine INPUT in Section 6.5 for a list of which variables must be supplied in this Namelist for the various antenna types.

Step 5. The patterns FDES, FU, and FL are to be loaded in this step. This can be done in two ways. First programming can be provided in Subroutine DESPAT to give a value to this arrays at every point. Or, a Subroutine DESPAT can be used to call READ for these arrays and then cards are read to load the arrays.

Step 6. The original pattern and original source are loaded in this step. If the Woodward-Lawson technique is satisfactory all that is necessary is to provide data cards with sample information. The first card is the number of samples NORG and uses an I5 format. The succeeding cards (NORG in number) contain UORG, VORG, AND CORG (the sample locations and values) on a 3F10.0 format. The original pattern F and current CURR and CURI may be loaded in any other fashion if the user replaces ORGPAT with programming that loads them directly or calls some device and reads them. Set NORG=0 in ORGPAT if Woodward-Lawson technique is not used.

Steps 7 and 8. If correction pattern and source functions other than the seven standard ones available are desired by the user, Subroutines SPECPT and SPSOR are to be written. Use ITYPE >7.

Step 9. If correction pattern and source functions other than the seven standard ones available are desired by the user, Subroutine SPLOC is to be written. Use ITYPE >7.
**Step 10.** At the completion of a program data may be stored for future use, such as with the ANTDATA program. After looking at ANTSYN print out the user can decide if further display is desired. We can then use the data stored to plot patterns, currents, etc. IDISK is used to control whether data is to be stored.
6.4 Program Variables

6.4.1 Correspondence Between Symbols Used in the Theory and Program Variables

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Computer Program Counterpart</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a(i) )</td>
<td>CORCOF( )</td>
</tr>
<tr>
<td>( n )</td>
<td>ARAD</td>
</tr>
<tr>
<td>( a_\lambda )</td>
<td>DISX</td>
</tr>
<tr>
<td>( d_x \lambda )</td>
<td>DISY</td>
</tr>
<tr>
<td>( d_y \lambda )</td>
<td></td>
</tr>
<tr>
<td>( f(K)(s,t) )</td>
<td>CURR(M,N)</td>
</tr>
<tr>
<td></td>
<td>CURI(M,N)</td>
</tr>
<tr>
<td>( F(i)(u,v) )</td>
<td>( F(M,n) )</td>
</tr>
<tr>
<td>( F_d(u,v) )</td>
<td>( FDES(M,N) )</td>
</tr>
<tr>
<td>( g_n(i)(s,t) )</td>
<td>SOURCE(J,K,US(L),US(L),ITYPE)</td>
</tr>
<tr>
<td>( G(u-u_n(i),v-v_n(i) )</td>
<td>PAT(U-US(L),V-VS(L),ITYPE)</td>
</tr>
<tr>
<td>( L_x \lambda )</td>
<td>LX</td>
</tr>
<tr>
<td>( L_y \lambda )</td>
<td>LY</td>
</tr>
<tr>
<td>( P_x )</td>
<td>PX</td>
</tr>
<tr>
<td>( P_y )</td>
<td>PY</td>
</tr>
<tr>
<td>( s )</td>
<td>S</td>
</tr>
<tr>
<td>( t )</td>
<td>T</td>
</tr>
<tr>
<td>( u )</td>
<td>U</td>
</tr>
<tr>
<td>( u_n(i) )</td>
<td>US( )</td>
</tr>
<tr>
<td>( v )</td>
<td>V</td>
</tr>
<tr>
<td>( v_n(i) )</td>
<td>VS( )</td>
</tr>
</tbody>
</table>
6.4.2. Definition of Some Integer Variables Used in the Program

**DIRECT**
Input variable controlling calculation and print out of directives DIRORG and DIRFNL; 0 No, 1 Yes – Default is 0. Original pattern is to be of Woodward-Lawson type.

**FCURCN**
Input variable controlling print out of contour map of final current distribution; 0 No, 1 Yes – Default is 0.

**FCURPR**
Input variable controlling print out of final current distribution profile or list; 0 None, 1 Profile (S and/or T axis) for continuous sources, 1 Table of element currents for arrays, 2 List (primarily for use with ITYPE = 7) – Default is 0.

**FCURPT**
Input variable controlling print out of a listing of the final current distribution; 0 No, 1 Yes – Default is 0.

**FDBCN**
Input variable controlling print out of contour map of final pattern in dB; 0 No, 1 Yes – Default is 0.

**FDBPR**
Input variable controlling print out of final pattern profile; 0 No, 1 Yes – Default is 0.

**FDBPT**
Input variable controlling print out of final pattern in dB; 0 No, 1 Yes – Default is 0.

**FDESPR**
Input variable controlling print out of desired pattern profile table; 0 No, 1 Yes (U and/or V axis) – Default is 0.

**FDESPT**
Input variable controlling print out of a listing of desired pattern; 0 No, 1 Yes – Default is 0.

**IC**
Subscript of CORCOF( ) array for latest correction.

**ICURCN**
Input variable controlling print out of contour map of initial current distribution; 0 No, 1 Yes – Default is 0.

**ICURPR**
Input variable controlling print out of initial current distribution profile or list; 0 None, 1 Profile (U and/or V axis), 2 List (primarily for use with ITYPE = 7) – Default is 0.

**ICURPT**
Input variable controlling print out of a listing of initial current distribution; 0 No, 1 Yes – Default is 0.

**IDISK**
Input variable controlling output of data to disk storage; 0 No, 1 Write if successful (ISUC = 1), 2 Write all final pattern data.

**IPASS**
Optional passphrase to protect disk storage

**ISUC**
Success counter; 0 If pattern specifications have not been met, 1 If they have.
ISYMM
Input variable describing the symmetry of the desired pattern; 0 if No symmetry, 1 for symmetry about U-axis, 2 for symmetry about V-axis, 3 for symmetry about both U and V axes, and 4 for symmetry about U, V and both 45 degree axes.

ITER
Number of iterations performed.

ITRMAX
Input variable giving the maximum number of iterations the program is allowed.

ITYPE
Input variable indicating what antenna type is to be used in the synthesis, the type descriptions follow.

<table>
<thead>
<tr>
<th>ITYPE</th>
<th>Antenna Type</th>
<th>Source Illumination Used to Form Correction Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Line Source</td>
<td>Uniform</td>
</tr>
<tr>
<td>2</td>
<td>Equally Spaced Linear Array</td>
<td>Uniform</td>
</tr>
<tr>
<td>3</td>
<td>Line Source</td>
<td>Triangular</td>
</tr>
<tr>
<td>4</td>
<td>Rectangular Aperture</td>
<td>Uniform</td>
</tr>
<tr>
<td>5</td>
<td>Rectangular Array</td>
<td>Uniform</td>
</tr>
<tr>
<td>6</td>
<td>Circular Aperture</td>
<td>Uniform</td>
</tr>
<tr>
<td>7</td>
<td>General Array</td>
<td>Uniform</td>
</tr>
<tr>
<td>GT7</td>
<td>SPECPT</td>
<td>SPSOR</td>
</tr>
</tbody>
</table>

MCENT
Input variable - First subscript of pattern array where pattern is to normalized to 0 dB.

MCUR
Input variable - Number of first subscripts of CURR and CURI arrays - Usually indicates quantization in S direction.

MMAX
Input variable - Number of points used in U direction for pattern arrays.

NCENT
Input variable - Second subscript of pattern array where pattern is to be normalized to 0 dB.

NCUR
Input variable - Number of second subscripts of CURR and CURI arrays - Usually indicates quantization in T direction.

NELMT
Total number of antenna array elements - Used as input when ITYPE=7.

NMAX
Input variable - number of points used in V direction for pattern arrays.

NORG
Input variable - Number of samples in original pattern.
NUMPAT Pattern number - Arbitrary sequence number for identifying synthesis problems.

NUMSKP( ) Variable on disk storage. If 0 space is available on track corresponding to subscript number. If 1 track contains previously generated data.

NUMTRK Reference number of a single track on disk storage.

ORGCN Input variable controlling print out of contour map of original pattern; 0 NO, 1 YES - Default is 0.

ORGPR Input variable controlling print out of original pattern; 0 NO, 1 YES (U and/or V axis) - Default is 0.

ORGPT Input variable controlling print out of original pattern; 0 NO, 1 YES - Default is 0.

PX Input variable - Number of array elements in X-direction.

PY Input variable - Number of array elements in Y-direction.

6.4.3. Definition of Some Real Variables Used in the Program

ARAD Input variable - Radius of circular aperture source in terms of a wavelength.

CONINT Interval between contour levels of CONTUR and PATCON print outs.

CONLOW Lowest contour level of CONTUR and PATCON print outs.

CONMAX Maximum level of CONTUR and PATCON print outs.

CORCOF( ) Correction coefficient

CORG( ) Correction coefficients (or sample values) for original pattern.

CURI( , ) Imaginary part of current.

CURR( , ) Real part of current.

DELCNON Increment above and below a contour level for which a function value is said to belong to that contour when using CONTUR and PATCON print outs.

DELTAS Input variable - Increment between print out points of current distribution in S direction.

DELTAT Input variable - Increment between print out points of current distribution in T direction.
DELTAU  Input variable - Increment between comparison points in U direction. Also, Increment between pattern print out points.

DELTAV  Input variable - Increment between comparison points in V direction. Also, increment between pattern print out points.

DIRFNL  Directivity of final pattern.

DIRORG  Directivity of original pattern.

DISX   Input variable - Spacing between antenna array elements in X direction normalized to a wavelength.

DISY   Input variable - Spacing between antenna array elements in Y direction normalized to a wavelength.

F( , )  Current pattern value.

FDES( , ) Input variable - Desired pattern value.

FINALS Input variable - Final point of current distribution print outs in S direction.

FINALT Input variable - Final point of current distribution print outs in T direction.

FINALU Input variable - Final point of pattern comparison and print outs in U direction.

FINALV Input variable - Final point of pattern comparison and print outs in V direction.

FL( , ) Input variable - Lower limit on synthesized pattern.

FNORM Factor by which pattern F( , ) is divided to normalize it to 0 dB at the point (MCENT, NCENT).

FU( , ) Input variable - Upper limit on synthesized pattern.

INITLS Input variable - Initial point of current distribution print outs in S direction.

INITLT Input variable - Initial point of current distribution print outs in T direction.

LX  Length of antenna in X direction in wavelengths - For continuous aperture sources this is an input variable.

LY  Length of antenna in Y direction in wavelengths - For continuous aperture sources this is an input variable.

S  Source coordinate X normalized to a wavelength.

SS( ) Antenna array element position in S direction - Input variable for ITYPE = 7.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STARTU</td>
<td>Input variable - Starting point in U direction for pattern comparisons and print outs.</td>
</tr>
<tr>
<td>STARTV</td>
<td>Input variable - Starting point in V direction for pattern comparisons and print outs.</td>
</tr>
<tr>
<td>T</td>
<td>Source coordinate Y normalized to a wavelength.</td>
</tr>
<tr>
<td>TT( )</td>
<td>Antenna array element position in T direction - Input variable for ITYPE - 7.</td>
</tr>
<tr>
<td>U</td>
<td>Pattern coordinate.</td>
</tr>
<tr>
<td>UORG( )</td>
<td>Input variable - Positions of sample points for original pattern in U direction.</td>
</tr>
<tr>
<td>US( )</td>
<td>Positions of corrections (samples) in U direction.</td>
</tr>
<tr>
<td>V</td>
<td>Pattern coordinate.</td>
</tr>
<tr>
<td>VORG( )</td>
<td>Input variable - Positions of sample points for original pattern in V direction.</td>
</tr>
<tr>
<td>VS( )</td>
<td>Positions of corrections (samples) in V direction.</td>
</tr>
</tbody>
</table>
6.5 Subroutine Descriptions

The subroutines are discussed in the order in which they appear in Fig. 6.1.

**SUBROUTINE INPUT**

This subroutine provides input to the program through the card reader. The Namelist labeled PATIN is used. Of the variables in this Namelist, only certain ones are to be specified for different values of ITYPE. The variables are defined in Section 6.4. The ones which are to be provided as input for each ITYPE are listed below. Remaining variables for a given ITYPE are to be omitted from the input deck.

<table>
<thead>
<tr>
<th>ITYPE</th>
<th>Variables to be provided as input for PATIN Namelist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LY, INITLT, DELTAT, FINALT, ITYPE</td>
</tr>
<tr>
<td>2</td>
<td>LY, PY, DISY, ITYPE</td>
</tr>
<tr>
<td>3</td>
<td>LY, INITLT, DELTAT, FINALT, ITYPE</td>
</tr>
<tr>
<td>4</td>
<td>LX, LY, INITLS, DELTAS, FINALS, INITLT, DELTAT, FINALT, ITYPE</td>
</tr>
<tr>
<td>5</td>
<td>LX, LY, PX, PY, DISX, DISY, ITYPE</td>
</tr>
<tr>
<td>6</td>
<td>INITLS, DELTAS, FINALS, INITLT, DELTAT, FINALT, ARAD, ITYPE</td>
</tr>
<tr>
<td>7</td>
<td>ITYPE, MCUR, NCUR</td>
</tr>
</tbody>
</table>

Greater than 7 SINPUT, written by user for his special problem.

For ITYPE=7 the source arrays are sized with MCUR and NCUR. The total number of elements in the array should be the product of MCUR and NCUR. If the number of elements is not easily factorable, one could always use an array with MCUR=number of elements and NCUR=1. This may require some dimension statement changes in the program. Two dimensional arrays for the source are used because of their convenience with the other source types.
INITLS, DELTAS, FINALS and INITLT, DELTAT, FINALT are used for prints of the source.

**SUBROUTINE SINPUT**

Currently this subroutine is a dummy subprogram. Inputs for programs not included in ITYPE through 7 should use this subroutine. It is to be written and added by the user. ITYPE as used in NAMELIST/PATIN/should have a value of 8 or greater. SINPUT is called from INPUT when ITYPE is 8 or greater.

**SUBROUTINE READ (F, MMAX, NMAX)**

This subroutine is used to load any two dimensional array in the program by reading in values off of cards. F is any real two dimensional array. MMAX rows and NMAX columns are to be loaded. The program in its present form does not use READ but subroutines DESPAT and ORGPAT can be used to call READ to load FDES, F, FU, FL, CURR, CURI. The arrays F, CURR, and CURI are then the original pattern, real part of original current, and the imaginary part of the original current.

The arrays are read in row by row. A new row is begun by a new card. The format is 6(I3,F10.0). The integer number is a multiplier, i.e., the following real number is to be repeated that many times. For example, if MMAX were 51 and all entries in the 5th row were to be 0.0, the card corresponding to the 5th row would have 51 in columns 2 and 3 and 0 in column 13.

**SUBROUTINE DESPAT (FDES, FU, FL, MMAX, NMAX, STARTU, STARTV, DELTAU, DELTAV)**

The purpose of this subroutine is to return arrays FDES, FU, and FL. They are all two dimensional and are loaded with MMAX rows and NMAX columns.
There are several ways that this subroutine can be written to load these arrays. Subroutine READ can be called for each of the arrays, if card input is convenient. If the patterns can be generated from FORTRAN expressions easily, the arrays can be loaded in the subroutine by incrementing thru U and V and assigning values to the arrays. This approach often avoids the need for a large input card deck.

The values of the patterns FDES, FU, and FL are to be positive real numbers and not dB values. This is done for computing efficiency. If one wishes to work with dB values it is an easy matter to convert dB to real values in this subroutine using 20.*ALOG10( ). It is best for the pattern maximum, if specified, to be close to 1.0.

**SUBROUTINE ORGPAT (F, MMAX, NMAX, STARTU, STARTV, DELTAU, DELTAV, CURR, CURI, MCUR, NCUR)**

This subroutine is used to initialize the pattern array F and current arrays CURR and CURI. These represent the original pattern and real and imaginary part of the original current distribution. The pattern arrays are to be specified in rows and columns starting with STARTU and STARTV and extending for MMAX and NMAX points with DELTAU and DELTAV being the separation between points. The current arrays give current values at positions in the ST plane which depend on ITYPE; see SOURCE.

The program presently loads the arrays using the Woodward-Lawson synthesis method. This amounts to a 0th iteration. First, the number of samples in the original pattern is read in as NORG on a single card under an I5 format. Next the sample positions US and VS and the correction coefficients CORG are read in on a card under 3F10.0 format. See [12] for an excellent discussion of the Woodward-Lawson method. Note that the Taylor
line source method is handled with this technique also. [13]

If the original pattern is something which is not satisfactorily represented by a Woodward-Lawson type pattern, the user can substitute for this subroutine. If the original pattern and current are experimentally obtained, the READ subroutine can be called to read in the values from cards or the arrays can be generated using analytic functions. In ORGPAT, NORG should be set to zero when not using Woodward-Lawson method to generate original state.

SUBROUTINE ANTSYN (ISUC, MMAX, NMAX, FDES, FU, FL, ITRMAX, ISYMM, CORCOF, IC, US, VS, STARTU, DELTAU, STARTV, DELTAV, MCENT, NCENT, ITER, FNORM, F)

This subroutine carries out the iteration procedure. The arrays FDES, FU, and FL are input and are the pattern specifications loaded by DESPAT. F is initially the original pattern found from ORGPAT. This array is changed as iterations are performed and is the current synthesized pattern state.

The subroutine cycles, or iterates, until either all points of F are between corresponding points of FU and FL or the maximum number of iterations ITRMAX is exceeded before each iteration F is normalized to 1.0 at the MCENT row and NCENT column. If the pattern specifications are not met, SEARCH is called to locate where the pattern exceeds its tolerances by the greatest amount. The weighting coefficient as given in (3-9) is returned as VAL and then is loaded into CORCOF. If the correction points are close to either the U or V axis but not on either and the pattern is symmetric, VAL is adjusted because of the strong correlation between the sample and its symmetrically placed samples. ANTSYN places other corrections corresponding to the level of symmetry ISYMM. The higher the level of symmetry in the desired pattern, the higher the level of symmetry of the corrections. After each correction,
UPDATE is called to recompute the pattern; CHECK is then called to see if corrections have ever been applied at the latest sample points. The iteration is now complete and control is transferred to the beginning of ANTSYN. This is repeated until the specifications are met or ITRMAX is exceeded. Then, control is returned to the main program where results are printed out.

SUBROUTINE SEARCH (II, J1, VAL, FDES, FU, FL, F, MMAX, NMAX, STARTU, STARTV, DELTAU, DELTAV)

This subroutine is called by ANTSYN subroutine to locate the point where the current pattern F exceeds the upper and lower limit patterns FU and FL by the largest amount. This point is returned from the subroutine as II and J1 of the pattern matrices. II and J1 are also used as input and is the first point where specifications are not met as found in ANTSYN. The search begins here to avoid searching points that were covered in ANTSYN. The V axis is searched in increments of DELTAV for NMAX points for each U value, which itself is incremented in DELTAU for NMAX points. The search is limited to the visible region inside the unit circle. The maximum deviation above FU or below FL is returned as VAL as computed by (3-9). The values of II, J1, and VAL are printed out and flagged with **SEARCH** so that the user can see a "time history" of the corrections applied.

SUBROUTINE UPDATE (IC, US, VS, CORCOF, F, MMAX, NMAX, FNORM, STARTU, STARTV, DELTAU, DELTAV)

This subroutine updates the F array to keep it current. Following each correction the array is recomputed in this subroutine. In ANTSYN the coordinates of the correction point are evaluated after II and J1 are returned from SEARCH and assigned as U1 and V1 and then as US(IC) and VS(IC). So IC is the subscript for US, VS, and CORCOF corresponding to the most recent
assignments to those arrays. IC and the whole arrays US, VS, and CORCOF are input to UPDATE. Then the pattern F is calculated using these arrays and PAT.

FUNCTION PAT (U, V, ITYPE)

This subprogram returns the value of the correction function at the point U, V. It does this for function types determined by the value of ITYPE. The seven antenna types corresponding to the numbers 1 through 7 for ITYPE as given in the integer variable definition section of this Chapter are discussed in detail in Section 3.5. If the user wishes to use some other correction function, a value of ITYPE greater than 7 will make PAT call SPECPT to find a value.

FUNCTION SPECPT (U, V, ITYPE)

Currently, this is a dummy subprogram. If a correction function other than one of the seven standard ones given in PAT is required, this function is to be used. The dummy subprogram is then replaced by a function which generates values at all points (U, V). See PAT.

SUBROUTINE CHECK (IC, VAL, US, VS, CORCOF, DELTAU, DELTAV)

This subroutine is used to save computing time and storage space. After a correction has been determined by SEARCH and applied by UPDATE, CHECK is called to see if the correction point has ever been used before. All previous sample points US and VS are searched for a match to US(IC) and VS(IC). If a match is found the correction coefficient CORCOF(IC) is added to the correction coefficient previously applied at that point. The number of correction coefficients is thus reduced by one each time a match is found.
SUBROUTINE CURREN (CURR, CURI, MCUR, NCUR, US, VS, CORCOF, IC)

This subroutine calculates the final current distribution necessary to produce the final pattern F. The real and imaginary parts of the current matrix, CURR and CURI, are initially that of the original current distribution (corresponding to the original pattern) as generated in ORGPAT. The source currents are calculated by summing all corrections together with the original pattern as in (3-11) and (3-12). The correction functions for the current are obtained from the SOURCE subprogram.

COMPLEX FUNCTION SOURCE (M, N, U, V, ITYPE)

This subprogram supplies values of the correction current for loading into the current arrays CURR and CURI at the point (M, N) for pattern sample point (U, V). This subprogram has seven sources corresponding to the seven patterns of PAT and they are flagged with an ITYPE number. If antennas other than these seven standard types are required, SPSOR is used to generate it. SPSOR will be called automatically if ITYPE is greater than 7. The sources in this subprogram are the Fourier Transform mates of the patterns in PAT.

COMPLEX FUNCTION SPSOR (M, N, U, V, ITYPE)

Currently, this is a dummy subprogram. It operates in the same manner as SOURCE. It is called from SOURCE when ITYPE exceeds seven. Then the dummy subprogram should be replaced by programming which generates values of the current distribution corresponding to the correction pattern of SPECPT and with correction point (U, V). The function of SPSOR and SPECPT should be Fourier transform mates.
SUBROUTINE LOCOR (M, N, S, T)

This subroutine is used to generate source coordinates S and T when given the subscripts M and N of the current arrays CURR and CURI. It depends, of course, on the antenna used and this is handled by the commoned variable ITYPE. For ITYPE greater than seven SPLOC is called automatically. The coordinates S and T obtained from this subroutine are used by SOURCE and in the excitation print out part of the main program.

SUBROUTINE SPLOC (M, N, S, T)

This is currently a dummy subroutine. It is called by LOCOR when ITYPE is greater than seven. When an antenna type other than one of the seven standard types is used, the user must supply FORTRAN coding to this subroutine to perform the function of LOCOR.

SUBROUTINE DIRCTV (CORG, UORG, VORG, NORG, US, VS, CORCOF, IC, MMAX, NMAX, DIRORG, DIRFNL)

This subroutine calculates the directivity of the original and final patterns, DIRORG and DIRFNL. The directivities are calculated as discussed in Section 3.6. The patterns are generated by adding up all weighted correction patterns. The original pattern must be of the Woodward-Lawson type. If this is not the case, programming may be changed to call ORGPAT for generation of the original pattern.

If these directivities are desired, output the variable DIRECT should be set to 1 in Namelist IPRINT.

SUBROUTINE PRINT (A, M, N, STARTU, STARTV, DU, DV)

Subroutine print is the general output subroutine. It will print out co-ordinates (U, V) and values A(I, J), 10 rows and 10 columns to a page.
U and V are calculated as follows:

\[ U = \text{STARTU} + (I - 1) \times DU \]
\[ V = \text{STARTV} + (J - 1) \times DV \]

where I and J correspond to A(I, J), the value printed.

The output format is such that for large sources the printout covers many pages. However, these pages may be pasted together to form a grid and then photo-reduced for ease of handling.

PRINT may be used for all patterns and for all sources except ITYPE = 7. To invoke PRINT code the following variables in Namelist IPRINT.

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desired pattern</td>
<td>FDESPT = 1</td>
</tr>
<tr>
<td>Original pattern</td>
<td>FORGPT = 1</td>
</tr>
<tr>
<td>Final pattern</td>
<td>FDBPT = 1</td>
</tr>
<tr>
<td>Original current</td>
<td>ICURPT = 1</td>
</tr>
<tr>
<td>Final current</td>
<td>FCURPT = 1</td>
</tr>
</tbody>
</table>

SUBROUTINE PROFIL (DATA1, NPT, NUMPAT)

Subroutine PROFIL prints a graph of the data in DATA1 with automatic scaling using NPT(NPT<401) number of points. The abscissa is stored in DATA1 (J, 1); the ordinate is stored in DATA1 (J, 2).

Because the line printer is a discrete device, the axes will be quantized. However, the true value of the ordinate is printed to the right of the graph.

PROFIL may only be used for pattern printouts. PROFIL gives both U-axis and V-axis profiles.

To invoke subroutine PROFIL, code the following variables in Namelist IPRINT.
**Pattern** | **Variable**
---|---
Original | FORGPR = 1
Final | FDBPR = 1

**SUBROUTINE CONTUR (K, L, DELCON, CONLOW, CONMAX, CONINT, A, NUMPAT)**

Subroutine CONTUR provides a contour map of data stored in array A (dimensioned A(51, 51)). It is used primarily for two-dimensional source distributions. (Subroutine PATCON is used for two-dimensional patterns.) Contour levels between CONLOW and CONMAX differing by CONINT are printed on a K by L grid (K, L ≤ 51).

To invoke this subroutine code the following variables in Namelist IPRINT.

<table>
<thead>
<tr>
<th>Source</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original distribution</td>
<td>ICURCN = 1</td>
</tr>
<tr>
<td>Final distribution</td>
<td>FCURCN = 1</td>
</tr>
</tbody>
</table>

Separate contour printouts are given for real and imaginary currents. Not intended for use with ITYPE=7 patterns.

**SUBROUTINE PATCON (RDATA, MMAX, NMAX, ICODE, CONLOW, CONMAX, CONINT, STARTU, STARTV, DELTUI, DELTAV, NUMPAT, ISYMM)**

Subroutine PATCON provides the user with a contour map of the desired pattern (ICODE = 0), the initial pattern (ICODE = 1), or the final pattern (ICODE = 2). Contour levels are given by CONLOW, CONMAX, and CONINT. There may be up to 10 contour levels. In addition, if the pattern at a particular point falls below CONLOW, then a MINUS sign is printed. If the pattern rises above CONMAX, a plus sign is printed. Approximate execution time of PATCON is 10 seconds.
To invoke this subroutine code the following variables in Namelist IPRINT.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>ICODE</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desired</td>
<td>0</td>
<td>FDESCN = 1</td>
</tr>
<tr>
<td>Original</td>
<td>1</td>
<td>FORGCN = 1</td>
</tr>
<tr>
<td>Final</td>
<td>2</td>
<td>FDBCN = 1</td>
</tr>
</tbody>
</table>

**SUBROUTINE LIST (CURR, CURI, MCUR, NCUR)**

The purpose of SUBROUTINE LIST is to print out array element coordinates and currents for the general array source (ITYPE = 7). The coordinates (S, T) are found from SUBROUTINE LOCSON and these are printed along with the appropriate value of current.

SUBROUTINE LIST is called by coding ICURPR = 2 or FCURPR = 2 in Namelist IPRINT. ICURPR = 2 will list initial element currents while FCURPR = 2 will list final element currents.

While written primarily for sources of ITYPE = 7, LIST may be used with any source.

**6.6 Statement Listing of ANTSYN**

**6.6. Job Control Language Statements**

```plaintext
//FORSY57 JOB IT762, COFFEY
*/MAIN TIME=3, REGION=220K, LINES=16, LARDS=0
*/PRIORITY PRIORITY
// EXEC FORT65, LIBS=55PLIB
// FORT.SYSIN UD *
/*
*/60.FLZ2PS31 DD SYSIN=ANTDATA, ACP=76, UNI=3330, VOL=SER=USERPK, LISP=SER
//60.SYSIN UD *
/*
```

**6.6.2 Source Listing**
MAIN PROGRAM TO SYNTHESIZE A PATTERN FOR A GIVEN SOURCE.

VERSION 3  73/164 -- JUNE 13, 1973

WRITTEN BY:  E. L. COFFEY
W. L. STUTZMAN

UNDER NASA GRANT: 47-004-103

LANGUAGE:  FORTRAN IV

SUBPROGRAMS REQUIRED:
  DIRCIV
  INPUT
  READ
  CRGPAT
  ANTSYN
  SEARCH
  CHECK
  UPDATE
  PAT
  SOURCE
  LOCSOR
  SPLOC
  SPECPT
  SPSOR
  SINPUT
  CURREN
  PRINT
  PROFIL
  CONTUR
  PATCCN
  LIST
  DESPAT
  DATE
  STIME
  BESJ
  ...STANDARD FORTRAN LIBRARY SUBPROGRAMS...

INPUT/OUTPUT SUPPORT:
  FTO5FC01 (SYSIN) -- CARD READER
  FTO6FO01 (SYSPRINT) -- LINE PRINTER
  FT22FC01 (ANTDATA.A507C2) -- AUXILIARY STORAGE

STORAGE REQUIREMENTS:  220K
DEFINE TITLE(20)

INTEGER NUMSKP(35),FDESPT,FDESCN,FDESPR
INTEGER FORGPT,FORGCN,FORGPR,FDBPT,FDBCN,FDBPR,DIRECT
REAL FDES(51,51),FU(51,51),FL(51,51),F(51,51)
REAL US(500),VS(500),CORCOF(500),CURR(51,51),CURI(51,51)
REAL UCHR(100),VORG(100),CORG(100)
REAL INITLS,INITLT

INTEGER FCURPT,FCURCN,FCURPR

COMMON /MPROG/ ICUR,NCUR
COMMON /START/ NORG,UORG,VORG,CURG
COMMON /PAT1/ P1,P2,P3,P4,P5,P6,PI,SS(400),IT(400),RK(400)
COMMON /PAT2/ 11,12,13,14,15
COMMON /LOC/ ITYPE

NAMELIST /PARAM/ IDISK,ISYM,ITRMAX,DELTAV,STARTU,STARTV,$MMAX,NMAX,MCENT,NCENT
NAMELIST /IPRINT/ FDESPT,FDESPR,FDESCN,FDBPT,FDBCN,FDBPR,$FORGPT,FORGCN,FORGPR,ICURPT,ICURCN,ICURPR,FCURPT,FCURCN,FCURPR,$DIRECT

BEGIN PROCESSING

READ(221,650) NUMPAT,NUMTRK,NUMSKP,IPASS

FORMAT(75A4,11(200A4))
NUMPAT=NUMPAT+1
CALL DATF(11,JI,K1)
CALL STIME(IT)
IHR=IT/10000
IFR=IT-IHR*10000
FHR=IFR/10000
FM=FHR*60.
IMIN=FM
IMSEC=FM-IMIN)*60.
WRITE(6,1) I,J1,K1,1HR,IMIN,ISEC,NUMPAT
1 FORMAT('1 ANTENNA SYNTHESIS PROGRAM VERSION 3 LEVEL 1',5X,'VPI EE DEPT.',5X,'DATE=',A2,'-',A2,'-',A2,'-',A2,$5X,'TIME=',12X,'12,12,12,5X,'PATTERN=',I4///)
A.27

DEFAULT PARAMETERS

34 IDISK = 0
35 ISYM = 0
36 ITRMAX = 100
37 MMAX = 1
38 NMAX = 1
39 MCENT = 1
40 NCENT = 1
41 DELTAU = 0.
42 DELTAV = 0.
43 STARTU = 0.
44 STARTV = 0.
45 MCUR = 1
46 NCUR = 1
47 FDESPT = 0
48 FDESCN = 0
49 FDBPT = 0
50 FDBCN = 0
51 FDEPR = 0
52 FDESPR = 0
53 FORGPT = 0
54 FORCCN = 0
55 ICURPT = 0
56 ICURCN = 0
57 ICURPR = 0
58 FCURPT = 0
59 FCURCN = 0
60 FCURPR = 0
61 FORGPR = 0
62 DIRECT = 0

63 FCNORM = 1.0
64 ISBC = 0
65 DELTAS = C.
66 DELTAT = 0.

INPUT

67 READ (5, PARAM)
68 WRITE (6, 1521) IDISK, STARTU, MMAX, ISYM, STARTV, NMAX, ITRMAX, DELTAU,
69 MCENT, DELTAV, NCENT
1521 FORMAT (9X, 'PROGRAM PARAMETERS', 36X, 'IDISK = ', 11, '12X', 'STARTU =
71 FC3, 12X, MMAX = ', 13, '30X', 'ISYM = ', 11, '12X', 'STARTV = ', FC3, 12X,
73 NMAX = ', 13, '30X', 'ITRMAX = ', 14, '22X', 'DELTAU = ', FC3, 12X,
75 MCENT = ', 13, '65X', 'DELTAU = ', FC3, '12X', NCENT = ', 13, '77X')
76 READ (5, P1NT)
77 WRITE (6, 1622) FDESPT, FURGPT, FURPT, ICURPT, FCURPT,
78 FDESCN, FORCCN, FDBCN, ICURCN, FCURCN,
79 FDEPR, FORGPR, FCBPR, ICURPR, FCURPR
1622 FORMAT (11X, 'PROGRAM PARAMETERS', 36X, 'FDESPT = ', 11, '5X', 'FURGPT = ', 11, '5X', 'FURPT = ', 11,
CALL INPUT
72 IF (ITYPE.EQ.7.AND.ICURPR.EQ.1) ICURPR = 2
73 IF (ITYPE.EQ.7.AND.FCURPR.EQ.1) FCURPR = 2
74 CALL LCCSR(11,INITLS,INITLT)
75 CALL LOCSOR(MCUR,NCUR,FINALS,FINALT)
76 IF (MCUR.NE.1) DELTAS = (FINALS - INITLS)/(MCUR - 1)
77 IF (NCUR.NE.1) DELTAT = (FINALT - INITLT)/(NCUR - 1)
78 CALL DESPAT(FDES,FU,FL,MMAX,NMAX,STARTU,STARTV,
$DELTAU,DELTAV)

79 IF (FDESPT) 300, 300, 301
80 WRITE(6,302)
81 FORMAT(1H1,1CX,'U-AXIS PROFILE OF DESIRED PATTERN ',14//
$12X,'U',16X,'V',15X,'FDES(U,V)',10X,'FU(U,V)',12X,'FL(U,V)'/
$V = STARTV+(MCENT-1)*DELTAV
90 DO 309 I = 1, MMAX
91 U = STARTU+(I-1)*DELTAU
92 WRITE(6,311) U, V, FDES(I, MCENT), FU(I, MCENT), FL(I, MCENT)
93 FORMAT(1H1,1CX,'V-AXIS PROFILE OF DESIRED PATTERN ',14//
$12X,'U',16X,'V',15X,'FDES(U,V)',10X,'FU(U,V)',12X,'FL(U,V)'/
$U = STARTU+(J-1)*DELTAV
94 DO 313 J = 1, NMAX
95 V = STARTV+(J-1)*DELTAV
96 WRITE(6,312) U, V, FDES(J, MCENT), FU(J, MCENT), FL(J, MCENT)
97 CONTINUE

C ENTER ORIGINAL PATTERN
103 CALL CRGCPAT(F,MMAX,NMAX,STARTU,STARTV,DELTAU,DELTAV,
$CURR,CURI,MCUR,NCUR)

C OUTPUT OF ORIGINAL PATTERN
104 IF (FORGPT) 400, 400, 401
105 WRITE(6,402)
106 FORMAT(1H1,1CX,'INITIAL PATTERN'
$CALL PRINT(F,MMAX,NMAX,STARTU,STARTV,DELTAU,DELTAV)
107 IF (FORGCA) 403, 403, 404
108 CONTINUE
109 CALL PATCON(F,MMAX,NMAX,STARTU,STARTV,DELTAU,DELTAV,
$CURR,CURI,MCUR,NCUR)
DC 408 J=1,401
U=(J-1)*C.C05-1.C
V=U
SUMU=0.
SUMV=C.
DO 409 K=1,NORG
SUMU=SUMU+CORG(K)*PAT(U-UORG(K),-VORG(K),ITYPE)
SUMV=SUMV+CORG(K)*PAT(-UORG(K),V-VORG(K),ITYPE)
CONTINUE
DATA1(J,1)=U
DATA1(J,2)=SUMU
DATA2(J,1)=V
DATA2(J,2)=SUMV
CONTINUE
IF(NMAX.LE.1) GO TO 2801
WRITE(6,410)
FORVAT(1H1,25X,'U-AXIS PROFILE OF INITIAL PATTERN')
CALL PROFIL(DATA1,401,NUMPAT)
2801 IF(NMAX.LE.1) GO TO 406
WRITE(6,411)
411 FORMAT(1H1,H1,25X,'V-AXIS PROFILE OF INITIAL PATTERN')
CALL PROFIL(DATA2,401,NUMPAT)
CONTINUE
ORIGINAL EXCITATION
IF(ICURPT) 500,500,501
500 WRITE(6,502)
502 FORMAT(1H1,65X,'INITIAL CURRENT')
CALL PRINT(CURR,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTAT)
WRITE(6,503)
503 IF(ICURPN) 500,500,504
504 WRITE(6,505)
505 FORMAT(1H1,65X,'INITIAL CURRENT')
CALL CONTUR(MCUR,NCUR,0.005,-0.04,0.04,0.0,CURI.,NUMPAT)
WRITE(6,506)
506 IF(ICURNP-1) 500,500,507
507 WRITE(6,508)
508 FORMAT(1H1,65X,'INITIAL CURRENT')
CALL CONTUR(MCUR,NCUR,0.005,-0.04,0.04,0.0,CURI.,NUMPAT)
510 FORMAT(1H1,65X,'S AXIS PROFILE OF INITIAL CURRENT')
WRITE(6,510)
S13X,'S',17X,'T',18X,'REAL',12X,'IMAGINARY',10X,'PHASE'/)
J=NCUR/2+1
DO 509 J=1,MCUR
CALL LOCSGR(I,J,S,T,ITYPE)
AMAG=SQRT(CURR(I,J)**2+CURI(I,J)**2)
IF(AMAG.EQ.0.) APH=0.
IF(AMAG.EQ.0.) GO TO 509
APH=ATAN2(CURI(I,J),CURR(I,J))*57.2957795
WRITE(6,511) S,T,CURR(I,J),CURI(I,J),AMAG,APH
511 FORMAT(1H1,65X,'S',17X,'T',18X,'REAL',12X,'IMAGINARY',10X,'PHASE'/)
508 IF(NCUR.LE.1) GO TO 506
510 WRITE(6,512)
512 FORMAT(1H1,10X,'T AXIS PROFILE OF INITIAL CURRENT'//
$13X,'S',17X,'T',18X,'REAL',12X,'IMAGINARY',10X,'MAGNITUDE',
$12X,'PHASE'/)
513 I=MCUR/2+1
514 DO 513 J=1,NCUR
515 CALL LCOSOR(I,J,S,T,ITYPE)
516 CR=CURT(I,J)
517 CI=CURR(I,J)
518 AMAG=SQRT(CR*CR+CI*CI)
519 IF(AMAG.EQ.0.) APH=0.
520 IF(AMAG.EQ.0.) GO TO 513
521 APH=ATAN2(CI,CR)*57.2957795/
523 WRITE(6,511) S,T,CR,CI,AMAG,APH
524 GO TO 506
525 WRITE(6,515)
526 FORMAT(IH1///10X,'INITIAL ELEMENT CURRENTS'//$J',10X,'S',15X,'T',15X,'CURRI,I X,ICURI')
527 CALL LIST(CURR,CURI,MCUR,NCUR)
506 CONTINUE

PRINT OUT RESULTS

591 FORMAT(1H1,52X,'-- FINAL COEFFICIENTS --'/45X,'J',7X,
$'US(J)',7X,'VS(J)',5X,'CORCOF(J)'//)
593 IF(IG.LE.0) WRITE(6,977)
594 IF(IG.LE.0) GO TO 978
595 IC=0
597 WRITE(6,35) J,US(J),VS(J),CORCOF(J)
599 FORMAT(44X,I3,5X,F7.4,5X,F7.4,5X, F7.4)
357 FORMAT(1H45X,'J',6X,'US(J)',6X,'VS(J)',6X,'CORCOF(J)'/)
377 J=1,NCUR
379 WRITE(6,497) ITER
497 FORMAT(1H0,9X,'NUMBER OF ITERATIONS = ',I6)
499 WRITE(6,496) FNORM
501 FORMAT(1H0,9X,'FNORM = ',F10.5)
503 WRITE(6,976) NUMPAT
505 CONTINUE

OUTPUT FINAL PATTERN IN DB

978 CONTINUE
290 DO 299 J=1,MMAX
292 IF(F(J,K)) 290,289,290
289 F(J,K)=-F(J,K).
A-31

204 GO TO 29
205 290 F(J,K)=20.*ALG10(ABS(F(J,K)))
206 29 CONTINUE

C
207 IF(FORPT) 600,600,601
208 601 WRITE(6,602)
209 602 FORMAT(1HI/////////////////////////////////////////////////////////////////55X,'FINAL PATTERN IN OR')
210 CALL PRINT(F,MMAX,NMAX,STARTU,STARTV,DELTU,DELTAV)

C
211 IF(FDENC) 603,603,604
212 604 CONTINUE
213 CALL PATCON(F,MMAX,NMAX,2,-45.,0.0,5.0,STARTU,STARTV,
$ DELTU,DELTAV,NUMPAT,ISYMM)
214 603 IF(FDPR) 606,606,607
215 607 CONTINUE
216 DO 608 J=1,401
217 U=(J-1)*C.005-1.0
218 V=U
219 SUMU=0.
220 SUMV=0.
221 DO 609 K=1,IC
222 SUMU=SUMU+CORCOF(K)*PAT(U-US(K),-VS(K),ITYPE)
223 SUMV=SUMV+CORCOF(K)*PAT(-US(K),V-VS(K),ITYPE)
224 609 CONTINUE
225 DATA1(J,1)=U
226 DATA2(J,1)=V
227 DATA1(J,2)=DATA1(J,2)+SUMU
228 DATA2(J,2)=DATA2(J,2)+SUMV
229 DATA1(J,2)=DATA1(J,2)+FNORM
230 DATA2(J,2)=DATA2(J,2)+FNORM
231 608 CONTINUE
232 IF(MMAX.LE.1) GO TO 2901
233 WRITE(6,610)
234 610 FORMAT(1HI,25X,'U-AXIS PROFILE OF FINAL PATTERN')
235 CALL PROFIL(DATA1,401,NUMPAT)
236 2901 IF(NMAX.LE.1) GO TO 606
237 WRITE(6,611)
238 611 FORMAT(1HI,25X,'V-AXIS PROFILE OF FINAL PATTERN')
239 CALL PROFIL(DATA2,401,NUMPAT)
240 606 CONTINUE

C
241 IF(FCURPT+FCURPR+FCURCN .LE. 0) GO TO 706
242 CALL CURREN(CURR,CURI,MCUR,NCUR,US,VS,CORCOF,IC)

C
243 IF(FCURPT) 700,700,701
244 701 WRITE(6,702)
245 702 FORMAT(1HI/////////////////////////////////////////////////////////////////55X,'FINAL CURR')
246 CALL PRINT(CURR,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTAT)
247 WRITE(6,782)
248 782 FORMAT(1HI///////////////////////////////////////////////////////////////////////55X,'FINAL CURR')
249 CALL PRINT(CURI,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTAT)
250 703 IF(FCURCN) 703,703,704
251 704 WRITE(6,705)
252 FORMAT(1H1///10X,'FINAL CURRENT')
253 CALL CONTUR(MCUR,NCUR,C.COS,-0.04,0.04,0.0,CURR,NUMPAT)
254 WRITE(6,705)
255 705 FORMAT(1H1///10X,'FINAL CURR')
256 CALL CONTUR(MCUR,NCUR,C.O5,-0.04,0.04,0.0,CURI,NUMPAT)
257 IF(FCURPR-1) 706,707,711
258 707 IF(NCUR.LE.1) GO TO 708
259 708 WRITE(6,710)
260 710 FORMAT(1H1,10X,'S AXIS PROFILE OF FINAL CURRENT'//
261 $13X,'S',17X,'T',18X,'REAL',12X,'IMAGINARY',10X,'MAGNITUDE',
262 $12X,'PHASE'/)
263 J=NCUR/2+1
264 DO 709 1=1,MCUR
265 WRITE(6,511) S,T,CR,CI,AMAG,APH
266 709 C
267 708 IF(NCUR.LE.1) GO TO 706
268 WRITE(6,712)
269 712 FORMAT(1H1,10X,'T AXIS PROFILE OF FINAL CURRENT'//
270 $13X,'S',17X,'T',18X,'REAL',12X,'IMAGINARY',10X,'MAGNITUDE',
271 $12X,'PHASE'/)
272 I=MCUR/2+1
273 DO 713 J=1,NCUR
274 WRITE(6,511) S,T,CR,CI,AMAG,APH
275 713 C
276 712 IF(NCUR.LE.1) GO TO 706
277 WRITE(6,714)
278 714 FORMAT(1H1///10X,'FINAL ELEMENT CURRENTS'//5X,
279 $16X,'S',15X,'T',15X,'CURR',15X,'CURI')
280 CALL LIST(CURR,CURI,MCUR,NCUR)
281 CONTINUE
282 C
283 ICOUNT=NUMPAT
284 WRITE(2?1,8850) ICOUNT,NUMTRK,NUMSPK,IPASS
285 8850 FORMAT(1H1,10X,'UCOUNT',NUMTRK,NUMSPK,IPASS)
286 IF(IMTRK.EQ.0) GO TO 9998
287 9998 WRITE(6,789) DDIRG,DIFNL
288 789 FORMAT(1H1///80X,'DIRORG,DIFNL')
IF (IDISK.EQ.C) GO TO 9997

C DISK OUTPUT

GO TO 7000 J=2,35

IF (NUMSKP(J) .EQ. 0) GO TO 79001

7000 CONTINUE

WRITE (6,7002)

7002 FORMAT (C, NO DISK SPACE AVAILABLE - DATA NOT STORED*)

GO TO 9999

7001 CONTINUE

C SPACE IS AVAILABLE ON RECORD "J"

NUMSKP(J)=1

WRITE (22,18850) NumPAT, J, NUMSKP, IPASS

WRITE (22,18850) NumPAT, TITLE, [SYMM, ITER, ISUC, F norm, Idisk, $NORG, IC, [UORG(M), VORG(M)], CORG(M), M=1, NORG], $(US(M), VS(M), CORCOF(M), M=1, IC), ITYPE, P1, P2, P3, P4, P5, P6, $P1, P1, P1, P1, IT(1), IT(2), IT(3), IT(4), IT(5), IT(6), IT(7), IT(8), IT(9), IT(10), IT(11), IT(12), IT(13), IT(14), IT(15), MCUR, NCUR

WRITE (6,7003) NumPAT, J

7003 FORMAT (0, PATTERN NUMBER 'I4', I4, J, HAS BEEN STORED ON RECORD' $I4$ OF ANDAT.A, A507C2')

9997 GO TO 9999

ENC

SUBROUTINE DIRCTV(CORG, UORG, VORG, NORG, US, VS, CORCOF, IC, MMAX, NMAX, 1 CIRG, CIRFNL)

THIS SUBROUTINE CALCULATES THE DIRECTIVITY OF THE ORIGINAL PATTERN , CIRG, AND OF THE FINAL PATTERN, CIRFNL

DIMENSION CORG(100), UORG(100), VORG(100), US(500), VS(500), CORCOF(500 $)

COMMON /LCC/ ITYPE

FORCSC=C.

FSC=0.

FMAX1=0.

FMAX2=0.

DO 10 J=1,101

U=-1.0+(J-1)*C.02

10 CONTINUE

DO 25 K=1,101

V=-1.0+(K-1)*C.02

25 CONTINUE

UVSQ=L*L+V*V

F=0.

IF (UVSQ.LE.1.0) GO TO 10.

10 F=F+CVORG(L)*PAT(U-UORG(L), V-VORG(L), ITYPE)

FCRGSQ=FCRGSQ+F**2/SQRT((1.0-UVSQ)

IF (ABS(F) .GT. FMAX1) FMAX1=ABS(F)

25 CONTINUE
A-34

332  FSC=F*CRGSO:
333  FMAX2=F*MAX1
334  IF(IC.LE.0) GO TO 10
335  CO 30 L=1,IC
336  3C F=F+FCCRCCE(L)*P(A(U-US(L),V-VS(L),ITYPE)
337  FSC=FSC+F**2/SQR(1.0-UVSQ)
338  IF(ABS(F).GT.FMAX2) FMAX2=ABS(F)
339  IC CONTINUE
340  FORGSO=FORGSO*0.0004/FMAX1
341  FSC=FSC+CC04/FMAX2
342  DIRORG=4.0*3.14159265/FORGSO
343  DIRFNL=4.0*3.14159265/FSQ
344  CIRCRG=4.0*3.14159265/FSQ
345  FSC=FSC*C.CCC4/FMAX2
346  CIRCRG=C1.*ALOGIO(DIRORG)
347  CIRFNL=LO.*ALCG10(01RFNL)
348  RETURN
349  ENC
350  SUBROUTINE INPUT
351  INTEGER PX,PY
352  REAL LX,LY,INITLS,INITLT
353  COMMON /PAT1/P1,P2,P3,P4,P5,P6,P7,SS(400),TT(400),RR(400)
354  COMMON /PAT2/I1,I2,I3,I4,I5
355  COMMON /LOC/ ITYPE
356  COMMON /PROG/ MCUR,NCUR
357  COMMON /SYN/ LX,LY
358  NAMELIST /PATIN/LX,LY,PX,PY,DISX,DISY,INITLS,DELTAS,FINALS,
359  $INITLT,CTATT,FINALT,NEMT,ARAU,ITYPE,MCUR,NCUR
360  WRITE(6,10)
361  10 FORMAT('///\55X,'SOURCE SPECIFICATIONS'//)
362  PI=3.14159265
363  READ(5,PATIN)
364  IF(ITYPE.GT.7) GO TO 990
365  GO TO (100,200,300,400,500,600,700), ITYPE
366  WRITE(6,2C) ITYPE
367  FCRIAT(1HO,(X,'***ERROR*** ITYPE
368  IN TERMINATE')
369  IF(ITYPE.LE.7) GO TO 990
370  NCUR=(FINALT-INITLT)/DELTAT+1.5
371  MCUR=1
WRITE(6,101) LY,INITLT,FINALT,DELTAT,NCUR
   101 FORMAT(1X,'ITYPE=1 -- UNIFORM LINE SOURCE'//15X,'LY = ',F7.3//
   $15X,'INITLT,FINALT,DELTAT = ',3(1X,F8.4)//15X,'NUMBER OF SAMPLE POINTS = NCUR = ',13)
374 GO TO 999

C
C
375 200 PI=LY
376   II=PY
377   LX=C.C
378   P2=DISY
379   NCUR=PY
380   MCLR=I
381 WRITE(6,201) LY,PY,DISY
382 201 FORMAT(1X,'ITYPE=2 -- UNIFORM LINEAR ARRAY'//
   $15X,'LY = ',F7.3//15X,'NUMBER OF ELEMENTS = ',13//15X,'INTER-ELEMENT SPACING = ',F6.3)
383 GC TO 999

C
C
384 300 P1=LY
385   LX=0.0
386   P2=INITLT
387   P3=DELTAT
388   NCUR=(FINALT-INITLT)/DELTAT+1.5
389   MCLR=I
390 WRITE(6,301) LY,INITLT,FINALT,DELTAT,NCUR
391 301 FORMAT(1X,'ITYPE=3 -- TRIANGULAR LINE SOURCE'//
   $15X,'LY = ',F7.3//15X,'T VARIATES FROM ',F8.4,' TO ',F6.4,5X,
   $DELTAT = ',F6.3//15X,'NUMBER OF SAMPLE POINTS = NCUR = ',13)
392 GC TO 999

C
C
393 400 P1=LX
394   P2=LY
395   P3=INITLS
396   P4=INITLT
397   P5=DELTAS
398   P6=DELTAT
399   MCLR=(FINALS-INITLS)/DELTAS+1.5
400   NCUR=(FINALT-INITLT)/DELTAT+1.5
401 WRITE(6,401) LX,LY,INITLS,DELTAS,FINALS,INITLT,DELTAT,FINALT,NCUR,NCUR
402 401 FORMAT(1X,'ITYPE=4 -- UNIFORM RECTANGULAR APERTURE'//
   $15X,'DIMENSIONS = LX,LY = ',F7.4,' X ',F7.4//
   $15X,'INITLS,DELTAS,FINALS = ',3(1X,F8.4,1X)//
   $15X,'INITLT,DELTAT,FINALT = ',3(F8.4,1X)//
   $15X,'MCLR,NCUR = ',2(I3,2X))
403 GC TO 999

C
C
500 500 P1=LX
501 P2=LY
502 II=PX
12 = PY
9
P4 = DISY
MCUR = 11
NCUR = 12
WRITE (6, 501) LX, LY, PX, PY, DISX, DISY
501 FORMAT (1X, 'ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY', I5, 1X, 'DIMENSIONS = LX, LY = ', F7.4, ' , ', F7.4)
   $15X,'NUMBER OF ELEMENTS = PX, PY = ', I3, ' , ', I3
   $15X,'INTER-ELEMENT SPACING = DISX, DISY = ', F6.3, ' , ', F6.3)
GO TO 999

C

601 FORMAT (1X, 'ITYPE = 6 -- UNIFORM CIRCULAR APERTURE', I5, 1X, 'ARAD = ', F7.3)
   $15X,'INITLS, DELTAS, FINALS, INITLT, DELTAT, FINALT, MCUR, NCUR
   $15X,'MCUR, NCUR: *, 2(13, 2X))
GO TO 999

701 FORMAT (1X, 'ITYPE = 7 -- GENERAL ARRAY', I5, 1X, 'ELEMENT', 7X, 'SS(J)*, 14X, 'TT(J)*')
   $15X,'ELEMENT', 7X, 'SS(J)*, 14X, 'TT(J)*')
CC 702 J = 1, NELMT
READ (5, 703) SS(J), TT(J)
703 FORMAT (3F13.0)
WRITE (6, 704) J, SS(J), TT(J)
704 FORMAT (17X, I3, 5X, 3(E14.7, 5X))
702 CONTINUE
GO TO 999
CALL SINPUT (PX, PY, DISX, DISY, INITLS, DELTAS, FINALS, INITLT, DELTAT, FINALT, NELMT, ARAD, ITYPE)
RETURN
SUBROUTINE READ (F, MMAX, NMAX)

DIMENSION F(51, 51), I(6), VAL(6)

DO 100 J = 1, MMAX
   K2 = 0
20 CONTINUE
   READ (5, 1) (I(L), VAL(L), L = 1, 6)
   FORMAT (6(I3, F10.0))
   DC 20 L = 1, 6
   IL = I(L)
   IF (IL .EQ. 0) GO TO 100
   K1 = K2 + 1
   K2 = K1 + IL - 1
   DO 10 K = K1, K2
      IC
      F(J, K) = VAL(L)
   CONTINUE
   IF (K2 .LT. NMAX) GO TO 200

100 CONTINUE
RETURN
END

SUBROUTINE ORGPNAT (F, MMAX, NMAX, STARTU, STARTV, DELTAU, Deltav, CURR,
$ CURI, MCUR, NCUR)

REAL F(51, 51), CURR(51, 51), CURI(51, 51)
REAL UORG(100), VORG(100), CORG(100)
COMPLEX SOURCE
COMPLEX TEMP
COMMON /START/, NORG, UORG, VORG, CORG
COMMON /LOC/, ITYPE

DO 10 N = 1, MMAX
   UC 10 N = 1, NMAX
100 F(M, N) = 0.

THIS ORGPNAT WILL BE "WOODWARD-LAWSON" INPUT.
DO 15 M=1,MCUR
CC 15 N=1,NCUR
15 CURRI(M,N)=0.

WRITE(6,17)

17 FORMAT(1H1,5X,50X,'-- INITIAL COEFFICIENTS --',/5X,'J',6X,'
$\text{UORG}(\text{J}), 5X, \text{VORG}(\text{J}), 5X, \text{CORG}(\text{J})$/)

REAC(5,1) NORG
1 FORMAT(15)

DO 20 IC=1,NORG
READ(5,2) US,VS,CORCOF
2 FORMAT(3F10.0)

UCRG(IC)=US
VORG(IC)=VS
CORO (IC )=CORCOF

U=STARTU+(M-1)*DELTAU
DL=U-US

V=STARTV+(N-1)*DELTAV
DV=V-VS

H(M,N)=FCM,N)+CORCOF*PAT(DU,DV,ITYPE)

CC 40 M=1,MCUR
CC 40 N=1,NCUR

TEMP=SOURCE(M,N,US,VS,ITYPE)

CURR(M,N)=CURR(M,N)+CORCOF*REAL(TEMP)

WRITE(6,50) IC,US,VS,CORCOF

10 FORMAT(44X, T3,5XF7.4,5X,F7.4,5X,F7.4)

CONTINUE

IFIC

SUBROUTINE ANTSYN(ISUC,MMAX,NMAX,FDES,FI,GL,ITRMAX,ISYM,CORCOF, $\text{IC,US,VS,STARTU,DELTAU,STARTV,DELTAV,MCENT,NCENT,ITER,FNORM,F}$$)$

REAL FDES(51,51),FI(51,51),FL(51,95),F(51,1)

REAL US(500),VS(500),CORCOF(500) US-51,51),VCOR(100)

REAL LX,LY,LXY

COMMON /SYN/ LX,LY

10 LXY=1./AAX(LX,LY)

ITER=0

27 ITER=ITER+1

C NORMALIZE...

FBIG=F(MCENT,NCENT)

DO 150 M=1,MMAX
DO 150 N=1,NMAX

150 F(M,N)=F(M,N)/FBIG

FNORM=FNORM/FBIG

151 CORG(1)=CORG(1)/FBIG

IF(1C.LE.5) GO TO 153

153 CONTINUE
-- ITERATION PROCEDURE --

SET IF SPECS ARE MET.

DO 24 J=1,NMAX
   U=STARTU+(J-1)*DELTAV
   DO 24 K=1,NMAX
      V=FINITV+(K-1)*DELTAV
      UVSU=U*U+V*V
      IF(UVSU.GT.1.0D0) GO TO 24
      IF(FL(J,K).GE.99.0) GO TO 24
      IF(FL(J,K).LE.0.0001) GO TO 24
      X1=ABS(F(J,K))
      IF(X1.GT.FU(J,K)) GO TO 25
      IF(X1.LT.FL(J,K)) GO TO 25
   24 CONTINUE
   IC=IC+1

SPECS ARE MET -- PROCEED TO PRINTOUT.

GO TO 75C

SPECS ARE NOT MET AT POINT (J,K)

IC=IC+1

IF(ITER/ITERMAX.EQ.ITER) WRITE(6,7117) ITER
   7117 FORMAT(10X,6,'ITERATIONS COMPLETED')

IF(ITER-ITRMAX) 22,22,23
   22 CONTINUE

FIND RELATIVE MAXIMUM ERROR

CALL SEARCH(J,K,VAL,FDSTES,FU,FL,F,NMAX,NMAX,STARTU,STARTV,DELTAV)

IF(VAL.NE.0.0) GO TO 248

VAL EQUALS ZERO

WRITE(6,100)
   100 FORMAT('ERROR IN SUBROUTINE SEARCH -- VAL=0.')

GO TO 75C

248 U1=(J-1)*DELTAV+STARTU
   VI=(K-1)*DELTAV+STARTV
   IF(ABS(U1).LE.0.1*DELTAV) U1=0.
   IF(ABS(V1).LE.0.1*DELTAV) VI=0.
   IF(LX.EQ.0.0) GO TO 1000

IF(U1.NE.0.0) AND ABS(U1).LE.0.5/LX) VAL=VAL/2.

IF(V1.NE.0.0) AND ABS(V1).LE.0.5/LY) VAL=VAL/2.
IF(ISYMM .NE. 4) GC TO 1001
ITEMP = C
553 UV = ABS(ABS(U1) - ABS(V1))
554 IF(UV .EQ. 0.) GC TO 1001
555 IF(UV*1.414 .LE. LXY) VAL = VAL/2.
556 1001 CONTINUE

BASIC CORRECTION -- INDEPENDENT OF ISYMM

557 US(IC) = U1
558 VS(IC) = V1
559 CORCOF(IC) = VAL
560 CALL UPDATE(IC, US, VS, CORCOF, F, MMAX, NMAX, FNORM, STARTU, STARTV, $DELTU, DELTAV)
561 CALL CHECK(IC, VAL, US, VS, CORCOF, DELTAU, DELTAV)
562 1001 IF(ISYMM) 26, 27, 26
563 26 CONTINUE
564 IF(ISYMM - 2) 261, 260, 260
565 260 CONTINUE

V-AXIS AND QUADRILATERAL SYMMETRY -- ISYMM = 2, 3, 4

566 IF(U1 .EQ. 0.) GC TO 261
567 IC = IC + 1
568 US(IC) = -U1
569 VS(IC) = V1
570 CORCOF(IC) = VAL
571 CALL UPDATE(IC, US, VS, CORCOF, F, MMAX, NMAX, FNORM, STARTU, STARTV, $DELTU, DELTAV)
572 CALL CHECK(IC, VAL, US, VS, CORCOF, DELTAU, DELTAV)
573 261 IF(ISYMM - 2) 259, 27, 259

U-AXIS AND QUADRILATERAL SYMMETRY -- ISYMM = 1, 3, 4

574 259 IF(V1 .EQ. 0.) GC TO 262
575 IC = IC + 1
576 US(IC) = U1
577 VS(IC) = -V1
578 CORCOF(IC) = VAL
579 CALL UPDATE(IC, US, VS, CORCOF, F, MMAX, NMAX, FNORM, STARTU, STARTV, $DELTU, DELTAV)
580 CALL CHECK(IC, VAL, US, VS, CORCOF, DELTAU, DELTAV)
581 262 IF(ISYMM .LT. 3) GO TO 27

QUADRILATERAL SYMMETRY ONLY -- ISYMM = 3, 4

582 IF(U1 .EQ. 0. OR. V1 .EQ. 0.) GO TO 2745
583 IC = IC + 1
584 US(IC) = -U1
585 VS(IC) = -V1
586 CORCOF(IC) = VAL
587 CALL UPDATE(IC, US, VS, CORCOF, F, MMAX, NMAX, FNORM, STARTU, STARTV, $DELTU, DELTAV)
588 CALL CHECK(IC, VAL, US, VS, CORCOF, DELTAU, DELTAV)
589 2745 IF(ISYMM .LT. 4 .OR. ITEMP .EQ. 1) GO TO 27

FOR BIQUADRILATERAL SYMMETRY ONLY -- ISYMM = 4

ITEMP = 1
IF(UI.EQ.VI) GC TO 27
IC=IC+1
UTEMP=UI
VTEMP=VI
U1=VTEMP
V1=UTEMP
GO TO 1001
CONTINUE
IC=IC-1
ITER=ITER-1
RETURN

SUBROUTINE SEARCH(I1,J1,VAL,FDES,FU,FL,F,MMAX,NMAX,STARTU,STARTV,DELTAU,DELTAV)
REAL FU(51,51),FL(51,51),F(51,51),FDES(51,51)
VAL=0.
EMAX=0.
I2=I1
J2=J1
GOTO 10
J2=JL
CC 10 J=I2,MMAX
U=STARTU+(J-1)*DELTAU
CC 20 K=J2,NMAX
V=STARTV+(K-1)*DELTAV
UVSQ=U*U+V*V
IF(UVSQ.GT.0.0) GO TO 20
FITER=ABS(F(J,K))
IF(FDES(J,K).EQ.99.0) GO TO 20
IF(FITER.GT.FU(J,K)) GO TO 2000
IF(FL(J,K).LE.0.0001 .AND. FITER.LE.1.E-4) GO TO 20
IF(FITER.GT.FL(J,K)) GO TO 20
C
X=FDES(J,K)
ERROR = FITER-X
IF(ABS(ERROR)-ABS(EMAX)) 20,20,21
EMAX=ERROR
VAL=SIGN(ERROR,F(J,K)*(X-FITER))
II=J
JI=K
C
WRITE(6,10C) II,JL,VAL
100 FCRMAT(5X,'**SEARCH**',I8,I8,5X,F7.4)
RETURN

SUBROUTINE CHECK(IC,VAL,US,VS,CCR,DELTAU,DELTAV)
REAL US(500),VS(500),CCR(500)
IF(IC.EQ.1) RETURN
CU=0.1*DELTAU
CV=0.1*DELTAV
IC1=IC-1
U=US(IC)
V=VS(IC)
SUBROUTINE UPDATE(IC, US, VS, CORCOF, F, MMAX, NMAX, FNORM, STARTU, STARTV, $DELTAU, DELTAV)
C
DIMENSION F(51, 51), US(500), VS(500), CORCOF(500)
C
COMMON /LOC/ ITYPE
C
C=CORCOF(IC)
C
DO 10 J=1, MMAX
U=STARTU+(J-I)*DELTAU
DU=U-US(IC)
C
DO 10 K=1, NMAX
V=STARTV+(K-I)*DELTAV
DV=V-VS(IC)
C
10 F(J,K)=F(J,K)+C*PAT(DU, DV, ITYPE)
C
CORCOF(IC)=CORCOF(IC)/FNORM
C
RETURN
END
C
FUNCTION PAT(U, V, ITYPE)
C
THIS SUBPROGRAM GIVES THE BASIC CORRECTION PATTERN F(U, V).
C
ITYPE = 1 -- UNIFORM LINE SOURCE LOCATED AT S=0.
2 -- UNIFORM LINEAR ARRAY LOCATED AT S=0.
3 -- TRIANGULAR LINE SOURCE LOCATED AT S=0.
4 -- UNIFORM RECTANGULAR APERTURE.
5 -- UNIFORM RECTANGULAR ARRAY.
6 -- UNIFORM CIRCULAR APERTURE.
7 -- GENERAL ARRAY.
C
ITYPE > 7 -- SPECIAL SOURCE (FUNCTION SPECPT(U, V, ITYPE) WILL BE CALLED.
C
VERSION 1  LEVEL 1
C
DATE OF LAST REVISION: 73/193 JULY 12, 1973
C
THIS WORK SUPPORTED BY NASA GRANT NGR 47-004-103
C
FOR FURTHER INFORMATION CONTACT:
W.L. STUTZMAN DEPT. OF ELEC. ENGR. 951-6624.
E.L. COFFEY DEPT. OF ELEC. ENGR. 951-5494
C
COMMON /PAT1/ P1, P2, P3, P4, P5, P6, P1, SS(400), TT(400), RR(400)
C
COMMON /PAT2/ 11, 12, 13, 14, 15
IF(ITYPE.GT.7) GO TO 990
GO TO (100,200,300,400,500,600,700),ITYPE
C ITYPE .LT. 1
C WRITE(6,10) ITYPE
C 10 FORMATT(1HC,5X,'***ERROR*** ITYPE HAS THE VALUE ',I,':',2X,'*$EXECUTION TERMINATED$')
STOP
C ITYPE = 1 -- UNIFORM LINE SOURCE.
C FLEN=P1
C CONTINUE
C PAT=1.0
C IF(V.NE.0.) PAT = SIN(PI*P1*V)/(PI*P1*V)
GO TO 999
C ITYPE = 2 -- UNIFORM LINEAR ARRAY
C FLEN=PI
C NELPT=I
C PAT=1.0
C IF(V.NE.0.) PAT=SIN(PI*P1*V)/(I*SIN(PI*P1*V/I))
GO TO 999
C ITYPE = 3 -- TRIANGULAR LINE SOURCE.
C FLEN=PI/2.
C PAT=1.0
C IF(V.NE.0.) PAT = (SIN(FLEN*PI*V)/(FLEN*PI*V))**2
GO TO 999
C ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE
C FLS=P1
C FLT=P2
C ARG1=PI*P1*U
C ARG2=PI*P2*V
C IF(ARG1) 401,402,401
C ARG2)
C 403 PAT=SIN(ARG1)/ARG1*SIN(ARG2)/ARG2
GO TO 999
C 404 PAT=SIN(ARG1)/ARG1
GO TO 999
C 405 PAT=SIN(ARG2)/ARG2
GO TO 999
C 406 PAT=1.0
GO TO 999
C ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY
699 5CC CONTINUE
C FLS=P1
C FLT=P2
C NELS=I1
C NELT=I2
700 ARC1=PI*P1*U
701 ARC2=PI*P2*V
702 IF(ARG1) 501,502,501
703 501 IF(ARG2) 503,504,503
704 503 PAT=SIN(ARG1)/(I1*SIN(ARG1/I1))*SIN(ARG2)/(I2*SIN(ARG2/I2))
705 504 PAT=SIN(ARG1)/(I1*SIN(ARG1/I1))
706 504 GO TO 999
707 502 IF(ARG2) 505,506,505
708 505 PAT=SIN(ARG2)/(I2*SIN(ARG2/I2))
709 505 GO TO 999
710 506 PAT=1.0
711 506 GO TO 999
712 600 C=SCRT(U*U+V*V)
C A=P1
713 IF(C.EQ.C.) GO TO 601
714 X=2.*PI*P1*C
715 601 PAT=2.*BJ/X
716 601 GO TO 999
717 601 PAT=1.0
718 601 GO TO 999

C ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.
C
721 IMAG=(C.C,1.C)
722 NELMT=I1*I2
723 TEMP=(C.C,C.0)
724 DO 701 J=1,NELMT
725 TEMP=TEMP+1.O*CEXP(IMAG*2.*PI*(U*SS(J)+V*TT(J)))
726 701 CONTINUE
727 PAT=REAL(TEMP)/NELMT
728 999 PAT=SPECPT(U,V,ITYPE)
729 999 RETURN
730 999 END

732 COMPLEX FUNCTION SOURCE(M,N,U,V,ITYPE)
C THIS SUBPROGRAM CALCULATES THE CURRENT AT POINT (M,N) DUE TO
C THE PATTERN AT POINT (U,V).
C
C ITYPE = 1 -- UNIFORM LINE SOURCE LOCATED AT S=0.
C
C ITYPE = 7 -- UNIFORM LINEAR ARRAY LOCATED AT S=0.
3 -- TRIANGULAR LINE SOURCE LOCATED AT S=0.
4 -- UNIFORM RECTANGULAR APERTURE.
5 -- UNIFORM RECTANGULAR ARRAY.
6 -- UNIFORM CIRCULAR APERTURE.
7 -- GENERAL ARRAY.

ITYPE > 7 -- SPECIAL SOURCE (FUNCTION SPSOR(M,N,U,V,ITYPE) WILL BE CALLED.)

VERSION 1 LEVEL 1

DATE OF LAST REVISION: 73/166 JULY 12, 1973

THIS WORK SUPPORTED BY NASA GRANT NGR 47-004-103.

FOR FURTHER INFORMATION CONTACT:
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  E. L. COFFEY DEPT. OF ELEC. ENGR. 951-5494.

733 COMMON /PAT1/ P1, P2, P3, P4, P5, P6, PI, SS(400), TT(400), RR(400)
734 COMMON /PAT2/ 11, 12, 13, 14, 15
735 C
736 IMAG=(0.0,1.0)
737 CALL LOCSCR(M,N,S,T)
738 IF(ITYPE.GT.7) GO TO 990
739 GO TO (100, 200, 300, 400, 500, 600, 700) ITYPE

C ITYPE .LT. 1

740 WRITE(6,10) ITYPE
741 10 FORMAT(1HC, 5X, '***ERROR*** ITYPE HAS THE VALUE ', I11, ' EXECUTION TERMINATED')
742 STCP

C ITYPE = 1 -- UNIFORM LINE SOURCE

743 100 CONTINUE
744 FLEN=P1
745 SOURCE=CEXP(-IMAG*PI*2.*T*V)/P1
746 GO TO 999

C ITYPE = 2 -- UNIFORM LINEAR ARRAY

747 200 CONTINUE
748 FLEN=P1
749 SOURCE=CEXP(-IMAG*2.*PI*V*T)/P1
750 GO TO 999

C ITYPE = 3 -- TRIANGULAR LINE SOURCE

753 300 CONTINUE
754 FLEN=P1
755 CON=ABS(2.*T/P1)
751 SOURCE=2.*P1*CEXP(-IMAG*2.*PI*T*V)*(1.-CON)
752 IF(CON.GT.1) SOURCE=(0.0,0.0)
753 GO TO 999

C
C ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE
C
754 CONTINUE
C FLS=P1
C FLT=P2
755 SOURCE=CEXP(-IMAG*2.*PI*(S*U+V*T))/(PI*P2)
756 GO TO 999

C
C ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY
C
757 CONTINUE
C FLS=P1
C FLT=P2
758 SOURCE=CEXP(-IMAG*2.*PI*(S*U+V*T))/(PI*P2)
759 GO TO 999

C
C ITYPE = 6 -- UNIFORM CIRCULAR APERTURE
C
760 RHC=SCRT(S*S+T*T)
C A=P1
761 SOURCE=(C,C,C,C)
762 IF(RHC.LE.P1) SOURCE=CEXP(-IMAG*2.*PI*(S*U+V*T))/(2.*PI*P1*P1)
763 GO TO 999

C
C ITYPE = 7 -- GENERAL ARRAY
C
764 CONTINUE
765 SOURCE=CEXP(-IMAG*2.*PI*(U*S+V*T))/(II*II)
766 GO TO 999
767 99C SOURCE=SPSOR(M,N,U,V,ITYPE)
768 999 RETURN
769 END

770 SUBROUTINE LCCSOR(M,N,S,T)
771 INTEGER PX,PY
772 REAL INITLS,INITLT
773 COMMON /PAT1/ P1,P2,P3,P4,P5,P6,PI,SS(400),TT(400),RR(400)
774 COMMON /PAT2/ II,IC,I3,I4,I5
775 COMMON /LCC/ ITYPE
C
776 IF(ITYPE.GT.7) GO TO 990
777 GC TO (100,200,300,400,500,600,700), ITYPE
778 WRITE(10,1C) ITYPE
779 1C FORMAT(1HC,5X,***ERROR***,ITYPE HAS THE VALUE ...,111,:,2X,*EXECUTICN TERMINATED*)
80 STOP
C 100 CONTINUE
C INITL=I
C DELTAT=P3
S=0.
T=(N-I1/2-1)*P2
IF(I1/2*2.EQ.I1) T=T+0.5*P2
GO TO 999
C
C 200 CONTINUE
C PY=I1
C DISY=P2
S=0.
T=(N-I1/2-1)*P2
IF(I1/2*2.EQ.I1) T=T+0.5*P2
GO TO 999
C
C 300 GO TO 100
C
C 400 CONTINUE
C INITL=S=P3
C INITL=T=P4
C DELTAS=P5
C DELTAT=P6
S=P3+(M-1)*P5
T=P4+(N-1)*P6
GO TO 999
C
C 500 CONTINUE
C PX=I1
C PY=I2
C DISX=P3
C DISY=P4
S=(M-I1/2-1)*P3
T=(N-I2/2-1)*P4
IF(I1/2*2.EQ.I1) S=S+0.5*P3
IF(I2/2*2.EQ.I2) T=T+0.5*P4
GO TO 999
C
C 600 GO TO 400
C
C 700 CONTINUE
C NELMT=(M-1)*I2+N
S=SS(NELMT)
T=TT(NELMT)
GO TO 999
C
C 990 CALL SPLCC(M,N,S,T)
999 RETURN
END
SUBROUTINE CURREN(CURR, CURI, MCUR, NCUR, US, VS, CURCOF, IC)

THIS SUBROUTINE CALCULATES THE FINAL CURRENT DISTRIBUTION
NECESSARY TO PRODUCE THE FINAL PATTERN F(U, V).


COMPLEX SOURCE, TEMP
REAL CURR(51, 51), CURI(51, 51), US(50), VS(50), CURCOF(50)
REAL UORG(100), VORG(100), CORG(100)
COMMON /START/ NORG, UORG, VORG, CORG

COMMON /LOC/ ITYPE
DO 100 M = 1, MCUR
DO 100 N = 1, NCUR
CURR(M, N) = 0.
100 CURR(M, N) = C.
DO 200 M = 1, MCUR
DO 200 N = 1, NCUR
DO 200 I = 1, NORG
TEMP = SOURCE(M, N, UORG(I), VORG(I), ITYPE)
CURR(M, N) = CURR(M, N) + CURCOF(I) * REAL(TEMP)
CURR(M, N) = CURR(M, N) + CURCOF(I) * AIMAG(TEMP)
200 CONTINUE
IF (IC .LT. 7) RETURN

DU 10 M = 1, MCUR
DO 10 N = 1, NCUR
DO 10 I = 1, 10
TEMP = SOURCE(M, N, US(I), VS(I), ITYPE)
CURR(M, N) = CURR(M, N) + CURCOF(I) * REAL(TEMP)
CURR(M, N) = CURR(M, N) + CURCOF(I) * AIMAG(TEMP)
10 CONTINUE
RETURN
END

SUBROUTINE PRINT(A, M, N, STARTU, STARTV, DU, DV)

SUBROUTINE PRINT IS THE GENERAL OUTPUT SUBROUTINE --
IT WILL PRINT OUT CO-ORDINATES (U, V) AND VALUES A(I, J)
10 ROWS AND 10 COLUMNS TO A PAGE.

DIMENSION A(51, 51), U(51), V(51)
WRITE(6, 1969)
6969 FORMAT(11H1)
628 CC 10 J = 1, 51
629 L(J) = STARTU + (J - 1) * DU
630 1C V(J) = STARTV + (J - 1) * DV
631 N2 = N / 10. + 0.99
632 M2 = M / 10. + 0.99
SUBROUTINE PRCFIL(DATA1,NPT,NUMPAT)
    INTEGER SF
    INTEGER OUTPUT(101)
    INTEGER BLANK,PLUS,SLASH,STAR
    REAL DATA(401,2),BOUND(101)
    REAL DATA1(401,2)
    DATA BLANK,PLUS,SLASH,STAR / ' ', ' ', ' ', ' ', ' ' /
    DO 47 J=1,401
      DATA(J,1)=DATA1(J,1)
      DATA(J,2)=DATA1(J,2)
    CONTINUE
    FIND THE RANGE OF DEPENDENT DATA AND SCALE IF NECESSARY
    IF(NPT.GT.600) GO TO 999
    BIG=-1.E10
    SMALL=1.E10
    GO TO 1,J=1,NPT
IF (DATA(J,2) .LT. -60.0) DATA(J,2) = -60.0
IF (DATA(J,2) .LT. SMALL) SMALL = DATA(J,2)
IF (DATA(J,2) .GT. BIG) BIG = DATA(J,2)
CONTINUE
DIFF = ABS(BIG - SMALL)
SF = C
IF (DIFF .LT. 1.) GO TO 10
IF (DIFF .LT. 100.) GO TO 21
DO 2 J = 1, 1C
IF (DIFF*10.**(-J) .GT. 100.) GO TO 2
SF = J
GO TO 20
2 CONTINUE
WRITE(6,1CC)
100 FORMAT( 'Y OUR DATA IS TOO LARGE FOR THIS PROGRAM.' )
RETURN
1C DO 3 J = 1, 1C
K = 11 - J
IF (DIFF*10**K .GT. 100.) GO TO 3
SF = - K
GO TO 20
3 CONTINUE
GO TO 400
2C DO 4 J = 1, NPT
DATA(J,2) = DATA(J,2) * 10.**(-SF)

CALCULATE BOUNDS

SCALE = DIFF / 100.
DO 5 J = 1, 1C1
K = J - 1
BOUND(J) = (BIG - K * SCALE) * 10.**(-SF)

PRINT TITLE

WRITE(6,64C) NUMPAT
64C FORMAT(26X,'PATTERN NUMBER ',15//)
IF (SF .EQ. C) GO TO 200
WRITE(6,4004) SF
4004 FORMAT(53X,'SCALE FACTOR IS 10**',12//)
WRITE(6,650) (BOUND(J), J = 1, 10)
650 FORMAT(/X,5(F7.3,13X),F7.3,2X,'REAL',5X,'C3.3')
DO 6 J = 1, NPT
J = NPT + 1 - J
50 K = 1, 1C1
CUTPUT(K) = BLANK
62 IF (((J - 1)/10 - (J - 1)) .EQ. 62, 61, 62
GO TO 87
CUTPUT(1) = SLASH
CUTPUT(1C1) = SLASH
SUBROUTINE CCNTRUR(K,L,DCON,CLOW,CMAX,CINT,A,NUMPAT)

C**************************************************************************
C THIS SUBPROGRAM GIVES A CONTOUR MAP OF THE MATRIX A
C K AND L ARE THE MAXIMUM VALUES OF I AND J
C IF K=L=51 OR 101 AXES WILL BE SET UP AS FOR A PATTERN PLOT
C DELCON=DELTA(INCREMENT) BETWEEN CONTOURS FOR CONUR SUBROUTINE
C CLLOW=LOWEST CONTOUR LEVEL
C CMAX=HIGHEST CONTOUR LEVEL
C CINT=CONTOUR INTERVAL
C NUMPAT=PATTERN NUMBER
C**************************************************************************

DIMENSION A(51,51)
DIMENSION ALPHA(10)
DIMENSION CL(101)
DATA ALPHA/1H9,1H7,1H5,1H3,1H1/1H9,1H7,1H5,1H3,1H1/
DATA BLANK,OUT/1H9,1H7,1H5,1H3,1H1/

IF(K.LE.1,CR.L.LE.1) RETURN
CINT=CINT
CLOW=CLOW
CMAX=CMAX
READ(6,87) NUMPAT
87 FORMAT(1HC,'FOR THE PATTERN NUMBERED',15)
IF(CINT) 99,99,10C
BIC=-1.E27
SMALL=1.E27
GO 98 1=1,K
GO 98 J=1,L
99 IF(A(I,J).GT.BIG) BIG=A(I,J)
98 CONTINUE
CONINT=(BIG-SMALL)/10.
DELCON=C*.5*CONINT
CCLOW=SMALL+DELCON
CONMAX=BIG-DELCON

WRITE(6,71) DELCON, CONLOW, CONMAX, CONINT

FORMAT(1HC, *DELCON='*, F10.5, 3X, *CONLOW=' *, F10.5, 3X, *CONMAX='*)

PRINT LEVEL DESIGNATIONS
MCHAR=ABS((CCNMAX-CONLOW)/CONINT+1.1)
CON=CONMAX+CONINT
ICON=M-1
ICON=CON-CONINT
WRITE(6,72) ICON, CON

FORMAT(1HC, 'CONTOUR LEVEL ', I2, ' = ', F10.5)

CONTINUE

WRITE HEADING
DO 32 J=1,101
COL(J)=BLANK
32 CONTINUE

IF(L.GT.51) GO TO 33
DO 35 J=1,101,2
COL(J)=DOT
35 CONTINUE
GO TO 34

CONTINUE
DO 38 J=1,101
COL(J)=DOT
CONTINUE
WRITE(6,200)

FORMAT(1HC)

N1=L*2
IF(N1.GT.101) N1=101
WRITE(6,101) (COL(J1), J1=1, N1)

FORMAT(/1HC, 14X, 101A1)

DO 1 1=1, K
CE 31 J=1,101
CCL(J)=BLANK
31 CONTINUE

J2=1
DO 2 J2=1, L
J2=J2+2
2 CONTINUE

ICON=N-1
ICON=CONMAX+CONINT
CO 50 M=1, MCHAR
ICON=ICON+1
CON=CON-CONINT
IF(A(I,J).GT.(CON+DELCN)) GO TO 50
IF(A(I,J).LT.(CON-DELCON)) GO TO 50
NOW A(I,J) IS LT CON+DELCON AND GT CON-DELCON

IF(L.LE.51) CCL(J2)=ALPHA(ICON+1)
IF(L.GT.51) COL(J)=ALPHA(ICON+1)
GO TO 2

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
SUBROUTINE PATCON(RDATA,MMAX,NMAX,ICODE,CONLOW,CONMAX,CONINT,
$STARTU,STARTV,DELTU,DELTAV,NUMPAT,ISYMM)

REAL RDATA(51,51),UAXIS(11),LOW(12),HIGH(12)
INTEGER CUTPUT(101),LEVEL(12),BLANK

DATA BLANK/' '/
DATA LEVEL/I'C',' ','21,'30,,',40,,50,,60,,70,,80,,90,,10//'

CALL DATE(I,J,K)
WRITE(6,10) I,J,K,NUMPAT
10 FORMAT(1H1, ' PATTERN CONTOUR SUBPROGRAM',34X,'DATE =',A2,'-',A2
,$,-',A2,3CX,'PATTERN NUMBER',I5/////)
1027 IF(ICODE.EQ.0) WRITE(6,11)
1028 IF(ICODE.EQ.1) WRITE(6,12)
1029 IF(ICODE.EQ.2) WRITE(6,13)
11 FORMAT(42X,'CONTOUR PLOT OF THE DESIRED PATTERN'///)
1112 FORMAT(46X,'CONTOUR PLOT OF THE INITIAL PATTERN'///)
1132 FORMAT(45X,'CONTOUR PLOT OF THE FINAL PATTERN IN DB.'///)

FINALU=STARTU+(NMAX-1)*DELTU
FINALV=STARTV+(NMAX-1)*DELTAV
U1=STARTU
U2=FINALU
V1=STARTV
V2=FINALV
VCOUNT=MMAX
NCOUNT=NMAX

IF(ISYM-1) 70,30,20
1042 UBIG=AMAX1(AABS(STARTU),ABS(FINALU))
1043 U1=-UBIG
1044 U2=UBIG
1045 MCOUNT=2*NCOUNT-1
1046 IF(ISYM.EQ.2) GO TO 70
1047 VBIG=AMAX1(AABS(STARTV),ABS(FINALV))
1048 V1=-VBIG
1049 V2=VBIG
1050 MCOUNT=2*NCOUNT-1

70 CONTINUE

ESTABLISH LOWER AND UPPER LIMITS
1052 \text{NUMCON}=(\text{CONMAX}-\text{CONLO})/\text{CONINT}+1.5 \\
1053 \text{DELCON}=% \text{CONINT}/2. \\
1054 \text{DC} 71 \text{ J}=1,\text{NUMCON} \\
1055 \text{LOW}(J)=\text{CONLOW}+(J-1)\times\text{CONINT}-\text{DELCON} \\
1056 \text{HIGH}(J)=\text{LOW}(J)+\text{CONINT}+0.0001 \\
1057 \text{71 CONTINUE} \\
1058 \text{LOW}(11)=-1.E30 \\
1059 \text{HIGH}(12)=1.E30 \\
1060 \text{HIGH}(11)=% \text{LOW}(1) \\
1061 \text{LOW}(12)=\text{HIGH}(\text{NUMCON}) \\
1062 \text{MSKIP}=100/(\text{MCOUNT}-1) \\
1063 \text{NSKIP}=100/(\text{NCOUNT}-1) \\
1064 \text{CU}=(U2-U1)/10. \\
1065 \text{DO} 40 \text{ I}=1,11 \\
1066 \text{40 UAXIS(I)}=U1+(I-1)\times\text{DU} \\
1067 \text{WRITE}(6,42) (\text{UAXIS(I)},\text{ I}=1,11) \\
1068 \text{42 FORMAT(13X,11(F7.4,3X)/16X,11('X',9X))} \\
1069 \text{DU}=(U2-U1)/100. \\
1070 \text{DV}=(V2-V1)/100. \\
1071 \text{N}=\text{NSKIP}-1 \\
1072 \text{DO} 50 \text{ N}=1,101,\text{NSKIP} \\
1073 \text{V}=V2-(N-1)\times\text{DV} \\
1074 \text{DO} 51 \text{ K}=1,101 \\
1075 \text{51 OUTPUT(K)=BLANK} \\
1076 \text{DO} 60 \text{ M}=1,101,\text{MSKIP} \\
1077 \text{U}=U1+(M-1)\times\text{DU} \\
1078 \text{IF(U*U+V*V.GT.1.0) GO TO 60} \\
1079 \text{FIND } F(U,V) \\
1080 \text{IJ}=1 \\
1081 \text{IK}=1 \\
1082 \text{J}=(U-\text{STARTU})/\text{DELTAU}+1.5 \\
1083 \text{K}=(V-\text{STARTV})/\text{DELTAV}+1.5 \\
1084 \text{IF(J.GE.1. AND. J.LE.MMAX) IJ=0} \\
1085 \text{IF(K.GE.1. AND. K.LE.NMAX) IK=0} \\
1086 \text{101 IF(IJ) 2CC,102,2CC} \\
1087 \text{102 IF(IK) 300,1000,300} \\
1088 \text{200 IF(ISYMM-1) 6C,6C,201} \\
1089 \text{201 J}=1.5-(U+\text{STARTU})/\text{DELTAU} \\
1090 \text{IF(J.GE.1. AND. J.LE.MMAX) IJ=0} \\
1091 \text{IF(IJ) 6C,202,60} \\
1092 \text{202 IF(IK) 3CC,10CC,300} \\
1093 \text{300 IF(ISYMM.EQ.0. OR. ISYMM.EQ.2) GO TO 60} \\
1094 \text{K}=(V+\text{STARTV})/\text{DELTAV} \\
1095 \text{IF(K.GE.1. AND. K.LE.NMAX) IK=0} \\
1096 \text{IF(IK) 60,1000,60} \\
1097 \text{10CC F=\text{RCATA(J,K)}} \\
1098 \text{IF(F.LE.LGW(1)) GO TO 1001} \\
1099 \text{IF(F.GT.HIGH(\text{NUMCON})) GO TO 1002}
SUBROUTINE LIST(CURR, CURI, MCUR, NCUR)

THIS SUBROUTINE LISTS ARRAY ELEMENT COORDINATES AND CURRENTS.


DIMENSION CURR(51, 51), CURI(51, 51)
C 10 M = 1, MCUR
C 10 N = 1, NCUR
J = (M-1)*NCUR+N
CALL LOCSCR(M, N, S, T)
WRITE(6, 1CC) J, S, T, CURR(M, N), CURI(M, N)
10 CONTINUE
C 100 FORMAT(3X, 14, 5X, 4(E14.7, 2X))
RETURN
ENC
7. Appendix: The ANTDATA Computer Program

7.1 Introduction

When dealing with two-dimensional antenna patterns data display becomes a very important phase of an antenna study. The ANTDATA computer program was written to accomplish this purpose. It is used for publication quality graphical display of patterns and source distributions. These plots are in one (profile), two (contour) and three dimensional forms. The program is written in FORTRAN IV and has been used on an IBM 370/155 with an on-line CALCOMP drum plotter.

This program is for support of the ANTSYN program. There are several subroutines of ANTSYN which provide data output, e.g. PRINT, PROFIL, CONTUR, PATCON and LIST. These may be sufficient for many needs and they do supply quantitative information. However, after synthesizing patterns using ANTSYN if further data display is desired ANTDATA can be used. In this way only those plots which are of interest to the designer are plotted. ANTSYN provides a preview capability for ANTDATA. Both programs could be combined. But when they are separate the program sizes are about 220 K for ANTSYN and 220 K for ANTDATA instead of one 440 K program. Also after previewing the results of ANTSYN, the user can easily select which (if any) of the plot options in ANTDATA he wishes to exercise.

ANTDATA is currently set up to use the correction positions and coefficients from ANTSYN to reconstruct the pattern and source distribution using some of the ANTSYN subroutines. This is done to minimize storage space. If storage is no problem the program could be altered to work directly from pattern and current arrays. Although, one must then use the resolution (array dimensions) used in ANTSYN, which may not be sufficient to see all of the detailed structure in the plots.
The original pattern is based on a Woodward-Lawson pattern. If the user wishes to use a different original pattern, he could write a subroutine, ORGPAT, and use it to initialize the pattern magnitude array A. The corrections found in ANTSYN and passed to ANTDATA would then be used to form the final pattern A as programmed here.

7.2 Program Organization

Again a modular structure using several subroutines has been used to allow for modifications. The main program generates the pattern and current arrays and controls which plots are made. Fig. 7.1 shows a block diagram of the program organization. Subroutines PAT, SPECPT, SOURCE, SPSOR, LOCSPR, and SPLOC are used in generating the pattern and source arrays and are also used in ANTSYN. PLOT1, PLOT1C and PLOT1P are used to plot profiles (cuts through one plane) of the pattern magnitude in dB, the source magnitude, and the source phase. PLOT2 and its subroutines (CNLAL and PLOTL) are used to draw accurate contour maps of the pattern magnitude in dB, the source magnitude, and/or the source phase. PLOT3 and its subroutines (THREE2, THREE3, THREE4, and THREE5) are used to plot the pattern magnitude in dB, the current magnitude, and/or the current phase with a three dimensional effect.

In the next section a description of how the user controls which plots are obtained is discussed. In Section 7.4 a list of important program variable definitions is given. Section 7.5 has descriptions of the subroutines shown in Fig. 7.1. Finally, Section 7.6 is a statement listing of the ANTDATA program.
Figure 7.1 Block diagram of ANTDATA program.
7.3 User's Guide to ANTDATA

The following steps are what the user must consider when he uses ANTDATA. When an input data card must be supplied it will be underlined.

**Step 1.** Specify pattern number and location in storage.

Read NUMPAT and NUMTRK from a card under a 1415 format. This is the pattern number of the job submitted to ANTDATA. NUMTRK is the track number of disk storage where the data for this pattern is thought to be stored. The program will look at that track first. If the pattern number on that track does not match NUMPAT, all tracks will be searched. If the pattern is found on an unexpected track or not found at all, messages will be printed out.

This step can be altered if the input form is different. For instance pattern data could be read in using cards.

**Step 2.** Array size.

Read MMAX and NMAX from a card under a 1415 format. These are the sizes of the pattern magnitude, current magnitude, and current phase arrays, all loaded into A(,), for PLOT 2 and PLOT 3. For the examples presented in Chapter 4 MMAX and NMAX were 151.

**Step 3.** Number of correction coefficients.

The variables ITEMP and ITEMP1 are read from disk storage. ITEMP is the number of correction coefficients of the original pattern. ITEMP1 is the number of correction coefficients for the final pattern, not including the original ones.

**Step 4.** Pattern data.

Data concerning the original and final patterns are read off of disk storage. They are NUMPAT, TITLE, ISYMM, ITER, ISUC, FNORM, IDISK, NORC, IC, (UORG(J), VORG(J), CORG(J), J=1, ITEMP), (US(J), VS(J), CORCOF(J), J=1, ITEMP1), ITYPE, P1, P2, P3, P4, P5, P6, PI, (SS(J), TT(J), J=1, 400), I1, I2, I3, I4, I5, MCUR, NCUR
Refer to the statement listing of subroutine INPUT of the ANTSYN program for a meaning of P1, P2,... and I1, I2,..... These vary with ITYPE.

If the original pattern is not of the Woodward-Lawson type the ORGPAT subroutine of ANTSYN could be used to load the original pattern and then corrections added to it to form the final pattern for use with ANTDATA.

**Step 5. Options for pattern magnitude plots.**

Read OPT1U, OPT1V, OPT2, and OPT3 from a card under a 411 format. Use zeros for no plot and ones for plot.

**Step 6. U profile location.**

Read CONST from a card under a 8F10.0 format. This is the value of V where the profile is made. In other words, the profile is parallel to the U-axis with a value of V equal to CONST. If CONST is zero the profile is on the U-axis. Use only if OPT1U=1.

**Step 7. V profile location.**

Read CONST from a card under a 8F10.0 format. This is the value of U where the profile is made. In other words, the profile is parallel to the V-axis with a value of U equal to CONST. If CONST is zero the profile is on the V-axis. Use only if OPT1V=1.

**Step 8. Parameters for PLOT2 and PLOT3 of pattern.**

Read LOWCON and DASH from a card under a 8F10.0 format. Use only if OPT2 and/or OPT3 is 1.

**Step 9. Pattern contour parameters.**

Read CONLOW, CONMAX, and CONINT from a card under a 8F10.0 format. Use only if OPT2 is 1.

**Step 10. Options for current magnitude plots.**

Read OPT1U, OPT1V, OPT2, and OPT3 from a card under a 411 format. Use zeros for no plot and ones for plot. OPT1U and OPT1V now refer to S and T profiles of the current magnitude.
Step 11. S profile location.

Read CONST from a card under a 8F10.0 format. This is the value of T where the profile is made. Use only if OPT1U now is 1.

Step 12. T profile location.

Read CONST from a card under a 8F10.0 format. This is the value of S where the profile is made. Use only if OPT1V now is 1.

Step 13. Parameters for PLOT2 and PLOT3 of current magnitude.

Read LOWCON and DASH from a card under a 8F10.0 format. Use only if OPT2 and/or OPT3 is 1.


Read CONLOW, CONMAX, and CONINT from a card under a 8F10.0 format. Use only if OPT2 is 1.

Step 15. Options for current phase plots.

Read OPT1U, OPT1V, OPT2, and OPT3 from a card under a 411 format. Use zeros for no plot and ones for plot. OPT1U and OPT1V now refer to profiles of current phase in the S and T directions.

Step 16. Parameters for PLOT2 and PLOT3 of current phase.

Read LOWCON and DASH from a card under a 8F10.0 format. Use only if OPT2 and/or OPT3 is 1.


Read CONLOW, CONMAX, and CONINT from a card under a 8F10.0 format. Use only if OPT2 is 1.

Step 18. Go to Step 1 if another job is to be run.
7.4 Program Variables

Many variables used in this program were also used in ANTSYN and their definitions are found in Section 6.4.

7.4.1 Definition of Some Important Integer Variables Used in ANTDATA

ITEMP = Number of original correction coefficients, CORG.

ITEMPl = Number of correction coefficients (not including original ones), CORCOF.

MMAX = Number of points of first subscript of arrays of pattern magnitude, current magnitude, and current phase used in PLOT2 and PLOT3.

NMAX = Number of points of second subscript of arrays of pattern magnitude, current magnitude, and current phase.

OPT1U = Plot control for subroutines PLOT1, PLOT1C, and PLOT1P. It controls profile plots of the pattern magnitude in the U direction, the current magnitude in the S direction, and/or the current phase in the S direction. If it is 1 a plot is made, otherwise no plot is made.

OPT1V = Plot control for subroutines PLOT1 PLOT1C and PLOT1P. It controls profile plots of the pattern magnitude in the V direction, the current magnitude in the T direction and/or the current phase in the T direction. If it is 1 a plot is made, otherwise no plot is made.

OPT2 = Plot control for PLOT2 subroutine. It controls contour plots of pattern magnitude, current magnitude, and current phase. If it is 1 or greater a plot is made, otherwise no plot is made.

OPT3 = Plot control for PLOT3 subroutine. It controls three dimensional plots of pattern magnitude, current magnitude, and current phase. If it is 1 or greater a plot is made, otherwise no plot is made.

7.4.2 Definition of Some Important Real Variables Used in ANTDATA

A( , ) = Two dimensional array with MMAX by NMAX entries. It must be dimensioned to handle these entries. It is used for the pattern magnitude in dB, the current magnitude, and the current phase.
CONINT = The interval between contour levels for PLOT2 subroutine.

CONLOW = The lowest contour level for PLOT2 subroutine.

CONMAX = The highest contour level for PLOT2 subroutine.

CONST = The amount a profile is displaced from an axis (U, V, S, or T).

DASH = The contour level for PLOT2 subroutine equal to and below which all contours will be dashed. Above this value contours will be solid.

LOWCON = The floor of the PLOT3 subroutine. Three dimensional plots will have all values below LOWCON set to zero. This is used to "clean up" the plot.

7.5 Subroutine Descriptions

The subprograms PAT, SPECPT, SOURCE, SP6OR, LOCSOR, and SPLOC have been discussed in Section 6.5. The remaining subprograms of ANTDATA are briefly described in this section. The contour and three dimensional plotting packages were obtained from other individuals and are so referenced. The one-dimensional plots were written by the authors and S. Kauffman. All of the plotting packages were written for use on the Virginia Tech CALCOMP plotter and as such require the use of some local plot subroutines. These are also explained.

7.5.1 ANTDATA Plot Subroutines

SUBROUTINE PLOT1

Purpose:

To produce a profile plot of far field pattern magnitude vs. an appropriate variable (U, V or THETA).

Usage:

CALL PLOT1 (PSTRT, PEND, IP, CODE, CONST, NUMPAT)
Description of Parameters:

PSTRT - Abscissa of first point to be plotted.
PEND - Abscissa of last point to be plotted.
IP    - Number of points to be plotted. This must be less than the dimension of array PTS. A reasonable choice is 4001.
CODE - Labeling code. If CODE = 0 the horizontal axis will be left blank and the value stored in CONST will be reproduced at the bottom of the plot in the form "THETA=CONST". If CODE=1, then the horizontal axis will be labeled "+V" and "-V" and the value stored in CONST will be reproduced as "U=CONST." If CODE=2, the horizontal axis will be labeled "+U" and "-U" and CONST will be reproduced as "V=CONST."
CONST - Label constant.
NUMPAT - Pattern number.

Remarks:

i. PSTRT and PEND may span any interval. However, PTS(1) must correspond to PSTRT, and PTS(IP) must correspond to PEND.

ii. Before each subroutine call, PTS must be loaded with the appropriate data points. PTS must be in dB, with points equally spaced from PSTRT to PEND.

COMMON Blocks Required: COMMON /PLT1/.PTS

Subroutines and Function Subprograms Required: FACTOR, PLOT, SYMBOL, NUMBER, AXIS.

SUBROUTINE PLOT1C

Purpose:

To produce a profile plot of line source or aperture current distribution magnitude vs. an appropriate variable (S, T or THETA).

Usage:

CALL PLOT1C (PSTRT, PEND, IP, CODE, CONST, NUMPAT)
Description of Parameters:

PSTRT - Abscissa of first point to be plotted.
PEND - Abscissa of last point to be plotted.
IP - Number of points to be plotted. This must be less than the dimension of array PTS. A reasonable choice is 4001.
CODE - Labeling code. If CODE = 0, the horizontal axis will be left blank and the value stored in CONST will be reproduced at the bottom of the plot in the form "THETA = CONST." If CODE = 1, then the horizontal axis will be labeled "+T" and "-T" and the value stored in CONST will be reproduced as "S=CONST." If CODE = 2, the horizontal axis will be labeled "+S" and "-S" and CONST will be reproduced as "T=CONST."

CONST - Label constant.
NUMPAT - Pattern number.

Remarks:

1. The vertical axis is automatically scaled from 0.0 to 0.05, 0.0 to 0.1, 0.0 to 0.2, 0.0 to 0.5, 0.0 to 1.0 depending on the range of the data in PTS.

2. Before each subroutine call, PTS must be loaded with appropriate data points none of which must be less than zero.

COMMON Blocks Required: COMMON /PLT1/, PTS

Subroutines and Function Subprograms Required: FACTOR, PLOT, SYMBOL, NUMBER, AXIS.

SUBROUTINE PLOT1P

Purpose:

To produce a profile plot of line source or aperture current distribution phase (in degrees) vs. an appropriate variable (S, T or THETA).

Usage:

CALL PLOT1P (PSTRT, PEND, IP, CODE, CONST, NUMPAT)
Description of Parameters:

PSTRT - Abscissa of first point to be plotted.
PEND - Abscissa of last point to be plotted.
IP - Number of points to be plotted. This must be less than the dimension of array PTS. A reasonable choice is 4001.
CODE - Labeling code. If CODE = 0, the horizontal axis will be left blank and the value stored in CONST will be reproduced at the bottom of the plot in the form "THETA=CONST." If CODE = 1, the horizontal axis will be labeled "+T" and "-T" and the value stored in CONST will be reproduced as "S=CONST." If CODE = 2, the horizontal axis will be labeled "+S" and "-S" and CONST will be reproduced as "T=CONST."

CONST - Label constant.
NUMPAT - Pattern number.

Remarks:

1. Before each subroutine call, PTS must be loaded with appropriate data points in degrees (-180 ≤ PTS ≤ 180).

COMMON Blocks Required: COMMON /PLT1/ PTS

Subroutines and Functions Required: FACTOR, PLOT, SYMBOL, NUMBER, AXIS

SUBROUTINE PLOT2

Purpose:

To draw a contour map of data in array A.

Usage:

CALL PLOT2 (N, M, CONLOW, CONMAX, CONINT, NUMPAT, DASH)

Description of Parameters:

N - Number of points to be plotted in horizontal direction.
M - Number of points to be plotted in vertical direction.
CONLOW - Lowest contour level to be plotted.
CONMAX - Highest contour level to be plotted.
CONINT - Interval between contour levels.
NUMPAT - Pattern number.
DASH - Contour levels below DASH will be dashed rather than solid

Remarks:

i. If CONINT = 0 or CONLOW = CONMAX, the subroutine will determine the contour levels to be plotted.

COMMON Blocks Required: COMMON /ARRAY/ A
Subroutine and Function Subprograms Required: CNLAL, PLOT, FACTOR, SYMBOL, NUMBER
Reference: D. A. Vossler, E. S. Robinson

SUBROUTINE CNLAL

Purpose:

To determine the maximum and minimum of array X. To calculate the increment that will give 10 equally spaced contours between the maximum and minimum of array X.

Usage:

CALL CNLAL (N, M, CNTRLO, CMAX, CNTRAL, NC)

Description of Parameters:

N - Number of points in horizontal direction.
M - Number of points in vertical direction.
CNTRLO - Least value of array X.
CMAX - Greatest value of array X.
CNTRAL - ABS(CMAX-CNTRLO)/10.
NC - IF NC=0: CNTRLO and CMAX are returned.
     IF NC=1: CNTRLO, CMAX, and CNTRAL are returned.
COMMON Blocks Required:  COMMON /ARRAY/ X

Subroutine and Function Subprogram Required:  None.

SUBROUTINE PLOTL

Purpose:

To plot a straight line between two points.

Usage:

CALL PLOTL(X1,Y1,X2,Y2,SCALE)

Description of Parameters:

X1  Abscissa of starting point.
Y1  Ordinate of starting point.
X2  Abscissa of end point.
Y2  Ordinate of end point.
SCALE  -  Scale factor used in converting (X1,Y1) and (X2,Y2) to proper plot size.

Remark:

PLOTL is equivalent to the following two statements:
CALL PLOT(SCALE*X1+2.,SCALE*Y1+0.25,3)
CALL PLOT(SCALE*X2+2.,SCALE*Y2+0.25,2)
Where PLOT is a standard VPI plot subroutine.

COMMON Blocks Required:  None.
Subroutine and Function Subprograms Required:  None.

SUBROUTINE PLOT3

Purpose:

To draw a perspective view of a contoured surface.

Description of Parameters and Important Variables:

N  -  Number of data points along first axis.
M  -  Number of data points along the second axis.
NUMPAT - Pattern number (for labeling)

K - Code that tells whether to draw the grid lines:
   K=1: Along the N-Dimension only.
   K=2: Along the M-Dimension only.
   K=3: Along both dimensions.

SDISTS - Distance from surface to eye when perspective is calculated -- SKISTS > .6 usually won't show any distortion due to PARALLAX.

YAW - (In degrees) How far the object is turned away from the viewer.

PITCH - (In degrees) How the surface is lowered or raised at the front edge. (Positive pitch tends to expose the top of the figure.)

SIZE - (In inches) The size of the cube that encloses the figure.

KODE - "Hidden Line" switch. If KODE=0, do not draw hidden lines...If KODE=1, all hidden lines are plotted.

MGN - Whether to draw the outline of the cube to help orient the viewer. MGN=0: Do not draw any outline of the cube. MGN=1: Draw the outline of the cube separate from the figure. MGN=2: Draw the outline of the cube superimposed on the surface plot. MGN=3: Draw only the three edges of the cube that meet at the origin, superimposed on the surface plot.

SCALE - How tall to make the surface relative to the height of the cube. SCALE=0: Do not scale the data at all but trust the user that the data is not so high that it runs off the paper. SCALE=1: Scale the data so the top of the data just touches the top of the cube. SCALE=0.3: Scale the data so the top of the surface is three-tenths as high as the cube.

Remarks:

i. It is very expensive to draw opaque surfaces, because the program has to determine the visibility of every point, the computer time doubles or triples...Depending on how many line segments are partially visible.

ii. The contents of array A are destroyed in computation.

COMMON Blocks Required:

COMMON /ARRAY/ A
COMMON /THREE6/ ANGA, ANGB, HV, V, SH, SV
COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, QX, QY, QZ, SD
Subroutine and Function Subprograms Required: THREE2, THREE3, THREE3, THREE4, THREE5, PLOT, FACTOR, SYMBOL, NUMBER.

Reference: Howard Jesperson, Iowa State University.

SUBROUTINE THREE2

Purpose:

To find the corners of a three-dimensional rotated cube.

Usage:

CALL THREE2(X, Y, Z, XP, H, V, KODE)

Description of Parameters:

(X,Y,Z) - Vectors of length 2. Position of rotated vertices.

XP  - Height above paper.

(H,V) - Vectors of length 10. Location of projected vertices on paper.

KODE - Dummy variable

COMMON Blocks Required: None

Subroutine and Function Subprograms Required: THREE4

SUBROUTINE THREE4

Purpose:

To find the location of a point in the rotated cube.

Usage:

CALL THREE4(X, Y, Z, XP, YP, ZP, KODE)

Description of Parameters:

(X,Y,Z) - Coordinates of point to be located.

XP  - Height above paper of point.

(YP,ZP) - Coordinates of projection on paper.
COMMON Blocks Required:

```
COMMON /THREE6/ ANGA, ANGB, HV, D, SH, SV
COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, QX, QY, QZ, SD
```

Subroutine and Function Subprograms Required: None.

SUBROUTINE THREE3

Purpose:

To plot a perspective of a three-dimensional figure.

Usage:

```
CALL THREE3(X, Y, N, M, H, V, K, KODE)
```

Description of Parameters:

- **X**: Vector of length 2
- **Y**: Vector of length 2
- **N**: Number of points in first direction
- **M**: Number of points in second direction
- **H, V**: Vectors of length 10...Coordinates of projected vertices of cube.
- **K**: Grid Line Code (See Subroutine PLOT3)
- **KODE**: Hidden Line Switch (See Subroutine PLOT3)

COMMON Blocks Required:

```
COMMON /THREE6/ ANGA, ANGB, HV, D, SH, SV
COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, QX, QY, QZ, SD
COMMON /ARRAY/ A
```

Subroutine and Function Subprograms Required: THREE4, THREE5, PLOT

SUBROUTINE THREE5

Purpose:

To see if a point on the projected three-dimensional figure is visible.

Usage:

```
CALL THREE5(XI, YJ, M, K, P, KODE)
```
Description of Parameters:

**XI** - Abscissa of the projected point.

**YJ** - Ordinate of the projected point.

**M** - Number of horizontal points.

**N** - Number of vertical points.

**P** - PLOT CODE; IF P = -1 INVISIBLE TO VISIBLE
        1 VISIBLE TO INVISIBLE
        0 VISIBLE TO VISIBLE OR
        INVISIBLE TO INVISIBLE.

**KODE** - Hidden Line Code (See Subroutine PLOT3)

COMMON Blocks Required:

COMM A/ ARRAY/ A
COMMON /THREE6/ ANGA, ANGB, HV, D, SH, SV
COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, QX, QY, QZ, SD

Subroutine and Function Subprograms Required: None.

7.5.2 Virginia Tech Subroutines

VPI UTILITY SUBPROGRAMS

<table>
<thead>
<tr>
<th>Subprograms</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATE</td>
<td>To return the current month, day, and year.</td>
</tr>
<tr>
<td>STIME</td>
<td>To return the time of day in ten thousandths of an hour (Integer Format)</td>
</tr>
<tr>
<td>TIMEON</td>
<td>To set the interval timer to zero</td>
</tr>
<tr>
<td>TIMECK</td>
<td>To return the amount of CPU time used in hundredths of seconds since the last call to TIMEON.</td>
</tr>
</tbody>
</table>

Reference: VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY, "COMPUTING CENTER USER'S GUIDE," VOL. 7, "UTILITY PROGRAMS."

VPI PLOTTER SUBROUTINES

<table>
<thead>
<tr>
<th>Subroutine</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>AXIS</td>
<td>To draw a labeled axis of a desired length with annotated tic marks every inch.</td>
</tr>
</tbody>
</table>
FACTOR To scale the plot in both the X and Y directions.

NUMBER To draw a floating point number.

PLOT To move the pen from one point to another, to draw a line between points, to establish a new origin, and to signal the end of a plot.

SYMBOL To plot a string of alphanumerical characters.

Reference: VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY, "COMPUTING CENTER USER'S GUIDE," VOL. 6, "THE PLOTTER."

INTEGER FUNCTION ICVT

Purpose:
   To convert an integer to character format internal coding.

Usage:
   ICHAR=ICVT(NUM)

Remark:
   This function was originally written in assembler. Object deck is read in under the SYSLIN dataset.
7.6 Statement Listing of ANTDATA

7.6.1 Job Control Language

Listed below are the JCL statements required for the ANTDATA program to run on the Virginia Tech IBM 370/155 system.

```
//B0663PL3 JOB 507C2,COFFEY
/*MAIN TIME=19,LINES=3,REGION=250K,CARDS=C
/*PRIORITY PRIORITY
/*FORMAT PL,FORMS=PFGURAGV,PEN=XXFIAE,DDNAME=CALCOMP
// EXEC FORTGCG,PARM.GO='PAPER=39,PTIME=119',EP=MAIN
//FORT.SYSIN DD *
/*
//GO.SYSLIB DD
// DD DSN=VPI.PLOTLIB,DISP=SHR
// DD DSN=VPI.SSPLIB,DISP=SHR
//GO.SYSLIN DD
// DD *
/*
//GO.FT22FO01 DD DSN=ANTDATA.A507C2,UNIT=3330,VOL=SER=tJSERPK,DISP=SHR
//GO.FT06F001 DD SYSOUT=A,DCB=(BLKSIZE=133,RECFM=F)
//GO.SYSIN DD *
/*
```

7.6.2 Source Listing

Listed below are the FORTRAN IV statements of the ANTDATA program.
PROGRAM DESCRIPTION:
ANTDATA IS THE OUTPUT PROGRAM USED IN CONJUNCTION WITH ANTSYN2.
BY SPECIFYING APPROPRIATE PARAMETERS ANTDATA WILL GIVE A ONE,
TWO, OR THREE DIMENSION PLOT OF THE PATTERN (IN DB.), THE SOURCE
MAGNITUDE, AND THE SOURCE PHASE.

INPUT/OUTPUT:
THE MAJORITY OF INPUT IS TAKEN FROM ANTSYN2 VIA DIRECT-ACCESS
UNIT 22 (ANTDATA.A507C2). PARAMETERS AND JOB OPTIONS ARE SUPPLED
THROUGH UNIT 5 (SYSIN). ALL OUTPUT IS CHANNELED TO UNIT 6
(SYSPRINT) AND THE PLOTTER (PLOT1).

VERSION 1 73 - 094 -- APRIL 5, 1973

WRITTEN BY: W. L. STUTZMAN
S. R. KAUFFMAN
E. L. COFFEY

UNDER NASA GRANT: 47-004-103

ADDITIONAL SUBPROGRAMS REQUIRED:
ICVT -- ASSEMBLER LANGUAGE SUBPROGRAM TO CONVERT AN INTEGER
TO A2 CHARACTER FORMAT.

DEFINE FILE 22(35,9100,E,NREC)

DIMENSION A(151,151),PTS(4001),US(500),VS(500),CURCOF(500)
DIMENSION UORG(100),VORG(100),CORG(100)
DIMENSION AV(151),AV(151)
INTEGER TITLE(20)
REAL INITLS,INITLT
REAL LOWCUN
INTEGER CPTIU,OPIVO,OPT2,OPT3,PK,PY
COMPLEX CTEMP,CI
COMMON /PLT1/ PTS
COMMON /ARRAY/ A
COMMON /PAT1/ P1,P2,P3,P4,P5,P6,P1,SS(400),TT(400),RR(400)
COMMON /PAT2/ 11,12,13,14,15
COMMON /LOC/ ITYPE
IPAGE=0
PI=3.14159265
CI=CMPLX(0.0,1.0)
call stime(iTIME)
TIME=0.
9999 continue
CALL TIMECN
IPAGE=IPAGE+1
CALL DATE(II,JI,K1)
CALL STIME(IT)
IHR=IT/10000
IFR=IT-IHR*10000
FM=IFR/10000.

IFR=IT-IHR*10000.
FM=IFR/10000.

FM=FHR*60.
IPIN=F
ISEC=(FM-I MIN)*60
IHR=ICVT(IHR)
IIN=ICVT(IMIN)
ISEC=ICVT(ISEC)
IPG=ICVT(IPAGE)
WRITE(6,1) II,JI,K1,ITHR,IMIN,ISEC,IPG

READ PATTERN NUMBER AND TRACK -- VERIFY THAT PATTERN IS ACTUALLY STORED

READ(5,10,END=999) NUMPAT,NUMTRK
10 FORMAT(I4,15)
IF(NUMPAT.EQ.0) GO TO 999
WRITE(6,704) NUMPAT
704 FORMAT(* PLOT OUTPUT FOR PATTERN*,15,* ;*)
READ(22*NUMTRK,20) NUM
20 FORMAT(A4)
IF(NUM.EQ.NUMPAT) GO TO 51
GO 30 I=2,25
READ(22*I,20) NUM

50 CONTINUE
NUMPAT IS NOT ON DISK
WRITE(6,60) NUMPAT
60 FORMAT(15,* PATTERN NUMBER*,15,* WAS NOT FOUND ON TRACK*,12, $* BUT WAS LOCATED ON TRACK*,12)
NUMTRK=I
51 CONTINUE
Numpat found on unexpected track
52 WRITE(6,60) NUMPAT,NUMTRK,I
53 60 FORMAT(15,* PATTERN NUMBER*,15,* WAS NOT FOUND ON TRACK*,12, $* BUT WAS LOCATED ON TRACK*,12)
NUMTRK=I
54 51 CONTINUE
BEGIN PROCESSING
READ(5,10) MMAX,NMAX
READ(22*NUMTRK,7C) ITEMP,ITEMP
70 FORMAT(104X,2A4)
READ(22,NUMTRK,101) NUMPAT,TITLE,ISYMM,ITER,ISUC,FNORM,IVISK,
$NCRG,IC,(UORG(J),VORG(J),CORG(J),J=1,ITEMP),
$(US(J),VS(J),CRCOF(J),J=1,ITEMP1),ITYPE,P1,P2,P3,P4,P5,P6,
$PI,(SS(J),IT(J),J=1,400),11,12,13,14,15,MCUR,NCUR

101 FORMAT(75A4,11(200A4))

C READ OPTIONS FOR PATTERN MAGNITUDE

61 READ(5,29) OPTIU,OPTIV,OPT2,OPT3
62 29 FORMAT(411)
63 IF(OPTIU-1) 80,81,60
64 81 CONTINUE
65 READ(5,31) CONST
66 IF(MMAX.LE.1) GO TO 80
67 DO 90 J=1,4001
68 U=(J-1)*0.0005-1.0
69 SUM=0.
70 DO 91 K=1,NCRG
71 SUM=SUM+CORG(K)*PAT(U-UORG(K),CONST-VORG(K),ITYPE)
72 IF(IDC.LE.0) GO TO 90
73 DO 91 K=1,IC
74 SUM=SUM+CRCOF(K)*PAT(U-US(K),CONST-VS(K),ITYPE)
75 91 CONTINUE
76 PTS(J)=2C.*A1OGL0(ABS(SUM))
77 WRITE(6,92) CONST
78 92 FORMAT(*CV-AXIS PROFILE PLOT REQUESTED -- V = ',F6.3)'
79 CALL PLOT1(-1.0,1.0,2,01,CONST,NUMPAT)
80 81 IF(OPTIV-1) 82,83,82
81 82 CONTINUE
82 READ(5,31) CONST
83 IF(MMAX.LE.1) GO TO 82
84 DO 90 J=1,4001
85 V=(J-1)*0.0005-1.0
86 SUM=0.
87 DO 90 K=1,NCRG
88 SUM=SUM+CORG(K)*PAT(CONST-UORG(K),V-VORG(K),ITYPE)
89 IF(IDC.LE.0) GO TO 90
90 DO 90 K=1,IC
91 SUM=SUM+CRCOF(K)*PAT(CONST-US(K),V-VS(K),ITYPE)
92 90 CONTINUE
93 WRITE(6,93) CONST
94 93 FORMAT(*CV-AXIS PROFILE PLOT REQUESTED -- U = ',F6.3)
95 CALL PLOT1(-1.0,1.0,4001,1,CONST,NUMPAT)
96 82 IF(OPT2+OPT3) 85,85,84
97 84 CONTINUE

C GENERATE PATTERN ARRAY

98 READ(5,31) LOWCON,DASH
99 IF(MMAX.LE.1 .OR. NMAX.LE.1) GO TO 239
100 DELTAV=2.0/(MMAX-1)
101 DELTAV=2.0/(MMAX-1)
102 CALL 6,761 LOWCON,LOWCON
103 CALL 701 FORMAT(*PATTERN IS NOW BEING GENERATED. IF PATTERN < ',F7.2,
90 * PATTERN = ',F7.2)
104 IF(ITYPE .GT. 5) GO TO 5000
A-78

C LOAD UP AU AND AV
C
1C5 DO 2CCG I=1,NMAX
106 U=(I-1)*DELTAV
1C7 2CCG AU(I)=PAT(U,0.,ITYPE)
108 DO 2010 J=1,NMAX
109 V=(J-1)*DELTAV
110 AV(J)=PAT(C-,V,ITYPE)

C BEGIN

C U=-1.0-DELTAV
112 DO 2040 M=1,NMAX
113 U=U+DELTAV
114 V=-1.0-DELTAV
115 DO 2040 N=1,NMAX
116 V=V+DELTAV
117 TEMP=C.
118 DO 2030 K=1,NORG
119 I=ABS(U-UORG(K))/DELTAV+1.5
120 J=ABS(V-VORG(K))/DELTAV+1.5
121 2030 TEMP=TEMP+CORG(K)*AU(I)*AV(J)
122 IF(1C.LT.0) GO TO 2020
123 DO 2040 K=1,IC
124 I=ABS(U-US(K))/DELTAV+L.5
125 J=ABS(V-VS(K))/DELTAV+1.5
126 2040 TEMP=TEMP+CORCOF(K)*AU(I)*AV(J)
127 2020 A(M,N)=20.*ALOG10(ABS(TEMP))
128 GO TO 239
129 5CC0 CONTINUE
130 DO 200 M=1,NMAX
131 U=-1.0+(M-1)*DELTAV
132 DO 201 N=1,NMAX
133 V=-1.0+(N-1)*DELTAV
134 TEMP=C.
135 DO 242 I=1,NORG
136 242 TEMP=TEMP+CORG(I)*PAT(U-UORG(I),V-VORG(I),ITYPE)
137 IF(1C.LT.0) GO TO 2021
138 DO 202 I=1,IC
139 202 TEMP=TEMP+CORCOF(I)*PAT(U-US(I),V-VS(I),ITYPE)
140 2021 CONTINUE
141 A(M,N)=20.*ALOG10(ABS(TEMP))
142 201 CONTINUE
143 2CC CONTINUE
144 239 CONTINUE
145 IF(OPT2) 210,210,211
146 211 RFAD59T31) CONLOW,CONMAX,CONINT
147 31 FORMAT(6F10.0)
148 IF(1MMAX.LT.0 OR 1MON,1M.LE.1) GO TO 230
149 DO 257 M=1,NMAX
150 DO 257 N=1,NMAX
151 IF(A(M,N).LT.LOWCON) A(M,N)=LOWCON
152 257 CONTINUE
153 WRITE(6,220) CONLOW,CONMAX,CONINT
A-79

154 220 FORMAT('CONTOUR PLOT OF PATTERN REQUESTED',/
        $'  LOWEST CONTOUR = ',F7.2/
        $'  HIGHEST CONTOUR = ',F7.2/
        $'  CONTOUR INTERVAL = ',F7.2)

155 CALL PLOT2(MMAX,NMAX,CONLOW,CONMAX,CONINT,NUMPAT,DASH)

6 21C IF(OPT3) 230,230,231

157 231 WRITE(6,24C)

158 240 FORMAT(1HO,'THREE - DIMENSIONAL PLOT OF PATTERN REQUESTED')

159 CALL PLOT3(MMAX,NMAX,NUMPAT)

160 23C CONTINUE

161 IF(MMAX.LE.1.OR.NMAX.LE.1) WRITE(6,23)

162 23 FORMAT('ONE DIMENSIONAL')

163 85 CONTINUE

C END OF PATTERN

C

164 IA=0

165 IF(ITYPE.EQ.1) GO TO 401

166 IF(ITYPE.EQ.3) GO TO 401

167 IF(ITYPE.EQ.4) GO TO 401

168 IF(ITYPE.EQ.6) GO TO 401

169 4CC WRITE(6,402)

170 402 FORMAT(1HO,'THE SOURCE IS AN ARRAY -- THIS PGM IS FOR CONTINUOUS SOURCES ONLY')

171 IA=1

172 401 CONTINUE

173 P3TEMP=P3

174 P5TEMP=P5

175 P6TEMP=P6

176 IF(ITYPE.EQ.1) 404,403,404

177 404 IF(ITYPE.EQ.3) 405,403,405

178 403 CONTINUE

C ITYPE = 1 OR 3

179 INITLS=0.

180 DELTAS=0.

181 FINALS=0.

182 INITLT=P2

183 FINALT=P2+P1

184 P3=P1/4CC0.

185 DELTAT=P3

186 GO TO 410

187 405 IF(ITYPE.EQ.4) 407,406,407

188 406 CONTINUE

C ITYPE = 4

189 INITLS=P3

190 FINALS=P3+P1

191 INITLT=P4

192 FINALT=P4+P2

193 P5=P2/4CC0.

194 P6=P2/4000.

195 DELTAT=P6

196 DELTAS=P5

197 GO TO 410

C ITYPE = 6

198 407 CONTINUE

199 IF(ITYPE.EQ.6) 410,409,410
409 INITLS=P3
409 FINALS=P3+2.*P1
409 INITLT=P4
409 FINALT=P4+2.*P1
409 DELTAT=P6
409 DELTAS=P5
410 CONTINUE
200 READ(5,29) OPT1U,OPT1V,OPT2,OPT3
201 IF(OPT1U-1) 302,301,302
202 CONTINUE
203 READ(5,31) CONST
204 IF(IA.EQ.1) GO TO 3000
205 IF(IMAX.LE.1) GO TO 302
206 J=1
207 IF(DELTAT.NE.0.) J=1.5+(CONST-INITLT)/DELTAT
208 DO 303 I=1,4001
209 CTEMP=(0.0,0.0)
210 IF(NORG.LE.0) GO TO 304
211 DO 305 K=1,NORG
212 CTEMP=CTEMP+CORG(K)*SOURCE(I,J,UORG(K),VORG(K),ITYPE)
213 CONTINUE
214 IF(IC.LE.0) GO TO 303
215 CO 306 K=1,IC
216 CTEMP=CTEMP+CORCOF(K)*SOURCE(I,J,US(K),VS(K),ITYPE)
217 WRITE(6,307) CONST
218 CALL PLOTIC(INITLS,FINALS,4001,2,CONST,NUMPAT)
219 CONTINUE
220 IF(CPT1V-1) 311,310,311
221 305 CTEMP=CTEMP+CORG(K)*SOURCE(I,J,UORG(K),VORG(K),ITYPE)
222 304 IF(IC.LE.0) GO TO 303
223 CONTINUE
224 306 CTEMP=CTEMP+CORCOF(K)*SOURCE(I,J,US(K),VS(K),ITYPE)
225 303 PTS(I)=CABS(CTEMP)
226 WRITE(6,317) CONST
227 FORMAT('CT-AXIS PROFILE PLOT REQUESTED -- S = ',F6.3)
228 CALL PLOTIC(INITLS,FINALS,4001,1,CONST,NUMPAT)
229 CONTINUE
230 IF(CPT1V-1) 311,310,311
231 CONTINUE
232 READ(5,31) CONST
233 IF(IA.EQ.1) GO TO 3000
234 IF(INMAX.LE.1) GO TO 322
235 J=1
236 IF(DELTAS.NE.0.) J=1.5+(CONST-INITLS)/DELTAS
237 DO 313 J=1,4001
238 CTEMP=(0.0,0.0)
239 IF(NORG.LE.0) GO TO 314
240 DO 315 K=1,NORG
241 CTEMP=CTEMP+CORG(K)*SOURCE(I,J,UORG(K),VORG(K),ITYPE)
242 CONTINUE
243 IF(IC.LE.0) GO TO 313
244 CONTINUE
245 316 CTEMP=CTEMP+CORCOF(K)*SOURCE(I,J,US(K),VS(K),ITYPE)
246 WRITE(6,317) CONST
247 313 PTS(J)=CABS(CTEMP)
248 CALL PLOTIC(INITLS,FINALT,4001,1,CONST,NUMPAT)
249 CONTINUE
250 CONTINUE
251 CONTINUE
252 P3=P3TEMP
253 P5=P5TEMP
254 P6=P6TEMP
255 MCUR=51
256 NCUR=51
IF(DOPT2+OPT3) 320,320,321
CONTINUE
READ(5,31) LOWCON,DASH
IF(IA.EQ.1) GO TO 333

C GENERATE CURRENT MAGNITUDE ARRAY
C
DO 330 M=1,MCUR
DO 331 N=1,NCUR
CALL LOCSOR(M,N,S,T)
CTEMP=0.
DC 339 K=1,NORG
CTEMP=CTEMP+CORG(K)*SOURCE(M,N,UORG(K),VORG(K),IYYPE)
DO 332 K=1,IC
CTEMP=CTEMP+CORCOF(K)*SOURCE(MNUS(K),VS(K),IFYPE)
A(P,N)=CABS(CTEMP)
CONTINUE
CONTINUE
CONTINUE
IF(OPT2) 350,350,351
READ(5,31) CONLOW,CONMAX,CONINT
IF(IA.EQ.1) GO TO 360
 IF(PMAX.LE.1.OR.NMAX.LE.1) GO TO 360
 WRITE(6,340) CONLOW,CONMAX,CONINT
340 FORMAT(' CONTOUR PLOT OF CURRENT MAGNITUDE REQUESTED*/'
$ LOWEST CONTOUR = ',F7.4/
$ HIGHEST CONTOUR = ',F7.4/
$ CONTOUR INTERVAL = ',F7.4)
CALL PLOT2 (MCUR,NCUR,CONLOW,CONMAX,CONINT,NUMPAT,DASH)
WRITE(6,355)
355 FORMAT('THREE DIMENSION PLOT OF CURRENT MAGNITUDE REQUESTED')
CALL PLOT3 (MCUR,NCUR,NUMPAT)
360 CONTINUE
IF(PMAX.LE.1.OR.NMAX.LE.1) WRITE(6,23)
32C CONTINUE

END OF CURRENT MAGNITUDE

READ OPTIONS FOR CURRENT PHASE
READ(5,29) OPT1U,OPT1V,OPT2,OPT3
IF(OPT2+CPT3) 520,520,521
CONTINUE
IF(IA.EQ.1) GO TO 533
READ(5,31) LOWCON,DASH

DO 530 M=1,MCUR
DO 531 N=1,NCUR
CALL LOCSOR(M,N,S,T)
CTEMP=0.
DO 549 K=1,NORG
CTEMP=CTEMP+CORG(K)*SOURCE(M,N,UORG(K),VORG(K),IYYPE)
SUBROUTINE PLOT1(PSTRT, PEND, IP, CODE, CONST, NUMPAT)

C
C SUBROUTINE PLOT1
C
C WRITTEN BY: S. R. KAUFMAN
C
C DATE: 73-113 APRIL 23, 1973
INPUT:

PSRT. -- BEGINNING OF PLOT
PEND -- END OF PLOT
IP -- NUMBER OF POINTS TO BE PLOTTED
CODE -- LABELLING VARIABLE. IF CODE=0: LABEL='\Theta';
        IF CODE=1: LABEL='U'; IF CODE = 2: LABEL = 'T = '
CONST -- CONSTANT PARAMETER FOR LABEL
NUMPAT -- NUMBER OF PATTERN FOR LABEL.

INTEGER NAME(2), CODE
DIMENSION PTS(4001)
COMMON /PLT1/ PTS
CALL FACTOR(0.5)
CALL PLOT(8.91.,-3)
IF(CODE.GT.0) GO TO 3
CALL SYMBOL(-1.2,-6.2,8\HTHETA = ,0.,8)
CALL NUMBER(-3.8,-2,CONST,0.,3)
GO TO 6
3 IF(CODE.GT.1) GO TO 4
CALL SYMBOL(-1.2,-8.2,1\HU,0.,1)
CALL SYMBOL(-2.2,-8,2,3H = ,0.,3)
CALL NUMBER(-2.5,-8,2,CONST,0.,3)
CALL SYMBOL(-2.6,-4,2,2\HTHETA,0.,2)
CALL SYMBOL(2.4,-4,2,2\HTHETA+V,0.,2)
GO TO 6
4 IF(CODE.GT.2) GO TO 5
CALL SYMBOL(-1.2,-8,2,1\HU,0.,1)
CALL SYMBOL(-2.2,-8,2,3H = ,0.,3)
CALL NUMBER(-2.5,-8,2,CONST,0.,3)
CALL SYMBOL(-2.6,-4,2,2\HTHETA-U,0.,2)
CALL SYMBOL(2.4,-4,2,2\HTHETA+U,0.,2)
GO TO 6
6 CONTINUE
PDEL=(PSRT-PEND)/IP
PTIC=(ABS(PSRT-PEND))/10.
CALL AXIS(-500,1H,14000,PSRT,PTIC)
PSRE=PSRT+(6.4*PTIC)+.00001
PTIC2=PTIC+.00001
CALL AXIS(10.0,0.1H,14000,PSRE,PTIC2)
CALL PLOT(-1.0,0.,3)
CALL PLOT(10.0,2)
CALL PLOT(0.0,3)
CALL PLOT(0.0,3)
CALL PLOT(0.0,3)
CALL PLOT(-0.05,-4.0,2,1\MO,0.,1)
X=0.05
CC 10 J=1,6
Y=0.5(J-1)*1.0
CALL PLOT(-X,Y,3)
10 CALL PLOT(-X,Y,2)
CALL PLOT(-0.0,0.3)
IF(PTS(1).LE.-50.) PTS(1)=-50.
FS=((PTS(1))/10.)*5.5
CALL PLCT(-5.,FSq3)
CC
THET=((PSTRT-(IWIPDEL))*5.)/(ABS(PSTRT))
FDBS=((PTS(IW1))/10.)*5.5
IF(FDBS.LT.0.5) GO TO 1
CALL PLCT(THETS,FDBS,2)
CONTINUE
CALL SYMBOL(-5.0,-0.8,0.125,10HPATTERN = ,0.0,1J)
FNUM=FLECTINUMPAT)
CALL NUMBER(-3.87,-0.8,0.125,FNUM,0.0,-1)
CALL AXES(-5.5,0.5,17HFAR FIELD PATTERN,17,5.0,90.,-90.,10.)
CALL PLCT(8.,-1.,-3)
RETURN

SUBROUTINE PLOTIC(PSTRT,PEND,IP,CODE,CONST,NUPAT)

INTEGER NAME(2),CODE
CALL FACTOR(.5)
CALL PLOT18.91.9-3D
CALL PLOT18.91.9-3D
CALL PLOT18.91.9-3D
IF(CODE GT 0) GO TO 3
CALL SYM8OL(-1.2,-0.8,0.6,8THETA = ,0.0,8)
CALL NUMBER(C.3,-0.8,0.2,CONST,0.0,3)
GO TO 6
3 IF(CODE GT 1) GO TO 4
CALL SYMBOL(-1.0,-0.8,0.2,1HS,0.0,1)
CALL SYMBOL(-0.9,-0.8,0.2,3H = ,0.0,3)
CALL NUMBER(-0.2,-0.8,0.2,CONST,0.0,3)
CALL SYMBOL(-2.6,-0.4,0.2,2H-T,0.0,2)
CALL SYMBOL(2.4,-0.4,0.2,2H+T,0.0,2)
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416   GO TO 6
417   4 IF(CODE.GT.2) GO TO 5
418   CALL SYMBOL(-1.0,-0.8,0.2,1HT,0.0,1)
419   CALL SYMBOL(-0.9,-0.8,0.2,3H = +0.0,3)
420   CALL NUMBER(-0.2,-0.8,0.2,CONST,0.0,3)
421   CALL SYMBOL(-2.6,-0.4,0.2,2H-5,0.0,2)
422   CALL SYMBOL(2.4,-0.4,0.2,2H+S,0.0,2)
423   6 CONTINUE
424      PDEL=(PSTRT-PEND)/IP
425      PTIC=((ABS(PSTRT-PEND))/10.0)
426      CALL AXIS(-5.C0,-C.0,1H ,1,4.0,0.0,PSTRT,PTIC)
427      PSTRE=PSTRT+(6.0*PTIC)+0.00001
428      PTIC2=PTIC+0.0001
429      CALL AXIS(1.0,0.0,1H ,1,4.0,0.0,PSTRE,PTIC2)
430      CALL PLOT(-1.0,0.0,3)
431      CALL PLOT(1.0,0.0,2)
432      CALL PLOT(0.0,5.8,2)
433      CALL PLOT(0.0,5.8,3)
434      CALL PLOT(-5.0,0.0,3)
435      CALL SYMBOL(-C.05,-C.4,0.2,1HO,0.0,1)
436      X=0.05
437      UC 10 J=1,6
438      Y=0.5+(J-1)*1.0
439      CALL PLOT(-X,Y,3)
440     10 CALL PLOT(X,Y,2)
441     CALL PLOT(C.0,0.3)
442     PSTRE=5.0-PSTRT
443     GMAX=0.0
444     DO 11W=1,IP
445        IF(PTS(IWI).GT.GMAX) GMAX=PTS(IWI)
446     1 CONTINUE
447        IF(GMAX.GT.0.5) ASCLE=1.
448        IF(GMAX.LE.0.5) ASCLE=0.5
449        IF(GMAX.LE.0.2) ASCLE=0.2
450        IF(GMAX.LE.0.1) ASCLE=0.1
451        IF(GMAX.LE.0.05) ASCLE=0.05
452        PTS=(PTS(IWI))/ASCLE*5.+0.5
453        CALL PLOT(-5.0,PTS,3)
454        DO 7 IW=1,IP
455          THETA=(PSTRT-(IW1*PDEL))
456          THETS=(THETA/(ABS(PSTRT)))*5.
457          APTS=((PTS(IWI))/ASCLE)*5.+0.5
458        CALL PLOT(THETS,APTS,2)
459     7 CONTINUE
460        IF(GMAX.GT.0.5) ATIC=0.2+0.0001
461        IF(GMAX.LE.0.5) ATIC=0.1+0.0001
462        IF(GMAX.LE.0.20) ATIC=0.04+0.0001
463        IF(GMAX.LE.0.1) ATIC=0.02+0.0001
464        IF(GMAX.LE.0.05) ATIC=0.01+0.0001
465        CALL AXIS(-5.5,-5.0,16H SOURCE MAGNITUDE,16,5.0,9C,0.0,ATIC)
466        CALL SYMBOL(-5.0,-0.8,0.2,125,10H PATTERN = ,0.,10)
467        FNUM=FLOAT(NUMPAT)
468        CALL NUMBER(-3.5,-0.8,0.125,FNUM,0.,-1)
469        CALL PLOT(-1.0,0,-3)
470     5 RETURN
471     ENC
SUBROUTINE PLOT1P(PSTRT,PEND,IP,CODE,CONST,NUMPAT)

SUBROUTINE PLOT1P

WRITTEN BY: S. R. KAUFMAN

DATE: 73-113 APRIL 24, 1973

INPUT:

PSTRT -- BEGINNING OF PLOT
PEND -- END OF PLOT
IP -- NUMBER OF POINTS TO BE PLOTTED (IP < 4062)
CODE -- LABELLING PARAMETER. IF CODE = 0: LABEL IS 'THETA = ';
        IF CODE = 1: LABEL IS 'S = ';
        IF CODE = 2: LABEL IS 'T = '.
CONST -- CONSTANT PARAMETER IN LABEL.
NUMPAT -- PATTERN NUMBER FOR LABEL.

INTEGER NAME(2), CODE
DIMENSION PTS(4001)
COMMON /PLTL/PTS
CALL FACTOR(0.5)
CALL PLCT(8.,1.,-3)
IF(CODE.GT.0) GO TO 3
CALL SYMBOL(-1.2,-6.,2,8HTHETA = ,0.,8)
CALL NUMBER(.3,-.8,.2,CONST,0.,3)
GO TO 6
3 IF(CODE.GT.1) GO TO 4
CALL SYMBOL(-1.,-8.,2,1HSO.,1)
CALL SYMBOL(-.9,-.8,2,3H = ,0.,3)
CALL NUMBER(-.2,-.8,2,CONST,0.,3)
CALL SYMBOL(-2.6,-.4,2,2H-T,.0,2)
CALL SYMBOL(-2.4,-.4,2,2H+T,.0,2)
GO TO 6
4 IF(CODE.GT.2) GO TO 5
CALL SYMBOL(-1.,-8.,2,1HT,0.,1)
CALL SYMBOL(-.9,-.8,2,3H = ,0.,3)
CALL NUMBER(-.2,-.8,2,CONST,0.,3)
CALL SYMBOL(-2.6,-.4,2,2H+5,.0,2)
CALL SYMBOL(-2.4,-.4,2,2H+S,0.,2)
GO TO 6
5 PDEL=(PSTRT-PEND)/IP
PTIC=ABS(PSTRT-PEND)/10.0
CALL AXIS(-5.0,0.0,0.1H ,1.4,0.0,0.0,PSTRT,PTIC)
PSTRE=PSTRT+(6.0*PTIC)+0.00001
PTIC2=PTIC+0.00001
CALL AXIS(1.0,1H ,1.4,0.0,PSTRE,PTIC2)
CALL PLCT(-1.,0.,3)
CALL PLCT(1.,0.,2)
CALL PLCT(C.,0.,3)
CALL PLCT(0.,5.8,2)
CALL PLCT(C.,0.,3)
SUBROUTINE PLOT2(N,M,CONLOW,CONMAX,CONINT,NUMPAT,DASH)

A = N BY M MATRIX OF DATA POINTS
CONLOW = LOWEST CONTOUR TO BE PLOTTED
CONMAX = HIGHEST CONTOUR TO BE PLOTTED
CONINT = INTERVAL BETWEEN CONTOURS
WORDS = TEXT OF PLOT LABEL
NCHAR = NUMBER OF CHARACTERS IN PLOT LABEL
CONTOURS BELOW -40. ARE PLOTTED AS DASHED LINES

DIMENSION A(151,151),RA(151),RB(151),X(151),Y(151)
COMMON /ARRAY/ A
CALL PLOT(8.,0.,-3)
CALL FACTOR(0.7)
MS=M
NS=N
RATIO=MS/NS
SCALE=10.
ANM=AMAX0(N-1,M-1)
IF(RATIO=1.0)1,3,4
1 SX=ANM
SY=RATIO*ANM
GO TO 3
2 SX=1.*RATIO*ANM
SY=ANM
3 SMAX=AMAX1(SX,SY)
SS=SX/SMAX
SYS=SY/SMAX
IF(CONINT=4.0)4,5
4 CALL CNLAL(N,M,CNTRLO,CMAX,CNTRL,0)
GO TO 7
551 CNTRAL=CNINT
552 IF(CNMX.EQ.CONLOW)GO TO 6
553 CMAX=CNMX
554 CNTRLO=CONLOW
555 GO TO 7
556 6 CALL CNLAL(N,M,CNTRLO,CMAX,CNTRAL,1)
557 7 CONTINUE
558 CONLOW=CNTRLO
559 CONMX=CMAX
560 CNINT=CNTRAL
561 CALL PLOTL(SS(SYS,0.,SYS,SCALE)
562 CALL PLOTL(0.,0.,SS,0.,SCALE)
563 CALL PLOTL(SS,0.,SYS,0.,SCALE)
564 CALL PLOTL(0.,SYS,0.,0.,SCALE)
565 CALL PLOT(1.00,0.25,3)
566 CALL PLOT(0.60,0.25,2)
567 CALL PLOT(0.60,0.25,2)
568 CALL PLOT(1.00,0.25,2)
569 CALL PLOT(1.00,0.25,2)
570 CALL SYMBOL (0.88,0.45,0.12,10HPATTERN = 90.,10)
571 FNUM=NUPAT
572 CALL NUMBER(0.88,2.075,0.12,FNUM,90.,-1)
573 YCCNA=1.0/SMAX
574 DELTAX=SX/FLOAT(N-1)
575 X(1)=0.0
576 Y(1)=0.0
577 RC(1) = A(1,1)
578 CC 27 J=2,N
579 RC(J) = A(J,1)
580 27 X(J) = X(J-1)+DELTAX
581 DELTAY=SY/FLOAT(M-1)
582 CC 28 J=2,M
583 28 Y(J) = Y(J-1)+DELTAY
584 CC 118 K=2,M
585 DC 30 J=1,N
586 RA(J) = RB(J)
587 30 RB(J) = A(J,K)
588 CC 118 J=2,N
589 35 ASSIGN 112 TO L
590 RR=RA(J)
591 XX=X(J)
592 YY=Y(K-1)
593 37 RL=RR
594 XL=XX
595 YL=YY
596 39 IF(RL-RA(J-1)) 41,40
597 40 IF(RL-RA(J)) 42,50
598 41 RL=RA(J-1)
599 XL=X(J-1)
600 YL=Y(K-1)
601 GO TO 40
602 42 RL=RB(J)
603 XL=X(J)
604 YL=Y(K)
605 GO TO 50
606 50 RS=RR
607 XS=XX
A-89

608  YS = YY
609  IF(RS-RA(J-1)) 52, 52, 53
610   52 IF(RS-RA(J)) 60, 60, 54
611  53 RS = RA(J-1)
612    XS = X(J-1)
613    YS = Y(K-1)
614    GO TO 52
615  54 RS = RB(J)
616    XS = X(J)
617    YS = Y(K)
618    GO TO 60
619  60 RM = HR
620    XM = XX
621    YM = YY
622    IF(RM-RS) 62, 62, 61
623  61 IF(RM-RL) 70, 62, 62
624  62 RM = RA(J-1)
625    XM = X(J-1)
626    YM = Y(K-1)
627    IF(RM-RS) 64, 64, 63
628  63 IF(RM-RL) 70, 64, 64
629  64 RM = RB(J)
630    XM = X(J)
631    YM = Y(K)
632  70 YCS = YS*YCONA
633    YCM = YM*YCONA
634    YCL = YL*YCONA
635  71 YS = YS-SY
636    YM = YM-SY
637    YL = YL-SY
638  72 XCS = XS/SMAX
639    XCM = XH/SMAX
640    XCL = XL/SMAX
641  RC = CNTRLO
642  80 IF(RC.GT.CMAX) GO TO 110
643    IF(RC.LE.RM) GO TO 91
644  81 IF(RM.LE.RS) GO TO 91
645    IF(RL.EQ.RM) GO TO 100
646  91 IF(RC-RS) 100, 95, 99
647  92 IF(RC-RM) 96, 93, 94
648  93 XPA = XCM
649    YPA = YCM
650    GO TO 99
651  94 IF(RC-RL) 106, 103, 110
652  95 Q = 0.0
653    GO TO 97
654  96 Q = (RC-RS)/(RM-RS)
655  97 XPA = XCS-Q*XCS-XCM
656    YPA = YCS-Q*YCS-YCM
657  99 Q = (RC-RS)/(RL-RS)
658    XPB = XCS-Q*XCS-XCL
659    YPB = YCS-Q*YCS-YCL
660  IF(RC-DASH) 10115, 10115, 10116
661  10115 XPH1 = 0.5*(XPA+XPB)
662    YPB1 = 0.5*(YPA+YPB)
663  IF(ABS(XPA-XPB1) = 001) 5001, 5002, 5002
664  5001 IF(ABS(YPA-YPB1) = 001) 100, 5002, 5002
5002 CALL PLOT(SCALE*XPA+2.,SCALE*YPA+0.25,3)
5003 CALL PLOT(SCALE*XPB+2.,SCALE*YPB+0.25,2)
GO TO 100
10116 IF(ABS(XPA-XPB)-.001)5003,5004,5004
5003 IF(ABS(YPA-YPB)-.001)100,5004,5004
5004 CALL PLOT(SCALE*XPA+2.,SCALE*YPA+0.25,3)
5004 CALL PLOT(SCALE*XPB+2.,SCALE*YPB+0.25,2)
100 RCl = RC + CNTRAL
GO TO 80
103 XPA = XCL
YPA = YCL
GO TO 99
106 C=(RC-RM)/(RL-RM)
XPA=XCM-C*(XCM-XCL)
YPA=YCM-C*(YCM-YCL)
GO TO 99
110 GC TO L,(112,118)
112 ASSIGN 118 TO L
118 CONTINUE
118 CALL PLOT(SCALE+6.,0.,-3)
RETURN
END

SUBROUTINE CNTRAL(N,M,CNTRAL,CMAX,CNTRLO,NC)
DIMENSION X(151,151)
COMMON /ARRAY/X
XMAX=X(1,1)
XMIN=X(1,1)
GO 10 J=1,M
10 XMAX=AMAX1(XMAX,X(I,J))
XMIN=AMIN1(XMIN,X(I,J))
IF(NC.EQ.1) GO TO 40
3C XCON=ABS(XMAX)
IF(ABS(XMIN).GT.ABS(XMAX))XCON=ABS(XMIN)
CMAX=XMAX
CNTRAL=CNTRAL*AINT(XMIN/CNTRAL)
RETURN
3C XCON=ABS(XMAX-XMIN)
CNTRAL=XCON/10.
CMAX=XMAX
CNTRLO=CNTRAL*AINT(XMIN/CNTRAL)
RETURN
4C CMAX=CNTRAL*AINT(XMAX/CNTRAL)
CNTRLO=CNTRAL*AINT(XMIN/CNTRAL)
RETURN
END
SUBROUTINE PLOTL(X1,Y1,X2,Y2,S)
    DIMENSION X(2),Y(2)
    X(1)= S *X1+2.
    X(2)= S *X2+2.
    Y(1)= S *Y1+0.25
    Y(2)= S *Y2+0.25
    CALL PLOTL(X(1),Y(1),3)
    CALL PLOTL(X(2),Y(2),2)
    RETURN
SUBROUTINE PLOT3

PURPOSE: TO DRAW A PERSPECTIVE VIEW OF A CONTOURED SURFACE.

DESCRIPTION OF PARAMETERS AND IMPORTANT VARIABLES:

N - NUMBER OF DATA POINTS ALONG FIRST AXIS.

M - NUMBER OF DATA POINTS ALONG THE SECOND AXIS.

NUMPAT - PATTERN NUMBER (FOR LABELLING).

K - CODE THAT TELLS WHETHER TO DRAW THE GRID LINES:
   K=1: ALONG THE N-DIMENSION ONLY.
   K=2: ALONG THE M-DIMENSION ONLY.
   K=3: ALONG BOTH DIMENSIONS.

DIST - DISTANCE FROM SURFACE TO EYE WHEN PERSPECTIVE IS
       CALCULATED -- SDIST > 6 USUALLY WON'T SHOW ANY
       DISTORTION DUE TO PARALLAX.

YAW - (IN DEGREES) HOW FAR THE OBJECT IS TURNED AWAY FROM
      THE VIEWER.

PITCH - (IN DEGREES) HOW THE SURFACE IS LOWERED OR RAISED AT
       THE FRONT EDGE. (POSITIVE PITCH TENDS TO EXPOSE THE
       TOP OF THE FIGURE).

SIZE - (IN INCHES) THE SIZE OF THE CUBE THAT ENCLOSES THE
       FIGURE.

KODE - "HIDDEN LINE" SWITCH. IF KODE=0 DO NOT DRAW HIDDEN
       LINES...IF KODE=1, ALL HIDDEN LINES ARE PLOTTED.

MGN - WHETHER TO DRAW THE OUTLINE OF THE CUBE TO HELP ORIENT
       THE VIEWER. MGN=0: DO NOT DRAW ANY OUTLINE OF THE
       CUBE. MGN=1: DRAW THE OUTLINE OF THE CUBE SEPARATE
       FROM THE FIGURE. MGN=2: DRAW THE OUTLINE OF THE
       CUBE SUPERIMPOSED ON THE SURFACE PLOT. MGN=3: DRAW
       ONLY THE THREE EDGES OF THE CUBE THAT MEET AT THE
       ORIGIN, SUPERIMPOSED ON THE SURFACE PLOT.

SCALE - HOW TALL TO MAKE THE SURFACE RELATIVE TO THE HEIGHT
       OF THE CUBE. SCALE=0: DO NOT SCALE THE DATA AT ALL
BUT TRUST THE USER THAT THE DATA IS NOT SO HIGH THAT
IT RUNS OFF THE PAPER. SCALE=1: SCALE THE DATA SO
THE TOP OF THE DATA JUST TOUCHES THE TOP OF THE CUBE.
SCALE=0.3: SCALE THE DATA SO THE TOP OF THE SURFACE IS
THREE TENTHS AS HIGH AS THE CUBE.

REMARKS.

I. IT IS VERY EXPENSIVE TO DRAW OPAQUE SURFACES, BECAUSE THE
PROGRAM HAS TO DETERMINE THE VISIBILITY OF EVERY POINT, THE
COMPUTER TIME DOUBLES OR TRIPLES...DEPENDING ON HOW MANY LINE
SEGMENTS ARE PARTIALLY VISIBLE.

II. THE CONTENTS OF ARRAY A ARE DESTROYED IN COMPUTATION.

COMMON BLOCKS REQUIRED:

COMMON /ARRAY/ A
COMMON /THREE6/ ANGTA, ANGB, HV, D, SH, SV
COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, OX, OY, OZ, SD

SUBROUTINE AND FUNCTION SUBPROGRAMS REQUIRED:
THREE2
THREE3
THREE4
THREE5
PLOT
FACTOR
SYMBOL
NUMBER

REFERENCE: HOWARD JESPERSOE, IOWA STATE UNIVERSITY.
MODIFIED FOR USE AT VPI BY: ROBERT C. KEPHART.
S. R. KAUFFMAN
W. L. STUTZMAN
E. L. COFFEY

SUBROUTINE PLOT3(NX, M, NUMPAT)

COMMON /ARRAY/ A
COMMON /THREE6/ ANGTA, ANGB, HV, D, SH, SV
COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, OX, OY, OZ, SD
DIMENSION H(10), V(10), X(2), Y(2), Z(2), XP(8), A(151, 151)

K = 2
SOISTS = 6.0
PITCH = 30.
YAW = 45.
SIZE = 10.
KOCF = 0
MGN = 0
SCALE = 1.
CALL FACTOR(1.1)
 CALL PLCT(8., 2., -3)
 CALL PLOT(4., 0., 2.)
 CALL PLOT(-4., 8., 2.)
 CALL PLCT(0., 8., 2.)
 CALL PLCT(0., 0., 2.)
 CALL PLOT(0., 0., 2.)
 CALL SYMBOL(0.3, 1.0, 0.12, 10)
 H = SIZE
 ANGA = (YAW + 270.) * 0.0174532
 ANGB = PITCH * 0.0174532
 H-V = SIZE
 C DIRECTION COMPONENTS TO THE EYE.
 SL = -COS(ANGA) * COS(ANGB)
 SM = -SIN(ANGA) * COS(ANGB)
 SN = -SIN(ANGB)
 IF (ABS(SN).NE.1.0) GO TO 10
 WRITE(6, 20)
 20 FORMAT('10 STRAIGHT DOWN (OR UP) AT THE SURFACE:')
 GO TO 2150
 10 CONTINUE
 SD = 1.0 / SQRT(1.0 - SN ** 2)
 X(1) = 1
 X(2) = N
 Y(1) = 1
 Y(2) = M
 T = MAXC(M, N)
 C FIND THE DIAGONAL OF THE CUBE.
 D = M ** 2 + N ** 2 + T ** 2
 D = SQRT(D)
 SCL = SOISTS * D
 C COORDINATES OF YOUR EYE.
 CX = -SL * SCL
 CY = -SM * SCL
 CZ = -SN * SCL
 C COORDINATES OF THE PROJECTION PLANE.
 QX = CX + D * SL
 QY = CY + D * SM
 QZ = CZ + D * SN
 C WRITE(6, 100) CX, CY, CZ
 WRITE(6, 100) QX, QY, QZ
 100 FORMAT(1X, 3F15.3)
 200 CALL GPLO(2.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0)
 2060 Z(2) = A(L, 1)
Z(1) = A(1, 1)
CC 1000 J = 1, N
CC 1000 K = 1, M
Z(1) = AMIN1(Z(1), A(J, K))
Z(2) = AMAX1(Z(2), A(J, K))
1000 CONTINUE
RANGE = (Z(2) - Z(1))
DCL = 1.0
IF (SCALE .NE. 0) DCL = T/RANGE * SCALE
C SCALE THE SURFACE TO MAKE A "CUBE".
DO 30 I = 1, N
DO 30 J = 1, M
A(I, J) = (A(I, J) - Z(1)) * DCL
30 CONTINUE
Z(1) = C.C
Z(2) = T
2000 CALL THREE2 (X, Y, Z, XP, H, V, KODE)
DO 2130 I = 1, 8
H(I) = ((XP(I) - OX) * SM - (H(I) - OY) * SL) * SD
V(I) = (V(I) - OZ) * SD
2130 CONTINUE
H(10) = H(1)
H(9) = H(1)
DO 1001 J = 1, 8
H(J) = AMIN1(H(9), H(J))
H(10) = AMAX1(H(10), H(J))
1001 CONTINUE
V(9) = V(1)
V(10) = V(1)
DO 1202 J = 1, 8
V(J) = AMIN1(V(9), V(J))
V(10) = AMAX1(V(10), V(J))
1202 CONTINUE
IF (MGN .EQ. 0) GO TO 2140
S = HV
IF (MGN .EQ. 1) S = 1.5
SH = S / (H(10) - H(9))
SV = S / (V(10) - V(9))
SH = SIGN(A MIN1(SH, SV), SH)
SV = SIGN(SH, SV)
IF (MGN .EQ. 1) CALL PLOT (0, 0, 0, -3)
CALL SYMBOL(H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 14, "0", 0.1
CALL SYMBOL(H(3) - H(9)) * SH, (V(3) - V(9)) * SV, 14, "M", 0.1
CALL SYMBOL(H(2) - H(9)) * SH, (V(2) - V(9)) * SV, 14, "Z", 0.1
CALL SYMBOL(H(5) - H(9)) * SH, (V(5) - V(9)) * SV, 14, "N", 0.1
CALL PLOT (0.3, 0.3, -3)
CALL PLOT (H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 3
CALL PLOT (H(2) - H(9)) * SH, (V(2) - V(9)) * SV, 2
CALL PLOT (H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 2
CALL PLOT (H(3) - H(9)) * SH, (V(3) - V(9)) * SV, 2
CALL PLOT (H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 2
CALL PLOT (H(5) - H(9)) * SH, (V(5) - V(9)) * SV, 2
IF (MGN .EQ. 3) GO TO 2139
CALL PLOT (H(6) - H(9)) * SH, (V(6) - V(9)) * SV, 2
CALL PLOT (H(2) - H(9)) * SH, (V(2) - V(9)) * SV, 2
CALL PLOT (H(4) - H(9)) * SH, (V(4) - V(9)) * SV, 2
CALL PLOT (H(7) - H(9)) * SH, (V(3) - V(9)) * SV, 2
IF (MGN .EQ. 0) GO TO 2140
S = HV
IF (MGN .EQ. 1) S = 1.5
SH = S / (H(10) - H(9))
SV = S / (V(10) - V(9))
SH = SIGN(A MIN1(SH, SV), SH)
SV = SIGN(SH, SV)
IF (MGN .EQ. 1) CALL PLOT (0, 0, 0, -3)
CALL SYMBOL(H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 14, "0", 0.1
CALL SYMBOL(H(3) - H(9)) * SH, (V(3) - V(9)) * SV, 14, "M", 0.1
CALL SYMBOL(H(2) - H(9)) * SH, (V(2) - V(9)) * SV, 14, "Z", 0.1
CALL SYMBOL(H(5) - H(9)) * SH, (V(5) - V(9)) * SV, 14, "N", 0.1
CALL PLOT (0.3, 0.3, -3)
CALL PLOT (H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 3
CALL PLOT (H(2) - H(9)) * SH, (V(2) - V(9)) * SV, 2
CALL PLOT (H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 2
CALL PLOT (H(3) - H(9)) * SH, (V(3) - V(9)) * SV, 2
CALL PLOT (H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 2
CALL PLOT (H(5) - H(9)) * SH, (V(5) - V(9)) * SV, 2
CALL PLOT (H(6) - H(9)) * SH, (V(6) - V(9)) * SV, 2
CALL PLOT (H(2) - H(9)) * SH, (V(2) - V(9)) * SV, 2
CALL PLOT (H(4) - H(9)) * SH, (V(4) - V(9)) * SV, 2
CALL PLOT (H(7) - H(9)) * SH, (V(3) - V(9)) * SV, 2
CALL PLOT (0, 0, 0, -3)
CALL SYMBOL(H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 14, "0", 0.1
CALL SYMBOL(H(3) - H(9)) * SH, (V(3) - V(9)) * SV, 14, "M", 0.1
CALL SYMBOL(H(2) - H(9)) * SH, (V(2) - V(9)) * SV, 14, "Z", 0.1
CALL SYMBOL(H(5) - H(9)) * SH, (V(5) - V(9)) * SV, 14, "N", 0.1
CALL PLOT (0.3, 0.3, -3)
A-95

837 CALL PLOT ( (H(7)-H(9))*SH, (V(7)-V(9))*SV,2)
838 CALL PLOT ( (H(5)-H(9))*SH, (V(5)-V(9))*SV,2)
839 CALL PLOT ( (H(6)-H(9))*SH, (V(6)-V(9))*SV,2)
840 CALL PLOT ( (H(8)-H(9))*SH, (V(8)-V(9))*SV,2)
841 CALL PLOT ( (H(4)-H(9))*SH, (V(4)-V(9))*SV,2)
842 CALL PLOT ( (H(8)-H(9))*SH, (V(8)-V(9))*SV,2)
843 CALL PLOT ( (H(7)-H(9))*SH, (V(7)-V(9))*SV,2)
844 2139 IF(MGN .NE. 1) GO TO 2140
845 CALL PLOT (2INT((H(10)-H(9))*SH+2.),-2.05,-3)
846 2140 CALL THREE3(X, Y, Z, XP, H, V, KODE)
847 215C CONTINUE
848 CALL PLOT(16.,-1.5,-3)
849 RETURN
850 END

851 SUBROUTINE THREE2 ( X, Y, Z, XP, H, V, KODE)
  C FIND THE CORNERS OF THE ROTATED CUBE.
  C
852 DIMENSION X(2), Y(2), Z(2), H(10), V(10), XP(6)
853 05C L = 0
854 07C DO 180 I = 1, 2
855 090 CG 170 J = 1, 2
856 11C DO 160 K = 1, 2
857 130 L = L + 1
858 14C CALL THREE4 ( X(I), Y(J), Z(K), XP( L ),
  H(L), V( L ), KODE )
859 160 CONTINUE
860 170 CONTINUE
861 180 CONTINUE
862 190 RETURN
863 END

864 SUBROUTINE THREE4 ( X, Y, Z, XP, YP, ZP, KODE)
  C FIND THE LOCATION OF A POINT IN THE ROTATED CUBE.
865 COMMON /THREE6/ ANGA, ANGB, HV, D, SH, SV
866 COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, QX, QY, QZ, SD
867 SK = D / ( ( X - CX ) * SL + ( Y - CY ) * SM + ( Z - CZ ) * SN)
868 XP = CX + SK * ( X - CX )
869 YP = CY + SK * ( Y - CY )
870 ZP = CZ + SK * ( Z - CZ )
871 RETURN
872 END

873 SUBROUTINE THREE3 ( X, Y, N, M, H, V, KODE)
  C DRAW THE FIGURE.
874 COMMON /THREE6/ ANGA, ANGB, HV, D, SH, SV
875 COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, QX, QY, QZ, SD
876 DIMENSION X(2), Y(2), H(10), V(10), A(151,151)
COMMON /ARRAY/ A
INTEGER UP, DOWN, PEN, P, C
INTEGER P1, PO

ENC = 1.0 / 16.0
CAN USE 1 / 32 OR 1 / 64 FOR FINER INTERPOLATION

UP = 3
DOWN = 2
SH = HV / ( H ( 10 ) - H ( 9 ) )
SV = HV / ( V ( 10 ) - V ( 9 ) )
SH = SIGN(AMIN1(SH, SV), SH)
SV = SIGN(SH, SV)
P = M
NN = N

IF(K-1) 100, 120, 100
IF(K-3) 1110, 120, 1110

DRAW LINES ALONG THE Y-AXIS
12C CONTINUE
L = 0
LD = 1
EC = 0.5 * LD

14C DO 1060 J = 1, M
Q = 0
YJ = J
16C DO 1030 I = 1, NN

L = L + LD
XI = L
CALL THREE5 ( XI, YJ, N, M, P, KODE)
PEN = UP
51C CONTINUE
IF ( P ) 510, 520, 530
51C CONTINUE
52C CONTINUE
IF ( Q ) 540, 550, 540
52C CONTINUE
IF ( Q ) 610, 1020, 610
53C CONTINUE
54C CONTINUE
PEN = DOWN
GOTO 170
55C CONTINUE
IF ( I <EQ. 1 ) GOTO 170
DI = CD
TC = L - LC
T = TC * DI
P1 = Q
560 IF ( ABS( DI ) .LT. END ) GOTO 570
CALL THREE5 ( T, YJ, N, M, P, KODE)
561 IF ( P0 .EQ. C ) GOTO 565
A-97

921  \( TC = T \)
922  \( PI = PO \)
923  \( T = T - DI \)
924  GO TO 560
925  565  \( T = T + DI \)
926  GO TO 56C
927  57C  CONTINUE
928  \( T = TO \)
929  IF ( \( PI * P \) ) 170, 170, 580
930  58C  CONTINUE
931  59C  CONTINUE
932  \( ZP = A(L-LC,J) + (T-L+LD)*(A(L,J) - A(L-LD,J))/LD \)
933  CALL THREE4(T,YJ,ZP,XP,HH,VV,KODE)
934  \( FH = ((XP-QX)*SM - (HH - QY)*SL)*SD \)
935  \( VV = (VV - QZ)*SD \)
936  \( HH = (HH - H(9)) * SH \)
937  \( VV = (VV - V(9)) * SV \)
938  CALL PLOT ( HH, VV, PEN )
939  60C  PEN = 5 - PEN
940  GO TO 170
941  61C  CONTINUE
942  PEN = DOWN
943  DI = DC
944  TO = L - LD
945  \( T = TO + DI \)
946  \( PI = Q \)
947  620  IF ( ABS(DI) .LT. END ) GO TO 630
948  CALL THREE5(T,YJ,PI,M,PO,KODE)
949  DI = DI * 0.5
950  IF ( \( PO .EQ. 0 \) ) GO TO 625
951  \( TO = T \)
952  \( PI = PO \)
953  \( T = T + DI \)
954  GO TO 620
955  625  \( T = T - DI \)
956  GO TO 62C
957  63C  CONTINUE
958  \( T = TC \)
959  IF ( \( PI * Q \) ) 600, 600, 590
960  17C  CALL THREE4(XI, YJ, A(L, J), XP, HH, VV, K6(L)
961  \( VV = (VV - QZ)*SD \)
962  \( HH = ((XP-QX)*SM - (HH - QY)*SL)*SD \)
963  19C  \( HH = (HH - H(9)) * SH \)
964  20C  \( VV = (VV - V(9)) * SV \)
965  CALL PLOT ( HH, VV, PEN )
966  102C  \( Q = P \)
967  1030  CONTINUE
968  \( L = L + LC \)
969  \( LC = -LD \)
970  \( DD = -DD \)
971  1060  CONTINUE
972  \( C \)
973  \( C \)
974  \( C \)
975  \( C \)
976  \( C \)
977  \( C \)
978  \( C \)
979  \( C \)
980  \( C \)
981  \( C \)
982  \( C \)
983  \( C \)
984  \( C \)
985  \( C \)
986  \( C \)
987  \( C \)
988  \( C \)
989  \( C \)
990  \( C \)
991  \( C \)
992  \( C \)
993  \( C \)
994  \( C \)
C DRAW LINES ALONG THE X-AXIS.

1110 CONTINUE

L = 0
LC = 1
CC = 0.5 * LD
XI = 1
YY = L
CALL THREE5 (XI, YJ, N, M, P, KODE)
PEN = UP
1510 CONTINUE
IF (P) 1510, 1520, 1530
1520 CONTINUE
IF (Q) 1540, 1550, 1540
1530 CONTINUE
IF (Q) 1540, 1550, 1540
1540 CONTINUE
PEN = DOWN
GO TO 1170
1550 CONTINUE
IF (J .EQ. 1) GO TO 1170
DI = DD
TC = L-LD
T = TO + DI
P1 = Q
1560 IF (ABS(DI) .LT. END) GO TO 1570
1565 CALL THREE5 (XI, T, N, M, PO, KODE)
1570 DI = DI * 0.5
1580 IF (PO .EQ. 0) GO TO 1565
1590 TO = T
1600 T = T - DI
1610 GO TO 1560
1620 T = T + DI
1630 GO TO 1560
1640 1650 CONTINUE
1660 T = TO
1670 IF (P1 * P) 1170, 1170, 1580
1680 CONTINUE
1690 1690 CONTINUE
1700 ZP = A(I, L-LD) + (T-L+LD) * (A(I, L) - A(I, L-LD))/LD
1710 CALL THREE4 (XI, T, ZP, XP, HH, VV, KODE)
1720 HH = (XP-QX)*SM - (HH - QY)*SL) * SI
1730 VV = (VV - CQ) * SD
1740 HH = (HH - H(9)) * SH
1750 VV = (VV - V(9)) * SV
1760 CALL PLOT (HH, VV, PEN)
1770 1600 PEN = 5 - PEN
1780 GO TO 1170
1790 1610 CONTINUE
1800 PEN = DOWN
A-99

1026   CO = DD
1027   TO = L - LC
1028   T = TO + CI
1029   PI = CO
1030   IF (ABS(DI) .LT. END) GO TO 1630
1031       CALL THREE5 (XI,T,N,M,PO,KODE)
1032       DI = DI * 0.5
1033       IF (PC .EQ. 0) GO TO 1625
1034       TO = T
1035       PI = PC
1036       T = T + DI
1037       GO TO 1620
1038       T = T - DI
1039       GO TO 1620
1040   CONTINUE
1041   CONTINUE
1042   IF (PI * C) 1600  1600  1590
1043       CALL THREE4 (XI, YJ, AI, L), XP, HH, VV, K0)
1044       HH = ((XP-QX)*SM - (HH - QY)*SL) * SD
1045       VV = (VV - GZ) * SD
1046       HH = (HH - HH) * SH
1047       VV = (VV - VV) * SV
1048       CALL PLOT (HH, VV, PEN)
1049       C = P
1050       CONTINUE
1051   CONTINUE
1052   L = L + LC
1053   LC = - LC
1054   DD = - DD
1055   CONTINUE
1056   RETURN
1057   END

1058   SUBROUTINE THREE5 (XI,YJ,M,N,P,KODE)
1059       DIMENSION Z(151,151)
1060       COMMON /THREE6/ ANGA, ANGB, HV, D, SH, SV
1061       COMMON /THREE7/SL,SM,SN,CX,CY, CZ, QX, QY, QZ, SD
1062       COMMON /ARRAY/ Z
1063       INTEGER CUM, CNT, P
1064       REAL I, J, II, JJ
1065       IF (KODE .EQ. 1) GO TO 78
1066       IR = XI
1067       JC = YJ
1068       ZB = Z (IR, JC)
1069       IF (XI .EQ. IR) GO TO 2
1070       ZB = Z(IR, JC) + (XI - IR) * (Z(IR + 1, JC) - Z(IR, JC))
1071       GO TO 4
1072       IF (YJ .EQ. JC) GO TO 4
1073       ZB = Z(IR, JC) + (YJ-JC)*(Z(IR,JC+1) - Z(IR,JC))
1074       CONTINUE
1075       XEND = CO
1076       CX = 0.0

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR
YMULT = C.C

ZMULT = C.G

IF ( XI .EQ. CX ) GO TO 10
YMULT = ( YJ - CY ) / ( XI - CX )
ZMULT = ( ZB - CZ ) / ( XI - CX )

CX = 1.0
XEND = M + 1

IF ( XI .LT. CX ) GO TO 10
CX = -1.0
XEND = 0.0

10 CONTINUE

YMULT = C.C

DY = 0.0
XMULT = 0.0

IF ( YJ .EQ. CY ) GO TO 20
XMULT = ( XI - CX ) / ( YJ - CY )

IF ( ZMULT .EQ. 0.0 ) ZMULT = ( ZB - CZ ) / ( YJ - CY )
DY = 1.0

YEND = N + 1

IF ( YJ .LT. CY ) GO TO 20

CONTINUE

DY = 0.0
YEND = C.C

20 CONTINUE

CUP = 0
CNY = 0
P = 0

XB = XI
YB = YJ

30 CONTINUE

II = AINT( XB )
JJ = AINT( YB )

XSTEP = DX
YSTEP = DY

IF ( XB .EQ. II ) GO TO 40
IF ( CX .LT. 0.0 ) XSTEP = 0.0

GO TO 45

40 IF ( YB .EQ. JJ ) GO TO 45
IF ( DY .LT. 0.0 ) YSTEP = 0.0

45 CONTINUE

I = II + XSTEP
J = JJ + YSTEP

IF ( I .EQ. XEND ) GO TO 80
IF ( J .EQ. YEND ) GO TO 80

XB = CX + XMULT * ( J - CY )
YB = CY + YMULT * ( I - CX )

IF ( CX .LT. 0.0 ) GO TO 55
IF ( XB .LT. I ) GO TO 60

50 XB = I
GO TO 65

55 IF ( XB .LT. I ) GO TO 50

60 YB = J

65 CONTINUE

ZB = CZ + ZMULT * ( XB - CX )

IR = I
JC = J

IF ( YB .NE. J ) GO TO 70

ICX = I - DX
ZS = Z( IR, JC ) - DX * ( XB - 1 ) * (Z(IDX,JC) - 7(IR,JC))

ZS = Z( IR, JC ) - DY * ( YB-J ) * (Z( IR, JDY ) - Z( IR, JC ) )

CONTINUE

SGN = 1

IF ( ZB .LT. ZS ) SGN = -1

CUM = CUM + SGN

CNT = CNT + 1

IF ( IABS ( CUM ) .EQ. CNT ) GO TO 30

GO TO 90

CONTINUE

IF ( ZB .LE. CZ ) GO TO 90

P = -1

GO TO 90C

CONTINUE

GO TO 95

RETURN

FUNCTION PAT(U,V,ITYPE)

THIS SUBPROGRAM GIVES THE BASIC CORRECTION PATTERN F(U,V).

ITYPE = 1 -- UNIFORM LINE SOURCE LOCATED AT S=0.

ITYPE = 2 -- UNIFORM LINEAR ARRAY LOCATED AT S=0.

ITYPE = 3 -- TRIANGULAR LINE SOURCE LOCATED AT S=0.

ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE.

ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY.

ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.

ITYPE = 7 -- GENERAL ARRAY.

ITYPE > 7 -- SPECIAL SOURCE (FUNCTION SPECPT(U,V,ITYPE) WILL BE CALLED.

VERSION 1  LEVEL 1


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COMPLEX TEMP, CEXP, IMAG

COMMON /PAT1/ P1, P2, P3, P4, P5, P6, PI, SS(100), IT(100), RR(100)

COMMON /PAT2/ 11, 12, 13, 14, 15
IF(ITYPE.GT.7) GO TO 990
GO TO (ICC,2CC,300,400,500,600,700),ITYPE
C
ITYPE .LT. 1

WRITE(6,10) ITYPE
10 FORMAT(1HC,5X,***ERROR***, ITYPE HAS THE VALUE ',111',';':,2X, $*EXECUTION TERMINATED*')
STOP
C
ITYPE = 1 -- UNIFORM LINE SOURCE.
C
100 CONTINUE
C
FLEN=P1
1167 PAT=1.0
1168 IF(V.NE.C.) PAT=SIN(P1*P1*V)/(P1*P1*V)

ITYPE = 2 -- UNIFORM LINEAR ARRAY.
C
200 CONTINUE
C
FLEN=P1
NELMT=11
PAT=1.0
1172 IF(V.NE.C.) PAT=SIN(P1*P1*V)/(11*SIN(P1*P1*V/11))

ITYPE = 3 -- TRIANGULAR LINE SOURCE.
C
300 FLN=PI/2.
1175 PAT=1.0
1176 IF(V.NE.C.) PAT=(SIN(FLN*PI*V)/(FLN*PI*V))**2

ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE.
C
400 CONTINUE
C FLS=P1
C FLT=P2
1180 ARG1=PI*P1*U
1181 ARG2=PI*P2*V
1182 IF(ARG1) 4C1,4C2,401
1183 IF(ARG2) 4C3,404,403
1184 IF(ARG1) 4C1,401
1185 IF(ARG2) 4C3,404,403
1186 PAT=SIN(ARG1)/ARG1*SIN(ARG2)/ARG2
1187 GO TO 999
1188 PAT=SIN(ARG1)/ARG1
1189 CC TO 999
1190 IF(ARG2) 4C5,406,405
1191 IF(ARG2) 4C5,406,405
1192 PAT=1.0
1193 GO TO 999
C
C  ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY
C
1193  500 CONTINUE
C  FLs=P1
C  FLT=P2
C  NELS=I1
C  NELT=I2
1194  ARG1=PI*PI*U
1195  ARG2=PI*PI*V
1196  IF(ARG1) 501,502,501
1197  501 IF(ARG2) 503,504,503
1198  503 PAT=SIN(ARG1)/(II*SIN(ARG1/II))*SIN(ARG2)/(12*SIN(ARG2/12))
1199  GO TO 999
1200  504 PAT=SIN(ARG1)/(II*SIN(ARG1/II))
1201  GO TO 999
1202  502 IF(ARG2) 505,506,505
1203  505 PAT=SIN(ARG2)/(II*SIN(ARG2/12))
1204  GO TO 999
1205  506 PAT=1.0
1206  GO TO 999
C
C  ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.
C
1207  600 C=SQR(T(U*U+V*V)
C  A=PI
1208  IF(C.EQ.0.) GO TO 601
1209  X=2.*PI*PI*C
1210  CALL BESJ(X,1,BJ,0.0001,IER)
1211  PAT=BJ/X*2.0
1212  GO TO 999
1213  601 PAT=1.0
1214  GO TO 999.
C
C  ITYPE = 7 -- GENERAL ARRAY
C
1215  700 IMAG=(0.0,1.0)
1216  NELMT=I1*12
1217  TEMP=(0.0,0.0)
1218  CC 701 J=1,NELMT
1219  701 TEMP=TEMP+1O*(CSEXP(IMAG*2.*PI*(U*SS(J)+V*TT(J))))
1220  CONTINUE
1221  PAT=REAL(TEMP)/NELMT
1222  GO TO 999
1223  999 PAT=SPECPT(U,V,ITYPE)
1224  RETURN
1225  ENC

1226  COMPLEX FUNCTION SOURCE(M,N,U,V,ITYPE)
C  THIS SUBPROGRAM CALCULATES THE CURRENT AT POINT (M,N) DUE TO
C  THE PATTERN AT POINT (U,V).
ITYPE = 1 -- UNIFORM LINE SOURCE LOCATED AT S=0.
2 -- UNIFORM LINEAR ARRAY LOCATED AT S=0.
3 -- TRIANGULAR LINE SOURCE LOCATED AT S=0.
4 -- UNIFORM RECTANGULAR APERTURE.
5 -- UNIFORM RECTANGULAR ARRAY.
6 -- UNIFORM CIRCULAR APERTURE.
7 -- GENERAL (3-D) ARRAY.

ITYPE > 7 -- SPECIAL SOURCE (FUNCTION SPSOR(M,N,U,W,ITYPE) WILL BE CALLED.)

VERSION 1 LEVEL C

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COMPLEX TEMP, CEXP, IMAG, SPSOR
COMMON /PAT1/ P1, P2, P3, P4, P5, P6, PI, SS(100), TT(100), RR(100)
COMMON /PAT2/ I1, I2, I3, I4, I5

IMAG=(0.C, 1.10)
CALL LOCSSOR(M, N, S, T)
IF (ITYPE.GT.7) GO TO 990
GO TO (100, 200, 300, 400, 500, 600, 700), ITYPE

WRITE (6, 10) ITYPE
FORMAT (1HC5X, 58**, ERROR**, ITYPE HAS THE VALUE ', '111', ': ', '11X, '
$EXECUTION TERMINATED$)
STOP

ITYPE = ITYPE

ITYPE = 1 -- UNIFORM LINE SOURCE

CONTINUE
FLEN=P1
SOURCE=CEXP(-J*IMAG*PI*2.*T*V)/P1
GO TO 999

ITYPE = 2 -- UNIFORM LINEAR ARRAY

CONTINUE
FLEN=P1
SOURCE=CEXP(-J*IMAG*2.*PI*V*T)/P1
GO TO 999

ITYPE = 3 -- TRIANGULAR LINE SOURCE
A-105

1243  3CC CONTINUE
   C FLEN=P1
1244       CON=ABS(2.*T/P1)
1245       SOURCE=2./P1*CEXP(-IMAG*2.*PI*T*V)*(1.-CON)
1246       IF(CON.GT.1) SOURCE=(0.0,0.0)
1247       GO TO 999
   C ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE
1248       400 CONTINUE
   C FLS=P1
   C FLT=P2
1249       SOURCE=CEXP(-IMAG*2.*PI*(S*U+V*T))/(P1*P2)
1250       GO TO 999
   C ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY
1251       500 CONTINUE
   C FLS=P1
   C FLT=P2
1252       SOURCE=CEXP(-IMAG*2.*PI*(S*U+V*T))/(P1*P2)
1253       GO TO 999
   C ITYPE = 6 -- UNIFORM CIRCULAR APERTURE
1254       600 RHC=SQR(T(S*T))
   C A=P1
1255       SOURCE=(0.0,0.0)
1256       IF(RHC.LE.P1) SOURCE=CEXP(-IMAG*2.*PI*(S*U+V*T))/(P1*P2)
1257       GO TO 999
   C ITYPE = 7 -- GENERAL ARRAY
1258       700 CONTINUE
1259       SOURCE=CEXP(-IMAG*2.*PI*(U*S+V*T))/(U*P2)
1260       GO TO 999
1261       990 SOURCE=SPSOR(M,N,U,V,ITYPE)
1262       999 RETURN
1263      END

1264  SUBROUTINE LOCSOR(M,N,S,T)  
1265      INTEGER PX,PY
1266      REAL INITLS,INITLT
1267      COMMON /PAT1/ P1,P2,P3,P4,P5,P6,P5,P6,P5,P6,SS(100),TT(100),RR(100)
1268      COMMON /PAT2/ 11,12,13,14,15
1269      COMMON /LOC/ ITYPE
   C ITYPE = 4 GO TO 999
1270      GO TO (100,200,300,400,500,600,700), ITYPE
A-106

1272 WRITE(6,10) ITYPE
1273 10 FORMAT(1HC5X,***ERROR***
*EXECUTION TERMINATED*)
1274 STCP

C

1275 20C CONTINUE
1276     INIITLT=P1
1277     CELTAT=P3
1278     S=G.
1279     T=P2+(N-1)*P3
1280     GO TO 999

C

1281 300 GC TO 100

C

1282 400 CONTINUE
1283     INITLS=P3
1284     INITLT=P4
1285     CELTAS=P5
1286     DELTAT=P6
1287     S=P3+(M-1)*P5
1288     T=P4+(N-1)*P6
1289     GO TO 999

C

1290 50C CONTINUE
1291     PX=11
1292     PY=12
1293     DISX=P3
1294     DISY=P4
1295     S=(N-11/2-1)*P3
1296     T=(N-12/2-1)*P4
1297     IF(11/2*2.EQ.11) S=S+0.5*P3
1298     IF(12/2*2.EQ.12) T=T+0.5*P4
1299     GO TO 999

C

1300 60C GO TO 400

C

1301 70C CONTINUE
1302     NELPT=(M-1)*I2+N
1303     S=SS(NELST)
1304     T=TT(NELPT)
1305     GO TO 999

C
C 990 CALL SPLOC(M,N,S,T)
1302 999 RETURN
1303 END

C COMPLEX FUNCTION SPSOR(M,N,U,V,ITYPE)
1304 C DUMMY SUBPROGRAM
1305 C SPSOR=(O.O,O.O)
1306 RETURN
1307 END

C FUNCTION SPECPT(U,V,ITYPE)
1308 C DUMMY SUBPROGRAM
1309 C SPECPT=C
1310 RETURN
1311 END

C SUBROUTINE SPLOC(M,N,S,T)
1312 C DUMMY SUBROUTINE
1313 RETURN
1314 END
8. Appendix: Example of Input/Output Used With Computer

Antenna Synthesis

In this chapter one example will be used to illustrate the input and output of ANTSYN and ANTDATA. The pattern to be synthesized is a rectangular shaped beam of extent

\[ (u,v) \leq \begin{array}{c}
-0.2 < u < 0.2 \\
-0.05 < v < 0.05
\end{array} \]

and a maximum sidelobe level of -25 dB. The source is a rectangular aperture (ITYPE=4) 10\( \lambda \) by 20\( \lambda \).

8.1 Input to ANTSYN

Since a rectangular aperture is included in our types of patterns (ITYPE=4) it is only necessary to include "dummy" subprograms for SINPUT, SPECPT, SPSOR, and SPLOC:

```fortran
SUBROUTINE SINPUT
RETURN
END

SUBROUTINE SPLOC
RETURN
END

FUNCTION SPECPT(U,V,ITYPE)
SPECPT=0.
RETURN
END

COMPLEX FUNCTION SPSOR(M,N,S,T,ITYPE)
SPSOR=(0.,0.)
RETURN
END
```

For this particular desired pattern, subroutine DESPAT is written as follows:
SUBROUTINE DESPAT(FDES, FU, FL, MMAX, NMAX, STARTU, STARTV, DELTAU, DELTAV)
  DIMENSION FDES(51,51), FU(51,51), FL(51,51)

C READ MAINBEAM LIMITS ULIM AND VLIM
C
READ(5,1) ULIM, VLIM
1 FORMAT(8F10.0)
C
C READ TRANSITION REGION LIMITS UTRAN AND VTRAN
C
READ(5,1) UTRAN, VTRAN
C
DO 10 M=1, MMAX
  U=STARTU+(M-1)*DELTAU
  DO 10 N=1, NMAX
    V=STARTV+(N-1)*DELTAV
    IF(U.LE.ULIM .AND. V.LE.VLIM) GO TO 20
    IF(U.GT.UTRAN .OR. V.GT.VTRAN) GO TO 30
C TRANSITION REGION
    FDES(M,N)=99.0
    FU(M,N)=99.0
    FL(M,N)=99.0
    GO TO 10
20 CONTINUE
C MAIN BEAM REGION
    FDES(M,N)=1.0
    FU(M,N)=1.06
    FL(M,N)=0.943
    GO TO 10
30 CONTINUE
C SIDELOBE REGION
    FDES(M,N)=0.
    FU(M,N)=0.057
    FL(M,N)=99.0
10 CONTINUE
C
RETURN
END

The value "99.0" in an array signals that a comparison is not to be made at that point (e.g., in the sidelobe region, FL( , ) = 99.0 since a lower bound is not specified).
The data cards for this example are:

<table>
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<tr>
<td>1</td>
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<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>1 &amp;PARAM</td>
</tr>
<tr>
<td>IDISK=1,ISYMM=3,DELTAU=0.02,DELTAV=0.01,MAX=26,NMAX=51,</td>
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<tr>
<td>&amp;END</td>
</tr>
<tr>
<td>4 &amp;PRINT</td>
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<tr>
<td>FDESCN=1,FDBPR=1,FDBCN=1,FCURPR=1,</td>
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<tr>
<td>&amp;END</td>
</tr>
<tr>
<td>7 &amp;PATIN</td>
</tr>
<tr>
<td>ITYPE=4,LX=10.,LY=20.,</td>
</tr>
<tr>
<td>INITS=-5.0,DELTA=0.2,FINALS=5.0,</td>
</tr>
<tr>
<td>INILT=-10.0,DELTAT=0.4,FINALT=10.0,</td>
</tr>
<tr>
<td>&amp;END</td>
</tr>
<tr>
<td>12 0.2 0.05</td>
</tr>
<tr>
<td>13 0.34 0.12</td>
</tr>
<tr>
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</tr>
<tr>
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<tr>
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</tr>
<tr>
<td>17 0.1 0.0 1.0</td>
</tr>
<tr>
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</tr>
<tr>
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<tr>
<td>29 -0.2 0.0 1.0</td>
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Notice that it is not necessary to code all the namelist variables. For example, STARTU is not coded because its default value is 0. (which is what we want). In order to better understand why certain parameters were coded, refer to section 6.3 to steps 2 through 10 as they are discussed below.

Step 2. Cards 1 to 3: Pattern Parameters
i. Put output data onto unit 22 if the synthesis is successful (IDISK=1)
ii. Use quadrilateral symmetry (ISYMM=3)
iii. Have a maximum of 100 iterations (ITRMAX=100)
iv. STARTU=STARTV=0., DELTAU=0.02,DELTAV=0.01
v. Make the comparisons at 26 points in the u direction and 51 points in the v direction (MMAX=26, NMAX=51)
vi. Assure that F(1,1)=0 dB. at all times (MCENT=1, NCENT=1)

Note that F(MMAX, NMAX) corresponds to (u,v)=(0.5,0.5); only part of the (u,v) plane is considered.

Step 3. Cards 4 to 6: Output Switches
i. Profiles of the final pattern and final current (FDBPR=FCURPR=1)
ii. Contour maps of the desired pattern (FDESCN=1) and final current (FCURCN=1) are to be made

Step 4. Cards 7 to 11: Source Specifications
i. Rectangular aperture (ITYPE=4)
ii. Dimensions of 10λ by 20λ (LX=10., LY=20.)
iii. The value of current will be calculated at 51 x 51 points from s = -5.0 to 5.0 by 0.2, and t = -10.0 to 10.0 by 0.4.
(INITLS=-5., FINALS=5., DELTAS=0.2; INITLT=-10., FINALT=10., DELTAT=0.4)

Step 5. Cards 12 to 13: The Desired Pattern
For a more complete explanation, see the listing of subroutine DESPAT earlier in this section.

Step 6. Cards 14, 15 to 29: Initial Pattern
These are the number of (NORG) and the values of (UORG, VORG, CORG) the original correction coefficients.

Steps 7, 8, 9. See subroutines INPUT, SPLOC, SPECPT, SPSOR.

8.2 Output from ANTSYN

This section is devoted to the actual output from the computer program ANTSYN with data as specified in Section 8.1. Due to page size limitations, some of the output has been edited. The omissions are indicated by an ellipsis(...).
ANTENNA SYNTHESIS PROGRAM  VERSION 3  LEVEL 1  VPI EE DEPT.

DATE = 09-25-73  TIME=  5:30:40  PATTERN  77

PROGRAM PARAMETERS

IDISK = 1  STARTU = 0.0  MMAX = 26
ISYMM = 3  STARTV = 0.0  NMAX = 51
ITRMAX = 200  DELTAU = 0.020  MCENT = 1

DELTAV = 0.010  NCENT = 1

FOFSPT = 0  FORGPT = 0  FDBPT = 0  ICURPT = 0  FCURPT = 0
FDESGN = 1  FORGPN = 0  FDBCN = 1  ICURCN = 0  FCURCN = 0
FDESPR = 0  FORGPR = 0  FDBPR = 1  ICURPR = 0  FCURPR = 1

ITYPE=4  --  UNIFORM RECTANGULAR APERTURE

DIMENSIONS = LX,LY = 10.0000, 20.0000

INITLS,DELTAS,FINALS:  -5.0000 0.2000 5.0000

INITLT,DELTAT,FINALT:  -10.0000 0.4000 10.0000

MCUR,NCUR:  51  51

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
CONTOUR LEVEL KEY

0: \(-0.6000000E\ 00\) TO \(-0.3999900E\ 00\)
1: \(-0.4000000E\ 00\) TO \(-0.1999900E\ 00\)
2: \(-0.2000000E\ 00\) TO 0.1000000E-04
3: 0.0 TO 0.2000099E 00
4: 0.2000000E 00 TO 0.4000099E 00
5: 0.4000000E 00 TO 0.6000099F 00
6: 0.5999998F 00 TO 0.8000098F 00
7: 0.7999997E 00 TO 0.1000010F 01
8: 0.9999995E 00 TO 0.1200008E 01
9: 0.1199999E 01 TO 0.1400008E 01
-: -0.9999999E 30 TO -0.6000000E 00
+: 0.1400008E 01 TO 0.9999999E 30

-- INITIAL COEFFICIENTS --

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9 14 0.1524
**SEARCH**

1 14 0.2088
**SEARCH**

11 6 0.1875
**SEARCH**

5 6 0.1962
**SEARCH**

9 18 -0.1572
**SEARCH**

1 18 -0.2146
**SEARCH**

1 22 0.1065
**SEARCH**

19 6 0.1304
**SEARCH**

8 14 0.1241
**SEARCH**

8 22 0.1394
**SEARCH**

1 14 0.1209
**SEARCH**

11 6 0.1322
**SEARCH**

4 6 0.1436
**SEARCH**

23 6 -0.1201
**SEARCH**

7 18 -0.1188
**SEARCH**

1 4 -0.0716
**SEARCH**

9 5 -0.1592
**SEARCH**

1 5 -0.1155
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**SEARCH**

1 5 -0.0900
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7 16 0.1005
**SEARCH**

11 6 0.0889
**SEARCH**

14 14 0.1093
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9 5 -0.0946
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11 1 0.1536
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19 1 0.1523
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**SEARCH**

23 1 -0.1235
**SEARCH**

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6 1 0.1176
**SEARCH**

6 6 0.0956
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11 6 0.1438
**SEARCH**

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**SEARCH**

5 1 0.0873
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5 6 0.1050
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5 6 0.0783
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**NUMBER OF ITERATIONS =** 62

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**PATTERN NUMBER =** NUMPAT = 77
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<td>4.8000</td>
<td>0.1624606E-01</td>
<td>0.2328306E-09</td>
</tr>
<tr>
<td>-0.0000</td>
<td>5.2000</td>
<td>0.8754738E-02</td>
<td>-0.1396984E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>5.6000</td>
<td>0.2147641E-02</td>
<td>0.1164153E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>6.0000</td>
<td>0.3115296E-02</td>
<td>-0.1862645E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>6.4000</td>
<td>0.6700821E-02</td>
<td>-0.3026798E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>6.8000</td>
<td>0.8532569E-02</td>
<td>-0.3026798E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>7.2000</td>
<td>0.8870188E-02</td>
<td>-0.2561137E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>7.6000</td>
<td>0.8307122E-02</td>
<td>0.3230306E-09</td>
</tr>
<tr>
<td>-0.0000</td>
<td>8.0000</td>
<td>0.7672135E-02</td>
<td>-0.3492460E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>8.4000</td>
<td>0.7850845E-02</td>
<td>0.2328306E-09</td>
</tr>
<tr>
<td>-0.0000</td>
<td>8.8000</td>
<td>0.9560246E-02</td>
<td>-0.4423782E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>9.2000</td>
<td>0.1313743E-01</td>
<td>-0.3725290E-05</td>
</tr>
<tr>
<td>-0.0000</td>
<td>9.6000</td>
<td>0.1838810E-01</td>
<td>-0.4423782E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>10.0000</td>
<td>0.2455102E-01</td>
<td>-0.1862645E-08</td>
</tr>
</tbody>
</table>

_PATTERN NUMBER 77 HAS BEEN STORED ON RECORD 20 OF ANTDATA.A507C2_
8.3 Input to ANTDATA

Referring to Section 7.3, the following cards were punched.

<table>
<thead>
<tr>
<th>Card Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 11 21</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>12121500020</td>
</tr>
<tr>
<td>1511510000151</td>
</tr>
<tr>
<td>1111</td>
</tr>
<tr>
<td>0.0</td>
</tr>
<tr>
<td>0.0</td>
</tr>
<tr>
<td>-35.0 -35.0</td>
</tr>
<tr>
<td>-30.0 0.0 5.0</td>
</tr>
<tr>
<td>0000</td>
</tr>
<tr>
<td>0000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step</th>
<th>Card</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>NUMPAT=77, NUMTRR=20</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Array dimensions are 151 x 151</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>All options for pattern magnitude are specified</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>U-profile location is 0. (V=0)</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>V-profile location is 0. (U=0)</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>LOWCON=-35.0, DASH=-35.0</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>CONLOW=-40.0, COMM=0.0, CONINT=5.0</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>No options for current magnitude are specified</td>
</tr>
<tr>
<td>15</td>
<td>9</td>
<td>No options for current phase are specified</td>
</tr>
</tbody>
</table>

8.4 Output from ANTDATA

The following is the printout from computer program ANTDATA.

PLOT OUTPUT FOR PATTERN 77:
U-AXIS PROFILE PLOT REQUESTED -- V=0.
V-AXIS PROFILE PLOT REQUESTED -- U=0.
CONTOUR PLOT OF PATTERN REQUESTED.
LOWEST CONTOUR = -30.0
HIGHEST CONTOUR = 0.0
CONTOUR INTERVAL = 5.0
PATTERN IS NOW BEING GENERATED. IF PATTERN < -35.00 PATTERN = -35.00
THREE-DIMENSIONAL PLOT OF PATTERN REQUESTED
EXECUTION TIME: 27.57 MINUTES.
Refer to Chapter 4 for plotter output.

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.26</td>
<td>U-axis profile</td>
</tr>
<tr>
<td>4.27</td>
<td>V-axis profile</td>
</tr>
<tr>
<td>4.28</td>
<td>Contour plot</td>
</tr>
<tr>
<td>4.29</td>
<td>Three-dimensional plot</td>
</tr>
</tbody>
</table>