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.

<table>
<thead>
<tr>
<th>Radiation Pattern Variables</th>
<th>Antenna Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Main Beams</td>
<td>I. Shape</td>
</tr>
<tr>
<td>A. Number</td>
<td>A. Linear</td>
</tr>
<tr>
<td>1. Single</td>
<td>1. Linear array</td>
</tr>
<tr>
<td>2. Multiple</td>
<td>2. Line source</td>
</tr>
<tr>
<td>B. Shape</td>
<td>B. Planar</td>
</tr>
<tr>
<td>1. Nominal</td>
<td>1. Planar array</td>
</tr>
<tr>
<td>2. Shape</td>
<td>2. Planar aperture</td>
</tr>
<tr>
<td>II. Side Lobes</td>
<td>II. Size</td>
</tr>
<tr>
<td>A. Nominal</td>
<td></td>
</tr>
<tr>
<td>B. Low</td>
<td></td>
</tr>
<tr>
<td>C. Complex</td>
<td></td>
</tr>
</tbody>
</table>

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
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 simpler 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:

<table>
<thead>
<tr>
<th>Continuous Aperture Sources</th>
<th>Arrays</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line source</td>
<td>Linear Array</td>
</tr>
<tr>
<td>Rectangular Aperture</td>
<td>Rectangular Array</td>
</tr>
<tr>
<td>Circular Aperture</td>
<td>Arbitrary Planar Array</td>
</tr>
</tbody>
</table>

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:

$$\mathbf{J}_S = \hat{n} \times \mathbf{H}_1$$  \hspace{1cm} (2-1)

$$\mathbf{J}_{MS} = -\hat{n} \times \mathbf{E}_1$$  \hspace{1cm} (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]

\[
\vec{A}(r) = \frac{1}{4\pi} \int J_S(r') e^{jkr'} dx'dy' \quad (2-3)
\]

\[
\vec{A}_M(r) = \frac{1}{4\pi} \int J_{MS}(r') e^{jkr'} dx'dy' \quad (2-4)
\]

where \( \vec{r}' = x'\hat{x} + y'\hat{y} \) 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

\[
\vec{J}_S = \hat{z} \times \nabla \times \hat{H}_a \tag{2-5}
\]

\[
\vec{J}_{MS} = -\hat{z} \times \nabla \times \hat{E}_a \tag{2-6}
\]

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

\[
E_\theta = -j\omega A_\theta - j\eta_0 A_{\phi} \tag{2-7}
\]

\[
E_\phi = -j\omega A_\phi + j\eta_0 A_M \tag{2-8}
\]

where \( \eta_0 = \sqrt{\mu_0 / \epsilon_0} \) and the magnetic fields are found using the plane wave relation

\[
\vec{H} = \hat{r} \times \vec{E}/\eta_0 \tag{2-9}
\]
As an example suppose we use only a magnetic current and the aperture electric field is $y$-directed. Then

$$J_{MS} = J_{MSx} \hat{x} = \hat{z} \times E_{ay} \hat{y} = E_{ay} \hat{x}$$  \hspace{1cm} (2-10)$$

and

$$A_{Mx} = \frac{\varepsilon_0}{4\pi r} e^{-jkr} \left[ \int \int_{\text{aperture}} 2 E_{ay} e^{jk\hat{r}' \cdot \hat{r}'} \, dx'dy' \right]$$  \hspace{1cm} (2-11)$$

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

$$A_{M\theta} = \cos \theta \cos \phi A_{Mx}$$  \hspace{1cm} (2-12)$$

$$A_{M\phi} = -\sin \phi A_{Mx}$$  \hspace{1cm} (2-13)$$

So

$$E_{\phi} = -j\omega_0 A_{M\phi}$$
$$= +j\omega_0 \sin \phi A_{Mx}$$  \hspace{1cm} (2-14)$$

$$E_{\phi} = +j\eta_0 A_{M\theta}$$
$$= j\eta_0 \cos \theta \cos \phi A_{Mx}$$  \hspace{1cm} (2-15)$$

And

$$A_{Mx} = \frac{\varepsilon_0}{2\pi r} e^{-jkr} \left[ \int \int_{\text{aperture}} E_{ay} e^{jk(x' \sin \theta \cos \phi + y' \sin \theta \sin \phi)} \, dx'dy' \right]$$  \hspace{1cm} (2-16)$$

So

$$E_{\phi} = \frac{jke^{-jkr}}{2\pi r} \sin \phi F_y$$  \hspace{1cm} (2-17)$$

$$E_{\phi} = \frac{jke^{-jkr}}{2\pi r} \cos \theta \cos \phi F_y$$  \hspace{1cm} (2-18)$$

where

$$F_y = \left[ \int \int_{\text{aperture}} E_{ay} e^{jk(x' \sin \theta \cos \phi + y' \sin \theta \sin \phi)} \, dx'dy' \right]$$  \hspace{1cm} (2-19)$$
If there is an x-directed component of the aperture electric field the far-field expressions become

\[ E_\theta = \frac{jke^{-jkr}}{2\pi r} (F_y \sin \phi + F_x \cos \phi) \]  \hspace{1cm} (2-20)

\[ E_\phi = \frac{jke^{-jkr}}{2\pi r} \cos \theta (F_y \cos \phi - F_x \sin \phi) \]  \hspace{1cm} (2-21)

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

\[ E_\theta = \frac{jke^{-jkr}}{2\pi r} \cos \theta (F_y \cos \phi - F_x \sin \phi) \]  \hspace{1cm} (2-22)

\[ E_\phi = \frac{jke^{-jkr}}{2\pi r} (F_y \sin \phi + F_x \cos \phi) \]  \hspace{1cm} (2-23)

where

\[ \mathbf{F} = \iint H_a (x', y') e^{jk(x' \sin \theta \cos \phi + y' \sin \theta \sin \phi)} \, dx' dy' \]  \hspace{1cm} (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 \( \vec{J}_S \) is an actual current and its Fourier transform \( \vec{A} \) 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

\[
\vec{J}_S = \hat{x} J_{sx} (x') J_{sx} (y') + \hat{y} J_{sy} (x') J_{sy} (y')
\]

(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 \( \vec{E}_a \) and \( \vec{H}_a \) 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

\[
E_\theta = E(r) [\cos \phi F_x + \sin \phi F_y] \quad (2-26)
\]

\[
E_\phi = E(r) [-\cos \theta \sin \phi F_x + \cos \theta \cos \phi F_y] \quad (2-27)
\]

where

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

This can be cast in a matrix form

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

where

\[
E_\theta(\theta,\phi) = E_\theta/E(r) \quad (2-30)
\]

\[
E_\phi(\theta,\phi) = E_\phi/E(r)
\]

and

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

\[
G_{\phi x} = -\cos \theta \sin \phi \quad G_{\phi y} = \cos \theta \cos \phi
\]

In still more compact form (2-29) becomes

\[
[E] = [G][F] \quad (2-32)
\]
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):

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

(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

\[
F_x(\theta, \phi) = \int \int E_{ax}(x', y') e^{jk(x' \sin \theta \cos \phi + y' \sin \theta \sin \phi)} dx' dy',
\]

(2-34)

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

(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

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

(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
\[ F_{x} = \int \int I_{x}(x',y') \ e^{j k \alpha} \ dx'dy' \] (2-37)

where we let

\[ \alpha = x' \sin \theta \cos \phi + y' \sin \theta \sin \phi \] (2-38)

becomes

\[ F_{x} = G_{x} \sum_{m=1}^{P} I_{xm} e^{j k \alpha_{m}} = G_{x} F_{arx} \] (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

\[ F_{y} = G_{y} \sum_{m=1}^{P} I_{ym} e^{j k \alpha_{m}} = G_{y} F_{ary} \] (2-41)

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

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

\[ F_{arx} = \sum_{m=1}^{P} I_{xm} e^{j k \alpha_{m}} \quad F_{ary} = \sum_{m=1}^{P} I_{ym} e^{j k \alpha_{m}} \] (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

\[ G_y = \sin \beta \]  

(2-47)

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

so

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

(2-48)

Now

\[ \mathbf{F}_{ary} = \sum_{j} \sum_{k} \alpha_m \mathbf{I}_{y_m} e^{jk \alpha_m} \]  

(2-49)

where

\[ \alpha_m = x_m' \sin \theta \cos \phi \]  

(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:

$$[V] = [Z][I]$$  \hspace{1cm} (2-51)

where

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

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

$$[Z] = \begin{bmatrix} Z_{11} & Z_{12} & \cdots \\ Z_{21} & \cdots \\ \vdots & \vdots \\ \end{bmatrix} = \text{mutual impedance matrix (known from calculations or experiment)}$$
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

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

(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
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

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

(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

\[ \Delta F^{(i)}(u,v) = \sum_n a_n^{(i)} G(u-u_n^{(i)}, v-v_n^{(i)}) \]  

(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 \( \{a_n^{(i)}\} \) are weighting coefficients determined such that the current pattern is forced to equal the desired pattern at the correction point as follows

\[ a_n^{(i)} = F_d(u_n^{(i)}, v_n^{(i)}) - F^{(i-1)}(u_n^{(i)}, v_n^{(i)}) \]  

(3-9)

In other words, at the point \( (u_n^{(i)}, v_n^{(i)}) \) the amount \( a_n^{(i)} \) is added to the \( (i-1)^{th} \) iteration pattern to obtain the desired pattern value at that point. The pattern is, of course, also changed at other points. 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 convergence. 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 patterns 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 \(g_n^{(i)}(s,t)\) related to it as follows:

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

\[ f^K(s,t) = f^0(s,t) + \sum_{i=1}^{K} \Delta f^i(s,t) \quad (3-11) \]

where

\[ \Delta f^i(s,t) = \sum_n a_n^i g_n^i(s,t) \quad (3-12) \]

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

\[ f^K(s,t) = \sum_{\lambda} \sum_{m} I^K_{\lambda m} \delta(s-s_{\lambda}, t-t_m) \quad (3-13) \]

where \( \delta \) is the dirac delta function and \( I^K_{\lambda m} \) are the currents for the \( \lambda \)th 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

\[ g_n^i(s,t) = \sum_{\lambda} \sum_{m} g_{\lambda m}^i \delta(s-s_{\lambda}, t-t_m) \quad (3-14) \]

for arrays. Then (3-10) becomes

\[ G(u-u_n(i), v-v_n(i)) = \sum_{\lambda} \sum_{m} g_{\lambda m}^i e^{2\pi(s_{\lambda} u + t_m v)} \quad (3-15) \]

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

\[ \Delta f^i(s,t) = \sum_n a_n^i \sum_{\lambda} \sum_{m} g_{\lambda m}^i \delta(s-s_{\lambda}, t-t_m) \quad (3-16) \]

and let

\[ \Delta f^i(s,t) = \sum_{\lambda} \sum_{m} I^{(1)}_{\lambda m} \delta(s-s_{\lambda}, t-t_m) \quad (3-17) \]

So
\[
\Delta I_{lm}^{(i)} = \sum_n a_n^{(i)} g_{n\#m}^{(i)}
\]

\[\text{and}\]

\[
I_{lm}^{(K)} = I_{lm}^{(0)} + \sum_{i=1}^{K} \Delta I_{lm}^{(i)}
\]

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, \(v_n^{(i)}\). The source correction function is

\[
g_n^{(i)}(t) = \begin{cases} 
L_{\gamma\lambda}^{-1} \exp(-j2\pi v_n^{(i)} t) & |t| \leq L_{\gamma\lambda}/2 \\
0 & \text{elsewhere}
\end{cases}
\]

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

\[
G(v-v_n^{(i)}) = \frac{\sin [L_{\gamma\lambda}(v-v_n^{(i)})\pi]}{L_{\gamma\lambda}(v-v_n^{(i)})\pi}
\]

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

\[ g_n^{(i)}(t) = \begin{cases} L_y/L_x \exp(-j2\pi v_n^{(i)}t) & |t| \leq L_y/2 \\ 0 & \text{elsewhere} \end{cases} \] (3-22)

The corresponding pattern found from (3-10) is

\[ G(v-v_n^{(i)}) = \left( \frac{\sin[L_y/(v-v_n^{(i)})\pi/2]}{L_y/(v-v_n^{(i)})\pi/2} \right)^2 \] (3-23)

### 3.5.2 Linear Array

The uniformly illuminated, linear phase, equally spaced linear array has currents

\[ g_{nm}^{(i)} = \frac{1}{P} \exp(-j2\pi v_n^{(i)}t_m) \] (3-24)

where \( t_m \) are the positions of the elements and equal \( m \lambda y \) and \( P \) is the total number of elements. The corresponding pattern is

\[ G(u-u_n^{(i)}) = \frac{\sin[P(v-v_n^{(i)})\pi d_y]}{P \sin[(v-v_n^{(i)})\pi d_y]} \] (3-25)

### 3.5.3 Rectangular Aperture

The uniformly illuminated, linear phase, rectangular aperture has excitation function

\[ g_n^{(i)}(s,t) = \begin{cases} L_x/L_y \exp(-j2\pi (u_n^{(i)}s + v_n^{(i)}t)) & |s| \leq L_x/2 \\ 0 & |t| \leq L_y/2 \end{cases} \] (3-26)

The pattern is

\[ G(u-u_n^{(i)}, v-v_n^{(i)}) = \frac{\sin[L_x/(u-u_n^{(i)})\pi]}{L_x/(u-u_n^{(i)})\pi} \cdot \frac{\sin[L_y/(v-v_n^{(i)})\pi]}{L_y/(v-v_n^{(i)})\pi} \] (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

$$g_{n \lambda m}^{(1)} = \frac{1}{P_x P_y} \exp \left[ -j2\pi \left( u_n^{(1)} s_x + v_n^{(1)} t_m \right) \right]$$  \hspace{1cm} (3-28)

The pattern is

$$G(u-u_n^{(1)}, v-v_n^{(1)}) = \frac{\sin [P_x (u-u_n^{(1)}) \pi d_x \lambda]}{P_x \sin [(u-u_n^{(1)}) \pi d_x \lambda]} \frac{\sin [P_y (v-v_n^{(1)}) \pi d_y \lambda]}{P_y \sin [(v-v_n^{(1)}) \pi d_y \lambda]}$$  \hspace{1cm} (3-29)

3.5.5 Circular Aperture

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

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

$$g_n^{(1)}(\rho', \phi') = \frac{1}{\pi a \lambda} \exp \left[ -j2\pi \rho' \left( \cos \phi' u_n^{(1)} + \sin \phi' v_n^{(1)} \right) \right] \rho' \leq a \lambda$$  \hspace{1cm} (3-31)

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

where

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

Now (3-33) is easily integrated as

\[ G (u-u_n \overset{(i)}{), v-v_n \overset{(i)}{)} = \frac{2\pi}{\pi a_\lambda^2} \int_0^{a_\lambda} \frac{J_0 (2\pi \rho_\lambda C)}{\rho_\lambda^2} d\rho'_\lambda \]
\[ = 2 \frac{J_1 (2\pi a_\lambda C)}{2\pi a_\lambda C} \quad (3-38) \]

If \( u_n \overset{(i)}{) = v_n \overset{(i)}{) = 0 \) we have

\[ G_n (u,v) = 2 \frac{J_1 (2\pi a_\lambda \sin \theta)}{2\pi a_\lambda \sin \theta} \quad (3-39) \]

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

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

Thus \( (u_n \overset{(i)}{, v_n \overset{(i)}{)} \) 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

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

\[ \Omega_A = \int_{0}^{2\pi} \int_{0}^{\pi} |P(\theta,\phi)|^2 \sin \theta \, d\theta \, d\phi \] (3-42)

where \( |P(\theta,\phi)| \) 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

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

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

\[
\Omega_A = \int_0^{\pi/2} \int_0^{\pi} |F(\theta, \phi)| \cos \theta \, d\Omega
\]

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

\[
du \, dv = \cos \theta \, d\Omega
\]

so

\[
d\Omega = \frac{du \, dv}{\cos \theta}
\]

But from (3-44)

\[
\cos \theta = \sqrt{1 - u^2 - v^2}
\]
\[ d\Omega = \frac{du \, dv}{\sqrt{1 - u^2 - v^2}} \quad (3-49) \]

Thus (3-45) becomes

\[ \Omega_A = \int \int_{u^2 + v^2 < 1} |F(u,v)|^2 \frac{du \, dv}{\sqrt{1 - u^2 - v^2}} \quad (3-50) \]

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

\[ \Omega_A = \int \int_{u^2 + v^2 < 1} |F(u,v)|^2 \sin \theta \, J \, du \, dv \quad (3-51) \]

where \( J \) is the Jacobian given by

\[ J = \frac{\partial (\theta, \phi)}{\partial (u,v)} = \frac{1}{\frac{\partial (u,v)}{\partial (\theta, \phi)}} \quad (3-52) \]

and

\[ \frac{\partial (u,v)}{\partial (\theta, \phi)} = \begin{vmatrix} \frac{\partial u}{\partial \theta} & \frac{\partial u}{\partial \phi} \\ \frac{\partial v}{\partial \theta} & \frac{\partial v}{\partial \phi} \end{vmatrix} = \begin{vmatrix} \cos \theta \cos \phi - \sin \theta \sin \phi \\ \cos \theta \sin \phi \sin \theta \cos \phi \end{vmatrix} = \cos \theta \sin \theta \quad (3-53) \]

So

\[ \sin \theta \, J \, du \, dv = \sin \theta \, \frac{du \, dv}{\cos \theta \sin \theta} = \frac{du \, dv}{\sqrt{1 - u^2 - v^2}} \quad (3-54) \]

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)

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

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

\[
\Omega_A = \int_0^{2\pi} d\phi \int_0^{\pi/2} \frac{r \, dr \, d\alpha}{\sqrt{1 - r^2}}
\]

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

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 $\sin \frac{x}{x}$ 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.

\[ \text{PATTERN} = \Phi \]
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>
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<td>(</td>
<td>v</td>
<td>&lt; 0.2 )</td>
<td>0. dB</td>
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<tr>
<td>( 0.4 &lt;</td>
<td>v</td>
<td>\leq 1.0 )</td>
<td>( - \infty )</td>
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</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 - ITYPE</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 source 1</td>
<td>L_yλ = 10</td>
<td>0.0886</td>
<td>0.0886</td>
<td>-13.3</td>
</tr>
<tr>
<td>Uniform linear array 2</td>
<td>P_y = 21 d_xλ =0.5</td>
<td>0.0886</td>
<td>0.0886</td>
<td>-13.3</td>
</tr>
<tr>
<td>Triangular line source 3</td>
<td>L_yλ = 10</td>
<td>0.128</td>
<td>0.128</td>
<td>-26.6</td>
</tr>
<tr>
<td>Uniform rectangular aperture 4</td>
<td>L_xλ = 10</td>
<td>0.0886</td>
<td>0.0886</td>
<td>-13.3</td>
</tr>
<tr>
<td>Uniform rectangular array 5</td>
<td>P_x = 21 d_xλ =0.5</td>
<td>0.0443</td>
<td>0.0443</td>
<td>-13.3</td>
</tr>
<tr>
<td>Uniform circular aperture 6</td>
<td>a_λ = 5</td>
<td>0.102</td>
<td>0.102</td>
<td>-17.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
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<td></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 0.0 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 $\text{ITYPE} = 7$ 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.
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 -25 dB 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 \(0.38 < v < 0.64\). The other beams were specified in a symmetric fashion. The region outside of these main beam regions had an upper limit of -25 dB 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

<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 0.26 )</td>
<td>0. dB</td>
</tr>
<tr>
<td>( 0.44 \leq</td>
<td>v</td>
<td>\leq 1.0 )</td>
<td>-20.</td>
</tr>
</tbody>
</table>

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:

$$
\begin{align*}
|u| & < 0.2, |u| < 0.05 & F_d(u,v) & = 0.0dB & F_H(u,v) & = 1.0dB & F_L(u,v) & = -0.9dB \\
0.36 < |u| & < 0.50 & -20.0 & -18.4 & \text{unspecified}
\end{align*}
$$

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.

PATTERN = SL
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>-25</td>
<td>unspecified</td>
</tr>
<tr>
<td>0.12&lt;v&lt;0.50</td>
<td></td>
<td></td>
<td></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/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>Device</th>
<th>Location</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Job assignment</td>
<td>Auxiliary storage</td>
<td>MAIN</td>
</tr>
<tr>
<td>2. Pattern parameters</td>
<td>Cards; use Namelist PARAM</td>
<td>MAIN</td>
</tr>
<tr>
<td>3. Output print control</td>
<td>Cards; use Namelist IPRINT</td>
<td>MAIN</td>
</tr>
<tr>
<td>4. Antenna parameters</td>
<td>Cards; use Namelist PATIN</td>
<td>INPUT</td>
</tr>
<tr>
<td></td>
<td>If ITYPE &gt;7 also use subroutine SINPUT</td>
<td>SINPUT</td>
</tr>
<tr>
<td>5. Desired pattern</td>
<td>Program statements to load FDES, FU and FL</td>
<td>DESPAT</td>
</tr>
<tr>
<td></td>
<td>Cards; call subroutine READ to load FDES, FU, and FL</td>
<td>DESPAT</td>
</tr>
<tr>
<td>6. 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>
</tr>
<tr>
<td></td>
<td>or</td>
<td>ORGPAT</td>
</tr>
<tr>
<td></td>
<td>Cards or program statements; if Woodward-Lawson is not used, load F, CURR, and CURI, set NORG=0</td>
<td>ORGPAT</td>
</tr>
<tr>
<td>7. Special correction pattern function</td>
<td>Program statements to generate values of PAT, ITYPE &gt;7</td>
<td>SPECPT</td>
</tr>
<tr>
<td>8. Special correction source function</td>
<td>Program statements to generate companion to special pattern, ITYPE &gt;7</td>
<td>SPSOR</td>
</tr>
<tr>
<td>9. Special location</td>
<td>Program statements to generate source coordinates given source array subscripts, use when ITYPE &gt;7</td>
<td>SPLOC</td>
</tr>
<tr>
<td>10. Job storage</td>
<td>Programming to write job data onto storage unit</td>
<td>MAIN</td>
</tr>
</tbody>
</table>
Step 4. This step provides input concerning the particular antenna to be used. It is read in on cards under

\begin{verbatim}
NAMELIST/PATIN/LX, LY, PX, PY, DISX, DISY, INITLS, DELTAS, FINALS, INITLS, DELTAT, FINALT, NEIMT, ARAD, ITYPE, MCUR, NCUR
\end{verbatim}

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></td>
</tr>
<tr>
<td>a_\lambda</td>
<td>ARAD</td>
</tr>
<tr>
<td>d_\chi_\lambda</td>
<td>DISX</td>
</tr>
<tr>
<td>d_\psi_\lambda</td>
<td>DISY</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 directivities 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 passwork 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.

DELCON  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.
STARTU
Input variable - Starting point in U direction for pattern comparisons and print outs.

STARTV
Input variable - Starting point in V direction for pattern comparisons and print outs.

T
Source coordinate Y normalized to a wavelength.

TT( )
Antenna array element position in T direction - Input variable for ITYPE = 7.

U
Pattern coordinate.

UORG( )
Input variable - Positions of sample points for original pattern in U direction.

US( )
Positions of corrections (samples) in U direction.

V
Pattern coordinate.

VORG( )
Input variable - Positions of sample points for original pattern in V direction.

VS( )
Positions of corrections (samples) in V direction.
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 $20.\times\text{ALOG10( }$ ). 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 LOCSOR (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 LOCSOR 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 LOCSOR.

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.

Source | Variable
-------|---------
Original distribution | ICURCN = 1
Final distribution | FCURCN = 1

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, DELTAU, 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 LOCSOR 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

//JANIA57 JOB SL72, COFFY
/*MAIN TIME=3,REGION=22OK,LINES=16, LARDS=0
/*PRIORITY PRIORITY
// EXEC FORT56,LIB=SSPLIB
// FORTSYSIN UD *
/*
/*GLF1Z2B01 DD DSN=ANTS3ATA,APPEND,UNIT=3330, VOL=SER=USERPK, LIST=SER
/*GLSYSIN UD *
/*
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:
  FT05FC01 (SYSIN) -- CARD READER
  FT06FO01 (SYSPRINT) -- LINE PRINTER
  FT22FC01 (ANTDATA.A507C2) -- AUXILIARY STORAGE

STORAGE REQUIREMENTS: 220K
DEFINE FILE 22(35,9100,E,NREC)

INTEGER TITLE(20)
INTEGER NUMSKP(35),FDESPT,FDESCN,FDESFR
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),COCOF(500),CURR(51,51),CURI(51,51)
REAL UCRG(100),VORG(100),CORG(100)
REAL INITLS,INITLT
COMPLEX SOURCE
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/ IYPE
DATA TITLE /'ANTENNA SYNTHESIS PROGRAM VERSION 3 LEVEL 1',
$'VPI EE DEPT.',5X,'DATE = ',A2,'-',A2,'-',A2,
$'TIME = ',12,'.',12,5X,'PATTERN ',I4///)
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 FCGRM=1.0
64 ISUC=0
65 DELTAS=C.
66 DELTAT=0.

READ(5, PARAM)
WRITE(6, 1521) IDISK, STARTU, MMAX, ISYM, STARTV, NMAX, ITRMAX, DELTAU,
MCENT, DELTAV, NCENT
1521 FORMAT(7X, 'PROGRAM PARAMETERS', 3X, 'IDISK = ', 11, 2X, 'STARTU = 
13/3X, 'ISYM = ', 11, 2X, 'STARTV = ', 13/3X, 'MMAX = ', 11, 2X, 'NMAX = 
13/3X, 'ITRMAX = ', 14, 2X, 'DELTAU = ', 14, 2X, 'DELTAV = ', 14, 2X, 'NCENT = ', 13/7X)
READ(5, PRINT)
WRITE(6, 1522) FDESPT, FORGPT, FCURPT, ICURPT, FCURPN, ICURPN
CALL INPUT
IF (ITYPE.EQ.7 .AND. ICURPR.EQ.1) ICURPR = 2
IF (ITYPE.EQ.7 .AND. FCURPR.EQ.1) FCURPR = 2
CALL LCSCSR(1,1,INITS,INILT)
CALL LCSSOR(MCUR,NCUR,FINALS,FINALT)
IF (NCUR.NE.1) DELTAS = (FINALS-INITLS)/(MCUR-1)
IF (NCUR.NE.1) DELTAT = (FINALT-INITLT)/(NCUR-1)
CALL DESPAT(FDES,FL,MMAX,NMAX,STARTU,STARTV, $DELTU,DELTAV)

C
C
IF (DESPT) 300, 300, 301
300 WRITE(6,302)
301 FORMAT(1H1,1X,'DESIRED PATTERN IN DB.)
302 CALL PRINT(FDES,MMAX,NMAX,STARTU,STARTV, $DELTU,DELTAV)

C
C
300 IF (DESCT) 303, 303, 304
303 CONTINUE
304 CALL PATCCN(FDES,MMAX,NMAX,0,-.5,1.3,.2,STARTU,STARTV, $DELTU,DELTAV,NUMPAT,ISYM)
305 IF (DESCT) 306, 306, 307
306 IF (MMAX.LE.1) GO TO 306
307 WRITE(6,310) NUMPAT
310 FORMAT(1H1,1X,'U-AXIS PROFILE OF DESIRED PATTERN ',14//, $12X,'U',16X,'V',15X,'FDES(U,V)',10X,'FU(U,V)',12X,'FL(U,V)'/)
311 U = STARTU+(I-1)*DELTU
312 DO 309 I = 1,MMAX
313 V = STARTV+(J-1)*DELTAV
314 WRITE(6,311) U,V,FDES(I,NCENT),FU(I,NCENT),FL(I,NCENT)
315 Formats(1H1,1X,'U-AXIS PROFILE OF DESIRE
316 Patterns',14//, $12X,'U',16X,'V',15X,'FDES(U,V)',10X,'FU(U,V)',12X,'FL(U,V)'/)
317 U = STARTU+(I-1)*DELTU
318 DO 309 J = 1,MAX
319 V = STARTV+(J-1)*DELTAV
320 WRITE(6,312) NUMPAT
321 Formats(1H1,1X,'V-AXIS PROFILE OF DESIRED P
322 TRAT PATTERN',14//, $12X,'V',16X,'U',15X,'FDES(U,V)',10X,'FU(U,V)',12X,'FL(U,V)'/)
323 U = STARTU+(I-1)*DELTU
324 DO 313 J = 1,MAX
325 V = STARTV+(J-1)*DELTAV
326 WRITE(6,313) U,V,FDES(MCENT,J),FU(MCENT,J),FL(MCENT,J)
327 CONTINUE

C
C
ENTER ORIGINAL PATTERN
C
C
CALL CRGPAT(F,MMAX,NMAX,STARTU,STARTV,DELTU,DELTAV, $CURR,CURR,MCUR,MCUR)
C
C
OUTPUT OF ORIGINAL PATTERN
C
C
IF (FORGPT) 400, 400, 401
400 WRITE(6,401)
401 FORMAT(1H1,1X,'INITIAL PATTERN')
402 CALL PRINT(F,MMAX,NMAX,STARTU,STARTV,DELTU,DELTAV)

C
C
400 IF (FORGET) 405, 405, 406
406 Write(6,406)
407 Formats(1H1,1X,'INITIAL PATTERN')
408 CALL PRINT(F,MMAX,NMAX,STARTU,STARTV,DELTU,DELTAV)

C
A-29

113 DC 408 J=1,401
114 U=(J-1)*C.C05-1.C
115 V=U
116 SUMU=0.
117 SUMV=C.
118 DO 409 K=1,NORG
119 SUMU=SUMU+CORG(K)*PAT(U-UORG(K),-VORG(K),ITYPE)
120 SUMV=SUMV+CORG(K)*PAT(-UORG(K),V-VORG(K),ITYPE)
121 409 CONTINUE
122 DATA1(J,1)=U
123 DATA1(J,2)=SUMU
124 DATA2(J,1)=V
125 DATA2(J,2)=SUMV
126 408 CONTINUE
127 IF(NMAX.LE.1) GO TO 2801
128 WRITE(6,410)
129 410 FORMAT(1H1,25X,'U-AXIS PROFILE OF INITIAL PATTERN')
130 CALL PROFIL(DATA1,401,NUMPAT)
131 2801 IF(NMAX.LE.1) GO TO 406
132 WRITE(6,411)
133 411 FORMAT(1H1,25X,'V-AXIS PROFILE OF INITIAL PATTERN')
134 CALL PROFIL(DATA2,401,NUMPAT)
135 406 CONTINUE

C ORIGINAL EXCITATION

C
136 IF(ICURPT) 500,500,501
137 500 WRITE(6,502)
138 502 FORMAT(1H1,55X,'INITIAL CURR')
139 CALL PRINT(CCUR,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTAT)
140 WRITE(6,502)
141 582 FORMAT(1H1,55X,'INITIAL CURR')
142 CALL PRINT(CCUR,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTAT)
143 500 IF(ICURCN) 503,503,504
144 504 WRITE(6,505)
145 505 FORMAT(1H1,10X,'INITIAL CURR')
146 CALL CONTUR(MCUR,NCUR,0.005,-0.04,0.04,0.0,CURR,NUMPAT)
147 WRITE(6,505)
148 585 FORMAT(1H1,10X,'INITIAL CURR')
149 CALL CONTUR(MCUR,NCUR,0.005,-0.04,0.04,0.0,CURR,NUMPAT)
150 503 IF(ICURP-1) 506,507,514
151 507 IF(MCUR.LT.1) GO TO 508
152 WRITE(6,510)
153 510 FORMAT(1H1,10X,'S AXIIX PROFILE OF INITIAL CURRENT'//
154 $13X,'S',17X,'T',18X,'REAL',12X,'IMAGINARY',10X,'MAGNITUDE',
155 $12X,'PHASE'/)
156 J=NCUR/2+1
157 DO 509 J=1,MCUR
158 CALL LOCGR(I,J,S,T,ITYPE)
159 AMAG=SQRT(CURR(I,J)**2+CURI(J)**2)
160 IF(AMAG.EQ.0.) APH=0.
161 IF(AMAG.EQ.0.) GO TO 509
162 APH=ATAN2(CURI(I,J),CURR(I,J))*57.2957195
163 WRITE(6,511) S,T,CURR(I,J),CURI(I,J),AMAG,APH
164 511 FORMAT(1H1,8.4,9X,8.4,9X,10X,4(E14.7,5X))
163 508 IF(NCUR.LE.1) GO TO 506
164 WRITE(6,512)
165 512 FORMAT(1H1,10X,"T AXIS PROFILE OF INITIAL CURRENT"/
167 $12X,"PHASE")
168 I=NCUR/2+1
169 DO 513 J=1,NCUR
170 CALL LCSOR(I,J,S,T,ITYPE)
171 CI=CURR(I,J)
172 AMAG=SQRT(CR*CR+CI*CI)
173 IF(AMAG.EQ.0.) APH=0.
174 APH=ATAN2(CI,CR)*57.2957795
175 513 WRITE(6,511) S,T,CR,CI,AMAG,APH
176 GO TO 506
177 514 WRITE(6,515)
178 515 FORMAT(1H1///10X,"INITIAL ELEMENT CURRENTS"///5X,
180 CALL LIST(CURR,CURI,MCUR,NCUR)
181 IC=0
182 WRITE(6,4747)
183 4747 FORMAT(1H1)
184 CALL ANTSYN(ISUC,MMAX,NMAX,FDES,FU,FL,ITRMAX,ISYMM,COCCF,IC,US
185 $,VS,STARTU,DELTU,STARTV,DELTAV,MCENT,NCENT,ITER,FNORM,F)
186 C PRINT OUT RESULTS
187 C
188 WRITE(6,391)
189 391 FORMAT(1H1,57X,"-- FINAL COEFFICIENTS --"///45X,"J",7X,
190 $"US(J)",7X,VS(J),5X,CORCCF(J)")
191 IF(IC.LE.0) WRITE(6,977)
192 977 FORMAT(10X,9X,"NUMBER OF ITERATIONS PERFORMED")
193 IF(IC.LT.C) GO TO 978
194 978 IC=IC+1
195 WRITE(6,35) J,US(J),VS(J),CORCCF(J)
196 35 FORMAT(44X,I3,5X,F7.4,5X,F7.4,5X,F7.4)
197 WRITE(6,497) ITER
198 497 FORMAT(1H0,9X,"PATTERN NUMBER = NUMPAT = ",I5)
199 978 CONTINUE
200 C OUTPUT FINAL PATTERN IN DB
201 C
202 WRITE(6,976)
203 976 FORMAT(1H0,9X,"PATTERN NUMBER = NUMPAT = ",I5)
GO TO 29

FI(J,K)=20.*ALCG10(ABS(F(J,K)))

CONTINUE

IF(FDPRPT) 600,600,601
WRITE(6,602)
FORMAT(1HI://///////////////////55X,'FINAL PATTERN IN DH.')
CALL PRINT(F,MMAX,NMAX,STARTU,STARTV,DELTAU,DELTAV)

CONTINUE

IF(FDPRCN) 603,603,604
CALL PATCON(F,MMAX,NMAX,2,-45.,0.0,5.0,STARTU,STARTV,
DELTAU,DELTAV,NUMPAT,ISYMM)

CONTINUE

DO 609 J=1,401
U=(J-1)*C.005-1.0
V=U
SUMU=0.
SUMV=0.
DO 609 K=1,IC
SUMU=SUMU+CORCOF(K)*PAT(U-US(K),-VS(K),ITYPE)
SUMV=SUMV+CORCOF(K)*PAT(-US(K),V-VS(K),ITYPE)
CONTINUE

DATA1(J,1)=U
DATA2(J,1)=V
DATA1(J,2)=DATA1(J,2)+SUMU
DATA2(J,2)=DATA2(J,2)+SUMV
DATA1(J,2)=DATA1(J,2)*FNORM
DATA2(J,2)=DATA2(J,2)*FNORM
CONTINUE

IF(MMAX.LE.1) GO TO 2901
WRITE(6,610)
FORMAT(1HI,/55X,'U-AXIS PROFILE OF FINAL PATTERN')
CALL PROFIL(DATA1,401,NUMPAT)

IF(NMAX.LE.1) GO TO 606
WRITE(6,611)
FORMAT(1HI,/55X,'V-AXIS PROFILE (IF FINAL PATTERN)')
CALL PROFIL(DATA2,401,NUMPAT)

CONTINUE

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

FINAL EXCITATION

IF(FCURPT) 700,700,701
WRITE(6,702)
FORMAT(1HI://///////////////////55X,'FINAL CURR')
CALL PRINT(CURR,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTAT)
WRITE(6,782)

IF(FCURCN) 703,703,704
CALL PRINT(CURI,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTAT)

IF(FCURCN) 705,705,706
WRITE(6,705)
252 705 FORMAT(1H1///10X,'FINAL CURR')
253    CALL CONTUR(MCUR,NCUR,C,COS,-0.04,0.04,0.0,CURR,NUMPAT)
254    WRITE(6,765)
255 785 FORMAT(1H1///10X,'FINAL CURR')
256    CALL CONTUR(MCUR,NCUR,C,COS,-0.04,0.04,0.0,CURR,NUMPAT)
257 703 IF(FCURPR-1) 706,707,711
258 707 IF(MCUR.LE.1) GO TO 708
259 WRITE(6,710)
260 710 FORMAT(1H1,10X,'S AXIS PROFILE OF FINAL CURRENT'//
      $13X,'S',17X,'T',18X,'REAL',12X,'IMAGINARY',10X,'MAGNITUDE',
      $12X,'PHASE')
261    J=NCUR/2+1
262    DO 709 1=1,MCUR
263       CALL LCCSCR(I,J,S,T,ITYPE)
264       CR=CURR(I,J)
265       CI=CURI(I,J)
266       AMAG=SQRT(CR*CR+CI*CI)
267       IF(AMAG.EQ.0.) APH=0.
268       IF(AMAG.EQ.0.) GO TO 709
269       APH=ATAN2(CI,CR)*57.2957795
270 709 WRITE(6,511) S,T,CR,CI,AMAG,APH
271 708 IF(NCUR.LE.1) GO TO 706
272 WRITE(6,712)
273 712 FORMAT(1H1,10X,'T AXIS PROFILE OF FINAL CURRENT'//
      $13X,'S',17X,'T',18X,'REAL',12X,'IMAGINARY',10X,'MAGNITUDE',
      $12X,'PHASE')
274    I=MCUR/2+1
275    DO 713 J=1,NCUR
276       CALL LCCSCR(I,J,S,T,ITYPE)
277       CR=CURR(I,J)
278       CI=CURI(I,J)
279       AMAG=SQRT(CR*CR+CI*CI)
280       IF(AMAG.EQ.0.) APH=0.
281       IF(AMAG.EQ.0.) GO TO 713
282       APH=ATAN2(CI,CR)*57.2957795
283 713 WRITE(6,511) S,T,CR,CI,AMAG,APH
284    GO TO 706
285 711 WRITE(6,714)
286 714 FORMAT(1H1///10X,'FINAL ELEMENT CURRENTS'//5X,
      $5'J',10X,5'S',15X,'T',15X,'CURR',15X,'CURI')
287    CALL LIST(CURR,CURI,MCUR,NCUR)
288 706 CONTINUE

C
289 707 ICOUNT=NUMPAT
290 WRITE(22,'(5F4.0)') ICOUNT,NUMTRK,NUMSKP,IPASS
291 IF(IRECT.EQ.0) GO TO 9998
292 CALL DIRECTV(CORG,UORG,VORG,WORG,US,VS,CORC,FC,IC,MMAX,NMAX,
      $3DIRCRG,DIRENL)
293 WRITE(6,769) DIRENL,DIRENL
294 6769 FORMAT('I',D9.2,'D8.2')
295 9998 CONTINUE
IF(IDISK.EQ.C) GO TO 9997
IF(IDISK.EQ.1 .AND. ISUC.NE. 1) GO TO 9997
C DISK OUTPUT
DO 7000 J=2,35
C CONTINUE
7000 CONTINUE
C WRITE(6,7002)
C 7002 FORMAT('NO DISK SPACE AVAILABLE -- DATA NOT STORED')
C GO TO 9999
C CONTINUE
C SPACE IS AVAILABLE ON RECORD "J"
NUMSKP(J)=1
WRITE(22,8850) NUMPAT,J,NUMSKP,IPASS
WRITE(22,8850) NUMPAT,J,NUMSKP,IPASS
WRITE(6,7003) NUMPAT,J
C 7003 FORMAT('O PATTERN NUMBER ',I4,' HAS BEEN STORED ON RECORD', $ I4,' OF ANTDATA,A507C2')
GO TO 9999
C ENC
C SUBROUTINE DIRCTV(CORG,UORG,VORG,NOR(,,US,VS,CORCOF,IC,MMAX,NMAX, I DIRORG,CIRFNL)
C THIS SUBROUTINE CALCULATES THE DIRECTIVITY OF THE ORIGINAL PATTERN $CIRG, AND OF THE FINAL PATTERN, DIRFNL
C DIMENSION CORG(100),UORG(100),VORG(100),US(500),VS(500),CORCOF(500 $)
C COMMON /LCC/ ITYPE
FORGSC=C.
FSC=0.
FMAX1=0.
FMAX2=0.
DO 10 J=1,101
U=-1.0+(J-1)*C.02
10 CONTINUE
DO 20 K=1,101
V=-1.0+(K-1)*C.02
20 CONTINUE
UVSQ=U*U+V*V
F=0.
IF(UVSC.GE.1.0) GO TO 25
C IF(NORG.LE.0) GO TO 25
IF(NORG.LE.0) GO TO 25
DO 20 L=1,NORG
C 2C F=F+CORG(L)*PAT(U-UORG(L),V-VORG(L),ITYPE)
F=SC+CORG(L)*PAT(U-UORG(L),V-VORG(L),ITYPE)
SC=SC+F**2/UVSQ
IF(ABS(F).GT. FMAX1) FMAX1=ABS(F)
CONTINUE
332  FSC=FCKGSQ
333  FMAX2=FMAX1
334  IF(IC LE 0) GO TO 10
335  CO 30 L=1,IC
336  FO=F+CRCDF(L)*PAT(U-US(L),V-VS(L),ITYPE)
337  FSQ=FSC+F**2/SQRT(1.0-UVSQ)
338  IF(ABS(F) GT FMAX2) FMAX2=ABS(F)
339  IC CONTINUE
340  FORGSQ=FORGSQ*0.0004/FMAX1
341  FSC=FSC*C.CC04/FMAX2
342  DIRORG=4.0*3.14159265/FORGSQ
343  DIRFNL=4.0*3.14159265/FSQ
344  DIRORG=IC.*ALOG10(DIRORG)
345  DIRFNL=LO.*ALCG10(DIRFNL)
346  RETURN
347  END

348  SUBROUTINE INPUT
349  INTEGER PX,PY
350  REAL LX,LY,INITLS,INITLT
351  COMMON /PAT1/ PI,P2,P3,P4,P5,P6,PI,SS(400),TT(400),RR(400)
352  COMMON /PAT2/ 11,12,13,14,15
353  COMMON /LOC/ ITYPE
354  COMMON /MPROP/ MCUR,NCUR
355  COMMON /SYN/ LX,LY
356  NAMELIST /PATIN/ LX,LY,PX,PY,DISX,DISY,INITLS,DELTAS,F INALS,$INITLT,DELTAT,FINALT,NEIMT,ARAO,ITYPE,MCUR,NCUR
357  WRITE(6,10)
358  10 FORMAT(////55X,'SOURCE SPECIFICATIONS'//)
359  PI=3.14159265
360  READ(5,PATIN)
361  IF(ITYPE GT 7) GO TO 990
362  GO TO (106,200,300,400,500,600,700), ITYPE
363  WRIT E(6,2C) ITYPE
364  2C FORMAT(1HO,5X,***ERROR*** ITYPE HAS THE VALUE ',IL1,'"'),2X,
365  EXECUTION TERMINATED)
366  STOP
367  1C PI=LY
368  P2=INITLT
369  P3=DELTAT
370  LX=C.0
371  MCUR=(FINALT-INITLT)/DELTAT+1.5
372  MCR=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 = ',I3)
374 GO TO 999

C
200 PI=LY
11=PY
LY=C,C
P2=DISY
NCUR=PY
MCLR=1
WRITE(6,201) LY,PI,DISY
201 FORMAT(10X,'ITYPE=2 -- UNIFORM LINEAR ARRAY'//
$15X,'LY = ',F7.3//15X,'NUMBER OF ELEMENTS = ',I3//15X,'INTER-ELEMENT SPACING = ',F6.3)
383 GO TO 999

C
300 PI=LY
LY=LY
P2=INITLT
P3=DELTAT
NCUR=(FINALT-INITLT)/DELTAT+1.5
MCLR=1
WRITE(6,301) LY,INITLT,FINALT,DELTAT,NCUR
301 FORMAT(10X,'ITYPE=3 -- TRIANGULAR LINE SOURCE'//
$15X,'LY = ',F7.3//15X,'T VARIATES FROM ',F8.4,' TO ',F8.4,'X',
$'DELTAT = ',F6.3//15X,'NUMBER OF SAMPLE POINTS = NCUR = ',I3)
392 GO TO 999

C
400 PI=LX
LY=LY
P2=LY
P3=INITLS
P4=DELTAS
P5=DELTAT
P6=DELTAT
NCUR=(FINALS-INITLS)/DELTAS+1.5
NCUR=(FINALT-INITLT)/DELTAT+1.5
WRITE(6,401) LX,LY,INITLS,DELTAS,FINALS,INITLT,DELTAT,FINALT,NCUR,
$NCUR
401 FORMAT(10X,'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 GO TO 999

C
500 PI=LX
11=PX
501 P2=LY
406
407        I2=PY
408        P3=DISX
409        P4=DISY
410        MCUR=11
411        NCUR=12
412      WRITE(6,501) LX,LY,PX,PY,DISX,DISY
413 501 FORMAT(LUX,'ITYPE=5 -- UNIFORM RECTANGULAR ARRAY'//
$15X,'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)
414 GO TO 999

CC
415 601 P1=ARAD
416        P3=INITLS
417        P4=INITLT
418        P5=DELTAS
419        P6=DELTAT
420        LX=ARAD*2.
421        LY=LY
422        MCUR=(FINALS-INITLS)/DELTAS+1.5
423        NCUR=(FINALT-INITLT)/DELTAT+1.5
424      WRITE(6,601) ARAD,INITLS,DELTAS,FINALS,INITLT,DELTAT,MCUR,$NCUR
425 601 FORMAT(1CX,'ITYPE=6 -- UNIFORM CIRCULAR APERTURE'//
$15X,'ARAD = ',F7.3//'15X,'INITLS,DELTAS,FINALS: ',3(F8.4,1X)//
$15X,'INITLT,DELTAT,FINALT: ',3(F8.4,1X)//
$15X,'MCUR,NCUR: ',2(I3,2X))
426 GO TO 999

CC
427 701 IL=MCUR
428        I2=NCUR
429        LX=1.0
430        LY=1.0
431        NELMT=IL*I2
432      WRITE(6,701)
433 701 FORMAT(1CX,'ITYPE=7 -- GENERAL ARRAY'//
$15X,'ELEMENT',7X,'SS(J)*,14X,'TT(J)*)
434 CC 702 J=1,NELMT
435      READ(5,703) SS(J),TT(J)
436 703 FORMAT(3F1C,C)
437      WRITE(6,704) J,SS(J),TT(J)
438 704 FORMAT(17X,I3,5X,3(E14.7,5X))
439 702 CONTINUE
440 GO TO 999
441 990 CALL SINPUT(PX,PY,DISX,DISY,INITLS,DELTAS,FINALS,INITLT,$DELTAT,FINALT,NELMT,ARAD,ITYPE)
442 995 RETURN
'3 ENC
SUBROUTINE READ (F,NMAX,NMAX)
DIMENSION F(51,51),I(6),VAL(6)
DO 100 J=1,NMAX
K2=0
2CC CONTINUE
READ (5,1) (I(L),VAL(L),L=1,6)
1 FORMAT(6(I3,F10.0))
DO 20 L=1,6
II=I(L)
IF(II.EQ.0) GO TO 100
K1=K2+1
K2=K1+II-1
DO 10 K=K1,K2
10 F(J,K)=VAL(L)
2CC CONTINUE
IF(K2.LT.NMAX) GO TO 2CC
100 CONTINUE
RETURN
END

SUBROUTINE ORGPAT(F,NMAX,NMAX,STARTU,STARTV,DELTU,DELTAV,
CURR,NCUR)
DIMENSION F(51,51),FI(51,51),FL(51,51)

CALL READ(FUES,FU,MMAX,NMAX)
CALL READ(FU,MMAX,NMAX)
CALL READ(FL,MMAX,NMAX)
RETURN
END

SUBROUTINE ORGPAT(F,NMAX,NMAX,STARTU,STARTV,DELTU,DELTAV,CURR,
CURR,CUR1,NCUR)
REAL F(51,51),CURR(51,51),CURR(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,NMAX
DC 10 N=1,NMAX
10 F(N,N)=0.

THIS CRGPAT WILL BE "WOODWARD-LAWSON" INPUT.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.
A-38

DO 15 M=1,MCUR
15 CURR(M,N)=0.

15 CURR(M,N)=C.

WRITE(6,17)

17 FORMAT(1X,50X,'-- INITIAL COEFFICIENTS --',/45X,'J',6X,
$'UORG(J)',5X,'VORG(J)',6X,'CORG(J)'/)

REAC(5,1) NORG
1 FORMAT(15)
DO 20 IC=1,NORG
20 READ(5,2) US,VS,CORCOF
2 FORMAT(3F10.0)

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

U=STARTU+(P-1)*CELTAU
DL=U-US
V=STARTV+(N-1)*CELTAV
DV=V-VS

3C F(M,N)=F(M,N)+CORCOF*PAT(DU,DV,ITYPE)

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

TEMP=SOURCE(M,N,US,VS,ITYPE)
CURR(M,N)=CURR(M,N)+CORCOF*REAL(TEMP)

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

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

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

SUBROUTINE ANTSYN(ISUC,MMAX,NMAX,FDES,FU,FL,ITRMAX,ISYMM,CORCOF,
 helicopters US,VS,STARTU,CELERU,CELERV,MCENT,NDENT,ITER,FNORM,F)

REAL FDES(51,51),FU(51,51),FL(51,51),F(51,51)

REAL US(500),VS(500),CORCOF(500) UCORC(1),UVRG(1C),URG(1C)

REAL LX,LY,LXY
COMMON /XK/ NORG, CORG, UORG, VORG
COMMON /SYN/ LX,LY

LXY=1./AMAX1(LX,LY)
ITER=0

27 ITER=ITER+1
C

NORMALIZE...

FBIG=F(MCEN,T,NCENT)
DO 150 M=1,MMAX
150 DO 150 N=1,NMAX
151 F(M,N)=F(M,N)/FBIG
152 F(NORM)=F(NORM)/FBIG
153 CONTINUE
-- ITERATION PROCEDURE --

SET IF SPECS ARE MET.

510 DO 24 J=1,NMAX
511 U=STARTU+(J-1)*DELTAV
512 K=1,NMAX
513 V=STARTV+(K-1)*DELTAV
514 UVSU=U*V+V*V
515 IF(UVSU.GT.1.0) GO TO 24
516 IF(FDES(J,K).EQ.99.) GO TO 24
517 IF(FL(J,K).LE.999999 .AND. ABS(F(J,K)).LE.1.E-4) GO TO 24
518 XL=ABS(F(J,K))
519 IF(XL.GT.FU(J,K)) GO TO 25
520 IF(XL.LT.FL(J,K)) GO TO 25
521 24 CONTINUE
522 IC=IC+1
523 IF(SPECs ARE MET -- PROCEED TO PRINTOUT.
524 GO TO 750
525 25 CONTINUE
526 IC=IC+1
527 IF(ITER/ICC*ICC.EQ.ITER) WRITE(6,7117) ITER
528 7117 FORMAT(* ITERATIONS COMPLETED*)
529 IF(ITER-ITRMAX) 22,22,23
530 23 WRITE(6,34) ITRMAX
531 34 FORMAT(*NUMBER OF ITERATIONS EXCEEDED; 15/
" PRINTOUT OF INTERMEDIATE RESULTS FOLLOWS.*)
532 GO TO 750
533 22 CONTINUE
534 FIND RELATIVE MAXIMUM ERROR
535 CALL SEARCH(J,K,VAL,FDES,FU,FL,F,MMAX,NMAX,STARTU,STARTV,DELTAV,
$DELTAV)
536 IF(VAL.NE.0.0) GO TO 248
537 VAL EQUALS ZERO
538 248 WRITE(6,100)
539 100 FORMAT(* ERROR IN SUBROUTINE SEARCH -- VAL=0.*
540 GO TO 750
541 248 U1=(J-1)*DELTAV+STARTU
542 V1=(K-1)*DELTAV+STARTV
543 IF(ABS(U1).LT.0.1*DELTAV) U1=0.
544 IF(ABS(V1).LT.0.1*DELTAV) V1=0.
545 IF(LX.EQ.0.0) GO TO 1000
546 IF(U1.NE.0.0 .AND. ABS(U1).LE. 0.5/LX) VAL=VAL/2.
547 1000 IF(V1.NE.0.0 .AND. ABS(V1).LE. 0.5/LY) VAL=VAL/2.
548 1000 IF(LY.EQ.0.0) GO TO 1000
549 1000 IF(LX.NE.0.0 .AND. ABS(LX).LE. 0.5/LX) VAL=VAL/2.
550 1000 IF(LY.NE.0.0 .AND. ABS(LY).LE. 0.5/LY) VAL=VAL/2.

A-39
A-40

551 IF(ISYMM .NE. 4) GO TO 1001

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557 "BASIC CORRECTION -- INDEPENDENT OF ISYMM"

558 US(IC) = UI

559 VS(IC) = VI

560 CORCOF(IC) = VAL

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

562 CALL CHECK(IC, VAL, US, VS, CORCOF, DTAU, DELTAU, DELTAV)

563 26 CONTINUE

564 IF(ISYMM .LT. 2) 261, 260, 260

565 260 CONTINUE

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

567 IF(UI.EQ.0.) GO TO 261

568 IC=IC+1

569 US(IC)=UI

570 VS(IC)=VI

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

572 CALL CHECK(IC, VAL, US, VS, CORCOF, DTAU, DELTAU, DELTAV)

573 261 IF(ISYMM .LT. 2) 259, 27, 259

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

575 259 IF(V1.EQ.0.) GO TO 262

576 IC=IC+1

577 US(IC)=-UI

578 VS(IC)=-VI

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

580 CALL CHECK(IC, VAL, US, VS, CORCOF, DTAU, DELTAU, DELTAV)

581 262 IF(ISYMM .LT. 3) GO TO 27

582 "QUADRILATERAL SYMMETRY ONLY -- ISYMM = 3, 4"

583 IF(U1.EQ.0. OR. V1.EQ.0.) GO TO 2745

584 IC=IC+1

585 US(IC)=-UI

586 VS(IC)=-VI

587 CORCOF(IC)=VAL

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

589 CALL CHECK(IC, VAL, US, VS, CORCOF, DTAU, DELTAU, DELTAV)

590 2745 IF(ISYMM .LT. 4 OR. ITEMP .EQ. 1) GO TO 27

591 "FOR BIQUADRILATERAL SYMMETRY ONLY -- ISYMM = 4"

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

SUBROUTINE SEARCH(I1,J1,VAL,FDES,FU,FL,F,MMAX,NMAX,STARTU,STARTV,DELTAV)
REAL FU(51,51),FL(51,51),F(51,51),FDES(51,51)
VAL=0.
EMAX=0.
I2=I1
J2=J1
CC 10 J=I2,MMAX
U=STARTU+(J-1)*DELTAV
CC 20 K=J2,NMAX
V=STARTV+(K-1)*DELTAV
UVSQ=U*U+V*V
IF(UVSQ.GT.1.0) GO TO 20
FITR=ABS(F(I1,K))
IF(FDES(I1,K).EQ.99.0) GO TO 20
IF(FITER.GT.FU(I1,K)) GO TO 2000
IF(FL(I1,K).LE.1.0.E-4) GO TO 20
IF(FITER.GT.FL(I1,K)) GC TO 20
X=FDES(I1,K)
ERROR = FITER-X
IF(ABS(ERROR)-ABS(EMAX)) 20,20,21
EMAX=ERROR
VAL=SIGN(ERROR,F(I1,K)*(X-FITER))
II=J
J1=K
2C CONTINUE
1C CONTINUE
WRITE(6,10C) II,J1,VAL
100 FORMAT(5X,'**SEARCH**',18,18,5X,F7.4)
RETURN

SUBROUTINE CHECK(IC,VAL,US,VS,CCRCOF,DELTAV)
REAL US(500),VS(500),CCRCOF(500)
IF(IC.EQ.1) RETURN
CU=C.1*DELTAV
CV=C.1*DELTAV
IC=IC-1
U=US(IC)
W=VS(IC)
DO 10 J=1,IC1
IF(ABS(U-US(J)).LE.U.ANO.ABS(V-VS(J)).LE.OV) GO TO 20
10 CONTINUE
RETURN
C
CORCOF(J)=CORCOF(J)+VAL
IC=IC-1
RETURN
ENC

SUBROUTINE UPDATE(IC,US,VS,CORCOF,F,MMAX,NMAX,FINORM,STARTU,STARTV,$DELTAU,DELTAV)
DIMENSION F(51,51),US(500),VS(500), CORCOF(500)
COMMON /LOC/ ITYPE
C=CORCOF(IC)
DO 10 J=1,MMAX
U=STARTU+(J-1)*DELTAU
DU=U-US(IC)
DO 10 K=1,NMAX
V=STARTV+(K-1)*DELTAV
DV=V-VS(IC)
10 F(J,K)=F(J,K)+C*PAT(DU,DV,ITYPE)
CORCOF(IC)=CORCOF(IC)/FINORM
RETURN
ENC

FUNCTION PAT(U,V,ITYPE)
THIS SUBPROGRAM GIVES THE BASIC CORRECTION PATTERN F(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 ARRAY.

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

VERSION 1  LEVEL 1
DATE OF LAST REVISION: 73/193 JULY 12, 1973

THIS WORK SUPPORTED BY NASA GRANT NGR 47-004-103
FOR FURTHER INFORMATION CONTACT:
E.L. STUTZMAN DEPT. OF ELEC. ENGR. 951-6624.
E.L. COFFEY DEPT. OF ELEC. ENGR. 951-5494

COMMON /PATI/ P,P2,P3,P4,P5,P6,P1,SS(400),TI(400),RR(400)
COMMON /PAT2/ 11,12,13,14,15
IF(ITYPE.GT.7) GO TO 990
GO TO (100,200,300,400,500,600,700), ITYPE

IF(ITYPE.LT.1) WRITE(6,10) ITYPE
10 FORMAT(1HC,5X,'***ERROR*** ITYPE HAS THE VALUE ',I11,'; 2X,  
  *EXECUTION TERMINATED')
STOP

ITYPE = 1 -- UNIFORM LINE SOURCE.
FLEN=P1
CONTINUE
PAT=1.0
IF(V.NE.0.) PAT = SIN(PI*P1*V)/(PI*P1*V)
GO TO 999

ITYPE = 2 -- UNIFORM LINEAR ARRAY
FLEN=PI
NELPT=II
PAT=1.0
IF(V.NE.0.) PAT=SIN(PI*PI*V)/(II*SIN(PI*PI*V/II))
GO TO 999

ITYPE = 3 -- TRIANGULAR LINE SOURCE.
FLEN=PI/2.
PAT=1.0
IF(V.NE.0.) PAT = (SIN(FLEN*PI*V)/(FLEN*PI*V))**2
GO TO 999

ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE
FLS=P1
FLT=P2
ARG1=PI*P1*U
ARG2=PI*P2*V
IF(ARG1) 401,402,401
401 IF(ARG2) 403,404,403
403 PAT=SIN(ARG1)/ARG1*SIN(ARG2)/ARG2
GO TO 999
404 PAT=SIN(ARG1)/ARG1
GO TO 999
405 PAT=SIN(ARG2)/ARG2
GO TO 999
406 PAT=1.0
GO TO 999

ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY
ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.

ITYPE = 7 -- GENERAL ARRAY

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

THIS SUPPRCGRAP CALCULATES THE CURRENT AT POINT (M,N) DUE TO
THE PATTERN AT POINT (U,V).

ITYPE = 1 -- UNIFORM LINE SOURCE LOCATED AT S=0.
ITYPE = 2 -- UNIFORM LINEAR ARRAY LOCATED AT S=0.
A-45

3 -- TRIANGULAR LINE SOURCE LOCATED AT S=0.
4 -- UNIFORM RECTANGULAR APERTUR.
5 -- UNIFORM RECTANGULAR ARRAY.
6 -- UNIFORM CIRCULAR APERTURE.
7 -- GENERAL ARRAY.

I TYPE > 7 -- SPECIAL SOURCE (FUNCTION SPSOR(M,N,U,V,I TYPE) 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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COMPLEX TEMP, CEXP, IMAG, SPSOR
COMMON /PAT1/ P1, P2, P3, P4, P5, P6, P1, SS(400), TT(400), RR(400)
COMMON /PAT2/ 11, 12, 13, 14, 15

IMAG=(0.0, 1.0)
CALL LOCSCOR(M, N, S, T)
IF (I TYPE.GT.7) GO TO 990
GO TO (100, 200, 300, 400, 500, 600, 700), I TYPE

I TYPE .LT. 1

WRITE(6,10) I TYPE
10 FORMAT (1HC, 5X, '***ERROR***', X, 'EXECUTING TERMINATED')

ITYPE = 1 -- UNIFORM LINE SOURCE

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

ITYPE = 2 -- UNIFORM LINEAR ARRAY

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

ITYPE = 3 -- TRIANGULAR LINE SOURCE

300 CONTINUE
FLEN=P1
CGN=ABS(2.*T/P1)
A-46

751 SOURCE = 2./P1*CEXP(-IMAG*2.*PI*T*V)*(1.-CON)
752 IF(CON.GT.1) SOURCE = (0.,0.,0.)
753 GC TO 999

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

C C C
C ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY C C C
757 500 CONTINUE
C FLS=P1
C FLT=P2
758 SOURCE = CEXP(-IMAG*2.*PI*(S*U+V*T))/(P1*P2)
759 GC TO 999

C C C
C ITYPE = 6 -- UNIFORM CIRCULAR APERTURE C C C
760 600 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*P2)
763 GO TO 999

C C C
C ITYPE = 7 -- GENERAL ARRAY C C C
764 700 CONTINUE
765 SOURCE = CEXP(-IMAG*2.*PI*(U*S+V*T))/(II*II)
766 GC TO 999
767 999 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,II,II,II,II,II
775 COMMON /LCC/ ITYPE
C C C
776 IF(ITYPE.GT.7) GC TO 990
777 GC TO (100,200,300,400,500,600,700), ITYPE
778 WRITE(6,10) ITYPE
779 10 FORMAT(1HC,5X,**ERROR*** ITYPE HAS THE VALUE ',I11,';2X,
80 *EXECUTION TERMINATED*)
81 STOP
C 100 CONTINUE
C INITL=I2
C DELTAT=P3
782 S=C.
783 T=P2+(N-1)*P3
784 GO TO 999
C
C 200 CONTINUE
C PY=I1
C DISY=P2
786 S=C.
787 T=(N-11/2-1)*P2
788 IF(11/2*2.EQ.11) T=T+0.5*P2
789 GO TO 999
C
C 300 GO TO 100
C
C 400 CONTINUE
C INITLS=P3
C INITLT=P4
C DELTAS=P5
C DELTAT=P6
792 S=P3+(M-1)*P5
793 T=P4+(N-1)*P6
794 GO TO 999
C
C 500 CONTINUE
C PX=I1
C PY=I2
C DISX=P3
C DISY=P4
796 S=(M-11/2-1)*P3
797 T=(N-12/2-1)*P4
798 IF(11/2*2.EQ.11) S=S+0.5*P3
799 IF(12/2*2.EQ.12) T=T+0.5*P4
800 GO TO 999
C
C 600 GO TO 400
C
C 700 CONTINUE
C NELMT=(M-1)*I2+N
803 S=SS(NELMT)
804 T=TT(NELMT)
805 GO TO 999
C
C 999 CALL SPLOC(M,N,S,T)
808 999 RETURN
809 END
SUBROUTINE CURRENT(CURR, CURR, MCUR, NCUR, US, VS, CURCIF, IC)

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


COMPLEX SOURCE, TEMP
REAL CURR(51, 51), CURR(51, 51), US(5, GO), VS(5, 50), CURCIF (500)
REAL UORG (100), VORG (100), CURG (100)
COMMON /START/ NORG, UORG, VORG, CURG
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) + CURG(I) * REAL(TEMP)
CURR(M, N) = CURR(M, N) + CURG(I) * AIMAG(TEMP)
200 CONTINUE
IF (IC.LE.0) RETURN

DU 10 M = 1, MCUR
DO 10 N = 1, NCUR
DO 10 I = 1, IC
TEMP = SOURCE(M, N, US(I), VS(I), ITYPE)
CURR(M, N) = CURR(M, N) + CURCIF(I) * REAL(TEMP)
CURR(M, N) = CURR(M, N) + CURCIF(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 1C COLUMNS TO A PAGE. 72/266 VERSION 3

DIMENSION A(51, 51), U(51), V(51)
WRITE(6, 6969)
6969 FORMAT(1H1)
628 CC 10 J = 1, 51
629 IC U(J) = STARTU+(J-1)*DU
630 IC V(J) = STARTV+(J-1)*DV
631 N2 = N/10.+C.99
632 M2 = M/1C.+0.99

824
A-49

833 DC 100 J1=1,M2
834 DC 200 K=1,N2
835 M3=1+(J1-1)*10
836 M4=M3+9
837 IF(M4.GT.N) M4=N
838 N3=1+(K-1)*10
839 N4=N3+9
840 IF(N4.GT.N) N4=N

C PRINT CUT A HEADING
C
841 WRITE(6,20) (V(I),I=N3,N4)
842 20 FORMAT(1H1,16X,F6.3,9(4X,F6.3))
843 WRITE(6,30)

C PRINT A PAGE
C
844 K2=(M4-M3+1)*6
845 DO 4000 J=1,(M4-M3+1*)6
846 J2=J/6
847 IF(J2#6-J) 27,28,27
848 J3=J2+M3-1
849 WRITE(6,29) U(J3),A(J3,I),I=N3,N4)
850 CC TO 4000
851 27 WRITE(6,31)
852 4000 CONTINUE
853 IF(N4.LE.N AND M4.EQ.M) GO TO 300
854 200 CONTINUE
855 100 CONTINUE
856 300 RETURN
857 29 FORMAT(3X,F6.3,'+',5X,10(F9.4,1X))
858 30 FORMAT(1CX,1H+,10(1OH--------+))
859 31 FORMAT(1CX,*1*)
860 ENC

SUBROUTINE PRCFIL(DATA1,NPT,NUMPAT)
861 INTEGER SF
862 INTEGER OUTPUT(101)
863 INTEGER BLANK,PLUS,SLASH,STAR
864 REAL DATA(401,2),BOUND(101)
865 REAL DATA1(401,2)
866 DATA BLANK,PLUS,SLASH,STAR '/','+',',','/*'
867 GO 47 J=1,401
868 DATA(J,1)=DATA1(J,1)
869 DATA(J,2)=DATA1(J,2)
870 47 CONTINUE
C FIND THE RANGE OF DEPENDENT DATA AND SCALE IF NECESSARY
C
872 IF(NPT.GT.600) GO TO 999
873 BIG=-1.E10
874 SMALL = 1.E10
875 GO 47 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)

1 CONTINUE
DIFF=ABS(BIG-SMALL)
SF=0
IF(DIFF.LT.1.) GO TO 10
IF(DIFF.LT.100.) GO TO 21
DO 2 J=1,10
IF(DIFF*10.**(J).GT.100.) GO TO 2
SF=J
GO TO 20
2 CONTINUE

400 WRITE(6,1CC)
100 FORMAT('YOUR DATA IS TOO LARGE FOR THIS PROGRAM.')
RETURN

1 DO 3 J=1,10
3 K=11-J
IF(DIFF*10.**K.GT.100.) GO TO 3
SF=-K
GO TO 20
3 CONTINUE
GO TO 400

20 CONTINUE

2 DO 4 J=1,NPT
4 DATA(J,2) = DATA(J,2)*10.**(SF)

CALCULATE BOUNDS
21 SCALE=DIFF/100.
DO 5 J=1,101
K=J-1
5 BOUND(J)=(BIG-K*SCALE)*10.**(SF)

PRINT TITLE
WRITE(6,64C) NUMPAT
64C FORMAT(26X,'PATTERN NUMBER ',15//)
IF (SF.EQ.0) GO TO 200
WRITE(6,4004) SF
4004 FORMAT(53X,'SCALE FACTOR IS 10*',12//)
WRITE(6,65C) (BOUND(J),J=1,101,20)
65C FORMAT(/X,5(F7.3,13X),F7.3,2X,'REAL',5X,'C9.9)
DO 6 J1=1,NPT
6 CUTPUT(K)=BLANK
IF((J-1)/IC*10-(J-1)) 62,61,62
IF((J-1)/IC*10-(J-1)) 62,61,62
61 CUTPUT(1)=PLUS
GO TO 87
62 CUTPUT(1)=SLASH
CUTPUT(101) = SLASH

CUTPUT(1)=SLASH
CUTPUT(101) = SLASH
SUBROUTINE CCNTUR(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 DCON=DELTA(INCREMENT) BETWEEN CONTOURS FOR CONUR SUBROUTINE
C CLOW=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 CCL AT LEAST L
DIMENSION COL(101)
DATA ALPHA/1HC,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9/
DATA BLANK,OUT/1H,1H7/

IF(K.LE.1,OR,L.LE.1) RETURN
CINT=CINT
CLOW=CLOW
CMAX=CMAX
WRITE(6,87) NUMPAT
87 FCRMAT(1HC,'FCR THE PATTERN NUMBERED',15)
IF(CINT) 99,99,100
99 DCON=-1.E27
SMALL=1.E27
GO 98 I=1,K
DO 98 J=1,L
IF(A(I,J).GT.BIG) BIG=A(I,J)
IF(A(I,J).LT.SMALL) SMALL=A(I,J)
98 CONTINUE
CONINT=(BIG-SMALL)/10.

DELCON=C.5*CONINT

CCNLOW=SALL+DELCON

CONMAX=BIG-DELCON

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

FORMAT(IHO, DELCON=',F10.5,3X,'CONLOW=',F10.5,3X,'CONMAX=',

F10.5,3X,'CONINT=',F10.5)

PRINT LEVEL DESIGNATIONS

MCHAR=ABS((CCNMAX-CONLOW)/CONINT+1.1)

CON=CCNMAX+CONINT

CO 40 M=1, MCHAR

ICON=M-1

CON=CON-CONINT

WRITE(6,72) ICON,CON

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

CONTINUE

WRITE HEADING

DC 32 J=1,101

COL(J)=BLANK

CONTINUE

IF(L.GT.51) GO TO 33

DC 30 J=1,101,2

COL(J)=DCT

CONTINUE

GO TO 34

CONTINUE

IF(L.GT.51) GO TO 33

WRITE(6,200)

FORMAT(IHO)

N1=L*2

IF(N1.GT.101) N1=101

WRITE(6,101) (COL(J),J=1, N1)

FORMAT(/IHC,14X,101A1)

CONTINUE

J2=1

CO 2 J=1, L

J2=J2+2

ICON=-1

CON=CCNMAX+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-DELCN)) 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.GE.51) COL(J)=ALPHA(ICON+1)

GO TO 2
A-53

1C12  5C  CONTINUE
1C13  2  CONTINUE
1C14  WRITE(6,140) (COL(J1),J1=1,101)
1C15  14C  FORMAT(1H1,13X,'*',1Cl41)
1C16  1  CONTINUE
1C17  RETURN
1C18  END

1C19  SUBROUTINE PATCON(RDATA,MMAX,NMAX,ICODE,CONLOW,CONMAX,CONINT,$STARTU,STARTV,DELTU,DELTAV,NUMPAT,ISYMM)
1C20  REAL RDATA(51,51),UAXIS(11),LOW(12),HIGH(12)
1C21  INTEGER CUTPUT(101),LEVEL(12),BLANK
1C22  DATA BLANK/' '/
1C23  DATA LEVEL/I'C',' ','21,'30,'40,'50,'60,'70,'80,'90','-','+'/
1C24  CALL DATE(I,J,K)
1C25  WRITE(6,10) I,J,K,NUMPAT
1C26  10 FORMAT(1H1, 'PATTERN CONTOUR SUBPROGRAM',34X,'DATE = ',A2,'-',A2,$+',-',A2,3CX,'PATTERN NUMBER',I5/)
1C27  IF(ICODE.EQ.0) WRITE(6,11)
1C28  IF(ICODE.EQ.1) WRITE(6,12)
1C29  IF(ICODE.EQ.2) WRITE(6,13)
1C30  11 FORMAT(42X,'CONTOUR PLOT OF THE DESIRED PATTERN'////)
1C31  12 FORMAT(46X,'CONTOUR PLOT OF THE INITIAL PATTERN'////)
1C32  13 FORMAT(45X,'CONTOUR PLOT OF THE FINAL PATTERN IN DB.'////)
1C33  FINALU=STARTU+(MMAX-1)*DELTU
1C34  FINALV=STARTV+(NMAX-1)*DELTV
1C35  U1=STARTU
1C36  U2=FINALU
1C37  V1=STARTV
1C38  V2=FINALV
1C39  NCOUNT=MMAX
1C40  NCOUNT=NMAX
1C41  IF(ISYMM.EQ.1) 70,30,20
1C42  2C UBIG=AMAX1(AABS(STARTU),ABS(FINALU))
1C43  U1=-UBIG
1C44  U2=UBIG
1C45  NCOUNT=2*NCOUNT-1
1C46  IF(ISYMM.EQ.2) GO TO 70
1C47  30 VBIG=AMAX1(AABS(STARTV),ABS(FINALV))
1C48  V1=-VBIG
1C49  V2=VBIG
1C50  NCOUNT=2*NCOUNT-1
1C51  70 CONTINUE
1C52  C
1C53  C
1C54  C
1C55  C
1C56  C
1C57  ESTABLISH LOWER AND UPPER LIMITS
NUMCON=(CONMAX-CONLOi)/CONINT+1.5
DELCON=CONINT/2.

DO 71 J=1,NUMCON
LOW(J)=CCNLW+(J-1)*CONINT-DELCON
HIGH(J)=LOW(J)+CONINT-DELCON/2.

1057 CONTINUE

LOW(11)=-1.E3C
HIGH(12)=1.E30
HIGH(11)=LOW(1)
LOW(12)=HIGH(NUMCON)
MSKIP=100/(MCOUNT-1)
NSKIP=100/(NCOUNT-1)

CU=(U2-U1)/10.
DO 40 I=1,11
UAXIS(I)=U1+(I-1)*DU
WRITE(6,42) (UAXIS(I),I=1,11)
42 FORMAT(13X,11(F7.4,3X)/16X,11(9X))

DU=(U2-U1)/100.
CV=(V2-V1)/100.
N1=NSKIP-1
DO 50 N=1,101,NSKIP
V=V2-(N-1)*CV
DO 51 K=1,101
51 OUTPUT(K)=BLANK
DO 60 M=1,101,NSKIP
U=U1+(K-1)*DU
IF(U*U+V*V.GT.1.0) GO TO 60
60 CONTINUE

FIND F(U,V)

IJ=1
IK=1

J=(U-STARTU)/DELTAF+1.5
K=(V-STARTV)/DELTAV+1.5
IF(J.GE.1.0 .AND. J.LE.MMAX) IJ=0
IF(K.GE.1.0 .AND. K.LE.NMAX) IK=0

1085 101 IF(IJ) 2CC,102,2CC
1086 102 IF(IK) 3CC,100,3CC

2CC IF(ISYMM-1) 6C,6C,2C1
201 J=1.5-(U+STARTU)/DELTAF
1085 201 IF(J.GE.1.0 .AND. J.LE.MMAX) IJ=0
1086 1090 IF(IJ) 6C,202,60
1087 202 IF(IK) 3CC,10CC,3CC

3CC IF(ISYMM.EQ.0 .OR. ISYMM.EQ.2) GO TO 60
1092 1093 IF(K.EQ.1.0 .AND. K.LE.NMAX) IK=0
1094 1095 IF(IK) 60,100,60

1CC IF(REDATA(J,K)) GO TO 1001
1096 IF(F.LT.LOW(1)) GO TO 1002

C

DO 61 K=1,NUMCON
IF(F.GT.LOW(K) .AND. F.LE.HIGH(K)) GO TO 62
61 CONTINUE
1002 OUTPUT(K)=LEVEL(12)
GO TO 60
1001 OUTPUT(K)=LEVEL(11)
GO TO 60
62 OUTPUT(M)=LEVEL(K)

6C CONTINUE
WRITE(6,64) (OUTPUT(K),K=1,101),V
64 FORMAT(7X,F7.4,1X,'.',101A1,'.',9X,F7.4)

IF(N1.EQ.0) GO TO 50
55 K=1,N1
WRITE(6,56)
56 FORMAT('')
55 CONTINUE

WRITE(6,43) (UAXIS(I),I=1,1L)
43 FORMAT(16X,3(A1,' : ',E14.7,TO ',E14.7,4X))
RETURN

SUBROUTINE LIST(CURR,CURI,MCUR,NCUR)
C
C THIS SUBROUTINE LISTS ARRAY ELEMENT COORDINATES AND CURRENTS
C
DIMENSION CURR(51,51),CURI(51,51)
DO 10 M=1,MCUR
DO 10 N=1,NCUR
J=(M-1)*NCUR+N
CALL LCCSCR(M,N,S,T)
WRITE(6,1CC) J,S,T,CURR(M,N),CURI(M,N)
10 CONTINUE
100 FCRMAT(3X,14,5X,4(E14.7,2X))
RETURN
1135 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, LOCسور, 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 ITEMPL are read from disk storage. ITEMP is the number of correction coefficients of the original pattern. ITEMPL 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, NORG, IC, (UORG(J), VORG(J), CORG(J), J=1, ITEMP), (US(J), VS(J), CORCOF(J), J=1, ITEMPL), 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 $P_1, P_2, \ldots$ and $I_1, I_2, \ldots$. 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 4I1 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 4I1 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 OPlU, 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

\[ \text{ITEMP} = \text{Number of original correction coefficients, CORG.} \]

\[ \text{ITEMP1} = \text{Number of correction coefficients (not including original ones), CORCOF.} \]

\[ \text{MMAX} = \text{Number of points of first subscript of arrays of pattern magnitude, current magnitude, and current phase used in PLOT2 and PLOT3.} \]

\[ \text{NMAX} = \text{Number of points of second subscript of arrays of pattern magnitude, current magnitude, and current phase.} \]

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

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

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

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

7.4.2 Definition of Some Important Real Variables Used in ANTDATA

\[ \text{A( , )} = \text{Two dimensional array with MMAX by NMAX entries. It must be dimensioned to handle these entries. It is used for the pattern magnitude in dB, the current magnitude, and the current phase.} \]
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 PLOTIC

Purpose:

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

Usage:

CALL PLOTIC (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:

i. 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.

ii. 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:
1. 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.
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.

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, 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, W, P, KODE)
Description of Parameters:

\[ \begin{align*}
XI & - \text{ Abscissa of the projected point.} \\
YJ & - \text{ Ordinate of the projected point.} \\
M & - \text{ Number of horizontal points.} \\
N & - \text{ Number of vertical points.} \\
P & - \text{ PLOT CODE; IF } P = -1 \text{ INVISIBLE TO VISIBLE} \\
& \quad \text{1 VISIBLE TO INVISIBLE} \\
& \quad \text{0 VISIBLE TO VISIBLE OR INVISIBLE TO INVISIBLE.} \\
\end{align*} \]

KODE - Hidden Line Code (See Subroutine PLOT3)

COMMON Blocks Required:

\[ \begin{align*}
\text{COMMON /ARRAY/} \ A \\
\text{COMMON /THREE6/ ANGA, ANGB, HV, D, SH, SV} \\
\text{COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, QX, QY, QZ, SD} \\
\end{align*} \]

Subroutine and Function Subprograms Required: None.

7.5.2 Virginia Tech Subroutines

VPI UTILITY SUBPROGRAMS

Subprograms | Purpose
--- | ---
DATE | To return the current month, day, and year.
STIME | To return the time of day in ten thousandths of an hour (Integer Format)
TIMEON | To set the interval timer to zero
TIMECK | To return the amount of CPU time used in hundredths of seconds since the last call to TIMEON.

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

VPI PLOTTER SUBROUTINES

Subroutine | Purpose
--- | ---
AXIS | To draw a labeled axis of a desired length with annotated tic marks every inch.
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.

```plaintext
//B0663PL3 JOB 507C2,COFFEY
/*MAIN TIME=19,LINES=3,REGION=250K,CARDS=0
/*PRIORITY PRIORITY
/*FORMAT PL,FORMS=PFGURAGV,PEN=XXFIAE,DDNAME=CALCAMP
// EXEC FORTGCG,PARM.GO='PAPER=39,PTIME=119',EP=MAIN
//FORT.SYSLIN DD *
/*
//GO.SYSLIB DD
// DD DSN=VPI.PLOTLIB,DISP=SHR
// GO.SYSLIB DD
// DD *
/*
//GO.FT22FOO DD DSN=ANTDATA.A507C2,UNIT=3330,VOL=SER=tJSERPK,DISP=SHR
// GO.FT06F001 DD SYSOUT=A,DCB=(BLKSIZE=133,RECFM=F)
// GO.SYSLIB 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 0D), 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 SUPPLIED 
THROUGH UNIT 5 (SYSIN). ALL OUTPUT IS CHANNELED TO UNIT 6 
(SYSPRINT) AND THE PLOTTING DEVICE (PLOT).

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 A 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 AU(151),AV(151)
INTEGER TITLE(20)
REAL INITS,INITLT
REAL LOWCON
INTEGER OPT1,OPTH,OPT2,OPT3,PK,PY
COMPLEX CTEMP,CI
COMMON /PLT1/ PTS
COMMON /ARRAY/ A
COMMON /PAT1/ P1,P2,P3,P4,P5,P6,PL5,SS(400),TT(400),RR(400)
COMMON /PAT2/ I1,I2,I3,I4,I5
COMMON /LOC/ ITYPE
IPAGE=0
PI=3.14159265
CI=CMPLX(0.0,1.0)
CALL STIME(ITIME)
TIME=0.
9999 CONTINUE
A-76

21 CALL TIMECN
22 IPAGE=IPAGE+1
23 CALL DATE(11,J1,K1)
24 CALL STIME(IT)
25 IHR=IT/10000
26 IFR=IT-IHR*10000.
27 FHR=IFR/10000.
28 FM=FHR*60.
29 IMIN=FM
30 ISEC=(FM-IMIN)*60
31 IHR=ICVT(IHR)
32 IIN=ICVT(IMIN)
33 ISEC=ICVT(ISEC)
34 IPC=ICVT(IPAGE)
35 WRITE(6,1) 11,J1,K1,IHR,IMIN,ISEC,IPG
36 1 FORMAT(1H1,12X,'ANTDATA I VERSION 1 LEVEL 2',
37 $8X,VPI EE DEPT.*,5X,DATE = 'A2,*-*,A2,*-*,A2,*-*,A2,*-*,A2,*-*,A2,*-*,A2,10X,PAGE 00,*A2 */)

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

37 READ(5,10,END=999) NUMPAT,NUMTRK
38 10 FORMAT(14I5)
39 IF(NUMPAT.EQ.0) GO TO 999
40 WRITE(6,704) NUMPAT
41 704 FORMAT(* PLOT OUTPUT FOR PATTERN*,15,*;')
42 READ(22)NUMTRK,20 NUM
43 20 FORMAT(A4)
44 IF(NUM.EQ.NUMPAT) GO TO 51
45 GO TO 30 I=2,25
46 READ(22*I,20) NUM
47 IF(NUM.EQ.NUMPAT) GO TO 50
48 30 CONTINUE

C C NUMPAT IS NOT ON DISK
C
49 WRITE(6,60) NUMPAT
50 60 FORMAT(1H0,*PATTERN NUMBER*,15,* WAS NOT LOCATED -- PROGRAM Halt')
51 GO TO 999

C C NUMPAT FOUND ON UNEXPECTED TRACK
C
52 50 WRITE(6,60) NUMPAT,NUMTRK,1
53 60 FORMAT(1H0,*PATTERN NUMBER*,15,* WAS NOT FOUND ON TRACK*,12,
54 $9 BUT WAS LOCATED ON TRACK*,12) NUMTRK=1
55 51 CONTINUE

C C REGEN PROCESSING
C
56 READ(5,10) NMAX,NMAX
57 READ(22)NUMTRK,7C) ITEMP,ITEMP1
58 70 FORMAT(104X,2A4)
READ(22,NUMTRK,101) NUMPAT,TITLE,ISYM,ITER,ISUC,FMAGM,IVSKE,
$NCRT,IC,(US(J),VORG(J),VURG(J),CORG(J),J=1,ITEMP)$
$((US(J),VS(J),CORG(J),J=1,ITEMP))$,
$ITYPE,P1,P2,P3,P4,P5,P6,
$SMP,(SS(J),T{T(J),J=1,400}),11,12,13,14,15,MCUR,NCUR

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

C   READ OPTIONS FOR PATTERN MAGNITUDE

C

READ(5,29) OPT1U,OPT1V,OPT2,OPT3
29 FORMAT(11I1)
IF(OPT1U-1) 80,81,80
81 CONTINUE
READ(5,31) CONST
IF(MMAX.LE.1) GO TO 80
DO 90 J=1,4001
90 U=(J-1)*0.0005-1.0
SUM=0.
91 CONTINUE
IF(MMAX.LE.1) GO TO 80
DO 90 K=1,NCRT
90 VT=K
SUM=SUM+CORG(K)*PAT(U-UORG(K),CONST-VORG(K),ITYPE)
IF(1C.LE.0) GO TO 90
DO 91 K=1,IC
91 SUM=SUM+CORG(K)*PAT(U-UORG(K),CONST-VORG(K),ITYPE)
91 CONTINUE
PTS(J)=2C.*ALOG10(ABS(SUM))
WRITE(6,92) CONST
92 FORMAT(1CU-AXIS PROFILE PLOT REQUESTED -- V = ',F6.3)
CALL PLOT1((-1.0,1.0,4001),2,CONST,NUMPAT)
IF(OPT1V-1) 82,83,82
83 CONTINUE
READ(5,31) CONST
IF(MMAX.LE.1) GO TO 82
DO 90 J=1,4001
90 V=(J-1)*0.0005-1.0
SUM=0.
DO 91 K=1,NCRT
91 SUM=SUM+CORG(K)*PAT(U-UORG(K),V-VORG(K),ITYPE)
IF(1C.LE.0) GO TO 90
DO 91 K=1,IC
91 SUM=SUM+CORG(K)*PAT(U-UORG(K),V-VORG(K),ITYPE)
91 CONTINUE
PTS(J)=2C.*ALOG10(ABS(SUM))
WRITE(6,93) CONST
93 FORMAT(1CU-AXIS PROFILE PLOT REQUESTED -- U = ',F6.3)
CALL PLOT1((-1.0,1.0,4001),1,CONST,NUMPAT)
IFpresso+UPT3) 85,85,84
84 CONTINUE
C   GENERATE PATTERN ARRAY
C
READ(5,31) LOWCON,DASH
IF(MMAX.LE.1 OR NMAX.LE.1) GO TO 239
DELTAU=2.0/(MMAX-1)
DELTAV=2.0/(NMX-1)
WRITE(6,761) LOWCON,LOWCON
101 FORMAT*CPATTERN IS NOW BEING GENERATED. IF PATTERN < ' ,F7.4,
90 PATTERN = ',F7.2)
102 IF(ITYPE GT 5) GO TO 5000
C
C   LOAD UP AU AND AV
C
1C5  DO 2CCG I=1,MMAX
106  U=(I-1)*DELTAW
1C7  2CCG AU(I)=PAT(U,O.,ITYPE)
108  DO 2010 J=1,NMAX
109  V=(J-1)*DELTAV
110  201C AV(J)=PAT(V,O.,ITYPE)

C   BEGIN
C
111  U=-1.0-DELTAV
112  DO 2020 M=1,MMAX
113  U=U+DELTAV
114  V=-1.0-DELTAV
115  DO 2020 N=1,NMAX
116  V=V+DELTAV
117  TEMP=0.
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(IC.LE.O) GO TO 2020
123  DO 2040 K=1,IC
124  I=ABS(U-US(K))/DELTAV+1.5
125  J=ABS(V-VS(K))/DELTAV+1.5
126  2040 TEMP=TEMP+CURCOF(K)*AU(I)*AV(J)
127  204C A(M,N)=20.*ALOG10(ABS(TEMP))
128  GC TO 239
129  5CCG CONTINUE
130  DO 200 M=1,MMAX
131  U=-1.0+(M-1)*DELTAV
132  DO 201 N=1,NMAX
133  V=-1.0+(N-1)*DELTAV
134  TEMP=0.
135  DO 242 I=1,NORG
136  242 TEMP=TEMP+CORG(I)*PAT(U-UORG(I),V-VORG(I),ITYPE)
137  IF(IC.LE.O) GO TO 2021
138  DO 202 I=1,IC
139  202 TEMP=TEMP+CURCOF(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(3PTZ) 210,210,211
146  211 RFAD59T31) CONLOW,CONMAX,CONINT
147  31 FORMAT(6FI0.0)
148  IF(MMAX.LE.1 .OR. NMAX.LE.1) GO TO 230
149  DO 257 M=1,MMAX
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
154 220 FORMAT('CONTOUR PLOT OF PATTERN REQUESTED')
   $1'  LOWEST CONTOUR = ',F7.2/
   $1'  HIGHEST CONTOUR = ',F7.2/
   $1'  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(IHO,'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('O TWO AND THREE DIM. PLOTS CANCELLED SINCE SOURCE IS
   $ONE DIMENSIONAL')
163 85 CONTINUE

C END OF PATTERN
C 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(IHO,'THE SOURCE IS AN ARRAY -- THIS PGM IS FOR CONTINUOUS SOURCES ONLY')
171 401 CONTINUE
172 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 CELTAT=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=P2/4CC0.
195 CELTAT=P6
196 DELTAS=P5
197 GO TO 41C
*98 407 CONTINUE
98 IF(ITYPE.EQ.6) 410,409,410
A-80

409 INITLS=P3
201 FINALS=P3+2.*P1
202 INITLT=P4
203 FINALT=P4+2.*P1
204 P5=P1/2000.
206 DELTAT=P6
207 DELTAS=P5
208 CONTINUE
209 READ(5,29) OPTIM,OPTIV,OPT2,OPT3
210 IF(OPTIM-1) 302,301,302
211 CONTINUE
212 READ(5,31) CONST
213 IF(IA.EQ.1) GO TO 3000
214 IF(INV.MAX.LE.1) GO TO 302
215 J=1
216 IF(DELTAT.NE.0.) J=1.5+(CONST-INITLT)/DELTAT
217 DO 303 I=1,4001
218 CTEMP=(0,0,0.0)
219 IF(NORG.LE.0) GO TO 304
220 DO 305 K=1,NORG
221 CTEMP=CTEMP+CORG(K)*SOURCE(I,J,UORG(K),VORG(K),ITYPE)
222 IF(IV.LE.0) GO TO 303
223 DO 306 K=1,IC
224 CTEMP=CTEMP+CORGOF(K)*SOURCE(I,J,US(K),VS(K),ITYPE)
225 PTS(I)=CABS(CTEMP)
226 WRITE(6,307) CONST
227 FORMAT('OS-AXIS PROFILE PLOT REQUESTED -- T=',F6.3)
228 CALL PLOTH(INITLT,FINALT,4001,2,CONST,NUMPAT)
229 CONTINUE
230 IF(CPTIV-1) 311,310,311
231 CONTINUE
232 READ(5,31) CONST
233 IF(IA.EQ.1) GO TO 3000
234 IF(INV.MAX.LE.1) GO TO 322
235 I=1
236 IF(DELTAS.NE.0.) I=1.5+(CONST-INITLT)/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 IF(IV.LE.0) GO TO 313
243 DO 316 K=1,IC
244 CTEMP=CTEMP+CORGOF(K)*SOURCE(I,J,US(K),VS(K),ITYPE)
245 PTS(J)=CABS(CTEMP)
246 WRITE(6,317) CONST
247 FORMAT('OS-AXIS PROFILE PLOT REQUESTED -- S=',F6.3)
248 CALL PLOTH(INITLT,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(OPT2+CPT3) 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),ITYPE)
DO 332 K=1,IC
CTEMP=CTEMP+CORCOF(K)*SOURCE(M,N,US(K),VS(K),ITYPE)
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
CALL PLOT2 (MCUR,NCUR,CONLOW,CONMAX,CONINT,NUMPAT,DASH)
IF(CPT3) 360,360,361
READ(5,31) CONLOW,DASH
IF(IA.EQ.1) GO TO 360
WRITE(6,355)
FORMAT(1HO,'THREE DIMENSION PLOT OF CURRENT MAGNITUDE REQUESTED')
CALL PLOT3 (MCUR,NCUR,NUMPAT)
CONTINUE
IF(PMAX.LE.1.OR.NMAX.LE.1) WRITE(6,23)
CONTINUE

C END OF CURRENT MAGNITUDE
C
C READ OPTIONS FOR CURRENT PHASE
C
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

C GENERATE CURRENT PHASE
C
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),ITYPE)
A-82

300 DO 532 K=1,IC
301 532 CTEMP=CTEMP+CORCOF(K)*SOURCE(M,N,US(K),VS(K),ITYPE)
302 CREAL = REAL(CTEMP)
303 CIMAG = AIMAG(CTEMP)
304 A(M,N) = ATAN2(CIMAG,CREAL)*180./PI
305 CONTINUE
306 53C CONTINUE
307 53C CONTINUE
308 IF(OPT2) 550,551,551
309 551 READ(5,31) CONLOW,CONMAX,CONINT
310 IF(IA.EQ.1) GO TO 560
311 IF(PMAX.LE.1.OR.NMAX.LE.1) GO TO 560
312 WRITE(6,540) CONLOW,CONMAX,CONINT
313 54C FORMAT('CONTOUR PLOT OF CURRENT PHASE REQUESTED /
314   $'\LOWEST CONTOUR = ',F7.2/
315 $'\HIGHEST CONTOUR = ',F7.2/
316 $'\CONTOUR INTERVAL = ',F7.2)
317 CALL PLOT2(MCUR,MCUR,CONLOW,CONMAX,CONINT,NUMPAT,DASH)
318 55C IF(OPT3) 560,560,561
319 561 IF(IA.EQ.1) GO TO 560
320 56C CONTINUE
321 IF(PMAX.LE.1.OR.NMAX.LE.1) WRITE(6,23)
322 52C CONTINUE
323 CALL TIMECK(ISEC)
324 FMIN=ISEC/6000.
325 WRITE(6,897) FMIN
326 897 FORMAT('EXECUTION TIME: ',F6.2,' MINUTES.').
327 TIME=TIME+FMIN
328 GO TO 9999
329 999 WRITE(6,600)
330 60C FORMAT('*** END OF EXECUTION ***')
331 CALL PLOT(0.0,0.0,-4)
332 WRITE(6,898) TIME
333 898 FORMAT('TOTAL EXECUTION TIME: ',F7.2,' MINUTES.').
334 CALL STIME(JTIME)
335 IT=JTIME-ITIME
336 FMIN=IT/10000.*60.
337 WRITE(6,899) FMIN
338 899 FORMAT('TOTAL ELAPSED TIME: ',F7.2,' MINUTES.').
339 STOP
340 END

SUBROUTINE PLOT1(PSRT,PEND,IP,CODE,CONST,NUMPAT)

C
C
C SUBROUTINE PLOT1
C
C WRITTEN BY: S. R. KAUFMAN
C
C DATE: 73-113 APRIL 23, 1973
INPUT:
PPSTRT. -- BEGINNING OF PLOT
PEND -- END OF PLOT
IP -- NUMBER OF POINTS TO BE PLOTTED
CODE -- LABELLING VARIABLE. IF CODE=0: LABEL='IHEAT';
       IF CODE=1: LABEL='U='; IF CODE = 2: LABEL = 'I=
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,-8,88THETA = 0.,8)
CALL NUMBER(-3,-8,-2,CONST,0.,3)
GO TO 6
3 IF(CODE.GT.1) GO TO 4
CALL SYMBOL(-1.3,-8,2,1HU,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-V,0.,2)
CALL SYMBOL(2.4,-4,2,2H+V,0.,2)
GO TO 6
4 IF(CODE.GT.2) GO TO 5
CALL SYMBOL(-1.3,-8,2,1HU,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-U,0.,2)
CALL SYMBOL(2.4,-4,2,2H+U,0.,2)
6 CONTINUE
PDEL=(PSTRT-PEND)/IP
PTIC=ABS(PSTRT-PEND)/10.
CALL AXIS(-5,0,1,1H,1400,PSTRT,PTIC)
PTRE=PSTRT+(6.*PTIC)+.00001
PTIC2=PTIC+.00001
CALL AXI(S10,0,1H,1400,0,PTS1,PTIC2)
CALL PLOT(-1.0,0.,3)
CALL PLOT(0.0,0.,3)
CALL PLOT(0.0,8,2)
CALL PLOT(0.0,0.,3)
CALL SYMBOL(-1.05,-9,-2,1MO,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(PTS1)LE-50. PTS1=-50.
FS=((PTS1)/10.)*5.5
CALL PLCT(-5.,Fsq3)
CC
THETS=((PSTRT-(IW1*PODEL))*(5.))/(ABS(PSTRT))
FDBS=((PTS(IW1))/10.)*6.5
IF(FDBS.LT.0.5) GO TO 1
CONTINUE
CALL PLCT(THETS,FDBS,2)
1 CONTINUE
CALL SYMBOL(-5.0,-0.8,0.125,IOHPATTERN = ,0.,1J)
FNUM=FLCATINUMPAT)
CALL SYMBOL(-3.87,-0.8,0.125,FNUM,0.,-1)
CALL AXES(-5.5,0.5,17HFAR FIELD PATTERN,17,5.0,90.,-90.,10.)
CALL PLCT(8.,-1.,-3)
5 RETURN
ENC
SURCUFINE

SUBROUTINE PLOTIC(PSTRT,PEND,IP,CODE,CONST,N(lMPAT)
C
C SUBROUTINE PLOTIC
C
C WRITTEN BY: S. R. KAUFMAN
C
DATE: 73-113 APRIL 24,1973
C
C INPUT:
C
PSTRT -- BEGINNING OF PLOT
PEND -- END OF PLOT
IP -- NUMBER OF POINTS TO BE PLOTTED
CODE -- LABELLING VARIABLE. IF CODE=0: LABEL IS 'THT= '
COD=1: LABEL IS 'S = '; IF CODE=2: LABEL IS 'I = '
CONST -- CONSTANT PARAMETER FOR LABEL.
NUPPAT -- PATTERN NUMBER FOR LABEL.
C
INTEGER NAME(2), CODE
CALL FACTOR(0.5)
CALL PLOT18.91.9-3D

COMMON /PLT1/ PTS
I=0
IF(CODE.GT.0) GO TO 3
41 CALL SYM6EBOL(-1.2,-0.6,0.2,8HTHETA = ,0.,8)
5 CALL NUMBER(0.3,-0.8,0.2,CONST,0.0,3)
3 GO TO 6
11 CALL SYMBOL(-1.0,-0.8,0.2,1H5,0.0,1)
52 CALL SYMBOL(-0.9,-0.8,0.2,3H = ,0.,0,3)
53 CALL NUMBER(-0.2,-0.8,0.2,CONST,0.0,3)
54 CALL SYMBOL(-2.6,-0.4,0.2,2H-T,0.0,2)
55 CALL SYMBOL(2.4,-0.4,0.2,2H+T,0.0,2)
416        GO TO 6
417       4 IF(CODE.GT.2) GO TO 5
418       CALL SYMPC(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(-5.0,-0.4,1H ,1,4.0,0.0,PSTRT,PTIC)
427       PSTRE=PSTRT+(6.0*PTIC)+0.00001
428         PTIC2=PTIC+0.00001
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(1.0,0.0,3)
432       CALL PLOT(0.0,5.8,2)
433       CALL PLOT(0.0,5.8,3)
434       CALL PLOT(0.0,5.8,2)
435       CALL PLOT(0.9,0.0,3)
436       X=0.05
437       CC 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       PSTRS=5.0*PSTRT
443       GMAX=0.0
444       DO 11 IW1=1,IP
445       IF(PST(IW1),GMAX) GMAX=PST(IW1)
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       PLSA=((PST(IW1))/ASCLE)*5.+0.5
453       CALL PLOT(-5.0,PST,3)
454       DO 7 IW1=1,IP
455       THETA=(PSTRT-(IW1*PDEL))
456       THETS=(THETA/(ABS(PSTRT)))*5.
457       APTS=((PST(IW1))/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(-5.5,0.5,16H SOURCE MAGNITUDE,16,5.0,90.0,0.0,0,ATIC)
466       CALL SYMBOL(-5.0,-0.8,0.125,10HPATTERN = 0,10)
467       FNUM=FLOAT(NUMPAT)
468       CALL NUMBER(-3.5,-0.8,C.125,FNUM,0.9,1)
469       CALL PLOT(8.0,-1.0,-3)
470       5 RETURN
471       ENC
SUBROUTINE PLCT1P(PSTRT, PEND, IP, CODE, CONST, NUMPAT)

SUBROUTINE PLCT1P

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 = "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, 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.,-.8,.2,1HS=0,.1)
CALL SYMBOL(-9, -8, 2, HTHETA = 0, 3)
CALL NUMBER(-2, -8, 2, CONST=0, 3)
CALL SYMBOL(-2.6, -.4, 2, H+T, 0, 2)
CALL SYMBOL(2.4, -.4, 2, H+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, HTHETA = 0, 3)
CALL NUMBER(-2, -8, 2, CONST=0, 3)
CALL SYMBOL(-2.6, -.4, 2, H+T, 0, 2)
CALL SYMBOL(2.4, -.4, 2, H+T, 0, 2)
GO TO 6
5 IF(CODE.GT.2) GO TO 6
CALL SYMBOL(-1.2, -6., 2, HTHETA = 0, 8)
CALL NUMBER(-.2, -.2, 8, CONST=0, 3)
CALL SYMBOL(-2.6, -.4, 2, H-5, 0, 2)
CALL SYMBOL(2.4, -.4, 2, H+S, 0, 2)
GO TO 6
6 PDEL=(PSTRT-PEND)/IP
PTIC=(ABS(PSTRT-PEND))/10.0
CALL AXIS(-.0,0,0,.1H ,1,4,0,0,PSTRT,PTIC)
PSTRE=PSTRT+(6.0*PTIC)+0.00001
PTIC2=PTIC+0.00001
CALL AXIS(1.0,1H ,1,4,0,PSTRE,PTIC2)
CALL PLOT(-1,0,3)
CALL PLOT(1,0,2)
CALL PLOT(0,5.8,2)
CALL PLOT(0,5.8,3)
CALL SYMBOL(-.05,-.4,.2,10H,0.,1)
CALL PLOT(-.05,-.4,.2,10H,0.,1)

506 CALL PLOT((-0.05,-0.4,0.2,10H,0.,1))
507 CALL PLOT((-0.05,-0.4,0.2,10H,0.,1))
508 X=C.05
509 Y=0.5+(J-1)*1.0
510 CALL PLOT((-X,Y,3))
511 CALL PLOT((-X,Y,3))

1C CALL PLOT((X,Y,2))
512 CALL PLOT((X,Y,2))
513 CALL PLOT((-0.05,-0.4,0.2,10H,0.,1))
514 DC 1 IW1=1,IP
515 THETA=(PSTR1-(IW1*PDEL))
516 THETS=((THETA/(ABS(PSTR1)))*5.
517 PANGS=PTS(IW1)/180.*4.+4.5
518 IF(IW1.EQ.1)CALL PLOT((THETS,PANGS,3))
519 IF(IW1.EQ.1)GO TO 1
520 CALL PLOT((THETS,PANGS,2))
521 CONTINUE
522 CALL AXIS(-5.5,0.5,14HAPERTURE PHASE,14,8.,90.,-180.,45.)
523 CALL SYMBOL((-5.0,-0.8,0.125,10HPATTERN=0.,10)
524 FNLM=FLOAT(NUPPAT)
525 CALL NUMBER((-3.5,-0.8,0.125,FNUM,0.,-1)
526 CALL PLOT((-3.5,-0.8,0.125,0.,-1)
527 RETURN
528 END

SUBROUTINE PLOT2(N,M,CONLOW,CONMAX,CONINT,NUPPAT,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

C

530 DIMENSION A(151,151),RA(151),RB(151),X(151),Y(151)
531 COMMON ARRAY/ A
532 CALL PLOT((-5.0,0.0,-3))
533 CALL FACTOR (0.7)
534 MS=M
535 NS=N
536 RATIO=MS/NS
537 SCALE=10.
538 ANM=AMAX0(N-1,M-1)
539 IF(RATIO-1.0)1,1,2
540 1 SX=ANM
541 SY=RATIO*ANM
542 GC TO 3
543 2 SX=1./RATIO*ANM
544 SY=ANM
545 3 SMA=AMAX1(SX,SY)
546 SS=SX/SMAX
547 SYS=SY/SMAX
548 IF(CONINT)4,4,5
549 4 CALL CNLAL(N,R,CNTRL0,CMAX,CNTRAL,0)
550 GC TO 7
A-88

551 5 CNTRAL=CNTRNT
552 IF(CNTRMAX.EQ.CNTRLOW) GO TO 6
553 CMAX=CNTRMAX
554 CNTRLO=CNTRLOW
555 GO TO 7
556 6 CALL CNLAL(N,M,CNTRLO,CMAX,CNTRAL,1)
557 7 CONTINUE
558 CNTRLOW=CNTRLO
559 CNTRMAX=CMAX
560 CNTRNT=CNTRAL
561 CALL PLOT(IS,SS,0.,SYS,SCALE)
562 CALL PLOT(C0,SS,0.,SYS,SCALE)
563 CALL PLOT(IS,0.,SYS,SCALE)
564 CALL PLOT(1.00,0.25,2)
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 FNUP=NUMPAT
572 CALL NUMBER(0.88,2.075,0.12,FNUM,90.,-1)
573 125 YCNNA=1.0/SMAX
574 DELTAX=SX/FLOAT(N-1)
575 X(1)=0.0
576 Y(1)=0.0
577 RB(1) = A(1,1)
578 DO 27 J=2,N
579 RB(J)=A(J,1)
580 27 X(J)=X(J-1)+DELTAX
581 DELTAY=SY/FLOAT(M-1)
582 DO 28 J=2,M
583 28 Y(J)=Y(J-1)+DELTAY
584 DO 118 K=2,M
585 DO 30 J=1,N
586 RA(J)=RB(J)
587 30 RB(J)=A(J,K)
588 DO 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 ,40
597 40 IF(RL-RB(J)) 42,50,50
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
YS=YY
IF(RS-RA(J-1)) 52, 52, 53
52 IF(RS-RA(J)) 60, 60, 54
RS=RA(J-1)
XS=X (J-1)
YS=Y (K-1)
GO TO 52
RS=RB(J)
XS=X (J)
YS=Y (K)
GO TO 60
RM=HR
XM=XX
YM=YY
IF(RM-RS) 62, 62, 61
IF(RM-RL) 62, 62, 62
RM=RA(J-1)
XM=X (J-1)
YM=Y (K-1)
IF(RM-RS) 64, 64, 63
IF(RM-RL) 70, 64, 64
RM=RB(J)
XM=X (J)
YM=Y (K)
YCS=YS*YCONA
YCM=YM*YCONA
YCL=YL*YCONA
YS=YS-SY
YM=YM-SY
YL=YL-SY
XCS=XS/SMAX
XCM=XP/SMAX
XCL=XL/SMAX
RC=CNTRL0
80 IF (RC.GTO.CMAX ) GO TO 110
81 IF ( RC .NE. RM ) GO TO 91
RC.EQ. RM ) GO TO 100
91 IF(RC-RS) 100, 95, 99
92 IF(RC-RM) 96, 93, 94
93 XPA=XCM
YPA=YCM
94 IF(RC-RL) 97, 103, 110
95 Q=0.0
96 Q = (RC-RS)/(RM-RS)
77 XPA = XCS-Q*(XCS-XCM)
YPA = YCS-Q*(YCS-YCM)
99 Q = (RC-RS)/(RL-RS)
XPB = XCS-Q*(XCS-XCL)
YPB = YCS-Q*(YCS-YCL)
160 IF(RC-DASH) 10115, 10115, 10116
161 10115 XPH1=Q.5*XPA*XPB
162 YPB1=Q.5*YPA*YPB
163 IF(ABS (XPA-XPB)>.001) 5001, 5002, 5002
164 5001 IF(ABS (YPA-YPB)>.001) 100, 5002, 5002
CALL PLOT(SCALE*XPA+2.,SCALE*YPA+0.25,3)
GO TO 100
CALL PLOT(SCALE*XPB1+2.,SCALE*YPB1+0.25,2)
GO TO 100
IF(ABS(XPA-XPB)-.001)5003,5004,5004
IF(ABS(YPA-YPB)-.001)1005004,5004
CALL PLOT(SCALE*XPA+2.,SCALE*YPA+0.25,3)
CALL PLOT(SCALE*XPB+2.,SCALE*YPB+0.25,2)
GO TO 100
RC = RC + CNTRAL
GO TO 80
XPA = XCL
YPA = YCL
GO TO 99
C=(RC-RM)/(RL-RM)
XPA=XCM-C*(XCM-XCL)
YPA=YCM-C*(YCM-YCL)
GO TO 99
GO TO L(112,118)
ASSIGN 118 TO L
RR =RB(J-1)
XX =X (J-1)
YY =Y (K)
GO TO 37
CONTINUE
CALL PLOT (SCALE+6.,0.,-3)
RETURN
END

SUBROUTINE CNTRLAL(N,M,CNTRL0,CMAX,CNTRAL,NC)
DIMENSION X(151,151)
COMMON /ARRAY/ X
XMAX=X(1,1)
XMIN=X(1,1)
GO 10 J=1,M
GO 10 I=1,N
XPA=AMAX1(XMAX,X(I,J))
XMIN=AMIN1(XMIN,X(I,J))
IF(NC.EQ.1) GO TO 40
IF(XMAX.EQ.0.) GO TO 20
SN=XMIN/XMAX
IF(SN).LE.20 GO 20,30
2C XCON=ABS(XMAX)
IF(ABS(XMIN).GT.ABS(XMAX))XCON=ABS(XMIN)
CNTRL0=XCON/10.
CMAX=XMAX
CNTRAL=CNTRL0*AINT(XMIN/CNTRAL)
RETURN
3C XCON=ABS(XMAX-XMIN)
CNTRL0=XCON/10.
CNTRAL=XMIN
CMAX=XMAX
RETURN
4C CMAX=CNTRL0*AINT(XMAX/CNTRAL)
CNTRAL=CNTRL0*AINT(XMIN/CNTRAL)
RETURN
END
SUBROUTINE PLCT(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 PLCT(X(1),Y(1),3)
CALL PLCT(X(2),Y(2),2)
RETURN
END

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.
DISTS - DISTANCE FROM SURFACE TO EYE WHEN PERSPECTIVE IS
         CALCULATED -- MDISTS > 6 USUALLY WONT' 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 MELT 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

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,D,SH,SV
COMMON /THREE7/ SL,SM,SN,CX,CY,CZ,QX,QY,QZ,SD

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

REFERENCE: HOWARD JESPERSON, IOWA STATE UNIVERSITY.

MODIFIED FOR USE AT VPI BY: ROBERT O. KEPHART.
S. R. KAUFFMAN
W. L. STUTZMAN
E. L. COFFEY

SUBROUTINE PLOT3(N,M,NUMPAT)

C***A=N BY M MATRIX OF DATA POINTS
C***BORDS= PLOT LABELING
C***NCHAR= NUMBER OF CHARACTERS IN THE PLOT LABEL+SPACES
C

COMMON /ARRAY/ A
COMMON /THREE6/ ANGA,ANGB,HV,D,SH,SV
COMMON /THREE7/ SL,SM,SN,CX,CY,CZ,QX,QY,QZ,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 PLOT(8., -2., -3)
CALL PLOT(-4., 0., 2)
CALL PLOT(-4., 8., 2)
CALL PLOT(0., 8., 2)
CALL PLOT(0., 0., 2)
CALL PLOT(0., 0., 2)
CALL SYMBOL(0.3, 1.0, 0.12, 10, HPATTERN = 90., 10)
FNLM = FLOAT(NUMPAT)
CALL NUMBER(0.3, 2.13, 90, 12, FNUM, 90., -1)
CALL PLOT(1.5, -.2, -.3)

C **** ****
ANCA = (YAW + 270.) * 0.174532
ANGB = PITCH * 0.174532
H = SIZE
C DIRECTION COMPONENTS TO THE EYE.
SL = -COS( ANCA ) * COS( ANGB )
SM = -SIN( ANCA ) * COS( ANGB )
SN = -SIN( ANGB )
IF ( ABS( SN ) .NE. 1.0 ) GO TO 10
WRITE(6, 20)
20 FORMAT ('1*', 20X, 201', 'YOU ARE ATTEMPTING TO LOCATE 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
GL TC 2060
C: WRITE(6,100) CX, CY, CZ
C: WRITE(6,100) QX, QY, QZ
100 FORMAT(1X, 3F15.3)
080 2060 Z(2) = A(L, L)
A-94

781  \[ Z(1) = A(I, J) \]
782  CC 1000 J=1,N
783  IC 1000 K=1,N
784  \[ Z(1) = \text{MIN}(Z(1), A(J, K)) \]
785  \[ Z(2) = \text{MAX}(Z(2), A(J, K)) \]
786  1000 CONTINUE
787  RANGE = \{ Z(2) - Z(1) \}
788  DCL= L.O
789  IF(SCALE .NE. 0) DOL=T/RANGE*SCALE
790  C SCALE THE SURFACE TO MAKE A "CUBE".
791  DO 30 I = 1, N
792  \[ A(I, J) = A(I, J) - Z(1) \] * DOL
793  30 CONTINUE
794  Z(1) = C.C
795  Z(2) = T
796  20do CALL THREE2 ( X, Y, Z, XP, H, V, KODE)
797  DO 2130 I = 1, 8
798  \[ H(I) = ( (XP(I) - OX) * SM - ( H(I) - QY ) * SL ) \] * SD
799  \[ V(I) = ( V(I) - QZ ) \] * SD
800  2130 CONTINUE
801  2100 H(10) = H(1)
802  H(9) = H(1)
803  DD 1001 J = 1
804  \[ H(9) = \text{MIN}(H(9), H(J)) \]
805  \[ H(10) = \text{MAX}(H(10), H(J)) \]
806  1001 CONTINUE
807  2120 V(9) = V(1)
808  V(10) = V(1)
809  DO 1002 J = 1, 8
810  \[ V(9) = \text{MIN}(V(9), V(J)) \]
811  \[ V(10) = \text{MAX}(V(10), V(J)) \]
812  1002 CONTINUE
813  IF( MGN .EQ. 0) GO TO 2140
814  S = H
815  IF( MGN .EQ. 1) S = 1.5
816  \[ SH = S / (H(10) - H(9)) \]
817  \[ SV = S / (V(10) - V(9)) \]
818  \[ SH = \text{SIGN}(\text{MIN}(SH, SV), SH) \]
819  \[ SV = \text{SIGN}(SH, SV) \]
820  IF( MGN .EQ. 1) CALL PLOT (0.0, 2.0, -3)
821  CALL SYMBOL( (H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 14, 'O', 0.0, 1)
822  CALL SYMBOL( (H(3) - H(9)) * SH, (V(3) - V(9)) * SV, 14, 'M', 0.0, 1)
823  CALL SYMBOL( (H(2) - H(9)) * SH, (V(2) - V(9)) * SV, 14, 'Z', 0.0, 1)
824  CALL SYMBOL( (H(5) - H(9)) * SH, (V(5) - V(9)) * SV, 14, 'N', 0.0, 1)
825  CALL PLOT(0.0, 0.05, -3)
826  CALL PLOT( (H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 3)
827  CALL PLOT( (H(2) - H(9)) * SH, (V(2) - V(9)) * SV, 2)
828  CALL PLOT( (H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 2)
829  CALL PLOT( (H(3) - H(9)) * SH, (V(3) - V(9)) * SV, 2)
830  CALL PLOT( (H(1) - H(9)) * SH, (V(1) - V(9)) * SV, 2)
831  CALL PLOT( (H(5) - H(9)) * SH, (V(5) - V(9)) * SV, 2)
832  IF( MGN .EQ. 3) GO TO 2139
833  CALL PLOT( (H(6) - H(9)) * SH, (V(6) - V(9)) * SV, 2)
834  CALL PLOT( (H(2) - H(9)) * SH, (V(2) - V(9)) * SV, 2)
835  CALL PLOT( (H(4) - H(9)) * SH, (V(4) - V(9)) * SV, 2)
836  CALL PLOT( (H(7) - H(9)) * SH, (V(3) - V(9)) * SV, 2)
SUBROUTINE THREE2 (X, Y, Z, XP, H, V, KODE)
C FIND THE CORNERS OF THE ROTATED CUBE.
C
DIMENSION X(2), Y(2), Z(2), H(10), V(10), XP(6)

L = 0
DO 180 I = 1, 2
C
J = 1, 2
K = 1, 2
L = L + 1
CALL THREE4 (X(I), Y(J), Z(K), XP(L), H(L), V(L), KODE)
CONTINUE
CONTINUE
CONTINUE
RETURN
END

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

SUBROUTINE THREE3 (X, Y, N, M, H, V, K, KODE)
C DRAW THE FIGURE.
COMMON /THREE6/ ANGA, ANGB, HV, D, SH, SV
COMMON /THREE7/ SP, SN, CX, CY, CZ, QX, QY, QZ, SD
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)

MV = 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

DC DO 1060 J = 1, M
C
G = 0
YJ = J
DC DO 1030 I = 1, NN
C
L = L + LD
XI = L
CALL THREE5 (XI, YJ, N, M, P, KODE)
PEN = UP
IF (P) 510, 520, 530
51C CONTINUE
IF (Q) 540, 550, 540
52C CONTINUE
IF (Q) 610, 1020, 610
53C CONTINUE
IF (Q) 540, 550, 540
54C CONTINUE
PEN = DOWN
GC TO 170
55C CONTINUE
IF (I .EQ. 1) GO TO 170
DI = CD
TC = L - LC
T = TC * D1
P1 = Q
IF (ABS(DI) .LT. END) GO TO 570
CALL THREE5 (T, YJ, N, M, P, KODE)
C
IF (PO .EQ. C) GO TO 565
TC = T
P1 = PO
T = T - DI
GO TO 560
565 T = T + DI
GO TO 56C
570 CONTINUE
575 T = TO
IF ( P1 * P ) 170, 170, 580
580 CONTINUE
590 CONTINUE
600 ZP = A(L-LC,J)+(T-L+LD)*(A(L,J)-A(L-LD,J))/LD
CALL THREE4(T,YJ,ZP,XP,HH,VV,KODE)
610 HH = (( XP-QX)*SM- (HH - QY )*SL ) * SD
VV = ( VV - QZ ) * SD
HH = ( HH - H(9) ) * SH
VV = ( VV - V(9) ) * SV
CALL PLOT ( HH, VV, PEN )
620 PEN = 5 - PEN
GO TO 170
610 PEN = DOWN
615 DI = OC
620 TO = L - LD
T = TO + DI
P1 = Q
625 IF ( ABS( DI ) .LT. END ) GO TO 630
CALL THREE5 ( T,YJ,N,M,PO,KODE )
DI = DI * 0.5
IF ( PO .EQ. 0 ) GO TO 625
630 T = T
P1 = PO
T = T + DI
GO TO 620
635 T = T - DI
GO TO 62C
640 CONTINUE
645 T = TC
IF ( P1 * Q ) 600, 600, 590
170 CALL THREE4 ( XI , YJ , A( L, J ) , XP , HH , VV , KB(L)
650 VV = ( VV - QZ ) * SD
660 HH = (( XP-QX)*SM- (HH - QY )*SL ) * SD
190 HH = ( HH - H(9) ) * SH
200 VV = ( VV - V(9) ) * SV
210 CALL PLOT ( HH, VV, PEN )
220 Q = P
230 CONTINUE
240 L = L + LD
250 LC = -LD
260 DD = -DD
1060 CONTINUE
C
C
C
C
C
C
C
DRAW LINES ALONG THE X-AXIS.

C

1110 CONTINUE
C

L = 0
LC = 1
CC = 0.5 * LD
L = L + LD
YJ = L
CALL THREE5 (XI, YJ, N, M, P, KODE)
PEN = UP

IF (P) 1510, 1520, 1530
1510 CONTINUE
IF (Q) 1540, 1550, 1540
1520 CONTINUE
IF (Q) 1610, 2010, 1610
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 IF (PO .EQ. 0) GO TO 1565
1570 CONTINUE
1580 CONTINUE

ZP = A(I, L - LD) + (T - L + LD) * (A(I, L) - A(I, L - LD)) / LD
CALL THREE4 (XI, T, ZP, XP, HH, VV, KODE)

HH = (XP - QX) * SM - (HH - QY) * SL * SI

VV = (VV - QZ) * SD
HH = (HH - H(9)) * SH
VV = (VV - V(9)) * SV
CALL PLOT (HH, VV, PEN)

PEN = 5 - PEN
GO TO 1170
CONTINUE

PEN = DOWN
SUBROUTINE THREES (XI,YJ,M,N,P,KODE)
C SEE IF A POINT IS VISIBLE.

DIMENSION Z(151,151)
COMMON /THREE6/ ANGA, ANGB, HV, DO, SH, SV
COMMON /THREE7/ SM, SN, CX, CY, CZ, QX, QY, QZ, SD
COMMON /ARRAY/ Z
INTEGER CUM, CNT, P
REAL I, J, II, JJ
IF (KODE .EQ. 1) GO TO 78
IR = XI
JC = YJ
ZB = Z (IR + JC)
IF (XI .EQ. IR) GO TO 2
ZB = Z (IR + JC) + (XI - IR) * (Z (IR + 1 + JC) - Z (IR, JC))
GO TO 4
ZB = Z (IR + JC) + (YJ - JC) * (Z (IR, JC + 1) - Z (IR, JC))
CONTINUE
XEND = C.C
CX = 0.0
YMULT = C.C
ZMULT = C.C

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

IC CONTINUE
YEND = 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

IC CONTINUE
YEND = C.C

20 CONTINUE
CUP = 0
CNT = 0
P = 0
XP = XI
YP = YJ

3C CONTINUE
II = AINT(XB)
JJ = AINT(YB)
XSTEP = DX
YSTEP = DY
IF (XB EQ. II) GO TO 40
IF (OX 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 NE. XEND) GO TO 80
IF (J NE. YEND) GO TO 80
XB = CX + XMULT * (J - CY)
YB = CY + YMULT * (I - CX)
IF (DX LT. 0.0) GO TO 55
IF (XB LT. I) GO TO 60

5C XB = I
GC TO 65

55 IF (XB LT. I) GO TO 50

6C YB = J

65 CONTINUE
ZB = CZ + ZMULT * (XB - CX)
IR = I
JC = J
IF (YB NE. J) GO TO 70
ICX = I - DX
A-101

1134  \( ZS = Z( IR, JC ) - DX \ast ( XB - 1 ) \ast ( Z(IDX,JC) - Z(IR,JC) ) \)
1135  GO TO 75
1136  \( \text{JOY} = J - \text{DY} \)
1137  \( ZS = Z( IR, JC ) - DY \ast ( YB - J ) \ast ( Z( IR, JODY ) - Z( IR, JC ) ) \)
1138  75 CONTINUE

1139  SGN = 1
1140  IF ( JOY .LT. ZS ) SGN = -1
1141  CUM = CUM + SGN
1142  CNT = CNT + 1
1143  IF ( IABS ( CUM ) .EQ. CNT ) GO TO 30
1144  GO TO 90

1145  78 \( P = 1 \)
1146  GO TO 95
1147  80 CONTINUE
1148  \( P = 1 \)
1149  IF ( CUM ) 84, 86, 90
1150  84 \( P = -1 \)
1151  GO TO 90
1152  86 CONTINUE
1153  IF ( JOY .LE. CZ ) GO TO 90
1154  \( P = -1 \)
1155  90 CONTINUE
1156  95 RETURN

ENC

1158  FUNCTION PAT(U,V,ITYPE)

C
C THIS SUBPROGRAM GIVES THE BASIC CORRECTION PATTERN F(U,V).
C
C ITYPE = 1 -- UNIFORM LINE SOURCE LOCATED AT S=0.
C ITYPE = 2 -- UNIFORM LINEAR ARRAY LOCATED AT S=1.
C ITYPE = 3 -- TRIANGULAR LINE SOURCE LOCATED AT S=0.
C ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE.
C ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY.
C ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.
C ITYPE = 7 -- GENERAL ARRAY.
C
C ITYPE > 7 -- SPECIAL SOURCE (FUNCTION SPECPT(U,V,ITYPE) WILL
C BE CALLED.)

VERSION 1 LEVEL 1


THIS WORK SUPPORTED BY NASA GRANT NGR 47-G04-103

FOR FURTHER INFORMATION CONTACT:
W.L. STUTZMAN DEPT. OF ELEC. ENGR. 951-6624.
E.L. COFFEY DEPT. OF ELEC. ENGR. 951-5494

1159 COMPLEX TEMPL,CEXP,IMAG
1160 COMMON /PAT1/ P1,P2,P3,P4,P5,P6,P7,SS(100),IT(100),RR(100)
1161 COMMON /PAT2/ 11,12,13,14,15
IF (ITYPE.GT.7) GO TO 990
GO TO (1CC,2CC,300,400,500,6CO,700),ITYPE
ITYPE .LT. 1
WRITE(6,10) ITYPE
1C FORMAT(1HC,5X,****ERROR*** ITYPE HAS THE VALUE ',111,'::',2X,'*EXECUTION TERMINATED*)
STOP

ITYPE = 1 -- UNIFORM LINE SOURCE.
FLEN=PI
CONTINUE
PAT=1.0
IF(V.NE.C.) PAT=SIN(PI*PI*V)/(PI*PI*V)
GO TO 999

ITYPE = 2 -- UNIFORM LINEAR ARRAY
FLEN=PI
NELMT=II
PAT=1.0
IF(V.NE.C.) PAT=SIN(PI*PI*V)/(II*SIN(PI*PI*V/I1))
GO TO 999

ITYPE = 3 -- TRIANGULAR LINE SOURCE.
FLEN=PI/2.
PAT=1.0
IF(V.NE.C.) PAT = (SIN(FLEN*PI*V)/(FLEN*PI*V))**2
GO TO 999

ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE
FLS=PI
FLT=P2
ARG1=PI*P1*U
ARG2=PI*P2*V
IF(ARG1) 4C1,4C2,401
IF(ARG2) 4C3,404,403
PAT=SIN(ARG1)/ARG1*SIN(ARG2)/ARG2
GO TO 999
PAT=SIN(ARG1)/ARG1
CC TO 999
PAT=SIN(ARG2)/ARG2
GO TO 999
PAT=1.0
GO TO 999
C ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY

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/I1))*SIN(ARG2)/(I2*SIN(ARG2/I2))
1199 GO TO 999
1200 504 PAT=SIN(ARG1)/(II*SIN(ARG1/I1))
1201 GO TO 999
1202 502 IF(ARG2) 505,506,505
1203 505 PAT=SIN(ARG2)/(I2*SIN(ARG2/I2))
1204 GO TO 999
1205 506 PAT=1.0
1206 GO TO 999

C

C ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.

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=BK/X*2.0
1212 GO TO 999
1213 601 PAT=1.0
1214 GO TO 999.

C

C ITYPE = 7 -- GENERAL ARRAY

1215 700 IMAG=(0.0,1.0)
1216 NELMT=I1*I2
1217 TEMP=(0.0,0.0)
1218 DO 701 J=1,NELMT
1219 TEMP=TEMP*1.0*CEXP(IMAG*2.0*PI*(U*SS(J)+V*TT(J)))
1220 701 CONTINUE
1221 PAT=REAL(TEMP)/NELMT
1222 GO TO 999
1223 999 PAT=SPECPT(U,V,ITYPE)
1224 999 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,V,ITYPE) WILL BE CALLED.)

VERSION 1 LEVEL C

DATE OF LAST REVISION: 73/166 JUNE 15, 1973

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FOR FURTHER INFORMATION CONTACT:
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COMPLEX TEMP, CEXP, IMAG, SPSOR
COMMON /PAT1/ P1, P2, P3, P4, P5, P6, P1, SS(100), TT(100), RR(100)
COMMON /PAT2/ 11, 12, 13, 14, 15

C IMAG=(O.C, 1.0)
CALL LOCSOR(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
10 FORMAT(1HC, 5X, '***ERROR*** ITYPE HAS THE VALUE ', I3, 'X, 
*EXECUTION TERMINATED')
STOP

ITYPE = 1 -- UNIFORM LINE SOURCE

1CC CONTINUE
FLEN=P1
SOURCE=CEXP(-IMAG*PI*2.*TV)/P1
GO TO 999

ITYPE = 2 -- UNIFORM LINEAR ARRAY

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

ITYPE = 3 -- TRIANGULAR LINE SOURCE
CONTINUE
C FLEN=P1
C CON=ABS(2.*T/P1)
C SOURCE=2.*P1*CEXP(-IMAG*2.*PI*T*V)*(1.-CON)
C IF(1246 CON.GT.1) SOURCE=(0.0,0.0)
C GO TO 999
C
C C C C TYPE = 4 -- UNIFORM RECTANGULAR APERTURE
C
C 400 CONTINUE
C FLS=P1
C FLT=P2
C SOURCE=CEXP(-IMAG*2.*PI*(S*U+V*T))/(PI*P2)
C GO TO 999
C
C C C C TYPE = 5 -- UNIFORM RECTANGULAR ARRAY
C
C 500 CONTINUE
C FLS=P1
C FLT=P2
C SOURCE=CEXP(-IMAG*2.*PI*(S*U+V*T))/(PI*P2)
C GO TO 999
C
C C C C TYPE = 6 -- UNIFORM CIRCULAR APERTURE
C
C 600 RHC=SCRT(S*S+T*T)
C A=PI
C SOURCE=(0.0,0.0)
C IF(RHC.LE.P1) SOURCE=CEXP(-IMAG*2.*PI*(S*U+T*V))/(PI*P2)
C GO TO 999
C
C C C C TYPE = 7 -- GENERAL ARRAY
C
C 700 CONTINUE
C SOURCE=CEXP(-IMAG*2.*PI*(U*S+V*T))/(I1*I2)
C GO TO 999
C 990 SOURCE=SPSOR(M,1,N,1,U,V,1,ITYPE)
C 999 RETURN
C 1263 END
C
SUBROUTINE LOCSOR(M,1,N,1,S,T)
INTEGER PX,PY
REAL INITLS,INITLT
COMMON /PAT1/ P1,P2,P3,P4,P5,P6,PI,SS(100),TT(100),RR(100)
COMMON /PAT2/ I1,I2,I3,I4,I5
COMMON /LOC/ ITYPE
C
C IF(1270 ITYPE.GT.7) GO TO 99C
C GO TO (100,200,300,400,500,600,700) ITYPE
**FUNCTION**

WRITE(6,10) ITYPE
1C FORMAT(1HC,5X,"***ERROR*** ITYPE HAS THE VALUE ",111,:,:*2X, 
**EXECUTION TERMINATED")
STCP
C
1C CONTINUE
C INITLT=P1
C CELTAT=P3
S=C.
T=P2+(N-1)*P3
GO TO 999
C
2C CONTINUE
C PY=I1
C DISY=P2
S=C.
T=(N-I1/2-1)*P2
IF(I1/2*2.EQ.11) T=T+0.5*P2
GO TO 999
C
30C GO TO 100
C
40C CONTINUE
C INITLS=P3
C INITLT=P4
C CELTAS=P5
C DELTAT=P6
S=P3+(M-1)*P5
T=P4+(N-I)*P6
GO TO 999
C
5C CONTINUE
C PX=I1
C PY=I2
C DISX=P3
C DISY=P4
S=(N-I1/2-1)*P3
T=(N-I2/2-1)*P4
IF(I1/2*2.EQ.11) S=S+0.5*P3
IF(I2/2*2.EQ.12) T=T+0.5*P4
GO TO 999
C
60C GO TO 400
C
70C CONTINUE
NELPT=(M-I12+N
S=SS(NELMT)
T=TT(NELPT)
GO TO 999
C
1361 999 CALL SPLOC(M,N,S,T)
1362 999 RETURN
1363 ENC
1364
CORD COMPLEX FUNCTION SPSOR(M,N,U,V,ITYPE)
1365 C DUMMY SUBPROGRAM
1366 SPSOR=(0.0,0.0)
1367 RETURN
1368 ENC
1369
1370 FUNCTION SPECPT(U,V,ITYPE)
1371 C DUMMY SUBPROGRAM
1372 SPECPT=C.
1373 RETURN
1374 ENC
1375
1376 SUBROUTINE SPLOC(M,N,S,T)
1377 C DUMMY SUBROUTINE
1378 RETURN
1379 ENC
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

\[
(u, v) \quad F_d(u,v) \quad F_u(u,v) \quad F_L(u,v)
\]

-0.2 \leq u \leq 0.2
-0.05 \leq v \leq 0.05

0. dB 0.5 dB -0.5 dB

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:

```
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 READ TRANSITION REGION LIMITS UTRAN AND VTRAN
C
READ(5,1) UTRAN, VTRAN

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:

```plaintext
Card 1

&PARAM
IDISK=1,ISYMM=3,DELTAU=0.02,DELTAV=0.01,NMAX=26,NMAX=51,
&END

&IPRINT
FDESCN=1,FDBPR=1,FDBCN=1,FCURPR=1,
&END

&PATIN
ITYPE=4,LX=10.,LY=20.,
INITLS=-5.0,DELTAS=0.2,FINALS=5.0,
INITLT=-10.0,DELTAT=0.4,FINALT=10.0,
&END

0.2 0.05
0.34 0.12
0.0015
0.0 0.0 1.0
0.0 0.05 1.0
0.0 -0.05 1.0
0.1 0.0 1.0
-0.1 0.0 1.0
0.1 -0.05 1.0
0.1 0.05 1.0
-0.1 0.05 1.0
-0.1 -0.05 1.0
0.2 0.05 1.0
0.2 -0.05 1.0
-0.2 0.05 1.0
-0.2 -0.05 1.0
0.2 0.0 1.0
-0.2 0.0 1.0
-0.2 0.0 1.0
0.2 -0.05 1.0
-0.2 0.0 1.0
```

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., DELTAV=0.02,DELTAV=0.01
v. Make the comparisons at 26 points in the $u$ direction and 51 points in the $v$ direction ($M_{\text{MAX}}=26, N_{\text{MAX}}=51$)

vi. Assure that $F(1,1)=0 \text{ dB}$ at all times ($M_{\text{CENT}}=1, N_{\text{CENT}}=1$)

Note that $F(M_{\text{MAX}}, N_{\text{MAX}})$ 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
1. Profiles of the final pattern and final current ($F_{\text{DBPR}}=F_{\text{CURPR}}=1$)
2. Contour maps of the desired pattern ($F_{\text{DESCN}}=1$) and final current ($F_{\text{CURCN}}=1$) are to be made

Step 4. Cards 7 to 11: Source Specifications
1. Rectangular aperture ($I_{\text{TYPE}}=4$)
2. Dimensions of $10\lambda$ by $20\lambda$ ($L_X=10., L_Y=20.$)
3. The value of current will be calculated at $51 \times 51$ points from $s = -5.0$ to $5.0$ by $0.2$, and $t = -10.0$ to $10.0$ by $0.4$. ($I_{\text{INITLS}}=-5., I_{\text{FINALS}}=5., I_{\text{DELTAS}}=0.2; I_{\text{INITLT}}=-10., I_{\text{FINALT}}=10., I_{\text{DELTAT}}=0.4$)

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 ($N_{\text{ORG}}$) and the values of ($U_{\text{ORG}}, V_{\text{ORG}}, C_{\text{ORG}}$) the original correction coefficients.

Steps 7, 8, 9. See subroutines SINPUT, 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

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ISYMM = 3  NMAX = 51
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DELTAV = 0.010

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INITLT,DELTAT,FINALT: -10.0000 0.4000 10.0000
MCUR,NCUR: 51 51

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
A-113

CONTOUR PLOT OF THE DESIRED PATTERN.

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A-120
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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.

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

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.

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