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. Realizability
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:

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

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

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

1) Use \( \mathbf{J}_S \) and \( \mathbf{J}_{MS} \) over S
2) Use \( \mathbf{J}_S \) over S with S a perfectly magnetic conducting surface
3) Use \( \mathbf{J}_{MS} \) over S with S a perfectly conducting surface

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

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

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

$$\vec{A}(r) = \frac{e^{-jkr}}{4\pi r} \int \int \vec{J}_S(r') e^{jk\hat{r} \cdot \vec{r}'} \, dx' \, dy'$$  \quad (2-3)

$$\vec{A}_M(r) = \frac{e^{-jkr}}{4\pi r} \int \int \vec{J}_{MS}(r') e^{jk\hat{r} \cdot \vec{r}'} \, dx' \, dy'$$  \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

\[
\vec{J}_{S} = \vec{z} \times \vec{H}_a
\]

\[
\vec{J}_{MS} = -\vec{z} \times \vec{E}_a
\]

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

\[
E_\theta = -j\omega A_\theta - j\omega \eta_o A_{M\phi}
\]

\[
E_\phi = -j\omega A_\phi + j\eta_o A_{M\theta}
\]

where \( \eta_o = \sqrt{\mu_o / \epsilon_o} \) and the magnetic fields are found using the plane wave relation

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

\[ J_{MS} = J_{MSx} \hat{x} = z \times E_{ay} \hat{y} = E_{ay} \hat{x} \]  

(2-10)

and

\[ A_{Mx} = \frac{\varepsilon_0}{4\pi r} e^{-jkr} \int \int \frac{2 E_{ay} e^{jk\hat{r} \cdot \hat{r}'}}{\text{aperture}} \, dx'dy' \]  

(2-11)

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

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

(2-12)

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

(2-13)

So

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

\[ = +j\omega_0 \sin \phi \, A_{Mx} \]  

(2-14)

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

\[ = j\omega_0 \cos \theta \cos \phi \, A_{Mx} \]  

(2-15)

And

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

(2-16)

So

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

(2-17)

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

(2-18)

where

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

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

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

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

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

where

\[
\mathbf{I} = \int \int \mathbf{H}_a(x',y') e^{j\left( x' \sin \theta \cos \phi + y' \sin \theta \sin \phi \right)} dx'dy' \tag{2-24}
\]

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

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

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

If a current distribution can be expressed as follows

$$\mathbf{J}_S = \mathbf{x} J_{Sx}(x') J_{Sx}(y') + \mathbf{y} J_{Sy}(x') J_{Sy}(y')$$

(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 $\mathbf{E}_a$ and $\mathbf{H}_a$ are usually separate and render the two-dimensional integrals of (2-19) and (2-24) a product of one-dimensional integrals.

2.3 Vector Radiation Fields

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

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

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

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

where

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

This can be cast in a matrix form

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

where

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

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

and

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

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

In still more compact form (2-29) becomes

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

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

(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
\[
F_x = \int \int I_x(x',y') e^{j\kappa} \, dx'dy',
\]

where we let

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

becomes

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

where

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

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

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

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

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

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

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

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

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

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

Since the current is y-directed we have

\[
F_x = 0
\]

\[
F_y = G_y F_{ary}
\]
The short dipole pattern is

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

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

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

Now

\[ F_y = \sum_{jm} jk \alpha_m e^{jym} \]  \hspace{1cm} (2-49)

where

\[ \alpha_m = x_m' \sin \theta \cos \phi \]  \hspace{1cm} (2-50)

since \( y_m' = 0 \).

2.4 Antenna Hardware Parameter Control

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

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

\[
[V] = [Z][I] \tag{2-51}
\]

where

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

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

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

3.1 History of the Iterative Sampling Method

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

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

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

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

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

3.2 Pattern Evaluation - What is an Acceptable Pattern?

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

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

3.3 The Integral Equation

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

\[
F(u, v) = \int_{\text{aperture}} \int E_a(x', y') \ e^{jk(x' u + y' v)} \ dx' dy' \tag{3-1}
\]

where

\[
u = \sin \theta \ \cos \phi \tag{3-2}
\]

\[
v = \sin \theta \ \sin \phi. \tag{3-3}
\]

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

\[
s = x'/\lambda \tag{3-4}
\]

\[
t = y'/\lambda
\]

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

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

\[ F(u, v) = \int \int f(s, t) e^{j2\pi(su + tv)} \, ds \, dt \]  

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

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

\( K \) 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

\[ \Delta F^{(i)}(u,v) = \sum_{n} a_n^{(i)} G(u-u_n^{(i)}, v-v_n^{(i)}) \quad (3-8) \]

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

\[ a_n^{(i)} = F_d(u_n^{(i)}, v_n^{(i)}) - F^{(i-1)}(u_n^{(i)}, v_n^{(i)}) \quad (3-9) \]

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:

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

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

where

\[ \Delta f^{(i)}(s,t) = \sum_{n} a^{(i)}_{n} g^{(i)}_{n}(s,t) \] (3-12)

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

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

\[ f^{(K)}(s,t) = \sum_{\lambda \mu} I^{(K)}_{\lambda \mu} \delta(s-s_{\lambda}, t-t_{\mu}) \] (3-13)

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

\[ g^{(i)}_{n}(s,t) = \sum_{\lambda \mu n \lambda m} a^{(i)} g_{n \lambda m} \delta(s-s_{\lambda}, t-t_{m}) \] (3-14)

for arrays. Then (3-10) becomes

\[ G(u-u_{n}^{(i)}, v-v_{n}^{(i)}) = \sum_{\lambda \mu n \lambda m} g^{(i)}_{n \lambda m} e^{j2\pi(s_{\lambda}u + t_{m}v)} \] (3-15)

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

\[ \Delta f^{(i)}(s,t) = \sum_{n} a^{(i)}_{n} \sum_{\lambda \mu} \delta(s-s_{\lambda}, t-t_{m}) \] (3-16)

and let

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

So
\[ \Delta I_{\ell m}^{(i)} = \sum_n a_n^{(i)} g_{n,\ell m} \]  
\[ I_{\ell m}^{(K)} = I_{\ell m}^{(o)} + \sum_{i=1}^{K} \Delta I_{\ell m}^{(i)} \]  
(3-18)  
(3-19)

3.5 Common Antenna Types

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

3.5.1 Line Sources

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

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

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

\[ G(v-v_n^{(i)}) = \frac{\sin \left[ \frac{L_y}{\lambda} (v-v_n^{(i)} \pi \right]}{L_y \pi (v-v_n^{(i)} \pi} \]  
(3-21)

This is the so-called \( \sin \pi \) 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

\[ g_n^{(i)}(t) = \begin{cases} L_y^{-1} \left( 1 - 2|t|/L_y \right) \exp (-j2\pi v_n^{(i)}t) & |t| \leq L_y/2 \\ 0 & \text{elsewhere} \end{cases} \quad (3-22) \]

The corresponding pattern found from (3-10) is

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

### 3.5.2 Linear Array

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

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

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

\[ G(u-u_n^{(i)}) = \frac{\sin \left[ P(v-v_n^{(i)})\pi d_y/2 \right]}{P \sin \left[ (v-v_n^{(i)})\pi d_y/2 \right]} \quad (3-25) \]

### 3.5.3 Rectangular Aperture

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

\[ g_n^{(i)}(s,t) = \begin{cases} L_x^{-1} L_y^{-1} \exp (-j2\pi (u_n^{(i)}s + v_n^{(i)}t)) & |s| \leq L_x/2, |t| \leq L_y/2 \\ 0 & \text{elsewhere} \end{cases} \quad (3-26) \]

The pattern is

\[ G(u-u_n^{(i)}, v-v_n^{(i)}) = \frac{\sin \left[ L_x (u-u_n^{(i)})\pi \right]}{L_x (u-u_n^{(i)})\pi} \frac{\sin \left[ L_y (v-v_n^{(i)})\pi \right]}{L_y (v-v_n^{(i)})\pi} \quad (3-27) \]
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

\[
g_{n \lambda m}^{(1)} = \frac{1}{P_x P_y} \exp \left[ -j2\pi(u_n^{(1)} s_l + v_n^{(1)} t_m) \right]
\]  

(3-28)

The pattern is

\[
G(u-u_n^{(1)}, v-v_n^{(1)}) = \frac{\sin [P_x(u-u_n^{(1)})\pi d_{x\lambda}]}{P_x \sin [(u-u_n^{(1)})\pi d_{x\lambda}]} \cdot \frac{\sin [P_y(v-v_n^{(1)})\pi d_{y\lambda}]}{P_y \sin [(v-v_n^{(1)})\pi d_{y\lambda}]} 
\]

(3-29)

3.5.5 Circular Aperture

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

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

(3-30)

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

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

(3-31)

The integral (3-10) over the source (3-31) is
\[ G (u-u_n (i), v-v_n (i)) \]
\[ = \int_{0}^{2\pi} \int_{0}^{a_\lambda} \frac{1}{\pi a_\lambda} \exp \{ j 2\pi \rho'_\lambda [(u-u_n (i)) \cos \phi'_\lambda + (v-v_n (i)) \sin \phi'_\lambda] \} \rho'_\lambda \ d\rho'_\lambda \ d\phi'_\lambda \]
\[ = \frac{1}{\pi a_\lambda} \int_{0}^{2\pi} \int_{0}^{a_\lambda} \exp \{ j 2\pi \rho'_\lambda C \cos (\alpha - \phi'_\lambda) \} \rho'_\lambda \ d\rho'_\lambda \ d\phi'_\lambda \]  
(3-32)

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

Now (3-33) is easily integrated as
\[ G (u-u_n (i), v-v_n (i)) = \frac{2\pi}{\pi a_\lambda} \int_{0}^{a_\lambda} J_0(2\pi \rho'_\lambda C) \rho'_\lambda \ d\rho'_\lambda \]
\[ = 2 \frac{J_1(2\pi a_\lambda C)}{2\pi a_\lambda C} \]  
(3-37)

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

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

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

3.5.6 Arbitrary Planar Array

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

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

There are M elements located at positions \((s_m^i, t_m^i)\) 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

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

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

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

\begin{align*}
u &= \sin \theta \cos \phi \\
v &= \sin \theta \sin \phi
\end{align*} \hfill (3-44)

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

\[ \Omega_A = \int_0^{\pi/2} \int_0^{\pi/2} |F(\theta, \phi)| \, du \, dv \hfill (3-45) \]

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

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

\[ du \, dv = \cos \theta \, d\Omega \hfill (3-46) \]

so

\[ d\Omega = \frac{du \, dv}{\cos \theta} \hfill (3-47) \]

But from (3-44)

\[ \cos \theta = \sqrt{1 - u^2 - v^2} \hfill (3-48) \]
so
\[
\frac{d\Omega}{d\omega} = \frac{du \, dv}{\sqrt{1 - u^2 - v^2}} \tag{3-49}
\]

Thus (3-45) becomes
\[
\Omega_A = \int \int \frac{|F(u,v)|^2 \, du \, dv}{\sqrt{1 - u^2 - v^2}} \tag{3-50}
\]

This result could also be obtained by a formal mathematical transformation of (3-45) as follows
\[
\Omega_A = \int \int \frac{|F(u,v)|^2 \, \sin \theta \, J \, du \, dv}{u^2 + v^2 < 1} \tag{3-51}
\]

where \( J \) is the Jacobian given by
\[
J = \frac{\partial(\theta, \phi)}{\partial(u,v)} = \frac{1}{\frac{\partial(u,v)}{\partial(\theta, \phi)}} \tag{3-52}
\]

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

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

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

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

Using (3-45)

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

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

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

Using (3-50)

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

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

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

\[ = \int_0^{2\pi} \frac{1}{\sqrt{2}} \, d\alpha \int_0^{-1/2} (-\frac{dx}{2}) = 2\pi \]

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

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

4.1 **Common Antenna Types**

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

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

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

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

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

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

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

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

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

4.2 Linear Antenna Synthesis

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

<table>
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<th>( F_d(v) )</th>
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<tr>
<td>(</td>
<td>v</td>
<td>\leq 0.2)</td>
<td>0. dB</td>
</tr>
<tr>
<td>0.4 (&lt;\</td>
<td>v</td>
<td>\leq 1.0)</td>
<td>(-\infty)</td>
</tr>
</tbody>
</table>

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

Figure 4.10 Profile along v-axis of the pattern from a uniform amplitude, uniform phase, 10 wavelength diameter circular aperture.
Figure 4.11 Contour map of the pattern from a uniform amplitude, uniform phase 10 wavelength diameter circular aperture.
Figure 4.12 Radiation pattern of a uniform amplitude, uniform phase 10 wavelength diameter circular aperture.
<table>
<thead>
<tr>
<th>Antenna Type - ITYPE</th>
<th>Source Dimensions ((\lambda))</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_y = 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_x = 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_y = 10)</td>
<td>0.128</td>
<td>0.128</td>
<td>-26.6</td>
</tr>
<tr>
<td>Uniform rectangular aperture - 4</td>
<td>(L_x = 10) (L_y = 20)</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_x = 0.5) (P_y = 41) (d_y = 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 = 5)</td>
<td>0.102</td>
<td>0.102</td>
<td>-17.6</td>
</tr>
</tbody>
</table>

Table 4.1 Pattern Parameters for Elementary Correction Patterns
side lobe region. The final pattern (which met the specifications) was obtained after 69 iterations. It deviated + 0.44 and - 0.42 dB over the main beam region and had a peak side lobe of - 40.79 dB in the specified side lobe region. The pattern is plotted in Fig. 4.13. The corresponding current distribution is given in Fig. 4.14.

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

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

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

Figure 4.16 Current amplitude distribution required to produce pattern of Fig. 4.15.
The element positions used as input to the program were found from [14] and are \( t_m = 0.0, \pm 0.496, \pm 0.983, \pm 1.926, \pm 2.372, \pm 3.188, \pm 3.545 \). 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

| \( |v| \leq 0.26 \) | \( \mathcal{F}_d(v) \) | \( \mathcal{F}_u(v) \) | \( \mathcal{F}_l(v) \) |
|-----------------|--------------|--------------|--------------|
| -20.0 dB        | +.42 dB      | -.42 dB      | unspecified  |

\( 0.44 \leq |v| \leq 1.0 \)
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 wave-
length in the s-direction and 40 elements spaced 0.5 wavelength in the 
t-direction. The pattern specifications are:

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

The pattern is unspecified at all other points of the uv-plane. The gap in 
specifications between the main beam and side lobe regions allows the main 
beam to roll off. The elementary correction functions used (see 4.1) will 
give side lobes below -20 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 com-
puter program converged to a final pattern which met specifications after 62 
iterrations. 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. to -40 dB in 5 dB steps and the -35. and -40 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 \(|u| < 0.866\).

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 \(|v| < 0.866\).
Figure 4.20 Contour map of a multiple beam, low side lobe pattern synthesized from a 10 by 10 wavelength aperture.
Figure 4.21 Multiple beam, low side lobe pattern synthesized from a 10 by 10 wavelength aperture.
Figure 4.22 Profile along u-axis of a rectangular main beam, low side lobe pattern synthesized from a 20 element, 0.5 wavelength spaced by 40 element, 0.5 wavelength spaced rectangular array.

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

<table>
<thead>
<tr>
<th>(u,v)</th>
<th>F_d(u,v)</th>
<th>F_H(u,v)</th>
<th>F_L(u,v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.2&lt;u&lt;0.2</td>
<td>0 dB</td>
<td>0.5 dB</td>
<td>-0.5 dB</td>
</tr>
<tr>
<td>-0.05&lt;v&lt;0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.34&lt;</td>
<td>u</td>
<td>&lt;0.50</td>
<td>-∞</td>
</tr>
<tr>
<td>0.12&lt;</td>
<td>v</td>
<td>&lt;0.50</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/FDESPT, FDESPR, FDESCN, FDBPT, FDBCN, FDBPR, FORGPT, FORGPN, 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>SININPUT</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>or Cards; call subroutine READ to load FDES, FU, and FL</td>
<td>DESPAT</td>
</tr>
<tr>
<td>6. Original pattern</td>
<td>Cards; read NORG, US, VS, CORG to generate original state using Woodward-Lawson method</td>
<td>ORGPAT</td>
</tr>
<tr>
<td>and original source</td>
<td>or Cards or program statements; if Woodward-Lawson is not used, load F, CURR, and CURI, set NORG=0</td>
<td>ORGPAT</td>
</tr>
<tr>
<td>7. Special correction</td>
<td>Program statements to generate pattern function, ITYPE &gt;7</td>
<td>SPECPT</td>
</tr>
<tr>
<td>pattern function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Special correction</td>
<td>Program statements to generate source function, companion to special pattern, ITYPE &gt;7</td>
<td>SPSOR</td>
</tr>
<tr>
<td>source function</td>
<td></td>
<td></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

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

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

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

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

Steps 7 and 8. If correction pattern and source functions other than the seven standard ones available are desired by the user, Subroutines SPECPAT 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>( a_n )</td>
<td>ARAD</td>
</tr>
<tr>
<td>( a_\lambda )</td>
<td>DISX</td>
</tr>
<tr>
<td>( d_{\chi_\lambda} )</td>
<td>DISY</td>
</tr>
<tr>
<td>( d_{\gamma_\lambda} )</td>
<td></td>
</tr>
<tr>
<td>( f^{(K)}(s,t) )</td>
<td>CURR(M,N)</td>
</tr>
<tr>
<td></td>
<td>CURI(M,N)</td>
</tr>
<tr>
<td>( F(i)(u,v) )</td>
<td>F(M,(i))</td>
</tr>
<tr>
<td>( F_d(u,v) )</td>
<td>FDES(M,N)</td>
</tr>
<tr>
<td>( g_n(i)(s,t) )</td>
<td>SOURCE(J,K,US(L),US(L),ITYPE)</td>
</tr>
<tr>
<td>( G(u-u_n(i),v-v_n(i) )</td>
<td>PAT(U-US(L), V-VS(L), ITYPE)</td>
</tr>
<tr>
<td>( L_{x_\lambda} )</td>
<td>LX</td>
</tr>
<tr>
<td>( L_{y_\lambda} )</td>
<td>LY</td>
</tr>
<tr>
<td>( P_x )</td>
<td>PX</td>
</tr>
<tr>
<td>( P_y )</td>
<td>PY</td>
</tr>
<tr>
<td>( s )</td>
<td>S</td>
</tr>
<tr>
<td>( t )</td>
<td>T</td>
</tr>
<tr>
<td>( u )</td>
<td>U</td>
</tr>
<tr>
<td>( u_n(i) )</td>
<td>US( )</td>
</tr>
<tr>
<td>( v )</td>
<td>V</td>
</tr>
<tr>
<td>( v_n(i) )</td>
<td>VS( )</td>
</tr>
</tbody>
</table>
6.4.2. Definition of Some Integer Variables Used in the Program

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

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

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

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

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

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

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

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

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

IC Subscript of CORCOF( ) array for latest correction.

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

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

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

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

IPASS Optional 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 be 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.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMPAT</td>
<td>Pattern number - Arbitrary sequence number for identifying synthesis problems.</td>
</tr>
<tr>
<td>NUMSKP( )</td>
<td>Variable on disk storage. If 0 space is available on track corresponding to subscript number. If 1 track contains previously generated data.</td>
</tr>
<tr>
<td>NUMTRK</td>
<td>Reference number of a single track on disk storage.</td>
</tr>
<tr>
<td>ORGCN</td>
<td>Input variable controlling print out of contour map of original pattern; 0 NO, 1 YES - Default is 0.</td>
</tr>
<tr>
<td>ORGPR</td>
<td>Input variable controlling print out of original pattern; 0 NO, 1 YES (U and/or V axis) - Default is 0.</td>
</tr>
<tr>
<td>ORGPT</td>
<td>Input variable controlling print out of original pattern; 0 NO, 1 YES - Default is 0.</td>
</tr>
<tr>
<td>PX</td>
<td>Input variable - Number of array elements in X-direction.</td>
</tr>
<tr>
<td>PY</td>
<td>Input variable - Number of array elements in Y-direction.</td>
</tr>
</tbody>
</table>

6.4.3. Definition of Some Real Variables Used in the Program

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARAD</td>
<td>Input variable - Radius of circular aperture source in terms of a wavelength.</td>
</tr>
<tr>
<td>CONINT</td>
<td>Interval between contour levels of CONTUR and PATCON print outs.</td>
</tr>
<tr>
<td>CONLOW</td>
<td>Lowest contour level of CONTUR and PATCON print outs.</td>
</tr>
<tr>
<td>CONMAX</td>
<td>Maximum level of CONTUR and PATCON print outs.</td>
</tr>
<tr>
<td>CORCOF( )</td>
<td>Correction coefficient</td>
</tr>
<tr>
<td>CORG( )</td>
<td>Correction coefficients (or sample values) for original pattern.</td>
</tr>
<tr>
<td>CURI( , )</td>
<td>Imaginary part of current.</td>
</tr>
<tr>
<td>CURR( , )</td>
<td>Real part of current.</td>
</tr>
<tr>
<td>DELCON</td>
<td>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.</td>
</tr>
<tr>
<td>DELTAS</td>
<td>Input variable - Increment between print out points of current distribution in S direction.</td>
</tr>
<tr>
<td>DELTAT</td>
<td>Input variable - Increment between print out points of current distribution in T direction.</td>
</tr>
</tbody>
</table>
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 \(20.0 \times \log_{10}(\ )\). 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 repre-
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, JL, 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 JL of the pattern matrices. II and JL 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, JL, 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 JL are returned from SEARCH and assigned as UI and VI 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:

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

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>FORCPT = 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

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

VERSION 3  73/164 -- JUNE 13, 1973

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

UNDER NASA GRANT: 47-004-103

LANGUAGE: FORTRAN IV

SUBPROGRAMS REQUIRED:
     DIRCIV
     INPUT
     READ
     CRGPAT
     ANTSYN
     SEARCH
     CHECK
     UPDATE
     PAT
     SOURCE
     LOCSON
     SPLOC
     SPECPT
     SPSOR
     SINPUT
     CURREN
     PRINT
     PROFIL
     CONUR
     PATCCN
     LIST
     DESPAT
     DATE
     STIME
     BESJ

...STANDARD FORTRAN LIBRARY SUBPROGRAMS...

INPUT/OUTPUT SUPPORT:

    FTC5FC01 (SYSIN) -- CARD READER
    FTC6FO01 (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,FDESPR
INTEGER FORGPT,FORGCN,FORGPR,FDBPT,FDBCN,FDBPR,DIRECT
REAL FDES(51,51),FU(51,51),FL(51,51),F(51,51)
REAL US(500),VS(500),CORCOF(500),CURR(51,51),CURI(51,51)
REAL UCHG(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/ PI,P2,P3,P4,P5,P6,PI,SS(400),IT(400),RK(400)
COMMON /PAT2/ 11,12,13,14,15
COMMON /LOC/ ITYPE
DATA TITLE /'ANTENNA SYNTHESIS PROGRAM VERSION 3 LEVEL 1',
VPI EE DEPT./
NAMELIST /PARAM/ IDISK,ISYMM,ITRMAX,DELTAV,STARTU,STARTV,
NMAX,NMAX,MCENT,NCENT
NAMELIST /IPRINT/ FDESPT,FDESPR,FDESCN,FDBPT,FDBCN,FDBPR,
FORGPT,FORGCN,FORGPR,ICURPT,ICURCN,ICURPR,FCURPT,FCURCN,FCURPR,
DIRECT

BEGIN PROCESSING

9999 CONTINUE
READ(22'1,6550) NUMPAT,NUMTRK,NUMSKP,IPASS

6550 FORMAT(75A4,11(200A4))
NUMPAT=NUMPAT+1
CALL DATE(11,J1,K1)
CALL STIME(IT)
IHR=IT/10000
IFR=IT-IHR*10000
FHR=IFR/10000
FM=FHR*60.
IMIN=FM
ISC=(FM-IMIN)*60.
WRITE(6,1)11,J1,K1,IHR,IMIN,ISEC,NUMPAT
1 FORMAT('1 ANTENNA SYNTHESIS PROGRAM VERSION 3 LEVEL 1',
'VPI EE DEPT.',5X,'DATE = ',A2,':-',A2,'-',A2,
'I2X,'TIME = ',I2,':',I2,'.',I2,'.',I2,5X,'PATTERN = ',I4)
C

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 FDDBPT=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=C
62 DIRECT=0

63 FNCRM=1.
64 ISIG=0
65 DELTAS=C.
66 DELTAT=0.

C

INPUT

C

READ (5,PARAM)
WRITE (6,1521) IDISK,STARTU,MMAX,ISYM,STARTV,NMAX,ITRMAX,DELTAU,
MCENT,DELTAV,NCENT
1521 FORMAT (7X, 'PROGRAM PARAMETERS', 5X, 'IDISK = ', 11, 26X, 'STARTU = ',
5F23.2X, 'MMAX = ', 13/30X, 'ISYM = ', 11, 26X, 'STARTV = ', 5F23.2X,
5F23.2X, 'NMAX = ', 13/30X, 'ITRMAX = ', 14, 22X, 'DELTAU = ', 5F23.2X,
5F23.2X, 'MCENT = ', 13/30X, 'DELTAV = ', 5F23.2X, 'NCENT = ', 13//)
REAL (5,PDINT)
WRITE (6,1522) FDESPT,FORGPT,FERCPT,ICURPT,FCURPT,
FDESCN,FORCCN,FEDCN,ICURCN,FCURCN,
FORGPR,FORCCPR,FEDPR,ICURPR,FCURPR,
1522 FORMAT (1X, 'PARAMETERS', 5X, 'FDESPT = ', 11, 5X, 'FORGPT = ', 11, 5X,
FCURPT = ', 11, 5X, 'FDESCN = ', 11, 5X, 'FORCCN = ', 11, 5X,
FEDCN = ', 11, 5X, 'ICURCN = ', 11, 5X, 'ICURPT = ', 11, 5X,
FEDPR = ', 11, 5X, 'ICURPR = ', 11, 5X, 'FCURPR = ', 11//)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
CALL INPUT
72 IF (ITYPE.EQ.7 .AND. ICURPR.EQ.1) ICURPR = 2
73 IF (ITYPE.EQ.7 .AND. FCURPR.EQ.1) FCURPR = 2
74 CALL LCCSCR(1,1,INITLS,INITLT)
75 CALL LOCSOR(NCUR,NCUR,FINALS,FINALT)
76 IF (NCUR.NE.1) DELTAS = (FINALS - INITIALS) / (NCUR - 1)
77 IF (NCUR.NE.1) DELTAT = (FINALT - INITIALT) / (NCUR - 1)
78 CALL DESPAT(FDES,FU,FL,MMAX,NMAX,STARTU,STARTV,
$ DELTA, DELTAV)
79 IF (FDESPT) 300, 300, 301
80 WRITE(6,302)
81 302 FORMAT(1H1/''/'''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''' ''
DC 408 J=1,401
U=(J-1)*C_C05-1*C
V=U
SUMU=0.
SUMV=C.
DO 409 K=1,NORG
SUMU=SUMU+CORG(K)*PAT(U-UORG(K),-VORG(K),ITYPE)
SUMV=SUMV+CORG(K)*PAT(-UORG(K),V-VORG(K),ITYPE)
CONTINUE
DATA1(J,1)=U
DATA1(J,2)=SUMU
DATA2(J,1)=V
DATA2(J,2)=SUMV
CONTINUE
IF(VMAX.LE.1) GO TO 2801
WRITE(6,410)
FORVAT(1H1,25X,'U-AXIS PROFILE OF INITIAL PATTERN')
CALL PROFIL(DATA1,401,NUMPAT)
2801 IF(NMAX.LE.1) GO TO 406
WRITE(6,411)
FORVAT(1H1,25X,'V-AXIS PROFILE OF INITIAL PATTERN')
CALL PROFIL(DATA2,401,NUMPAT)
CONTINUE
ORIGINAL EXCITATION
IF(ICURPT) 500,500,501
501 WRITE(6,502)
502 FORMAT(1H1,10X,'INITIAL CURR')
503 CALL PRINT(CURR,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTAT)
504 WRITE(6,505)
505 FORMAT(1H1,10X,'INITIAL CURR')
506 CALL CONTUR(MCUR,NCUR,0.005,-0.04,0.04,0.0,CURI,NUMPAT)
507 WRITE(6,508)
508 FORMAT(1H1,10X,'INITIAL CURR')
509 IF(ICURPR-1) 506,507,504
510 FORMAT(1H1,10X,'S AXIS PROFILE OF INITIAL CURRENT'//
$13X,'S',17X,'T',18X,'REAL',12X,'IMAGINARY',10X,'MAGNITUDE',
$12X,'PHASE'/)
J=NCUR/2+1
DO 509 J=1,MCUR
CALL LOCSGR(I,J,S,T,ITYPE)
AMAG=SQRT(CURR(I,J)**2+CURI(J)**2)
IF(AMAG.EQ.0.) APH=0.
509 IF(AMAG.LE.0.) GO TO 509
APH=ATAN2(CURI(I,J),CURR(I,J))*57.2957795
WRITE(6,511) S,T,CURR(I,J),CURI(I,J),AMAG,APH
FORMAT(9X,F8.4,9X,F8.4,10X,4(E14.7,5X))
A-30

163 508 IF(INCUR.LE.1) GO TO 506
164 WRITE(6,512)
165 512 FORMAT(1H1,10X,*'T AXIS PROFILE OF INITIAL CURRENT'//
166 $13X,*'S',17X,*'T',18X,*'REAL',12X,*'IMAGINARY',10X,*'MAGNITUDE',
167 $12X,*'PHASE'*)
168 IC=MCUR/2+1
169 DO 513 J=1,NCUR
170 CALL LCSCOR(I,J,S,T,ITYPE)
171 CR=CURR(I,J)
172 CI=CURI(I,J)
173 AMAG=SQRT(CR*CR+CI*CI)
174 IF(AMAG.EQ.0.) APH=0.*
175 IF(AMAG.EQ.0.) GO TO 513
176 APH=ATAN2(CI,CR)*57.2957795
177 513 WRITE(6,511) S,T,CR,CI,AMAG,APH
178 GO TO 506
179 514 WRITE(6,515)
180 515 FORMAT(1H1///10X,*'INITIAL ELEMENT CURRENTS'///5X,
181 $J',10X,*'S',15X,*'T',15X,*'CURR',11X,*'CURI')
182 CALL LIST(CURR,CURI,MCUR,NCUR)
183 506 CONTINUE
184 4747 FORMAT(1H1)
185 CALL ANTSYN (ISUC,MMAX,NMAX,FDES,FU,FL,ITRMAX,ISYMM,CORC0F,IC,US
186 S,VS,STARTU,DELTAV,STARTV,DELTAU,MCENT,NCENT,ITER,FNORM,F)
187 PRINT OUT RESULTS
188 WRITE(6,391)
189 391 FORMAT(1H1,52X,*'FINAL COEFFICIENTS'///45X,*'J',7X,
190 $'US(J)',7X,VS(J),5X,CORC(J)'/)
191 IF(IC.LE.0.) WRITE(6,977)
192 977 FORMAT(10X,*'NO ITERATIONS PERFORMED')
193 IF(IC.LT.0.) GO TO 978
194 978 IC=0
195 DO 498 J=1,IC
196 498 WRITE(6,35) J,US(J),VS(J),CORC(J)
197 35 FORMAT(44X,I3,5X,F7.4,5X,7.4)
198 WRITE(6,497) ITER
199 497 FORMAT(1H0,9X,*'NUMBER OF ITERATIONS = ',16)
200 WRITE(6,496) FNORM
201 496 FORMAT(1H0,9X,*'FNORM = ',F10.5)
202 WRITE(6,976) NUMPAT
203 976 FORMAT(1H0,9X,*'PATTERN NUMBER = NUMPAT = ',15)
204 C
205 C OUTPUT FINAL PATTERN IN DB
206 C
207 978 CONTINUE
208 DO 29 J=1,MMAX
209 29 CONTINUE
210 DO 29 K=1,MMAX
211 29 CONTINUE
212 IF(F(J,K)) 290,289,290
213 289 F(J,K)=-20C.
A-31

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

C

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

C

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

C

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

C

243 IF(FCURPT) 700,700,701
244 701 WRITE(6,702)
245 702 FORMAT(1HI///////////////////////////////55X,'FINAL CURR*)
246 CALL PRINT(CURR,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTA)
247 WRITE(6,702)
248 782 FORMAT(1HI///////////////////////////////55X,'FINAL CURR*)
249 CALL PRINT(CURR,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTA)
250 704 WRITE(6,705)
251 705
252 705 FCRMAT(1H1///10X,'FINAL CURR')
253 CALL CONTUR(MCUR,NCUR,C.COS,-0.04,0.04,0.0,CURR,NUMPAT)
254 WRITE(6,705)
255 785 FCRMAT(1H1///10X,'FINAL CURR')
256 CALL CONTUR(MCUR,NCUR,C.COS,-0.04,0.04,0.0,CURR,NUMPAT)
257 CALL CONTUR(MCUR,NCUR,0.005,-0.04,0.04,0.0,CURR,NUMPAT)
258 IF(FCURPR-1) 706,707,711
259 703 IF(FCURPR-1) 706,707,711
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 I=1,MCUR
263 CALL LCCSCR(I,J,S,T,ITYPE)
264 CR=CURR(I,J)
265 CI=CURI(I,J)
266 AMAG=SCRT(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 WRITE(6,511) S,T,CR,CI,AMAG,APH
271 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',
$12X,'PHASE')/
274 I=MCUR/2+1
275 DO 713 J=1,NCUR
276 CALL LCCSCR(I,J,S,T,ITYPE)
277 CR=CURR(I,J)
278 CI=CURI(I,J)
279 AMAG=SCRT(CR*CR+CI*CI)
280 IF(AMAG.EQ.0.) APH=0.
281 IF(AMAG.EQ.0.) GO TO 713
282 APH=ATAN2(CI,CR)*57.2957795
283 713 WRITE(6,511) S,T,CR,CI,AMAG,APH
284 GO TO 706
285 711 WRITE(6,714)
286 714 FORMAT(1H1///10X,'FINAL ELEMENT CURRENTS'//5X,$
5'J',10X,'S',15X,'T',15X,'CURR',15X,'CURI')
287 CALL LIST(CURR,CURI,MCUR,NCUR)
288 706 CONTINUE

C
289 IGCOUNT=NUMPAT
290 WRITE(22,'(I5,6F8.5)') IGCOUNT,NUMTRK,NUMSKP,IPASS
291 IF(IEXC.X.EQ.0.) GO TO 9998
292 CALL DIRECVICORG, UORG, VORG, NORG, US, VS, CORCOF, IC, MMAX, NMAX,
$DIRORG,CIRFNLS
293 WRITE(6,6789) DIRORG, CIRFNLS
294 6789 FORMAT('I',5F7.2,' DB.'/
$0 CIRFNLS = ',F7.2,' DB.')
295 9998 CONTINUE
IF(IDISK.EQ.C) GO TO 9997
C DISK OUTPUT
GO 7000 J=2,35
IF(NUMSKP(J).EQ.0) GO TO 7001
7000 CONTINUE
WRITE(6,7002)
7002 FORMAT('NO DISK SPACE AVAILABLE -- DATA NOT STORED')
GO TO 9999
7001 CONTINUE

SPACE IS AVAILABLE ON RECORD "J"
NUMSKP(J)=1
WRITE(22,8850) NUMPAT,J,NUMSKP,IPASS
WRITE(22,J,8850) NUMPAT,TITLE,SYM,ITER,ISUC,FNORM,IDISK,$NORG,IC,UCRG(M),VORG(M),CORCOF(M),M=1,NORG,$US(M),VS(M),CCRCOF(M),M=1,NORG,ITYPE,P1,P2,P3,P4,P5,P6,$PI,ISS(M),TT(M),M=1,1400,11,12,13,14,15,MCUR,NCUR
WRITE(6,7003) NNUMPAT,J
7003 FORMAT('PATTERN NUMBER ',I4,' HAS BEEN STORED ON RECORD', $I4,' OF ANIDATA, A507C2')
9997 GO TO 9999

END

SUBROUTINE DIRCTV(CORG,UORG,VORG,NORG,US,VS,CORCOF,IC,MMAX,NMAX,$1 CIRG,DIRFNL)
C THIS SUBROUTINE CALCULATES THE DIRECTIVITY OF THE ORIGINAL PATTERN
DIMENSION CORG(I),UORG(I),VORG(I),US(I),VS(I),CORCOF,IC,MMAX,NMAX,$
COMMON /LCC/ ITYPE
FORGSC=C.
FSC=0.
FMAX1=0.
FMAX2=0.
DO 10 J=1,101
U=-1.0+(J-1)*0.02
10 CONTINUE
DO 25 K=1,101
V=-1.0+(K-1)*0.02
UVSQ=L*L+V*V
F=0.
IF(ABS(F).GT.1.0) GO TO 10.
1 C
IF(NORG.LE.0) GO TO 25
25 DC 20 L=1,NORG
   F=F*CORGL(L)*PAT(U-UCRG(L),V-VORG(L),ITYPE)
   FORGSC=FORGSC+F**2/SCRT(1.0-UVSQ)
   IF(ABS(F).GT. FMAX1) FMAX1=ABS(F)
25 CONTINUE
FSC=FCKGSQ:
FMAX2=FMAX1
IF(IC.LE.0) GO TO 10
C0 30 L=1,IC
30 F=F+CCRCF(L)*PAT(U-US(L),V-VS(L),ITYPE)
FSC=FSC+F**2/SQRT(1.0-UVSQ)
IF(ABS(F).GT.FMAX2) FMAX2=ABS(F)
10 CONTINUE
FORGSQ=FORGSQ*.0004/FMAX1
FSC=FSC*C.CCC4/FMAX2
DIRC##################################################################
=4.0*3.14159265/FORGSQ
DIRFNL=4.0*3.14159265/FSC
C
SUBLTINE INPUT.
C
INTEGER PX,PY
REAL LX,LY,INITLS,INITLT
C
COMMON /PAT1/ P1,P2,P3,P4,P5,P6,PI,SS(400),TT(400),RR(400)
COMMON /PAT2/ P11,P12,P13,P14,P15
COMMON /LOC/ ITYPE
COMMON /MPROG/ MCUR,NCUR
COMMON /SYN/ LX,LY
C
NAMELIST /PATIN/ LX,LY,PX,PY,DISX,DISY,INITLS,DELTAS,FINALS,
$INITLT,DELTA1,FINALT,NEELMT,ARAO,ITYPE,MCUR,NCUR
C
WRITE(6,10)
10 FORMAT(////55X,'SOURCE SPECIFICATIONS'//)
PI=3.14159265
READ(5,PATIN)
IF(ITYPE.GT.7) GO TO 990
GO TO (100,200,300,400,500,600,700), ITYPE
WRITE(6,2C) ITYPE
2C FORMAT(1HO,5X,***ERROR*** ITYPE HAS THE VALUE 'IL1',:,'2X,
$EXECUTION TERMINATED!')
STOP
C
10C PI=LY
P2=INITLT
3 P3=DELTAT
LX=C.O
NCUR=(FINALT-INITLT)/DELTAT+1.5
MCUR=1
WRITE(6,101) LY,INITLT,FINALT,DELTAT,NCUR
101 FORMAT(1X,'ITYPE=1 -- UNIFORM LINE SOURCE'//15X,LY = ',F7.3//' $15X,INITLT,FINALT,DELTAT: ',3(1X,F8.4)//15X,NUMBER OF SAMPLE POINTS = NCUR = ',I3)
GO TO 999

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)
GO TO 999

300 PI =LY
LY =0.0
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 ',F6.4,5X, $DELTAT = ',F6.3//15X,NUMBER OF SAMPLE POINTS = NCUR = ',I3)
GO TO 999

400 PI =LX
LY =0.0
P2 =LY
P3 =INITLS
P4 =INITLT
P5 =DELTAS
P6 =DELTAT
MCLR = (FINALS - INITLS) / DELTAS + 1.5
NCUR = (FINALT - INITLT) / DELTAT + 1.5
WRITE(6,401) LX,LY,INITLS,DELTAS,FINALS,INITLT,DELTAT,FINALT,MCLR,NCUR
401 FORMAT(10X,'ITYPE=4 -- UNIFORM RECTANGULAR APERTURE'// $15X, 'DIMENSIONS = LX,LY = ',F7.4, ', ',F7.4//' $15X,'INITLS,DELTAS,FINALS: ',3(F8.4,1X)// $15X,'INITLT,DELTAT,FINALT: ',3(F8.4,1X)// $15X,'MCLR,NCUR: ',2(I3,2X))
GO TO 999

500 PI =LX
LY =0.0
P2 =LY
11 =PX
A-36

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

C C
415 601 P1=ARAD
416 P3=INITLS
417 P4=INITLT
418 P5=DELTAS
419 P6=DELTAT
420 LX=ARAD*2.
421 LY=LX
422 MCUR=(FINALS-INITLS)/DELTAS+1.5
423 NCUR=(FINALT-INITLT)/DELTAT+1.5
424 WRITE(6,601) ARAD,INITLS,DELTAS,FINALS,INITLT,DELTAT,FINALT,MCUR,
$NCUR
425 601 FORMAT(ICX,'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

C C
427 701 I1=MCUR
428 I2=NCUR
429 LX=1.0
430 LY=1.0
431 NELMT=I1*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(F1C.0)
437 WRITE(6,704) J,SS(J),TT(J)
438 704 FORMAT(17X,I3,5X,3(F14.7,5X))
439 702 CONTINUE
440 GO TO 999
441 CALL SINPUT(PX,PY,DISX,DISY,INITLS,DELTAS,FINALS,INITLT,
$DELTAT,FINALT,NELMT,ARAD,ITYPE)
442 999 RETURN
43 ENC
SUBROUTINE READ (F, NMAX, NMAX)

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

DO 100 J = 1, NMAX

K2 = 0

22 CONTINUE

READ (5, 1) (I(L), VAL(L), L = 1, 6)

1 F = (I3, F10.0)

DC 20 L = 1, 6

II = I(L)

IF (II .EQ. 0) GO TO 100

K1 = K2 + 1

K2 = K1 + II - 1

10 K = K1, K2

IC F(J, K) = VAL(L)

22 CONTINUE

IF (K2 .LT. NMAX) GO TO 220

100 CONTINUE

RETURN

END

SUBROUTINE CRGPAT(F, NMAX, NMAX, STARTU, STARTV, DELTAU, DELTAV,

CURR, "$CURR", MCUR, NCUR)

DIMENSION F(51, 51), CURR(51, 51), CURR(51, 51)

REAL 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(M, N) = C.

SUBROUTINE READ (F, NMAX, NMAX)

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

DO 100 J = 1, NMAX

K2 = 0

22 CONTINUE

READ (5, 1) (I(L), VAL(L), L = 1, 6)

1 F = (I3, F10.0)

DC 20 L = 1, 6

II = I(L)

IF (II .EQ. 0) GO TO 100

K1 = K2 + 1

K2 = K1 + II - 1

10 K = K1, K2

IC F(J, K) = VAL(L)

22 CONTINUE

IF (K2 .LT. NMAX) GO TO 220

100 CONTINUE

RETURN

END
DO 15 M=1,MCUR
CC 15 N=1,NCUR
CURR(M,N)=0.
15 CURR(M,N)=C.
WRITE(6,17)
17 FORMAT(1HL,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,NCRG
READ(5,2) US,VS,CORCOF
2 FORMAT(3FLCO.0)
UORG(IC)=US
VORG(IC)=VS
CORG(IC)=CORCOF
DO 30 M=1,MMAX
U=STARTU+(M-1)*DELTAU
DL=U-US
DO 30 N=1,NMAX
V=STARTV+(N-1)*DELTAV
DV=V-VS
30 CONTINUE
WRITE(6,50) IC,US,VS,CORCOF
50 FORMAT(44X, T3,5XF7.4,5X,F7.4,5X,F7.4)
CCNTINUi
RFTURN
ENC
SUBROUTINE ANTSYN(ISUC,MMAX,NMAX,FDES,FU,FL,ITRMAX,ISYMM,CORCOF,
$IC,US,VS,STARTU,DELTAU,STARTV,DELTAV,MCENT,NCENT,ITER,FNORM,F)
REAL FDES(51,51),FU(51,51),FL(51,51),F(51,51)
REAL US(500),VS(500),CORCOF(500),UOR(1000),VOR(1000),CORC(1000)
REAL LX,LY,LXY
COMMON /SYN/ LX,LY
COMMON /FAK/ NORG, UORG, VORG, CORG
LXY=1./AMAX1(LX,LY)
ITER=0
27 ITER=ITER+1
C NORMALIZE...
FBIG=F(MCENT,NCENT)
DO 150 M=1,MMAX
DO 150 N=1,NMAX
150 F(M,N)=F(M,N)/FBIG
FNORM=FNORM/FBIG
DO 151 I=1,NORG
151 CORG(I)=CORG(I)/FBIG
IF(IC,LY,6) GO TO 153
LG 152 I=1,IC
153 CONTINUE
-- ITERATION PROCEDURE --

SPECS ARE MET.

DO 24 J=1,NMAX
    U=STARTU+(J-1)*DELTAV
  24 CONTINUE

DO 24 K=1,NMAX
    V=STARTV+(K-1)*DELTAV
    UVSU=(U+V)*V
    IF(UVSU.GT.1.0) GO TO 24

IF(FDES(J,K).EQ.99.) GO TO 24

IF(FL(J,K).LE.0.00001 .AND. ABS(F(J,K)).LE.1.E-4) GO TO 24

XI=ABS(F(J,K))

IF(XI.GT.FU(J,K)) GO TO 25

IF(XI.LT.FL(J,K)) GO TO 25

24 CONTINUE

IC=IC+1

IF(ITER/ICC*ICC.*EQ.*ITER) WRITE(6,7117) ITER

7117 FORMAT(10X,6,' ITERATIONS COMPLETED')

IF(ITER-ITRMAX) 22,22,23

23 WRITE(6,34) ITRMAX

34 FORMAT(10X,9X,'NUMBER OF ITERATIONS EXCEEDED', 15/
      'PRINTOUT OF INTERMEDIATE RESULTS FOLLOWS.')

GO TO 75C

22 CONTINUE

IF(FVAL.NE.0.0) GC 248

CALL SEARCH(J,K,VAL,FDES,FU,FL,F,MMAX,NMAX,STARTU,STARTV,DELTAV,
      $DELTAV)

IF(VAL.NE.0.0) GO TC 248

VAL EQUALS ZERO

WRITE(6,100)

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

GO TO 73C

248 U1=(J-1)*DELTAV+STARTU

248 V1=(K-1)*DELTAV+STARTV

IF(ABS(U1).LT.0.1*DELTAV) U1=0.

IF(ABS(V1).LT.0.1*DELTAV) V1=0.

IF(LX.GE.0.) GO TC 1000

IF(U1.NE.0. .AND. ABS(U1).LE.0.5/LX) VAL=VAL/2.

199 ICCC IF(LY.GE.C.) GO TC 1CCC

550 IF(V1.NE.0. .AND. ABS(V1) .LE. 0.5/LY) VAL=VAL/2.
IF(ISYVN.NE.4) GC TO 1001
ITEMP=C
UV=ABS(ABS(U1)-ABS(V1))
IF(UV.EQ.0.) GC TO 1001
IF(UV*1.414.LE.LXY) VAL=VAL/2.
1001 CONTINUE

BASIC CORRECTION -- INDEPENDENT OF ISYMM

US(IC)=U1
VS(IC)=V1
CORCOF(IC)=VAL
CALL UPDATE(IC,US,VS,CORCOF,F,MMAX,NMAX,FNORM,STARTU,STARTV $,DELTAU,DELTAV)
CALL CHECK(IC,VAL,US,VS,CORCOF,DELTAU,DELTAV)
IF(ISYMM) 26,27,26
26 CONTINUE
IF(ISYMM-2) 261,260,260
260 CONTINUE

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

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

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

IF(V1.EQ.0.) GC TO 262
IC=IC+1
US(IC)=U1
VS(IC)=V1
CORCOF(IC)=VAL
CALL UPDATE(IC,US,VS,CORCOF,F,MMAX,NMAX,FNORM,STARTU,STARTV $,DELTAU,DELTAV)
CALL CHECK(IC,VAL,US,VS,CORCOF,DELTAU,DELTAV)
262 IF(ISYMM.LT.3) GO TO 27

QUADRILATERAL SYMMETRY ONLY -- ISYMM = 3,4

IF(U1.EQ.0. OR V1.EQ.0.) GO TO 2745
IC=IC+1
US(IC)=U1
VS(IC)=V1
CORCOF(IC)=VAL
CALL UPDATE(IC,US,VS,CORCOF,F,MMAX,NMAX,FNORM,STARTU,STARTV $,DELTAU,DELTAV)
CALL CHECK(IC,VAL,US,VS,CORCOF,DELTAU,DELTAV)
2745 IF(ISYMM.LT.4. OR ITEMP.EQ.1) GO TO 27

FOR RIGID QUADRILATERAL SYMMETRY ONLY -- ISYMM = 4

ITEMP=1
A-41

591 IF(U1.EQ.V1) GO TO 27
592 IC=IC+1
593 UTEM=U1
594 VTEM=V1
595 U1=VTEM
596 V1=UTEM
597 GO TO 1001
598 CONTINUE
599 IC=IC-1
600 ITER=ITER-1
601 RETURN
602 END

603 SUBROUTINE SEARCH(II,J1,VAL,FDES,FU,FL,F,MMAX,NMAX,STARTU,$STARTV,DELTAU,DELTAV)
604 REAL FU(51,51),FL(51,51),F(51,51),FDES(51,51)
605 VAL=0.
606 EMAX=0.
607 12=II
608 J2=J1
609 CC 10 J=I2,MMAX
610 U=STARTU+(J-1)*DELTAU
611 CC 20 K=J2,NMAX
612 V=STARTV+(K-1)*DELTAV
613 UVSQ=U*U+V*V
614 IF(UVSQ.GT.1.0) GO TO 20
615 FITER=ABS(F(J,K))
616 IF(FDES(J,K).EQ.99.0) GO TO 20
617 IF(FITER.GT.FU(J,K)) GO TO 2000
618 IF(FL(J,K).LE.1.0E-4) GO TO 20
619 IF(FITER.GT.FL(J,K)) GO TO 20
620 2CCX=FDES(J,K)
621 ERROR = FITER-X
622 1F(ABS(ERRORCR)-ABS(EMAX)) 20,20,21
623 21 EMAX=ERRORCR
624 VAL=SIGN(ERRORCR,F(J,K)*(X-FITER))
625 11=J
626 J1=K
627 CC 2C CONTINUE
628 1C CONTINUE
630 WRITE(6,10C) II,J1,VAL
631 100 FORMAT(5X,18,18,5X,F7.4)
632 RETURN
633 ENC

634 SUBROUTINE CHECK(IC,VAL,US,VS,COF,DELTAU,DELTAV)
635 REAL COF,US(500),VS(500),DELTAU,DELTAV
636 IF(IC.EQ.1) RETURN
637 CU=C.1*DELTAU
638 CV=C.1*DELTAV
639 IC1=IC-1
640 U=US(IC)
641 W=VS(IC)
A-42

642 DO 10 J=1,IC1
643 IF(ABS(U-US(J)).LE.DU.AND.ABS(V-VS(J)).LE.OV) GO TO 20
644 IC CONTINUE
645 RETURN
646 IC=IC-1
647 RETURN
649 ENC

650 SUBROUTINE UPDATE(IC,US,V5,CORCOF,F,MMAX,NMAX,FRNORM,STARTU,STARTV,$DELTAU,DELTAV)
651 DIMENSION F(51,51),US(500),VS(500), CORCOF(500)
652 COMMON /LOC/ ITYPE
653 C=CORCOF(IC)
654 DO 10 J=1,MMAX
655 U=STARTU+(J-1)*DELTAU
656 DU=U-US(IC)
657 DO 10 K=1,NMAX
658 V=STARTV+(K-1)*DELTAV
659 DV=V-VS(IC)
660 IC $F(J,K)=F(J,K)+C*PAT(DU,DV,ITYPE)
661 CORCOF(IC)=CORCOF(IC)/FNORM
662 RETURN
663 ENC

664 FUNCTION PAT(U,V,ITYPE)

This subroutine 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 SPECFT(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:
K.L. STUTZMAN DEPT. OF ELEC. ENGR. 951-6624.
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COMMON /PAT1/ P1,P2,P3,P4,P5,P6,P7,SS(400),TT(400),RR(400)
COMMON /PAT2/ 11,12,13,14,15
IF(ITYPE.GT.7) GO TO 990
GO TO (1CO,200,300,400,500,600,700),ITYPE

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

IF(V.NE.0.) PAT = SIN(P1*PI*V)/(PI*P1*V)
GO TO 999

ITYPE = 2 -- UNIFORM LINEAR ARRAY
FLEN=P1
NELPT=11
PAT=1.0

IF(V.NE.0.) PAT=SIN(P1*PI*V)/((11*SIN(P1*PI*V/11))
GO TO 999

ITYPE = 3 -- TRIANGULAR LINE SOURCE.
FLEN=P1/2.

IF(V.NE.0.) PAT = (SIN(FLEN*PI*V)/(FLEN*PI*V))**2
GO TO 999

ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE

ARG1=PI*P1*U
ARG2=PI*P2*V

IF(ARG1) 401,402,401
401 IF(ARG2) 403,404,401
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
CONTINUE

FLS=PI

FLT=P2

NELS=I1

NELT=I2

ARC1=PI*P1*U

ARG2=PI*P2*V

IF(ARG1) 501,502,501

IF(ARG2) 503,504,505

PAT=SIN(ARG1)/(I1*SIN(ARG1/I1))*SIN(ARG2)/(12*SIN(ARG2/12))

GO TO 999

PAT=SIN(ARG1)/(I1*SIN(ARG1/11))

GO TO 999

IF(ARG2) 506,507,508

PAT=SIN(ARG2)/(12*SIN(ARG2/I2))

GO TO 999

PAT=1.0

GO TO 999

ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.

C
130 C=SCRT(U*U+V*V)

A=PI

IF(C.EQ.C.) GO TO 601

X=2.*PI*PI*C

CALL BESJ(x,1,BJ,0.0001,IER)

PAT=2.*BJ/X

GO TO 999

PAT=1.0

GO TO 999

ITYPE = 7 -- GENERAL ARRAY

C

IMAG=(C.C,1.C)

NELMT=I1*I2

TEMP=(C.C,C.0)

DO 701 J=1,NELMT

TEMP=TEMP+1.O*CEXP(IMAG*2.*PI*(U*SS(J)+V*TT(J)))

CONTINUE

PAT=REAL(TEMP)/NELMT

GO TO 999

PAT=SPECPT(U,V,ITYPE)

999 RETURN

END

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

C

THIS SUBPROGRAM CALCULATES THE CURRENT AT POINT (M,N) DUE TO

THE PATTERN AT POINT (U,V).

C

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

C

? -- 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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733 COMPLEX TEMP, CEXP, IMAG, SPSOR
734 COMMON /PAT1/ P1, P2, P3, P4, P5, P6, PI, SS(400), TT(400), RR(400)
735 COMMON /PAT2/ II, I2, I3, I4, I5

736 IMAG=(0.0,1.0)
737 CALL LOCSCR(M, N, S, T)
738 IF(I TYPE.GT.7) GO TO 990
739 GO TO (100, 200, 300, 400, 500, 600, 700), I TYPE
740 C
741 WRITE(6,10) I TYPE
742 10 FORMAT(1HC,5X,***ERROR*** I TYPE HAS THE VALUE ',111,':',2X,
743 2'EXECUTING TERMINATED')

744 C
745 I TYPE .LT. 1

746 C
747 I TYPE = 1 -- UNIFORM LINE SOURCE
748 100 CONTINUE
749 C
750 FLEN=P1
751 SOURCE=CEXP(-IMAG*PI*2.*T*V)/PI
752 GO TO 999

753 C
754 I TYPE = 2 -- UNIFORM LINEAR ARRAY
755 200 CONTINUE
756 C
757 FLEN=P1
758 SOURCE=CEXP(-IMAG*2.*PI*V*T)/PI
759 GO TO 999

760 C
761 I TYPE = 3 -- TRIANGULAR LINE SOURCE
762 300 CONTINUE
763 C
764 FLEN=P1
765 CON=ABS(2.*T/P1)
SOURCE = 2.*P1*CEXP(-IMAG*2.*PI*T*V)*(1.-CON)
IF(CON.GT.1) SOURCE = (0.,0.,0.)
GO TO 999

ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE

4CC CONTINUE
FLS = P1
FLT = P2
SOURCE = CEXP(-IMAG*2.*PI*(S*U+V*T))/(P1*P2)
GO TO 999

ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY

500 CONTINUE
FLS = P1
FLT = P2
SOURCE = CEXP(-IMAG*2.*PI*(S*U+V*T))/(P1*P2)
GO TO 999

ITYPE = 6 -- UNIFORM CIRCULAR APERTURE

600 RHC = SCRT(S*S+T*T)
A = P1
SOURCE = (C.C,C.C,C.C)
IF(RHC.LE.P1) SOURCE = CEXP(-IMAG*2.*PI*(S*U+T*V))/(2.*PI*P1**2)
GO TO 999

ITYPE = 7 -- GENERAL ARRAY

700 CONTINUE
SOURCE = CEXP(-IMAG*2.*PI*(U*S+V*T))/(11*I2)
GO TO 999
999 RETURN
END

SUBROUTINE LCCSOR(M,N,S,T)
INTEGER PX,PY
REAL INITLS,INITLT
COMMON /PAT1/ P1,P2,P3,P4,P5,P6,PI,SS(400),TT(400),RR(400)
COMMON /PAT2/ 11,12,13,14,15
COMMON /LCC/ ITYPE

IF(ITYPE.GT.7) GO TO 990
GO TO (100,200,300,400,500,600,700), ITYPE
WRITE(6,10)
IC FORMAT(1HC,5X,'***ERROR*** ITYPE HAS THE VALUE ',111,' ',2X,
'*EXECUTION TERMINATED*')
STOP
CONTINUE

C

781 100 CONTINUE
C INITLI=P2
C DELTAT=P3
782 S=0.
783 T=P2+(N-1)*P3
784 GO TO 999
C
C
785 200 CONTINUE
C PY=I1
C DISY=P2
786 S=0.
787 T=(N-11/2-1)*P2
788 IF(I1/2*2.EQ.11) T=T+0.5*P2
789 GO TO 999
C
C
790 300 GO TO 100
C
C
791 400 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
795 500 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(I1/2*2.EQ.11) S=S+0.5*P3
799 IF(I2/2*2.EQ.12) T=T+0.5*P4
800 GO TO 999
C
C
801 600 GO TO 400
C
C
802 700 CONTINUE
C NELMT=(M-1)*I2+N
803 S=SS(NELMT)
804 T=TT(NELMT)
805 GO TO 999
C
C
807 990 CALL SPLOC(M,N,S,T)
808 999 RETURN
809 END
SUBROUTINE CURRENT(CURR, CUR1, MCUR, NCUR, US, VS, CURCOF, IC)

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


COMPLEX SOURCE, TEMP
REAL CURR(51,51), CURI(51,51), US(500), VS(500), CURCOF(500)
REAL UORG(100), VORG(100), CORR(100)
COMMON /START/ NORG, UORG, VORG, CORR
COMMUN /LOC/ ITYPE
DO 100 M=1, MCUR
DO 100 N=1, NCUR
CURR(M,N)=0.
100 CURI(M,N)=0.
DO 200 M=1, MCUR
DO 200 N=1, NCUR
DO 200 I=1, NORG
TEMP=SOURCE(M,N, UORG(I), VORG(I), ITYPE)
CURR(M,N)=CURR(M,N)+CURCOF(I)*REAL(TEMP)
CURI(M,N)=CURI(M,N)+CURCOF(I)*AIMAG(TEMP)
200 CONTINUE
IF(IC.LT.0) RETURN

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. 72/266 VERSION 3

DIMENSION A(51,51), U(51), V(51)
WRITE(6, 6969)
6969 FORMAT(1H1)
60 CC 10 J=1, 51
61 CC 1C U(J)=STARTU+(J-1)*DU
62 CC 1C V(J)=STARTV+(J-1)*DV
63 CC 1C N2=N/10.+0.99
64 CC 1C M2=M/10.+0.99

RETURN
END
A-49

DC 100 J1=1,M2
DC 200 K=1,N2
M3=1+(J1-1)*10
M4=M3+9
IF(N4.GT.N) N4=N

PRINT CUT A HEADING
WRITE(6,20) (V(I),I=N3,N4)
2C FORMAT(1H1,16X,F6.3,9(4X,F6.3))
WRITE(6,30)

PRINT A PAGE
K2=(M4-M3+1)*6
DO 4000 J=1,K2
J2=J/6
IF(J2*6-J) 27,28,27
J3=J2+M3-1
WRITE(6,29) U(J3),A(J3,I),I=N3,N4)
CC TO 4000
27 WRITE(6,31)
4000 CONTINUE
IF(N4.GE.N .AND. M4.EQ.M) GO TO 300
2CC CONTINUE
1CC CONTINUE
30 CONTINUE
29 FORMAT(1X,F6.3,15X,5X,10(F9.4,1X))
3C FORMAT(1C1,1H+,10(1OH---------+))
31 FORMAT(1C1,*1*)}
30 CONTINUE

SUBROUTINE PRCFIL(DATA1,NPT,NUMPAT)
INTEGER SF
INTEGER OUTPUT(101)
REAL DATA1(401,2),BOUND(101)
REAL DATA(401,2)
DATA BLANK,PLUS,SLASH,STAR
CATA(J,1)=CATAL(J,1)
CATA(J,2)=CATAL(J,2)
CONTINUE

SUBROUTINE PRCFIL(DATA1,NPT,NUMPAT)
IF(NPT.GT.600) GC TO 999
BIG=-1.E10
SMALL = 1.E10
CC 1 J=1,NPT
IF(DATA(J,2) .LT. -60.0) DATA(J,2) = -60.0
IF(DATA(J,2) .LT. SMALL) SMALL = DATA(J,2)
IF(DATA(J,2) .GT. BIG) BIG = DATA(J,2)

1 CONTINUE
DIFF = ABS(BIG - SMALL)
SF = C
IF(DIFF .LT. 1.) GO TO 10
IF(DIFF .LT. 100.) GO TO 21
DO 2 J = 1, IC
IF(DIFF*IC**(-J) .GT. 100.) GO TO 2
SF = J
GO TO 20
2 CONTINUE
400 WRITE(6, 1CC)
100 FORMAT('O YOUR DATA IS TOO LARGE FOR THIS PROGRAM.'
RETURN
1C DO 3 J = 1, IC
3 K = 11 - J
IF(DIFF*IC**K .GT. 100.) GO TO 3
SF = -K
GO TO 20
3 CONTINUE
GO TO 400
2C DO 4 J = 1, NPT
4 DATA(J,2) = DATA(J,2) * 10.**(-SF)

CALCULATE BOUNDS

SCALE = DIFF/100.
DO 5 J = 1, IC
5 K = J - 1
BOUND(J) = (BIG - K*SCALE)*10.**(-SF)
PRINT TITLE
WRITE(6, 64C) NUMPAT
64C FORMAT(26X, 'PATTERN NUMBER ', 15X)
IF (SF .EQ. C) GO TO 200
WRITE(6, 6004) SF
6004 FORMAT(53X, 'SCALE FACTOR IS 10*-', 12X)
WRITE(6, 65C) (BOUND(J), J = 1, 101, 20)
65C FORMAT(/X, 5(F7.3, 13X), F7.3, 2X, 'REAL', 5X, 'C3.*')
DO 6 J = 1, NPT
6 CONTINUE
J = NPT + 1 - J
CC 50 K = 1, 101
IF((J - 1)/10 - (J - 1)) 62, 61, 62
6 CO CUTPUT(K) = BLANK
61 IF((J - 1)/10 - (J - 1)) 62, 61, 62
62 CUTPUT(1) = SLASH
SUBROUTINE CCNTUR(K, L, DCN, CLOW, CMAX, CINT, A, NUMPAT)

C*************************************************************PRINT2*************************************************************
C THIS SUBPROGRAM GIVES A CONTOUR MAP OF THE MATRIX A
C K AND L ARE THE MAXIMUM VALUES OF I AND J
C IF K=L=51 OR 101 AXES WILL BE SET UP AS FOR A PATTERN PLOT
C DELCON=DELTA(INCREMENT) BETWEEN CONTOURS FOR CONTUR SUBROUTINE
C CCONL=LOWEST CONTOUR LEVEL
C CCONM=HIGHEST CONTOUR LEVEL
C CCONI=CONTOUR INTERVAL
C NUMPAT=PATTERN NUMBER
C

DIMENSION A(51,51)
DIMENSION ALPHA(10)
DIMENSION CC(101)
DATA ALPHA/1HC,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9/
DATA BLANK,OUT/1H/1H/1H/1H/

IF(K.LE.1.OR.L.LE.1) RETURN
CONINT=CINT
CCONL=CCM
CCONM=CCMAX
CCONI=CCDN
WRITE(6,87) NUMPAT
87 FFORMAT ('FCR THE PATTERN NUMBERED',15)
IF(CONINT) 99,99,100
99 BIG=-1.E27
99,99,100 SMALL=1.E27
GO 98 1=1,K
GO 98 J=1,L
IF(A(I,J) .LT. SMALL) SMALL = A(I,J)
IF(A(I,J) .GT. BIG) BIG = A(I,J)
CONTINUE
CCNINT = (BIG - SMALL) / 10.
DELCON = C (CONINT
CCALOW = SMALL + DELCON
CONMAX = BIG - DELCON
100 WRITE (6, 71) DELCON, CONLOW, CONMAX, CONINT
71 FORMAT (1HO, 'DELCON=', F10.5, 3X, 'CONLOW=', F10.5, 3X, 'CONMAX=', F10.5, 3X, 'CONINT=', F10.5)
C PRINT LEVEL DESIGNATIONS
MCHAR = ABS ((CCNMAX - CONLOW) / CONINT + 1.1)
CON = CONMAX + CONINT
ICON = M - 1
CON = CON - CONINT
WRITE (6, 72) ICON, CON
72 FORMAT (1HC, 'CONTOUR LEVEL ', I2, ' = ', F10.5)
40 CONTINUE
C WRITE HEADING
DC 32 J = 1, 101
32 CONTINUE
33 CONTINUE
DC 35 J = 1, 101
35 CONTINUE
34 CONTINUE
WRITE (6, 200)
200 FORMAT (1H1)
N1 = L * 2
IF (N1 .GT. 101) N1 = 101
WRITE (6, 101) (CCL(J1), J1 = 1, N1)
101 FORMAT (/1HC, 14X, 101Al)
CE 31 J = 1, 101
CCL(J) = BLANK
31 CONTINUE
J2 = -1
CO 2 J = 1, L
J2 = J2 + 2
ICCN = -1
CON = CONMAX + CONINT
CO 50 M = 1, MCHAR
ICCN = ICCN + 1
CON = CON - CONINT
IF (A(I, J) .GT. (CON + DELCON)) GO TO 50
IF (A(I, J) .LT. (CON - DELCON)) GO TO 50
Now A(I, J) IS LT CON + DELCON AND GT CON - DELCON
IF (L .LE. 51) CCL(J2) = ALPHA(IICON + 1)
IF (L .GT. 51) CCL(J) = ALPHA(IICON + 1)
GO TO 2
SUBROUTINE PATCON(RDATA, MMAX, NMAX, ICODE, CONLOW, CONMAX, CONINT, STARTU, STARTV, DELTAU, DELTAV, NUMPAT, ISYM)

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

DATA BLANK/' '/
DATA LEVEL/I'C',' ','21','3','4','5','6','7','8','9','10'/

CALL DATE(I,J,K)
WRITE(6,10) I, J, K, NUMPAT
FORMAT(1H1, 'PATTERN CONTOUR SUBPROGRAM', 34X, 'DATE = A2, A2 $, A2,3X, 'PATTERN NUMBER', 15///)
IF(ICCD.EQ.0) WRITE(6,11)
IF(ICCD.EQ.1) WRITE(6,12)
IF(ICCD.EQ.2) WRITE(6,13)
11 FORMAT(42X,'CONTOUR PLOT OF THE DESIRED PATTERN'///)
12 FORMAT(46X,'CONTOUR PLOT OF THE INITIAL PATTERN'///)
13 FORMAT(45X,'CONTOUR PLOT OF THE FINAL PATTERN IN DB.'///)

FINALU=STARTU+(MMAX-1)*DELTAU
FINALV=STARTV+(NMAX-1)*DELTAV

UI=STARTU
U2=FINALU
V1=STARTV
V2=FINALV
NCOUNT=NMAX

IF(ISYM-1) 70,30,20
2C UBIG=AMAX1(AABS(STARTU),AABS(FINALU))
UI=-UBIG
U2=UBIG
NCOUNT=2*NCOUNT-1
IF(ISYM.EQ.2) GO TO 70

30 VBIG=AMAX1(AABS(STARTV),AABS(FINALV))
V1=-VIG
V2=VBIG
NCOUNT=2*NCOUNT-1

70 CONTINUE

ESTABLISH LOWER AND UPPER LIMITS
NUMCON=(CONMAX-CONLO)/CONINT+1.5
DELCON=CONINT/2.

DO 71 J=1,NUMCON
LOW(J)=CCNL+(J-1)*CONINT/DELCON
HIGH(J)=LOW(J)+CONINT+0.0001
71 CONTINUE

LOW(11)=-1.E3C
HIGH(12)=1.E3O
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
40 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.
DV=(V2-V1)/100.
N=NSkip-1
DO 51 K=1,101
51 OUTPUT(K)=BLANK
DO 60 M=1,101,MSkip
U=U1+(M-1)*DU
IF(U*V*V.GT.1.0) GO TO 60
C

FIND F(U,V)

IJ=1
IK=1
J=(U-STARTU)/DELTU+1.5
K=(V-STARTV)/DELTAV+1.5
IF(IJ.GE.1.AND. J.LE.MMAX) IJ=0
IF(IK.GE.1.AND. K.LE.NMAX) IK=0

101 IF(IJ) 2CC,102,2CC
102 IF(IK) 3CC,1000,300
2CC
103 IF(ISYMM-1) 6G,6G,2G1
104 J=1.5-(U-STARTU)/DELTU
105 IF(IJ.GE.1.AND. J.LE.MMAX) IJ=0
106 IF(IJ) 6G,202,60
107 K=1.5-(V-STARTV)/DELTAV
108 IF(IK.GE.1.AND. K.LE.NMAX) IK=0
109 IF(IK) 6G,1000,60
300 IF(ISYMM.EQ.0.OR. ISYMM.EQ.2) GO TO 60
109 K=1.5-(V-STARTV)/DELTAV
109 IF(IK.GE.1.AND. K.LE.NMAX) IK=0
109 IF(IK) 6G,1000,60
202 IF(IK) 3CC,10CC,300

300 IF(ISYMM.EQ.0.OR. ISYMM.EQ.2) GO TO 60
1000 IF(IJ.GE.1.AND. J.LE.MMAX) IJ=0
1001 IF(IK.GE.1.AND. K.LE.NMAX) IK=0
202 IF(IK) 3CC,10CC,300
103 IF(ISYMM.EQ.0.OR. ISYMM.EQ.2) GO TO 60
1000 IF(IJ.GE.1.AND. J.LE.MMAX) IJ=0
1001 IF(IK.GE.1.AND. K.LE.NMAX) IK=0
202 IF(IK) 3CC,10CC,300

1000 IF(IJ.GE.1.AND. J.LE.MMAX) IJ=0
1001 IF(IK.GE.1.AND. K.LE.NMAX) IK=0
202 IF(IK) 3CC,10CC,300

IF(U*V*V.GT.1.0) GO TO 60
C

F=RCATA(J,K)
1001 IF(F.LE.LCW(1)) GO TO 1001
1002 IF(F.GT.HIGH(NUMCON)) GO TO 1002
C
DO 61 K=1,NUMCON
   IF(F.GT.LOW(K) .AND. F.LE.HIGH(K)) GO TO 62
   61 CONTINUE
   60 CONTINUE
   62 OUTPUT(M)=LEVEL(K)
   GO TO 60
   63 CONTINUE
   WRITE(6,64) V, (OUTPUT(K), K=1,101), V
   64 FORMAT(7X,F7.4,1X,' ',101A1,' ',1X,F7.4)
   IF(N1.EQ.0) GO TO 50
   50 CONTINUE
   WRITE(6,56)
   56 FORMAT(' ')
   55 CONTINUE
   WRITE(6,56) (UAXIS(I), I=1,1L)
   57 FORMAT(5X,11('.',9X)/13X,11(F7.4,3X))
   58 FORMAT(/56X, 'CONTOUR LEVEL KEY'//)
   59 WRITE(6,44) V, (OUTPUT(K), K=1,101), V
   44 FORMAT:///56X, 'CONTOUR LEVEL KEY'//)
   45 WRITE(6,46) (LEVEL(J), LOW(J), HIGH(J), J=1,12,4)
   46 FORMAT(5X,3(A1,' : ',E14.7,' TO ',E14.7,4X))
   RETURN

SUBROUTINE LIST(CURR,CURI,MCUR,NCUR)
   DIMENSION CURR(51,51), CURI(51,51)
   CALL LOGSOR(M,N,S,T)
   WRITE(6,1CC) J,S,T,CURR(M,N), CURI(M,N)
   10 CONTINUE
   1CC CONTINUE
   100 FORMAT(3X,14,5X,4(E14.7,2X))
   RETURN
   ENC
   ENC


   THIS SUBROUTINE LISTS ARRAY ELEMENT COORDINATES AND CURRENTS
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, LOCSON, and SPLOC are used in generating the pattern and source arrays and are also used in ANTSYN. PLOT1, PLOT1C and PLOT1P are used to plot profiles (cuts through one plane) of the pattern magnitude in dB, the source magnitude, and the source phase. PLOT2 and its subroutines (CNLAL and PLOTL) are used to draw accurate contour maps of the pattern magnitude in dB, the source magnitude, and/or the source phase. PLOT3 and its subroutines (THREE2, THREE3, THREE4, and THREE5) are used to plot the pattern magnitude in dB, the current magnitude, and/or the current phase with a three dimensional effect.

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

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

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

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

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

**Step 2.** Array size.

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

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

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

**Step 4.** Pattern data.

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

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

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

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

**Step 6. U profile location.**

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

**Step 7. V profile location.**

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

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

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

**Step 9. Pattern contour parameters.**

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

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

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

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

Step 12. T profile location.

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

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

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


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

Step 15. Options for current phase plots.

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

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

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


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

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

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

7.4.1 Definition of Some Important Integer Variables Used in ANTDATA

ITEMP = Number of original correction coefficients, CORG.

ITEMP1 = Number of correction coefficients (not including original ones), CORCOF.

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

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

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

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

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

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

7.4.2 Definition of Some Important Real Variables Used in ANTDATA

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

CONLOW = The lowest contour level for PLOT2 subroutine.

CONMAX = The highest contour level for PLOT2 subroutine.

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

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

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

7.5 Subroutine Descriptions

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

7.5.1 ANTDATA Plot Subroutines

SUBROUTINE PLOT1

Purpose:

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

Usage:

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

**PSTRT** - Abscissa of first point to be plotted.

**PEND** - Abscissa of last point to be plotted.

**IP** - Number of points to be plotted. This must be less than the dimension of array PTS. A reasonable choice is 4001.

**CODE** - Labeling code. If CODE = 0 the horizontal axis will be left blank and the value stored in CONST will be reproduced at the bottom of the plot in the form "THETA=CONST". If CODE=1, then the horizontal axis will be labeled "+V" and "-V" and the value stored in CONST will be reproduced as "U=CONST." If CODE=2, the horizontal axis will be labeled "+U" and "-U" and CONST will be reproduced as "V=CONST."

**CONST** - Label constant.

**NUMPAT** - Pattern number.

Remarks:

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

2. 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 $\text{CODE}=0$, the horizontal axis will be left blank and the value stored in $\text{CONST}$ will be reproduced at the bottom of the plot in the form "$\text{THETA}=\text{CONST.}" If $\text{CODE}=1$, the horizontal axis will be labeled "+T" and "-T" and the value stored in $\text{CONST}$ will be reproduced as "$S=\text{CONST.}" If $\text{CODE}=2$, the horizontal axis will be labeled "+S" and "-S" and $\text{CONST}$ will be reproduced as "$T=\text{CONST.}"$

CONST - Label constant.
NUMPAT - Pattern number.

Remarks:

i. Before each subroutine call, $\text{PTS}$ must be loaded with appropriate data points in degrees ($-180 \leq \text{PTS} \leq 180$).

COMMON Blocks Required: COMMON /PLT1/ PTS

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

SUBROUTINE PLOT2
Purpose:
To draw a contour map of data in array $A$.
Usage:

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

Description of Parameters:

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

Remarks:

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

COMMON Blocks Required: COMMON /ARRAY/ A

Subroutine and Function Subprograms Required: CNLAL, PLOT, FACTOR, SYMBOL, NUMBER

Reference: D. A. Vossler, E. S. Robinson

SUBROUTINE CNLAL

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

Usage:

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

Description of Parameters:

N - Number of points in horizontal direction.
M - Number of points in vertical direction.
CNTRLO - Least value of array X.
CMAX - Greatest value of array X.
CNTRAL - ABS(CMAX-CNTRLO)/10.
NC - IF NC=0: CNTRLO and CMAX are returned.
     IF NC=1: CNTRLO, CMAX, and CNTRAL are returned.
Subroutine and Function Subprogram Required: None.

SUBROUTINE PLOTL

Purpose:
To plot a straight line between two points.

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

Description of Parameters:

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

Remark:

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

COMMON Blocks Required: None.

Subroutine and Function Subprograms Required: None.

SUBROUTINE PLOT3

Purpose:
To draw a perspective view of a contoured surface.

Description of Parameters and Important Variables:

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

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

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

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

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

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

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

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

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

Remarks:

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

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

COMMON Blocks Required:

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

Reference: Howard Jesperson, Iowa State University.

SUBROUTINE THREE2

Purpose:

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

Usage:

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

Description of Parameters:

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

XP - Height above paper.

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

KODE - Dummy variable

COMMON Blocks Required: None

SUBROUTINE 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, N, P, KODE)
Description of Parameters:

XI - Abscissa of the projected point.

YJ - Ordinate of the projected point.

M - Number of horizontal points.

N - Number of vertical points.

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

KODE - Hidden Line Code (See Subroutine PLOT3)

COMMON Blocks Required:

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: 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.

```
//B0663PL3 JOB 507C2,COFFEY
/*MAIN TIME=19,LINES=3,REGION=250K,CARDS=0
/*PRIORITY PRIORITY
/*FORMAT PL,FORMS=PFGURAGV,PPEN=XXFINAE,DDNAME=CALCOM
// EXEC FORTGCG,PARM.GO='PAPER=39,PTIME=119',EP=MAIN
//FORT.SYSLIN DD *
/*
//GO.SYSLIB DD
// DD DSN=VPI.PLOTLIB,DISP=SHR
// DD DSN=VPI.SSPLIB,DISP=SHR
//GO.SYSLIB DD
// DD *
/*
//GO.FT22F001 DD DSN=ANTDATA.A507C2,UNIT=3330,VOL=SER=tJSERPK,DISP=SHR
//GO.FT06F001 DD SYSOUT=A,DCB=(BLKSIZE=133,RECFM=F)
//GO.SYSIN DD *
/*
//
```

7.6.2 Source Listing

Listed below are the FORTRAN IV statements of the ANTDATA program.
PROGRAM DESCRIPTION:
ANTDATA IS THE OUTPUT PROGRAM USED IN CONJUNCTION WITH ANTSYN2. 
BY SPECIFYING APPROPRIATE PARAMETERS ANTDATA WILL GIVE A ONE,
TWO, OR THREE DIMENSION PLOT OF THE PATTERN (IN 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 SUPPL
THROUGH UNIT 5 (SYSIN). ALL OUTPUT IS CHANNELLED TO UNIT 6
(SYSPRINT) AND THE PLOTTER (PLOT1).

VERSION 1 73 - 094 -- APRIL 5, 1973

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

UNDER NASA GRANT: 47-004-103

ADDITIONAL SUBPROGRAMS REQUIRED:
ICVT -- ASSEMBLER LANGUAGE SUBPROGRAM TO CONVERT AN 12 INTEGER
TO A2 CHARACTER FORMAT.

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

DIMENSION A(151,151),PTS(4001),US(500),VS(500),CORCOF(500)
DIMENSION UORG(100),VORG(100),CORG(100)
DIMENSION AU(151),AV(151)
INTEGER TITLE(20)
REAL INITLS,INITLT
REAL LOWCON
INTEGER OPT1V,OPT2,OPT3,PX,PY
COMPLEX CTEMP,CI
COMMON /PLT1/ PTS
COMMON /ARRAY/ A
COMMON /PAT1/ PL1,P2,P3,P4,P5,P6,P1,SS(400),TT(400),RR(400)
COMMON /PAT2/ 11,12,13,14,15
COMMON /LOC/ I TYPE
IPAGE=0
PI=3.14159265
C=CMPLX(0.0,1.0)
CALL STIME(ITIME)
TIME=0.
9999 CONTINUE
CALL TIMES
IPAGE=IPAGE+1
CALL DATE(I1,J1,K1)
CALL STIME(IT)
IHR=IT/10000
IFR=IT-IHR*10000
FM=IFR/10000.
IMIN=FM
ISEC=(FM-IMIN)*60
IHR=ICVT(IHR)
IMIN=ICVT(IMIN)
ISEC=ICVT(ISEC)
IPG=ICVT(IPAGE)
WRITE(6,1) I1,J1,K1,IHR,IMIN,ISEC,IPG
FORMAT(1H1,2X,ANTDATA VERSION 1 LEVEL 2,20X,VPI EE DEPT.,5X,DATE = 'A2,-*,A2,'-1,A2,
85X,TIME = 'A20,900,A20,900,A2,10X,PAGE 00,'A2 */)
READ PATTERN NUMBER AND TRACK -- VERIFY THAT PATTERN IS ACTUALLY STORED
READ(5,10,END=999) NUMPAT,NUMTRK
10 FORMAT(1415)
IF(NUMPAT.EQ.0) GO TO 999
WRITE(6,704) NUMPAT
704 FORMAT(' PLOT OUTPUT FOR PATTERN',I5,:')
READ(22,20) NUM
IF(NUM.EQ.NUMPAT) GO TO 50
CONTINUE
NUMPAT IS NOT ON DISK
WRITE(6,60) NUMPAT
60 FORMAT(' PATTERN NUMBER WAS NOT FOUND ON TRACK I2 BUT WAS LOCATED ON TRACK I2)
GO TO 999
NUMPAT FOUND ON UNEXPECTED TRACK
WRITE(6,60) NUMPAT,NUMTRK,1
60 FORMAT(' PATTERN NUMBER WAS NOT FOUND ON TRACK I2, NUMTRK=1
CONTINUE
REGIN PROCESSING
READ(5,10) MMAX,NMAX
READ(22,NUMTRK,7C) ITEMPE,
70 FORMAT(104X,2A4)
READ(22,NUMTRK,101) NUMPAT,TITLE,ISYM,ITER,ISUC,FNORM,IVISK, $NCRG,IC,(UORG(J),VORG(J),CORG(J),J=1,ITEMP), $(US(J),VS(J),CRCOF(J),J=1,ITEMP1),ITYPE,P1,P2,P3,P4,P5,P6, $PI,(SS(J),IT(J),J=1,400),IL,12,13,14,15,MCUR,NCUR

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

C C READ OPTIONS FOR PATTERN MAGNITUDE C

READ(5,29) OPTIU,OPTIV,OPT2,OPT3
29 FORMAT(4I1)
IF(OPTIU-1) 80,81,60
81 CONTINUE
READ(5,31) CONST
IF(MMAX.LE.1) GO TO 80
DO 90 J=1,4001
U=(J-1)*0.0005-1.0
SUM=0.
90 CONTINUE
DO 91 K=1,NCRG
SUM=SUM+CRCF(K)*PAT(U-US(K),V-VS(K),ITYPE)
91 CONTINUE
IF(NMAX.LE.1) GO TO 239
PILAU=2.0/(MMAX-1)
DELTAU=7.0/(NMAX-1)
WRITE(6,761) LOWCON,DASH
761 IF(P-MAX.LE.1.OR.NMAX.LE.1) GO TO 239
WRITE(6,821) LOWCON
821 FORMAT('PATTERN IS NOW BEING GENERATED. IF PATTERN < *,F7.2, "5")
834 IF(ITYPE.GT.5) GO TO 5000
C LOAD UP AU AND AV

C
GO 2000 I=1,MMAX
U=(I-1)*DELTAU
GO 2010 J=1,NMAX
V=(J-1)*DELTAV
AV(J)=PAT(0.,V,ITYPE)

C BEGIN

U=-1.0-DELTAU
GO 2040 K=1,NORG
I=ABS(U-UORG(K))/DELTAU+1.5
J=ABS(V-VORG(K))/DELTAV+1.5
TEMP=0.
GO TO 239
CONTINUE

DO 200 M=1,MMAX
U=-1.0+(M-1)*DELTAU
GO 201 N=1,NMAX
V=-1.0+(N-1)*DELTAV
TEMP=0.
GO TO 239
CONTINUE

A(M,N)=20.0*ALOG10(ABS(TEMP))
CONTINUE
CONTINUE
CONTINUE
CONTINUE
IF(MMAX.LE.1.OR.NMAX.LE.1) GO TO 230
GO 257 M=1,MMAX
GO 257 N=1,NMAX
IF(A(M,N).LT.LOWCON) A(M,N)=LOWCON
CONTINUE
WRITE(6,220) CONLOW,CONMAX,CONINT
A-79

154  220 FORMAT(*CONTOUR PLOT OF PATTERN REQUESTED*)
155         LOWEST CONTOUR = 'F7.2/
156         HIGHEST CONTOUR  = 'F7.2/
157         CONTOUR INTERVAL = 'F7.2 /

158      CALL PLOT2(MMAX,NMAX,CONLOW,CONMAX,CONINT,NUMPAT,DASH)
159      CALL PLOT3(MMAX,NMAX,NUMPAT)

160      CONTINUE

161      IF(MMAX.LE.1.OR.NMAX.LE.1) WRITE(6,23)
162      23 FORMAT(0 -- TWO AND THREE DIM. PLOTS CANCELLED SINCE SOURCE IS
163           ONE DIMENSIONAL')

164      CONTINUE

C
C END OF PATTERN
C
C
IA=0
165      IF(ITYPE.EQ.1) GO TO 401
166      IF(ITYPE.EQ.3) GO TO 401
167      IF(ITYPE.EQ.4) GO TO 401
168      IF(ITYPE.EQ.6) GO TO 401
169      4CC WRITE(6,402)
170      402 FORMAT(1HO,*THE SOURCE IS AN ARRAY -- THIS PGM IS FOR CONTIGUS SOURCES ONLY*)

171      IA=1
172      401 CONTINUE
173      P3TEMP=P3
174      P5TEMP=P5
175      P6TEMP=P6
176      IF(ITYPE.EQ.1) 404,403,404
177      404 IF(ITYPE=3) 405,403,405
178      403 CONTINUE
C
C  ITYPE= 1 OR 3
179      INITLS=0.
180      DELTAS=0.
181      FINALS=0.
182      INITLT=P2
183      FINALT=P2+P1
184      P3=P1/4CC0.
185      DELTAT=P3
186      GO TO 410
187      405 IF(ITYPE-4) 407,406,407
188      406 CONTINUE
C
C  ITYPE=4
189      INITLS=P3
190      FINALS=P3+P1
191      INITLT=P4
192      FINALT=P4+P2
193      P5=P2/4CC0.
194      P6=P2/400.
195      DELTAT=P6
196      DELTAS=P5
197      GO TO 410
198      407 CONTINUE
199      IF(ITYPE=6) 410,409,410

"98 407 CONTINUE

409 INITLS=P3
410 CONTINUE
411 READ(5,29) OPTIU,OPTIV,OPT2,OPT3
412 IF(OPTIu-1) 302,301,302
413 CONTINUE
414 READ(5,31) CONST
415 IF(IA.EQ.1) GO TO 3000
416 IF(I.MAX.LE.1) GO TO 302
417 J=1
418 IF(DELTAT.NE.0.0) J=1.5+(CONST-INITLT)/DELTAT
419 DO 303 I=1,4001
420 CTEMP=(0.0,0.0)
421 IF(NORG.LE.0.0) GO TO 304
422 DO 305 K=1,NORG
423 CTEMP=CTEMP+CORG(K)*SOURCE(I,J,UORG(K),VORG(K),ITYPE)
424 IF(IC.LE.0.0) GO TO 303
425 PTS(I)=CABS(CTEMP)
426 WRITE(6,307) CONST
427 CALL PLOTIC(INITLS,FINALS,4001,2,CONST,NUMPAT)
428 CONTINUE
429 IF(CPTIV-1) 311,310,311
430 CONTINUE
431 READ(5,31) CONST
432 IF(IA.EQ.1) GO TO 3000
433 IF(N.MAX.LE.1) GO TO 322
434 J=1
435 IF(DELTAS.NE.0.0) J=1.5+(CONST-INITLS)/DELTAS
436 DO 313 J=1,4001
437 CTEMP=(0.0,0.0)
438 IF(NCRG.LE.0.0) GO TO 314
439 DO 315 K=1,NCRG
440 CTEMP=CTEMP+CORG(K)*SOURCE(I,J,UORG(K),VORG(K),ITYPE)
441 IF(IC.LE.0.0) GO TO 313
442 PTS(J)=CABS(CTEMP)
443 WRITE(6,317) CONST
444 CALL PLOTIC(INITLT,FINALT,4001,1,CONST,NUMPAT)
445 CONTINUE
446 P3=P3TEMP
447 P5=P5TEMP
448 P6=P6TEMP
449 MCUR=51
450 NCUR=51
A-81

257 IF(OPT2+OPT3) 320,320,321
258 321 CONTINUE
259 READ(5,31) LOWCON,DASH
260 IF(IA.EQ.1) GO TO 333

C GENERATE CURRENT MAGNITUDE ARRAY

C DO 32 C M=1,MCUR
261 DO 33 N=1,NCUR
262 CALL LOCSOR(M,N,S,T)
263 CTEMP=0.
264 DC 339 K=1,NORG
265 CTEMP=CTEMP+CORG(K)*SOURCE(M,N,UORG(K),VORG(K),ITYPE)
266 DC 332 K=1,IC
267 CTEMP=CTEMP+CORCOF(K)*SOURCE(M,N,US(K),VS(K),ITYPE)
268 A(P,N)=ABS(CTEMP)
269 331 CONTINUE
270 333 CONTINUE

271 IF(OPT2) 350,350,351
272 351 READ(5,31) CONLOW,CONMAX,CONINT
273 IF(IA.EQ.1) GO TO 360
274 IF(VMAX.LE.1.OR.NMAX.LE.1) GO TO 360
275 WRITE(6,340) CONLOW,CONMAX,CONINT
276 340 FORMAT('CURRENT MAGNITUDE REQUESTED'/'
$\$ \$ \$ LOWEST CONTOUR = ',F7.4/
$\$ \$ HIGHEST CONTOUR = ',F7.4/
$\$ \$ CONTOUR INTERVAL = ',F7.4)
277 WRITE(69355) MCUR,NCUR,CONLOW,CONMAX,CONINT,NUMPAT,DASH
278 355 FORMAT('THREE DIMENSION PLOT OF CURRENT MAGNITUDE REQUESTED')
279 CALL PLOT2 (MCUR,NCUR,CONLOW,CONMAX,CONINT,NUMPAT,DASH)
280 IF(OPT3) 360,360,361
281 361 IF(IA.EQ.1) GO TO 360
282 WRITE(6,355)
283 355 FORMAT('THREE DIMENSION PLOT OF CURRENT MAGNITUDE REQUESTED')
284 CALL PLOT3 (MCUR,NCUR,NUMPAT)
285 360 CONTINUE
286 IF(VMAX.LE.1.OR.NMAX.LE.1) WRITE(6,23)
287 32C CONTINUE

C END OF CURRENT MAGNITUDE

C READ OPTIONS FOR CURRENT PHASE

C READ(5,29) OPT1U,OPT1V,OPT2,OPT3
289 IF(OPT2+OPT3) 520,520,521
290 521 CONTINUE
291 IF(IA.EQ.1) GO TO 533
292 READ(5,31) LOWCON,DASH

C GENERATE CURRENT PHASE

C DO 530 M=1,MCUR
293 DO 531 N=1,NCUR
294 CALL LOCSOR(M,N,S,T)
295 CTEMP=0.
296 DC 549 K=1,NORG
297 CTEMP=CTEMP+CORG(K)*SOURCE(M,N,UORG(K),VORG(K),ITYPE)
A subroutine PLOT1 is defined, which is used to plot current phase contours. The subroutine plots the lowest, highest, and interval contours based on the user's request. It also calculates and prints the execution time and elapsed time of the program. The subroutine is written by S. R. Kaufman and dated April 23, 1973.
INPUT:

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

INTEGER NAME(2), CODE
DIMENSION PTS(4001)
COMMON /PL1/ PTS
CALL FACTOR(0.5)
CALL PLOT(8.91.,-3)
IF(CODE.GT.0) GO TO 3
CALL SYMBOL(-1.2,-6,2.8,H=0,8)
CALL NUMBER(-3,-8,2,CONST,0,8)
GO TO 6
3 IF(CODE.GT.1) GO TO 4
CALL SYMBOL(-1.2,-8,2,1THETA = 0,8)
CALL NUMBER(-3,-8,2,CONST,0,3)
GO TO 6
4 IF(CODE.GT.2) GO TO 5
CALL SYMBOL(-1.2,-8,2,1HV,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
5 CONTINUE
PDEL=(PSTRT-PEND)/IP
PTIC=(ABS(PSTRT-PEND))/10.
CALL AXIS(-5.0,1H,1.4,0,PSTRT,PTIC)
PSTRE=PSTRT+(6.*PTIC)+.00001
PTIC2=PTIC+.00001
CALL AXIS(1.0,1H,1.4,0,PSTRE,PTIC2)
CALL PLOT(-1.0,9,3)
CALL PLOT(0.0,9,2)
CALL PLOT(0.0,9,3)
CALL PLOT(0.0,9,2)
CALL PLOT(0.0,9,3)
CALL SYMBOL(-0.05,-0.2,110,0,1)
X=0.05
J=1
Y=0.5+(J-1)*1.0
CALL PLOT(-X,Y,3)
10 CALL PLOT(X,Y,2)
CALL PLOT(0.0,0,2)
IF(PTS(1) .LE. -50.) PTS(1)= -50.
FS= ((PTS(1))/10.)+5.5
SUBROUTINE PLOTIC(PSTRT, PEND, IP, CODE, CONST, NUPAT)

INTEGER NAME(2), CODE
CALL FACTOR(0.5)
CALL PLOT(8.5, 1.5, -3)
COMMON /PLT1/ PTS

I = C
IF (CODE .GT. 0) GO TO 3
CALL SYMBOL(-1.2, -0.6, 0.2, 8, 'THETA = ', 0.0, 8)
CALL NUMBER(0.3, -0.8, 0.2, CONST, 0.0, 3)
GO TO 6
3 IF (CODE .GT. 1) GO TO 4
CALL SYMBOL(-1.0, -0.8, 0.2, 1HS, 0.0, 1)
CALL SYMBOL(-0.9, -0.8, 0.2, 3H = , 0.0, 3)
CALL NUMBER(-0.2, -0.8, 0.2, CONST, 0.0, 3)
CALL SYMBOL(-2.6, -0.4, 0.2, 2H-T, 0.0, 2)
CALL SYMBOL(2.4, -0.4, 0.2, 2H+T, 0.0, 2)
GO TO 6

417 IF(CODE.GT.2) GO TO 5

418 CALL SYMPCOL(-1.0,-0.8,0.2,1H,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 CONTINUE

424 PCEL=(PSTRT-PEND)/IP

425 PTIC=ABS(PSTRT-PEND)/10.0

426 CALL AXIS(-5.0,-0.0,1H,1,4.0,0.0,PSTRT,PTIC)

427 PSTRE=PSTRT+(6.0*PTIC)+0.00001

428 PTIC2=PTIC+0.001

429 CALL AXIS(1.0,0.0,1H,1,4.0,0.0,PSTRE,PTIC2)

430 CALL PLOT(-1.0,0.0,3)

431 CALL PLOT(1.0,0.0,2)

432 CALL PLOT(0.0,5.0,2)

433 CALL PLOT(0.0,0.0,3)

434 CALL SYMBOL(-0.05,-0.4,0.2,1H,0.0,1)

436 X=0.05

437 CC 10 J=1,6

438 Y=0.5+(J-1)*1.0

439 CALL PLOT(-X,Y,3)

10 CALL PLOT(X,Y,2)

440 CALL PLOT(C.0,0.3)

441 PSTRE=5.0*PSTRT

442 GMAX=0.0

443 DO 11W1=1,IP

444 IF (PTS(IW1).GT.GMAX) GMAX=PTS(IW1)

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 PTSA=((PTS(IW1))/ASCLE)*5.+0.5

453 CALL PLOT(-5.0,PTSA,3)

454 DO 7 IW1=1,IP

455 THERET=(PSTRT-(IW1*PDEL))

456 THERET=(THERET/(ABS(PSTRT)))*5.

457 APTS=((PTS(IW1))/ASCLE)*5.+0.5

458 CALL PLOT(INER,APTS,2)

7 CONTINUE

460 IF (GMAX.GT.0.5) ATIC=0.2+0.0001

461 IF (GMAX.LE.0.5) ATIC=0.1+0.0001

462 IF (GMAX.LE.0.20) ATIC=0.04+0.0001

463 IF (GMAX.LE.0.1) ATIC=0.02+0.0001

464 IF (GMAX.LE.0.05) ATIC=0.01+0.0001

465 CALL AXIS(-5.5,-5.16H,SOURCE MAGNITUDE,16.5,0.90,0.0,1,0.0,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.,-1)

469 CALL PLOT(4.0,-1.0,-3)

5 RETURN

ENC
SUBROUTINE PLOT1P(PSTRT, PEND, IP, CODE, CONST, NUMPAT)

SUBROUTINE PLOT1P

WRITTEN BY: S. R. KAUFMAN

DATE: 73-113 APRIL 24, 1973

INPUT:

PSTRT -- BEGINNING OF PLOT
PEND -- END OF PLOT
IP -- NUMBER OF POINTS TO BE PLOTTED (IP < 4002)
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 /PLTI/PTS
CALL FACTOR(0.5)
CALL PLOT(8., 1., -3)
IF(CODE.GT.0) GO TO 3
CALL SYMBOL(-1.2, -6., .2, 8HTHETA = , 0., 8)
CALL NUMBER(.3, -8., 2, CONST, 0., 3)
GO TO 6
3 IF(CODE.GT.1) GO TO 4
CALL SYMBOL(-1., -8., 2, 1HS, 0., 1)
CALL SYMBOL(-.9, -.8, 2, 3H = , 0., 3)
CALL NUMBER(-.2, -.8, 2, 2H, 3H = , 0., 3)
CALL SYMBOL(-2.6, -.4, 2, 2H+T, *0.2)
CALL SYMBOL(2.4, -.4, 2, 2H+S, T, .0, 2)
GO TO 6
4 IF(CODE.GT.2) GO TO 5
CALL SYMBOL(-1., -8., 2, 1HT, 0., 1)
CALL SYMBOL(-.9, -.8, 2, 3H = , 0., 3)
CALL NUMBER(-.2, -.8, 2, 2H, 3H = , 0., 3)
CALL SYMBOL(-2.6, -.4, 2, 2H-5, *0.2)
CALL SYMBOL(2.4, -.4, 2, 2H+S, T, .0, 2)
GO TO 6
5 PCEL=(PSTRT-PEND)/IP
PTIC=ABS(PSTRT-PEND)/10.0
CALL AXIS(-5.0, 0., 0., 1H , 1, 4, 0, 0., PSTR, PTIC)
PSTRE=PSTRT+(6.0*PTIC)+0.00001
PTIC2=PTIC+0.00001
CALL AXIS(1., -0., 1H , 1, 4, 0., PSTM, PTIC2)
CALL PLOT(-1., 0., 3)
CALL PLOT(-1., 0., 2)
CALL PLOT(1., 0., 3)
CALL PLOT(0., 5.8, 2)
CALL PLOT(0., 5.8, 2)
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506 CALL SYMBOL(-.05,-.4,.2,100.0,.1)
507 CALL PLOT(-.0,.0,.3)
508 X=C.05
509 GO TO J=1,9
510 Y=0.5+(J-1)*1.0
511 CALL PLOT(-X,Y,.3)
512 IC CALL PLOT(X,Y,2)
513 CALL PLOT(0.0,0.0,.3)
514 DC 1 IW1=1,IP
515 THETA=(PSTRT-(IW1*PDEL))
516 THETS=(THETA/(ABS(PSTRT)))*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 1 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(NUMPAT)
525 CALL NUMBER(-3.5,-0.8,0.125,FNUM,0.,-1)
526 CALL PLOT(-3.,-1.,-3)
527 5 RETURN
528 END

SUBROUTINE PLOT2(N,M,CONLOW,CONMAX,CONINT,NUMPAT,DASH)
C A = N BY M MATRIX OF DATA POINTS
C CONLOW = LOWEST CONTOUR TO BE PLOTTED
C CONMAX = HIGHEST CONTOUR TO BE PLOTTED
C CONINT = INTERVAL BETWEEN CONTOURS
C WORDS = TEXT OF PLOT LABEL
C NCHAR = NUMBER OF CHARACTERS IN PLOT LABEL
C CONTOURS BELOW -40. ARE PLOTTED AS DASHED LINES
C
D M A S 1 , M A S S 1 , R A S 1 , R B S 1 , X S 1 , Y S 1
C
DIMENSION A(151,151),RA(151),RB(151),X(151),Y(151)
C
COMMON /ARRAY/ A
C
CALL PLOT(-3.,-1.,-3)
C
CALL FACTOR(0.7)
C
MS=M
C
NS=N
C
RATIO=MS/NS
C
SCALE=10.
C
ANM=AMAX1(N-1,M-1)
C
IF(RATIO-1.0)1,2
C
1 SX=ANM
C
SY=RATIO*ANM
C
GO TO 3
C
2 SX=1./RATIO*ANM
C
SY=ANM
C
3 SMAX=AMAX1(SX,SY)
C
SS=SX/SMAX
C
SYS=SY/SMAX
C
IF(CONINT)4,495
C
4 CALL CNLAL(N,H,CNTRL0,CMAX,CNTRL,0)
C
GO TO 7
551 5 CNTRL=CNTRAL
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,CNTRL,1)
557   7 CONTINUE
558   CONLOW=CNTRLO
559   CONMAX=CMAX
560   CONINT=CNTRAL
561   CALL PLOTL(SS,SY,SYS,0.,SYS,SCALE)
562   CALL PLOTL(0.,0.,SS,0.,SYS,SCALE)
563   CALL PLOTL(SS,0.,SYS,0.,0.,SCALE)
564   CALL PLOTL(1.00,0.25,3)
565   CALL PLOTL(0.60,0.25,2)
566   CALL PLOTL(0.60,0.25,2)
567   CALL PLOTL(1.00,0.25,2)
568   CALL SYMBOL(0.88,0.45,0.12,10HPATTERN = .90.,10)
569   FNUM=NUMPAT
570   CALL NUMBER(0.88,2.075,0.12,FNUM,90.,-1)
571
572  1125 YCCNA=1.0/SMAX
573    DELTAX=SQ/FLOAT(N-1)
574    X(1)=0.0
575    Y(1)=0.0
576    RB(1)=A(1,1)
577    DO 27 J=2,N
578       RB(J)=A(J,1)
579    27 X(J)=X(J-1)+DELTAX
580    DELTAY=SY/FLOAT(M-1)
581    DO 28 J=2,M
582       Y(J)=Y(J-1)+DELTAY
583    28 Y(J)=Y(J-1)+DELTAY
584    DO 118 K=2,N
585       RA(J)=RB(J)
586    118 RB(J)=A(J,K)
587    30 RX=RX
588    35 ASSIGN 112 TO L
589    RR=RA(J)
590    XX=X(J)
591    YY=Y(K-1)
592    37 RL=RR
593    XL=XX
594    YL=YY
595
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    601 GO TO 40
602    42 RL=RB(J)
603    XL=X(J)
604    604 YL=Y(K)
605    GO TO 50
606    50 RS=RR
607    XS=XX
608  \( YS = YY \)
609  IF (RS - RA(J-1)) 52, 52, 53
610  \( 52 \) IF (RS - RB(J)) 60, 60, 54
611  RS = RA(J-1)
612  \( XS = X(J-1) \)
613  \( YS = Y(K-1) \)
614  GO TO 52
615  \( 54 \) RS = RB(J)
616  \( XS = X(J) \)
617  \( YS = Y(K) \)
618  GO TO 60
619  \( 60 \) RM = RR
620  \( XM = XX \)
621  \( YM = YY \)
622  IF (RM - RS) 62, 62, 61
623  IF (RM - RL) 62, 62, 62
624  RM = RA(J-1)
625  \( XM = X(J-1) \)
626  \( YM = Y(K-1) \)
627  IF (RM - RS) 64, 64, 63
628  IF (RM - RL) 70, 64, 64
629  \( 64 \) RM = RB(J)
630  \( XM = X(J) \)
631  \( YM = Y(K) \)
632  \( 70 \) YCS = YS*YCONA
633  YCM = YM*YCONA
634  YCL = YL*YCONA
635  \( 71 \) YS = YS - SY
636  \( YM = YM - SY \)
637  \( YL = YL - SY \)
638  \( 72 \) XCS = XS / SMAX
639  XCM = XP / SMAX
640  XCL = XL / SMAX
641  \( RC = CNTRLO \)
642  \( 80 \) IF (RC GT CMAX) GO TO 110
643  \( IF \{ RC .NE. RM \} \) GO TO 91
644  \( 81 \) IF (RM .NE. RS) GO TO 91
645  \( 82 \) IF (RL EQ. RM) GO TO 100
646  \( 91 \) IF (RC - RS) 100, 95, 92
647  \( 92 \) IF (RC - RM) 96, 93, 94
648  \( 93 \) XPA = XCM
649  \( YPA = YCM \)
650  GO TO 99
651  \( 94 \) IF (RC - RL) 101, 103, 110
652  \( 95 \) Q = 0.0
653  \( GO TO 97 \)
654  \( 96 \) Q = (RC - RS) / (RM - RS)
655  \( 97 \) XPA = XCS - Q \( \times \) XCS - XCM
656  \( YPA = YCS - Q \times YCS - YCM \)
657  \( 99 \) Q = (RC - RS) / (RL - RS)
658  \( XPB = XCS - Q \times XCS - XCL \)
659  \( YPB = YCS - Q \times YCS - YCL \)
660  \( IF \{ RC = DASH \} 10115, 10115, 10116 \)
661  \( 10115 \) XPH1 = 0.5 \( \times \) XPA + XPB
662  \( YPB1 = 0.5 \( \times \) YPA + YPB \)
663  IF (ABS (XPA - XPB1) = .001) 5001, 5002, 5002
664  \( 5001 \) IF (ABS (YPA - YPB1) = .001) 100, 5002, 5002
A-90

5002 CALL PLCT(SCALE*XPA+2.,SCALE*YPA+0.25,3)
5003 CALL PLCT(SCALE*XPB+2.,SCALE*YPB+0.25,2)
GO TO 100

1C16 IF(ABS(XPA-XPB)-.001)5003,5004,5004
5003 IF(ABS(YPA-YPB)-.001)100,5004,5004
5004 CALL PLCT(SCALE*XPA+2.,SCALE*YPA+0.25,3)
5005 CALL PLCT(SCALE*XPB+2.,SCALE*YPB+0.25,2)
GO TO 100
RC = RC + CNTRAL
GO TO 80

XPA = XCL
YPA = YCL
GO TO 99

106 C=(RC-RM)/(RL-RM)
XPA=XCM-C*(XCM-XCL)
YPA=YCM-C*(YCM-YCL)
GO TO 99

110 GC TO L,(112,118)

112 ASSIGN 118 TO L
RR =RB(J-1)
XX =X (J-1)
YY =Y (K)
GO TO 37.
CONTINUE

118 CALL PLCT(SCALE+6.,0.,-3)
RETURN
END

SUBROUTINE CNTRL,(N,M,CNTRLO,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
XMAX=A MAX(XMAX,X(I,J))
XMIN=A MIN(XMIN,X(I,J))
10 IF(NC.EQ.1) GO TO 40
IF(XMAX.EQ.0.) GO TO 20
SN=XMIN/XMAX
IF(SN).GE.20.20,30
20 XCON=ABS(XMAX)
IF(ABS(XMIN).GT.ABS(XMAX))XCON=ABS(XMIN)
CNTRAL=XCON/10.
CMAX=XMAX
CNTRAL=CNTRAL*AINT(XMIN/CNTRAL)
RETURN
30 XCON=ABS(XMAX-XMIN)
CNTRAL=XCON/10.
CNTRAL=CNTRAL*AINT(XMIN/CNTRAL)
RETURN
40 CMAX=CNTRAL*AINT(XMAX/CNTRAL)
CNTRAL=CNTRAL*AINT(XMIN/CNTRAL)
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 -- SDISTS > 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

REMARKS.

1. 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/ ANG, 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 C. KEPHART.
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W. L. STUTZMAN
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SUBROUTINE PLOT3IN(M, N, NUMPAT)

COMMON /ARRAY/ A
COMMON /THREE6/ ANG, ANGB, HV, D, SH, SV
COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, QX, QY, QZ, SD
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733 DIMENSION H(10),V(10),X(2),Y(2),Z(2),XP(8),A(151,151)
734 K=2
735 SOISTS=6.0
736 PITCH=30.
737 YAW=45.
738 SIZE=10.
739 KOCF=0
740 MGN=0
741 SCALE=1.
742 CALL FACTOR(1.1)
743 CALL PLOT(8.,-2.,-3)
744 CALL PLOT(4.,0.,2)
745 CALL PLOT(4.,8.,2)
746 CALL PLOT(0.,8.,-2)
747 CALL PLOT(0.,0.,2)
748 CALL SYMBOL(0.3,1.0,0.12,10HPATTERN = .90.,10)
749 FNUP=FLOAT(NUMPAT)
750 CALL NUMBER(0.3,2.130,90.,-I)
751 CALL PLOT(1.5,-.2,-3)
752 ANGA = (YAW+270.) * .0174532
753 ANGB = PITCH * .0174532
754 HV = SIZE
755 SL = -COS( ANGA ) * COS( ANGB )
756 SM = -SIN( ANGA ) * COS( ANGB )
757 SN = -SIN( ANGB )
758 IF (ABS( SN ) .NE. 1.0) GO TO 10
759 WRITE( 6 , 20 )
760 20 FORMAT ( '1' , 20X, 20L(1**, ) , / '0' , 'YOU ARE ATTEMPTING TO \n:K STRAIGHT DOWN ( OR UP ) AT THE SURFACE * )
761 GO TO 2150
762 10 CONTINUE
763 SD = 1.0 / SCRT( 1.0 - SN ** 2 )
764 X(1) = 1
765 X(2) = N
766 Y(1) = 1
767 Y(2) = M
768 T=MAXC(M,N)
769 DO = M ** 2 + N ** 2 + T ** 2
770 D = SCRT( D )
771 SCL = SOISTS * D
772 CX = -SL * SCL
773 CY = -SM * SCL
774 CZ = -SN * SCL
775 QQ = CX + D * SL
776 QY = CY + D * SM
777 QZ = CZ + D * SN
778 GL TO 2060
779 100 FORMAT(1X,3F15.3)
780 2060 Z(2)=A(L,1)
Z(I)=A(I,J)

CC 1000 J=1,N

CC 1000 K=1,M

Z(I)=AMIN1(Z(I),A(J,K))

Z(2)=AMAX1(Z(2),A(J,K))

1000 CONTINUE

RANGE= (Z(2)-Z(1))

DCL=1.0

IF(SCALE.NE.0) DCL=T/RANGE*SCALE

C SCALE THE SURFACE TO MAKE A *CUBE*.

DO 30 I = 1 , N

CC 30 J = 1 , M

A (I, J) = ( A (I, J) - Z (1)) * DCL

30 CONTINUE

Z(1) = C.C

Z(2) = T

20CC CALL THREE2 ( X, Y, Z, XP, H, V, KODE)

DO 213C I = 1, 8

H( I ) = ( (XP(I) - OX) * SM - ( H(I) - QY ) * SL ) * SD

V( I ) = ( V( I ) - QZ ) * SD

213C CONTINUE

2100 H(10)=H(1)

H(9)=H(1)

DO 1001 J=1,8

H(9)=AMIN1(H(9),H(J))

H(10)=AMAX1(H(10),H(J))

1001 CONTINUE

2120 V(9)=V(1)

V(10)=V(1)

DO 1002 J=1,8

V(9)=AMIN1(V(9),V(J))

V(10)=AMAX1(V(10),V(J))

1002 CONTINUE

IF( MGN .NE. 0) GO TO 2140

S=H

IF(MGN .EQ. 1) S=1.5

SH = S/ (H(10)-H(9) )

SV = S/ (V(10)-V(9) )

SH = SIGN( AMIN1(SH,SV), SH )

SV = SIGN(SH,SV)

IF(MGN .EQ. 1)CALL PLOT (0.,2.,-3)

CALL SYMBOL(H(1)-H(9))*SH, (V(1)-V(9))*SV, 14.,'O',0.,1)

CALL SYMBOL(H(3)-H(9))*SH, (V(3)-V(9))*SV, 14.,'Z',0.,1)

CALL SYMBOL(H(2)-H(9))*SH, (V(2)-V(9))*SV, 14.,'Z',0.,1)

CALL SYMBOL(H(5)-H(9))*SH, (V(5)-V(9))*SV, 14.,'N',0.,1)

CALL PLOT(0.,0.,0.,-3)

CALL PLOT ( (H(1)-H(9))*SH, (V(1)-V(9))*SV, 3)

CALL PLOT ( (H(2)-H(9))*SH, (V(2)-V(9))*SV, 2)

CALL PLOT ( (H(1)-H(9))*SH, (V(1)-V(9))*SV, 2)

CALL PLOT ( (H(3)-H(9))*SH, (V(3)-V(9))*SV, 2)

CALL PLOT ( (H(1)-H(9))*SH, (V(1)-V(9))*SV, 2)

CALL PLOT ( (H(5)-H(9))*SH, (V(5)-V(9))*SV, 2)

IF( MGN .EQ. 3) GO TO 2139

CALL PLOT ( (H(6)-H(9))*SH, (V(6)-V(9))*SV, 2)

CALL PLOT ( (H(2)-H(9))*SH, (V(2)-V(9))*SV, 2)

CALL PLOT ( (H(4)-H(9))*SH, (V(4)-V(9))*SV, 2)

CALL PLOT ( (H(7)-H(9))*SH, (V(3)-V(9))*SV, 2)
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(16)
C
DO 180 I = 1, 2
C
DO 160 J = 1, 2
C
DO 150 K = 1, 2
C
L = L + 1
CALL THREE4 (X(I),Y(J),Z(K),XP(L),
H(L),V(L),KODE)
180 CONTINUE
160 CONTINUE
150 CONTINUE
140 CONTINUE
130 CONTINUE
END

SUBROUTINE THREE4 (X,Y,Z,XP,YP,ZP,KODE)
C FIND THE LOCATION OF A POINT IN THE ROTATED CUBE.
C
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,H,V,K,KODE)
C DRAW THE FIGURE.
C
COMMON /THREE6/ ANGA, ANGB, HV, D, SH, SV
COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, QX, QY, QZ, SD
C
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
C CAN USE 1 / 32 OR 1 / 64 FOR FINER INTERPOLATION
C

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)
M0 = M
NN = N
C 010 IF(K-1) 100,120,100
C 100 IF(K-3) 1110,120,1110
C
C DRAW LINES ALONG THE Y-AXIS
120 CONTINUE
L = 0
LD = 1
EC = 0.5 * LD

140 DO 1060 J = 1, M
C
160 DO 1030 I = 1, NN

L = L + LD
XI = L
CALL THREE3 ( XI, YJ, N, M, P, KODE) PEN = UP
IF ( P ) 510, 520, 530
510 CONTINUE
IF ( Q ) 540, 550, 540
520 CONTINUE
IF ( Q ) 610, 1020, 610
530 CONTINUE
IF ( Q ) 540, 550, 540
540 CONTINUE
PEN = DOWN
GC TO 170
550 CONTINUE
IF ( I .EQ. 1 ) GO TO 170
DI = CD
170 TC = L - LC
T = TC + DI
P1 = Q
600 IF ( ABS(DI).LT. END ) GO TO 570
CALL THREE3 (T, YJ, N, M, PO, KODE)
650 IF ( PO .EQ. C ) GO TO 565
TC = T
P1 = PO
T = T - DI
GO TO 560

565 T = T + DI
GO TO 56C

57C CONTINUE
T = T0
IF ( P1 * P ) 170 , 170 , 580

58C CONTINUE

59C CONTINUE
ZP = A(L-LC,J)+(T-L+L0)*(A(L,J)-A(L-LD,J))/LD
CALL THREE4(T,YJ,ZP,XP,HH,VV,KODE)

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)

GO TO 170

60C PEN = 5 - PEN
GO TO 170

61C CONTINUE
PEN = DOWN
DI = DC
TO = L - LD
T = TO + DI
P1 = Q

62C 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

TC = T
P1 = PO
T = T + DI
GO TO 620

625 T = T - DI
GO TO 62C

63C CONTINUE
T = TC
IF ( P1 * Q ) 600 , 600 , 590

17C CALL THREE4(XI,YJ,A(L,J),XP,HH,VV,K6(L)
VV = (VV-QZ)*SD
HH = ((XP-QX)*SM-(HH-QY)*SL)*SD

19C HH = (HH-H(9))*SH

200 VV = (VV-V(9))*SV
CALL PLOT(HH,VV,PEN)

102C Q = P

1030 CONTINUE
C

L = L + LD
LC = -LD
DD = -DD

C

1060 CONTINUE
C
C
C109C IF(K-3) 2060,111C,206C
DRAW LINES ALONG THE X-AXIS.

C

L = 0
LC = 1
CC = 0.5 * LD

DC 2040 I = 1, N
XI = I
C = C

DO 2020 J = 1, MM
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
1570 CALL THREE5 (XI, T, N, M, P, KODE)

DI = DI * 0.5

1580 IF ( PO .EQ. 0 ) GO TO 1565
1590 CONTINUE
TO = T

1600 PEN = 5 - PEN
1610 GO TO 1170

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 - GZ ) * SD

HH = ( HH - H(9) ) * SH

VV = ( VV - V(9) ) * SV

CALL PLOT ( HH, VV, PEN )

1620 PEN = 5 - PEN
1630 GO TO 1170
1640 CONTINUE

PEN = DOWN
A-99

1026   DO 1030 D1 = 0.0
1027   TO = L - LC
1028   T = TO + DI
1029   P1 = C
1030   1620 IF ( ABS( D1 ) .LT. END ) GO TO 1630
1031   CALL THREE5 ( XI, T, N, M, PO, KODE )
1032   DI = D1 * 0.5
1033   IF ( PC .EQ. 0 ) GO TO 1625
1034   TO = T
1035   P1 = PO
1036   T = T + DI
1037   GO TO 1620
1038   1625 T = T - DI
1039   GO TO 1620
1040   1630 CONTINUE
1041   T = TO
1042   IF ( P1 * C ) 1600 , 1600 , 1590
1043   CALL THREE4 ( XI, YJ, A(I, L), XP, HH, VV, KODE)
1044   HH = ( ( XP - QX ) * SM - ( HH - QY ) * SL ) * SD
1045   VV = ( VV - QZ ) * SD
1046   HH = ( HH - H(9) ) * SH
1047   VV = ( VV - V(9) ) * SV
1048   CALL PLOT ( HH, VV, PEN )
1049   2010 C = P
1050   2020 CONTINUE
1051   L = L + LC
1052   LC = - LC
1053   DO = - DD
1054   2040 CONTINUE
1055   2060 CONTINUE
1056   2130 RETURN
1057   END

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

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.
A-100

1077  YMULT = C.C
1078  ZMULT = C.C
1079  IF ( XI .EQ. CX ) GO TO 10
1080  YMULT = (YJ - CY) / (XI - CX)
1081  ZMULT = (ZB - CZ) / (XI - CX)
1082  CX = 1.0
1083  XEND = N + 1
1084  IF ( XI .LT. CX) GO TO 10
1085  CX = -1.0
1086  XEND = 0.0
1087  1C CONTINUE
1088  YMULT = C.C
1089  DY = 0.0
1090  XMULT = 0.0
1091  IF ( YJ .EQ. CY ) GO TO 20
1092  XMULT = ( XI - CX ) / (YJ - CY)
1093  IF ( ZMULT .EQ. 0.0 ) ZMULT=(ZB - CZ) / (YJ - CY)
1094  DY = 1.0
1095  YEND = N + 1
1096  IF ( YJ .LT. CY ) GO TO 20
1097  DY = -1.0
1098  YEND = C.C
1099  2C CONTINUE
1100  CX = I
1101  CNT = 0
1102  P = 0
1103  XB = XI
1104  YB = YJ
1105  3C CONTINUE
1106  II = AINT( XB )
1107  JJ = AINT( YB )
1108  XSTEP = DX
1109  YSTEP = DY
1110  IF ( XB .EQ. II ) GO TO 40
1111  IF ( CX .LT. 0.0 ) XSTEP = 0.0
1112  GO TO 45
1113  4C IF ( YB .EQ. JJ ) GO TO 45
1114  IF ( DY .LT. 0.0 ) YSTEP = 0.0
1115  45 CONTINUE
1116  I = II + XSTEP
1117  J = JJ + YSTEP
1118  IF ( I .EQ. XEND ) GO TO 80
1119  IF ( J .EQ. YEND ) GO TO 80
1120  XB = CX + XMULT * ( J - CY)
1121  YB = CY + YMULT * ( I - CX)
1122  IF ( DX .LT. 0.0 ) GO TO 55
1123  IF ( XB .LT. I ) GO TO 60
1124  5C XB = I
1125  GO TO 65
1126  55 IF ( XB .LT. I ) GO TO 50
1127  6C YB = J
1128  65 CONTINUE
1129  ZB = CZ + ZMULT * ( XB - CX)
1130  ICI = I
1131  JC = J
1132  IF ( YB .NE. J ) GO TO 70
1133  ICX = I - CX
FUNCTION PAT(U,V,ITYPE)

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


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

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

COMPLEX TEMP,CSEXPI,IMAG
COMMON /PAT1/ P1,P2,P3,P4,P5,P6,P1,SS(100),IT(100),RR(100)
COMMON /PAT2/ 11,12,13,14,15
IF(ITYPE.GT.7) GO TO 990
GO TO (1CC,2CC,300,400,500,600,700),ITYPE
ITYPE .LT. 1
WRITE(6,10) ITYPE
10 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(P1*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(P1*PI*V)/(II*SIN(P1*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
CC TO 999
PAT=1.0
GO TO 999
ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY

CONTINUE

FLS=P1
FLT=P2
NELS=I1
NELT=I2

ARG1=PI*P1*U
ARG2=PI*P2*V

IF(ARG1) 501,502,501
IF(ARG2) 503,504,503

PAT=SIN(ARG1)/(II*SIN(ARG1/II))*SIN(ARG2)/(12*SIN(ARG2/12))
GO TO 999

PAT=SIN(ARG1)/(II*SIN(ARG1/II))
GO TO 999

IF(ARG2) 505,506,505

PAT=SIN(ARG2)/(II2*SIN(ARG2/12))
GO TO 999

PAT=1.0
GO TO 999

ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.

C=SQR(U*U+V*V)
A=PI

IF(C.EQ.0.) GO TO 601
X=2.*PI*PI*C
CALL BESJ(X,1,BJ,0.0001,IER)
PAT=BJ/X*2.0
GO TO 999

PAT=I.C
GO TO 999.

ITYPE = 7 -- GENERAL ARRAY

IMAG=(0.0,1.0)
NELMT=I1*I2
TEMP=(0.0,0.0)
CC 701 J=1,NELMT
TEMP=TEMP*1.0*CEXP(IMAG*2.*PI*(U*SS(J)+V*TT(J)))
CONTINUE

PAT=REAL(TEMP)/NELMT
GO TO 999

PAT=SPECPT(U,V,ITYPE)
GO TO 999
RETURN
ENC

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

THIS SUBPROGRAM 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.

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

ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE.

ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY.

ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.

ITYPE > 7 -- 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

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

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

COMPLEX TEMP, CEXP, IMAG, SPSOR
COMMON /PAT1/ P1, P2, P3, P4, P5, P6, PI, SS(100), TT(100), R(100)
COMMON /PAT2/ 11, 12, 13, 14, 15

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

ITYPE .LT. 1
WRITE(6, 10) ITYPE
IC FORMAT(1HC,5X,0***ERROR*** ITYPE HAS THE VALUE ', ITYPE, ', EXECUTION TERMINATED')
STEP

ITYPE = 1 -- UNIFORM LINE SOURCE

CONTINUE
FLEN=P1
SOURCE=CEXP(-IMAG*2.0*PI*T)/P1
GO TO 999

ITYPE = 2 -- UNIFORM LINEAR ARRAY

CONTINUE
FLEN=P1
SOURCE=CEXP(-IMAG*2.0*PI*V)/P1
GO TO 999

ITYPE = 3 -- TRIANGULAR LINE SOURCE
A-105

3CC CONTINUE
C FLEN=PI
1244 CON=ABS(2.*T/PI)
1245 SOURCE=2.*PI*CEXP(-IMAG*2.*PI*T*V)*(1.-CON)
1246 IF(CON.GT.1) SOURCE=(0.0,0.0)
1247 GO TO 999
C
C ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE
C
1248 400 CONTINUE
C FLS=PI
C FLT=P2
1249 SOURCE=CEXP(-IMAG*2.*PI*(S*U+V*T))/(PI*P2)
1250 GO TO 999
C
C ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY
C
1251 500 CONTINUE
C FLS=PI
C FLT=P2
1252 SOURCE=CEXP(-IMAG*2.*PI*(S*U+V*T))/(PI*P2)
1253 GO TO 999
C
C ITYPE = 6 -- UNIFORM CIRCULAR APERTURE
C
1254 600 RHC=SCRT(S*S+T*T)
C A=PI
1255 SOURCE=(0.0,0.0)
1256 IF(RHC.LE.PI) SOURCE=CEXP(-IMAG*2.*PI*(S*U+T*V))/(2.*PI*PI*PI)
1257 GO TO 999
C
C ITYPE = 7 -- GENERAL ARRAY
C
1258 700 CONTINUE
1259 SOURCE=CEXP(-IMAG*2.*PI*(U*S+V*T))/(11*12)
1260 GO TO 999
1261 990 SOURCE=SPSOR(M,N,U,V,ITYPE)
1262 999 RETURN
1263 END

SUBROTLTINE LOCSOR(M,N,S,T)
1264 INTEGER PX,PY
1265 REAL INITLS,INITLT
1266 COMMON /PAT1/ P1,P2,P3,P4,P5,P6,PI,SS(100),TT(100),RR(100)
1267 COMMON /PAT2/ 11,12,13,14,15
1268 COMMON /LOC/ ITYPE
C
C IF(ITYPE.GT.7) GO TO 99C
1270 GO TO (1100,2100,3100,4100,5100,6100,7100), ITYPE
A-106

1272 WRITE(6,10) ITYPE
1273 10 FORMAT(1HC,5X,***ERROR***
  1274 S=EXECUTION TERMINATED*)
1275 STCP
C
1276 100 CONTINUE
C INITLT=P1
C CELTAT=P3
1277 S=G.
1278 T=P2+(N-1)*P3
1279 GO TO 999
C
1279 200 CONTINUE
C PY=I1
C DISY=P2
1280 S=G.
1281 T=(N-I1/2-1)*P2
1282 IF(I1/2*2.EQ.11) T=T+0.5*P2
1283 GO TO 999
C
1284 300 GC TO 100
C
1285 400 CONTINUE
C INITLS=P3
C INITLT=P4
C CELTAS=P5
C DELTAT=P6
1286 S=P3+(M-1)*P5
1287 T=P4+(N-1)*P6
1288 GO TO 999
C
1289 500 CONTINUE
C PX=I1
C PY=I2
C DISX=P3
C DISY=P4
1290 S=(N-11/2-1)*P3
1291 T=(N-I2/2-1)*P4
1292 IF(I1/2*2.EQ.11) S=S+0.5*P3
1293 IF(I2/2*2.EQ.12) T=T+0.5*P4
1294 GO TO 999
C
1295 600 GC TO 400
C
1296 700 CONTINUE
C NELPT=(M-1)*I2+N
1297 S=SS(NELPT)
1298 T=TT(NELPT)
1300 GO TO 999
C
C
1301 99C CALL SPLOC(M,N,S,T)
1302 999 RETURN
1303 ENC

1304 COMPLEX FUNCTION SPSOR(M,N,U,V,ITYPE)
1305 C DUMMY SUBPROGRAM
1306 SPSOR=(0.0,0.0)
1307 RETURN
1308 ENC

1308 FUNCTION SPECPT(U,V,ITYPE)
1309 C DUMMY SUBPROGRAM
1309 SPECPT=0.
1310 RETURN
1311 ENC

1312 SUBROUTINE SPLOC(M,N,S,T)
1313 C DUMMY SUBROUTINE
1314 RETURN
1314 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

\[
\begin{array}{c|c|c|c}
(u,v) & F_d(u,v) & F_u(u,v) & F_L(u,v) \\
\hline
-0.2 \leq u \leq 0.2 & 0. \text{ dB} & 0.5 \text{ dB} & -0.5 \text{ dB} \\
-0.05 \leq v \leq 0.05 & & & \\
\end{array}
\]

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

8.1 Input to ANTSYN

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

```fortran
SUBROUTINE SINPUT
RETURN
END

SUBROUTINE SPLOC
RETURN
END

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

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

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

C READ MAINBEAM LIMITS ULIM AND VLIM
C
READ(5,1) ULIM, VLIM
1 FORMAT(8Fi0.0)
C
C READ TRANSITION REGION LIMITS UTRAN AND VTRAN
C
READ(5,1) UTRAN, VTRAN
C
DO 10 M=1, MMAX
U=STARTU+(M-1)*DELTAU
DO 10 N=1, NMAX
V=STARTV+(N-1)*DELTAV
IF(U.LE.ULIM .AND. V.LE.VLIM) GO TO 20
IF(U.GT.UTRAN .OR. V.GT.VTRAN) GO TO 30
C TRANSITION REGION
FDES(M,N)=99.0
FU(M,N)=99.0
FL(M,N)=99.0
GO TO 10
20 CONTINUE
C MAIN BEAM REGION
FDES(M,N)=1.0
FU(M,N)=1.06
FL(M,N)=0.943
GO TO 10
30 CONTINUE
C SIDELOBE REGION
FDES(M,N)=0.
FU(M,N)=0.057
FL(M,N)=99.0
10 CONTINUE
C
RETURN
END

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

<table>
<thead>
<tr>
<th>Card Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 11 21 31 41 51 61</td>
</tr>
<tr>
<td>-------------</td>
</tr>
</tbody>
</table>

```
&PARAM
IDISK=1,ISYMM=3,DELTAU=0.02,DELTAV=0.01,MMAX=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
00015
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
0.2 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 -0.05 1.0
-0.2 -0.05 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., DELTAU=0.02,DELTAV=0.01
v. Make the comparisons at 26 points in the \( u \) direction and 51 points in the \( v \) direction (\( \text{MMAX}=26, \text{NMAX}=51 \))

vi. Assure that \( F(1,1)=0 \text{ dB} \) at all times (\( \text{MCENT}=1, \text{NCENT}=1 \))

Note that \( F(\text{MMAX}, \text{NMAX}) \) corresponds to \( (u,v)=(0.5,0.5) \): only part of the \((u,v)\) plane is considered.

Step 3. Cards 4 to 6: Output Switches

i. Profiles of the final pattern and final current (\( \text{FDBPR}=\text{FCURPR}=1 \))

ii. Contour maps of the desired pattern (\( \text{FDESCN}=1 \)) and final current (\( \text{FCURCN}=1 \)) are to be made

Step 4. Cards 7 to 11: Source Specifications

i. Rectangular aperture (\( \text{ITYPE}=4 \))

ii. Dimensions of 10\( \lambda \) by 20\( \lambda \) (\( \text{LX}=10., \text{LY}=20. \))

iii. The value of current will be calculated at 51 x 51 points from \( s = -5.0 \) to \( 5.0 \) by 0.2, and \( t = -10.0 \) to \( 10.0 \) by 0.4. (\( \text{INITLS}=-5., \text{FINALS}=5., \text{DELTAS}=0.2; \text{INITLT}=-10., \text{FINALT}=10., \text{DELTAT}=0.4 \))

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 (\( \text{NORG} \)) and the values of (\( \text{UORG}, \text{VORG}, \text{CORG} \)) the original correction coefficients.

Steps 7, 8, 9. See subroutines \( \text{SINPUT}, \text{SPLOC}, \text{SPECPT}, \text{SPSOR} \).

8.2 Output from ANTSYN

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

DATE = 09-25-73  TIME= 5.30.40  PATTERN 77

PROGRAM PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDISK</td>
<td>1</td>
</tr>
<tr>
<td>ISYMM</td>
<td>3</td>
</tr>
<tr>
<td>ITRMAX</td>
<td>200</td>
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INITLT,DELTAT,FINALT: -10.0000  0.4000  10.0000
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### AXIS PROFILE OF FINAL CURRENT

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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.

Card Column

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<th>Column</th>
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<th>11</th>
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Below is a table of the cards and their descriptions:

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<th>Card</th>
<th>Description</th>
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<tr>
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<td>2</td>
<td>Array dimensions are 151 x 151</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>All options for pattern magnitude are specified</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>U-profile location is 0. (V=0)</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>V-profile location is 0. (U=0)</td>
</tr>
<tr>
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<td>6</td>
<td>LOWCON=-35.0, DASH=-35.0</td>
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<td>CONLOW=-40.0, COMMAX=0.0, CONINT=5.0</td>
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8.4 Output from ANTDATA

The following is the printout from computer program ANTDATA.

PLOT OUTPUT FOR PATTERN 77:

U-AXIS PROFILE PLOT REQUESTED -- V=0.
V-AXIS PROFILE PLOT REQUESTED -- U=0.

CONTOUR PLOT OF PATTERN REQUESTED.

LOWEST CONTOUR = -30.0
HIGHEST CONTOUR = 0.0
CONTOUR INTERVAL = 5.0

PATTERN IS NOW BEING GENERATED. IF PATTERN < -35.00 PATTERN = -35.00
THREE-DIMENSIONAL PLOT OF PATTERN REQUESTED
EXECUTION TIME: 27.57 MINUTES.
Refer to Chapter 4 for plotter output.

<table>
<thead>
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<tr>
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<td>Contour plot</td>
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<td>4.29</td>
<td>Three-dimensional plot</td>
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