FINAL REPORT

on

Synthesis of Multiple Shaped Beam Antenna Patterns

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Submitted To: National Aeronautics and Space Administration
Washington, D. C.

NASA GRANT NUMBER NGR 47-004-103

August 31, 1973

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

1.2 A Practical Approach to Antenna Synthesis

The synthesis problem may be formulated as follows: Given a desired antenna pattern (which may have multiple shaped beams plus controlled side lobe structure), we wish to find antenna structures which will approximate the desired pattern within acceptable limits subject to realizability criteria. 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
The final stage is then one of determining which antenna type does the best job of meeting pattern and system specifications.

The antenna design problem is then described in three stages:

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

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

1.3 Scope of the Research

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

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

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

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

2.1 Equivalent Currents

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

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

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

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

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

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

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

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

\[
\vec{A}(r) = \frac{1}{\mu_0} \frac{e^{-jkr}}{4\pi r} \left[ \int J_s(r') e^{jk\hat{r}\cdot\hat{r}'} dx'dy' \right] \tag{2-3}
\]

\[
\vec{A}_M(r) = \frac{1}{\varepsilon_0} \frac{e^{-jkr}}{4\pi r} \left[ \int J_{MS}(r') e^{jk\hat{r}\cdot\hat{r}'} dx'dy' \right] \tag{2-4}
\]

where \( \hat{r}' = x'^\hat{x} + y'^\hat{y} \) and the coordinate system is shown below.

![Coordinate system diagram](image-url)
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

\[
\mathbf{j}_S = \hat{z} \times \mathbf{H}_a \\
\mathbf{j}_{MS} = -\hat{z} \times \mathbf{E}_a
\]

(2-5)

(2-6)

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

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

(2-7)

(2-8)

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

\[
\mathbf{H} = \hat{r} \times \mathbf{E} / \eta_o
\]

(2-9)
As an example suppose we use only a magnetic current and the aperture electric field is $y$-directed. Then

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

and

$$A_{Mx} = \frac{\epsilon_0}{4\pi r} e^{-jkr} \int_{\text{aperture}} \int 2 E_{ay} e^{jkr \cdot \mathbf{r}'} \, dx'dy'$$  \hspace{1cm} (2-11)

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

$$A_{M0} = \cos \theta \cos \phi \, A_{Mx}$$  \hspace{1cm} (2-12)

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

So

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

$$E_\phi = +j\omega_0 A_{M0}$$  \hspace{1cm} (2-15)

And

$$A_{Mx} = \frac{\epsilon_0}{2\pi r} e^{-jkr} \int_{\text{aperture}} \int E_{ay} e^{j[k(x' \sin \theta \cos \phi + y' \sin \theta \sin \phi)]} \, dx'dy'$$  \hspace{1cm} (2-16)

So

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

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

where

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

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

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

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

\[
E_\theta = \frac{jkn e^{-jkr}}{2\pi r} \cos \theta (F_y \cos \phi - F_x \sin \phi) \quad (2-22)
\]

\[
E_\phi = \frac{-jkn e^{-jkr}}{2\pi r} (F_y \sin \phi + F_x \cos \phi) \quad (2-23)
\]

where

\[
\vec{F} = \iint \vec{H}_a (x', y') e^{jk(x' \sin \phi + y' \sin \theta \sin \phi)} dx'dy' \quad (2-24)
\]

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 \( \hat{A} \) in (2-3) is used in the far-field expression (2-7). So quantitatively there is little difference from actual and equivalent current problems. The actual currents may be used in array antenna solutions.

If a current distribution can be expressed as follows

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

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

\[
E_\theta = E(r) \left[ \cos \phi F_x + \sin \phi F_y \right] \tag{2-26}
\]

\[
E_\phi = E(r) \left[ -\cos \theta \sin \phi F_x + \cos \theta \cos \phi F_y \right] \tag{2-27}
\]

where

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

This can be cast in a matrix form

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

where

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

\[
E_\phi(\theta, \phi) = E_\phi/E(r) \tag{2-31}
\]

and

\[
G_\theta x = \cos \phi \quad G_\theta y = \sin \phi \tag{2-32}
\]

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

In still more compact form (2-29) becomes

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

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

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

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
\[ F_x = \int \int x (x', y') e^{jk\alpha} \, dx'dy' \]  
(2-37)

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

becomes
\[ F_x = G_x \sum_{m=1}^{P} I_{xm} e^{jk\alpha_m} = G_x F_{arx} \]  
(2-39)

where
\[ \alpha_m = x'_m \sin \theta \cos \phi + y'_m \sin \theta \sin \phi \]  
(2-40)

and \((x'_m, y'_m)\) are the element phase center locations. Similarly
\[ F_y = G_y \sum_{m=1}^{P} I_{ym} e^{jk\alpha_m} = G_y F_{ary} \]  
(2-41)

These element factors may be combined into \([G]\) giving
\[ [G_{ar}] = \begin{bmatrix} \cos \theta \cos \phi & - \cos \theta \sin \phi & G_x \\ - \sin \phi & G_x & - \cos \phi & G_y \end{bmatrix} \]  
(2-42)

The antenna equation (2-32) for the array problem becomes
\[ [E] = [G_{ar}] [F_{ar}] \]  
(2-43)

where the \([F_{ar}]\) entries are the array factors
\[ F_{arx} = \sum_{m=1}^{P} I_{xm} e^{jk\alpha_m} \quad F_{ary} = \sum_{m=1}^{P} I_{ym} e^{jk\alpha_m} \]  
(2-44)

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

Since the current is y-directed we have
\[ F_x = 0 \]  
(2-45)
\[ F_y = G_y F_{ary} \]  
(2-46)
The short dipole pattern is

\[ G_y = \sin \beta \] (2-47)

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

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

Now

\[ F_{ary} = \sum_{jk} \alpha_m e^{j k a} \] (2-49)

where

\[ \alpha_m = x_m' \sin \theta \cos \phi \] (2-50)

since \( y_m' = 0 \).

2.4 Antenna Hardware Parameter Control

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

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

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

where

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

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

\[ \mathbf{Z} = \begin{bmatrix} Z_{11} & Z_{12} & \cdots \\ Z_{21} & Z_{22} & \cdots \\ \vdots & \vdots & \ddots \end{bmatrix} = \text{mutual impedance matrix (known from calculations or experiment)} \]
3. The Iterative Sampling Method for Planar Sources

3.1 History of the Iterative Sampling Method

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

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

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

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

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

3.2 Pattern Evaluation - What is an Acceptable Pattern?

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

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

3.3 The Integral Equation

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

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

(3-1)

where

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

(3-2)

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

(3-3)

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

$$s = x'/\lambda$$

(3-4)

$$t = y'/\lambda$$

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

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

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

This integral extends over the whole st-plane and is recognized as a two-dimensional Fourier transform. The analysis problem is straightforward. Given an aperture distribution \( f \) we can calculate \( F \) from (3-6) by integration. The synthesis problem, however, is very difficult. Suppose we are given a desired pattern \( F_d(u,v) \), which can be found from a desired electric field using (2-33). We wish to find an \( f \) (which is aperture-limited) giving an \( F \) which approximates \( F_d \) in some specified manner.

### 3.4 Mathematical Development of the Method

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

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

(3-7)

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

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

(3-8)

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

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

(3-9)

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

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

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

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

where

$$\Delta f^i(s,t) = \sum_{n} a^i_n g^i_n(s,t)$$  \hspace{1cm} (3-12)$$

The pattern $P^K(u,v)$ 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

$$f^K(s,t) = \sum_{\ell,m} I^K_{\ell m} \delta(s-s_{\ell m}, t-t_{\ell m})$$  \hspace{1cm} (3-13)$$

where $\delta$ is the dirac delta function and $I^K_{\ell m}$ are the currents for the $\ell m$ 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

$$g^i_n(s,t) = \sum_{\ell,m} g^i_{\ell m} \delta(s-s_{\ell m}, t-t_{\ell m})$$  \hspace{1cm} (3-14)$$

for arrays. Then (3-10) becomes

$$G(u-u_n^i, v-v_n^i) = \sum_{\ell,m} g^i_{\ell m} e^{j2\pi(s_{\ell m} + t_{\ell m})}$$  \hspace{1cm} (3-15)$$

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

$$\Delta f^i(s,t) = \sum_{\ell,m} a^i_n \sum_{\ell,m} g^i_{\ell m} \delta(s-s_{\ell m}, t-t_{\ell m})$$  \hspace{1cm} (3-16)$$

and let

$$\Delta f^i(s,t) = \sum_{\ell,m} \Delta I^i_{\ell m} \delta(s-s_{\ell m}, t-t_{\ell m})$$  \hspace{1cm} (3-17)$$

So
\[ \Delta I_{lm}(i) = \sum_{n} a_{n} g_{n} \]  
\[ \text{and} \]
\[ I_{lm}(K) = I_{lm}(0) + \sum_{i=1}^{K} \Delta I_{lm}(i) \]

### 3.5 Common Antenna Types

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

#### 3.5.1 Line Sources

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

\[ g_{n}^{(i)}(t) = \begin{cases} 
L_{y\lambda}^{-1} \exp(-j2\pi v_{n}^{(i)}t) & |t| \leq L_{y\lambda}/2 \\
0 & \text{elsewhere}
\end{cases} \]  
\[ (3-20) \]

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

\[ G(v-v_{n}^{(i)}) = \frac{\sin [L_{y\lambda}(v-v_{n}^{(i)})\pi]}{L_{y\lambda}(v-v_{n}^{(i)})\pi} \]  
\[ (3-21) \]

This is the so-called \( \sin x/x \) pattern.
An excitation which gives no edge illumination is the triangular line source. Its pattern has lower side lobes but larger beam width than the uniform line source pattern. The excitation function is

\[
g_n(t) = \begin{cases} 
  \frac{L_y}{L_y} \left(1 - \left|t/L_y\right|\right) \exp(-j2\pi t_n) & |t| \leq L_y/2 \\
  0 & \text{elsewhere}
\end{cases}
\]

(3-22)

The corresponding pattern found from (3-10) is

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

(3-23)

3.5.2 Linear Array

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

\[
g_{nm}(i) = \frac{i}{P} \exp(-j2\pi t_n)
\]

(3-24)

where \(t_n\) are the positions of the elements and equal \(md_{y}\) and \(P\) is the total number of elements. The corresponding pattern is

\[
G(u-v) = \frac{\sin \left[P(\nu-v_n)^\pi d_{y}\right]}{P \sin \left[(\nu-v_n)^\pi d_{y}\right]}
\]

(3-25)

3.5.3 Rectangular Aperture

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

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

(3-26)

The pattern is

\[
G(u-v_n) = \frac{\sin \left[L_x(\nu-u_n)^\pi\right]}{L_x(\nu-u_n)^\pi} \frac{\sin \left[L_y(\nu-v_n)^\pi\right]}{L_y(\nu-v_n)^\pi}
\]

(3-27)
3.5.4 Rectangular Array

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

\[
g_{n\lambda m}(i) = \frac{1}{P_x P_y} \exp \left[ -j2\pi \left( u_n(i) s_k + v_n(i) t_m \right) \right] \quad (3-28)
\]

The pattern is

\[
G(u-u_n(i), v-v_n(i)) = \frac{\sin \left[ P_x(u-u_n(i))d_{x\lambda} \right]}{P_x \sin \left[ (u-u_n(i))d_{x\lambda} \right]} \frac{\sin \left[ P_y(v-v_n(i))d_{y\lambda} \right]}{P_y \sin \left[ (v-v_n(i))d_{y\lambda} \right]} \quad (3-29)
\]

3.5.5 Circular Aperture

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

\[
g_n(i)(s,t) = \frac{1}{\pi a_\lambda^2} \exp \left[ -j2\pi (u_n(i) s + v_n(i) t) \right] \quad \sqrt{s^2 + t^2} \leq a_\lambda \quad (3-30)
\]

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

\[
g_n(i)(r',\phi') = \frac{1}{\pi a_\lambda^2} \exp \left[ -j2\pi r'(\cos \phi' u_n(i) + \sin \phi' v_n(i)) \right] \quad \rho' \leq a_\lambda \quad (3-31)
\]

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

\[ = \frac{1}{\pi a_{\lambda}} \int_{o}^{a} \int_{0}^{\lambda} \exp \left\{ j \frac{2\pi p'}{\lambda} \left[ C \cos (\alpha - \phi') \right] \right\} d\rho' d\phi' \quad (3-33) \]

where

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

\[ \alpha = \tan^{-1} \frac{u-u_n(i)}{v-v_n(i)} \quad (3-35) \]

Now (3-33) is easily integrated as

\[ G(u-u_n(i), v-v_n(i)) = \frac{2\pi}{\pi a_{\lambda}} \int_{o}^{a} \exp \left\{ 2j(2\pi p' \lambda) \right\} d\rho' \]

\[ = \frac{J_1(2\pi a_{\lambda} p')}{2\pi a_{\lambda} p'} \quad (3-38) \]

If \( u_n(i) = v_n(i) = 0 \) we have

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

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

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

### 3.5.6 Arbitrary Planar Array

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

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

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

3.6 Calculation of Directivity

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

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

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

The beam solid angle $\Omega_A$ is given by

$$\Omega_A = \int_{\theta_0}^{\pi} \int_{\phi_0}^{2\pi} |F(\theta, \phi)|^2 \, d\Omega$$  (3-42)

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

$$\sin \theta \, d\theta \, d\phi$$  (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} \tag{3-44}

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

\begin{equation}
  \Omega_A = \int_0^{\pi/2} \int_0^{\pi} |F(\theta, \phi)| \ d\Omega \tag{3-45}
\end{equation}

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

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

\begin{equation}
  du \ dv = \cos \theta \ d\Omega \tag{3-46}
\end{equation}

so

\begin{equation}
  d\Omega = \frac{du \ dv}{\cos \theta} \tag{3-47}
\end{equation}

But from (3-44)

\begin{equation}
  \cos \theta = \sqrt{1 - u^2 - v^2} \tag{3-48}
\end{equation}
so

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

Thus (3-45) becomes

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

(3-50)

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

\[ \Omega_A = \int \int |F(u,v)|^2 \sin \theta \, J \, du \, dv \]

(3-51)

where \( J \) is the Jacobian given by

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

(3-52)

and

\[ \frac{\partial (u,v)}{\partial (\theta, \phi)} = \begin{vmatrix} \frac{\partial u}{\partial \theta} & \frac{\partial u}{\partial \phi} \\ \frac{\partial v}{\partial \theta} & \frac{\partial v}{\partial \phi} \end{vmatrix} \]

\[ = \begin{vmatrix} \cos \theta \cos \phi - \sin \theta \sin \phi \\ \cos \theta \sin \phi \sin \theta \cos \phi \end{vmatrix} \]

\[ = \cos \theta \sin \theta \]

(3-53)

So

\[ \sin \theta \, J \, du \, dv = \sin \theta \frac{du \, dv}{\cos \theta \sin \theta} \]

(3-54)

\[ = \frac{du \, dv}{\sqrt{1 - u^2 - v^2}} \]

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)

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

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

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

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

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

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

4.1 Common Antenna Types

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

The first example is that of a uniform amplitude, uniform phase, line source. The length was chosen to be ten wavelengths. All of these patterns will change with changing antenna size, however the beam widths change in almost an inverse linear way with aperture size.
The side lobe levels do not depend on aperture size. In Fig. 4.1 is shown the pattern for this line source. (Aperture amplitude and phase distributions will be presented only when they are nonuniform.) This is the typical \( \sin \frac{x}{\lambda} \) 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 \( 0, -5, -10, \ldots, -40 \) 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.

PATTERN = $\Phi$
Synthesis capability is provided for circular aperture by inclusion of an elementary pattern from such an aperture which is uniformly excited in amplitude. Figs. 4.9 and 4.10 show u and v axis profiles of the pattern from a uniform amplitude, uniform phase, five wavelength radius circular aperture. These plots are, of course, identical. A contour map of this pattern in the uv - plane for the whole visible region is shown in Fig. 4.11. The three dimensional view of the pattern is shown in Fig. 4.12.

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

4.2 Linear Antenna Synthesis

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

|v|  | $F_d(v)$ | $F_u(v)$ | $F_L(v)$ |
|----|---------|---------|---------|
|0.2 | 0. dB   | 0.5 dB  | - 0.5 dB|
|1.0 | -∞      | - 40.   | unspecified|

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 4.1 Pattern Parameters for Elementary Correction Patterns

<table>
<thead>
<tr>
<th>Antenna Type - ITYPE</th>
<th>Source Dimensions (λ)</th>
<th>Beam Width</th>
<th>Side Lobe Level (dB)</th>
<th>Directivity (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Theory</td>
<td>Computer</td>
<td>Theory</td>
</tr>
<tr>
<td>Uniform line source - 1</td>
<td>( L_y \lambda = 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\lambda} = 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 \lambda = 10 )</td>
<td>0.128</td>
<td>0.128</td>
<td>-26.6</td>
</tr>
<tr>
<td>Uniform rectangular aperture - 4</td>
<td>( L_y \lambda = 10 )</td>
<td>0.0886</td>
<td>0.0886</td>
<td>-13.3</td>
</tr>
<tr>
<td>Uniform rectangular array - 5</td>
<td>( P_x = 21 \ d_{x\lambda} = 0.5 )</td>
<td>( P_y = 41 \ d_{y\lambda} = 0.5 )</td>
<td>34.0</td>
<td>33.9</td>
</tr>
<tr>
<td>Uniform circular aperture - 6</td>
<td>( a_\lambda = 5 )</td>
<td>0.102</td>
<td>0.102</td>
<td>-17.6</td>
</tr>
</tbody>
</table>
side lobe region. The final pattern (which met the specifications) was obtained after 69 iterations. It deviated +0.44 and -0.42 dB over the main beam region and had a peak side lobe of -40.79 dB in the specified side lobe region. The pattern is plotted in Fig. 4.13. The corresponding current distribution is given in Fig. 4.14.

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

Occasionally it is desirable to use linear arrays which are not equally spaced. The 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.
| \( |v| \) | \( F_d(v) \) | \( F_u(v) \) | \( F_L(v) \) |
|---|---|---|---|
| \( |v| \leq 0.26 \) | 0. dB | +.42 dB | -.42 dB |
| \( 0.44 \leq |v| \leq 1.0 \) | -20. | -18.4 | unspecified |

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

### 4.3 Rectangular Antenna Synthesis

The multibeam capability of this technique is displayed with the synthesis of a pattern with pencil beams positioned at (0.5, 0.5), (0.5, -0.5), (-0.5, -0.5), and (0.5, 0.5). The side lobe upper limit was specified to be -25 dB in the visible region outside the main beams, i.e. (for example, the beam centered at (0.5, 0.5) was specified for \( 0.38 < u < 0.64 \) and \( 0.38 < v < 0.64 \). The other beams were specified in a symmetric fashion. The region outside of these main beam regions had an upper limit of -25 dB and no lower limit.

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

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

<table>
<thead>
<tr>
<th>$u$, $v$</th>
<th>$F_d(u,v)$</th>
<th>$F_{II}(u,v)$</th>
<th>$F_t(u,v)$</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</td>
</tr>
<tr>
<td>$0.12 &lt;</td>
<td>v</td>
<td>&lt; 0.50$</td>
<td>-20.0</td>
</tr>
</tbody>
</table>

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

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

Figure 4.23 Profile along v-axis of a rectangular main beam, low side lobe pattern synthesized from a 20 element, 0.5 wavelength spaced by 40 element, 0.5 wavelength spaced rectangular array.
Figure 4.24 Contour map of a rectangular beam, low side lobe pattern synthesized from a 20 element, 0.5 wavelength spaced by 40 element, 0.5 wavelength spaced rectangular array.

PATTERN = SL
Figure 4.25 Rectangular beam, low side lobe pattern synthesized from a 20 element, 0.5 wavelength spaced by 40 element, 0.5 wavelength spaced rectangular array.
Tighter tolerances are easily achieved. This example is a rectangular beam with the following specifications:

<table>
<thead>
<tr>
<th>( (u,v) )</th>
<th>( F_d(u,v) )</th>
<th>( F_p(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>(-\infty)</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, FORGCN, FORGPR, ICURPT, ICURCN, ICURPR, FCURPT, FCURCN, FCURPR, DIRECT

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

NAMELIST/PATIN/LX, LY, PX, PY, DISX, DISY, INITLS, DELTAS, FINALS, INITLS, DELTAT, FINALT, NELMT, 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 these arrays at every point. Or, a Subroutine DESPAT can be used to call READ for these arrays and then cards are read to load the arrays.

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

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

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

#### 6.4.1 Correspondence Between Symbols Used in the Theory and Program Variables

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

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

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

**FCURPR**
Input variable controlling print out of final current distribution profile or list; 0 None, 1 Profile (S and/or T axis) for continuous sources, 2 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 pro-  
gram 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</th>
<th>Used to Form Correction Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Line Source Uniform</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Equally Spaced Linear Array Uniform</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Line Source Triangular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Rectangular Aperture Uniform</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rectangular Array Uniform</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Circular Aperture Uniform</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>General Array Uniform</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GT7</td>
<td>SPECPT SPSOR</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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

IMMAX  Input variable - Number of points used in V 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>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>DELTAU</td>
<td>Input variable - Increment between comparison points in U direction. Also, increment between pattern print out points.</td>
</tr>
<tr>
<td>DELTAV</td>
<td>Input variable - Increment between comparison points in V direction. Also, increment between pattern print out points.</td>
</tr>
<tr>
<td>DIRFNL</td>
<td>Directivity of final pattern.</td>
</tr>
<tr>
<td>DIRORG</td>
<td>Directivity of original pattern.</td>
</tr>
<tr>
<td>DISX</td>
<td>Input variable - Spacing between antenna array elements in X direction normalized to a wavelength.</td>
</tr>
<tr>
<td>DISY</td>
<td>Input variable - Spacing between antenna array elements in Y direction normalized to a wavelength.</td>
</tr>
<tr>
<td>F( , )</td>
<td>Current pattern value.</td>
</tr>
<tr>
<td>FDES( , )</td>
<td>Input variable - Desired pattern value.</td>
</tr>
<tr>
<td>FINALS</td>
<td>Input variable - Final point of current distribution print outs in S direction.</td>
</tr>
<tr>
<td>FINALT</td>
<td>Input variable - Final point of current distribution print outs in T direction.</td>
</tr>
<tr>
<td>FINALU</td>
<td>Input variable - Final point of pattern comparison and print outs in U direction.</td>
</tr>
<tr>
<td>FINALV</td>
<td>Input variable - Final point of pattern comparison and print outs in V direction.</td>
</tr>
<tr>
<td>FL( , )</td>
<td>Input variable - Lower limit on synthesized pattern.</td>
</tr>
<tr>
<td>FNORM</td>
<td>Factor by which pattern F( , ) is divided to normalize it to 0 dB at the point (MCENT, NCENT).</td>
</tr>
<tr>
<td>FU( , )</td>
<td>Input variable - Upper limit on synthesized pattern.</td>
</tr>
<tr>
<td>INITLS</td>
<td>Input variable - Initial point of current distribution print outs in S direction.</td>
</tr>
<tr>
<td>INITLT</td>
<td>Input variable - Initial point of current distribution print outs in T direction.</td>
</tr>
<tr>
<td>LX</td>
<td>Length of antenna in X direction in wavelengths - For continuous aperture sources this is an input variable.</td>
</tr>
<tr>
<td>LY</td>
<td>Length of antenna in Y direction in wavelengths - For continuous aperture sources this is an input variable.</td>
</tr>
<tr>
<td>S</td>
<td>Source coordinate X normalized to a wavelength.</td>
</tr>
<tr>
<td>SS( )</td>
<td>Antenna array element position in S direction - Input variable for ITYPE = 7.</td>
</tr>
</tbody>
</table>
STARTU  Input variable - Starting point in U direction for pattern comparisons and print outs.

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

T       Source coordinate Y normalized to a wavelength.

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

U       Pattern coordinate.

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

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

V       Pattern coordinate.

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

VS(     )  Positions of corrections (samples) in V direction.
6.5 Subroutine Descriptions

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

**SUBROUTINE INPUT**

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

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

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

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

SUBROUTINE SINPUT

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

SUBROUTINE READ (F, MMAX, NMAX)

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

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

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

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

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

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

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

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

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

SUBROUTINE ANTSYN (ISUC, MMAX, NMAX, FDES, FU, FL, ITRMAX, ISYMM, CORCOF, IC, US, VS, STARTU, DELTAV, DELTAU, 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 U1 and V1 and then as US(IC) and VS(IC). So IC is the subscript for US, VS, and CORCOF corresponding to the most recent
assignments to those arrays. IC and the whole arrays US, VS, and CORCOF are input to UPDATE. Then the pattern F is calculated using these arrays and PAT.

FUNCTION PAT (U, V, ITYPE)

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

FUNCTION SPECPT (U, V, ITYPE)

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

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

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

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

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

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

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

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

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

SUBROUTINE SPLOC (M, N, S, T)

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

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

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

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

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

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

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

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

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

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

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

SUBROUTINE PROFIL (DATA1, NPT, NUMPAT)

Subroutine PROFIL prints a graph of the data in DATA1 with automatic scaling using \(NPT(NPT\leq401)\) 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.
SUBROUTINE CONUR (K, L, DELCON, CONLOW, CONMAX, CONINT, A, NUMPAT)

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

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

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

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

SUBROUTINE PATCON (RDATA, MMAX, NMAX, ICODE, CONLOW, CONMAX, CONINT, STARTU, STARTV, 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>FDECN = 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

//F0662A57 JOB 527, COFFEE
//MAIN TIME=3, REGION=220K, LINES=10, LARDS=0
//PRIORITY PRIORITY
// EXEC FORTRAN, LIB3=SSPLIB
//FORT. SYSIN UD *
//*
//60.F122F91 DD DSN=ANTSIN, AR=7C, UNI=3330, VOL=8K, USERPK, DISF=STK
//60.SYSIN UD *
//*
//*

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

VERSION 3 73/164 -- JUNE 13, 1973

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

UNDER NASA GRANT: 47-004-103

LANGUAGE: FORTRAN IV

SUBPROGRAMS REQUIRED:

SUBROUTINES:

DIRECT
INPUT
READ
GRGPAT
ANTSYN
SEARCH
CHECK
UPDATE
SOURCE
LOCATE
SPLOC
SPECPT
SPSOR
SINPUT
CURRENT
PRINT
PROFIL
CONTR
PATCCN
LIST
DESPAT
DATE
STIME
BESJ

...STANDARD FORTRAN LIBRARY SUBPROGRAMS...

INPUT/OUTPUT SUPPORT:

FT05FC01 (SYSIN) -- CARD READER
FT06FC01 (SYSPRINT) -- LINE PRINTER
FT22FC01 (ANTDATA_A507C0) -- AUXILIARY STORAGE

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

INTEGER TITLE(20)
INTEGER NUMSKP(35),FDSPM,FDESPT,FDESN,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 UCRG(100),VORG(100),CORG(100)
REAL INITLS,INITLT
INTEGER FCURPT,FCURCN,FCURPR

COMMON /MPROG/ ICUR,NCUR
COMMON /START/ NORG,UORG,VORG,CURG
COMMON /PAT1/ P1,P2,P3,P4,P5,P6,P7,SS(400),IT(400),RK(400)
COMMON /PAT2/ 11,12,13,14,15
COMMON /LOC/ IYPE
DATA TITLE /'ANTENNA SYNTHESIS PROGRAM VERSION 3 LEVEL 1',
$'VPI EE DEPT.',5X,'DATE = ',A2,'-',A2,'-',A2,
$'TIME = ',12,' : ',12,' : ',12,' PATTERN ',5X,'/14///)
DEFAULT PARAMETERS

IDISK = 0
ISYM = 0
ITRMAX = 100
MMAX = 1
NMAX = 1
MCENT = 1
NCENT = 1
DELTAV = 0.
DELTAV = 0.
STARTU = 0.
STARTV = 0.
MCUR = 1
NCUR = 1
FDESPT = 0
FDESCN = 0
FDBPT = 0
FDBCN = 0
FDEPR = 0
FDESPR = 0
FORGPT = 0
FORCCN = 0
ICURPT = 0
ICURCN = 0
ICURPR = 0
FCURPT = 0
FCURCN = 0
FCURPR = 0
FORCPR = C
DIRECT = 0
FNCRN = 1.0
ISUC = 0
DELTAS = C.
DELTAT = 0.

READ(5, PARAM)
WRITE(6, 1521) IDISK, STARTU, MMAX, ISYM, STARTV, NMAX, ITRMAX, DELTAU,
MCENT, DELTAV, NCENT
1521 FORMAT(7X, 'PROGRAM PARAMETERS'//3X, 'IDISK = ', 11, 'X', 'STARTU = '+
13/3X, 'ISYM = ', 13/3X, 'STARTV = ', 13/3X, 'ITRMAX = ', 13/3X, 'NMAX = ',
13/3X, 'ITRMAX = ', 13/3X, 'DELTAV = ', 13/3X, 'DELTAS = ', 13/3X, 'DIRECT = '+
13/3X, '
READ(5, PRINT)
WRITE(6, 1522) FDESPT, FORGPT, FCLSPT, ICURPT, FCURPT,
FDESCN, FORCCN, FDBCN, ICURCN, FCURCN,
FDEPR, FORCPR, FDBPR, ICURPR, FCURPR
1522 FORMAT(11X, 'FDESPT = ', 13/5X, 'FORGPT = ', 13/5X, 'FCLSPT = ', 13/5X,
ICURPT = ', 13/5X, 'ICURCN = ', 13/5X, 'ICURPR = ', 13/5X, 'FCURPT = ', 13/5X,
FCURCN = ', 13/5X, 'FCURPR = ', 13/5X, 'FCURPT = ', 13/5X, 'FCURCN = ',
FCURPR = ', 13/5X, 'FCURPR = ', 13/5X, 'DIRECT = '+
13/5X, )
CALL INPUT

IF(ITYPE.EQ.7.AND.ICURPR.EQ.1) ICURPR = 2
IF (ITYPE.EQ.7 .AND. FCURPR.EQ.1) FCURPR = 2

CALL LOCSCR(1,1,INITLS,INITLT)

CALL LOCSOR(NCUR,NCUR,FINALS,FINALT)

IF (FCUR.PR.EQ.1) DELTAS = (FINALS - INITLS) / (MCUR - 1)

CALL DESEPAT(FDES,FU,FL,MMAX,NMAX,STARTU,STARTV,$DELTAU,DELTAV)

IF (FCUR.PR.EQ.1) CONTINUE

CALL PACTCON(FDES,MMAX,NMAX,0,-0.5,1.3,0.2,STARTU,STARTV,$DELTAU,DELTAU,NUMPAT,ISYMM)

CALL PRINT(FDES,MMAX,NMAX,STARTU,STARTV,DELTAU,DELTAV)

CONTINUE

CALL CRGCPAT(F,MMAX,NMAX,STARTU,STARTV,DELTAU,DELTAV,$CURR,CURI,NCUR,NCUR)

CALL PRINT(F,MMAX,NMAX,STARTU,STARTV,DELTAU,DELTAV)

CONTINUE
A-29

DC 408 J=1,401
U=(J-1)*C.C.O5-1.C
V=U
SUMU=0.
SUMV=C.
DO 409 K=1,NORG
SUMU=SUMU+CORG(K)*PAT(U-UORG(K),-VORG(K),ITYPE)
SUMV=SUMV+CORG(K)*PAT(-UORG(K),V-VORG(K),ITYPE)
CONTINUE
DATA1(J,1)=U
DATA1(J,2)=SUMU
DATA2(J,1)=V
DATA2(J,2)=SUMV
CONTINUE
IF(NMAX.LE.1) GO TO 2601
WRITE(6,410)
FORVAT(1H1,25X,'U-AXIS PROFILE OF INITIAL PATTERN')
CALL PROFIL(DATA1,401,NUMPAT)
2601 IF(NMAX.LE.1) GO TO 406
WRITE(6,411)
411 FORMAT(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')
CALL PRINT(CURR,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTAT)
WRITE(6,502)
503 IF(ICURPR) 504,504,506
504 WRITE(6,505)
505 FORMAT(1H1,10X,'INITIAL CURR')
CALL CONTUR(MCUR,NCUR,CURR,0.005,-0.04,0.04,0.0,CURR,NUMPAT)
WRITE(6,505)
506 IF(MCUR.LT.1) GO TO 520
WRITE(6,510)
510 FORMAT(1H1,10X,'S AXIS PROFILE OF INITIAL CURRENT'//
'S13X,'S',17X,'T',18X,'REAI',12X,'IMAGINARY',10X,'MAGNITUDE',
$12X,'PHASE'/)
J=NCUR/2+1
DO 509 J=1,MCUR
CALL LOCSCGR(I,J,S,T,ITYPE)
AMAG=SQRT(CURR(I,J)**2+CURR(I,J)**2)
IF(AMAG.EQ.0.) APH=0.
IF(AMAG.EQ.0.) GO TO 509
APH=ATAN2(CURR(I,J),CURR(I,J))*57.296715
WRITE(6,511) S,T,CURR(I,J),CURR(I,J),AMAG,APH
511 FORMAT(9X,6.4,9X,6.4,10X,4(E14.7,5X))
163  508 IF(NCUR.LE.1) GO TO 506
164   WRITE(6,512)
165  512 FORMAT(1H1,10X,*'T AXIS PROFILE OF INITIAL CURRENT'//
   $'13X,'S',17X,'T',18X,'REAL',12X,'IMAGINARY',10X,'MAGNITUDE',
   $12X,'PHASE')
   I=M CUR/2+1
166   DC 513 J=1,NCUR
167  CALL LCSOR(I,J,S,T,ITYPE)
168   CR=CURR(I,J)
169   CI=CURI(I,J)
170   AMAG=SQRT(CR*CR+CI*CI)
171   IF(AMAG.EQ.0.) APH=0.
172   IF(AMAG.EQ.0.) GO TO 513
173   APH=ATAN2(CI,CR)*57.2957795
174  513 WRITE(6,511) S,T,CR,CI,AMAG,APH
175  GO TO 506
176  514 WRITE(6,515)
177  515 FORMAT(1H1///10X,*'INITIAL ELEMENT CURRENTS'//5X,
   $'J',10X,'S',15X,'CURR',11X,'CURRI')
178  CALL LIST(CURR,CURI,MCUR,NCUR)
179  506 CONTINUE
180   IC=0
181   WRITE(6,4747)
182  4747 FORMAT(1H1)
183   WRITE(6,497)
184   CALL ANTSYN(ISUC,MMAX,NMAX,FDES,FU,FL,ITRMAX,ISYMM,CORC,IC,US
   S,VS,STARTU,DELTU,STARTV,DELTAV,MCENT,NCENT,ITER,FNORM,F)
C
C PRINT OUT RESULTS
C
185   WRITE(6,391)
186   391 FORMAT(1H1,52X,*'FINAL COEFFICIENTS'--'//5X,'J',7X,
   $'US(J)',7X,'VS(J)',5X,'CORCOF(J)'//)
187   IF(IC.LE.0) WRITE(6,977)
188  977 FORMAT(10X,*'NO ITERATIONS PERFORMED')
189  IF(IC.LE.0) GO TO 978
190   DO 498 J=1,IC
191  498 WRITE(6,35) J,US(J),VS(J),CORCOF(J)
192   35 FORMAT(44X,I3,5X,F7.4,5X,F7.4,5X,F7.4)
       WRITE(6,497) ITER
193   3074 FORMAT(1H1///45X,'J',5X,'UORG(J)',5X,'VORG(J)',6X,'CUR (J)'//)
194   IF 3077 J=1,NORD
195   3077 WRITE((J,35)) J,UORG(J),VORG(J),CURC(J)
196   WRITE(6,497) ITER
197  497 FORMAT(1HO,9X,*'NUMBER OF ITERATIONS = ',16)
198  496 FORMAT(1HO,9X,*'FNORM = ',F10.5)
199  496 WRITE(6,976) NUMPAT
200  976 FORMAT(1HO,9X,*'PATTERN NUMBER = NUMPAT = ',15)
C
C OUTPUT FINAL PATTERN IN DB
C
201  978 CONTINUE
202   DO 29 J=1,MMAX
203   29 FORMAT(1H1,9X,'J',5X,45X)
204   IF(F(J,K)) 290,289,290
205  289 F(J,K)=-2CC.
206  290 FORMAT(1H1,9X,'J',5X,45X)
204  GO TO 29
205  290 F(J,K)=20.*ALCG10(ABS(F(J,K)))
206  29 CONTINUE

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

C
C
211  IF(FDPRCN) 603,603,604
212  604 CONTINUE
213  CALL PATCON(F,MMAX,NMAX,2,-45.,0.0,5.0,STARTU,STARTV,
214   DELTAU,DELTAV,NUMPAT,ISYMM)
215  603 IF(FDPRPR) 606,606,607
216  607 CONTINUE
217  DO 608 J=1,401
218     U=(J-1)*0.005-1.0
219  608 V=U
220  SUMU=U.
221  SUMV=V.
222  DO 609 K=1,IC
223     SUMU=SUMU+CORCOF(K)*PAT(U-US(K),-VS(K),ITYPE)
224     SUMV=SUMV+CORCOF(K)*PAT(-US(K),V-VS(K),ITYPE)
225  609 CONTINUE
226  DATA1(J,1)=U
227  DATA2(J,1)=V
228  DATA1(J,2)=DATA1(J,2)+SUMU
229  DATA2(J,2)=DATA2(J,2)+SUMV
230  DATA1(J,2)=DATA1(J,2)*FNORM
231  DATA2(J,2)=DATA2(J,2)*FNORM
232  IF(MMAX.LE.1) GO TO 2901
233  WRITE(6,610)
234  610 FORMAT(1HI,25X,'U-AXIS PROFILE OF FINAL PATTERN'
235  CALL PROFIL(DATA1,401,NUMPAT)
236  2901 IF(NMAX.LE.1) GO TO 606
237  WRITE(6,611)
238  611 FORMAT(1HI,25X,'V-AXIS PROFILE OF FINAL PATTERN'
239  CALL PROFIL(DATA2,401,NUMPAT)
240  606 CONTINUE

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

C
C
C
243  IF(FCURPT) 700,700,701
244  700 WRITE(6,702)
245  702 FORMAT(1HI///////////55X,'FINAL CURR'
246  CALL PRINT(CURR,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTAT)
247  WRITE(6,782)
248  782 FORMAT(1HI///////////55X,'FINAL CURI'
249  CALL PRINT(CURI,MCUR,NCUR,INITLS,INITLT,DELTAS,DELTAT)
250  704 WRITE(6,705)
252  705  FORMAT(1H1,///10X,'FINAL CURR')
253       CALL CONTUR(MCUR,NCUR,C,COS,-0.04,0.04,0.0,CURR,NUMPAT)
254       WRITE(6,706)
255
256  785  FORMAT(1H1,///10X,'FINAL CURR')
257       CALL CONTUR(MCUR,NCUR,C,COS,-0.04,0.04,0.0,CURR,NUMPAT)
258       IF(FCUNPR-1) GO TO 707,711
259  703  IF(MCUR.LE.1) GO TO 708
260
260  710  FORMAT(1H1,10X,'S AXIS PROFILE OF FINAL CURRENT'//
261       $13X,'S','17X,'T','18X,'REAL','12X,'IMAGINARY','10X,'MAGNITUDE',
262       $12X,'PHASE'/)
263       J=NCUR/2+1
264       CALL LCCSCR(I,J,S,T,ITYPE)
265       CR=CURR(I,J)
266       CI=CURI(I,J)
267       AMAG=SQRT(CR*CR+CI*CI)
268       IF(AMAG.EQ.0.) APH=0.
269       APH=ATAN2(CI,CR)*57.2957795
270       WRITE(6,511) S,T,CR,CI,AMAG,APH
271  706  IF(NCUR.LE.1) GO TO 706
272       WRITE(6,712)
273  712  FORMAT(1H1,10X,'T AXIS PROFILE OF FINAL CURRENT'//
274       $13X,'S','17X,'T','18X,'REAL','12X,'IMAGINARY','10X,'MAGNITUDE',
275       $12X,'PHASE'/)
276       I=MCUR/2+1
277       CALL LCCSCR(I,J,S,T,ITYPE)
278       CR=CURR(I,J)
279       CI=CURI(I,J)
280       AMAG=SQRT(CR*CR+CI*CI)
281       IF(AMAG.EQ.0.) APH=0.
282       APH=ATAN2(CI,CR)*57.2957795
283       WRITE(6,511) S,T,CR,CI,AMAG,APH
284  706  IF(NCUR.LE.1) GO TO 706
285       WRITE(6,714)
286  714  FORMAT(1H1,///10X,'FINAL ELEMENT CURRENTS'//5X,
287       $5'I',10X,'5',15X,'T',15X,'CURR',15X,'CURI')
288       CALL LIST(CURR,CURI,MCUR,NCUR)
289  706  CONTINUE
290
290  790  ICOUNT=NUMPAT
291  791  WRITE(22,8850) ICOUNT,NUMTRK,NUMSKP(IPASS)
292       IF(DIRECT.EQ.0.) GO TO 9998
293       CALL DRCSTV(CORG,UORG,VORG,US,VS,CORC[3],IC,MMAX,NMAX,DIRCRG,DIRFNL)
294       WRITE(6,6789) DIRORG,DIRFNL
295  6789  FORMAT('D IRORG = ',F7.2,' DB.'/
296       $0 CIRFNL = ',F7.2,' DB.')
297  9998  CONTINUE
IF(IOISK.EQ.C) GO TO 9997

C DISK OUTPUT

GO TO 7001

IF(NUMSKP(J).EQ. 0) GO TO 7001

CONTINUE

WRITE(6,7002)

7002 FORMAT('NO DISK SPACE AVAILABLE -- DATA NOT STORED')

GO TO 9999

CONTINUE

SPACE IS AVAILABLE ON RECORD "J"

NUMSKP(J)=1

WRITE(22*1,8850) NUMPAT,J,NUMSKP,IPASS

WRITE(22*J,8850) NUMPAT,TITLE,SYMM,ITER,ISUC,FHORM,IDISK,
  $NOR,IC,UCRG(0),VORG(0),CORRG(0),M=1,100$, $US(0),VS(0),CRGOF(0),I=1,100$, $US(0),VS(0),CRGOF(0),I=1,100$, $PI,TT(M),M=1,400$, $11,12,13,14,15,MCUR,NCUR$

WRITE(6,7003) NUMPAT,J

7003 FORMAT('PATTERN NUMBER ',I4,' HAS BEEN STORED ON RECORD ',
  $I4', OF ANO0ATA.A507C2')

GO TO 9999

SUBROUTINE DIRTG(CORR,UCRG,VORG,NOR,US,VS,CRGOF,IC,MMAX,NMAX,
  1 DICORR,DIRFN)

C THIS SUBROUTINE CALCULATES THE DIRECTIVITY OF THE ORIGINAL PATTERN
  , DIRCRG, AND OF THE FINAL PATTERN, DIRFN

C DIMENSION CORR(100),UORG(100),VORG(100),US(500),VS(500),CRGOF(500
  $)$

COMMON /LCC/ ITYPE

FORRGSC=0.

FMAX1=0.

FMAX2=0.

DO 10 J=1,101
  U=-1.0+(J-1)*C.02
10  CONTINUE

DO 20 K=1,101
  V=-1.0+(K-1)*C.02
20  CONTINUE

UVSQ=U*U+V*V

F=0.

IF(UVSC.GE.1.0) GO TO 10.

IF(NCRG.LE.0) GO TO 25

IF(NOR.GE.1.NOR)

F=F+UCRG(L)*PAT(U-UCRG(L),V-VORG(L),ITYPE)

F=SC+2/SCRT(1.0-UVSQ)

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

CONTINUE

25
FSC=FCKGSQ;
FMAX2=FMAX1
IF (IC LE 0) GO TO 10
CO 30 L = 1, IC
30 F = F + CCRCCF(L) * PAT(U-US(L), V-WS(L), ITYPE)
FSQ = FSC+F**2/SQRT(1.0-UVSQ)
IF (ABS(F).GT.FMAX2) FMAX2 = ABS(F)
10 CONTINUE
FORGSQ = FORGSQ*0.0004/FMAX1
FSC = FSQ*C.CCC4/FMAX2
DIRORG = 4.0*1.4159265/FORGSQ
DIFNFL = 4.0*1.4159265/FSQ
C
C
DIRORG = 10.*ALOG10(DIRORG)
DIFNFL = 10.*ALOG10(DIFNFL)
RETURN
END

SUBROUTINE 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/ II, I2, I3, I4, I5
COMMON /LOC/ ITYPE
COMMON /MPROG/ MCUR, NCUR
COMMON /SYN/ LX, LY
C
C
COMMON /PATIN/ LX, LY, PX, PY, DISX, DISY, INITLS, DELTAS, FINALS,
$INITLT, CELTAT, FINALT, NELMT, ARAU, ITYPE, MCUR, NCUR
C
C
NAMELIST /PATIN/ LX, LY, PX, PY, DISX, DISY, INITLS, DELTAS, FINALS,
$INITLT, CELTAT, FINALT, NELMT, ARAU, ITYPE, MCUR, NCUR
C
C
WRITE (6, 10)
10 FORMAT (55X, 'SOURCE SPECIFICATIONS' )
35 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 ' , I11, ' , 2X,
$EXECUTION TERMINATED')
STOP
C
C
10C PI = LY
P2 = INITLT
P3 = DELTAT
LX = 0.0
NCUR = (FINALT - INITLT) / DELTAT + 1.5
MCUR = 1
WRITE(6,101) LY,INITLT,FINALT,DELTAT,NCUR
101 FORMAT(1X,'ITYPF=1 -- UNIFORM LINE SOURCE'/15X,'LY = ',F7.3//'15X,'INITLT,FNALT,DELTAT: ',3(1X,F8.4)//15X,'NUMBER OF SAMPLE POINTS = NCUR = ','I3)
374 GO TO 999

375 200 P1=LY
376 11=PY
377 LY=C,C
378 P2=DISY
379 NCUR=PY
380 MCLR=1
381 WRITE(6,201) LY,PY,DISY
382 201 FORMAT(10X,'ITYPF=2 -- UNIFORM LINEAR ARRAY'/15X,'LY = ',F7.3//15X,'NUMBER OF ELEMENTS = ',I3//'15X,'INTER-ELEMENT SPACING = ',F6.3)
383 GO TO 999

384 300 P1=LY
385 LX=0.0
386 P2=INITLT
387 P3=DELTAT
388 NCUR=(FINALT-INITLT)/DELTAT+1.5
389 MCLR=1
390 WRITE(6,301) LY,INITLT,FINALT,DELTAT,NCUR
391 301 FORMAT(10X,'ITYPF=3 -- TRIANGULAR LINE SOURCE'/15X,'LY = ',F7.3//15X,'T VARYES FROM ',F6.4,' TO ',F6.4,5X,'DELTAT = ',F6.3//15X,'NUMBER OF SAMPLE POINTS = NCUR = ','I3)
392 GO TO 999

393 400 P1=LX
394 P2=LY
395 P3=INITLS
396 P4=INITLT
397 P5=DELTAS
398 P6=DELTAT
399 MCLR=(FINALS-INITLS)/DELTAS+1.5
400 NCUR=(FINALT-INITLT)/DELTAT+1.5
401 WRITE(6,401) LX,LY,INITLS,DELTAS,FINALS,INITLT,DELTAT,FINALT,MCLR,NCUR
402 401 FORMAT(10X,'ITYPF=4 -- UNIFORM RECTANGULAR APERTURE'/15X,'DIMENSIONS = LX,LY = ',F7.4,' ',F7.4//'15X,'INITLS,DELTAS,FINALS: ',3(1X,F8.4,1X)//15X,'INITLT,DELTAT,FINALT: ',3(F8.4,1X)//15X,'MCLR,NCUR: ',2(I3,2X))
403 GO TO 999

404 500 P1=LX
405 P2=LY
406 II=PX
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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 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

60C P1=ARAD
606 P3=INITLS
607 P4=INITLT
608 P5=DELTAS
609 P6=DELTAT
610 LX=ARAD*2.
611 LY=LY
612 MCUR=(FINALS-INITLS)/DELTAS+1.5
613 NCUR=(FINALT-INITLT)/DELTAT+1.5
614 WRITE(6,601) ARAD,INITLS,DELTAS,FINALS,INITLT,DELTAT,MCUR,
$NCUR
615 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))
616 GO TO 999

C

70C I1=MCUR
702 I2=NCUR
703 LX=1.0
704 LY=1.0
705 NELMT=II*I2
706 WRITE(6,701)
707 FORMAT(1CX,'ITYPE=7 -- GENERAL ARRAY'//
$15X,'ELEMENT',7X,'SS(J)*,14X,'TT(J)*)
708 CC 702 J=1,NELEMT
709 READ(5,7C3) SS(J),TT(J)
710 FORMATA(3F12.3,C)
711 WRITE(6,704) J,SS(J),TT(J)
712 FORMAT(17X,I3,5X,3(E14.7,5X))
713 712 CONTINUE
714 GO TO 999
715 CALL SINPUT(PX,PY,DISX,DISY,INITLS,DELTAS,FINALS,INITLT,
$DELTAT,FINALT,NELMT,ARAD,ITYPE)
716 995 RETURN
717 'ENC
SUBROUTINE READ (F,PMAX,NMAX)
DIMENSION F(51,51),I(6),VAL(6)
CO 100 J=1,MMAX
K2=0
2C CONTINUE
READ(5,1) (I(L),VAL(L),L=1,6)
1 FORMAT(6(I3,F10.0))
CC 20 L=1,6
II=I(L)
IF(II.EQ.0) GO TO 100
K1=K2+1
K2=K1+II-1
DO 10 K=K1,K2
10 CONTINUE
1C F(J,K)=VAL(L)
2C CONTINUE
IF(K2.LT.NMAX) GO TO 2C00
100 CONTINUE
RETURN
END

SUBROUTINE DBGPAT(FMIX,FMIX,NMAX,STARTU,STARTV,DELTAU,DELTAV,CUR1,CURI,NCUR)
DIMENSION FMIX(51,51),FMIX(51,51),FMIX(51,51)
THIS LEADS THE DESIRED PATTERN AND UPPER AND LOWER LIMITS
CALL READ(FMIX,MMAX,NMAX)
CALL READ(FMIX,MMAX,NMAX)
CALL READ(FMIX,MMAX,NMAX)
RETURN
END

SUBROUTINE CRGPAT(F,PMAX,NMAX,STARTU,STARTV,DELTAU,DELTAV,CUR1,CURI,NCUR)
REAL F(51,51),CUR1(51,51),CUR1(51,51)
REAL URG(1CC),VORG(100),CORG(100)
COMPLEX SOURCE
COMPLEX TEMP
COMMON /START/ NORG,UORG,VORG,CORG
COMMON /LOC/ ITYPE
THIS CRGPAT WILL BE "WOODWARD-LAWSON" INPUT.

DO 10 N=1,MMAX
CC 10 F(M,N)=0.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
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```fortran
DO 15 M=1,MCUR
DO 15 N=1,NCUR
CURRE(M,N)=0.
15 CURR(M,N)=C.
WRITE(6,17)
17 FORMAT(1H4,50X,-- 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
20 IC=US
2 FORMAT(3F10.0)
UORG(IC)=US
VORG(IC)=VS
CORC(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 M=1,MMAX
F(M,N)=F(M,N)+CORCOF*PAT(DU,DV,ITYPE)
DO 40 M=1,MCUR
DO 40 N=1,NCUR
TEMP=SOURCE(M,N,US,VS,ITYPE)
CURR(M,N)=CURR(M,N)+CORCOF*REAL(TEMP)
40 CURR(M,N)=CURR(M,N)+CORCOF*AIMAG(TEMP)
WRITE(6,50) IC,US,VS,CORCOF
50 FORMAT(44X, T3,5XF7.4,5X,F7.4,5X,F7.4)
SUBROUTINE Antsyn(ISUC,MMAX,NMAX,FDES,FL,ITRMAX,ISYM,CORCOF,
$IC,US,VS,STARTU,DELTAU,STARTV,DELTAV,MECNT,NCENT,ITER,FNORM,F)
REAL FDES(51,51),FU(51,51),FL(51,51),F(51,51)
REAL US(500),VS(500),CORCOF(500) UG(500) VE(100) COR(100)
REAL LX,LY,LXY
COMMON /PAR/ NORG,UORG,VORG,CORG
COMMON /SYN/ LX,LY
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
F(M,N)=F(M,N)/FBIG
FNORM=FNORM/FBIG
150 M=1,MMAX
CORG(IC)=CORG(IC)/FBIG
IF(1C.LT.0) GO TO 153
LG 152 I=1,IC
153 CONTINUE
```
**ITERATION PROCEDURE**

**IF SPECS ARE MET.**

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

519 IF(FDES(J,K).GT.99.) GO TO 24
520 IF(FL(J,K).LE.0.00001 .AND. ABS(F(J,K)).LE.1.E-4) GO TO 24
521 XI=ABS(F(J,K))
522 IF(XI.GT.FU(J,K)) GO TO 25
523 IF(FL(J,K).GT.99.0) GO TO 24
524 IF(XI.LT.FL(J,K)) GO TO 25
525 24 CONTINUE
526 ISUC=1
527 IC=IC+1

**SPECS ARE MET -- PROCEED TO PRINTOUT.**

GO TO 75C
528 25 CONTINUE

**SPECS ARE NOT MET AT POINT (J,K)**

IC=IC+1
531 IF(ITER/ICC*ICC .EQ. ITER) WRITE(6,7117) ITER
532 7117 FORMAT(10X,16,'ITERATIONS COMPLETED')
533 IF(ITER-ITRMAX) 22,22,23
534 22 WRITE(6,34) ITRMAX
535 34 FORMAT(IHO,9X,'NUMBER OF ITERATIONS EXCEEDED', 15/
536               10X,'PRINTOUT OF INTERMEDIATE RESULTS FOLLOWS.' )
537 GO TO 75C
538 22 CONTINUE

**FIND RELATIVE MAXIMUM ERROR**

CALL SEARCH(J,K,VAL,FDES,FL,FU,FL,F,MMAX,NMAX,STARTU,STARTV,DELTAV,$DELTAV)
539 IF(VAL.NE.0.0) GO TO 248

VAL EQUALS ZERO
540 WRITE(6,100)
541 100 FORMAT('ERROR IN SUBROUTINE SEARCH -- VAL=0.')
542 GO TO 75C
543 248 UI=(J-1)*DELTAV+STARTU
544 VI=(K-1)*DELTAV+STARTV
545 IF(ABS(UI).LE.0.1*DELTAV) UI=0.
546 IF(ABS(VI).LE.0.1*DELTAV) VI=0.
547 IF(LX.EQ.0.) GO TO 1000
548 IF(U1.NE.0. .AND. ABS(UI).LE.0.5/LX) VAL=VAL/2.
549 1000 IF(LY.EQ.0. .AND. ABS(V1).LE.0.5/LY) VAL=VAL/2.
550 1001 IF(V1.NE.0. .AND. ABS(V1).LE.0.5/LY) VAL=VAL/2.
551 IF(ISYM\$NE.4) GC TO 1001
552 ITEMP=C
553 UV=ABS(ABS(U1)-ABS(V1))
554 IF(UV.EQ.0.) GC TO 1001
555 IF(UV*1.414.LE.LXY) VAL=VAL/2.
556 1001 CONTINUE

C BASIC CORRECTION -- INDEPENDENT OF ISYM/N

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

C V-AXIS AND QUADRILATERAL SYMMETRY -- ISYM/N = 2,3,4

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

C U-AXIS AND QUADRILATERAL SYMMETRY -- ISYM/N = 1,3,4

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

C QUADRILATERAL SYMMETRY ONLY -- ISYM/N = 3,4

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

C FOR BIQUADRILATERAL SYMMETRY ONLY -- ISYM/N = 4

C 590 ITEMP=1
IF(UI.EQ.VI) GC TO 27
IC=IC+1
UTEMP=UI
VTEMP=VI
UL=VTEMP
VI=UTEMP
GO TO 1001
750 CONTINUE
IC=IC-1
ITER=ITER-1
RETURN

SUBROUTINE SEARCH(I1,J1,VAL,FDES,FU,FL,F,MMAX,NMAX,STARTU,STARTV,DELTAU,DELTAV)
REAL FU(51,51),FL(51,51),F(51,51),FDES(51,51)
VAL=0.
EMAX=0.
I2=I1
J2=J1
CC 10 J=12,MMAX
U=STARTU+(J-1)*DELTAU
CC 20 K=J2,NMAX
V=STARTV+(K-1)*DELTAV
UVSQ=U*U+V*V
IF(UVSQ.GT.1.0) GO TO 20
FITER=ABS(F(J,K))
IF(FDES(J,K).EQ.99.0) GO TO 20
IF(FITER.GT.FU(J,K)) GO TO 2000
IF(FL(J,K).LE.1.E-4) GO TO 20
IF(FITER.GT.FL(J,K)) GO TO 20
X=FDES(J,K)
ERROR = FITER-X
IF(ABS(ERRORCR)-ABS(EMAX)) 20,20,21
21 EMAX=ERRORCR
VAL=SIGN(ERRORCR,F(J,K))*(X-FITER))
II=J
JL=K
CC CONTINUE
WRITE(6,10C) II,JL,VAL
100 FORMAT(5X,'**SEARCH**',I8,I8,5X,F7.4)
RETURN

SUBROUTINE CHECK(IC,VAL,US,VS,CORCOF,DELTAU,DELTAV)
REAL US(5CO),VS(5CO),CORCOF(500)
IF(IC.EQ.1) RETURN
CU=C*1*DELTAU
CV=C*1*DELTAV
IC=IC-1
U=US(IC)
W=VS(IC)
SUBROUTINE UPDATE(IC,US,VS,CORCOF,F,MMAX,NMAX,FNORM,STARTU,STARTV,$DELTAU,DELTAV)

DIMENSION F(51,51),US(500),VS(500), CORCOF(500)
COMMON /LOC/ ITYPE

C=CORCOF(IC)
DO 10 J=1,MMAX
U=STARTU+(J-1)*DELTAU
DU=U-US(IC)
DO 10 K=1,NMAX
V=STARTV+(K-1)*DELTAV
DV=V-VS(IC)
10 F(J,K)=F(J,K)+C*PAT(DU,DV,ITYPE)
CORCOF(IC)=CORCOF(IC)/FNORM
RETURN
ENC

FUNCTION PAT(U,V,ITYPE)
C
C THIS SUBPROGRAM GIVES THE BASIC CORRECTION PATTERN F(U,V).
C
C ITYPE = 1 -- UNIFORM LINE SOURCE LOCATED AT S=0.
C 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 BE CALLED.
C
VERSION 1 LEVEL 1

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

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

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

COMMON /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 (100, 200, 300, 400, 500, 600, 700), ITYPE
C ITYPE .LT. 1
C
WRITE(6,10) ITYPE
10 FORMAT(1HC,5X,***ERROR*** ITYPE HAS THE VALUE '111', 2X, $*EXECUTION TERMINATED*)
STOP
C
C ITYPE = 1 -- UNIFORM LINE SOURCE.
C
FLEN=P1
CONTINUE
PAT=1.0
IF(V.NE.0.) PAT = SIN(PI*PI*V)/(PI*PI*V)
GO TO 999
C
C ITYPE = 2 -- UNIFORM LINEAR ARRAY
C
CONTINUE
FLEN=P1
NELPT=II
PAT=1.0
IF(V.NE.0.) PAT=SIN(PI*PI*V)/(II*SIN(PI*PI*V/II))
GO TO 999
C
C ITYPE = 3 -- TRIANGULAR LINE SOURCE.
C
FLEN=P1/2.
PAT=1.0
IF(V.NE.0.) PAT = (SIN(FLEN*PI*V)/(FLEN*PI*V))**2
GO TO 999
C
C ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE
C
CONTINUE
FLS=P1
FLT=P2
ARG1=PI*PI*U
ARG2=PI*PI*V
IF(ARG1) 401,402,401
IF(ARG2) 403,404,403
401 IF(ARG2) 402,403,401
402 IF(ARG2) 405,406,402
403 IF(ARG1) 404,401,403
404 IF(ARG2) 405,402,404
405 IF(ARG1) 406,402,405
406 PAT=1.C
C
C ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY
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699 5CC CONTINUE
C  FLS=P1
C  FLT=P2
C  NELS=I1
C  NELT=I2
700 ARC1=PI*P1*U
701 ARC2=PI*P2*V
702 IF(ARG1) 501,502,501
703 501 IF(ARG2) 503,504,503
704 503 PAT=SIN(ARG1)/(I1*SIN(ARG1/I1))*SIN(ARG2)/(I2*SIN(ARG2/I2))
705 GO TO 999
706 504 PAT=SIN(ARG1)/(I1*SIN(ARG1/I1))
707 GO TO 999
708 502 IF(ARG2) 505,506,505
709 505 PAT=SIN(ARG2)/(I2*SIN(ARG2/I2))
710 GO TO 999
711 506 PAT=1.0
712 GO TO 999

C C C
ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.
C
713 600 C=SCRT(U*U+V*V)
C A=P1
714 IF(C.EQ.C.) GO TO 601
715 X=2.*PI*PI*C
16 CALL BESSJ(X,1,BJ,0.0001,IER)
717 PAT=2.*BJ/X
718 GO TO 999
719 601 PAT=1.0
720 GO TO 999

C C
ITYPE = 7 -- GENERAL ARRAY
C
721 7CC IMAG=(C.C,1.C)
722 NELMT=I1*I2
723 TEMP=(C.C,C.O)
724 DO 701 J=1,NELM T
725 TEMP=TEMP+1.0*CEXP(IMAG*2.*PI*(U*SS(J)+V*TT(J)))
726 701 CONTINUE
727 PAT=REAL(TEMP)/NELMT
728 GO TO 999
729 99C PAT=SPECPT(U,V,ITYPE)
730 999 RETURN
731 END

732 COMPLEX FUNCTION SOURCE(M,N,U,V,ITYPE)
C C THIS SUBPROGRAM CALCULATES THE CURRENT AT POINT (M,N) DUE TO
C THE PATTERN AT POINT (U,V).
C C ITYPE = 1 -- UNIFORM LINE SOURCE LOCATED AT S=0.
C ITYPE = 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 SPSPOR(M,N,U,V,ITYPE)
WILL BE CALLED.)

VERSION 1 LEVEL 1

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

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

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

COMMON /PAT1/ P1, P2, P3, P4, P5, P6, P1, SS(400), TT(400), RR(400)
COMMON /PAT2/ I1, I2, I3, I4, I5

ITYPE .LT. 1

ITYPE = 1 -- UNIFORM LINE SOURCE

1CC CONTINUE
FLN=P1
SOURCE=CEXP(-IMAG*PI*2.*T*V)/P1
GO TO 999

ITYPE = 2 -- UNIFORM LINEAR ARRAY

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

ITYPE = 3 -- TRIANGULAR LINE SOURCE

3CC CONTINUE
FLN=P1
C CNG=ABS(2.*T/P1)
source = 2. \times P1 \times CEXP(-IMAG \times 2. \times PI \times T \times V) \times (1 - CON)

if (CON.GT.1) source = (0.0, 0.0)

ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE

cc continue
fls = P1
flt = P2
source = CEXP(-IMAG \times 2. \times PI \times (S \times U + V \times T)) / (P1 \times P2)

GO TO 999

ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY

500 continue
fls = P1
flt = P2
source = CEXP(-IMAG \times 2. \times PI \times (S \times U + V \times T)) / (P1 \times P2)

GO TO 999

ITYPE = 6 -- UNIFORM CIRCULAR APERTURE

600 RHC = SCRT(S \times S + T \times T)

a = P1

source = (C.C, C.C, C.C)

if (RHC.LE.P1) source = CEXP(-IMAG \times 2. \times PI \times (S \times U + T \times V)) / (2 \times PI \times P1 \times P2)

GO TO 999

ITYPE = 7 -- GENERAL ARRAY

700 continue
source = CEXP(-IMAG \times 2. \times PI \times (U \times S + V \times T)) / (11 \times I2)

GO TO 999

999 source = SPSOR(M, N, U, V, ITYPE)

999 return

end

subroutine lccsor(m, n, s, t)
integer px, py
real inits, initl
common / pat1 / P1, P2, P3, P4, P5, P6, PI, SS(400), TT(400), RR(400)
common / pat2 / I1, I2, I3, I4, I5
common / lcc / ITYPE

cc

if (ITYPE.GT.7) go to 990

cc go to (100, 200, 300, 400, 500, 600, 700), ITYPE

write(1, 10) ITYPE

10 format(1hc, 5x, '***ERROR*** ITYPE HAS THE VALUE', 111, ':', 2x, 'EXECUTION TERMINATED')

stop
CONTINUE

C  INITLT=P2
C  DELTAT=P3
S=C.
T=P2+(N-1)*P3
GO TO 995

C

CONTINUE

C  PY=I1
C  DISY=P2
S=0.
T=(N-I1/2-1)*P2
IF(I1/2*2.EQ.I1) T=T+0.5*P2
GO TO 999

C

GO TO 100

C

CONTINUE

C  INITLS=P3
C  INITLT=P4
C  DELTAS=P5
C  DELTAT=P6
S=P3+(M-1)*P5
T=P4+(N-1)*P6
GO TO 999

C

GO TO 400

C

CONTINUE

C  PX=I1
C  PY=I2
C  DISX=P3
C  DISY=P4
S=(M-I1/2-1)*P3
T=(N-I2/2-1)*P4
IF(I1/2*2.EQ.I1) S=S+0.5*P3
IF(I2/2*2.EQ.I2) T=T+0.5*P4
GO TO 999

C

GO TO 400

C

CONTINUE

NEMT=(M-1)*I2+N
S=SS(NEMT)
T=TT(NEMT)
GO TO 999

C

999 CALL SPLOC(M,N,S,T)
999 RETURN
END
SUBROUTINE CURRENT(CURR, CURI, MCUR, NCUR, US, VS, CURCOF, IC)

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


COMPLEX SOURCE, TEMP
REAL CURR(51, 51), CURI(51, 51), US(500), VS(500), CURCOF(500)
REAL UORG(100), VORG(100), CORG(100)
COMMON /START/ NORG, UORG, VORG, CORG
COMMON /LOC/ ITYPE
DO 100 M = 1, MCUR
DO 100 N = 1, NCUR
CURR(M, N) = 0.
100 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.LE.0) RETURN

C

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

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

SUBROUTINE PRINT IS THE GENERAL OUTPUT SUBROUTINE --
IT WILL PRINT OUT CO-ORDINATES (U, V) AND VALUES A(I, J)
10 ROWS AND 10 COLUMNS TO A PAGE. 72/266 VERSION 3

DIMENSION A(51, 51), U(51), V(51)
WRITE(6, 969)
969 FORMAT(1H1)
CC 10 J = 1, 51
C(J) = STARTU + (J - 1) * DU
10 V(J) = STARTV + (J - 1) * DV
M2 = N/10. + 0.99
M2 = M/10. + 0.99

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
A-49

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

C PRINT CUT A HEADING
C
841 WRITE(6,20) (V(I),I=N3,N4)
842 2C FORMAT(1H1,16X,F6.3,9(4X,F6.3))
843 WRITE(6,30)

C PRINT A PAGE
C
844 K2=(M4-M3+1)*6
845 DO 4000 J=1,K2
846 J2=J/6
847 IF(J2*6-J) 27,28,27
848 J3=J2+M3-1
849 WRITE(6,29) U(J3),A(J3,I),I=N3,N4)
850 CC TO 4000
851 27 WRITE(6,31)
852 4000 CONTINUE

C CONTINUE
C
853 IF(N4.EC.N .AND. M4.E0.M) GO TO 300
854 2CC CONTINUE
855 1CC CONTINUE
856 3CC RETURN
857 29 FORMAT(3X,F6.3,15X,5X,10(F9.4,1X))
858 3C FORMAT(1CX,1H+,10(1OH---------+))
859 31 FORMAT(1CX,'I')
860 END

SUBROUTINE PRCFIL(DATA1,NPT,NUMPAT)
861 INTEGER SF
862 INTEGER OUTPUT(101)
863 INTEGER BLANK,PLUS,SLASH,STAR
864 REAL DATA(401,2),BOUND(1C1)
865 REAL DATA1(401,2)
866 DATA BLANK,PLUS,SLASH,STAR /'*','+',',',','/',','/'
867 DO 47 J=1,401
868 DATA(J,1)=DATA1(J,1)
869 DATA(J,2)=DATA1(J,2)
870 47 CONTINUE

C FIND THE RANGE OF DEPENDENT DATA AND SCALE IF NECESSARY
C
871 IF(NPT.EC.600) GO TO 999
872 BIG=-1.E10
873 SMALL = 1.E10
874 CC 1 J=1,NPT
A-50

876 IF(DATA(J,2).LT.-60.0) DATA(J,2)=-60.0
877 IF(DATA(J,2).LT.SMALL) SMALL=DATA(J,2)
878 IF(DATA(J,2).GT.BIG) BIG=DATA(J,2)
879 CONTINUE
880 DIFF=ABS(BIG-SMALL)
881 SF = C
882 IF(DIFF.LT.1.) GO TO 10
883 IF(DIFF.LT.100.) GO TO 21
884 DO 2 J=1,1C
885 IF(DIFF*1C**(-J).GT.100.) GO TO 2
886 SF=J
887 GO TO 20
888 CONTINUE

889 WRITE(6,100)
890 100 FORMAT('YOUR DATA IS TOO LARGE FOR THIS PROGRAM.')
891 RETURN
892 CONTINUE
893 DO 3 J=1,1C
894 K=11-J
895 IF(DIFF*1C**K.GT.100.) GO TO 3
896 SF=-K
897 CONTINUE
898 DO 40 K=1,101
899 CUTPUT(K)=SLASH
900 CONTINUE

901 SCALE=DIFF/100.
902 DO 5 J=1,101
903 K=J-1
904 BOUND(J)=(BIG-K*SCALE)*10.**(-SF)

905 WRITE(6,64C) NUMPAT
906 64C FORMAT(26X,'PATTERN NUMBER ',15//)
907 IF (SF.EQ.C) GO TO 200
908 WRITE(6,6504) SF
909 6504 FORMAT(53X,'SCALE FACTOR IS 10**',12/)
910 WRITE(6,665C) (BOUND(J),J=1,101,20)
911 665C FORMAT(1X,F7.3,13X,F7.3,2X,'REAL',5X,'C9.')
912 DO 6 J1=1,NPT
913 J=NPT+1-J1
914 CC 50 K=1,101
915 50 CUTPUT(K)=BLANK
916 IF((J-1)/1C*10-((J-1)) 62,61,62
917 61 CC 40 K=1,101,10
918 40 CUTPUT(K)=PLUS
919 GO TO 87
920 62 CUTPUT(1)=SLASH
921 CUTPUT(101) = SLASH
SUBROUTINE CCNTR(U,K,L,DELC,DELG,CONMG,CONINT,NUMPAT)
C*****************************************************************************
C THIS SUBPROGRAM GIVES A CONTOUR MAP OF THE MATRIX A
C K AND L ARE THE MAXIMUM VALUES OF I AND J
C IF K=L=51 OR 101 AXES WILL BE SET UP AS FOR A PATTERN PLOT
C DELC=DELTA(INCREMENT) BETWEEN CONTOURS FOR CCNTR SUBROUTINE
C DELO=LOWEST CONTOUR LEVEL
C CMAX=HIGHEST CONTOUR LEVEL
C CMINT=CONTOUR INTERVAL
C NUMPAT=PATTERN NUMBER
C*****************************************************************************
DIMENSION A(51,51)
DIMENSION ALPHA(10)
DIMENSION COL(101)
DATA ALPHA/1HC,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9/
DATA BLANK,OUT/H1,H2/H,
IF(K.LE.1,CR,K.LE.1) RETURN
CONINT=CMNTR
CONMG=CMAX
DELO=DELC
WRITE(6,87) NUMPAT
87 FRMAT(1HC,'FOR THE PATTERN NUMBERED',I5)
IF(CONINT) 89,99,100
89 BIC=-1.E27
SMALL=1.E27
GO 98 1=1,K
98 GO 98 J=1,L
IF(A(I,J) GT BIG) BIG=A(I,J)
IF(A(I,J) LT SMALL) SMALL = A(I,J)
98 CONTINUE
CONINT = (BIG - SMALL) / 10.
DELCRN = C.5 * CONINT

CCNLOW = SMALL + DELCRN

CONMAX = BIG - DELCRN

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

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

PRINT LEVEL DESIGNATIONS

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

CON = CONMAX + CONINT

ICON = M - 1

CON = CON - CONINT

WRITE (6, 72) ICON, CON

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

CONTINUE

WRITE HEADING

DO 32 J = 1, 101

COL(J) = BLANK

CONTINUE

IF (L .GT. 51) GO TO 33

DO 30 J = 1, 101, 2

COL(J) = DOT

CONTINUE

GO TO 34

CONTINUE

DO 35 J = 1, 101

COL(J) = DOT

CONTINUE

CONTINUE

WRITE (6, 200)

FORMAT (1H1)

N1 = L * 2

IF (N1 .GT. 101) N1 = 101

WRITE (6, 101) (COL(J1), J1 = 1, N1)

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

CO 1 I = 1, K

CC 31 J = 1, 101

CCL(J) = BLANK

CONTINUE

CONTINUE

J2 = -1

CO 2 J = 1, L

J2 = J2 + 2

ICON = -1

CON = CONMAX + CONINT

CO 50 M = 1, MCHAR

ICON = ICON + 1

CON = CON - CONINT

IF (A(I, J) .GT. (CON + DELCRN)) GO TO 50

IF (A(I, J) .LT. (CON - DELCRN)) GO TO 50

NOW A(I, J) IS LT CON + DELCRN AND GT CON - DELCRN

IF (L .LE. 51) CCL(J2) = ALPHA(ICON + 1)

IF (L .GT. 51) COL(J) = ALPHA(ICON + 1)

GO TO 2
SUBROUTINE PATCON(RDATA, MMAX, NMAX, ICODE, CONLOW, CONMAX, CONINT, STARTU, STARTV, DELTAU, DELTAV, NUPAT, ISYMM)

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

DATA BLANK/' '/

CALL DATE(I,J,K)
WRITE(6,10) I,J,K,NUPAT

IF(ICCDE.EQ.0) WRITE(6,11)
IF(ICCDE.EC.1) WRITE(6,12)
IF(ICCDE.EQ.2) WRITE(6,13)

IF(ISYM.EC.1) GO TO 70
IF(ISYM.EC.2) GO TO 70

U1=STARTU
U2=FINALU
V1=STARTV
V2=FINALV
NCOUNT=MMAX

IF(ISYM.EC.1) 70,30,20

UBIG=AMAX1(ABS(STARTU),ABS(FINALU))
U1=-UBIG
U2=UBIG
NCOUNT=2*NCOUNT-1

VBIG=AMAX1(ABS(STARTV),ABS(FINALV))
V1=-VBIG
V2=VBIG
NCOUNT=2*NCOUNT-1

CONTINUE

ESTABLISH LOWER AND UPPER LIMITS
NUMCON=(CONMAX-CONLO)/CONINT+1.5
          DC 71 J=1,NUMCON
LOW(J)=CCNL+(J-1)*CONINT-DELCON
HIGH(J)=LOW(J)+CONINT+0.0001
            CONTINUE
LOW(11)=-1.E3C
HIGH(12)=1.E3C
HIGH(11)=LOW(1)
LOW(12)=HIGH(NUMCON)
MSKIP=100/(MCOUNT-1)
NSKIP=100/(NCOUNT-1)
              DO 40 I=1,11
UAXIS(I)=UI+(I-1)*DU
WRITE(6,42) (UAXIS(I),I=1,11)
32 F FORMAT(13X,11(F7.4,3X)/16X,11(' ',9X))
            DU=(U2-UI)/100.
            DV=(V2-V1)/100.
N1=NSKIP-1
DO 50 N=1,101,NSKIP
V=V2-(N-1)*DV
            DO 51 K=1,101
OUTPUT(K)=BLANK
            DO 60 M=1,101,MSKIP
U=UI+(M-1)*DU
        IF(U*L+V*$V.GT.1.0) GO TO 60
C FIND F(U,V)
IJ=1
IK=1
J=(U-STARTU)/DELTAU+1.5
K=(V-STARTV)/DELTAV+1.5
IF(J.GE.1 .AND. J.LE.MMAX) IJ=0
IF(K.GE.1 .AND. K.LE.NMAX) IK=0
101 IF(IJ) 2CC,102,2CC
102 IF(IK) 300,1000,300
200 IF(ISYM-1) 6C,6C,201
201 J=1.5-(U+STARTU)/DELTAV
202 IF(IJ) 6C,202,60
1091 IF(IK) 7CC,1CCC,300
300 IF(ISYMN.EQ.0 .OR. ISYMN.EQ.2) GO TO 60
1093 K=1.5-(V+STARTV)/DELTAV
1094 IF(K.GE.1 .AND. K.LE.NMAX) IK=0
1095 IF(IK) 60,1000,60
1096 CCC F=RCATA(J,K)
1097 IF(F.LE.LGW(1)) GO TO 1001
1098 IF(F.GT.HIGH(NUMCON)) GO TO 1002
DO 61 K=1,NUMCON
1110 IF (F.GT.LOW(K).AND. F.LE.HIGH(K)) GO TO 62
1111 61 CONTINUE
1112 60 CONTINUE
1113 OUTPUT(K)=LEVEL(12)
1114 GO TO 60
1115 OUTPUT(K)=LEVEL(11)
1116 GO TO 60
1117 OUTPUT(M)=LEVEL(K)
1118 CONTINUE
1119 WRITE (6,64) V, (OUTPUT(K), K=1,101), V
1120 64 FORMAT (7X,F7.4,1X,' ',101A1,' ',1X,F7.4)
1121 IF (N1.EQ.0) GO TO 50
1122 50 WRITE (6,56)
1123 56 FORMAT(' ')
1124 55 CONTINUE
1125 CONTINUE
1126 WRITE (6,43) (UAXIS(I), I=1,11)
1127 43 FORMAT (16X,11(' ',9X)/13X,11(F7.4,3X))
1128 CONTINUE
1129 WRITE (6,44)
1130 44 FORMAT (' ',56X,'CONTOUR LEVEL KEY'//)
1131 45 CONTINUE
1132 WRITE (6,46) (LEVEL(J), LOW(J), HIGH(J), J=I,12,4)
1133 46 FORMAT (5X,3(A1,' : ',E14.7,' TO ',E14.7,4X))
1134 RETURN
1135 ENC

SUBROUTINE LIST(CURR,CURI,MCUR,NCUR)

THIS SUBROUTINE LISTS ARRAY ELEMENT COORDINATES AND CURRENTS


DIMENSION CURR(51,51), CURI(51,51)
1127 DO 10 M=1,MCUR
1128 DO 10 N=1,NCUR
1129 J=(M-1)*NCUR+N
1130 CALL LCCSCR(M,N,S,T)
1131 WRITE (6,1CC) J,S,T,CURR(M,N), CURI(M,N)
1132 10 CONTINUE
1133 100 FORMAT (3X,14,5X,4(E14.7,2X))
1134 RETURN
1135 ENC
7. Appendix: The ANTDATA Computer Program

7.1 Introduction

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

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

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

7.2 Program Organization

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

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

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

Step 1. Specify pattern number and location in storage.

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

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

Step 2. Array size.

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

Step 3. Number of correction coefficients.

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

Step 4. Pattern data.

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

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

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

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

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

Step 12. T profile location.

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

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

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


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

Step 15. Options for current phase plots.

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

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

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


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

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

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

7.4.1 Definition of Some Important Integer Variables Used in ANTDATA

ITEMP = Number of original correction coefficients, CORG.

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

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

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

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

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

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

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

7.4.2 Definition of Some Important Real Variables Used in ANTDATA

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

CONLOW = The lowest contour level for PLOT2 subroutine.

CONMAX = The highest contour level for PLOT2 subroutine.

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

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

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

7.5 Subroutine Descriptions

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

7.5.1 ANTDATA Plot Subroutines

SUBROUTINE PLOT1

Purpose:

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

Usage:

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

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

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

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

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

**CONST** - Label constant.

**NUMPAT** - Pattern number.

Remarks:

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

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

**COMMON** Blocks Required: **COMMON /PLT1/ PTS**

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

**SUBROUTINE PLOTIC**

Purpose:

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

Usage:

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

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

Remarks:

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

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

COMMON Blocks Required: COMMON /PLT1/, PTS
Subroutines and Function Subprograms Required: FACTOR, PLOT, SYMBOL, NUMBER, AXIS.

SUBROUTINE PLOT1P
Purpose:

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

Usage:

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

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

Remarks:

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

COMMON Blocks Required: COMMON /PLT1/ PTS

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

SUBROUTINE PLOT2

Purpose:

To draw a contour map of data in array A.

Usage:

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

Description of Parameters:

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

Remarks:

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

COMMON Blocks Required: COMMON /ARRAY/ A

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

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

SUBROUTINE CNLAL

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

Usage:

CALL CNLAL (N, M, CNTRL0, CMAX, CNTRAL, NC)

Description of Parameters:

N  -  Number of points in horizontal direction.
M  -  Number of points in vertical direction.
CNTRL0  -  Least value of array X.
CMAX  -  Greatest value of array X.
CNTRAL  -  ABS(CMAX-CNTRL0)/10.
NC  -  IF NC=0: CNTRL0 and CMAX are returned.
     IF NC=1: CNTRL0, CMAX, and CNTRAL are returned.
SUBROUTINE PLOTL

Purpose:

To plot a straight line between two points.

Usage:

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

Description of Parameters:

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

Remark:

PLOTL is equivalent to the following two statements:

CALL PLOT(SCALE*X1+2.,SCALE*Y1+0.25,3)
CALL PLOT(SCALE*X2+2.,SCALE*Y2+0.25,2)

Where PLOT is a standard VPI plot subroutine.

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 and Function Subprograms Required: THREE4

SUBROUTINE THREE4

Purpose:

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

Usage:

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

Description of Parameters:

(X,Y,Z) - Coordinates of point to be located.
XP - Height above paper of point.
(YP,ZP) - Coordinates of projection on paper.
COMMON Blocks Required:

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

Subroutine and Function Subprograms Required: None.

SUBROUTINE THREE3

Purpose:
To plot a perspective of a three-dimensional figure.

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

Description of Parameters:

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

COMMON Blocks Required:

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

Subroutine and Function Subprograms Required: THREE4, THREE5, PLOT

SUBROUTINE THREE5

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

Usage:
CALL THREE5(XI, YJ, M, W, P, KODE)
Description of Parameters:

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.

```plaintext
//B0663PL3 JOB 507C2,COFFEY
/*MAIN TIME=19,LINES=3,REGION=250K,CARDS=C
/*PRIORITY PRIORITY
/*FORMAT PL,FORMS=PFGURAGV,PEN=XXFI A,E,DDNAME=CALCAMP
// EXEC FORTGCG,PARM.GO='PAPER=39,PTIME=119',EP=MAIN
//FORT.SYIN DD *
/*
//GO.SYSLIB DD
// DD DSN=VPI.PLOTLIB,DISP=SHR
// DD DSN=VPI.SSPLIB,DISP=SHR
//GO.SYSLIN DD
// DD *
/*
//GO.FT22FOO DD DSN=ANTDATA.A507C2,UNIT=3330,VOL=SER=tJSERPK,DISP=SHR
//GO.FT06FOO DD SYSOUT=A,DCB=(BLKSIZE=133,RECFM=F)
//GO.SYIN DD *
/*
```

7.6.2 Source Listing

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

INPUT/OUTPUT:
THE MAJORITY OF INPUT IS TAKEN FROM ANTSYN2 VIA DIRECT-ACCESS
UNIT 22 (ANTDATA,AS07C). PARAMETERS AND JOB OPTIONS ARE SUPPL
THROUGH UNIT 5 (SYGIN). ALL OUTPUT IS CHANTED TO UNIT 6
(SYSPRINT) AND THE PLOTTER (PLOT1).

VERSION 1 73 - 094 -- APRIL 5, 1973

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

UNDER NASA GRANT: 47-004-103

ADDITIONAL SUBPROGRAMS REQUIRED:

ICVT -- ASSEMBLER LANGUAGE SUBPROGRAM TO CONVERT AN INTEGER
TO A CHARACTER FORMAT.

DEFINE FILE 22(35,9100,ENREC)

DIMENSION A(151,151),PTS(4001),US(500),VS(500),CURCOF(500)
DIMENSION UORG(100),VORG(100),CORG(100)
DIMENSION AU(151),AV(151)
INTEGER TITLE(20)
REAL INITLS,NITLT
REAL LOWCON
INTEGER OPT1,V,OPT2,OPT3,PX,PY
COMPLEX CTEMP,CI
COMMON /PLT1/ PTS
COMMON /ARRAY/ A
COMMON /PAT1/ Pl,P2,P3,P4,P5,P6,P1,SS(400),TT(400),RR(400)
COMMON /PAT2/ 11,12,13,14,15
COMMON /LOC/ ITYPE
IPAGE=0
PI=3.14159265
CI=CMPLX(0.0,1.0)
CALL STIME(ITIME)
TIME=0.
9999 CONTINUE
CALL TIMECN
IPAGE=IPAGE+1
CALL DATE(I1,J1,K1)
CALL STIME(IT)
IHR=IT/10000
IFR=IT-IHR*10000
FHR=IFR/10000.
FM=FHR*60.
IHR=ICVT(IHR)
IFR=ICVT(IMIN)
ISEC=ICVT(ISEC)
IPG=ICVT(IPAGE)
WRITE(6,1) I1, J1, K1, IHR, IMIN, ISEC, IPG
1 FORMAT(1H1,2X, 'ANTDATA I VERSION 1 LEVEL 2',
8X, 'DATE = ', A29, ' - ', A2, ' - ', A2, ' - ', A2,
READ PATTERN NUMBER AND TRACK -- VERIFY THAT PATTERN IS ACTUALLY
STORED
READ(5,10,END=999) NUMPAT, NUMTRK
10 FORMAT(14I5)
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 51
CONTINUE
NUMPAT IS NOT ON DISK
WRITE(6,60) NUMPAT
60 FORMAT(1H0, 'PATTERN NUMBER', I5, ' WAS NOT FOUND ON TRACK', I2,
8X, ' BUT WAS LOCATED ON TRACK', I2)
CONTINUE
NUMTRK=1
CONTINUE
REGAIN PROCESSING
READ(5,10) NMAX, NMAX
READ(22,70) ITEM, ITEMP
10 FORMAT(104X,2A4)
READ(22, NUMTRK, 101) NUMPAT, TITLE, ISYM, ITER, ISUC, FNORM, IUISK, $NCRG, IC, (UORG(J), VORG(J), CORG(J), J=1, ITMP3), $(US(J), VS(J), CCORCF(J), J=1, ITMP3), ITYPE, P1, P2, P3, P4, P5, P6, $PI, (SS(J), TT(J), J=1, 1400), 11, 12, 13, 14, 15, MCUR, NCUR

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

C READ OPTIONS FOR PATTERN MAGNITUDE

C

READ(5, 29) OPTIU, OPTIV, OPT2, OPT3
29 FORMAT(4(1I1))

IF(OPTIU-1) 80, 81, 60

81 CONTINUE

READ(5, 31) CONST

IF(NMAX.LE.1) GO TO 80

DO 90 J=1, 4001

U=(J-1)*0.0005-1.0

SUM=0.

90 CONTINUE

CONTINUE

91 SUM=SUM+CCRG(K)*PAT(U-UORG(K), CONST-VORG(K), ITYPE)

IF (IC.LE.0) GO TO 900

DO 91 K=1, IC

SUM=SUM+CCORCF(K)*PAT(U-US(K), CONST-VS(K), ITYPE)

91 CONTINUE

92 PTS(J)=2C.*ALOG10(ABS(SUM))

WRITE(6, 92) CONST

CALL PLOT(1, F5.3)

93 CALL PLOT(1, F5.3)

94 900 CONTINUE

95 IF (PATTERN = '5', F7.2) GO TO 900

96 CALL PLOT(1, F5.3)

97 CONTINUE

C GENERATE PATTERN ARRAY

C

READ(5, 31) LOWCON, DASH

IF(NMAX.LE.1 .OR. NMAX.LE.1) GO TO 239

DELTAU=2.0/(MMAX-1)

DELTAU=2.0/(NMAX-1)

WRITE(6, 701) LOWCON, LOWCON

701 FORMAT(*PATTERN IS NOW BEING GENERATED. IF PATTERN < '5', F7.4, $ .9 PATTERN = '5', F7.2)

100 IF (ITYPE .EQ. 5) GO TO 5000
LOAD UP AU AND AV.

C C C LOAC UP AU ANC AV.
C
GO 2CCO I=1,MMAX
U=(I-1)*DELTAV
2CCO AU(I)=PAT(U,O.,ITYPE)
GO 2010 J=1,NMAX
V=(J-1)*DELTAV
201C AV(J)=PAT(C-,V,TYPE)
C C BEGIN
C
U=-1.0-DELTAV
GO 2020 M=1,MMAX
U=U+DELTAV
V=-1.0-DELTAV
GO 2020 N=1,NMAX
V=V+DELTAV
TEMP=0.
2030 TEMP=TEMP+CORG(K)*AU(I)*AV(J)
IF(1IC.LE.0) GO TO 2020
GO 2040 K=1,NORG
I=ABS(U-UORG(K))/DELTAV+1.5
J=ABS(V-VORG(K))/DELTAV+1.5
2040 TEMP=TEMP+CORCOF(K)*AU(I)*AV(J)
202C A(M,N)=20.*ALOG10(ABS(TEMP))
GO TO 239
5CCO CONTINUE
GO 2CCO M=1,MMAX
U=-1.0+(M-1)*DELTAV
GO 201 N=1,NMAX
V=-1.0+(N-1)*DELTAV
TEMP=0.
GO 242 I=1,NORG
242 TEMP=TEMP+CORG(I)*PAT(U-UORG(I),V-VORG(I),ITYPE)
IF(1IC.LE.0) GO TO 2021
GO 202 I=1,IC
202 TEMP=TEMP+CORCOF(I)*PAT(U-US(I),V-VS(I),ITYPE)
2021 CONTINUE
A(M,N)=20.*ALOG10(ABS(TEMP))
GO TO 239
2CCO CONTINUE
GO 201 210,210,211
RFAD59T31) CONLOW,CONMAX,CONINT
31 FORMAT(6F10.0)
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
257 CONTINUE
WRITE(6,220) CONLOW,CONMAX,CONINT
154 220 FORMAT(10 CONTour Plot of Pattern Requested)
    * LOwest Contour = ',F7.2/
    * HIghest Contour = ',F7.2/
    * Contour Interval = ',F7.2)
155 CALL PLOT2(MMAX,NMAX,CONLOW,CONMAX,CONINT,NUMPAT,HASH)
156 IF(OPT3) 230,231
157 WRITE(6,24C)
158 IF(MMAX.LE.1.OR.NMAX.LE.1) WRITE(6,23)
159 IF(0.TWO AND THREE DIM. PLOTS CANCELLED SINCE SOURCE IS
160 ONE DIMENSIONAL)
161 CONTINUE
C ENd Of Pattern
C
164 IA=O
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 CONTINUE
C TYPE= 1 OR 3
170 402 FORMAT(1H0,'THE SOURCE IS AN ARRAY -- THIS PGM IS FOR CONTINUOUS SOURCES ONLY')
171 IA=1
172 401 CONTINUE
173 P3TEMP=P3
174 P5TEMP=P5
175 P6TEMP=P6
176 IF(ITYPE=1) 404,403,404
177 404 IF(ITYPE=3) 405,403,405
178 403 CONTINUE
C TYPE=4
179 INITLS=P3
180 DELTAS=P3
181 FINALS=P3
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 TYPE=6
189 INITLS=P3
190 FINALS=P3+P1
191 INITLT=P4
192 FINALT=P4+P2
193 P5=P2/4CC0.
194 P6=P2/4000.
195 DELTAT=P6
196 DELTAS=P5
197 GO TO 410
198 407 CONTINUE
199 IF(ITYPE=6) 410,409,410
INITLS = P3
FINALS = P3 + 2. * P1
INITLT = P4
FINALT = P4 + 2. * P1
DELTA = P6
DELTAS = P5

CONTINUE
READ(5,29) OPTIU, OPTIV, OPT2, OPT3
IF(OPTIU-1) 302, 301, 302
CONTINUE
READ(5,31) CONST
IF(IA.EQ.1) GO TO 3000
IF(IVAL.EQ.1) GO TO 302
J = 1
IF(DELTAT .NE. 0.) J = 1.5 + (CONST - INITLT) / DELTAT
DO 303 I = 1, 4001
CTEMP = (0.0, 0.0)
IF(NORG .LE. 0) GO TO 304
DO 305 K = 1, NORG
CTEMP = CTEMP + COR(K) * SOURCE(I, J, UORG(K), VORG(K), TYP(K))
305 CONTINUE
IF(IC .LE. 0) GO TO 303
304 CONTINUE
DO 306 K = 1, IC
CTEMP = CTEMP + COR(K) * SOURCE(I, J, US(K), VS(K), TYP(K))
WRITE(6, 307) CONST
307 FORMAT(*OS-AXIS PROFILE PLOT REQUESTED -- T = ', F6.3)
CALL PLOTIC(INITLT, FINALT, 4001, 1, CONST, NUMPAT)
CONTINUE
IF(OPTIV-1) 311, 310, 311
CONTINUE
READ(5,31) CONST
IF(IA.EQ.1) GO TO 3000
IF(NVAX .LE. 1) GO TO 322
I = 1
IF(DELTAS .NE. 0.0) I = 1.5 + (CONST - INITLT) / DELTAS
DO 313 J = 1, 4001
CTEMP = (0.0, 0.0)
IF(NCRG .LE. 0) GO TO 314
DO 315 K = 1, NCRG
CTEMP = CTEMP + COR(K) * SOURCE(I, J, UCRG(K), VCRG(K), TYP(K))
315 CONTINUE
IF(IC .LE. 0) GO TO 313
314 CONTINUE
DO 316 K = 1, IC
CTEMP = CTEMP + COR(K) * SOURCE(I, J, US(K), VS(K), TYP(K))
WRITE(6, 317) CONST
317 FORMAT(*OT-AXIS PROFILE PLOT REQUESTED -- S = ', F6.3)
CALL PLOTIC(INITLT, FINALT, 4001, 1, CONST, NUMPAT)
CONTINUE
CONTINUE
CONTINUE
CONTINUE
P3 = P3TEMP
P5 = P5TEMP
P6 = P6TEMP
MCUR = 51
NCUR = 51
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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
261 DO 330 M=1,MCUR
262 DO 331 N=1,NCUR
263 CALL LOCSOR(M,N,S,T)
264 CTEMP=0.
265 DC 339 K=1,NORG
266 CTEMP=CTEMP+CORG(K)*SOURCE(M,N,UORG(K),VORG(K),ITYPE)
267 DO 332 K=1,1C
268 CTEMP=CTEMP+CORGOF(K)*SOURCE(M,N,US(K),VS(K),ITYPE)
269 A(N,M)=ABS(CTEMP)
270 331 CONTINUE
271 330 CONTINUE
272 333 CONTINUE
273 IF(OPT2) 350,350,351
274 351 READ(5,31) CONLOW,CONMAX,CONINT
275 IF(IA.EQ.1) GO TO 360
276 IF(VMAX.LE.1.OR.NMAX.LE.1) GO TO 360
277 WRITE(6,340) CONLOW,CONMAX,CONINT
278 340 FORMAT('CURRENT MAGNITUDE REQUESTED'/
$\quad$ LOWEST CONTOUR = ',F7.4/
$\quad$ HIGHEST CONTOUR = ',F7.4/
$\quad$ CONTOUR INTERVAL = ',F7.4)
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(1HO,'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
288 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
293 DO 530 M=1,MCUR
294 DO 531 N=1,NCUR
295 CALL LOCSOR(M,N,S,T)
296 CTEMP=0.
297 DO 549 K=1,NORG
298 CTEMP=CTEMP+CORG(K)*SOURCE(M,N,UORG(K),VORG(K),ITYPE)
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300 CONTINUE
301 DO 532 K=1,IC
302 CTEMP = CTEMP + CORCOF(K) * SOURCE(M,N,US(K),VS(K),ITYPE).
303 CREAL = REAL(CTEMP)
304 CIMAG = AIMAG(CTEMP)
305 A(M,N) = ATAN2(CIMAG,CREAL) * 180./PI
306 CONTINUE
307 CONTINUE
308 CONTINUE
309 IF(OPT2) 550,550,551
310 551 READ(5,31) CONLOW,CONMAX,CONINT
311 IF(IA.EQ.1) GO TO 560
312 IF(PMAX.OE.000000.000000.1) GO TO 560
313 WRITE(6,540) CONLOW,CONMAX,CONINT
314 540 FORMAT('CONTOUR PLOT OF CURRENT PHASE REQUESTED' /
315 'LOWEST CONTOUR = ',F7.2/
316 'HIGHEST CONTOUR = ',F7.2/
317 'CONTOUR INTERVAL = ',F7.2)
318 CALL PLOT2(NCUR,NCUR,CONLOW,CONMAX,CONINT,NUMPAT,DASH)
319 550 IF(OPT3) 560,560,561
320 IF(IA.EQ.1) GO TO 560
321 WRITE(6,555)
322 555 FORMAT('THREE DIMENSION PLOT OF CURRENT PHASE REQUESTED')
323 CALL PLOT3(MCUR,NCUR,NUMPAT)
324 IF(PMAX.LE.1.OR.NMAX.LE.1) WRITE(6,23)
325 WRITE(6,23)
326 23 FORMAT('EXECUTION TIME: ',F6.2,' MINUTES.')
327 FMIN=ISEC/600.0
328 WRITE(6,897) FMIN
329 897 FORMAT('TOTAL EXECUTION TIME: ',F7.2,' MINUTES.')
330 CALL TIMECK(ISEC)
331 FMIN=ISEC/600.0
332 WRITE(6,899) FMIN
333 899 FORMAT('TOTAL ELAPSED TIME: ',F7.2,' MINUTES.')
334 SUBROUTINE PLOT1(PSTRT,PEND,IP,CODE,CONST,NUMPAT)
335 WRITTEN BY: S. R. KAUFMAN
336 DATE: 73-113 APRIL 23, 1973
INTEGER NAME(2), CODE
DIMENSION PTS(4001)
COMMON /PLT1/ PTS
CALL FACTOR(0.5)
CALL PLOT(8.91.,-3)
IF(CODE.GT.0) GO TO 3
CALL SYMBOL(-1.2,-6,2;8;THETA = ,0.,8)
CALL NUMBER(.3,-3,.2;CONST,0,3)
GO TO 6
3 IF(CODE.GT.1) GO TO 4
CALL SYMBOL(-1.5,-8,.2;1H;0,0,11)
CALL SYMBOL(-.9,-8,.2;3H = ,0,0,3)
CALL NUMBER(-.2,-8,.2;CONST,0,0,3)
CALL SYMBOL(-2.6,-4,.2;2H-V,0,0,2)
CALL SYMBOL(2.4,-4,.2;2H+V,0,0,2)
GO TO 6
4 IF(CODE.GT.2) GO TO 5
CALL SYMBOL(-1.5,-8,.2;1H;0,0,11)
CALL SYMBOL(-.9,-8,.2;3H = ,0,0,3)
CALL NUMBER(-.2,-8,.2;CONST,0,0,3)
CALL SYMBOL(-2.6,-4,.2;2H-U,0,0,2)
CALL SYMBOL(2.4,-4,.2;2H+U,0,0,2)
6 CONTINUE
PDEL=(PSTRT-PEND)/IP
PTIC=(ABS(PSTRT-PEND))/10.
CALL AXIS(-5.0,0,1H,-1.4,0,PSTRT,PTIC)
PSTRE=PSTRT+6.0*PTIC+.00001
PTIC2=PTIC*.00001
CALL AXIS(1.0,0,1H,-1.4,0,PSTRE,PTIC2)
CALL PLOT(-1.0,0,3)
CALL PLOT(1.0,0,2)
CALL PLOT(0.0,0,3)
CALL PLOT(0.0,0,3)
CALL PLOT(0.0,0,3)
CALL SYMBOL(-.05,-3,.2;1H;0,0,11)
X=0.05
CC 10 J=1,6
Y=0.5*(J-1)*1.0
CALL PLOT(-X,Y,3)
10 CALL PLOT(X,Y,2)
CALL PLOT(0.0,0,0,3)
IF(PTS(1).LE.-50.) PTS(1)=-50.
FS=((PTS(1))/10.)*5.5
CALL PLCT(-5.,FSq3)
CALL PLCT(IWI=1,IP)
THETS=((PSTRT-(IW1*PODEL))*5.))/(ABS(PSTRT))
FOBS=((PTS(IW1))/10.)*5.5
IF(FOBS.LT.0.5) GO TO 1
CALL PLCT(THETS,FOBS,2)
CONTINUE
CALL SYMBOL(-5.0,-0.8,0.125,10HPATTERN = 0.,1)
NUM=FLCAT(NUMPAT)
CALL NUMBER(-3.87,-0.8,0.125,FNUM,0.,-1)
CALL AXES(-5.5,0.5,17HFAR FIELD PATTERN,17,5.0,90.0,-50.,10.)
CALL PLCT(8.0,-1.0,-3)
RETURN
END

SUBROUTINE PLOTIC(PSTRT,PEND,IP,CODECONST,N(lMPAT)

SUBROUTINE PLOTIC

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
CODE -- LABELLING VARIABLE. IF CODE=0: LABEL IS 'THETA = ';
        IF CODE=1: LABEL IS 'S = '; IF CODE=2: LABEL IS 'T = '
CONST -- CONSTANT PARAMETER FOR LABEL.
NUMPAT -- PATTERN NUMBER FOR LABEL.

INTEGER NAME(2),CODE
CALL FACTOR(0.5)
CALL PLOT18.9,1.9,-3D
CIPENSICN
CCPMCN /PLTI/ PTS

I=C
IF(CODE.GT.0) GO TO 3
CALL SYMBOL(-1.2,-0.6,0.2,8HTHETA = ,0.0,8)
CALL NUMBER(I,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 = ,0.0,1)
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)
416 GO TO 6

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

418 CALL SYMPL(-1.0,-0.8,0.2,1HT,0.0,1)

419 CALL SYMBOL(-0.9,-0.8,0.2,3H ,0.0,3)

420 CALL NUMBER(-0.2,-0.8,0.2,CONST,0.0,3)

421 CALL SYMBOL(-2.6,-0.4,0.2,2H-5,0.0,2)

422 CALL SYMBOL(2.4,-0.4,0.2,2H+S,0.0,2)

423 CONTINUE

424 PDEL=(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+0.00001

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

430 CALL PLOT(-1.0,0.0,3)

431 CALL PLOT(1.0,0.0,2)

432 CALL PLOT(0.0,5.8,2)

433 CALL PLOT(0.0,0.0,3)

434 CALL PLOT(0.0,5.8,2)

435 CALL PLOT(-5.0,0.0,3)

436 X=0.05

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

438 CALL PLOT(-X,Y,2)

439 CALL PLOT(X,Y,2)

440 CALL PLOT(-5.0,PSTSA,3)

441 DO 10 IWI=1,IP

442 IF(PTS(IWI).GT.GMAX) GMAX=PTS(IWI)

443 CONTINUE

444 IF(GMAX.GT.0.5) ASCLE=0.2

445 IF(GMAX.LE.0.5) ASCLE=0.1

446 IF(GMAX.LE.0.04) ASCLE=0.04

447 IF(GMAX.LE.0.02) ASCLE=0.02

448 IF(GMAX.LE.0.01) ASCLE=0.01

449 IF(GMAX.LE.0.005) ASCLE=0.005

450 IF(GMAX.LE.0.004) ASCLE=0.004

451 IF(GMAX.LE.0.002) ASCLE=0.002

452 IF(GMAX.LE.0.001) ASCLE=0.001

453 IF(GMAX.LE.0.0005) ASCLE=0.0005

454 IF(GMAX.LE.0.0001) ASCLE=0.0001

455 CALL AXIS(-5.5,0.5,16H SOURCE MAGNITUDE,16,5.0,90.0,0.0,ATIC)

456 CALL SYMBOL(-5.0,-0.8,0.2,1HT,0.0,1)

457 CALL PLOT(-3.5,-0.8,0.2,1HT,PNUM,0.0,1)

458 CALL PLOT(1.0,-1.0,-3)

459 RETURN

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

SUBROUTINE PLOT1P

WRITTEN BY: S. R. KAUFMAN

DATE: 73-113 APRIL 24, 1973

INPUT:

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

INTEGER NAME(2), CODE
DIMENSION PTS(4001)
COMMON /PLTL/PTS
CALL FACTOR(0.5)
CALL 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, 1HSO., 1)
CALL SYMBOL(-.9, -.8, .2, 3H = , 0.3)
CALL NUMBER(-.2, -.8, .2, CONST, 0., 3)
CALL SYMBOL(-.6, -.4, .2, 2H-T, .0, 2)
CALL SYMBOL(2.4, -.4, .2, 2H+T, .0, 2)
GO TO 6
4 IF (CODE.GT.2) GO TO 5
CALL SYMBOL(-1., -.8, .2, 1HT, 0., 1)
CALL SYMBOL(-.9, -.8, .2, 3H = , 0.3)
CALL NUMBER(-.2, -.8, .2, CONST, 0., 3)
CALL SYMBOL(-2.6, -.4, .2, 2H-S, 0.2)
CALL SYMBOL(2.4, -.4, .2, 2H+5, 0.2)
GO TO 6
5 CALL SYMBOL(2.4, -.4, .2, 2H+5, 0.2)
CALL SYMBOL(-1., -.8, .2, 1HT, 0., 1)
CALL SYMBOL(-.9, -.8, .2, 3H = , 0.3)
CALL NUMBER(-.2, -.8, .2, CONST, 0., 3)
CALL SYMBOL(-.6, -.4, .2, 2H-T, .0, 2)
CALL SYMBOL(2.4, -.4, .2, 2H+T, .0, 2)
GO TO 6
6 PCEL=(PSTRT-PEND)/IP
PTIC=ABS(PSTRT-PEND))/10.0
CALL AXIS(5.0, 0.0, 0.0, 1H, 1, 0.0, 0.0, PSTRT, PTIC)
PTST=PSTRT+(6.0*PTIC)+0.00001
PTIC2=PTIC+0.00001
CALL AXIS(1.0, 0.0, 1H, 1, 4.0, 0.0, PSTST, PTIC2)
CALL PLOT(-1.0, 0.3)
CALL PLOT(1.0, 0.3)
CALL PLOT(0.5, 8.2)
CALL PLOT(0.0, 0.3)
CALL SYMBOL(-.05,-.4,.2,lHO,0.,1)
CALL PLCT(0.,0.,O3)
X=C.05
Y=0.5+(J-1)*1.0
CALL PLCT(-X,Y,3)
CALL PLOT(X,Y,2)
DC 1 IW1=1,IP
THETA=(PSTRT-(IW1*PDEL))
THETS=(THETA/(ABS(PSTRT)))*5.
PANGS=PTS(IW1)/180.*4.+4.5
IF(IW1.EQ.1)CALL PLOT(THETS,PANGS,3)
IF(IW1.EQ.1)GO TO 1
CALL PLOT(THETS,PANGS,2)
CONTINUE
CALL AXIS(-5.5,0.5,14HAPERTURE PHASE,14,8.,90.,-90.,45.)
CALL SYMBOL (-5.0,-0.8,O.125,10HPATTERN =O.,10)
FNLM=FLOAT(NUPPAT)
CALL NUMBER(-3.5,-0.8,0.125,FNUM,0.,-1)
CALL PLCT(8.,-1.,-3)
RETURN
END

SUBROUTINE PLOT2(N,M,CONLOW,CONMAX,CONINT,NUPPAT,DASH)
A= N BY M MATRIX OF DATA POINTS
CONLOW= LOWEST CONTOUR TO BE PLOTTED
CONMAX= HIGHEST CONTOUR TO BE PLOTTED
CONINT= INTERVAL BETWEEN CONTOURS
WORDS= TEXT OF PLOT LABEL
NCHAR= NUMBER OF CHARACTERS INPLOT LABEL
CONTours BELOW -40. ARE PLOTTED AS DASHED LINES

DIMENSION A(151,151),RA(151),RB(151),X(151),Y(151)
COMMON /ARRAY/ A
CALL PLOT(8.,0.,-3)
CALL FACTOR (0.7)
MS=M
NS=N
RATIO=MS/NS
SCALE=100
ANM=AMAX0(N-1,M-1)
IF(RATIO-1.0)1,2
1 SX=ANM
SY=RATIO*ANM
GC TO 3
2 SX=1./RATIO*ANM
SY=ANM
3 SMAX=AMAX1(SX,SY)
SS=SX/SMAX
SYS=SY/SMAX
IF(CONINT)4,45
4 CALL CNLAL(N,M,CNTRLO,CMAX,CNTRAL,0)
GC TO 7
551 5 CNTRAL=CNINT
552  IF(CCNMAX.EQ.CONLOW) GO TO 6
553  CMAX=CCNMAX
554  CNTRLO=CONLOW
555  GO TO 7
556  6 CALL CNLAL(N, M, CNTRLO, CMAX, CNTRAL, 1)
557  7 CONTINUE
558  CONLOW=CNTRLO
559  CONMAX=CMAX
560  CONINT=CNTRAL
561  CALL PLOTL(SS, SYS, 0., SYS, SCALE)
562  CALL PLOTL(0., 0., SS, 0., SCALE)
563  CALL PLOTL(SS, 0., SS, SYS, SCALE)
564  CALL PLOTL(0., SYS, 0., 0., SCALE)
565  CALL PLOT(1.00, 0.25, 3)
566  CALL PLOT(0.60, 0.25, 2)
567  CALL PLOT(0.60, 0.25, 2)
568  CALL PLOT(1.00, 0.25, 2)
569  CALL PLOT(1.00, 0.25, 2)
570  CALL SYMBOL(0.88, 0.45, 0.12, 10, PATTERN = .9C., 10)
571  FNUM=NUMPAT
572  CALL NUMBER(0.88, 2.075, 0.12, FNUM, 90., -1)
573  125 YCCNA=1.0/SMAX
574  DELTAX=SS/FLOAT(N-1)
575  X(1)=0.0
576  Y(1)=0.0
577  RB(1) = A(1, 1)
578  DO 27 J=2, N
579  RB(J) = A(J, 1)
580  27 X(J) = X(J-1) + DELTAX
581  DELTAY=SY/FLOAT(M-1)
582  DO 28 J=2, M
583  28 Y(J) = Y(J-1) + DELTAY
584  DO 118 K=2, M
585  RA(J) = RB(J)
586  118 RA(J) = A(J, K)
587  DO 118 J=2, N
588  118 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  39 IF(RL-RA(J-1)) 41, 40, 40
596  40 IF(RL-RA(J)) 42, 50, 50
597  41 RL=RA(J-1)
598  XL=X(J-1)
599  601 GO TO 40
600  42 RL=RB(J)
601  XL=X(J)
602  YL=Y(K)
603  GO TO 50
604  50 RS=RR
605  XS=XX
YS = YY
IF(RS-RA(J-1)) 52, 52, 53
52 IF(RS-RB(J)) 60, 60, 54
RS = RA(J-1)
XS = X (J-1)
YS = Y(K-1)
GO TO 52
RS = RB(J)
XS = X (J)
YS = Y(K)
GO TO 60
RM = HR
XM = X (J)
YM = Y(K)
RCS = YS*YCONA
YCM = YM*YCONA
YCL = YL*YCONA
YS = YS-SY
YM = YM-SY
YL = YL-SY
XCS = XS/SMAX
XCM = XH/SMAX
XCL = XH/SMAX
RC = CNTRL0
80 IF (RC.GT.CMAX) GO TO 110
81 IF (RC .NE. RM) GO TO 91
82 IF (RL.EQ. RM) GO TO 100
91 IF(RC-RS)100, 95, 99
92 IF(RC-RM)96, 93, 94
93 XPA = XCM
YPA = YCM
GO TO 99
94 IF(RC-RL)106, 103, 110
95 C = 0.0
96 Q = (RC-RS)/(RM-RS)
97 XPA = XCS-Q*XCS-XCM
YPA = YCS-Q*YCS-YCM
99 Q = (RC-RS)/(RL-RS)
XPB = XCS-Q*XCS-XCL
YPB = YCS-Q*YCS-YCL
101 IF(RC-DASH) 10115, 10115, 10116
102 XPAH = 0.5*(XPA+XPB)
YPBH = 0.5*(YPA+YPB)
103 IF(ABS (XPA-XPBI) < 0.01) 5001, 5002, 5002
5001 IF(ABS (YPA-YPBI) < 0.01) 100, 5002, 5002
5002 CALL PLOT(SCALE*XPA+2.,SCALE*YPA+0.25,3)
5003 CALL PLOT(SCALE*XPB+2.,SCALE*YPB+0.25,2)
5116 IF(ABS(XPA-XPB)<.001)5004,5004
5004 CALL PLOT(SCALE*XPA+2.,SCALE*YPA+0.25,3)
5005 CALL PLOT(SCALE*XPB+2.,SCALE*YPB+0.25,2)
100 RC = RC + CNTRAL
GO TO 80
103 XPA = XCL
YP = YCL
GO TO 99
106 C=(RC-RM)/(RL-RM)
XP=XCM-Q*(XCM-XCL)
YP=YCM-Q*(YCM-YCL)
GO TO 99
110 GC TO L,(112,118)
112 ASS I N 118 TO L
RR = RB(J-1)
XX = X(J-1)
YY = Y(K)
GO TO 37
118 CONTINUE
118 CALL PLOT(SCALE+.0.,-.3)
119 RETURN
END

SUBROUTINE CNTRL(N,M,CNTRL0,CMAX,CNTRAL,NC)
DIMENSION X(151,151)
COMMON /ARRAY/ X
XMAX=X(1,1)
XMIN=X(1,1)
GO 10 J=1,M
GO 10 I=1,N
XPA=A MAX(XMAX,X(I,J))
10 XMIN=A MIN(XMIN,X(I,J))
IF(NC.EQ.1) GO TO 40
IF(XMAX.EQ.0.) GO TO 20
SN=XMIN/XMAX
IF(SN)2G2C,30
2C XCON=ABS(XMAX)
IF(ABS(XMIN).GT. ABS(XMAX)) XCON=ABS(XMIN)
CNTRL= XCON/10.
CMAX=XMAX
CNTRL0=CNTRL*AINT(XMIN/CNTRAL)
RETURN
3C XCON=ABS(XMAX-XMIN)
CNTRL= XCON/10.
CNTRL0= XMIN
CMAX=XMAX
RETURN
4C CMAX=CNTRL*AINT(XMAX/CNTRAL)
CNTRL0=CNTRL*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.

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,OX,OY,OZ,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,
S. R. KAUFFMAN
W. L. STUTZMAN
E. L. COFFEY

SUBROUTINE PLOT3(IN,M,NUMPAT)

COMMON /ARRAY/ A
COMMON /THREE6/ ANGA,ANGB,HV,D,SH,SV
COMMON /THREE7/ SL,SM,SN,CX,CY,CZ,OX,OY,OZ,SD
A-93

DIMENSION H(10),V(10),X(2),Y(2),Z(2),XP(8),A(151,151)

K=2
SOISTS=6.0
PITCH=30.
YAW=45.
SIZE=10.
KOCE=0

PITCH=30.

CALL FACTOR(1.1)
CALL PLOT(8.,-2.,-3)
CALL PLOT(-4.0,0.,2)
CALL PLOT(-4.8,0.,2)
CALL PLOT(0.,-8.,2)
CALL PLOT(0.,0.,2)
CALL SYMBOL(0.3,1.0,0.12,10HPATTERN = 090,10)

FNLM=FLOAT(NUMPAT)
CALL NUMERO(0.3,2.130,90,12,FNUM,90.,-I)

CALL PLOT(1.5,-.2,-3)

ANGA = (YAW+270.) * 0174532
ANGB = PITCH * 0174532

H= SIZE

C DIRECTION COMPONENTS TO THE EYE.

SL = -COS( ANGA ) * COS( ANGB )
SM = -SIN( ANGA ) * COS( ANGB )
SN = -SIN( ANGB )

IF ( ABS( SN ) .NE. 1.0 ) GO TO 10

WRITE(6,20)

20 FORMAT ( '1°, 20X, 20(***), / 'O', 'YOU ARE ATTEMPTING TO LOC
:K STRAIGHT DOWN ( OR UP ) AT THE SURFACE ' )

GO TO 2150

10 CONTINUE

SD = 1.0 / SQRT( 1.0 - SN ** 2 )

X(1) = 1
X(2) = N
Y(1) = 1
Y(2) = M
T=MAXC(M,N)

C FIND THE DIAGONAL OF THE CUBE.

D = M ** 2 + N ** 2 + T ** 2

D = SQRT ( D )

SCL = SOISTS * D

C COORDINATES OF YOUR EYE.

CX = -SL * SCL
CY = -SM * SCL
CZ = -SN * SCL

C COORDINATES OF THE PROJECTION PLANE.

QX = CX + D * SL
QY = CY + D * SM
QZ = CZ + D * SN

C Ppppppppppppppppppppppppppppppppppppp

GL TC 2060

C WRITE(6,100) CX,CY,CZ
C WRITE(6,100) QX,QY,QZ

100 FORMAT(1X,3F15.3)

060 Z(2)=A(L+1)
Z(1)=A(I,1)
CC 1000 J=1,N
CC 1000 K=1,M
Z(1)=AMIN(Z(1),A(J,K))
Z(2)=AMAX1(Z(2),A(J,K))
1000 CONTINUE
RANGE=(Z(2)-Z(1))
DCL=1.0
IF(SCALE.NE.0) DCL=T/RANGE*SCALE
C SCALE THE SURFACE TO MAKE A "CUBE".
DO 30 I = 1, N
DO 30 J = 1, M
A ( I , J ) = ( A ( I , J ) - Z ( 1 ) ) * DCL
30 CONTINUE
Z(1) = C.C
Z(2) = T
2060 CALL THREE2 ( X, Y, Z, XP, H, V, KODE)
DO 2130 I = 1, 8
H( I ) = ( (XP(I) - OX) * SM - ( H(I) - QY ) * SL ) * SD
DO 2130 CONTINUE
H(9)=H(1)
H(10)=H(1)
1001 CONTINUE
V(9)=V(1)
V(10)=V(1)
1002 CONTINUE
V(9)=AMIN(V(9),V(J))
V(10)=AMAX(V(10),V(J))
1002 CONTINUE
IF ( MGN .EQ. 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( AMIN(V,SH),SH )
SV = SIGN(SH,SV)
IF (MGN .EQ. 1) CALL PLOT (0,0.5,0.5,3)
CALL SYMBOL(H(1)-H(9))*SH, (V(1)-V(9))*SV,-14."0",0,1
CALL SYMBOL(H(2)-H(9))*SH, (V(2)-V(9))*SV,-14."X",0,1
CALL SYMBOL(H(3)-H(9))*SH, (V(3)-V(9))*SV,-14."",0,1
CALL SYMBOL(H(4)-H(9))*SH, (V(4)-V(9))*SV,-14."",0,1
CALL SYMBOL(H(5)-H(9))*SH, (V(5)-V(9))*SV,-14."",0,1
CALL PLOT(-0.3,-0.5,3)
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(3)-H(9))*SH, (V(3)-V(9))*SV,2)
CALL PLOT (H(4)-H(9))*SH, (V(4)-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(5)-H(9))*SH, (V(5)-V(9))*SV,2)
A-95

CALL PLOT ( (H(7)-H(9))*SH, (V(7)-V(9))*SV,2)
CALL PLOT ( (H(5)-H(9))*SH, (V(5)-V(9))*SV,2)
CALL PLOT ( (H(6)-H(9))*SH, (V(6)-V(9))*SV,2)
CALL PLOT ( (H(8)-H(9))*SH, (V(8)-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(7)-V(9))*SV,2)

IF (MGN .NE. 1) GO TO 2140
CALL PLOT (AI6T((H(10)-H(9))*SH+2.), -2.05, -3)
CALL THREE3(X(0), Y(0), Z(0), XP, H, V, KODE)
CONTINUE
CALL PLOT(16., -1.5, -3)
RETURN
END

SUBROUTINE THREE2 ( X, Y, Z, XP, H, V, KODE)
C FIND THE CORNERS OF THE ROTATED CUBE.
DIMENSION X(2), Y(2), Z(2), H(10), V(10), XP(6)
L = 0
DO 180 I = 1, 2
CG 170 J = 1, 2
DO 190 K = 1, 2
L = L + 1
CALL THREE4 (X(I), Y(J), Z(K), XP(L), H(L), V(L), KODE)
CONTINUE
CONTINUE
CONTINUE
RETURN
END

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

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

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

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

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

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

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

L = L + LD
XI = L
CALL THREE5 (XI,YJ,N,M,P,KODE)
PEN = UP
IF (P) 510, 520, 530
51C CONTINUE
IF (Q) 540, 550, 540
52C CONTINUE
IF (Q) 610, 1020, 610
53C CONTINUE
IF (Q) 540, 550, 540
54C CONTINUE
PEN = DOWN
GC TO 170
55C CONTINUE
IF (I .EQ. 1) GO TO 170
DI = CD
TC = L - LC
T = TC * DI
P1 = Q
56C IF (ABS(DI) .LT. END) GO TO 570
CALL THREE5 (T,YJ,N,M,PO,KODE)
57C IF (PO .EQ. C) GO TO 565
A-97

921 \( TC = T \)
922 \( P1 = PO \)
923 \( T = T - DI \)
924 GO TO 560
925 \( 565 \ T = T + DI \)
926 GO TO 56C
927 \( 57C \) CONTINUE
928 \( T = TO \)
929 \( IF \ ( P1 \times P) \ 170 , 170 , 580 \)
930 \( 58C \) CONTINUE
931 \( 59C \) CONTINUE
932 \( ZP = A(L-LC,J)+(T-L+LD)*(A(L,J)-A(L-LD,J))/LD \)
933 CALL THREE4(T,YJ,XP,HH,VV,KODE)
934 \( HF = ((XP-QX)*SM-(HH-QY)*SL) \times SD \)
935 \( VV = (VV-QZ) \times SD \)
936 \( HH = (HH-H(9)) \times SH \)
937 \( VV = (VV-V(9)) \times SV \)
938 CALL PLOT(HH,VV,PEN)
939 \( 60C \) PEN = 5 - PEN
940 GO TO 170
941 \( 61C \) CONTINUE
942 \( PEN = DOWN \)
943 \( DI = OC \)
944 \( TO = L - LD \)
945 \( T = TO + DI \)
946 \( P1 = Q \)
947 \( 62O \) IF \( ( \text{ABS}(DI) \cdot \text{LT. END}) \) GO TO 630
948 CALL THREE5(T,YJ,N,M,PO,KODE)
949 \( DI = DI \times 0.5 \)
950 \( IF \ ( PO \ .EQ. 0 ) \) GO TO 625
951 \( TC = T \)
952 \( P1 = PO \)
953 \( T = T + DI \)
954 GO TO 620
955 \( 625 \) \( T = T - DI \)
956 GO TO 62C
957 \( 63C \) CONTINUE
958 \( T = TC \)
959 \( IF \ ( P1 \times Q ) \) 600 , 600 , 590
960 \( 17C \) CALL THREE4(XI,YJ,A(L,J),XP,HH,VV,K6(L))
961 \( VV = (VV-QZ) \times SD \)
962 \( HH = ((XP-QX)*SM-(HH-QY)*SL) \times SD \)
963 \( 19C \) \( HH = (HH-H(9)) \times SH \)
964 \( 20C \) \( VV = (VV-V(9)) \times SV \)
965 CALL PLOT(HH,VV,PEN)
966 \( 102C \) Q = P
967 \( 1030 \) CONTINUE

C

968 \( L = L + LD \)
969 \( LC = -LD \)
970 \( DD = -DD \)

C

971 \( 1060 \) CONTINUE
C
C
C
C \( 109C \) IF(K-3) 2060,111C,206C
DRAW LINES ALONG THE X-AXIS.

C

1110 CONTINUE
C

L = 0

LC = 1

CC = 0.5 * LD

XI = 1

C = C

1160 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. I) GO TO 1170

DI = DD

TC = L - LD

T = TO + DI

PI = Q

1560 IF (ABS(DI) .LT. END) GO TO 1570

1570 CALL THREE5 (XI, T, N, M, P, KODE)

1580 DI = DI * 0.5

1590 IF (PO .EQ. 0) GO TO 1565

TO = T

1600 IF (P1 * P) 1170, 1170, 1580

1570 CONTINUE

T = TO

1610 CONTINUE

ZP = A(I, L - LD) + (T - L + LD) * (A(I, L) - A(I, L - LD)) / LD

1590 CONTINUE

1590 CONTINUE

1600 PEN = 5 - PEN

GO TO 1170
SUBROUTINE THREES (XI,YJ,M,N,P,KODE)
C SEE IF A POINT IS VISIBLE.
DIMENSION Z(151,151)
COMMON /THREE6/ ANGA, ANGB, HV, D, SH, SV
COMMON /THREE7/ SL, SM, SN, CX, CY, CZ, QX, QY, QZ, SD
COMMON /ARRAY/ Z
INTEGER CUM, CNT, P
REAL I, J, II, JJ
IF ( KODE .EQ. 1) GO TO 78
IR = XI
JC = YJ
ZB = Z ( IR + JC )
IF ( XI .LE. IR ) GO TO 2
ZB = Z ( IR , JC ) + ( XI - IR ) * ( Z ( IR + 1 , JC ) - Z ( IR , JC ) )
GO TO 4
ZB = Z ( IR , JC ) + ( YJ - JC ) * ( Z ( IR , JC + 1 ) - Z ( IR , JC ) )
CONTINUE
XEND = C .C
CX = 0 .C
YMULT = C.C
ZMULT = C.C

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

CX = 1.0
XEND = X + 1
IF ( XI .LT. CX) GO TO 10
CX = -1.0
XEND = 0.0

1C CONTINUE

1C CONTINUE

YEND = C.C

DY = 0.0
XMULT = 0.0
IF ( YJ .EQ. CY ) GO TO 20
XMULT = ( XI - CX ) / ( YJ - CY )

IF ( ZMULT .EQ. 0.0 ) ZMULT=( ZB - CZ ) / ( YJ - CY )
DY = 1.0
YEND = N + 1
IF ( YJ . LT. CY ) GO TO 20

1C7
DY = -1.0

YEND = C.C

2C CONTINUE

CUP = 0
CNT = 0
P = 0
XP = XI
YB = YJ

3C CONTINUE

II = AINH( XB )
JJ = AINH( YB )
XSTEP = DX
YSTEP = DY
IF ( XB .EQ. II ) GO TO 40
IF ( CX .LT. 0.0 ) XSTEP = 0.0
GO TO 45

4C IF ( YB .EQ. JJ ) GO TO 45
IF ( DY .LT. 0.0 ) YSTEP = 0.0

4C CONTINUE

I = II + XSTEP
J = JJ + YSTEP
IF ( I .EQ. XEND ) GO TO 80
IF ( J .EQ. YEND ) GO TO 80
XB = CX + XMULT * ( J - CY )
YB = CY + YMULT * ( I - CX )
IF ( DX .LT. 0.0 ) GO TO 55
IF ( XB .LT. I ) GO TO 60

5C XB = I
GO TO 65

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

6C YB = J

6C CONTINUE

ZB = CZ + ZMULT * ( XB - CX )
IR = I
JC = J
IF ( YB .NE. J ) GO TO 70
ICX = I - DX
FUNCTION PAT(U,V,ITYPE)

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

ITYPE = 1 -- UNIFORM LINE SOURCE LOCATED AT S=0.
ITYPE = 2 -- UNIFORM LINEAR ARRAY LOCATED AT S=L.
ITYPE = 3 -- TRIANGULAR LINE SOURCE LOCATED AT S=0.
ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE.
ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY.
ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.
ITYPE = 7 -- GENERAL ARRAY.
ITYPE > 7 -- SPECIAL SOURCE (FUNCTION SPECPT(U,V,ITYPE) WILL BE CALLED.)

VERSION 1 LEVEL 1


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

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

COMPLEX TEP:CEXP:IMAG
COMMON /PAT1/ PI,P2,P3,P4,P5,P6,PI,SS100),IT100),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,SX,'***ERROR*** ITYPE HAS THE VALUE ',111,':',2X, '*EXECUTION TERMINATED*) STOP

ITYPE = 1 -- UNIFORM LINE SOURCE.

FLEN=PI

100 CONTINUE

PAT=1.0

IF(V.NE.C.) PAT=SIN(PI*PI*V)/(PI*PI*V)

GO TO 999

ITYPE = 2 -- UNIFORM LINEAR ARRAY

FLEN=PI

NELMT=II

PAT=1.0

IF(V.NE.C.) PAT=SIN(PI*PI*V)/(II*SIN(PI*PI*V/I1))

GO TO 999

ITYPE = 3 -- TRIANGULAR LINE SOURCE.

FLEN=PI/2.

PAT=1.0

IF(V.NE.C.) PAT=(SIN(FLEN*PI*V)/(FLEN*PI*V)))**2

GO TO 999

ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE

FLS=PI

FLT=P2

ARG1=PI*PI*U

ARG2=PI*PI*V

IF(ARG1) 4C1402,401

401 IF(ARG2) 4C3v404,403

403 PAT=SIN(ARG1)/ARG1/SIN(ARG2)/ARG2

GO TO 999

404 PAT=SIN(ARG1)/ARG1

CC TO 999

405 PAT=SIN(ARG2)/ARG2

GO TO 999

406 PAT=1.0

GO TO 999
C
C      ITYPE = 5  -- UNIFORM RECTANGULAR ARRAY
C
500 CONTINUE
C      FLS=P1
C      FLT=P2
C      NELS=I1
C      NELT=I2
1194    ARG1=PI*P1*U
1195    ARG2=PI*P2*V
1196    IF(ARG1) 501,502,501
1197    501 IF(ARG2) 503,504,503
1198    503 PAT=SIN(ARG1)/(I1*SIN(ARG1/I1))*SIN(ARG2)/(12*SIN(ARG2/12))
1199    GO TO 999
1200    504 PAT=SIN(ARG1)/(I1*SIN(ARG1/I1))
1201    GO TO 999
1202    502 IF(ARG2) 505,506,505
1203    505 PAT=SIN(ARG2)/(I2*SIN(ARG2/I2))
1204    GO TO 999
1205    506 PAT=1.0
1206    GO TO 999
C
C      ITYPE = 6  -- UNIFORM CIRCULAR APERTURE.
C
600    C=SQRT(U*U+V*V)
C      A=P1
1207    IF(C.EQ.0.) GO TO 601
1208    X=2.*PI*P1*C
1209    CALL BESJ(X,1,BJ,0.0001,IER)
1210    PAT=BJ/X*2.0
1211    GO TO 999
1212    601 PAT=I.C
1213    GO TO 999.
C
C      ITYPE = 7  -- GENERAL ARRAY
C
700    IMAG=(0.0,1.0)
1215    NELMT=I1*I2
1216    TEMP=(0.0,0.0)
1217    DC 701 J=1,NELMT
1218    TEMP=TEMP+IMAG*2.*PI*(U*SS(J)+V*TT(J))
1219    CONTINUE
1220    701 CONTINUE
1221    PAT=REAL(TEMP)/NELMT
1222    GO TO 999
1223    99C PAT=SPECPT(U,V,ITYPE)
1224    999 RETURN
1225    ENC
C
C    COMPLEX FUNCTION SOURCE(M,N,U,V,ITYPE)
C    THIS SUBPROGRAM CALCULATES THE CURRENT AT POINT (M,N) DUE TO
C    THE PATTERN AT POINT (U,V).
ITYPE = 1 -- UNIFORM LINE SOURCE LOCATED AT S=0.
ITYPE = 2 -- UNIFORM LINEAR ARRAY LOCATED AT S=0.
ITYPE = 3 -- TRIANGULAR LINE SOURCE LOCATED AT S=0.
ITYPE = 4 -- UNIFORM RECTANGULAR APERTURE.
ITYPE = 5 -- UNIFORM RECTANGULAR ARRAY.
ITYPE = 6 -- UNIFORM CIRCULAR APERTURE.
ITYPE = 7 -- GENERAL (3-D) ARRAY.

ITYPE > 7 -- SPECIAL SOURCE (FUNCTION SPSOR(M,N,U,*,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:
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E. L. COFFEY DEPT. OF ELEC. ENGR. 951-5494.

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

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

WRITE(6, 10) ITYPE
10 FORMAT (1HC5X, "$ERROR!! ITYPE HAS THE VALUE '", I11, '':', 2X, $EXECUTION TERMINATED")
STEP

ITYPE = 1 -- UNIFORM LINE SOURCE

1C CONTINUE
FLEN=P1
SOURCE=CEXP(-IMAG*PI/2.*T*V)/P1
GO TO 999

ITYPE = 2 -- UNIFORM LINEAR ARRAY

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

ITYPE = 3 -- TRIANGULAR LINE SOURCE
CC CONTINUE
C FLEN=P1
C CON=ABS(2.*T/P1)
1245 SOURCE=2.*P1*CEXP(-IMAG*2.*P1*T*V)*(1.-CON)
1246 IF(CON.GT.1) SOURCE=(0.0,0.0)
1247 GO TO 999

CC IF TYPE = 4 -- UNIFORM RECTANGULAR APERTURE
1248 CC CONTINUE
C FLS=P1
C FLT=P2
1249 SOURCE=CEXP(-IMAG*2.*P1*(S*U+V*T))/(P1*P2)
1250 GO TO 999

CC IF TYPE = 5 -- UNIFORM RECTANGULAR ARRAY
1251 CC CONTINUE
C FLS=P1
C FLT=P2
1252 SOURCE=CEXP(-IMAG*2.*P1*(S*U+V*T))/(P1*P2)
1253 GO TO 999

CC IF TYPE = 6 -- UNIFORM CIRCULAR APERTURE
1254 CC CONTINUE
C RHC=SCRT(S*S+T*T)
C A=P1
1255 SOURCE=(0.0,0.0)
1256 IF(RHC.LE.P1) SOURCE=CEXP(-IMAG*2.*P1*(S*U+V*T))/(P1*P1*P2)
1257 GO TO 999

CC IF TYPE = 7 -- GENERAL ARRAY.
1258 CC CONTINUE
1259 SOURCE=CEXP(-IMAG*2.*P1*(U*S+V*T))/(P1*P1)
1260 GO TO 999
1261 990 SOURCE=SPSOR(M,N,U,V,ITYPE)
1262 999 RETURN
1263 END

SUBROUTINE 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
1270 IF(ITYPE.GT.7) GO TO 99C
1271 GO TO (100,200,300,400,500,600,700), ITYPE
A-106

1272 WRITE(6,10) ITYPE
1273 10 FORMAT(1HC5X,***ERROR***
1274     *ITYPE HAS THE VALUE '111', '11', '2',
1275     *EXECUTION TERMINATED*)
1276 SCIP
1277 CONTINUE
1278 INITL=PI
1279 CELTA=P3
1280 S=0.
1281 T=P2+(N-1)*P3
1282 GO TO 999
1283 CONTINUE
1284 PY=II
1285 DISY=P2
1286 S=0.
1287 T=(N-1/2-1)*P2
1288 IF(II/2*2.EQ.11) T=T+0.5*P2
1289 GO TO 999
1290 CONTINUE
1291 PX=II
1292 PY=12
1293 DISX=P3
1294 DISY=P4
1295 S=(N-1/2-1)*P3
1296 T=(N-12/2-1)*P4
1297 IF(II/2*2.EQ.11) S=S+0.5*P3
1298 IF(II/2*2.EQ.12) T=T+0.5*P4
1299 GO TO 999
1300 CONTINUE
1301 PX=II
1302 PY=12
1303 DISX=P3
1304 DISY=P4
1305 S=(N-1/2-1)*P3
1306 T=(N-12/2-1)*P4
1307 IF(II/2*2.EQ.11) S=S+0.5*P3
1308 IF(II/2*2.EQ.12) T=T+0.5*P4
1309 GO TO 999
1310 CONTINUE
1311 NELPT=(M-IDb12+N
1312 S=SS(NELMT)
1313 T=TT(NELPT)
1314 GO TO 999
1315 CONTINUE
1316 NELPT=(M-IDb12+N
1317 S=SS(NELMT)
1318 T=TT(NELPT)
1319 GO TO 999
CALL SPLCC(v,N,S,T)
RETURN

COMPLEX FUNCTION SPSOR(M,N,U,V,ITYPE)
    DUMMY SUBPROGRAM
    SPSOR=(0.0,0.0)
    RETURN
END

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

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

Antenna Synthesis

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

<table>
<thead>
<tr>
<th>(u,v)</th>
<th>( F_d(u,v) )</th>
<th>( F_u(u,v) )</th>
<th>( F_L(u,v) )</th>
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<tbody>
<tr>
<td>(-0.2 \leq u \leq 0.2)</td>
<td>0. dB</td>
<td>0.5 dB</td>
<td>-0.5 dB</td>
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<tr>
<td>(-0.05 \leq v \leq 0.05)</td>
<td></td>
<td></td>
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</table>

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

8.1 Input to ANTSYN

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

```fortran
SUBROUTINE SINPUT
  RETURN
END

SUBROUTINE SPLOC
  RETURN
END

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

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

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

READ MAINBEAM LIMITS ULIM AND VLIM
READ(5,1) ULIM,VLIM
1 FORMAT(8F10.0)

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

DO 10 M=1,MMAX
  U=STARTU+(M-1)*DELTAU
  DO 10 N=1,NMAX
    V=STARTV+(N-1)*DELTAV
    IF(U.LE.ULIM .AND. V.LE.VLIM) GO TO 20
    IF(U.GT.UTRAN .OR. V.GT.VTRAN) GO TO 30
  C  TRANSITION REGION
    FDES(M,N)=99.0
    FU(M,N)=99.0
    FL(M,N)=99.0
  GO TO 10
  20 CONTINUE

  C  MAIN BEAM REGION
  FDES(M,N)=1.0
  FU(M,N)=1.06
  FL(M,N)=0.943
  GO TO 10
  30 CONTINUE

  C  SIDELOBE REGION
  FDES(M,N)=0.
  FU(M,N)=0.057
  FL(M,N)=99.0
  10 CONTINUE

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:

Card Column

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Notice that it is not necessary to code all the namelist variables. For example, STARTU is not coded because its default value is 0. (which is what we want). In order to better understand why certain parameters were coded, refer to section 6.3 to steps 2 through 10 as they are discussed below.

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

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

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

Step 3. Cards 4 to 6: Output Switches

i. Profiles of the final pattern and final current (FDBPR=FCURPR=1)

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

Step 4. Cards 7 to 11: Source Specifications

i. Rectangular aperture (ITYPE=4)

ii. Dimensions of 10λ by 20λ (LX=10.,LY=20.)

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

Step 5. Cards 12 to 13: The Desired Pattern

For a more complete explanation, see the listing of subroutine DESPAT earlier in this section.

Step 6. Cards 14, 15 to 29: Initial Pattern

These are the number of (NORG) and the values of (UORG,VORG,CORG) the original correction coefficients.

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

8.2 Output from ANTSYN

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

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

PROGRAM PARAMETERS

IDISK = 1
ISYMM = 3
ITRMAX = 200
STARTU = 0.0
STARTV = 0.0
DELTAV = 0.010
DELTAV = 0.020

MMAX = 26
NMAX = 51
MCENT = 1
NCENT = 1

ITRMAX = 200
DELTAV = 0.010

MCENT
NCENT

FCURPT = 0
FCURPT = 0
FCURPR = 1
FCURPR = 1

ITYPE=4 -- UNIFORM RECTANGULAR APERTURE

DIMENSIONS = LX, LY = 10.0000, 20.0000

INITLS, DELTAS, FINALS: -5.0000, 0.2000, 5.0000

INITLT, DELTAT, FINALT: -10.0000, 0.4000, 10.0000

MCUR, NCUR: 51, 51

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
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<td>-0.1164153E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>7.2000</td>
<td>-0.8870188E-02</td>
<td>-0.1164153E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>7.6000</td>
<td>-0.8307122E-02</td>
<td>-0.1164153E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>8.0000</td>
<td>-0.7672135E-02</td>
<td>-0.1164153E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>8.4000</td>
<td>-0.7850584E-02</td>
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<tr>
<td>-0.0000</td>
<td>8.8000</td>
<td>-0.9560246E-02</td>
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</tr>
<tr>
<td>-0.0000</td>
<td>9.2000</td>
<td>-0.1313743E-01</td>
<td>-0.1164153E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>9.6000</td>
<td>-0.1838810E-01</td>
<td>-0.1164153E-08</td>
</tr>
<tr>
<td>-0.0000</td>
<td>10.0000</td>
<td>-0.2455102E-01</td>
<td>-0.1164153E-08</td>
</tr>
</tbody>
</table>

**PATTERN NUMBER 77 HAS BEEN STORED ON RECORD 20 OF ANTDATA.A507C2**
8.3 Input to ANTDATA

Referring to Section 7.3, the following cards were punched.

<table>
<thead>
<tr>
<th>Card Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
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</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
</tbody>
</table>

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

8.4 Output from ANTDATA

The following is the printout from computer program ANTDATA.

**PLOT OUTPUT FOR PATTERN 77:**

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

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

**CONTOUR PLOT OF PATTERN REQUESTED.**

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

**PATTERN IS NOW BEING GENERATED. IF PATTERN < -35.00 PATTERN = -35.00**

**THREE-DIMENSIONAL PLOT OF PATTERN REQUESTED**

**EXECUTION TIME:** 27.57 MINUTES.
Refer to Chapter 4 for plotter output.

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