AD-773 769

WAMP: A USERS MANUAL FOR THE WIRE ANTENNA MODELING PROGRAM

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Prepared for:

Coast Guard

10 December 1973

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WAMP: A Users Manual for the Wire Antenna Modeling Program

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December 10, 1973	~~106~~ 110	10

USCG MIPR #Z-70099-2-20568	UCID-30084

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ABSTRACT

Program WAMP is a Wire Antenna Modeling Program written in FORTRAN IV and applicable to arbitrary antenna and support structures. WAMP models an antenna as a series of interconnected straight wire segments, and solves the electromagnetic boundary value problems by numerically evaluating an electric field integral equation.

Antennas may be analyzed in free space, over a perfect ground, a radial ground screen or in the presence of any homogeneous media. Antenna input impedance, current distributions, near-electric fields and far-field radiation patterns are also calculated.

The users manual covers both the theory and numerical techniques employed in WAMP. The program's input variables are defined, and illustrative examples are used to demonstrate the program's capabilities.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Antenna						
Computer Modeling						
Computer Program						
Thin-Wire						
Integral-Equation						
Program Users Manual						
Ground Interaction						
Ground Screen						

I. INTRODUCTON

WAMP (Wire Antenna Modeling Program) is a general purpose frequency domain antenna modeling computer program. Antennas of arbitrary form and orientation may be modeled and analyzed in both free-space and in the presence of a conducting half space.

The WAMP users manual is written to serve two purposes. The first, and prime purpose, is to provide the user with a basic working knowledge of the program's input requirements and capabilities. Examples will be employed to illustrate the use of the program. The second purpose of this manual is to present a brief description of the theoretical formulation behind the numerical techniques used in the WAMP code.

Section II, which immediately follows, presents a brief development of the thin-wire electric field integral equation (EFIE). This is followed in Section III by a description of the numerical techniques used to solve the EFIE for a segmented structure, and the methods employed to model an antenna in the presence of an imperfectly conducting half-space. (A listing of the program's subroutines and their function is provided in Appendix A).

Sections IV, V, AND VI are devoted to applications. Section IV describes in detail the program input parameters needed to model an antenna structure, Section V contains a series of illustrative examples designed to demonstrate the WAMP program, and Section VI concludes with a section on modeling guidelines and special calculations.

II. THEORETICAL DEVELOPMENT OF THE ELECTRIC FIELD INTEGRAL EQUATION

Discussion of the Boundary Value Problem. The solution to Maxwell's equation which satisfies specified behavior of the fields at given locations or boundaries, requires treatment of a boundary value problem. Classically, such problems have been successfully treated only for special boundary surfaces to which the method of separation of variables could be applied. This eliminated complex surface shapes from consideration and restricted the three-dimensional solutions to the sphere and various simple sphere modifications. This situation resulted principally from inability to calculate the eigenfunctions for the various special geometries, although considerable progress has been made in this area in recent years due to availability of numerical techniques and more sophisticated computers. An additional problem arises in these special coordinate systems since the boundary condition equations may be coupled, so that a solution of an infinite matrix is required, in principle at least, rather than the term-by-term solution which is encountered for the spherical case. At any rate, the shapes to which the classical analysis are restricted force the use of a different approach to problems which involve complex geometrical shapes.

Integral Equations Formulation. Because of the problems cited above, general three-dimensional boundary value problems require a basically numerical approach. This approach usually begins from an integral-equation viewpoint rather than the differential equation

approach implicit in the classical method. There is, however, no unique integral equation formulation for a given problem, so some leeway in treatment is afforded at the outset. For reasons to be clarified later, our attention is restricted here to the electric field integral equation (EFIE). As a starting point, the electric field $\bar{E}$ due to a volume current distribution $\bar{J}$ is written by means of Green's dyadic as

$$\bar{E}(\bar{r}_0) = \iiint_V i\omega\mu_0 \, \bar{J}(\bar{r}) \cdot \bar{\bar{G}}(\bar{r},\bar{r}_0) \, dV \tag{1}$$

where $\bar{r}_0$ and $\bar{r}$ are the observation and source points, respectively, and the Green's dyadic is expressed in the usual notation as

$$\bar{\bar{G}}(\bar{r},\bar{r}_0) = -(1/4\pi)\,[\bar{\bar{I}} + (1/k^2)\ \nabla\nabla]\, g$$

where

$$g = \exp(-ik|\bar{r}-\bar{r}_0|)/|(\bar{r}-\bar{r}_0)|$$

and $\bar{\bar{I}}$ is the unit second-rank tensor. The suppressed time variation is $\exp(i\omega t)$ with ω the radian frequency. The plane wave propagation constant is k, and is related to ε_0 and μ_0, the permittivity and permeability of free space respectively, and ω by

$$k = \omega\sqrt{\mu_0\varepsilon_0}$$

When the current distribution is limited to the surface of a perfectly conducting body, Equation (1) becomes

$$\bar{E}(\bar{r}_0) = \iint_S i\omega\mu_0 \, \bar{K}(\bar{r}) \cdot \bar{\bar{G}}(\bar{r},\bar{r}_0) \, dA \tag{2}$$

with $\bar{K}$ the surface current density. If this surface current is induced by an incident electric field $\bar{E}^I$, then an integral equation for the unknown surface current $\bar{K}$ can be obtained from Equation (2) and the boundary condition that

$$\hat{n}(\bar{r}_0) \times [\bar{E}^S(\bar{r}_0) + \bar{E}^I(\bar{r}_0)] = 0 \tag{3}$$

with $\hat{n}(\bar{r}_0)$ a surface normal at $\bar{r}_0$ and $\bar{E}^S$ the scattered field of the individual current distribution. Equating $\bar{E}^S$ of Equation (3) with $\bar{E}$ of Equation (2) leads to

$$-\hat{n}(\bar{r}_0) \times \bar{E}^I(\bar{r}_0) = \hat{n}(\bar{r}_0) \times \int_s \int i\omega\mu_0 \bar{K}(\bar{r}) \cdot \bar{\bar{G}}(\bar{r},\bar{r}_0)\, dA \qquad (4)$$

Thin Wire Approximation. Upon restricting our attention to circular cross-section bodies of small diameter compared with the wavelength, the azimuthal current may be neglected, and Equation (4) becomes

$$\hat{n}(\bar{r}_0) \times \bar{E}^I(\bar{r}_0) = \hat{n}(\bar{r}_0) \times \frac{1}{4\pi} \int_s \int \{i\omega_0\mu_0 K_s(\bar{r}) [\hat{s} + \frac{\hat{s}\cdot\nabla\nabla}{k^2}] g(\bar{r},\bar{r}_0)\}\, dA \qquad (5)$$

where $\hat{s}$ is the unit tangent vector at $\bar{r}$ pointing in the direction of the current. A scalar integral equation for the current is obtained by taking the dot product of Equation (5) with the unit tangent vector $\hat{s}_0$ at the observation point $\bar{r}_0$ as

$$\hat{s}_0 \cdot \bar{E}^I(\bar{r}_0) = \frac{1}{4\pi} \int_s \int i\omega\mu_0 K_s(\bar{r}_0)[\hat{s} \cdot \hat{s}_0 + (\hat{s} \cdot \nabla)^2 \frac{1}{k^2}] g(\bar{r},\bar{r}_0)\, dA \qquad (6)$$

If the assumption is now made that the surface current, K_s is independent of the azimuthal variable, Equation (6) can be written

$$\hat{s}_0 \cdot \bar{E}^I(r_0) = \frac{1}{4\pi} \int_s ai\omega_0\mu_0 K_s(S) \int_0^{2\pi} [\hat{s} \cdot \hat{s}_0 + \frac{1}{k^2} \frac{\partial^2}{\partial s \partial s_0}] g(\bar{r},\bar{r}_0)\, d\phi ds \qquad (7)$$

where a is the wire radius and the s integration is over the entire length of wire.

A final approximation is that the current may be realistically represented as a filament of strength $I_s(s) = 2\pi a K_s(s)$ flowing on the wire axis while the field is evaluated on the wire surface, allowing Equation (7) to be written as

$$\hat{s}_0 \cdot \bar{E}^I(\bar{r}_0) = (i\omega\mu_0/4\pi) \int_L I(s)[\hat{s} \cdot \hat{s}_0 + \frac{1}{k^2} \frac{\partial^2}{\partial s \partial s_0}] g(\bar{r},\bar{r}_0)\, ds \qquad (8)$$

where $|\bar{r} - \bar{r}_0|$ is now measured from the wire axis, or source point, to the observation point on the wire surface, which can thus never be closer than the wire radius a. By considering the current as a tubular sheet on the wire axis while evaluating the electric field on the wire surface, one can resolve the ambiguity in the azimuth involved. The form of Equation (8) is not changed using this convention, but the interpretation of the tangential field evaluation is simplified when non-parallel, non-planar wires are considered.

III. METHOD OF NUMERICAL SOLUTION

A numerical solution to an integral equation may be undertaken by the method of moments. This is a well-founded mathematical technique briefly stated as a method for finding the unknown by forcing the integral equation which is solved by the method of moments described below.

Reduction to Linear System (Collocation) - Equation (8) may be written symbolically as:

$$L(f) = g \tag{9}$$

following Harrington's (1968) notation. The solution of Equation (8) (or of Equation 9) is obtained by the method of moments. An intuitive approach to solving Equation (9) for the unknown function f is to set f equal to a constant f_j within N subintervals of the domain of L, and to require Equation (9) to be satisfied at N points over the range of L, thus acquiring N equations in the f_j unknowns. This is a specialized application of the method of moments which is more generally written as follows. Let

$$f = \sum \alpha_n f_n$$

with the basis functions f_n defined in the domain of L so that Equation (9) may be written

$$\sum \alpha_n L(f_n) = g \tag{10}$$

Then, with the set of weighting functions w_m, defined in the range of L, the inner product is formed as

$$\sum \alpha_n \langle w_m, L(f_n) \rangle = \langle w_m, g \rangle \tag{11}$$

where m = 1, 2, 3, ... N, Equation (11) can be written in matrix form as

$$[G_{mn}][\alpha_n] = [s_m] \tag{12}$$

where

$$G_{mn} = \langle w_m, L(f_n) \rangle$$

and

$$s_m = \langle w_m, g \rangle$$

and the matrix G_{mn} is referred to in this case as the structure matrix. If the inverse of G_{mn} exists, then the α_n can be found and thus the function f which is the desired solution, for any specified source function s_m.

The proper choice of weighting functions and basis functions, as well as the subsectioning of the domain of L is not an obvious one. Although there is some leeway in the matter, careful consideration of the physics of the problem and the nature of the expected solution will show that some representations for the f_n will be more efficient than others in terms of computer time and accuracy. Constant, linear, quadratic, trigonometric and Fourier series have all been used for this role. The weighting functions have generally been more restricted in choice than f_n. The special case, $w_n = f_n$, is referred to as Galerkin's method (see, for example, Harrington, 1968). More often, the weights are δ-functions, a method referred to as collocation, so that the inner product (Eq. 11) merely becomes the sequence of values $L(f_n)_m$ and g_m. These are, respectively, the tangential electric fields due to current segment n at observation point m and the tangential incident electric field at observation point m. It is interesting to note that Galerkin's method is equivalent to the Rayleigh-Ritz variational method. Harrington (1968) thoroughly discusses the method moments.

Current Expansion - The WAMP thin-wire program employes the collocation method with constant, sine and cosine terms for the f_n segment or current basis function, i.e.,

$$I(s) = \sum_{i=1}^{N} U_i(s)[A_i + B_i \sin k(s-s_i) + C_i \cos k(s-s_i)] =$$

$$\sum_{i=1}^{N} U_i(s)\, I_i(s) \qquad (13)$$

where $U_i(s)$ is 1 when s is on segment i and zero otherwise. Equation (13) is disadvantageous because three constants are required to specify the current on each segment, so that apparently 3N linear equations need be solved. This prompts the question, why use the sine and cosine terms for the current at all? There are a number of reasons for using this sinusoidal current expansion, but they are essentially summarized by the observation that a more physically realistic current solution is obtained with this expansion.

It is not necessary to employ the integral equation itself to find the extra unknowns introduced by the sinusoidal expansion. Two of the three constants for each segment may be obtained by requiring the current on adjacent segments to satisfy some specified mutual conditions. The extrapolated current from a given segment must match the center current values on two adjacent segments to satisfy the required condition for two-wire junctions in the thin-wire program. Junctions of three or more wires are handled in similar fashion (Maxum, et al, 1969).

The sinusoidal current expansion appears to make the system of equations resulting from collocation somewhat more involved, but the required computer time is not significantly increased when compared with the same number of current unknowns without using the sinusoidal expansion. Other current expansion functions - linear, quadratic, Fourier series - could be used in place of the constant-sine-cosine expression, but this particular expansion has a number of additional advantages over the other possibilities mentioned. For instance, a solution for the current to a specified accuracy for a half-wave dipole scatterer and antenna requires the fewest current segments using the sinusoidal expansion (Neureuther, et al, 1968). This advantage can be expected to carry over to more complex geometries. Second, the solution will more accurately exhibit the required dependence on wire radius (Andreason, 1968) because the constant current term produces infinite tangential electric field on the current axis, as opposed to the sine and cosine terms which do not.

Third, the parallel and perpendicular electric field components (due to the sine and cosine current terms) and the radial field components (due to constant current terms) may be analytically evaluated. This eliminates the necessity for extensive numerical integration to evaluate all the elements in the coefficient matrix G_{mn}. Only the tangential electric field excited by the constant current terms requires numerical integration and this is handled by applying a Romberg variable-interval width technique (Miller, 1970) to the difference integrand.

Calculation of the Structure Matrix - It is worthwhile to discuss here the form of the matrix elements which result from applying the method of collocation to the integral Equation (8). Each entry G_{ij} in the structure matrix represents the tangential electric field at observation point i on the structure produced by unit current flowing on segment j. The boundary condition on the tangential electric field is enforced at each observation point. The collocation method of solving the integral equation is thus basically one of calculating electric field components at specific points due to the induced current on the structure.

It was stated that the thin-wire approximation involves the explicit assumption that the effects of azimuthal currents can be neglected in comparison with those of axially directed currents and that, in addition,

the cylindrical tube of axial current has no azimuthal dependence. The former assumption allows us to consider only one current component rather than two, while the latter provides partial justification for reducing the surface integral to a line integral. It may be deduced from an examination of Equations (7) and (8), however, that even where K_s is independent of ϕ the kernel of the integration equation depends in general upon both ϕ and s. However, the integrand is independent of ϕ in the special case where the observation point is located on the axis of a linear tube of current, and the ϕ integration of Equation (7) may be replaced without approximation by the factor 2π.

We choose to locate the observation points where the tangential electric field is to be calculated on the axis rather than on the surface of each wire segment. The ϕ integration in Equation (7) is thus exact for the self-field as well as the mutual fields for all current segments having a common axis. In addition, the possible ambiguity involved in evaluating the incident field over a 2π variation in ϕ on the wire surface is resolved. As a final point, the observation point is always at least as far as the wire radius from the source point.

When the mutual fields of non-axially aligned current segments are required, the ϕ integration is not so simply performed. And if no approximation were used, the ϕ integration would require numerical evaluation. The most obvious approach is to then consider the tubular current source to approximate a linear filament on the wire axis, a procedure which again replaced the ϕ integration by a 2π factor. Unfortunately, this approximation eliminates the influence of the wire radius from all mutual field terms on the phase change and geometrical attenuation of the field caused by the separation of the source and observation points.

An alternative to the above method is replacement of the current tube by a current filament which is not located on the wire axis but is displaced in distance from it by the wire radius. The direction of displacement is perpendicular to the plane of the wire axis and the line joining the observation point and wire axis midpoint (the observation point for the self-term field). The geometry of this method is shown in Figure 1.

To summarize briefly, the surface integral is reduced to a line integral by neglecting azimuthal* currents and azimuthal variation of the axial current. Self-field terms are calculated with the observation point on the axis of a cylindrical current tube, while mutual field terms are calculated at the same observation point with the current represented as a filament displaced from the wire axis by the wire radius.

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* Taken here to mean the direction measured along the intersection of the current tube surface with a plane perpendicular to the axis of the current tube.

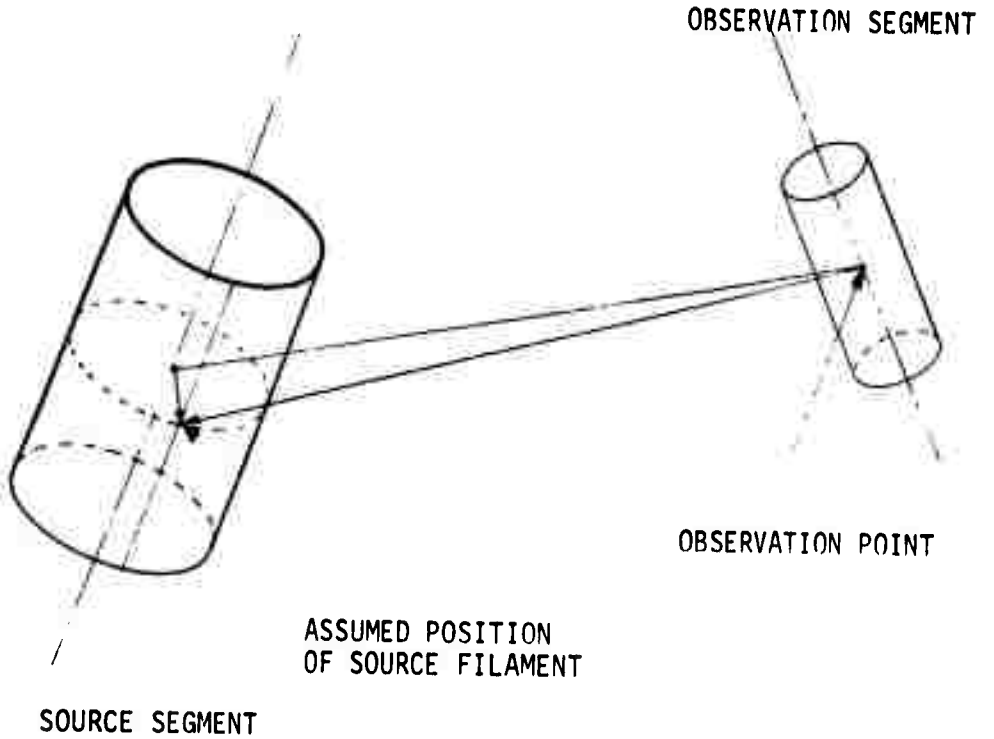


Figure 1a. Thin-wire Current Approximation

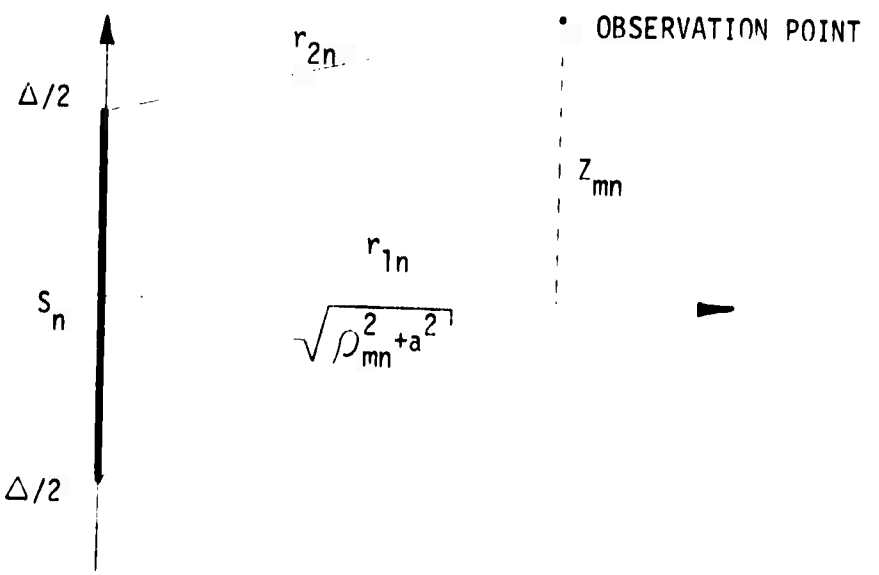


Figure 1b. Geometric Parameters for Field Evaluation.

We can now write the integral Equation (8) in the form

$$E_m = (i\omega\mu_o/4\pi) \sum_{M=1}^{N} \int_{\Delta S_n} [\hat{s}_m \cdot \hat{s}_n + \frac{1}{k^2} \frac{\partial^2}{\partial s \partial s_o}] g(r_m, r) I_m(s) \, ds \qquad (14)$$

$m=1, 2, \ldots, N$ observation points

where Δs_n denotes the length of source segment n,

$$g(r_m, r) = \frac{\exp[-ik\sqrt{\rho^2 + (s_m - s)^2}}{\sqrt{\rho^2 + (s_m - s)^2}}$$

and it should be noted that the integration over L has been reduced to a summation of N separate straight-wire segment integrals. It is convenient to rewrite Equation (14) in terms of cylindrical coordinates referred to the wire segment being integrated. Then we get

$$E_m = (i\omega\mu_o/4\pi) \sum_{m=1}^{N} \int_{\Delta z_n} [\hat{z}_n \cdot s_m - \frac{1}{k^2} \frac{\partial^2}{\partial z_n \partial s_m}] g(r_{mn}, z_n) I_n(z_n) \, dz_n \qquad (15)$$

where

$$g(r_{mn}, z_n) = \exp(-ikr_{mn})/r_{mn}$$

and

$$r_{mn} = \sqrt{(z_{mn} - z_m)^2 + \rho_{mn}^2 + a_n^2}$$

a_n is the radius of wire segment n, and ρ_{mn} and z_{mn} are the radial and z-coordinates of the observation point at the center of segment m referred to the midpoint of source segment n.

Ground Effects - The integral equations (14) and (15) apply only to wire structures located in free space, or more generally in a homogeneous medium having electrical constants μ and ϵ. Location of the structure near the interface between two electrically dissimilar media, however, leads to reflected fields which can modify the free space current distributions, and thus an additional term must be added to the integral equation for it to apply to the antenna problems of interest here.

Historically, the basic work on the solution of this problem was formulated in 1909 by A. Sommerfeld (1964). By deriving field expressions for vertical and horizontal electric and magnetic Hertzian dipoles in free space as influenced by the ground plane, Sommerfeld obtained the Green's functions which permit equations (14) or (15) to be rigorously extended to the interface problem.

Unfortunately, the solution of the Sommerfeld integrals requires a double numerical integration which can be very costly in terms of computer time. Miller, et al., (1972a, 1972b) describes an approximation that is used in the WAMP program. The approximation is to represent ground reflected fields via plane wave reflection coefficients. This procedure is basically quite simple, involving decomposition of the image fields into TM and TE modes relative to the vertical plane containing the image and observation points, after which the reflected fields are obtained by multiplying the image fields by the appropriate reflection coefficients. The advantage of this technique lies in the fact that it represents but a simple extension to the free space integral-equation treatment.

Impedance Loading - The discussion has been thus far limited to the case of a perfectly conducting element. The approach may also be generalized to allow for lumped loading of the structure by introducing a voltage drop term in the integral equation. If the impedance loading per unit length on segment m is z_m, then Equation (15) becomes:

$$E_m - I_m z_m = \text{same R.H.S. as Equation (15)}$$

Solution of the System of Equations - The solution of the integral equation is reduced by the method of collocation to the problem of solving a linear system of equations for the N sampled current values. The problem is far from being resolved at this point, however, since the linear system which is generated may contain a very large number of complex unknowns. A numerical solution of such a system would be impractical without the availability of a large-core, high-speed digital computer. An additional factor of importance in the linear system solution is the use of an efficient and accurate numerical technique; an especially significant aspect of the problem since the solution time increases as the cube of the number of unknowns (see, for example, Forsythe & Moler, 1967). The method used to solve the linear system of equations is discussed next.

The final step in solving the integral equation for the induced current is a matrix multiplication of the solution or inverse matrix times the source vector.

The induced current solution can be written in the form

$$[I] = -[G]^{-1}[E] \tag{16}$$

The values then obtained for the sampled current values at the centers of the N segments on the structure are used to obtain the current interpolation functions for each segment.

The solution technique employed in the WAMP program to solve the system of equations is the Gauss-Doolittle method (Ralston, 1965). The basic step in the Gauss-Doolittle method is factorization of the structure matrix [G] into the product of an upper triangular matrix [U], and a lower triangular matrix [L], i.e.

$$[G] = [L][U] \tag{17}$$

and thus,

$$[L][U][I] = -[E] \tag{18}$$

Let

$$[U][I] = [F] \tag{19}$$

so that

$$[L][F] = -[E] \tag{20}$$

Next, equation (20) is solved for the elements of [F] by forward substitution using the known elements of [E]. Equation (19) is then solved for the elements of [I] by backward substitution using the known elements of [F].

Matrix Symmetry - Many antenna structures exhibit geometric symmetries which may be exploited to a great advantage in terms of computer storage requirements and execution times. Structure symmetry can be used to increase the calculation efficiency by reducing the time required to fill the structure matrix G, and by decreasing the computations required to factor and solve the linear system of equations. The matrix fill time, for example, is reduced by a factor on the order of $1/n$, and the inversion time by $1/n^2$, for a structure with n-fold rotational symmetry.

The reduction in matrix fill time is easily understood. Consider a structure having 4-fold rotational symmetry, such as Figure 2 below,

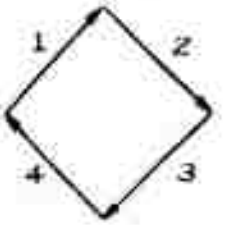


Figure 2. Structure with 4-fold Rotational Symmetry.

which will have a structure matrix [G] of the form:

$$[G] = \begin{bmatrix} g_{11} & g_{12} & g_{13} & g_{14} \\ g_{21} & g_{22} & g_{23} & g_{24} \\ g_{31} & g_{32} & g_{33} & g_{34} \\ g_{41} & g_{42} & g_{43} & g_{44} \end{bmatrix} \tag{21}$$

where

$$\begin{aligned} g_{11} &= g_{22} = g_{33} = g_{44} \\ g_{12} &= g_{23} = g_{34} = g_{41} \\ g_{13} &= g_{24} = g_{31} = g_{42} \\ g_{14} &= g_{21} = g_{32} = g_{43} \end{aligned} \tag{22}$$

Thus, rather than their being $N^2 = 16$ matrix elements to calculate, there are only N^2/n or 4 to obtain, and the reduction in the structure matrix fill time and storage is on the order of $1/n$.

This version of the WAMP code is set up to handle rotationally symmetric structures with elements located on the axis of rotational symmetry. An example of such a structure is shown in Figure 3.

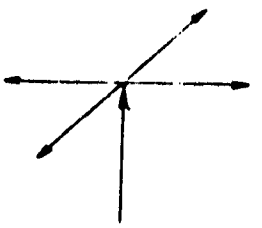


Figure 3. A structure with 4-fold rotational symmetry and center wire. (Turnstile Antenna)

The structure matrix is of the form given by (23):

$$[G] = \left[\begin{array}{cccc:c} A_1 & A_2 & A_3 & A_4 & B_1 \\ A_4 & A_1 & A_2 & A_3 & B_2 \\ A_3 & A_4 & A_1 & A_2 & B_3 \\ A_2 & A_3 & A_4 & A_1 & B_4 \\ \hdashline C_1 & C_2 & C_3 & C_4 & D_1 \end{array}\right] \tag{23}$$

$$B_1 = B_2 = B_3 = B_4 \tag{24}$$

and

$$C_1 = C_2 = C_3 = C_4$$

which is stored in the computer as:

$$\left[\begin{array}{ccccc} A_1 & A_2 & A_3 & A_4 & B_1 \\ C_1 & C_1 & C_1 & C_1 & D_1 \end{array}\right] \tag{25}$$

The solution to a system of equations of this symmetric form may be accomplished by the following operations. First write the matrix equation, noting the partitioning:

$$\left[\begin{array}{c:c} A_{nxn} & B_{nxm} \\ \hdashline C_{mxn} & D_{mxm} \end{array}\right] \left[\begin{array}{c} X_n \\ \hdashline Y_m \end{array}\right] \quad \left[\begin{array}{c} U_n \\ \hdashline V_m \end{array}\right] \tag{26}$$

where we have the relationships:

$$A_{mxn}\ X_n + B_{nxm}\ Y_m = U_n$$

and

$$C_{mxn}\ X_n + D_{mxm}\ Y_m = V_m \tag{27}$$

or

$$X_n = A^{-1}_{mxn}\ U_n - A^{-1}_{nxn}\ B_{nxm}\ Y_m \tag{28}$$

and

$$(D_{mxm} - C_{mxn}\ A^{-1}_{nxn}\ B_{nxm})\ Y_m = V_m - C_{mxn}\ A^{-1}_{Un} \tag{29}$$

To solve the equations (28) and (29) for the X_n and Y_m matrices, we perform the following sequence of operations:

1. Factor A_{nxn} in place.
2. Compute $E_{nxm} = A^{-1}_{nxn}\ B_{nxm}$ by solving $A_{nxn}\ E_{nxm} = B_{nxm}$ in place and storing the result in B.
3. Compute $F_{mxm} = D_{mxm} - C_{mxn}\ E_{nxm}$ and store the result in D.
4. Now factor D_{mxm} in place.
5. Then compute $W_n = A^{-1}_{nxn}\ U_n$ in place.
6. Compute $Z_m = V_m - C_{mxn}\ W_n$ and store in V_m.
7. Solve $F_{mxm}\ Y_m = Z_m$ for Y_m and store in V_m.
8. Finally, compute $X_n = W_n - E_{nxm}\ Y_m$ and store the result in U_n.

Solution Sequence - We may now list the sequence of operations performed in WAMP to obtain the solution for an antenna structure. The basic steps are listed below:

1. Initialize WAMP and read in the antenna input frequency and the media over which the antenna is located, i.e., free space, over a perfect ground or a finite homogeneous media.

2. Convert a physical description of the antenna structure given in terms of the cartesian end-point coordinates of wire elements into a series of interconnected short straight-line wire segments. The segments will be used to describe the structure's line integral path.

3. With the structure defined, the structure matrix is then computed by the methods outlined earlier in this section. The electric field integral equation is first evaluated for the antenna in free space, where the co-location technique is used to fill in all the entries of the structure matrix.

   If it is selected to model the antenna over a homogeneous halfspace, the structure matrix entries are then recalculated and modified by the ground reflected terms. The reflected fields are found by first computing the perfect ground image fields, and then these fields are modified by the appropriate ground reflection coefficient which is a function of the ground media and the specular angle between thesource and the observation points.

4. If segments on the structure are impedance loaded, e.g. an inductive load used for resonating an antenna, the loading may be simply included in the structure's impedance matrix at this point.

5. The structure matrix may then be factored as outlined in the previous section. Structure symmetries are exploited to minimize the amount of core storage required and the amount of computations needed.

6. Once the structure matrix is factored, the antenna source vector is setup by applying a tangential E-field to those segments excited.

7. The factored structure matrix and the source field vector are then solved to yield the unknown currents at the center of each of the N segments.

8. Once the segment currents are known, the antenna input impedance and admittance may be calculated.

9. The coefficients A, B and C of the current basis function, Equation (13) are next determined and their values printed out.

10. The two last steps in the program are the computations of the near and far electric fields. These computations are only made if selected as program options.

This completes the description of the WAMP code. The next section describes in some detail the input parameters required to use the program.

IV. PROGRAM INPUTS

WAMP is written to conform with ANSI X 3.0 FORTRAN, and allows for in core execution on a 147K CDC 3300 computer system. All program inputs are via punched card data decks, and all program outputs appear on an on-line printer output. A main executive program, and 20 subroutines comprise this version of the WAMP code.* Most of the program's inputs are requested by the MAIN program, however, several subroutines (DATAGN, CMSETUP and NEFLD) may also request additional data inputs. Figure 4 provides a basic flow diagram of the sequence of data inputs, which is followed by more complete details on the program's input variables.

DATA DECK STRUCTURE

The structure of the input data deck for WAMP is illustrated in the flow chart of Figure 4. Note that not all inputs are requested by the program, and they are dependent on the run options selected by the second input data card. Additional details on each data input parameter follows.

Run Comments - (Format [10A8]) The first card of a data deck is used to provide 80 characters of run identification. Any text which fits on one card may be used, and the message will appear on the first page of the program output.

Run Options (Format [16I5]) The option card allows the user to select several program options at execution time. The parameters are listed below:

NPRINT --- Controls level of printed output. Input Range 0-2, with more detailed outputs are given for higher numbers. Typically NPRINT = 1.

ILOAD --- If the structure has impedance loaded elements, make ILOAD = 1. The load values will be read in later.

IPGND --- If you want to model the structure over a perfect ground plane, set IPGND = 1.

IGSCRN --- If IGSCRN = 1, a radial wire ground screen is modeled. Screen parameters are read-in in subroutine CMSETUP later.

---

* A listing of WAMP is included in Appendix A. A brief description of each subroutine is also included.

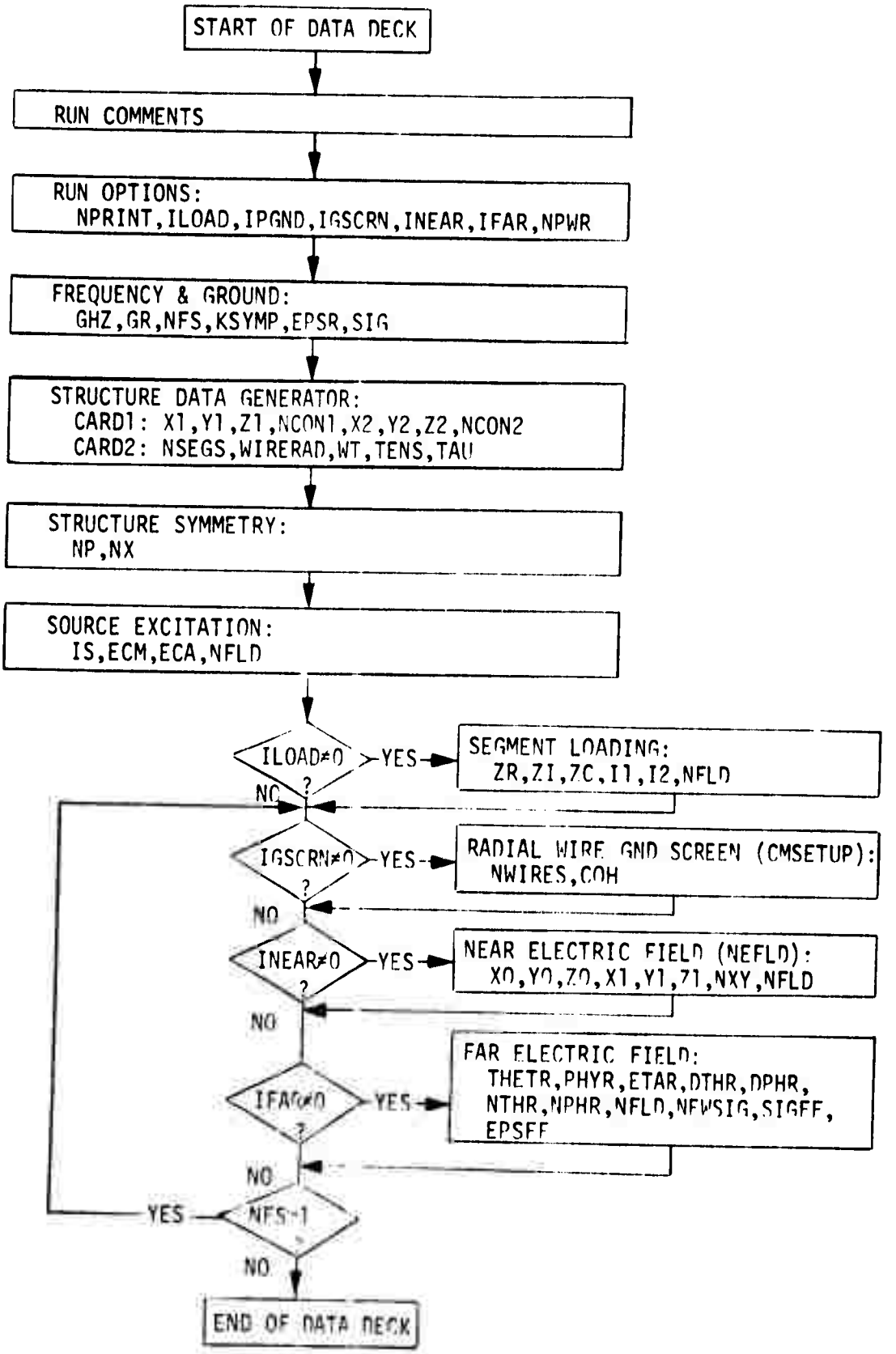


Figure 4. Flowchart of WAMP Input Data Deck Cards

INEAR --- If INEAR = 1 the near field subroutine is called. The location of the field observation points to be evaluated are requested by the NEFLD subroutine.

IFAR --- Far field calculations are performed if IFAR = 1. The far field observation angles are read in later.

NPWR --- If NPWR = 1, the total input power to the antenna is normalized to 1 watt. All field values will also be normalized to this power.

Frequency and Ground (Format [2F10.5, 2I5, 2F10.5]) The frequency and ground card allows the user to specify the frequency at which the analysis is to be performed, a Δ frequency, and the number of Δ frequency steps to be evaluated. The user also has the option of performing the analysis in free-space or over a conducting half space. If the latter is selected, the ground media parameters must be supplied.

GHZ --- Input frequency in Giga-Hertz.

GR --- Δ frequency in GHz. If NFS is greater than 1, the frequency is changed by GHz = GHz + GR each frequency step.

NFS --- NFS is the number of frequency steps, and it must be greater than or equal to 1.

KSYMP -- For analysis in free space, set KSYMP = 1. For an analysis over a halfspace, set KSYMP = 2. KSYMP must be either 1 or 2.

EPSR -- If KSYMP = 2, then read in the value of the relative dielectric constant of the ground media.

SIG --- If KSYMP = 2, then read in the value of the ground conductivity expressed in mhos/metre.

Structure Data Generator Inputs - After the frequency and ground cards are read, the main program calls the DATAGN subroutine. The purpose of this subroutine is to transform a physical model of an antenna structure into quantities which describe the structure to the WAMP code. Basically, all structures are modeled by straight-line wire elements. (A catenary element is a special feature allowed by this subroutine and is described in more detail in Section VI). The elements in turn are subdivided into a number of straight-line segments, and it is the segments which are used as the structure descriptors to the program.

Each wire segment is specified by its center-point coordinates, its orientation angles, its length, and its radius. In addition to the segment's physical parameters, electrical inter-connection data must also be provided. The two arrays, ICON1 and ICON2 of COMMON BLOCK/1/ are used to store the connection data relative to the negative and positive ends respectively of each segment.

All structure elements are specified to the program in terms of their cartesian end point coordinates, with dimensions given in metres. Elements are described to the DATAGN subroutine by specifying on one card the two end point coordinates, and interconnection data, and on a second card the number of segments to be used to describe the element, the element's wire radius, plus some additional details if a catenary is to be modeled, or if a variable length segment is to be used to model the element.

The connection data must conform to the following rules: Given a positive reference direction of the i-th segment defined by α_i and β_i and the arrow as illustrated in segment coordinate system of Figure 5, ICON1(i) must contain the index of the segment to which the negative end of the i-th wire is connected. A multiple connection is identified by assigning a unique negative number to the endpoint connection value of each segment connected to the junction, and an unconnected segment is assigned a value 0 at the unconnected end. One rule which must be observed is that if two segments are connected and the negative or positive ends coincide, as illustrated by Example 3 of Figure 6, this junction although not a multiple junction must also be assigned a unique negative number. Segments which are grounded must be given an ICON value equal to the segment's own index, see Example 4, Figure 6.

ICON2(i) array is similar and refers to the positive endpoint.

The input variables NCON1 and NCON2 allow the user to specify the ICON1 value (negative end) of the first segment of an element, and NCON2 allows the user to specify ICON2 value (positive end) of the last segment of the element. These rules are illustrated by a few examples as shown in Figure 6.

Thus the data generator input variables are described as follows:

DATAGN Card 1 (Format [3F10.5, I5, 3F10.5, I5]):

X1, Y1, Z1 --- Cartesian coordinates of the negative end point of the line element. Dimensions are in metres.

NCON1 --- Specifies the ICON1 value for the first segment of the element.

X2, Y2, Z2 --- Cartesian coordinates of the positive end point of the line element.

NCON2 --- Specifies the ICON2 value of the last segment of the element.

DATAGN Card 2 (Format [I5, 4F10.5]):

NSEGS* --- Number of segments in the line element.

WIRERAD --- Segment wire radius given in metres.

WT --- Wire weight given in pounds/metre. (Needed only if a catenary element is desired.)

TENS --- Wire tension in pounds, which is needed only for a catenary. If TENS $\leq$ 1., no catenary is used.

TAU --- Segment length expansion (contraction) factor.

Note: additional details on this factor are given later in Section VI and Appendix B.

Structure Symmetry (Format [16I5]) After the antenna structure has been described, structure symmetries must be specified. The WAMP code is set up to exploit either no symmetry or up to 12 sectors of rotational symmetry. In addition, elements on the axis of rotational symmetry may also be used. The symmetry card requires the following parameters:

NP --- NP equals the number of segments in a rotationally symmetric sector. (Excluding segments on axis of symmetry.)

NX --- NX equals the number of segments on the axis of rotational symmetry.

Note that the program will work for the special case where NP = N (no symmetry) and NX = 0. NP + NX must be less than or equal to 22 for this version of WAMP.

If structure symmetry is to be exploited, a formalism exists which must be followed if a proper structure matrix is to be set up. Basically, the rules for setting up the proper structure symmetry are as follows:

1. All elements in a sector of rotational symmetry must be completely specified before going to the next sector.

---

* Note: If NSEGS is a positive number, the DATAGN subroutine jumps back to request an additional pair of line element cards to specify the next element of the structure. Input continues until a NSEGS (negative number of segments) is used to specify the last element of the structure. At this point, the program control returns to the main program.

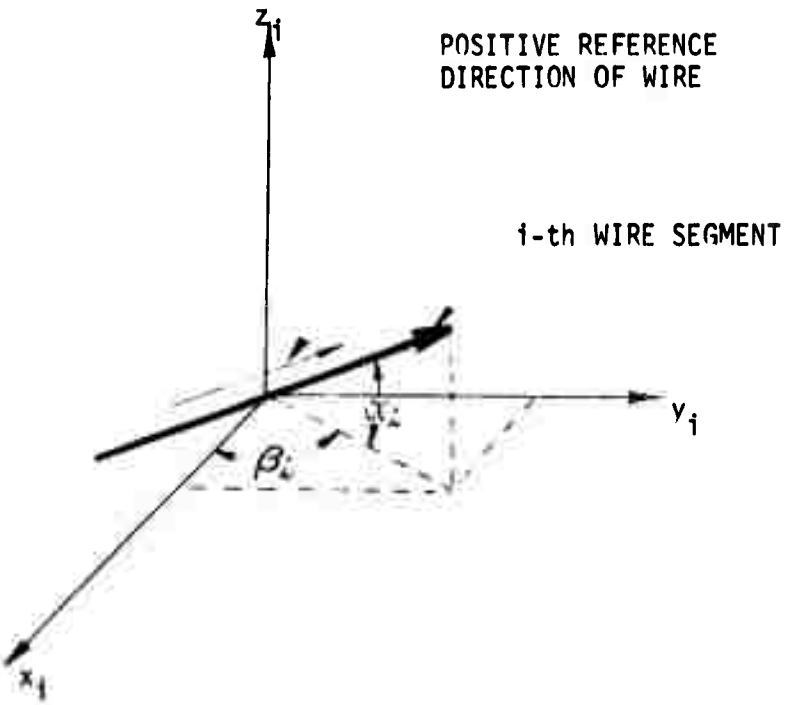
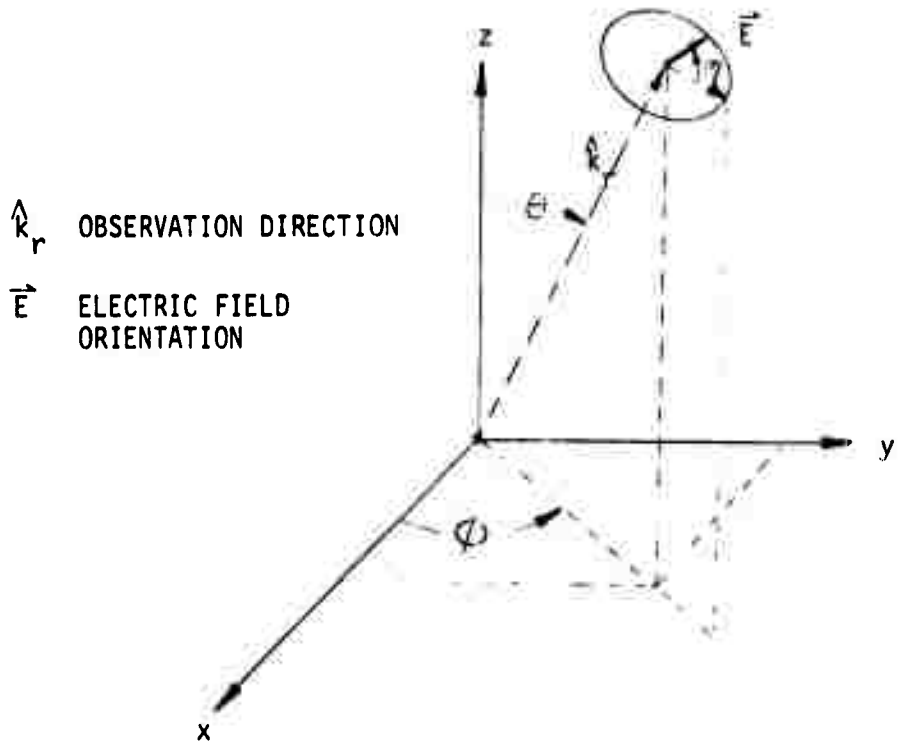


Figure 5a. Segment Coordinate System.

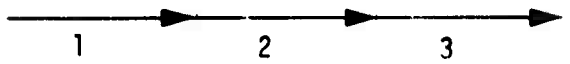


Fibure 5b. Field Coordinate System

WAMP COORDINATE SYSTEM

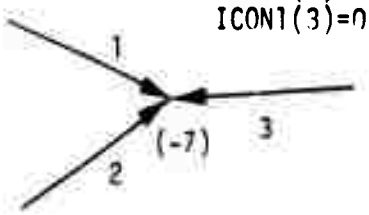
EXAMPLE 1

ICON1(1)=0 ICON2(1)=2
ICON1(2)=1 ICON2(2)=3
ICON1(3)=2 ICON2(3)=0



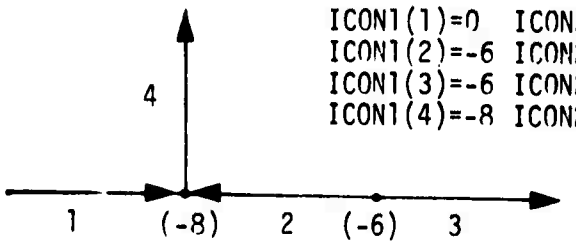
EXAMPLE 2

ICON1(1)=0 ICON2(1)=-7
ICON1(2)=0 ICON2(2)=-7
ICON1(3)=0 ICON2(3)=-7



EXAMPLE 3

ICON1(1)=0 ICON2(1)=-8
ICON1(2)=-6 ICON2(2)=-8
ICON1(3)=-6 ICON2(3)=0
ICON1(4)=-8 ICON2(4)=0



EXAMPLE 4

ICON1(1)=1 ICON2(1)=2
ICON1(2)=1 ICON2(2)=0

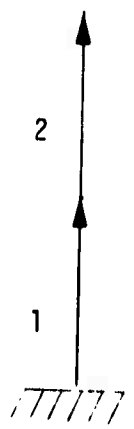


Figure 6. Examples of the ICON Connection Values for Various Types of Segment Junctions.

2. One may progress in either a clockwise or counter clockwise fashion around the axis of symmetry in describing the structure.

3. Elements located on the axis of rotational symmetry must be specified last to the data generator subroutine.

Source Excitation (Format [I5, 2F10.5, I5]) The source card allows the user to specify the segments which are driven. Any of the segments may be driven, and no symmetry of the excitation is assumed. In order to compute a correct input impedance, a 1.0 V at 0° phase angle source must be used.

IS --- Segment number to which the source is applied.

ECM --- Magnitude of driving source voltage in volts.

ECA --- Phase of source in degrees.

NFLD --- If NFLD = 1, an additional source card is read in. Input of source cards continues until NFLD = 0. This feature is used to specify multiple excitations.

This completes a normal data deck. Additional inputs may be required if certain options are selected on the run option card. These inputs are described below.

Segment Loading (Format [3E10.3, 3I5]): If ILOAD on the RUN OPTION card $\neq$ 0, the segment loading option is selected. Resistive and reactive loading of segments is allowed. Symmetric loading of rotationally symmetric segments is assumed, and only one sector of symmetric loads need be specified. The inputs are listed below:

ZR -- Resistance value in ohms distributed on each of the specified segments.

ZI -- Inductance value in henrys distributed on each of the specified segments.

ZC -- Series capacitance in Farads on each segment (Note: if ZC = 0. On input, no capacitive loading is included.)

I1,I2 -- Specify the range of segments numbers which are loaded. All segments from I1 to I2 each receive the above load values.

NFLD -- If NFLD $\neq$ 0, an additional load card may be specified.

Radial Wire Ground Screen (Format [I5, E10.5]) If IGSCRN on the RUN OPTION card ≠ 0, a radial wire ground screen model is placed in parallel with the normal ground media. The ground screen parameters listed below are read in by subroutine CMSETUP.

NWIRES -- Number of radial wires.

COH -- Wire radius in metres of the radial wires.

Near-Electric Field (Format [6F10.5, 2I5]) Subroutine NEFLD is used to compute the near E-field at specified points in the structure's coordinate system. NEFLD is called only if INEAR = 1 on OPTION CARD.

XØ, YØ, ZØ --- Are the initial field evaluation coordinates. (metres)

X1, Y1, Z1 --- Are the final field evaluation coordinates. (metres)

NXY --- NXY + 1 field evaluation points are made along the straight line connecting point Ø with point 1.

NFLD --- If NFLD ≠ 0 an additional near field evaluation path may be specified.

Far-Electric Field (Format [5F10.5, 4I5, 2F5.1]) A far field radiation pattern will be computed if IFAR on the OPTION CARD = 1. A provision is made to allow a far field calculation over a media which is different than the media over which the antenna is located. The farfield inputs, which refer to Figure 5, are listed below:

THETR --- Initial Theta angle in degrees.

PHYR --- Initial Phi angle in degrees.

ETAR --- Polarization angle Eta in degrees. (See Figure 5)

DTHR --- Delta Theta step size in degrees.

DPHR --- Delta Phi step size in degrees.

NTAR --- Number of Theta angle steps.

NPHR --- Number of Phi angle steps.

NFLD --- If NFLD ≠ 0, another far field card may be read in. Up to five cards may be specified.

NEWSIG --- If NEWSIG = 1, new values of sigma and epsilon will be read in for the far field.

SIGFF --- Far field sigma value in mhos per metre.

EPSFF --- Relative dielectric constant for far field.

Note that if a new value of sigma and epsilon are not requested, the far field ground media is the same as the ground media of the antenna.

Multiple Data Decks - The above cards complete the data for one specific structure. Multiple data decks may be stacked one behind another to provide for multiple runs. The program control returns to read the next comment card, and if an end-of-file is encountered, the run is terminated.

V. SAMPLE PROBLEMS

Perhaps the easiest way to gain a working familiarity with the WAMP code is to use it to model some simple antenna structures which are familiar, and which we can compare the computed results with known data. This section illustrates the use of WAMP by a series of examples. The input data decks and the pertinent output will be shown.

Example 1 - Half Wavelength Horizontal Dipole - A half wavelength electric dipole is a good place to start. For this example, the antenna specifications are given as follows:

Frequency - 10 MHz

Length - $\lambda/2$ = 15 meters

Wire radius - 8.3 mm (Ω = 15)

Height above ground - 10 meters

Ground media - ε_r = 25, σ = 10^{-2} mhos/m.

The first step is to describe the structure in terms of straight line elements whose end point coordinates are given in terms of the system's cartesian coordinates. For the dipole, this is simple, and is illustrated in Figure 8.

The input data deck may now be set up. (Refer to the previous section for a more detailed description of the input parameters)

Card 1: Comment Card

Halfwave Horizontal Dipole -- Example 1A

Card 2: Run Options

NPRINT = 2 Get a printout

ILOAD = 0 No loading

IPGND = 0 No perfect ground

IGSCRN = 0 No ground screen

INEAR = 0 No near field calculations

IFAR = 0 No far field calculations

NPWR = 0 Don't normalize input to 1 watt

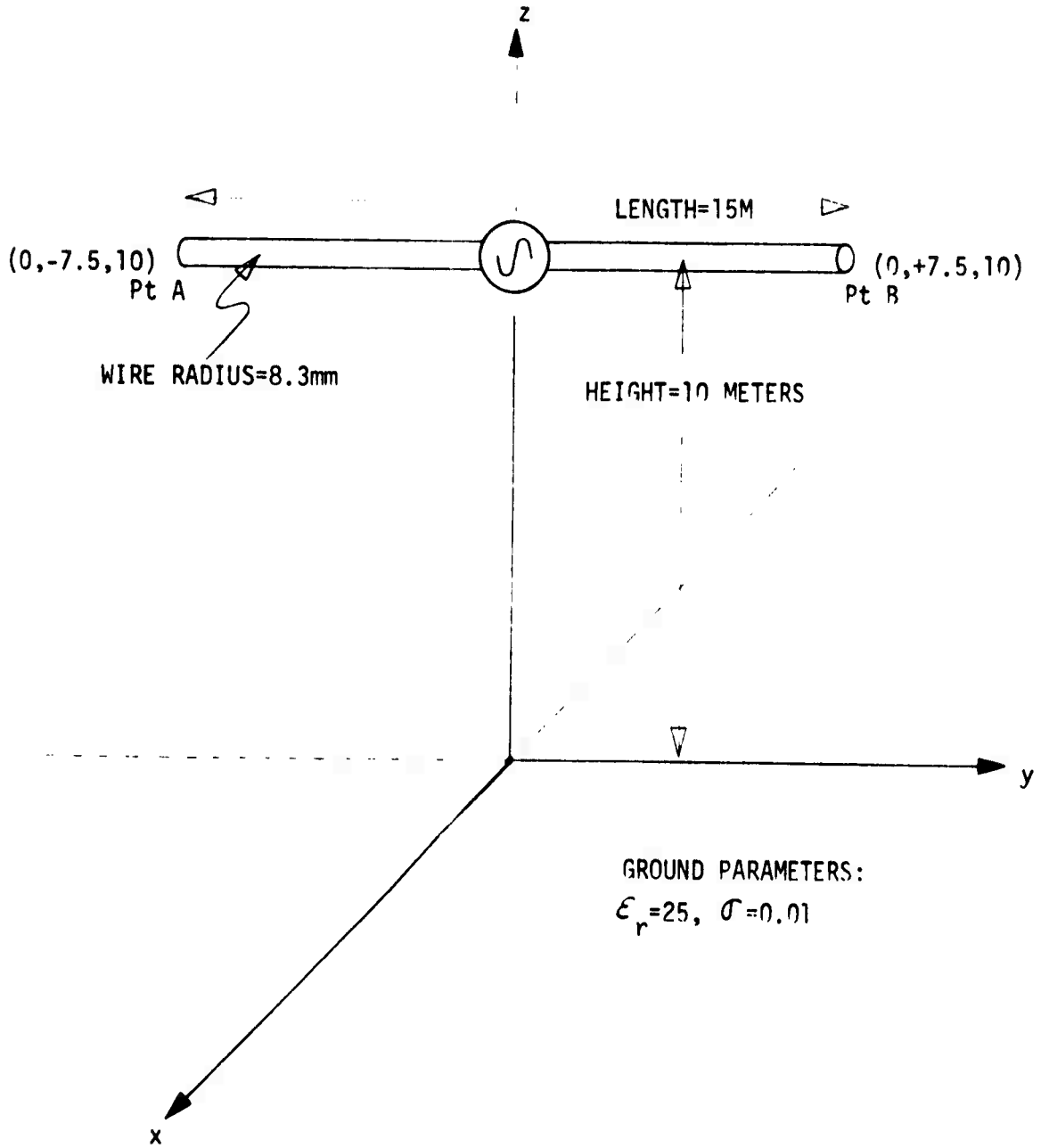


Figure 8. Half Wavelength Horizontal Dipole for Example 1.

We have chosen a very simple example, and none of the program's options have been selected.

Card 3: Frequency and Ground

GHZ	=	0.01	Input frequency = 10 MHz
GR	=	0.	No frequency steps
NFS	=	1	One frequency
*KSYMP	=	1	First model antenna in free space
EPSR	=	25.	Ground dielectric constant
SIG	=	0.01	Ground conductivity mhos/m

*Note that since the analysis is first being made in free space, ε_r and σ of the ground are not required at this point, but were included for later use.

Cards 4 and 5: Data Generator Inputs

CARD 4	X1	=	0	Coordinates
	Y1	=	-7.5	of end point
	Z1	=	10.	A
	NCON1	=	0	End point A is an open circuit
	X2	=	0	Coordinates
	Y2	=	7.5	of end point
	Z2	=	10.	B
	NCON2	=	0	End point B is an open circuit
CARD 5	NSEGS	=	-7	Model with 7 segments (number is negative to end data generator inputs)
	WIRERAD	=	0.0083	The radius of the dipole is 8.3 mm
	WT	=	0.	No catenary
	TEN	=	0.	
	TAU	=	0.	No variable length segment, all =

The DATAGN will use this data to form a seven segment description of the dipole as shown in theprogram's output, Figure 10.

Card 6: Structure Symmetry

NP = 7		No symmetry will be used, NP = NSEGS = 7
NX = 0		No segments on axis of symmetry

Card 7: Source Excitation

IS = 4		Excite the center segment
ECM = 1.		Use a 1.0 volt,
ECA = 0.		0. degree source
NFLD = 0		Only one source card needed.

This completes the data deck requirements. The next step is to submit the program for execution and obtain the computer printout. The punched data deck is shown in Figure 9, while the numerical results are shown below in Figure 10.

```
HALF WAVE HORIZONTAL DIPOLE -- EXAMPLE 1A
  2    0    0    0    0    0
      .01        0.    1    1       25.       .01
       0.      -7.5       10    0        0.      7.5       10.    0
 -7      .0083          0.         0.         0.
  7    0
  4         1.         0.    0
```

```
|**************************

 WIRE ANTENNA MODELING PROGRAM

 **************************


  HALF WAVE HORIZONTAL DIPOLE -- EXAMPLE 1A

    2    0    0    0    0    0   -0

 FREQUENCY            =  1.00000E-02
 FREQUENCY INCREMENT  =        .0E+00
 NO. FREQUENCY STEPS  =   1
 WAVELENGTH (METERS)  =  2.99793E+01



 ANTENNA IS MODELED IN FREE SPACE



 DATA GENERATOR INPUT DATA CARDS

       .0  -7.50000  10.00000     0          0   7.50000  10.00000     0
  -7    .00830          .0          .0         .0


 NUMBER OF SEGMENTS   =   7
 NO. SEG. IN A SECTOR =   7
 NO. SEG. ON AXIS OF ROTATION =    0



 STRUCTURE GEOMETRY  (DIMENSIONS IN WAVELENGTHS)

   COORDINATES OF SEG. CENTER      SEG.       WIRE     ORIENTATION ANGLES    CONNECTION DATA
       X         Y         Z      LENGTH     RADIUS      ALPHA      BETA     I-    I    I+
    -.00000   -.21443    .33356    .07148  .00027686        .0    90.000     0    1    2
    -.00000   -.14296    .33356    .07148  .00027686        .0    90.000     1    2    3
    -.00000   -.07148    .33356    .07148  .00027686        .0    90.000     2    3    4
    -.00000   -.00000    .33356    .07148  .00027686        .0    90.000     3    4    5
    -.00000    .07148    .33356    .07148  .00027686        .0    90.000     4    5    6
    -.00000    .14296    .33356    .07148  .00027686        .0    90.000     5    6    7
    -.00000    .21443    .33356    .07148  .00027686        .0    90.000     6    7    0

  TOTAL WIRE LENGTH    = 5.00345238214E-01

  ANTENNA SOURCE DISTRIBUTIONS
    SEG.          VOL    TAGE
    NO.      MAG.       PHASE
     4   1.00000          .0    0

  I=  1
  -4.934E+01  3.542E+04 -5.608E+01 -1.347E+04 -5.198E+01  9.222E+01 -4.680E+01 -1.011E+02 -4.017E+01 -4.397E+01
  -3.287E+01 -1.662E+01 -2.232E+01 -2.883E+00

  I=  2
  -4.894E+01 -1.127E+04 -5.216E+01  1.980E+04 -5.527E+01  1.086E+04 -5.198E+01 -9.222E+01  4.680E+01  1.011E+02
  -4.053E+01 -4.394E+01 -2.921E+01 -1.635E+01

  I=  3
  -4.584E+01 -9.044E+01 -5.595E+01 -1.086E+04 -5.640E+01  1.972E+04 -5.527E+01 -1.086E+04 -5.198E+01 -9.222E+01
  -4.727E+01 -1.012E+02 -3.576E+01 -4.182E+01

  I=  4
  -4.149E+01 -9.641E+01 -5.256E+01 -9.239E+01 -5.527E+01 -1.086E+04 -5.640E+01  1.972E+04 -5.527E+01 -1.086E+04
  -5.256E+01 -9.239E+01 -4.145E+01 -9.641E+01

  I=  5
  -3.576E+01 -4.182E+01 -4.727E+01 -1.012E+02 -5.198E+01 -9.222E+01 -5.527E+01 -1.086E+04 -5.640E+01  1.972E+04
  -5.595E+01 -1.086E+04 -4.584E+01 -9.044E+01

  I=  6
  -2.921E+01 -1.635E+01 -4.053E+01 -4.394E+01 -4.680E+01 -1.011E+02 -5.198E+01 -9.222E+01 -5.527E+01 -1.086E+04
  -5.718E+01  1.980E+04 -4.854E+01 -1.127E+04

  I=  7
  -2.232E+01 -2.883E+00 -3.287E+01 -1.662E+01 -4.017E+01 -4.397E+01 -4.680E+01 -1.011E+02 -5.198E+01 -9.222E+01
  -5.608E+01 -1.347E+04 -4.934E+01  3.542E+04
```

```
 SEGMENT EXCITATION (VOLTS/WAVELENGTH)
 SEG NUMBER   REAL PART    IMAGINARY PART

      4       -1.398E+01        -.0E+00
```

SEG. NO.	CURRENT - REAL	IMAGINARY	MAGNITUDE	PHASE	SEG. NO.	CURRENT - REAL	IMAGINARY	MAGNITUDE	PHASE
1	2.4803E-03	-1.5673E-03	2.93403718E-03	-32.289	5	9.0704E-03	-5.1156E-03	1.04134882E-02	-29.423
2	6.4306E-03	-3.8720E-03	7.50633360E-03	-31.053	6	6.4306E-03	-3.8720E-03	7.50633388E-03	-31.053
3	9.0704E-03	-5.1156E-03	1.04134882E-02	-29.423	7	2.4803E-03	-1.5673E-03	2.93403721E-03	-32.289
4	1.0002E-02	-5.0998E-03	1.12272401E-02	-27.014					

ADMIT= 1.0002E-02 -5.0998E-03 ZPED= 7.9351E+01 4.0458E+01
1.1227E-02 -27.014 8.9069E+01 27.014

I	AR	AI	BR	BI	CR	CI
1	-3.5004E-03	3.5049E-03	1.0485E-02	-6.4689E-03	5.9807E-03	-5.0722E-03
2	-1.7703E-04	1.4781E-03	7.5093E-03	-4.0863E-03	6.6078E-03	-5.3502E-03
3	4.5920E-04	1.2354E-03	4.1133E-03	-1.4137E-03	8.8112E-03	-6.3510E-03
4	8.0482E-04	-5.2611E-03	3.9307E-11	-9.1031E-11	9.3974E-03	1.8158E-04
5	4.5920E-04	1.2354E-03	-4.1133E-03	1.4137E-03	8.8112E-03	-6.3510E-03
6	-1.7703E-04	1.4781E-03	-7.5093E-03	4.0863E-03	6.6078E-03	-5.3502E-03
7	-3.5004E-03	3.5049E-03	-1.0485E-02	6.4689E-03	5.9807E-03	-5.0722E-03

Example 1B. -- The results of example 1A were obtained for the dipole in free-space. It is a very simple matter to now model the antenna over an imperfectly conducting halfspace, as specified on Figure 8. Only the KSYMP variable on card 3 need be set to 2, as shown on the data card in Figure 12.

```
HALF WAVE HORIZONTAL DIPOLE -- EXAMPLE 1B
   2    0    0    0    0    0
       .01        0.    1    2       25.        .01
        0.       -7.5        10.    0        0.        7.5       10.    0
  -7      .0083          0.          0.         0.
   7    0
   4          1.          0.    0
```

```
********************************

 WIRE ANTENNA MODELING PROGRAM

********************************


  HALF WAVE HORIZONTAL DIPOLE -- EXAMPLE 1B

    2    0    0    0    0    0   -0

FREQUENCY            =  1 00000E-02
FREQUENCY INCREMENT  =       .0E+00
NO. FREQUENCY STEPS  =   1
WAVELENGTH (METERS)  =  2.99793E+01


GROUND PLANE AT Z = 0.
DIELECTRIC CONSTANT  =  2.50000E+01
CONDUCTIVITY         =  1.00000E-02



 DATA GENERATOR INPUT DATA CARDS

        .0  -7.50000  10.00000     0          .0   7.50000  10.00000     0
   -7    .00830          .0          .0          .0


NUMBER OF SEGMENTS   =   7
NO. SEG. IN A SECTOR =   7
NO. SEG. ON AXIS OF ROTATION =     0



 STRUCTURE GEOMETRY  (DIMENSIONS IN WAVELENGTHS)

 COORDINATES OF SEG. CENTER      SEG.      WIRE     ORIENTATION ANGLES    CONNECTION DATA
     X         Y         Z     LENGTH    RADIUS      ALPHA      BETA     I-    I    I+
  -.00000   -.21443    .33356   .07148 .00027686         .0    90.000    0    1    2
  -.00000   -.14296    .33356   .07148 .00027686         0     90.000    1    2    3
  -.00000   -.07148    .33356   .07148 .00027686         .0    90.000    2    3    4
  -.00000   -.00000    .33356   .07148 .00027686         .0    90.000    3    4    5
  -.00000    .07148    .33356   .07148 .00027686         .0    90.000    4    5    6
  -.00000    .14296    .33356   .07148 .00027686         .0    90.000    5    6    7
  -.00000    .21443    .33356   .07148 .00027686         .0    90.000    6    7    0

TOTAL WIRE LENGTH    = 5.00345238214E-01

ANTENNA SOURCE DISTRIBUTIONS
  SEG.        VOLTAGE
  NO.      MAG.       PHASE
   4    1.00000         .0     0

 I= 1
-6.135E+01  3.541E+04 -6.977E+01 -1.348E+04 -6.483E+01 -9 338E+01 -5.863E+01 -1.011E+02 -5.065E+01 -4.278E+01
-4.184E+01 -1.417E+01 -2.873E+01 -5.232E-04

 I= 2
-8.039E+01 -1.127E+04 -7.106E+01  1.979E+04 -6.877E+01 -1 086E+04 -6.483E+01 -9 338E+01 -5 863E+01 -1 011E+02
-5.111E+01 -4.270E+01 -3.712E+01 -1.435E+01

 I= 3
-5.715E+01 -9.153E+01 -6 962E+01 -1.086E+04 -7.012E+01  1 972E+04 -6.877E+01 -1.086E+04 -6.483E+01 -9.338E+01
-5.923E+01 -1.012E+02 -4.504E+01 -4.087E+01

 I= 4
-5.189E+01 -9.655E+01 -6.557E+01 -9.353E+01 -6.877E+01 -1 086E+04 -7.012E+01  1.972E+04 -6.877E+01 -1.086E+04
-6.557E+01 -9.353E+01 -5.189E+01 -9.655E+01

 I= 5
-4.504E+01 -4.087E+01 -5.923E+01 -1.012E+02 -6.483E+01 -9 338E+01 -6.877E+01 -1.086E+04 -7.012E+01  1.972E+04
-6.962E+01 -1.086E+04 -5.715E+01 -9.153E+01

 I= 6
-3.712E+01 -1.435E+01 -5.111E+01 -4.270E+01 -5.863E+01 -1 011E+02 -6.483E+01 -9.338E+01 -6.877E+01 -1.086E+04
-7.106E+01  1.979E+04 -8.039E+01 -1.127E+04

 I= 7
-2.873E+01 -5.232E-04 -4.184E+01 -1.417E+01 -5.065E+01 -4.278E+01 -5.863E+01 -1.011E+02 -6.483E+01 -9.338E+01
-6.977E+01 -1.348E+04 -6.135E+01  3.541E+04
```

```
 SEGMENT EXCITATION (VOLTS/WAVELENGTH)
 SEG NUMBER    REAL PART    IMAGINARY PART

      4        -1.398E+01         -.0E+00
```

SEG. NO.	CURRENT - REAL	IMAGINARY	MAGNITUDE	PHASE	SEG. NO.	CURRENT - REAL	IMAGINARY	MAGNITUDE	PHASE
1	2.1481E-03	-1.1743E-03	2.44809552E-03	-28.664	5	7.0629E-03	-3.6798E-03	8.68132977E-03	-25.078
2	5.5727E-03	-2.8538E-03	6.26084806E-03	-27.115	6	5.5727E-03	-2.8538E-03	6.26084813E-03	-27.115
3	7.0629E-03	-3.6798E-03	8.68132971E-03	-25.078	7	2.1481E-03	-1.1743E-03	2.44809555E-03	-28.664
4	8.8717E-03	-3.5162E-03	9.35749739E-03	-22.072					

ADMIT= 8.8717E-03 -3.5162E-03 ZPED= 9.9034E+01 4.0157E+01
9.3575E-03 -22.072 1.0687E+02 22.072

I	I	AR	AI	BR	BI	CR	CI
	1	-3.0077E-03	2.9457E-03	9.0855E-03	-4.8090E-03	5.1958E-03	-4.1200E-03
	2	-1.4703E-04	1.4489E-03	6.5815E-03	-2.8853E-03	5.7197E-03	-4.3025E-03
	3	3.9338E-04	1.3090E-03	3.5689E-03	-7.6312E-04	7.4698E-03	-4.9886E-03
	4	5.1588E-04	-5.1638E-03	3.3652E-11	-8.4748E-11	8.1559E-03	1.6476E-03
	5	3.9338E-04	1.3090E-03	-3.5689E-03	7.6312E-04	7.4698E-03	-4.9886E-03
	6	-1.4703E-04	1.4489E-03	-6.5815E-03	2.8853E-03	5.7197E-03	-4.3025E-03
	7	-3.0077E-03	2.9457E-03	-9.0855E-03	4.8090E-03	5.1958E-03	-4.1200E-03

Example 2 - Two 5/8 Wavelength Monopoles, 1/3 Wavelength Apart

As a second example, we will model two antennas, both fed, and compute the far field space radiation pattern. This example serves to illustrate the use of structure symmetry, the grounding of antenna elements and the use of the far-field option. The physical configuration is that shown in Figure 13, where we have made use of the structure's symmetry in the selection of the coordinate system's origin. The structure of the data deck is as follows:

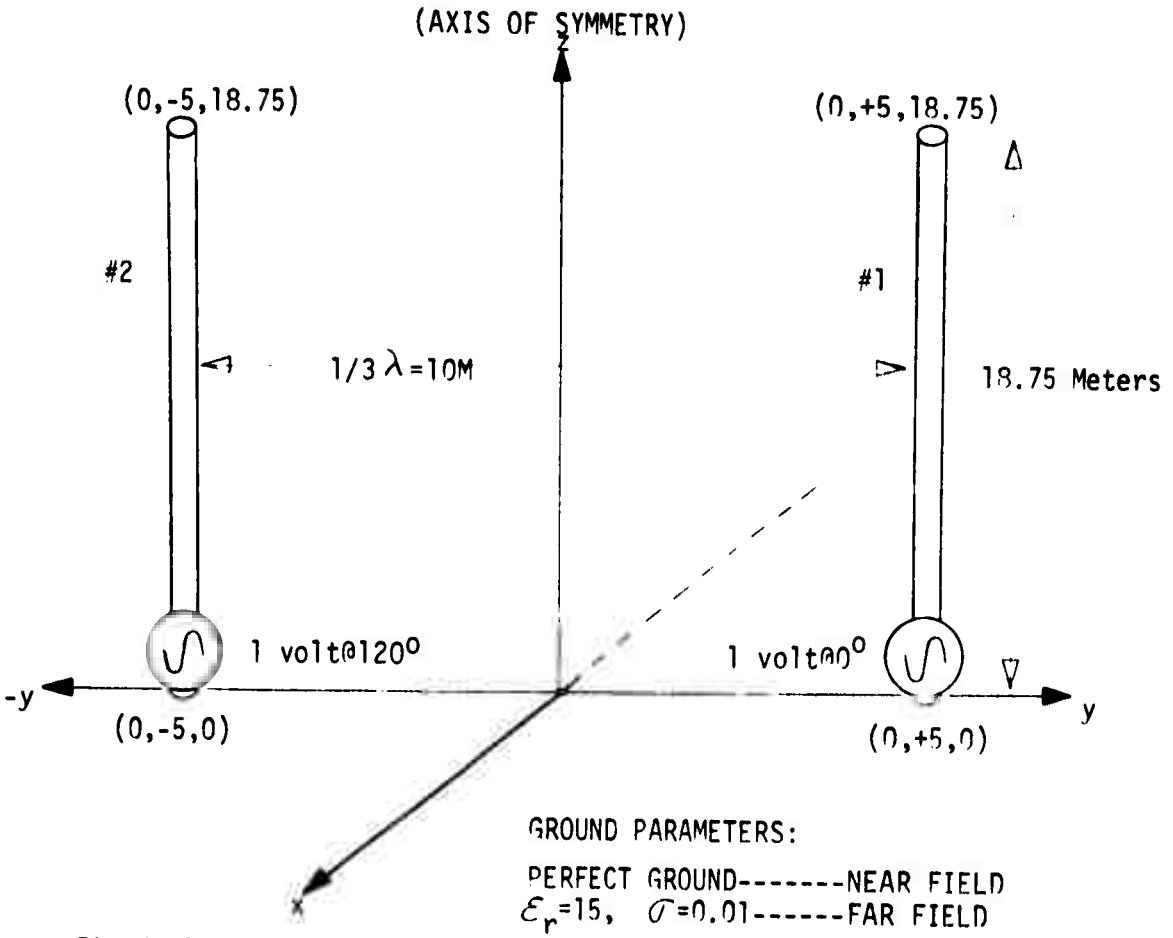
Card 1: Run Comments

Card 2: Run Options

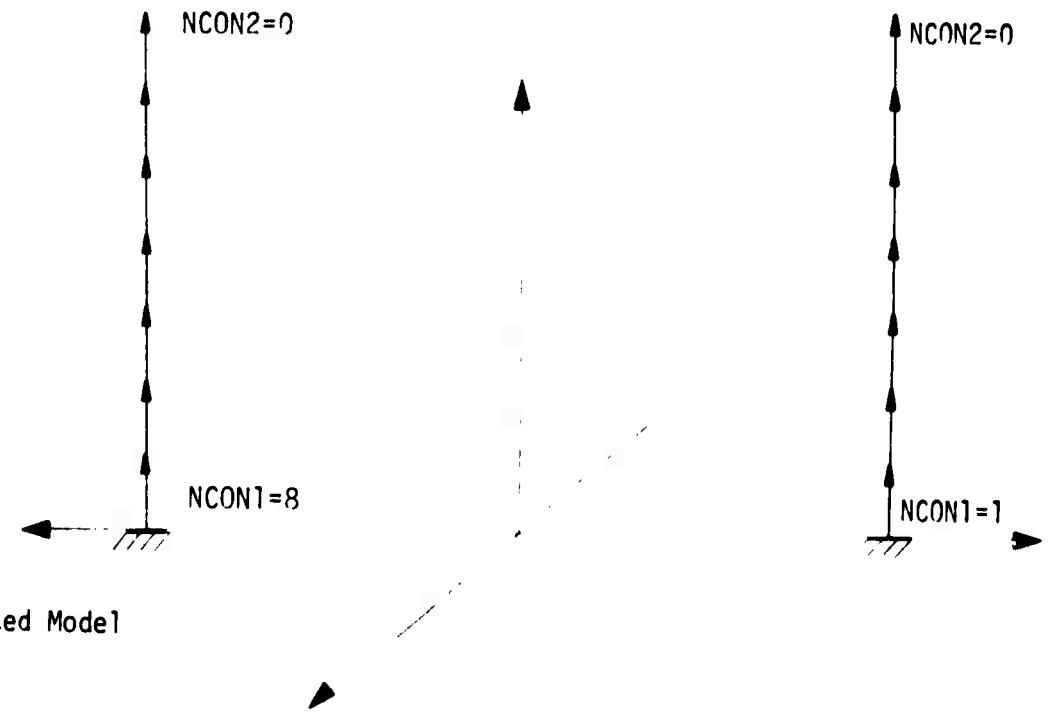
NPRINT	=	1	Nominal printout
ILOAD	=	0	No loading
IPGND	=	1	Use a perfect ground
IGSCRN	=	0	No ground screen
INEAR	=	0	No near fields
IFAR	=	1	Select far fields
NPWR	=	0	Don't normalize power

Card 3: Frequency and Grounds

GHZ	=	0.01	10 MHz input frequency
GR	=	0	No frequency steps
NFS	=	1	Only one frequency
KSYMP	=	2	Analyze over ground
EPSR	=	1.	Set EPSR = 1 as a dummy value even though
SIG	=	0.	ϵ_r and σ are not used.



a. Physical Model



b. Segmented Model

Figure 13 Two 5/8 Wavelength Monopoles--Both Fed.

Cards 4, 5, 6, and 7: Data Generator Inputs (see Figure 13)

Cards 4 & 5 — Model Monopole #1

X1	= 0.	Coordinates of bottom
Y1	= 5.	end of
Z1	= 0.	Monopole 1
NCON1	= 1	Segment 1 is grounded
X2	= 0.	Coordinates of top
Y2	= 5.	end of
Z2	= 18.75	Monopole 1
NCON2	= 0	Segment 7 is unconnected
NSEGS	= +7	7 segments uased (A +7 means another set of data cards will be read)
WIRERAD	= 0.01	10 cm radius wire
WT	= 0.	No catenary
TENS	= 0.	No catenary
TAU	= 0.	Equal length segments

Cards 6 & 7 — Model Monopole #2

X1	= 0.	Coordinates of bottom
Y1	= -5.	of
Z1	= 0.	Monopole #2
NCON1	= 8	Segment #8 is grounded
X2	= 0.	Coordinates of top
Y2	= -5.	of
Z2	= 18.75	Monopole #2
NCON2	= 0	Segment #14 is unconnected
NSEGS	= -7	7 segments for monopole #2 (minus # ends input)
WIRERAD	= 0.01	10 cm radius wire
WT	= 0.	No catenary
TENS	= 0.	No catenary
TAU	= 0.	

Card 8: Structure Symmetry

NP = 7		7 segments per symmetric section - (2 sectors of symmetry)
NX = 0		No segments on axis of symmetry

Cards 9 and 10: Source Excitation

IS = 1	Excite segment #1
ECM = 1.	1 volt source
ECA = 0.	0 degree phase
NFLD = 1	Read in another source card
IS = 8	Also excite segment #8
ECM = 1.	1 volt source
ECA = +120.	+120° phase
NFLD = 0	End source input

Card 11: Far Field Input

THETR = 0.	Initial θ angle
PHYR = -180.	Initial ϕ angle
ETAR = 0.	Polarization angle = 0°
DTHR = 5.	5 degree step in θ
DPHR = 10.	10 degree step in ϕ
NTHR = 19	19 steps in θ
NPHR = 19	19 steps in ϕ
NFLD = 0	No more farfield inputs
NEWSIG = 1	Compute far field over finite ground
SIGFF = 0.01	Conductivity of far field medium in mhos/metre
EPSFF = 15	Relative dielectric content of far field.

The completed data deck for example 2 is shown in Figure 14, and the computed results are shown in Figure 15. The far field radiation pattern is shown in Figure 16.

```
2 MONOPOLES 5/8 WAVELENGTH -- 1/3 WAVELENGTH APART -- EXAMPLE 2
   1    0    1    0    0    1    0
      01         0.    1    2         1         0.
      0.         5.         0.    1         0.        5.     18.75    0
   7         .01          0.         0.         0.
      0.        -5.         0.    8         0.        -5.     18.75    0
  -7         .01          0.         0.         0.
   7    0
   1         1.          0.    1
   8         1         120.    0
      0.       -90.         0.         5.        10.   19   19    0    1   .01   15.
```

```
|*****************************

 WIRE ANTENNA MODELING PROGRAM

 *****************************


  2 MONOPOLES 5/8 WAVELENGTH -- 1/3 WAVELENGTH APART -- EXAMPLE 2

    1    0    1    0    0    1    0

 FREQUENCY            =  1.00000E-02
 FREQUENCY INCREMENT  =        .0E+00
 NO. FREQUENCY STEPS  =   1
 WAVELENGTH (METERS)  =  2.99793E+01


 A PERFECT GROUND PLANE AT Z=0.
```

```
 I DATA GENERATOR INPUT DATA CARDS

         .0   5.00000         .0    1         .0   5.00000  18.75000    0
    7    .01000         .0         .0         .0
         .0  -5.00000         .0    8         .0  -5.00000  18.75000    0
   -7    .01000         .0         .0         .0


 NUMBER OF SEGMENTS   =  14
 NO. SEG. IN A SECTOR =   7
 NO. SEG. ON AXIS OF ROTATION =    0
```

```
 STRUCTURE GEOMETRY  (DIMENSIONS IN WAVELENGTHS)

  COORDINATES OF SEG  CENTER      SEG       WIRE     ORIENTATION ANGLES    CONNECTION DATA
      X         Y         Z       LENGTH    RADIUS      ALPHA      BETA     I-     I     I+
   -.00000    .16678    04467     08935  .00033356    90 000          0     1     1     2
   -.00000    .16678    13402     08935   00033356    90 000          0     1     2     3
   -.00000    .16678    22337     08935   00033356    90 000          0     2     3     4
   -.00000    .16678    31272     08935   00033356    90 000         .0     3     4     5
   -.00000    .16678    40206     08935   00033356    90 000          0     4     5     6
   -.00000    .16678    49141     08935   00033356    90 000          0     5     6     7
   -.00000    .16678    58076     08935   00033356    90 000          0     6     7     0
   -.00000   - 16678    04467     08935   00033356    90 000          0     8     8     9
   -.00000   - 16678    13402     08935   00033356    90 000          0     8     9    10
   -.00000   -.16678    22337     08935   00033356    90 000         .0     9    10    11
   -.00000   - 16678    31272     08935   00033356    90 000          0    10    11    12
   -.00000   - 16678    40206     08935   00033356    90 000          0    11    12    13
   -.00000   - 16678    49141     08935   00033356    90 000          0    12    13    14
   -.00000   - 16678    58076     08935   00033356    90 000          0    13    14     0

  TOTAL WIRE LENGTH     = 1 25086309554E+00

  ANTENNA SOURCE DISTRIBUTIONS
    SEG.          VOLTAGE
    NO       MAG          PHASE
     1    1 00000            .0     1
     8    1.00000 120 00000     0
```

```
 SEGMENT EXCITATION (VOLTS/WAVELENGTH)
  SEG NUMBER    REAL PART     IMAGINARY PART

       1        -1 119E+01          - 0E+00

       8         5.596E+00         -9 693E+00
```

SEG. NO	CURRENT - REAL	IMAGINARY	MAGNITUDE	PHASE
1	9 4610E-04	2 4985E-03	2.671671139E-03	69 260
2	7.4950E-04	3 2809E-04	8 181617449E-04	23 641
3	4.2282E-04	-1 8219E-03	1 87036486E-03	-76 935
4	7.4905E-05	-3 3470E-03	3 34779155E-03	-88 718
5	-1.8073E-04	-3 8063E-03	3.81059325E-03	-92 719
6	-2.6253E-04	-3 0521E-03	3.06341972E-03	-94 916
7	-1 4182E-04	-1.2557E-03	1.26363391E-03	-96 444
8	-1 9377E-03	-7 7683E-04	2 08758554E-03	-158 154

SEG. NO	CURRENT - REAL	IMAGINARY	MAGNITUDE	PHASE
8	-1.9377E-03	7 7683E-04	2.08758554E 03	-158.154
9	-1 0512E-04	2 4689E-04	2.68340310E-04	113.062
10	1 6795E-03	1 2123E-03	2.07129504E-03	35.822
11	2 9194E-03	1.8427E-03	3.45231094E-03	32.260
12	3.2594E-03	1 9521E-03	3.79929258E-03	30.918
13	2.5887E-03	1 5005E-03	2.99215487E-03	30.097
14	1.0588E-03	5 9774E-04	1.21587527E-03	29.447

```
 I     AR          AI          BR          BI          CR          CI
    1  3.0563E-04 -4.5722E-03  -1 8465E-04 -2 0385E-03   6.4046E-04  7 0707E-03
    2  3.2573E-04  3.9462E-04  -4 9147E-04 -4 0579E-03   4 2377E-04 -6 6532E-05
    3  3.5366E-04  2 1421E-04  -6.3359E-04 -3 4517E-03   6 9161E-05 -2.0362E-03
    4  3.7551E-04  1 2464E-04  -5.6686E-04 -1 8637E-03  -3.0060E-04 -3 4716E-03
    5  3.8559E-04  1.4695E-04  -3.1692E-04  2.7688E-04  -5.6632E-04 -3 9533E-03
    6  3.9719E-04  3 4351E-04   3 6550E-05  2 3956E-03   6 5972E-04 -3.3957E-03
    7  5.2205E-04  1.4402E-03   4 1815E-04  4 1518E-03  -6 6387E-04 -2.6959E-03
    8  4 0322E-03  2 5582E-03   1.7212E-03  9 6150E-04   5 9699E-03 -3 3350E-03
    9 -2.8127E-04  5 6747E-05   3.3973E-03  1 8682E-03   1.5615E 04  1 9015E-04
   10 -9.5079E-05  1 2132E-04   2 8406E 03  1 4988E-03   1 7746E-03  1 0909E 03
   11 -1.1977E-05  ..4505E-04   1.4839E-03  6 9487E-04   2 9314E 03  1 6977E-03
   12 -3.3312E-05  1.2455E-04   -3 1053E-04  3 2147E-04   3 2928E-03  1 8275E-03
   13 -2.1048E-04  3.0969E-05   -2.0669E-03  1 2720E 03   2 7992E-03  1 4695E-03
   14 -1.1484E-03 -4 7789E-04   -3 5103E-03  2 0056E 03   2 2072E-03  1 0756E-03
```

1 2 MONOPOLES 5/8 WAVELENGTH -- 1/3 WAVELENGTH APART -- EXAMPLE 2

DIELECTRIC CONSTANT = 1.5000E+01 AND CONDUCTIVITY = 1.0000E-02 FOR FAR FIELD CALCULATIONS

OBSERVATION ANGLES		ELECTRIC FIELD				
THETA	PHI	R-COMPONENT	THETA-COMPONENT	PHI-COMPONENT	MAGNITUDE	PHASE
0	-90.000	2.3936E-15	3.0859E-22	6.0467E-11	6.0467E-11	-116.2122
5.000	-90.000	2.8695E-15	2.0783E-02	3.6020E-11	2.0783E-02	-52.5110
10.000	-90.000	2.5039E-15	3.1645E-02	3.0825E-11	3.1645E-02	-55.5531
15.000	-90.000	1.3415E-15	3.2644E-02	2.5367E-11	3.2644E-02	-61.2927
20.000	-90.000	1.1698E-15	2.5259E-02	1.9265E-11	2.5259E-02	-74.3210
25.000	-90.000	1.6653E-16	1.5471E-02	1.2188E-11	1.5471E-02	-116.3613
30.000	-90.000	1.0146E-15	2.2725E-02	4.1005E-12	2.2725E-02	176.2860
35.000	-90.000	7.4683E-16	4.2057E-02	6.2834E-12	4.2057E-02	151.8711
40.000	-90.000	1.5464E-15	6.0345E-02	1.6897E-11	6.0345E-02	139.9473
45.000	-90.000	1.0053E-15	7.2481E-02	2.8708E-11	7.2481E-02	129.6603
50.000	-90.000	1.4433E-15	7.6358E-02	3.9249E-11	7.6358E-02	116.9156
55.000	-90.000	1.5424E-15	7.4257E-02	4.8868E-11	7.4257E-02	97.9356
60.000	-90.000	8.8991E-16	7.5224E-02	5.5771E-11	7.5224E-02	70.6651
65.000	-90.000	5.6610E-16	8.9595E-02	5.8709E-11	8.9595E-02	42.4816
70.000	-90.000	1.2947E-15	1.1407E-01	5.6703E-11	1.1407E-01	22.4997
75.000	-90.000	7.3277E-16	1.3455E-01	4.9276E-11	1.3455E-01	9.9769
80.000	-90.000	4.7073E-16	1.3517E-01	3.6620E-11	1.3517E-01	1.5081
85.000	-90.000	1.2261E-16	9.8724E-02	1.9664E-11	9.8724E-02	-5.4658
90.000	-90.000	8.3861E-27	8.4204E-12	1.1907E-21	8.4204E-12	166.4396
.0	-80.000	2.3936E-15	1.0500E-11	5.9548E-11	6.0467E-11	63.7878
5.000	-80.000	3.2760E-15	2.0854E-02	3.5561E-11	2.0854E-02	-52.4842
10.000	-80.000	1.9565E-15	3.1931E-02	3.0548E-11	3.1931E-02	-55.4619
15.000	-80.000	7.4683E-16	3.3272E-02	2.5295E-11	3.3272E-02	-61.0111
20.000	-80.000	9.8767E-16	2.6262E-02	1.9430E-11	2.6262E-02	-73.2583
25.000	-80.000	7.1642E-16	1.6209E-02	1.2630E-11	1.6209E-02	-111.1011
30.000	-80.000	6.8448E-16	2.1416E-02	4.8026E-12	2.1416E-02	-179.3314
35.000	-80.000	8.6711E-16	3.9867E-02	5.2034E-12	3.9867E-02	153.7073
40.000	-80.000	1.2009E-15	5.7788E-02	1.5378E-11	5.7788E-02	141.1025
45.000	-80.000	8.0059E-16	6.9816E-02	2.6295E-11	6.9816E-02	130.6083
50.000	-80.000	1.6012E-15	7.3741E-02	3.6980E-11	7.3741E-02	117.8362
55.000	-80.000	8.8861E-16	7.1640E-02	4.6321E-11	7.1640E-02	98.8812
60.000	-80.000	1.4655E-15	7.2280E-02	5.3067E-11	7.2280E-02	71.4541
65.000	-80.000	1.1802E-15	8.6008E-02	5.6008E-11	8.6008E-02	42.8807
70.000	-80.000	8.8991E-16	1.0986E-01	5.4194E-11	1.0986E-01	22.6324
75.000	-80.000	4.9651E-16	1.2997E-01	4.7156E-11	1.2997E-01	10.0016
80.000	-80.000	2.2658E-16	1.3082E-01	3.5074E-11	1.3082E-01	1.4932
85.000	-80.000	1.7085E-16	9.5652E-02	1.8843E-11	9.5652E-02	-5.4950
90.000	-80.000	2.1867E-25	8.1613E-12	1.1408E-21	8.1613E-12	166.4035
.0	-70.000	2.3936E-15	2.0681E-11	5.6820E-11	6.0467E-11	63.7878
5.000	-70.000	3.2451E-15	2.1066E-02	3.4181E-11	2.1066E-02	-52.4056
10.000	-70.000	2.4183E-15	3.2782E-02	2.9688E-11	3.2782E-02	-55.2004
15.000	-70.000	9.0366E-16	3.5136E-02	2.5021E-11	3.5136E-02	-60.2340
20.000	-70.000	1.0123E-15	2.9284E-02	1.9836E-11	2.9284E-02	-70.5355
25.000	-70.000	4.0341E-16	1.9060E-02	1.3826E-11	1.9060E-02	-98.3347
30.000	-70.000	9.3095E-17	1.0455E-02	6.8280E-12	1.0455E-02	-163.1064

1 2 MONOPOLES 5/8 WAVELENGTH -- 1 3 WAVELENGTH APART -- EXAMPLE 2

DIELECTRIC CONSTANT = 1 5000E+01 AND CONDUCTIVITY = 1 0000E-02 FOR FAR FIELD CALCULATIONS

OBSERVATION ANGLES		ELECTRIC FIELD				
THETA	PHI	R-COMPONENT	THETA COMPONENT	PHI-COMPONENT	MAGNITUDE	PHASE
35 000	-70.000	6.7132E-16	3 3648E-02	2.4639E-12	3 3648E 02	160 5371
40 000	-70 000	9 6946E-16	5 0326E-02	1 1104E 11	5 0326E 02	145 2187
45 000	-70 000	1 4476E 15	6 1983E-02	2 0870E 11	6 1983E 02	133 9014
50 000	-70 000	1 0533E-15	6 6037E 02	3 0518E 11	6 6037E 02	120 9982
55 000	-70.000	9 8092E-16	6 3932E-02	3 9044E 11	6 3934E 02	102 1435
60 000	-70 000	1 1271E-15	6 3554E 02	4 5321E 11	6 3554E 02	74 2274
65.000	-70 000	1 0934E-15	7 5312E-02	4 8255E 11	7 5312E 02	44 2902
70 000	-70 000	1 2225E-15	9 7192E 02	4 6976E 11	9 7192E 02	23.0948
75 000	-70 000	5 2369E-16	1 1618E-01	4 1048E 11	1 1618E 01	10 0863
80 000	-70 000	4 6848E-16	1 1773E 01	3 0616E 11	1 1773E 01	1.4422
85 000	-70.000	5 8981E 17	8 6391E 02	1 6474E 11	8 6391E 02	5.5939
90 000	-70.000	4 0915E-25	7 3790E 12	9 9829E 22	7 3790E 12	166.2969
0	-60.000	2 3936E 15	3 0233E 11	5 2366E 11	6 0467E 11	63 7878
5.000	-60 000	3 2141E 15	2 1410E 02	3 1876E 11	2 1410E 02	-52 2806
10 000	-60 000	2 0795E-15	3 4167E-02	2 8169E 11	3 4167E-02	-54.8014
15 000	-60.000	1 0164E-15	3 8181E 02	2 4384E 11	3 8181E-02	-59.1284
20 000	-60 000	7 8505E-16	3 4310E 02	2 0222E 11	3 4310E 02	-67 1319
25 000	-60 000	7 3014E 16	2 5044E 02	1 5408E 11	2 5044E 02	-84.8314
30 000	-60.000	6 2373E-16	1 7894E-02	9 7517E 12	1 7894E 02	-130 0149
35 000	-60 000	2.1377E-16	2 5125E 02	3 3939E 12	2 5125E 02	178.4790
40.000	-60.000	1 4433E-15	3 8883E-02	4 9582E-12	3 8883E 02	155.2477
45 000	-60.000	1 3007E-15	4 9669E-02	1 2858E-11	4 9669E 02	141.4751
50.000	-60 000	9.4206E-16	5 3869E-02	2 0881E 11	5 3869E-02	128.0777
55.000	-60 000	0 2523E-16	5 1765E-02	2 8115E 11	5 1765E-02	109.5291
60 000	-60.000	7 7728E-16	4 9552E-02	3 3625E-11	4 9552E 02	80.8418
65 000	-60 000	4.9651E-16	5 7703E-02	3 6495E 11	5 7703E 02	47.7207
70 000	-60.000	6.6613E-16	7 6134E-02	3 5989E 11	7 6134E-02	24.1837
75 000	-60 000	5 7220E-16	9 3152E-02	3 1723E 11	9 3152E 02	10.2793
80.000	-60 000	5 8039E-16	9 5811E-02	2 3795E 11	9 5811E 02	1.3286
85.000	-60.000	2.0206E-16	7 0867E-02	1 2845E 11	7 0867E 02	-5.8117
90 000	-60.000	4.2861E-25	6 0669E-12	7 7881E 22	6 0669E-12	166.0510
.0	-50 000	2.3936E-15	3 8867E-11	4 6320E-11	6 0467E-11	63.7878
5 000	-50.000	2.4975E-15	2 1876E-02	2 8643E-11	2 1876E 02	-52 1173
10.000	-50.000	2 8098E-15	3 6039E-02	2 5880E-11	3 6039E-02	-54 3088
15 000	-50.000	1 2959E-15	4 2307E-02	2 3144E-11	4 2307E-02	-57.8821
20.000	-50.000	1.6136E-15	4 1230E-02	2 0196E-11	4.1230E 02	-63.8513
25.000	-50.000	5 0440E-16	3 4373E-02	1.6809E-11	3 4373E 02	-74.7121
30.000	-50 000	8 9088E-16	2 5185E-02	1 2801E-11	2 5185E-02	-97.1350
35.000	-50.000	7.7765E-16	2 1080E-02	8 0941E-12	2 1080E 02	-139.6731
40.000	-50.000	1.3990E-15	2 7006E-02	2 9450E-12	2 7006E-02	-170.6291
45.000	-50 000	7.2184E-16	3 5249E-02	3 8583E 12	3 5249E 02	159 8010
50.000	-50.000	9.2389E-16	3 9326E-02	9 7135E-12	3 9326E 02	144 3826
55.000	-50.000	8.9681E-16	3 7351E-02	1 5286E-11	3 7351E 02	126 8940
60.000	-50.000	1 6739E-15	3 2342E-02	1 9768E 11	3 2342E 02	98 7211
65.000	-50.000	4 7103E-16	3 4106E-02	2 2463E-11	3 4106E 02	58 0442

1 2 MONOPOLES 5/8 WAVELENGTH -- 1/3 WAVELENGTH APART -- EXAMPLE 2

DIELECTRIC CONSTANT = 1.5000E+01 AND CONDUCTIVITY = 1.0000E-02 FOR FAR FIELD CALCULATIONS.

OBSERVATION ANGLES		ELECTRIC FIELD				
THETA	PHI	R-COMPONENT	THETA-COMPONENT	PHI-COMPONENT	MAGNITUDE	PHASE
70.000	-50.000	6.8943E-16	4.7025E-02	2.2806E-11	4.7025E-02	27.2373
75.000	-50.000	1.7772E-16	6.1103E-02	2.0487E-11	6.1103E-02	10.7769
80.000	-50.000	1.7145E-16	6.5209E-02	1.5552E-11	6.5209E-02	1.0504
85.000	-50.000	1.8697E-16	4.9150E-02	8.4513E-12	4.9150E-02	-6.3309
90.000	-50.000	5.5558E-25	4.2321E-12	5.1389E-22	4.2321E-12	165.4820
0	-40.000	2.3936E-15	4.6320E-11	3.0867E-11	6.0467E-11	63.7878
5.000	-40.000	3.1626E-15	2.2448E-02	2.4494E-11	2.2448E-02	-51.9253
10.000	-40.000	2.2549E-15	3.0334E-02	2.2702E-11	3.0334E-02	-53.7676
15.000	-40.000	1.6012E-15	4.7374E-02	2.1031E-11	4.7374E-02	-56.6440
20.000	-40.000	1.2947E-15	4.9815E-02	1.9306E-11	4.9815E-02	-61.0866
25.000	-40.000	1.7040E-15	4.6575E-02	1.7359E-11	4.6575E-02	-68.0248
30.000	-40.000	1.9142E-15	3.9469E-02	1.5038E-11	3.9469E-02	-79.4766
35.000	-40.000	9.9690E-16	3.1583E-02	1.2240E-11	3.1583E-02	-98.8210
40.000	-40.000	7.4683E-16	2.7154E-02	8.9511E-12	2.7154E-02	-127.6475
45.000	-40.000	1.2403E-15	2.7984E-02	5.2846E-12	2.7984E-02	-156.7538
50.000	-40.000	1.0602E-15	3.0171E-02	1.7577E-12	3.0171E-02	177.4751
55.000	-40.000	1.3668E-16	2.9183E-02	2.9747E-12	2.9183E-02	167.6040
60.000	-40.000	4.7752E-16	2.3228E-02	6.1398E-12	2.3228E-02	152.5092
65.000	-40.000	3.6638E-16	1.3982E-02	8.4883E-12	1.3982E-02	123.6922
70.000	-40.000	3.3537E-16	1.1787E-02	9.5618E-12	1.1787E-02	52.3137
75.000	-40.000	1.2795E-16	2.0796E-02	9.1273E-12	2.0796E-02	13.5232
80.000	-40.000	4.0520E-16	2.6571E-02	7.1827E-12	2.6571E-02	-.1849
85.000	-40.000	1.3660E-16	2.1684E-02	3.9789E-12	2.1684E-02	-8.4214
90.000	-40.000	3.9223E-25	1.9095E-12	2.4333E-22	1.9095E-12	163.2208
.0	-30.000	2.3936E-15	5.2366E-11	3.0233E-11	6.0467E-11	63.7878
5.000	-30.000	3.3343E-15	2.3107E-02	1.9465E-11	2.3107E-02	-51.7147
10.000	-30.000	3.1365E-15	4.0973E-02	1.8538E-11	4.0973E-02	-53.2161
15.000	-30.000	2.0480E-15	5.3198E-02	1.7786E-11	5.3198E-02	-55.5034
20.000	-30.000	1.4571E-15	5.9739E-02	1.7108E-11	5.9739E-02	-58.8407
25.000	-30.000	1.8611E-15	6.0983E-02	1.6386E-11	6.0983E-02	-63.6646
30.000	-30.000	2.3479E-15	5.7862E-02	1.5514E-11	5.7862E-02	-70.6805
35.000	-30.000	1.5414E-15	5.1989E-02	1.4394E-11	5.1989E-02	-80.9330
40.000	-30.000	1.0190E-15	4.5676E-02	1.2967E-11	4.5676E-02	-95.5104
45.000	-30.000	1.1116E-15	4.1421E-02	1.1225E-11	4.1421E-02	-114.0983
50.000	-30.000	1.8377E-15	4.0341E-02	9.2173E-12	4.0341E-02	-133.2809
55.000	-30.000	5.1179E-16	4.1018E-02	7.0609E-12	4.1018E-02	-148.9558
60.000	-30.000	7.3277E-16	4.0942E-02	4.9251E-12	4.0942E-02	-159.9453
65.000	-30.000	8.9088E-16	3.8470E-02	3.0067E-12	3.8470E-02	-167.0884
70.000	-30.000	2.8177E-16	3.3352E-02	1.4957E-12	3.3352E-02	-171.4498
75.000	-30.000	4.6476E-16	2.6398E-02	5.7367E-13	2.6398E-02	-173.8519
80.000	-30.000	2.2602E-16	1.8738E-02	3.6724E-13	1.8738E-02	-175.2032
85.000	-30.000	1.3986E-17	1.0717E-02	2.7577E-13	1.0717E-02	-177.2573
90.000	-30.000	1.7401E-25	8.3547E-13	1.8760E-23	8.3547E-13	-3.4473
.0	-20.000	2.3936E-15	5.6820E-11	2.0681E-11	6.0467E-11	63.7878
5.000	-20.000	2.8231E-15	2.3832E-02	1.3623E-11	2.3832E-02	-51.4953

1 2 MONOPOLES 5/8 WAVELENGTH -- 1/3 WAVELENGTH APART -- EXAMPLE 2

DIELECTRIC CONSTANT = 1.5000E+01 AND CONDUCTIVITY = 1.0000E-02 FOR FAR FIELD CALCULATIONS

OBSERVATION ANGLES		ELECTRIC FIELD				
THETA	PHI	R-COMPONENT	THETA-COMPONENT	PHI-COMPONENT	MAGNITUDE	PHASE
10.000	-20.000	2.8475E-15	4.3864E-02	1.3335E-11	4.3864E-02	-52.6828
15.000	-20.000	1.7244E-15	5.9569E-02	1.3227E-11	5.9569E-02	-54.4999
20.000	-20.000	2.1102E-15	7.0610E-02	1.3248E-11	7.0610E-02	-57.1037
25.000	-20.000	1.7902E-15	7.6886E-02	1.3339E-11	7.6886E-02	-60.7443
30.000	-20.000	1.9270E-15	7.8628E-02	1.3432E-11	7.8628E-02	-65.8097
35.000	-20.000	1.7772E-15	7.6558E-02	1.3455E-11	7.6558E-02	-72.8762
40.000	-20.000	2.0015E-15	7.2063E-02	1.3336E-11	7.2063E-02	-82.7018
45.000	-20.000	1.1226E-15	6.7281E-02	1.3013E-11	6.7281E-02	95.9377
50.000	-20.000	7.4683E-16	6.4736E-02	1.2442E-11	6.4736E-02	-112.2253
55.000	-20.000	9.5505E-16	6.6064E-02	1.1598E-11	6.6064E-02	-129.3306
60.000	-20.000	8.9509E-16	7.0665E-02	1.0484E-11	7.0665E-02	-144.3904
65.000	-20.000	6.7760E-16	7.6081E-02	9.1237E-12	7.6081E-02	156.1380
70.000	-20.000	1.0130E-15	7.9383E-02	7.5554E-12	7.9383E-02	-164.9302
75.000	-20.000	1.0873E-16	7.7797E-02	5.8244E-12	7.7797E-02	-171.6780
80.000	-20.000	2.4286E-16	6.8290E-02	3.9106E-12	6.8290E-02	-177.3438
85.000	-20.000	1.3895E-16	4.6040E-02	2.0237E-12	4.6040E-02	176.9568
90.000	-20.000	4.5525E-25	3.8249E-12	1.2040E-22	3.8249E-12	-10.7511
.0	-10.000	2.3936E-15	5.9548E-11	1.0500E-11	6.0467E-11	63.7878
5.000	-10.000	2.9528E-15	2.4600E-02	7.0820E-12	2.4600E-02	-51.2756
10.000	-10.000	3.4294E-15	4.6908E-02	7.1181E-12	4.6908E-02	-52.1864
15.000	-10.000	2.0015E-15	6.6254E-02	7.2754E-12	6.6254E-02	-53.6411
20.000	-10.000	2.3714E-15	8.1999E-02	7.5387E-12	8.1999E-02	-55.7551
25.000	-10.000	2.5895E-15	9.3562E-02	7.8888E-12	9.3562E-02	-58.7164
30.000	-10.000	2.5631E-15	1.0052E-01	8.2952E-12	1.0052E-01	62.8245
35.000	-10.000	2.7465E-15	1.0282E-01	8.7179E-12	1.0282E-01	-68.5455
40.000	-10.000	2.5662E-15	1.0107E-01	9.1051E-12	1.0107E-01	76.5738
45.000	-10.000	2.4582E-15	9.6999E-02	9.3982E-12	9.6999E-02	-87.7852
50.000	-10.000	1.8073E-15	9.3733E-02	9.5321E-12	9.3733E-02	-102.7434
55.000	-10.000	2.8021E-15	9.5089E-02	9.4414E-12	9.5089E-02	-120.4518
60.000	-10.000	1.6505E-15	1.0300E-01	9.0673E-12	1.0300E-01	-137.8700
65.000	-10.000	1.3506E-15	1.1527E-01	8.3642E-12	1.1527E-01	-152.2656
70.000	-10.000	2.0260E-15	1.2660E-01	7.3075E-12	1.2660E-01	-163.1043
75.000	-10.000	8.9207E-16	1.3039E-01	5.8976E-12	1.3039E-01	-171.2092
80.000	-10.000	5.5720E-16	1.1909E-01	4.1656E-12	1.1909E-01	-177.7025
85.000	-10.000	1.4120E-16	8.2354E-02	2.1710E-12	8.2354E-02	176.1562
90.000	-10.000	1.0041E-24	6.8996E-12	1.3017E-22	6.8996E-12	-11.7009
.0	.0	2.3936E-15	6.0467E-11	0E+00	6.0467E-11	63.7878
5.000	0	3.1287E-15	2.5387E-02	0E+00	2.5387E-02	-51.0629
10.000	0	3.2880E-15	5.0005E-02	0E+00	5.0005E-02	-51.7374
15.000	0	3.1426E-15	7.3016E-02	0E+00	7.3016E-02	-52.9186
20.000	0	2.7104E-15	9.3466E-02	0E+00	9.3466E-02	-54.7044
25.000	0	2.5317E-15	1.1030E-01	0E+00	1.1030E-01	-57.2587
30.000	0	2.1557E-15	1.2247E-01	0E+00	1.2247E-01	-60.8481
35.000	0	3.5958E-15	1.2916E-01	0E+00	1.2916E-01	-65.9000
40.000	.0	3.7221E-15	1.3029E-01	0E+00	1.3029E-01	-73.0832

1 2 MONOPOLES 5/8 WAVELENGTH -- 1/3 WAVELENGTH APART -- EXAMPLE 2

DIELECTRIC CONSTANT = 1.5000E+01 AND CONDUCTIVITY = 1.0000E-02 FOR FAR FIELD CALCULATIONS.

OBSERVATION ANGLES		ELECTRIC FIELD				
THETA	PHI	R-COMPONENT	THETA-COMPONENT	PHI-COMPONENT	MAGNITUDE	PHASE
45.000	.0	3.5804E-15	1.2715E-01	.0E+00	1.2715E-01	-83.3473
50.000	.0	2.5177E-15	1.2324E-01	.0E+00	1.2324E-01	-97.6294
55.000	.0	1.6910E-15	1.2420E-01	.0E+00	1.2420E-01	-115.5959
60.000	.0	2.7822E-15	1.3454E-01	.0E+00	1.3454E-01	-134.3442
65.000	.0	1.4043E-15	1.5287E-01	.0E+00	1.5287E-01	-150.2797
70.000	.0	4.9651E-16	1.7171E-01	.0E+00	1.7171E-01	-162.2340
75.000	.0	2.2861E-15	1.8065E-01	.0E+00	1.8065E-01	-171.0011
80.000	.0	7.7743E-16	1.6772E-01	.0E+00	1.6772E-01	-177.0531
85.000	.0	3.6638E-16	1.1714E-01	.0E+00	1.1714E-01	175.8318
90.000	.0	1.2941E-24	9.8491E-12	.0E+00	9.8491E-12	-12.0854
0	10.000	2.3936E-15	5.9548E-11	1.0500E-11	6.0467E-11	63.7878
5.000	10.000	3.1632E-15	2.6167E-02	7.4178E-12	2.6167E-02	-50.8629
10.000	10.000	3.7364E-15	5.3055E-02	7.8142E-12	5.3055E-02	-51.3403
15.000	10.000	2.2542E-15	7.9626E-02	8.3808E-12	7.9626E-02	-52.3175
20.000	10.000	3.4844E-15	1.0460E-01	9.1258E-12	1.0460E-01	-53.8807
25.000	10.000	2.7756E-15	1.2644E-01	1.0047E-11	1.2644E-01	-56.1801
30.000	10.000	2.9790E-15	1.4350E-01	1.1124E-11	1.4350E-01	-59.4639
35.000	10.000	5.6173E-15	1.5428E-01	1.2308E-11	1.5428E-01	-64.1373
40.000	10.000	3.3009E-15	1.5804E-01	1.3522E-11	1.5804E-01	70.8516
45.000	10.000	1.7772E-15	1.5566E-01	1.4652E-11	1.5566E-01	-80.5836
50.000	10.000	1.9860E-15	1.5097E-01	1.5557E-11	1.5097E-01	-94.4488
55.000	10.000	3.3009E-15	1.5112E-01	1.6075E-11	1.5112E-01	-112.5426
60.000	10.000	3.9534E-15	1.6307E-01	1.6037E-11	1.6307E-01	-132.1183
65.000	10.000	2.2204E-15	1.8644E-01	1.5294E-11	1.8644E-01	-149.0520
70.000	10.000	3.1402E-15	2.1183E-01	1.3740E-11	2.1183E-01	-161.7139
75.000	10.000	1.3809E-15	2.2536E-01	1.1338E-11	2.2536E-01	-170.8807
80.000	10.000	9.7799E-16	2.1097E-01	8.1375E-12	2.1097E-01	-177.9380
85.000	10.000	1.9107E-16	1.4810E-01	4.2028E-12	1.4810E-01	175.6514
90.000	10.000	1.8515E-24	1.2469E-11	2.5758E-22	1.2469E-11	-12.2885
.0	20.000	2.3936E-15	5.6820E-11	2.0681E-11	6.0467E-11	63.7878
5.000	20.000	3.1846E-15	2.6917E-02	1.4926E-11	2.6917E-02	-50.6000
10.000	20.000	3.6701E-15	5.5964E-02	1.6034E-11	5.5964E-02	-50.9863
15.000	20.000	2.0837E-15	8.5874E-02	1.7511E-11	8.5874E-02	-51.8218
20.000	20.000	3.5108E-15	1.1502E-01	1.9393E-11	1.1502E-01	-53.2317
25.000	20.000	3.3984E-15	1.4141E-01	2.1689E-11	1.4141E-01	-55.3644
30.000	20.000	3.4684E-15	1.6282E-01	2.4362E-11	1.6282E-01	-58.4544
35.000	20.000	6.2686E-15	1.7714E-01	2.7312E-11	1.7714E-01	-62.8910
40.000	20.000	5.2779E-15	1.8304E-01	3.0356E-11	1.8304E-01	-69.3114
45.000	20.000	2.4349E-15	1.8110E-01	3.3231E-11	1.8110E-01	-78.7023
50.000	20.000	2.8658E-15	1.7537E-01	3.5597E-11	1.7537E-01	-92.2851
55.000	20.000	2.3804E-15	1.7431E-01	3.7055E-11	1.7431E-01	-110.4331
60.000	20.000	3.9721E-15	1.8705E-01	3.7197E-11	1.8705E-01	-130.5657
65.000	20.000	2.2204E-15	2.1422E-01	3.5651E-11	2.1422E-01	-148.2022
70.000	20.000	1.8971E-15	2.4485E-01	3.2155E-11	2.4485E-01	-161.3602
75.000	20.000	1.7841E-15	2.6208E-01	2.6613E-11	2.6208E-01	-170.8002

1 2 MONOPOLES 5/8 WAVELENGTH -- 1/3 WAVELENGTH APART -- EXAMPLE 2

DIELECTRIC CONSTANT = 1.5000E+01 AND CONDUCTIVITY = 1.0000E-02 FOR FAR FIELD CALCULATIONS.

OBSERVATION ANGLES		ELECTRIC FIELD				
THETA	PHI	R-COMPONENT	THETA-COMPONENT	PHI-COMPONENT	MAGNITUDE	PHASE
80.000	20.000	6.8189E-16	2.4647E-01	1.9141E-11	2.4647E-01	-177.9941
85.000	20.000	3.3887E-16	1.7348E-01	1.0086E-11	1.7348E 01	175.5332
90.000	20.000	1.6899E-24	1.4623E-11	6.0672E-22	1.4623E 11	-12.4275
0	30.000	2.3936E-15	5.2366E-11	3.0233E-11	6.0467E-11	63.7878
5.000	30.000	3.9629E-15	2.7616E-02	2.2248E-11	2.7616E 02	-50.5174
10.000	30.000	4.3002E-15	5.8647E-02	2.4302E-11	5.8647E-02	-50.7043
15.000	30.000	3.5423E-15	9.1579E-02	2.6928E-11	9.1579E 02	-51.4175
20.000	30.000	3.0627E-15	1.2443E-01	3.0202E-11	1.2443E 01	-52.7198
25.000	30.000	3.3009E-15	1.5476E-01	3.4152E-11	1.5476E-01	-54.7390
30.000	30.000	5.1789E-15	1.7983E-01	3.8726E-11	1.7983E-01	-57.6984
35.000	30.000	5.4616E-15	1.9700E-01	4.3764E-11	1.9700E-01	-61.9751
40.000	30.000	4.1895E-15	2.0446E-01	4.8967E 11	2.0446E-01	-68.1941
45.000	30.000	7.1063E-15	2.0255E-01	5.3895E 11	2.0255E 01	-77.3454
50.000	30.000	2.6853E-15	1.9554E-01	5.7973E 11	1.9554E 01	-90.7172
55.000	30.000	3.6621E-15	1.9294E-01	6.0545E 11	1.9294E 01	108.8824
60.000	30.000	2.6738E-15	2.0570E-01	6.0924E-11	2.0570E 01	-129.4103
65.000	30.000	1.8971E-15	2.3536E-01	5.8496E-11	2.3536E 01	-147.5703
70.000	30.000	1.8971E-15	2.6975E-01	5.2825E 11	2.6975E-01	-161.0994
75.000	30.000	1.7764E 15	2.8965E-01	4.3757E 11	2.8965E 01	-170.7414
80.000	30.000	9.0632E-16	2.7305E-01	3.1489E-11	2.7305E 01	-178.0348
85.000	30.000	7.9201E-16	1.9245E-01	1.6598E-11	1.9245E 01	175.4479
90.000	30.000	2.1765E-24	1.6226E-11	9.9857E-22	1.6226E 11	-12.5237
.0	40.000	2.3936E-15	4.6320E 11	3.8867E-11	6.0467E 11	63.7878
5.000	40.000	3.9931E-15	2.8243E-02	2.9094E 11	2.8243E-02	-50.3774
10.000	40.000	3.6557E-15	6.1031E-02	3.2222E-11	6.1031E-02	-50.4623
15.000	40.000	3.6338E-15	9.6594E-02	3.6109E 11	9.6594E-02	-51.0925
20.000	40.000	3.7813E-15	1.3260E-01	4.0871E 11	1.3260E 01	-52.3185
25.000	40.000	3.9284E-15	1.6619E-01	4.6560E-11	1.6619E-01	-54.2579
30.000	40.000	4.8698E-15	1.9418E-01	5.3109E-11	1.9418E 01	-57.1254
35.000	40.000	5.5644E-15	2.1346E-01	6.0290E-11	2.1346E-01	-61.2879
40.000	40.000	4.5722E-15	2.2190E-01	6.7674E-11	2.2190E 01	-67.3609
45.000	40.000	4.6364E-15	2.1964E-01	7.4646E 11	2.1964E 01	-76.3338
50.000	40.000	4.0288E-15	2.1118E-01	8.0400E-11	2.1118E-01	-89.5399
55.000	40.000	4.5084E-15	2.0684E 01	8.4016E-11	2.0684E 01	-107.7006
60.000	40.000	2.5121E-15	2.1898E-01	8.4550E-11	2.1898E 01	-128.5177
65.000	40.000	2.8436E-15	2.4994E-01	8.1161E-11	2.4994E-01	-147.0805
70.000	40.000	2.2644E-15	2.8667E-01	7.3264E-11	2.8667E 01	-160.8980
75.000	40.000	2.2267E-15	3.0823E-01	6.0658E-11	3.0823E 01	-170.6962
80.000	40.000	4.5776E-16	2.9085E-01	4.3634E-11	2.9085E-01	-178.0660
85.000	40.000	5.5788E-16	2.0512E-01	2.2993E-11	2.0512E-01	175.3826
90.000	40.000	2.5701E-24	1.7298E-11	1.3831E-21	1.7298E 11	-12.5981
.0	50.000	2.3936E-15	3.8867E-11	4.6320E 11	6.0467E 11	63.7878
5.000	50.000	3.3420E-15	2.8780E-02	3.5174E-11	2.8780E-02	-50.2614
10.000	50.000	4.7080E-15	6.3058E-02	3.9388E 11	6.3058E-02	-50.2680
15.000	50.000	3.3839E-15	1.0081E-01	4.4512E-11	1.0081E-01	-50.0377

1 2 MONOPOLES 5/8 WAVELENGTH -- 1/3 WAVELENGTH APART -- EXAMPLE 2

DIELECTRIC CONSTANT = 1.5000E+01 AND CONDUCTIVITY = 1.0000E-02 FOR FAR FIELD CALCULATIONS.

OBSERVATION ANGLES		ELECTRIC FIELD				
THETA	PHI	R-COMPONENT	THETA-COMPONENT	PHI-COMPONENT	MAGNITUDE	PHASE
20.000	50.000	3.8058E-15	1.3938E-01	5.0710E-11	1.3938E-01	-52.0091
25.000	50.000	3.4542E-15	1.7554E-01	5.8045E-11	1.7554E-01	-53.8918
30.000	50.000	5.1789E-15	2.0571E-01	6.6429E-11	2.0571E-01	-56.6929
35.000	50.000	5.6741E-15	2.2844E-01	7.5564E-11	2.2844E-01	-60.7717
40.000	50.000	5.7732E-15	2.3533E-01	8.4911E-11	2.3533E-01	-66.7358
45.000	50.000	5.4672E-15	2.3247E-01	9.3674E-11	2.3247E-01	-75.5727
50.000	50.000	3.5537E-15	2.2252E-01	1.0085E-10	2.2252E-01	-88.6464
55.000	50.000	5.1263E-15	2.1641E-01	1.0528E-10	2.1641E-01	-106.7905
60.000	50.000	4.9302E-15	2.2755E-01	1.0582E-10	2.2755E-01	-127.8208
65.000	50.000	2.5895E-15	2.5887E-01	1.0143E-10	2.5887E-01	-146.6858
70.000	50.000	1.7342E-15	2.9674E-01	9.1438E-11	2.9674E-01	-160.7397
75.000	50.000	1.8784E-15	3.1910E-01	7.5614E-11	3.1910E-01	-170.6607
80.000	50.000	8.8821E-16	3.0116E-01	5.4341E-11	3.0116E-01	-178.0905
85.000	50.000	6.7422E-16	2.1240E-01	2.8618E-11	2.1240E-01	175.3314
90.000	50.000	2.0417E-24	1.7912E-11	1.7213E-21	1.7912E-11	-12.6522
.0	60.000	2.3936E-15	3.0233E-11	5.2366E-11	6.0467E-11	63.7878
5.000	60.000	4.4171E-15	2.9213E-02	4.0222E-11	2.9213E-02	-50.1704
10.000	60.000	3.9923E-15	6.4678E-02	4.5418E-11	6.4678E-02	-50.1193
15.000	60.000	3.0867E-15	1.0415E-01	5.1639E-11	1.0415E-01	-50.6460
20.000	60.000	3.2953E-15	1.4468E-01	5.9081E-11	1.4468E-01	-51.7791
25.000	60.000	5.6741E-15	1.8274E-01	6.7819E-11	1.8274E-01	-53.6217
30.000	60.000	6.0606E-15	2.1443E-01	7.7744E-11	2.1443E-01	-56.3751
35.000	60.000	3.4684E-15	2.3607E-01	8.8494E-11	2.3607E-01	-60.3930
40.000	60.000	4.0698E-15	2.4506E-01	9.9418E-11	2.4506E-01	-66.2764
45.000	60.000	4.1792E-15	2.4149E-01	1.0958E-10	2.4149E-01	-75.0108
50.000	60.000	6.2247E-15	2.3016E-01	1.1780E-10	2.3016E-01	-87.9810
55.000	60.000	4.0214E-15	2.2244E-01	1.2277E-10	2.2244E-01	-106.1037
60.000	60.000	1.7342E-15	2.3243E-01	1.2316E-10	2.3243E-01	-127.2877
65.000	60.000	2.3915E-15	2.6351E-01	1.1784E-10	2.6351E-01	-146.3986
70.000	60.000	2.8087E-15	3.0170E-01	1.0604E-10	3.0170E-01	-160.6177
75.000	60.000	4.0156E-15	3.2429E-01	8.7557E-11	3.2429E-01	-170.6334
80.000	60.000	1.5545E-15	3.0598E-01	6.2851E-11	3.0598E-01	-178.1093
85.000	60.000	5.5511E-16	2.1573E-01	3.3076E-11	2.1573E-01	175.2920
90.000	60.000	1.3705E-24	1.8191E-11	1.9885E-21	1.8191E-11	-12.7060
.0	70.000	2.3936E-15	2.0681E-11	5.6820E-11	6.0467E-11	63.7878
5.000	70.000	4.5041E-15	2.9531E-02	4.4006E-11	2.9531E-02	-50.1051
10.000	70.000	4.6242E-15	6.5859E-02	4.9901E-11	6.5859E-02	-50.0144
15.000	70.000	3.2972E-15	1.0656E-01	5.7058E-11	1.0656E-01	-50.5124
20.000	70.000	3.4542E-15	1.4847E-01	6.5455E-11	1.4847E-01	-51.6200
25.000	70.000	3.8148E-15	1.8782E-01	7.5255E-11	1.8782E-01	-53.4356
30.000	70.000	4.2422E-15	2.2050E-01	8.6326E-11	2.2050E-01	-56.1567
35.000	70.000	5.5644E-15	2.4262E-01	9.8251E-11	2.4262E-01	-60.1324
40.000	70.000	4.9851E-15	2.5153E-01	1.1030E-10	2.5153E-01	-65.9587
45.000	70.000	6.2804E-15	2.4730E-01	1.2143E-10	2.4730E-01	-74.6215
50.000	70.000	3.7060E-15	2.3486E-01	1.3034E-10	2.3486E-01	-87.5163

1 2 MONOPOLES 5/8 WAVELENGTH -- 1/3 WAVELENGTH APART -- EXAMPLE 2

DIELECTRIC CONSTANT = 1.5000E+01 AND CONDUCTIVITY = 1.0000E-02 FOR FAR FIELD CALCULATIONS.

OBSERVATION ANGLES		ELECTRIC FIELD				
THETA	PHI	R-COMPONENT	THETA-COMPONENT	PHI-COMPONENT	MAGNITUDE	PHASE
55.000	70.000	3.7568E-15	2.2585E-01	1.3559E-10	2.2585E-01	-105.6185
60.000	70.000	4.3113E-15	2.3482E-01	1.3577E-10	2.3482E-01	-126.9069
65.000	70.000	2.2204E-15	2.6542E-01	1.2966E-10	2.6542E-01	-146.1865
70.000	70.000	2.9790E-15	3.0349E-01	1.1648E-10	3.0349E-01	-160.5297
75.000	70.000	2.2542E-15	3.2599E-01	9.6042E-11	3.2599E-01	-170.6136
80.000	70.000	6.6905E-16	3.0741E-01	6.8868E-11	3.0741E-01	-178.1229
85.000	70.000	4.4674E-16	2.1669E-01	3.6218E-11	2.1669E-01	175.2634
90.000	70.000	9.6187E-25	1.8271E-11	2.1774E-21	1.8271E-11	-12.7325
.0	80.000	2.3936E-15	1.0500E-11	5.9548E-11	6.0467E-11	63.7878
5.000	80.000	4.5912E-15	2.9725E-02	4.6350E-11	2.9725E-02	-50.0658
10.000	80.000	4.3356E-15	6.6577E-02	5.2825E-11	6.6577E-02	-49.9520
15.000	80.000	3.1421E-15	1.0802E-01	6.0444E-11	1.0802E-01	-50.4334
20.000	80.000	4.4367E-15	1.5074E-01	6.9440E-11	1.5074E-01	-51.5265
25.000	80.000	5.6741E-15	1.9084E-01	7.9897E-11	1.9084E-01	-53.3265
30.000	80.000	4.0943E-15	2.2405E-01	9.1667E-11	2.2405E-01	-56.0286
35.000	80.000	5.3660E-15	2.4640E-01	1.0430E-10	2.4640E-01	-59.9795
40.000	80.000	6.3584E-15	2.5520E-01	1.1701E-10	2.5520E-01	-65.7733
45.000	80.000	2.5895E-15	2.5050E-01	1.2869E-10	2.5050E-01	-74.3916
50.000	80.000	3.1735E-15	2.3734E-01	1.3797E-10	2.3734E-01	-87.2402
55.000	80.000	1.7798E-15	2.2751E-01	1.4334E-10	2.2751E-01	-105.3279
60.000	80.000	2.2315E-15	2.3577E-01	1.4334E-10	2.3577E-01	-126.6769
65.000	80.000	2.3604E-15	2.6595E-01	1.3671E-10	2.6595E-01	-146.0572
70.000	80.000	1.6012E-15	3.0380E-01	1.2267E-10	3.0380E-01	-160.4761
75.000	80.000	1.7841E-15	3.2613E-01	1.0104E-10	3.2613E-01	-170.6016
80.000	80.000	1.3184E-16	3.0742E-01	7.2398E-11	3.0742E-01	-178.1313
85.000	80.000	6.7132E-16	2.1664E-01	3.8057E-11	2.1664E-01	175.2460
90.000	80.000	5.0965E-25	1.8267E-11	2.2872E-21	1.8267E-11	-12.7633
.0	90.000	2.3936E-15	3.0859E-22	6.0467E-11	6.0467E-11	-116.2122
5.000	90.000	4.0945E-15	2.9790E-02	4.7144E-11	2.9790E-02	-50.0526
10.000	90.000	5.1182E-15	6.6817E-02	5.3791E-11	6.6817E-02	-49.9312
15.000	90.000	4.2855E-15	1.0850E-01	6.1595E-11	1.0850E-01	-50.4073
20.000	90.000	4.0762E-15	1.5150E-01	7.0795E-11	1.5150E-01	-51.4956
25.000	90.000	4.2422E-15	1.9183E-01	8.1474E-11	1.9183E-01	-53.2905
30.000	90.000	5.7732E-15	2.2522E-01	9.3479E-11	2.2522E-01	-55.9863
35.000	90.000	6.6790E-15	2.4764E-01	1.0635E-10	2.4764E-01	-59.9291
40.000	90.000	7.7557E-15	2.5638E-01	1.1927E-10	2.5638E-01	-65.7118
45.000	90.000	3.6621E-15	2.5152E-01	1.3113E-10	2.5152E-01	-74.3155
50.000	90.000	2.6820E-15	2.3811E-01	1.4053E-10	2.3811E-01	-87.1485
55.000	90.000	5.0096E-15	2.2799E-01	1.4593E-10	2.2799E-01	-105.2309
60.000	90.000	1.6012E-15	2.3600E-01	1.4585E-10	2.3600E-01	-126.5998
65.000	90.000	2.3604E-15	2.6602E-01	1.3904E-10	2.6602E-01	-146.0137
70.000	90.000	3.2024E-15	3.0377E-01	1.2471E-10	3.0377E-01	-160.4581
75.000	90.000	1.8453E-15	3.2603E-01	1.0269E-10	3.2603E-01	-170.5975
80.000	90.000	8.9207E-16	3.0727E-01	7.3556E-11	3.0727E-01	-178.1341
85.000	90.000	6.6844E-16	2.1651E-01	3.8659E-11	2.1651E-01	175.2402

1 2 MONOPOLES 5/8 WAVELENGTH -- 1/3 WAVELENGTH APART -- EXAMPLE 2

DIELECTRIC CONSTANT = 1.5000E+01 AND CONDUCTIVITY = 1.0000E-02 FOR FAR FIELD CALCULATIONS.

OBSERVATION ANGLES		ELECTRIC FIELD				
THETA	PHI	R-COMPONENT	THETA-COMPONENT	PHI-COMPONENT	MAGNITUDE	PHASE
90.000	90.000	3.5213E-27	1.0255E-11	2.3236E-21	1.0255E-11	-12.7637

Figure 16. Far Field Radiation Pattern for Two Monopoles, $\beta = 45°$, Example 2

Example 3 - Top Loaded Monopole - As a third example we will model the antenna shown in Figure 17. This antenna, used for LORAN-C, has a high degree or rotational symmetry. It also has an element on the axis of rotational symmetry and a multiple junction of elements. We will model this antenna over a radial wire ground screen, and compute the electric field from one of the top-loaded radials to ground for a normalized input power of 1 watt.

The input data deck for this antenna shown in Figure 18 is similar to those of the previous examples, however, the following points should be noted.

Card 2: We select a ground screen, near field and normalization of input power.

Card 3: The input frequency of this antenna is 100 kHz, and the ground media parameters are needed.

Card 4 —— 30 are used to describe the antenna. Note that the NCON1 value of all the top-load radials is given a value of -1000 to designate that it is a multiple junction of wires and that the NCON2 value of each top load radial is 0 since they are unconnected. A catenary model is used to specify the physical droop of the wires, and thus a wire weight of 1.586 pounds/metre and a wire tension of 1000 pounds is specified. The last element specified is the tower which is on the axis of symmetry and note that its base is grounded, so that NCON1 of the tower element is 97 and NCON2 of the tower is -1000 since it connects with the top-load radials.

Card 31: Specifies the structure symmetry. Note that 24 sectors of rotational symmetry actually exist on this structure, but since the program limits the user to 12 sectors, two top load radials are included in each of the 12 allowed sectors. Four segments are used for each radial load, and four segments are used for the tower, so NP = 8 and NX = 4. The total number of segments used equals 100, which is the limit of this version of WAMP.

Card 32: Specifies that the base segment, Number 97, of the monopole is driven, and card 33 specifies that 180 radials of #8 AWG wire are used for the ground screen.

Card 34: is the last card, and it specifies that we want to compute the near field from the ground up to the vicinity of one of the top-load radials. 41 points will be evaluated along the path between the two points, and the electric field tangent to the path will be integrated to give the potential between the two end points.

The complete data deck is shown in Figure 18 and the computed results are shown in Figure 19.

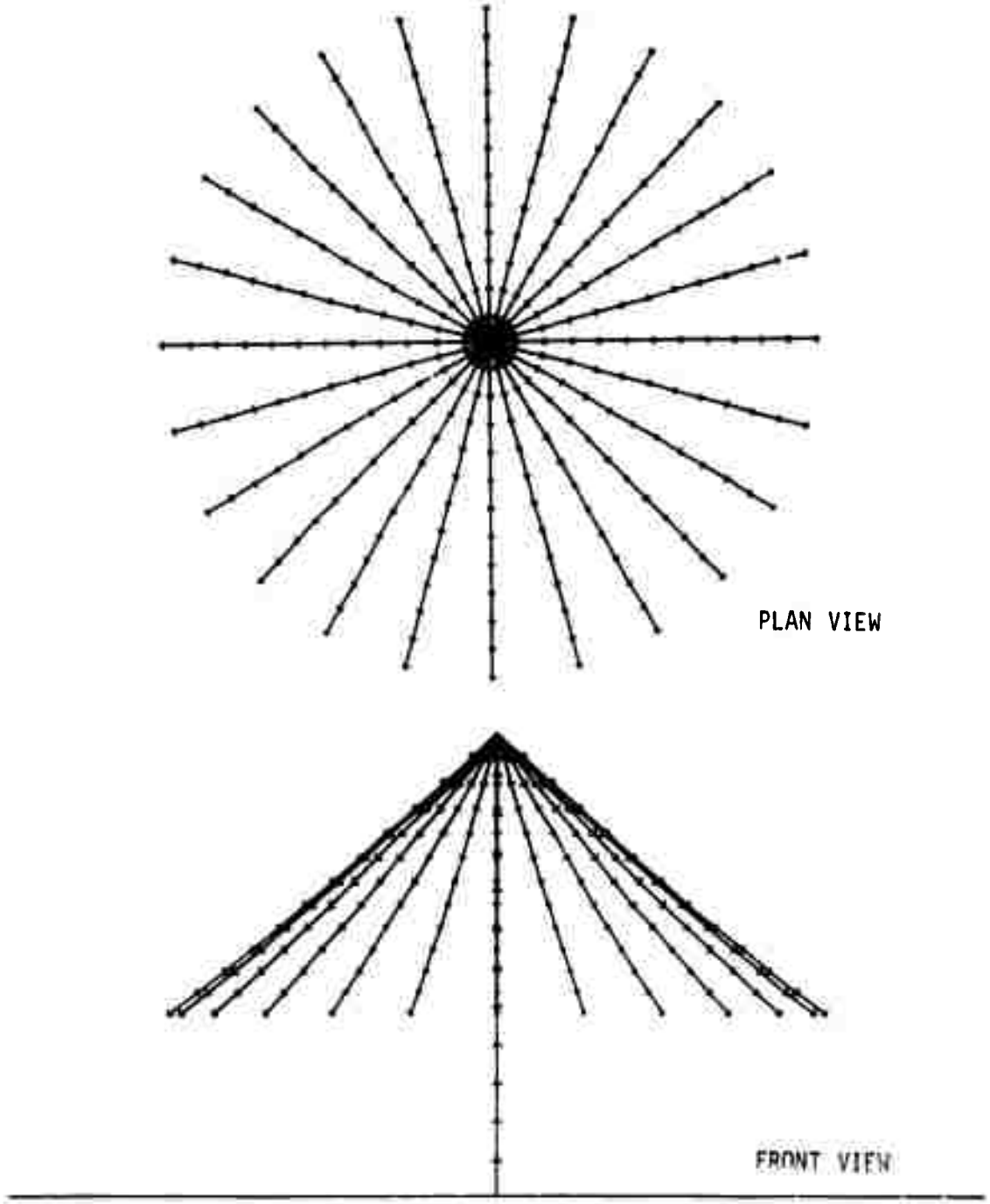


Figure 17. Computer Drawn Model of U. S. Coast Guard Top Loaded Monopole (Note: More segments are shown than actually used in example.)

```
USCG TOP LOADED MONOPOLE ANTENNA -- EXAMPLE 3
   1     0     0     1     1     0     1
  .00010          0.     1     2          15.          .01
       .0          .0 192.94    -1000 140.21                .0  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000 135.43587  36.29681  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000 121.42163  70.10009  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000  99.14901  99.14923  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000 70.079982 121.42179  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000  36.29651 135.43595  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000   -.00031 140.21     75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000 -36.29711 135.43579  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000 -70.10036 121.42148  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000 -99.14945  99.14879  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000-121.42194 70.079955  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000-135.43603  36.29621  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000-140.21       -.00062  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000-135.43571 -36.29741  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000-121.42132 -70.10053  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000 -99.14857 -99.14967  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000 -70.07992 -121.4221  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000 -36.29591-135.43611  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000     .00093-140.21     75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000  36.29771-135.43563  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000  70.10089-121.42117  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000  99.14969 -99.14835  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000 121.42225 -70.07990  75.90        0
   4     .00914      1.586 1000.0              0.
       .0          .0 192.94    -1000 135.43619 -36.29561  75.90        0
   4     .00914      1.586 1000.0              0.
      0.          0.          0.   97          0.          0.    192.94-1000
  -4      .3048       0.          0.          0.
   8     4
  97         1.        0.     0
 180      .00163
    140.3          0.          0.       140.3          0.       75.85   40    0
```

Figure 18. Data Deck for Example 3.

```
!*****************************

 WIRE ANTENNA MODELING PROGRAM

 *****************************


  USCG TOP LOADED MONOPOLE ANTENNA -- EXAMPLE 3

    1    0    0    1    1    0    1

 FREQUENCY              =  1 00000E-04
 FREQUENCY INCREMENT    =         0E+00
 NO. FREQUENCY STEPS    =  1
 WAVELENGTH (METERS)    =  2 99793E+03


 GROUND PLANE AT Z = 0
 DIELECTRIC CONSTANT    =  1 50000E+01
 CONDUCTIVITY           =  1 00000E-02



 DATA GENERATOR INPUT DATA CARDS

       .0        .0 192.94000-1000 140 21000          0  75.90000    0
    4   .00914    1 586001000 00000          0
       0         .0 192 94000-1000 135 43587  36 29681  75.90000    0
    4   .00914    1.586001000 00000          0
       .0         0 192 94000-1000 121.42163  70 10009  75.90000    0
    4   .00914    1 586001000 00000          0
       .0        .0 192 94000-1000  99.14901  99 14923  75.90000    0
    4   .00914    1.586001000 00000          .0
       .0         0 192 94000-1000  70 07998 121 42179  75.90000    0
    4   .00914    1.586001000.00000          0
       .0         0 192.94000-1000  36.29651 135 43595  75.90000    0
    4   .00914    1 586001000 00000          0
       .0        .0 192.94000-1000   - 00031 140 21000  75 90000    0
    4   .00914    1 586001000.00000          0
       .0        .0 192.94000-1000 -36 29711 135 43579  75 90000    0
    4   .00914    1.586001000 00000          0
       .0        .0 192 94000-1000 -70.10036 12  42148  75.90000    0
    4   .00914    1.586001000 00000          0
       0         .0 192.94000-1000 -99 14945  99 14879  75 90000    0
    4   .00914    1.586001000 00000          0
       .0        .0 192.94000-1000-121 42194  70 07996  75.90000    0
    4   .00914    1 586001000.00000          0
       .0        .0 192 94000-1000-135 43603  36 29621  75 90000    0
    4   .00914    1 586001000 00000          0
       0         0 192.94000-1000-140 21000      00062  75 90000    0
    4    00914    1.586001000 00000          0
       0         .0 192 94000-1000-135 43571  36 29741  75 90000    0
    4   .00914    1.586001000 00000          0
       .0        .0 192 94000-1000-121 42132  70 10063  75 90000    0
    4   .00914    1.586001000.00000          0
       .0         0 192 94000-1000 -99 14857 -99 14967  75 90000    0
    4    00914    1.586001000.00000          0
       0         .0 192.94000-1000 -70 07992-121 42210  75 90000    0
    4   .00914    1.586001000 00000          0
       .0         0 192.94000-1000 -36 29591-135 43611  75 90000    0
    4   .00914    1.586001000 00000          0
       .0         0 192 94000-1000      00093-140 21000  75 90000    0
    4   .00914    1.586001000 00000          0
       .0         0 192.94000-1000  36 29771-135 43563  75 90000    0
    4    00914    1.586001000 00000          0
       0         0 192.94000-1000  70 10089-121 42117  75 90000    0
    4    00914    1.586001000 00000          0
      .0        .0 192.94000-1000  99 14989 -99 14835  75 90000    0
    4   .00914    1.586001000 00000          0
      .0        .0 192 94000-1000 121 42225 -70 07990  75 90000    0
    4   .00914    1.586001000 00000          0
      .0        .0 192.94000-1000 135 43619 -36 29561  75.90000    0
    4   .00914    1 586001000 00000          0
      .0        .0          0   97          0          0 192 94000-1000
   -4   .30480          0          0          0


 NUMBER OF SEGMENTS     = 100
 NO. SEG. IN A SECTOR   =   0
 NO. SEG. ON AXIS OF ROTATION =    4
```

I STRUCTURE GEOMETRY (DIMENSIONS IN WAVELENGTHS)

COORDINATES OF SEG. CENTER			SEG.	WIRE	ORIENTATION ANGLES		CONNECTION DATA		
X	Y	Z	LENGTH	RADIUS	ALPHA	BETA	I-	I	I+
.00585	.0	.05099	.01587	.00000305	-42.556	0	-1000	1	2
.01754	.0	.04858	.01544	.00000305	-40.779	0	1	2	3
.02923	.0	.03882	.01502	.00000305	-38.902	0	2	3	4
.04092	.0	.02971	.01462	.00000305	-36.920	0	3	4	0
.00585	.00151	.05099	.01587	.00000305	-42.555	15.003	-1000	5	6
.01694	.00454	.04858	.01544	.00000305	-40.778	15.003	5	6	7
.02824	.00757	.03882	.01502	.00000305	-38.901	15.003	6	7	8
.03953	.01059	.02971	.01463	.00000305	-36.918	15.003	7	8	0
.00506	.00292	.05099	.01587	.00000305	-42.557	29.999	-1000	9	10
.01519	.00877	.04858	.01544	.00000305	-40.780	29.999	9	10	11
.02531	.01461	.03882	.01502	.00000305	-38.903	29.999	10	11	12
.03544	.02046	.02971	.01462	.00000305	-36.921	29.999	11	12	0
.00413	.00413	.05099	.01587	.00000305	-42.555	45.000	-1000	13	14
.01240	.01240	.04858	.01544	.00000305	-40.778	45.000	13	14	15
.02067	.02067	.03882	.01502	.00000305	-38.900	45.000	14	15	16
.02894	.02894	.02971	.01463	.00000305	-36.918	45.000	15	16	0
.00292	.00506	.05099	.01587	.00000305	-42.559	60.008	-1000	17	18
.00877	.01519	.04858	.01544	.00000305	-40.782	60.008	17	18	19
.01461	.02531	.03882	.01502	.00000305	-38.905	60.008	18	19	20
.02045	.03544	.02971	.01462	.00000305	-36.923	60.008	19	20	0
.00151	.00585	.05099	.01587	.00000305	-42.555	74.997	-1000	21	22
.00454	.01694	.04858	.01544	.00000305	-40.778	74.997	21	22	23
.00757	.02824	.03882	.01502	.00000305	-38.901	74.997	22	23	24
.01059	.03953	.02971	.01463	.00000305	-36.918	74.997	23	24	0
-.00000	.00585	.05099	.01587	.00000305	-42.556	90.000	-1000	25	26
-.00000	.01754	.04858	.01544	.00000305	-40.779	90.000	25	26	27
-.00000	.02923	.03882	.01502	.00000305	-38.902	90.000	26	27	28
-.00000	.04092	.02971	.01462	.00000305	-36.920	90.000	27	28	0
-.00151	.00585	.05099	.01587	.00000305	-42.555	105.003	-1000	29	30
-.00454	.01694	.04858	.01544	.00000305	-40.778	105.003	29	30	31
-.00757	.02824	.03882	.01502	.00000305	-38.901	105.003	30	31	32
-.01059	.03953	.02971	.01463	.00000305	-36.918	105.003	31	32	0
-.00292	.00506	.05099	.01587	.00000305	-42.557	119.999	-1000	33	34
-.00877	.01519	.04858	.01544	.00000305	-40.780	119.999	33	34	35
-.01461	.02531	.03882	.01502	.00000305	-38.903	119.999	34	35	36
-.02046	.03544	.02971	.01462	.00000305	-36.921	119.999	35	36	0
-.00413	.00413	.05099	.01587	.00000305	-42.555	135.000	-1000	37	38
-.01240	.01240	.04858	.01544	.00000305	-40.778	135.000	37	38	39
-.02067	.02067	.03882	.01502	.00000305	-38.900	135.000	38	39	40
-.02894	.02894	.02971	.01463	.00000305	-36.918	135.000	39	40	0
-.00506	.00292	.05099	.01587	.00000305	-42.559	150.008	-1000	41	42
-.01519	.00877	.04858	.01544	.00000305	-40.782	150.008	41	42	43
-.02531	.01461	.03882	.01502	.00000305	-38.905	150.008	42	43	44
-.03544	.02045	.02971	.01462	.00000305	-36.923	150.008	43	44	0
-.00585	.00151	.05099	.01587	.00000305	-42.555	164.998	-1000	45	46

I STRUCTURE GEOMETRY (DIMENSIONS IN WAVELENGTHS)

COORDINATES OF SEG. CENTER			SEG.	WIRE	ORIENTATION ANGLES		CONNECTION DATA		
X	Y	Z	LENGTH	RADIUS	ALPHA	BETA	I-	I	I+
-.01694	.00454	.04858	.01544	.00000305	-40.778	164.998	45	46	47
-.02824	.00757	.03882	.01502	.00000305	-38.901	164.998	46	47	48
-.03953	.01059	.02971	.01463	.00000305	-36.918	164.998	47	48	0
-.00585	-.00000	.05899	.01587	.00000305	-42.556	-180.000	-1000	49	50
-.01754	-.00000	.04858	.01544	.00000305	40.779	-180.000	49	50	51
-.02923	-.00000	.03882	.01502	.00000305	38.902	-180.000	50	51	52
-.04092	-.00000	.02971	.01462	.00000305	36.920	180.000	51	52	0
-.00565	-.00151	.05899	.01587	.00000305	-42.555	164.997	-1000	53	54
-.01694	-.00454	.04858	.01544	.00000305	40.778	164.997	53	54	55
-.02824	-.00757	.03882	.01502	.00000305	38.901	164.997	54	55	56
-.03953	-.01059	.02971	.01463	.00000305	36.918	164.997	55	56	0
-.00506	-.00292	.05899	.01587	.00000305	42.557	150.001	-1000	57	58
-.01519	-.00877	.04858	.01544	.00000305	40.780	150.001	57	58	59
-.02531	-.01461	.03882	.01502	.00000305	38.903	150.001	58	59	60
-.03544	-.02046	.02971	.01462	.00000305	36.921	150.001	59	60	0
-.00413	-.00413	.05899	.01587	.00000305	42.555	135.000	1000	61	62
-.01240	-.01240	.04858	.01544	.00000305	40.778	-135.000	61	62	63
-.02067	-.02067	.03882	.01502	.00000305	38.900	-135.000	62	63	64
-.02894	-.02894	.02971	.01463	.00000305	36.918	135.000	63	64	0
-.00292	-.00506	.05899	.01587	.00000305	-42.559	119.992	-1000	65	66
-.00877	-.01519	.04858	.01544	.00000305	40.782	-119.992	65	66	67
-.01461	-.02531	.03882	.01502	.00000305	38.905	-119.992	66	67	68
-.02046	-.03544	.02971	.01462	.00000305	36.923	-119.992	67	68	0
-.00151	-.00565	.05899	.01587	.00000305	-42.555	105.002	-1000	69	70
-.00454	-.01694	.04858	.01544	.00000305	40.778	-105.002	69	70	71
-.00757	-.02824	.03882	.01502	.00000305	38.901	-105.002	70	71	72
-.01059	-.03953	.02971	.01463	.00000305	-36.918	-105.002	71	72	0
.00000	-.00585	.05899	.01587	.00000305	-42.556	-90.000	-1000	73	74
.00000	-.01754	.04858	.01544	.00000305	-40.779	-90.000	73	74	75
.00000	-.02923	.03882	.01502	.00000305	-38.902	-90.000	74	75	76
.00000	-.04092	.02971	.01462	.00000305	-36.920	-90.000	75	76	0
.00151	-.00565	.05899	.01587	.00000305	-42.555	-74.997	-1000	77	78
.00454	-.01694	.04858	.01544	.00000305	40.778	-74.997	77	78	79
.00757	-.02824	.03882	.01502	.00000305	-38.901	-74.997	78	79	80
.01059	-.03953	.02971	.01463	.00000305	-36.918	-74.997	79	80	0
.00292	-.00506	.05899	.01587	.00000305	42.557	60.001	1000	81	82
.00877	-.01519	.04858	.01544	.00000305	-40.780	-60.001	81	82	83
.01461	-.02531	.03882	.01502	.00000305	-38.903	-60.001	82	83	84
.02046	-.03544	.02971	.01462	.00000305	-36.921	-60.001	83	84	0
.00413	-.00413	.05899	.01587	.00000305	-42.555	-45.000	-1000	85	86
.01240	-.01240	.04858	.01544	.00000305	-40.778	-45.000	85	86	87
.02067	-.02067	.03882	.01502	.00000305	-38.900	-45.000	86	87	88
.02894	-.02894	.02971	.01463	.00000305	-36.918	-45.000	87	88	0
.00506	-.00292	.05899	.01587	.00000305	-42.559	-29.992	-1000	89	90
.01519	-.00877	.04858	.01544	.00000305	-40.782	-29.992	89	90	91

```
 STRUCTURE GEOMETRY  (DIMENSIONS IN WAVELENGTHS)

  COORDINATES OF SEG. CENTER      SEG.       WIRE    ORIENTATION ANGLES    CONNECTION DATA
     X          Y          Z     LENGTH     RADIUS      ALPHA       BETA     I-     I    I+
   .02531    -.01461    .03882    .01502  .00000305    -38.905    -29.982    90    91    92
   .03544    -.02045    .02871    .01462  .00000305    -38.923    -29.982    91    92     0
   .00585    -.00151    .05098    .01587  .00000305    -42.555    -15.002 -1000    93    94
   .01894    -.00454    .04058    .01544  .00000305    -40.778    -15.002    93    94    95
   .02824    -.00757    .03882    .01502  .00000305    -38.901    -15.002    94    95    96
   .03853    -.01059    .02871    .01463  .00000305    -36.918    -15.002    95    96     0
  -.00000          .0    .00804    .01609  .00010167     90.000          .0    97    97    98
  -.00000          .0    .02413    .01609  .00010167     90.000          .0    97    98    99
  -.00000          .0    .04022    .01609  .00010167     90.000          .0    98    99   100
  -.00000          .0    .05631    .01609  .00010167     90.000          .0    99   100 -1000

 TOTAL WIRE LENGTH     = 1.52746229115E+00

 ANTENNA SOURCE DISTRIBUTIONS
   SEG.          VOLTAGE
   NO.      MAG.         PHASE
   97    1.00000           .0     0


 A RADIAL GROUND SCREEN OF    180 RADIALS WITH A WIRE RADIUS OF    5.4371E-07 WAVELENGTH WAS USED.



 SEGMENT EXCITATION (VOLTS/WAVELENGTH)
 SEG NUMBER    REAL PART     IMAGINARY PART

    97        -6.215E+01         -.0E+00
```

ISEG. NO.	CURRENT - REAL	IMAGINARY	MAGNITUDE	PHASE
1	7.6227E-04	3.5172E-03	3.59982600E-03	77 772
2	6.3462E-04	2.9566E-03	3.02391799E-03	77.885
3	4.4515E-04	2.0931E-03	2 13989524E-03	77 993
4	1.7951E-04	8.5059E-04	8.69322332E-04	78.083
5	7.6233E-04	3.5174E-03	3.59909304E-03	77 772
6	6.3467E-04	2.9568E-03	3 0241287 4E-03	77 885
7	4.4518E-04	2.0932E-03	2.14003639E-03	77 993
8	1.7953E-04	8.5064E-04	8.69382102E-04	78 083
9	7.6227E-04	3.5172E-03	3.59982600E-03	77 772
10	6.3462E-04	2.9566E-03	3.02391799E-03	77 885
11	4.4515E-04	2.0931E-03	2 13989524E-03	77 993
12	1.7951E-04	8.5059E-04	8 69322332E-04	78 083
13	7.6233E-04	3.5174E-03	3.59909304E-03	77 772
14	6.3467E-04	2.9568E-03	3 0241287 4E-03	77 885
15	4.4518E-04	2.0932E-03	2 14003639E-03	77 993
16	1.7953E-04	8.5064E-04	8 69382102E-04	78.083
17	7.6227E-04	3 5172E-03	3 59982600E-03	77 772
18	6.3462E-04	2 9566E-03	3 02391799E-03	77 885
19	4.4515E-04	2 0931E-03	2.13989524E-03	77 993
20	1.7951E-04	8.5059E-04	8.69322332E-04	78 083
21	7.6233E-04	3 5174E-03	3.59909304E-03	77 772
22	6.3467E-04	2 9568E-03	3.02412874E-03	77 885
23	4.4518E-04	2.0932E-03	2 14003639E-03	77 993
24	1.7953E-04	8 5064E-04	8.69382102E-04	78 083
25	7.6227E-04	3 5172E-03	3 59982600E-03	77 772
26	6.3462E-04	2.9566E-03	3 02391799E-03	77 885
27	4.4515E-04	2.0931E-03	2 13989524E-03	77 993
28	1.7951E-04	8.5059E-04	8 69322332E-04	78.083
29	7.6233E-04	3.5174E-03	3.59909304E-03	77 772
30	6.3467E-04	2.9568E-03	3.02412874E-03	77 885
31	4.4518E-04	2.0932E-03	2 14003639E-03	77 993
32	1.7953E-04	8.5064E-04	8.69382102E-04	78 083
33	7.6227E-04	3.5172E-03	3.59982600E-03	77 772
34	6.3462E-04	2.9566E-03	3 02391799E-03	77 885
35	4.4515E-04	2.0931E-03	2 13989524E-03	77 993
36	1.7951E-04	8.5059E-04	8.69322332E-04	78 083
37	7.6233E-04	3.5174E-03	3 59909304E-03	77 772
38	6.3467E-04	2 9568E-03	3.02412874E-03	77 885
39	4.4518E-04	2.0932E-03	2 14003639E-03	77 993
40	1.7953E-04	8.5064E-04	8.69382102E-04	78 083
41	7.6227E-04	3.5172E-03	3 59982600E-03	77 772
42	6.3462E-04	2.9566E-03	3 02391799E-03	77 885
43	4.4515E-04	2.0931E-03	2 13989524E-03	77 993
44	1.7951E-04	8.5059E-04	8 69322332E-04	78 083
45	7 6233E-04	3.5174E-03	3 59909304E-03	77 772

SEG NO.	CURRENT - REAL	IMAGINARY	MAGNITUDE	PHASE
51	4.4515E-04	2.0931E-03	2.13989524E-03	77.993
52	1.7951E-04	8.5059E-04	8.69322332E-04	78.083
53	7.6233E-04	3.5174E-03	3.59909304E-03	77.772
54	6.3467E-04	2.9568E-03	3.02412874E-03	77.885
55	4.4518E-04	2 0932E-03	2.14003639E-03	77.993
56	1.7953E-04	8.5064E-04	8.69382102E-04	78.083
57	7.6227E-04	3.5172E-03	3 59982600E-03	77.772
58	6.3462E-04	2.9566E-03	3.02391799E-03	77.885
59	4.4515E-04	2.0931E-03	2.13989524E-03	77.993
60	1.7951E-04	8.5059E-04	8.69322332E-04	78.083
61	7.6233E-04	3 5174E-03	3.59909304E-03	77.772
62	6.3467E-04	2.9568E-03	3 0241287 4E-03	77.885
63	4 4518E-04	2.0932E-03	2.14003639E-03	77.993
64	1.7953E-04	8.5064E-04	8.69382102E-04	78.083
65	7.6227E-04	3.5172E-03	3.59982600E-03	77.772
66	6 3462E-04	2.9566E-03	3.02391799E-03	77.885
67	4 4515E-04	2 0931E-03	2.13989524E-03	77.993
68	1 7951E-04	8.5059E-04	8.69322332E-04	78.083
69	7 6233E-04	3.5174E-03	3 59909304E-03	77.772
70	6.3467E-04	2 9568E-03	3 0241287 4E-03	77.885
71	4.4518E-04	2 0932E-03	2 14003639E-03	77.993
72	1.7953E-04	8 5064E-04	8.69382102E-04	78.083
73	7 6227E-04	3.5172E-03	3.59982600E-03	77.772
74	6 3462E-04	2 9566E-03	3.02391799E-03	77.885
75	4 4515E-04	2 0931E-03	2.13989524E-03	77.993
76	1 7951E-04	8.5059E-04	8.69322332E-04	78.083
77	7 6233E-04	3.5174E-03	3.59909304E-03	77.772
78	6.3467E-04	2.9568E-03	3.02412874E-03	77.885
79	4 4518E-04	2 0932E-03	2.14003639E-03	77.993
80	1.7953E-04	8.5064E-04	8.69382102E-04	78.083
81	7.6227E-04	3 5172E-03	3.59982600E-03	77.772
82	6 3462E-04	2 9566E-03	3.02391799E-03	77.885
83	4 4515E-04	2.0931E-03	2.13989524E-03	77.993
84	1 7951E-04	8.5059E-04	8 69322332E-04	78.083
85	7 6233E-04	3 5174E-03	3.59909304E-03	77.772
86	6.3467E-04	2.9568 -03	3.02412874E-03	77.885
87	4.4518E-04	2.0932E-03	2.14003639E-03	77.993
88	1.7953E-04	8.5064E-04	8.69382102E-04	78.083
89	7 6227E-04	3.5172E-03	3.59982600E-03	77.772
90	6.3462E-04	2.9566E-03	3.02391799E-03	77.885
91	4 4515E-04	2 0931E-03	2 13989524E 03	77.993
92	1.7951E-04	8 5059E-04	8 69322332E-04	78.083
93	7 6233E-04	3 5174E-03	3 5990930 4E-03	77.772
94	6.3467E-04	2 9568E-03	3.02412874E-03	77.885
95	4.4518E-04	2 0932E-03	2 14003639E 03	77.993

ISEG NO.	CURRENT - REAL	IMAGINARY	MAGNITUDE	PHASE
46	6.3467E-04	2.9568E-03	3 02412874E-03	77 885
47	4.4518E-04	2.0932E-03	2 14003639E-03	77 993
48	1.7953E-04	8 5064E-04	8 69382102E-04	78 083
49	7 6227E-04	3 5172E-03	3 59982600E-03	77 772
50	6 3462E-04	2 9566E-03	3 02391799E-03	77 885
51	4 4515E-04	2 0931E-03	2 13989524E-03	77 993

SEG NO.	CURRENT - REAL	IMAGINARY	MAGNITUDE	PHASE
96	1.7953E-04	8 5064E-04	8 69382102E-04	78.083
97	1.8351E-02	8 4925E-02	8.68847318E-02	77.806
98	1.8364E-02	8 4784E 02	8 67965522E-02	77.779
99	1 8393E-02	8 4832E-02	8 68025469E-02	77.767
100	1.8422E-02	8 4954E 02	8.69280175E-02	77.785

ADMIT= 1.8351E-02 8 4925E-02 ZPED= 2 4310E+00 -1 1250E+01
8 6885E-02 77 806 1 1510E+01 -77 806

I	AR	AI	BR	BI	CR	CI
1	5.2288E-04	4.6061E-04	-1.2078E-03	-5.5573E-03	2.3939E-04	3.0566E-03
2	-6.3994E-03	-3.1312E-02	-1.6459E-03	-7.3947E-03	7.0340E-03	3.4268E-02
3	-0.7956E-03	-4.3852E-02	-2.4253E-03	-1.1227E-02	9.2407E-03	4.5745E-02
4	-1.4947E-02	-7.3319E-02	-3.5609E-03	-1.6815E-02	1.5126E-02	7.4169E-02
5	5.2181E-04	4.5601E-04	-1.2078E-03	-5.5575E-03	2.4052E-04	3.0614E-03
6	-6.3994E-03	-3.1312E-02	-1.6460E-03	-7.3952E-03	7.0340E-03	3.4268E-02
7	-0.7955E-03	-4.3851E-02	-2.4254E-03	-1.1227E-02	9.2408E-03	4.5744E-02
8	-1.4948E-02	-7.3321E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4172E-02
9	5.2270E-04	4.5978E-04	-1.2078E-03	-5.5574E-03	2.3957E-04	3.0574E-03
10	-6.3997E-03	-3.1313E-02	-1.6459E-03	-7.3949E-03	7.0343E-03	3.4270E-02
11	-0.7960E-03	-4.3854E-02	-2.4253E-03	-1.1227E-02	9.2411E-03	4.5747E-02
12	-1.4948E-02	-7.3322E-02	-3.5610E-03	-1.6816E-02	1.5127E-02	7.4172E-02
13	5.2189E-04	4.5640E-04	-1.2079E-03	-5.5575E-03	2.4043E-04	3.0610E-03
14	-6.3992E-03	-3.1311E-02	-1.6460E-03	-7.3951E-03	7.0339E-03	3.4268E-02
15	-0.7953E-03	-4.3850E-02	-2.4254E-03	-1.1227E-02	9.2404E-03	4.5743E-02
16	-1.4947E-02	-7.3320E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4170E-02
17	5.2240E-04	4.5834E-04	-1.2079E-03	-5.5576E-03	2.3987E-04	3.0588E-03
18	-6.4003E-03	-3.1316E-02	-1.6460E-03	-7.3952E-03	7.0349E-03	3.4273E-02
19	-0.7967E-03	-4.3857E-02	-2.4254E-03	-1.1227E-02	9.2418E-03	4.5750E-02
20	-1.4948E-02	-7.3320E-02	-3.5612E-03	-1.6816E-02	1.5128E-02	7.4170E-02
21	5.2181E-04	4.5601E-04	-1.2079E-03	-5.5575E-03	2.4052E-04	3.0614E-03
22	-6.3994E-03	-3.1312E-02	-1.6460E-03	-7.3952E-03	7.0340E-03	3.4269E-02
23	-0.7955E-03	-4.3851E-02	-2.4254E-03	-1.1227E-02	9.2406E-03	4.5744E-02
24	-1.4948E-02	-7.3321E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4172E-02
25	5.2288E-04	4.6061E-04	-1.2078E-03	-5.5573E-03	2.3939E-04	3.0566E-03
26	-6.3994E-03	-3.1312E-02	-1.6459E-03	-7.3947E-03	7.0340E-03	3.4268E-02
27	-0.7956E-03	-4.3852E-02	-2.4253E-03	-1.1227E-02	9.2407E-03	4.5745E-02
28	-1.4947E-02	-7.3319E-02	-3.5609E-03	-1.6815E-02	1.5126E-02	7.4169E-02
29	5.2181E-04	4.5601E-04	-1.2079E-03	-5.5575E-03	2.4052E-04	3.0614E-03
30	-6.3994E-03	-3.1312E-02	-1.6460E-03	-7.3952E-03	7.0340E-03	3.4269E-02
31	-0.7955E-03	-4.3851E-02	-2.4254E-03	-1.1227E-02	9.2406E-03	4.5744E-02
32	-1.4948E-02	-7.3321E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4172E-02
33	5.2270E-04	4.5978E-04	-1.2078E-03	-5.5574E-03	2.3957E-04	3.0574E-03
34	-6.3997E-03	-3.1313E-02	-1.6459E-03	-7.3949E-03	7.0343E-03	3.4270E-02
35	-0.7960E-03	-4.3854E-02	-2.4253E-03	-1.1227E-02	9.2411E-03	4.5747E-02
36	-1.4948E-02	-7.3322E-02	-3.5610E-03	-1.6816E-02	1.5127E-02	7.4172E-02
37	5.2189E-04	4.5640E-04	-1.2079E-03	-5.5575E-03	2.4043E-04	3.0610E-03
38	-6.3992E-03	-3.1311E-02	-1.6460E-03	-7.3951E-03	7.0339E-03	3.4268E-02
39	-0.7953E-03	-4.3850E-02	-2.4254E-03	-1.1227E-02	9.2404E-03	4.5743E-02
40	-1.4947E-02	-7.3320E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4170E-02
41	5.2240E-04	4.5836E-04	-1.2079E-03	-5.5576E-03	2.3987E-04	3.0588E-03
42	-6.4003E-03	-3.1316E-02	-1.6460E-03	-7.3952E-03	7.0349E-03	3.4273E-02
43	-0.7967E-03	-4.3857E-02	-2.4254E-03	-1.1227E-02	9.2418E-03	4.5750E-02
44	-1.4948E-02	-7.3320E-02	-3.5612E-03	-1.6816E-02	1.5128E-02	7.4170E-02
45	5.2181E-04	4.5601E-04	-1.2079E-03	-5.5575E-03	2.4052E-04	3.0614E-03
46	-6.3994E-03	-3.1312E-02	-1.6460E-03	-7.3952E-03	7.0340E-03	3.4269E-02
47	-0.7955E-03	-4.3851E-02	-2.4254E-03	-1.1227E-02	9.2406E-03	4.5744E-02
48	-1.4948E-02	-7.3321E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4172E-02
49	5.2288E-04	4.6061E-04	-1.2078E-03	-5.5573E-03	2.3939E-04	3.0566E-03
50	-6.3994E-03	-3.1312E-02	-1.6459E-03	-7.3947E-03	7.0340E-03	3.4268E-02
51	-0.7956E-03	-4.3852E-02	-2.4253E-03	-1.1227E-02	9.2407E-03	4.5745E-02
52	-1.4947E-02	-7.3319E-02	-3.5609E-03	-1.6815E-02	1.5126E-02	7.4169E-02
53	5.2181E-04	4.5601E-04	-1.2079E-03	-5.5575E-03	2.4052E-04	3.0614E-03
54	-6.3994E-03	-3.1312E-02	-1.6460E-03	-7.3952E-03	7.0340E-03	3.4269E-02
55	-0.7955E-03	-4.3851E-02	-2.4254E-03	-1.1227E-02	9.2406E-03	4.5744E-02
56	-1.4948E-02	-7.3321E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4172E-02
57	5.2270E-04	4.5978E-04	-1.2078E-03	-5.5574E-03	2.3957E-04	3.0574E-03
58	-6.3997E-03	-3.1313E-02	-1.6459E-03	-7.3949E-03	7.0343E-03	3.4270E-02
59	-0.7960E-03	-4.3854E-02	-2.4253E-03	-1.1227E-02	9.2411E-03	4.5747E-02
60	-1.4948E-02	-7.3322E-02	-3.5610E-03	-1.6816E-02	1.5127E-02	7.4172E-02
61	5.2189E-04	4.5840E-04	-1.2079E-03	-5.5575E-03	2.4043E-04	3.0610E-03
62	-6.3992E-03	-3.1311E-02	-1.6460E-03	-7.3951E-03	7.0339E-03	3.4268E-02
63	-0.7953E-03	-4.3850E-02	-2.4254E-03	-1.1227E-02	9.2404E-03	4.5743E-02

64	-1.4947E-02	-7.3320E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4170E-02
65	5.2241E-04	4.5838E-04	-1.2879E-03	-5.5576E-03	2.3886E-04	3.0588E-03
66	-6.4003E-03	-3.1316E-02	-1.6460E-03	-7.3952E-03	7.0349E-03	3.4273E-02
67	-8.7967E-03	-4.3657E-02	-2.4254E-03	-1.1227E-02	9.2418E-03	4.5750E-02
68	-1.4949E-02	-7.3327E-02	-3.5612E-03	-1.6816E-02	1.5128E-02	7.4178E-02
69	5.2181E-04	4.5801E-04	-1.2879E-03	-5.5575E-03	2.4052E-04	3.0614E-03
70	-6.3994E-03	-3.1312E-02	-1.6460E-03	-7.3952E-03	7.0340E-03	3.4269E-02
71	-8.7955E-03	-4.3651E-02	-2.4254E-03	-1.1227E-02	9.2406E-03	4.5744E-02
72	-1.4948E-02	-7.3321E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4172E-02
73	5.2288E-04	4.6061E-04	-1.2878E-03	-5.5573E-03	2.3939E-04	3.0566E-03
74	-6.3994E-03	-3.1312E-02	-1.6459E-03	-7.3947E-03	7.0340E-03	3.4268E-02
75	-8.7956E-03	-4.3652E-02	-2.4253E-03	-1.1227E-02	9.2407E-03	4.5745E-02
76	-1.4947E-02	-7.3319E-02	-3.5609E-03	-1.6815E-02	1.5126E-02	7.4169E-02
77	5.2181E-04	4.5801E-04	-1.2879E-03	-5.5575E-03	2.4052E-04	3.0614E-03
78	-6.3994E-03	-3.1312E-02	-1.6460E-03	-7.3952E-03	7.0340E-03	3.4269E-02
79	-8.7955E-03	-4.3651E-02	-2.4254E-03	-1.1227E-02	9.2406E-03	4.5744E-02
80	-1.4948E-02	-7.3321E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4172E-02
81	5.2270E-04	4.5978E-04	-1.2878E-03	-5.5574E-03	2.3957E-04	3.0574E-03
82	-6.3997E-03	-3.1313E-02	-1.6459E-03	-7.3949E-03	7.0343E-03	3.4270E-02
83	-8.7960E-03	-4.3654E-02	-2.4253E-03	-1.1227E-02	9.2411E-03	4.5747E-02
84	-1.4948E-02	-7.3322E-02	-3.5610E-03	-1.6816E-02	1.5127E-02	7.4172E-02
85	5.2188E-04	4.5840E-04	-1.2879E-03	-5.5575E-03	2.4043E-04	3.0610E-03
86	-6.3992E-03	-3.1311E-02	-1.6460E-03	-7.3951E-03	7.0339E-03	3.4268E-02
87	-8.7953E-03	-4.3650E-02	-2.4254E-03	-1.1227E-02	9.2404E-03	4.5743E-02
88	-1.4947E-02	-7.3320E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4170E-02
89	5.2241E-04	4.5840E-04	-1.2879E-03	-5.5576E-03	2.3886E-04	3.0588E-03
90	-6.4003E-03	-3.1316E-02	-1.6460E-03	-7.3952E-03	7.0349E-03	3.4273E-02
91	-8.7967E-03	-4.3657E-02	-2.4254E-03	-1.1227E-02	9.2418E-03	4.5750E-02
92	-1.4949E-02	-7.3327E-02	-3.5612E-03	-1.6816E-02	1.5128E-02	7.4178E-02
93	5.2181E-04	4.5801E-04	-1.2879E-03	-5.5575E-03	2.4052E-04	3.0614E-03
94	-6.3994E-03	-3.1312E-02	-1.6460E-03	-7.3952E-03	7.0340E-03	3.4269E-02
95	-8.7955E-03	-4.3651E-02	-2.4254E-03	-1.1227E-02	9.2406E-03	4.5744E-02
96	-1.4948E-02	-7.3321E-02	-3.5611E-03	-1.6816E-02	1.5127E-02	7.4172E-02
97	1.9552E-02	7.1130E-02	6.0744E-05	-6.9786E-04	-1.2007E-03	1.3795E-02
98	2.0033E-02	1.0326E-01	2.0595E-04	-4.6118E-04	-1.6696E-03	-1.0473E-02
99	1.0392E-02	9.2104E-02	2.9034E-04	8.4128E-04	1.3485E-06	-7.2728E-03
100	2.9727E-03	1.9711E-02	-4.9131E-04	-2.0914E-03	1.5449E-02	6.5243E-02

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   VOLTAGE TO DRIVE ANTENNA AT 1-WATT =      10.43954

     ALL FIELDS ARE NORMALIZED TO THIS INPUT POWER

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1 E-FIELD FROM 140.3000 .0 .0 METERS TO 140.3000 .0 75.0500 METERS

POSITION ON PATH (METERS)	E-TANGENT (V/M)	TOTAL E-FIELD (V/M)
.0E+00	5.17051E-01	5.20094E-01
1.88625E+00	5.20804E-01	5.23061E-01
3.79250E+00	5.24430E-01	5.26110E-01
5.68875E+00	5.27996E-01	5.29327E-01
7.58500E+00	5.31554E-01	5.32740E-01
9.48125E+00	5.35146E-01	5.36400E-01
1.13775E+01	5.38810E-01	5.40344E-01
1.32737E+01	5.42576E-01	5.44606E-01
1.51700E+01	5.46474E-01	5.49214E-01
1.70662E+01	5.50520E-01	5.54200E-01
1.89625E+01	5.54765E-01	5.59591E-01
2.08587E+01	5.59209E-01	5.65418E-01
2.27550E 01	5.63884E-01	5 71710E-01
2.46512E+01	5.68817E-01	5.78500E 01
2.65475E+01	5.74035E-01	5.85824E-01
2.84437E+01	5.79568E-01	5.93721E-01
3.03400E+01	5.85449E-01	6.02234E-01
3.22362E+01	5.91715E-01	6.11413E-01
3.41325E+01	5.98411E-01	6.21318E-01
3.60287E+01	6.05586E-01	6.32014E-01
3.79250E+01	6.13302E-01	6.43583E-01
3.98212E+01	6.21634E-01	6 56124E-01
4.17175E+01	6.30674E-01	6.69753E-01
4.36137E+01	6.40538E-01	6.84621E-01
4.55100E+01	6.51377E-01	7.00915E-01
4.74062E+01	6.63388E-01	7.18876E-01
4.93025E+01	6.76832E-01	7.38820E-01
5.11987E+01	6.92068E-01	7.61171E-01
5.30950E+01	7.09592E-01	7.86505E-01
5.49912E+01	7.30105E-01	8.15627E-01
5.68875E+01	7.54607E-01	8.49663E-01
5.87837E+01	7.84644E-01	8.90360E-01
6.06800E+01	8.22537E-01	9.40301E-01
6.25762E+01	8.72026E-01	1.00364E+00
6.44725E+01	9 39431E-01	1.08740E+00
6.63687E+01	1.03620E+00	1.20430E+00
6.82650E+01	1.18535E+00	1.38004E+00
7.01612E+01	1.44027E+00	1.67458E+00
7.20575E+01	1.95912E+00	2.26672E+00
7.39537E+01	3.50338E+00	4.02825E+00
7.58500E+01	3.44369E+01	6.31509E+01

THE INTEGRAL OF THE E-FLD TANGENT TO THE PATH IS 9.10214E+01 VOLTS. 41 POINTS USED TO EVALUATE INTEGRAL.

VI. MODELING GUIDELINES AND SPECIAL CALCULATIONS

Experience with the WAMP antenna modeling program has proven the old adage that "Garbage in equals garbage out" is applicable. If care in setting up the numerical model is not taken, completely erroneously results may be realized. In this section, I will try to cover a few important modeling rules which can help to achieve good numerical results. It is always important to carefully question numerical results for reasonability, and if possible, compare with experimental data.

Segmentation - Often the key to a good numerical model lies in the segmentation of the physical structure. Miller, et al. (1971) established some fundamental segmentation guidelines for a variety of structures. Typically, at least six segments per wavelength must be used for reasonable accuracy. At the other extreme, one must not over segment a structure such that "pancake" segments are formed --- this violates the thin-wire approximations.

Multiple junctions and segment length discontinuities, particularly in regions near sources, can lead to troubles. A good rule of thumb is to make all segments at a multiple wire junction of equal length. (Often times this is difficult to achieve when a limited number of segments are available due to computer core-size limitations and execution times.)

The data generator in the WAMP code has a provision for modeling elements with variable length segments. The factor TAU, read in by the DATAGN allows for an exponential increase or decrease in segment length on an element. For an element of N segments, the segment lengths vary by the relation (30):

$$L_i = L_0(1 + \tau)^{(i-1)} \tag{30}$$

If we know the initial length we need, L_0, the total length of the element, L, and the number of segments available to model the element, N, Table I of Appendix B can be used to find the proper value of TAU.

Miller and Deadrick (1973) have studied in greater detail the consequences of segment length discontinuities and the possible remedies available to achieve good numerical impedance data. These techniques, i.e. accurate near field integrations, however, are expensive in terms of computer times, and should be avoided whenever possible.

Near Field Anomalies - the near electric field subroutine in the WAMP code has been thoroughly checked and found to give good, consistent, numerical results. If one evaluates the near field at the surface of the wire segements, however, large field perturbations may be found near segment ends. These field perturbations are due to segment

current discontinuities at segment junctions; a result of the current interpolation method used WAMP. Care should be exercised in interpreting near field results in these regions, particularly if you are trying to evaluate the voltage across a gap region used to model an insulator.

Horizontal Elements Near the Interface - The reflection coefficient approach used to model structures in the vicinity of an imperfectly conducting halfspace has been found (Miller, et al. (1972)) to give stable numerical results for horizontal structures whose height above the interface is greater than 0.1 wavelength. Below this height, the results may become invalid to the point of producing negative input impedances. Long horizontal elements of several wavelengths near the interface can exhibit growing currents. One approximation which has proven to "cure" some of the above limitations has been to fix the angle of incidence of the reflected wave to $\pi/2$. This may be accomplished by setting the variable CTH = 1.0 in the subroutine CMSETUP.

Radial Wire Ground Screen Model - The model used to simulate a radial wire ground screen is relatively simple in form in this program. (A radially varying screen impedance is modeled in parallel with the normal ground plane wave impedance.) The results with this model are quite good, except for vertical structures located at the center of the radial system. In this case the screen appears to the program as a perfect ground, and other techniques, i.e., application of the compensation theorem, (Maley, et al, 1963) must be employed.

Special Calculations - The WAMP code may be used to compute many antenna parameters which often times are difficult to experimentally measure. Listed below are some of the procedures required to compute some of these special quantities.

Bandwidth-Efficiency - The bandwidth efficiency product is of interest to the designers of pulsed Loran systems. Equation (31) defines this parameter

$$\eta_{BW} = \frac{2R_r}{\frac{dx}{df} + \frac{|x|}{f}} \qquad (31)$$

where R_r is the antenna radiation resistance and X and $\frac{dx}{df}$ are the reactance and rate of change of reactance at a frequency f. A calculation of this quantity is easily performed by determining the input resistance and reactance for the antenna over a perfect ground (no losses in ground), and then computing the input reactance for two different frequencies to compute $\Delta X/\Delta f$.

Insulator Modeling - Often times it is necessary to access the potential across support insulators to estimate breakdown problems. Several ways have been found to model insulators. One can impedance load a segment with a very high value of resistance, solve for the segment current and compute an IR drop across the segment. Another technique is to model the insulator as a physical gap and use the near field routine to integrate the fields across the gap. This technique has been found to give somewhat high results, while if you take the E-field at the center of the gap and multiply it by the gap length, you can get a lower bound estimate. These techniques allow an estimation of the insulator voltage drops. One can either reference the drops to a 1 volt input, or normalize the antenna power to 1 watt. See Miller and Deadrick (1973) for more details on insulator modeling.

Corona Discharge Assessment - By using the near-field subroutine to follow a path along the surface of the antenna wire, one may examine the potential for corona discharge. The coordinates of the field evaluation path should be displaced a wire radius away, and sufficient points should be evaluated to resolve the segment end near field discontinuities mentioned above. Again, the fields may be referenced to a 1 volt input source or normalized to a 1 watt input.

Catenary Model - A special feature of the DATAGN subroutine in this program is the inclusion of a catenary model to account for the drop in long length wires used in some of the large LORAN antennas. The catenary curve is modeled by a series of straight line segments which approximate the catenary curve of the form shown in Figure 20.

Number of Segments Limitation

This version of WAMP is designed to operate specifically on the CDC 3300 hardware configuration for the U. S. Coast Guard headquarters in Washington, D. C., and as such, limits have been placed on the number of segments which may be used to model an antenna structure. A total of 100 segments may be used, and in one sector of symmetry, only 22 segments may be used. This means that if no structure symmetry is employed, only 22 segments are allowed. The number of segments in one sector of symmetry plus the number of segments on the axis of symmetry must be less than or equal to 22. The program allows up to 12 sectors of rotational symmetry maximum. To illustrate this point, see example 3.

In order to adapt this program to larger machines, one must increase the size of the arrays and also check to see that the error checking limits in the MAIN program are modified accordingly. The structure array; CM (N,N) is a complex element array, and as such uses two floating point variables for each entry. It is the primary user of core in this program. The EINC array and the P array of common block /2/ are the excitation vector to the system, and an array of pivotals respectively used by the factor and solve routines.

EQUATION OF CATENARY:

$$Z=Z_2 - (X_2-X)[W/2T\ (X-X_1) + (Z_2-Z_1)/(X_2-X_1)]$$

W=WIRE WEIGHT/M
T=WIRE TENSION

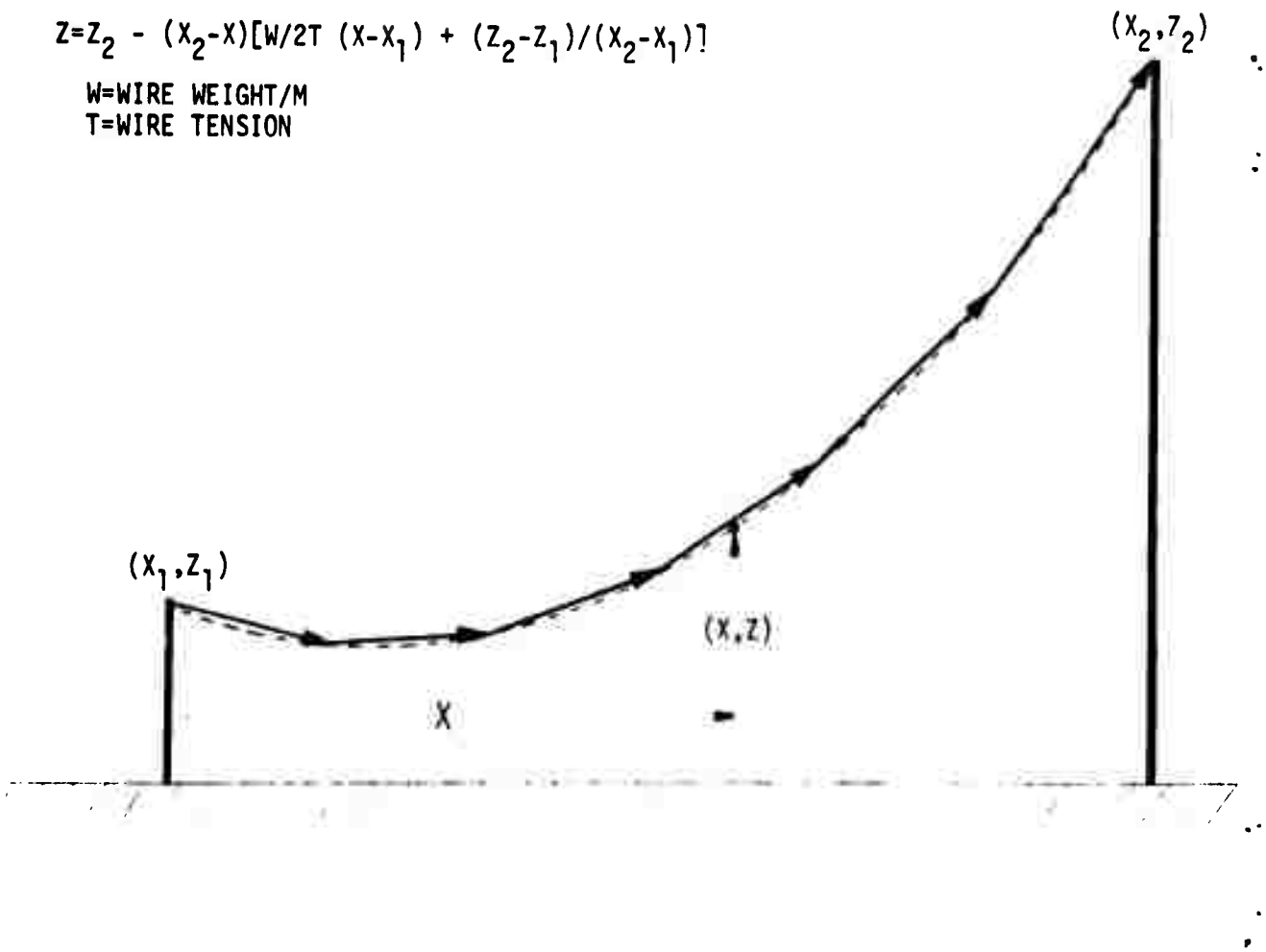

Figure 20. Catenary Element Modeled by Subroutine DATAGN.

Common block /1/ contains the physical description of the structure in terms of wavelength dimensions and direction angles, plus the electrical interconnection data.

Common block /3/ contains the direction cosines for each of the N segments.

Common block /4/ is used to hold data on multiple junctions set up by subroutine TRIO and JUNC. Presently, the program limits multiple junctions to 25 segments at a point, however, this is easily expanded.

Common block /SCRATM/ is used as a temporary scratch location by the factor and solve routines, and should be set by the size of the CM matrix.

Common block /SMAT/ is a square scratch matrix used by the symmetric factor and solve routines. Its dimensions are of the order of the number of symmetric sectors allowed, i.e., 12 x 12 in this version.

Dimensioned variables, CURR, CURI, ZLR, ZLI, ZLC, AIR, AII, BIR, BII, CIR, CII in the main program and NEFLD subroutine must also be expanded to the appropriate size of the maximum structure allowed.

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APPENDIX A WAMP PROGRAM LISTING

```
      PROGRAM WAMP                                                          A   1
C                                                                           A   2
      INTEGER P                                                             A   3
      COMPLEX ZRATI,ADMIT,ZPED,RRV,RRH,ZRSIN,RRD,ERX,ERY,ERZ,EPX,EPY        A   4
      COMPLEX CM,FJ,EINC,EXA,CIX,CIY,CIZ,ERC                               A   5
      DIMENSION CURR(100), CURI(100), ZLR(22), ZLI(22), ZLC(22), COM(10)    A   6
      DIMENSION THETR(5), PHYR(5), ETAR(5), DTHR(5), DPHR(5), NTHR(5), N    A   7
     1PHR(5)                                                                A   8
      DIMENSION AIR(100), AII(100), BIR(100), BII(100), CIR( 00), CII(10    A   9
     10)                                                                    A  10
      DIMENSION ISEG(13), ENCR(12), ENCI(12)                                A  11
      DIMENSION CME(2,22,100)                                               A  12
      COMMON /1/ N,NP,X(100),Y(100),Z(100),S(100),BI(100),ALP(100),BET(     A  13
     1100),ICON1(100),ICON2(100),COLAM,NX                                   A  14
      COMMON /2/ CM(22,100),EINC(100),P(100)                                A  15
      COMMON /3/ CAB(100),SAB(100),SALP(100)                                A  16
      COMMON /4/ NCOX,JOX(25),NCIX,JIX(25),NCOZ,JOZ(25),NCIZ,JIZ(25)        A  17
      EQUIVALENCE (CM,CME)                                                  A  18
      NROW=22                                                               A  19
      NCOL=100                                                              A  20
      NRPAGE=45                                                             A  21
      FJ=CMPLX(0.,1.)                                                       A  22
      ZZ=376.72727                                                          A  23
      PI=3.14159265                                                         A  24
      TP=2.*PI                                                              A  25
      TA=.0174532925                                                        A  26
      TD=57.29577951                                                        A  27
      CONST=ZZ/(2.*TP)                                                      A  28
C                                                                           A  29
C     **********RUN COMMENTS**********                                      A  30
C                                                                           A  31
C     READ IN 1ST DATA CARD--80 COLUMNS OF RUN COMMENTS                     A  32
C                                                                           A  33
 1    READ (60,68) (COM(I),I=1,10)                                          A  34
      IF (EOF,60) 65,2                                                      A  35
C                                                                           A  36
C     **********RUN OPTIONS**********                                      A  37
C     READ 2ND DATA CARD TO SELECT RUN OPTIONS                              A  38
C       NPRINT = SELECTS LEVEL OF DIAGNOSTIC PRINTOUTS:  0 TO 2             A  39
C       ILOAD  = SELECTS LOADED ELEMENT OPTION. =0 FOR NO LOAD, =1 LOAD     A  40
C       IPGND  = SELECTS A PERFECT GROUND FOR IPGND = 1, = 0 FOR FINITE     A  41
C       IGSCRN = SELECTS A RADIAL GROUND SCREEN OPTION IN CMSETUP           A  42
C       INEAR  = SELECTS NEAR-FIELD CALCULATION IF = 1, = 0 FOR NO CALC     A  43
C       IFAR   = SELECTS FAR-FIELD CALCULATION IF = 1, = 0 FOR NO CALC      A  44
C       NPWR   = A,B,C CURRENTS AND FIELD CALC ARE NORMALIZED TO 1 WATT     A  45
C                                                                           A  46
 2    READ (60,69) NPRINT,ILOAD,IPGND,IGSCRN,INEAR,IFAR,NPWR                A  47
C                                                                           A  48
C     **********FREQUENCY AND GROUND**********                            A  49
C                                                                           A  50
C     READ IN 3RD DATA CARD                                                 A  51
C       GHZ    = ANTENNA FREQUENCY IN GIGA-HERTZ                          A  52
C       GR     = DELTA-FREQ IN GHZ IF NFS  GT 1 -- FREQ = GHZ + GR STEPS  A  53
C       NFS    = NUMBER OF FREQUENCY STEPS TO CALC--GREATER OR = 1         A  54
C       KSYMP  = FREE SPACE ANTENNA = 1, OVER GROUND = 2                   A  55
C       EPSR   = RELATIVE DIELECTRIC CONSTANT OF GROUND                    A  56
C       SIG    = CONDUCTIVITY OF GROUND -- MHOS/METER                      A  57
C                                                                           A  58
      READ (60,70) GHZ,GR,NFS,KSYMP,EPSR,SIG                               A  59
      COLAM=0.299793/GHZ                                                    A  60
      IF (KSYMP.EQ.2) GO TO 3                                               A  61
      EPSR=1.                                                               A  62
      SIG=0.                                                                A  63
      KSYMP=1                                                               A  64
```

```
  3   WRITE (61,71)                                                          A  65
      WRITE (61,72)                                                          A  66
      WRITE (61,73)                                                          A  67
      WRITE (61,74) (CON(I),I=1,10)                                          A  68
      WRITE (61,69) NPRINT,ILOAD,IPGND,IOSCRN,INEAR,IFAR,NPWR                A  69
      WRITE (61,75) GHZ,GR,NFS,COLAM                                         A  70
      IF (IPGND.EQ.1) WRITE (61,103)                                         A  71
      IF (KSYMP.EQ.2.AND.IPGND.EQ.0) WRITE (61,76) EPSR,SIG                  A  72
      IF (KSYMP.EQ.1) WRITE (61,66)                                          A  73
C                                                                            A  74
C     BEFORE READING IN MORE DATA CARDS IN THE MAIN PROGRAM, CALL THE        A  75
C     DATA GENERATOR TO FILL UP THE GEOMETRY ARRAYS -- THE DATAGN            A  76
C     WILL REQUIRE THE NEXT-N-DATA CARDS--SEE THE APPROPRIATE DATA GN        A  77
C     SUBROUTINE FOR ADDITIONAL DETAILS.                                     A  78
C                                                                            A  79
C                                                                            A  80
      CALL DATAGN                                                            A  81
C                                                                            A  82
C     **********STRUCTURE SYMMETRY**********                                 A  83
C                                                                            A  84
C     NEXT READ IN NP AND NX TO SET UP SYMMETRY CALCULATIONS                 A  85
C     NP=NUMBER OF SEGMENTS IN A ROTATIONALLY SYMMETRIC SECTION              A  86
C     NX=NUMBER OF SEGMENTS ON THE AXIS OF ROTATION                          A  87
C     NOTE THAT THE PROGRAM WILL WORK IF NP=N AND NX=0                       A  88
C                                                                            A  89
      READ (60,69) NP,NX                                                     A  90
      WRITE (61,77) N,NP,NX                                                  A  91
      NSIZE=NP+NX                                                            A  92
      NCOLSYM=N NX                                                           A  93
C                                                                            A  94
C     IF NSIZE IS GREATER THAN 22, TOO MANY SEGMENTS PER SECTOR ARE USED     A  95
C     AND IERR=1.                                                            A  96
C                                                                            A  97
      IF (NSIZE.LE.22) GO TO 4                                               A  98
      IERR=1                                                                 A  99
      GO TO 64                                                               A 100
  4   IP=NRPAGE                                                              A 101
      SLEN=0.                                                                A 102
      DO 8 I=1,N                                                             A 103
      IF (NPRINT+1) 7,5,5                                                    A 104
  5   AP=ALP(I)*TD                                                           A 105
      BT=BET(I)*TD                                                           A 106
      IP=IP+1                                                                A 107
      IF (IP.LE.NRPAGE) GO TO 6                                              A 108
      WRITE (61,78)                                                          A 109
      IP=1                                                                   A 110
  6   WRITE (61,79) X(I),Y(I),Z(I),S(I),B(I),AP,BT,ICON1(I),I,ICON2(I)       A 111
  7   ALPI=ALP(I)                                                            A 112
      BETI=BET(I)                                                            A 113
      CALP=COS(ALPI)                                                         A 114
      SALP(I)=SIN(ALPI)                                                      A 115
      CAB(I)=CALP*COS(BETI)                                                  A 116
      SAB(I)=CALP*SIN(BETI)                                                  A 117
      SLEN=SLEN+S(I)                                                         A 118
      IF (S(I).GT.0.0) GO TO 8                                               A 119
      WRITE (61,80) I                                                        A 120
      STOP                                                                   A 121
  8   CONTINUE                                                               A 122
      WRITE (61,81) SLEN                                                     A 123
      ISEG(13)=0                                                             A 124
      DO 9 K=1,12                                                            A 125
      ISEG(K)=0                                                              A 126
      ENCR(K)=0.0                                                            A 127
  9   ENCI(K)=0.0                                                            A 128
```

```
      IM=0                                                              A 129
      WRITE (61,82)                                                     A 130
C                                                                       A 131
C     **********SOURCE EXCITATION**********                            A 132
C     READ N+5TH DATA CARD FOR THE SOURCE TO DRIVE ANTENNA              A 133
C       IS      = EXCITED SEGMENT NUMBER                                A 134
C       ECM     = MAGNITUDE OF SEGMENT EXCITATION--VOLTS                A 135
C       ECA     = PHASE OF EXCITATION IN DEGREES                        A 136
C       NFLD    = NFLD=1 IF MORE SEGMENTS ARE TO BE EXCITED, =0 TO END  A 137
C     USE 1.0 VOLT AT 0 DEG PHAZE FOR CORRECT INPUT IMPEDANCE CALC      A 138
C     1 TO 12 SEGMENTS MAY BE SIMULTANEOUSLY EXCITED.                   A 139
C                                                                       A 140
 10   READ (60,83) IS,ECM,ECA,NFLD                                      A 141
      WRITE (61,83) IS,ECM,ECA,NFLD                                     A 142
      IF (1.LE.IS.AND.IS.LE.N) GO TO 11                                 A 143
C                                                                       A 144
C     IERR=2 IF SOURCE SEGMENT IS LT 1 OR GREATER THAN NUM OF SEGS USED A 145
C                                                                       A 146
      IERR=2                                                            A 147
      GO TO 64                                                          A 148
 11   K=ISEG(13)+1                                                      A 149
      IF (K.LE.12) GO TO 12                                             A 150
C                                                                       A 151
C     IERR=3 IF TOO MANY SEGMENTS ARE SELECTED FOR SOURCES              A 152
C                                                                       A 153
      IERR=3                                                            A 154
      GO TO 64                                                          A 155
 12   ISEG(13)=K                                                        A 156
      ISEG(K)=IS                                                        A 157
      ECA=ECA*TA                                                        A 158
      ECR(K)=ECM*COS(ECA)                                               A 159
      ECI(K)=ECM*SIN(ECA)                                               A 160
      IF (NFLD.NE.0) GO TO 10                                           A 161
      IF (ILOAD) 13,18,13                                               A 162
 13   DO 14 I=1,NP                                                      A 163
      ZLC(I)=0.0                                                        A 164
      ZLR(I)=0.0                                                        A 165
 14   ZLI(I)=0.0                                                        A 166
C                                                                       A 167
C     **********SEGMENT LOADING**********                              A 168
C     IF ILOAD = 1, THEN READ IN SEGMENT LOAD PARAMETERS                A 169
C       ZR      = RESISTANCE IN OHMS ON EACH OF THE SPECIFIED SEGMENTS  A 170
C       ZI      = INDUCTANCE IN HENRYS ON EACH OF THE SPECIFIED SEGMENTS A 171
C       ZC      = CAPACITANCE IN FARADS ON EACH OF THE SPECIFIED SEGMENTS A 172
C       I1      = LOADS ARE CONNECTED FROM                              A 173
C       I2      = SEGMENTS I1 TO I2 INCLUSIVE                           A 174
C       NFLD    = 1 FOR MORE LOAD CARDS, =0 FOR END OF LOAD INPUT DATA  A 175
C                                                                       A 176
C     NOTE  IF SYMMETRY IS EMPLOYED AND A ROTATIONALLY SYMMETRIC SEGMENT A 177
C     IS LOADED, THEN ALL LIKE SYMMETRIC SEGMENTS WILL ALSO BE LOADED.  A 178
C                                                                       A 179
 15   READ (60,85) ZR,ZI,ZC,I1,I2,NFLD                                  A 180
      IF (I2.EQ.0) I2=I1                                                A 181
      WRITE (61,86) I1,I2,ZR,ZI,ZC                                      A 182
      IF (I2.LT.I1) GO TO 17                                            A 183
      IF (I1.LE.NCOLSYM) I1=MOD(I1,NP)                                  A 184
      IF (I2.LE.NCOLSYM) I2=MOD(I2,NP)                                  A 185
      IF (I1.GT.NCOLSYM) I1=MOD(I1,NCOLSYM)+NP                          A 186
      IF (I2.GT.NCOLSYM) I2=MOD(I2,NCOLSYM)+NP                          A 187
      DO 16 I=I1,I2                                                     A 188
      ZLC(I)=ZLC(I)+ZC                                                  A 189
      ZLR(I)=ZLR(I)+ZR                                                  A 190
 16   ZLI(I)=ZLI(I)+ZI                                                  A 191
 17   CONTINUE                                                          A 192
```

```
      IF (NFLD.NE.0) GO TO 15                                          A 193
C                                                                      A 194
C     **********BEGIN FREQUENCY DO LOOP**********                      A 195
C                                                                      A 196
   10 DO 83 MKS=1,NFS                                                  A 197
      FR=(GHZ+DR)/GHZ                                                  A 198
      IF (MKS.EQ.1) FR=1.                                              A 199
      GHZ=GHZ*FR                                                       A 200
      COLAM=0.299793/GHZ                                               A 201
C                                                                      A 202
C     ZRATI = THE RATIO OF THE HALF-SPACE TO FREE-SPACE PLANE WAVE IMPED A 203
C                                                                      A 204
      ZRATI=CSQRT(1./(EPSR-FJ*SIG*COLAM*59.92))                        A 205
      IF (MKS.EQ.1) GO TO 23                                           A 206
      IF (NPRINT) 20,19,19                                             A 207
   19 WRITE (61,87) GHZ                                                A 208
   20 DO 22 I=1,N                                                      A 209
      X(I)=X(I)*FR                                                     A 210
      Y(I)=Y(I)*FR                                                     A 211
      Z(I)=Z(I)*FR                                                     A 212
      SI(I)=SI(I)*FR                                                   A 213
      B(I)=B(I)*FR                                                     A 214
      IF (NPRINT) 22,21,21                                             A 215
   21 WRITE (61,87) X(I),Y(I),Z(I),SI(I),B(I)                          A 216
   22 CONTINUE                                                         A 217
   23 CONTINUE                                                         A 218
C                                                                      A 219
C     CMSETUP IS USED TO SET UP THE COMPLEX IMPEDANCE MATRIX           A 220
C                                                                      A 221
      CALL CMSETUP (ZRATI,KSYMP,IPGND,IGSCRN)                          A 222
C                                                                      A 223
C     NOW ADD IN THE IMPEDANCE LOADING ON THE SELF TERMS.              A 224
C                                                                      A 225
      IF (ILOAD.EQ.0) GO TO 25                                         A 226
      DO 24 I=1,NSIZE                                                  A 227
      J=I                                                              A 228
      IF (I.GT.NP) J=NCOLSYM+I-NP                                      A 229
      IF (ZLC(I) GT.0) CM(I,J)=CM(I,J)+FJ/(TP*GHZ*1 E+9*ZLC(I)*SI(I))  A 230

   24 CM(I,J)=CM(I,J)-ZLR(I)/SI(I)-FJ*TP*GHZ*1 E+9*ZL(I)/SI(I)         A 231
   25 IF (NPRINT-1) 28,28,26                                           A 232
   26 CONTINUE                                                         A 233
      DO 27 I=1,NSIZE                                                  A 234
   27 WRITE (61,88) I,((CM(KAY,I,J),KAY=1,2),J=1,N)                    A 235
C                                                                      A 236
C     **********SOLUTION OF THE MATRIX EQUATION**********              A 237
C                                                                      A 238
   28 CONTINUE                                                         A 239
C                                                                      A 240
C     FACTOR THE IMPEDANCE MATRIX                                      A 241
C                                                                      A 242
C                                                                      A 243
C     NOP=NUMBER OF SYMETRIC SECTIONS--MUST BE .LE. 12                 A 244
C                                                                      A 245
      NOP=(N-NX)/NP                                                    A 246
      CALL FACTRS (NP,NOP,NX,CM,P,NROW,NCOL,1)                         A 247
C                                                                      A 248
C     SET UP THE EXCITATION SOURCE VECTOR - ANY OF THE N SEGMENTS MAY  A 249
C     BE EXCITED.                                                      A 250
C                                                                      A 251
      DO 29 I=1,N                                                      A 252
   29 EINC(I)=CMPLX(0 .0 )                                             A 253
      ISEGL=ISEG(13)                                                   A 254
      DO 30 I=1,ISEGL                                                  A 255
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      IS=ISEG(I)                                                        A 256
   30 EINC(IS)=-CMPLX(ENCR(I),ENCI(I))/SI(IS)                           A 257
      IF (NPRINT.LT.0) GO TO 32                                         A 258
      WRITE (61,90)                                                     A 259
      DO 31 IP=1,N                                                      A 260
      X1=REAL(EINC(IP))                                                 A 261
      X2=AIMAG(EINC(IP))                                                A 262
      IF (X1.NE.0 .OR.X2.NE.0.) WRITE (61,89) IP,X1,X2                  A 263
   31 CONTINUE                                                          A 264
   32 CONTINUE                                                          A 265
C                                                                       A 266
C     SOLVE THE SYSTEM OF EQUATIONS FOR SEGMENT CURRENTS---THE EINC     A 267
C       ARRAY IS THE EXCITING SOURCE MATRIX TO THE SOLVE SUBROUTINE     A 268
C       AND THE CURRENTS ARE RETURNED FROM SOLVE IN THIS ARRAY.         A 269
C          CURI = INV(CM) * EINC)                                       A 270
C                                                                       A 271
      CALL SOLVECS (NP,NOP,NX,CM,P,EINC,NROW,NCOL)                      A 272
C                                                                       A 273
C     THE SEGMENT CURRENTS ARE RETURNED THROUGH THE EINC ARRAY          A 274
C                                                                       A 275
      DO 33 I=1,N                                                       A 276
      CURR(I)=REAL(EINC(I))                                             A 277
   33 CURI(I)=AIMAG(EINC(I))                                            A 278
      NHALF=(N+1)/2                                                     A 279
      IP=NRPAGE                                                         A 280
      DO 34 I=1,N                                                       A 281
      J=I+NHALF                                                         A 282
      IP=IP+1                                                           A 283
      CMAG=SQRT(CURR(I)*CURR(I)+CURI(I)*CURI(I))                        A 284
      PH=TD*AATAN2(CURI(I),CURR(I))                                     A 285
      IF (J.GT.N) GO TO 35                                              A 286
      CMAGP=SQRT(CURR(J)*CURR(J)+CURI(J)*CURI(J))                       A 287
      PHP=TD*AATAN2(CURI(J),CURR(J))                                    A 288
      IF (IP.LE.NRPAGE) GO TO 34                                        A 289
      WRITE (61,91)                                                     A 290
      IP=1                                                              A 291
   34 WRITE (61,92) I,CURR(I),CURI(I),CMAG,PH,J,CURR(J),CURI(J),CMAGP,PH A 292
     IP                                                                 A 293
   35 WRITE (61,92) I,CURR(I),CURI(I),CMAG,PH                           A 294
C                                                                       A 295
C     IF MORE THAN 1 SEGMENT IS EXCITED, AN INPUT IMPEDANCE IS NOT CALC A 296
C                                                                       A 297
C     TO OBTAIN THE CORRECT INPUT IMPEDANCE THE ANTENNA SEGMENTS        A 298
C     MUST BE EXCITED WITH A 1.0 VOLT AT 0 DEG PHASE SOURCE.            A 299
C                                                                       A 300
      IF (ISEGL.GT.1) GO TO 36                                          A 301
      ADMIT=CURR(IS)+FJ*CURI(IS)                                        A 302
      ADMAG=CABS(ADMIT)                                                 A 303
      ADFAZ=AATAN2(CURI(IS),CURR(IS))*TD                                A 304
      ZPED=1./ADMIT                                                     A 305
      ZMAG=1./ADMAG                                                     A 306
      ZFAZ=-ADFAZ                                                       A 307
      ADMITR=REAL(ADMIT)                                                A 308
      ADMITI=AIMAG(ADMIT)                                               A 309
      ZPEDR=REAL(ZPED)                                                  A 310
      ZPEDI=AIMAG(ZPED)                                                 A 311
      WRITE (61,93) ADMITR,ADMITI,ZPEDR,ZPEDI,ADMAG,ADFAZ,ZMAG,ZFAZ     A 312
   36 CONTINUE                                                          A 313
      IF (NPRINT.GT.0) WRITE (61,94)                                    A 314
C                                                                       A 315
C     EXPAND THE SOLVED CURRENTS AT SEGMENT CENTERS INTO A CONSTANT PLUS A 316
C      A SINE AND COSINE TERM: I(S) = A + B*SIN(K*S) + C*COS(K*S)       A 317
C                                                                       A 318
      DO 54 I=1,N                                                       A 319
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      CALL TRIO (I,JCO1,JCO2,DIL,DIK)                                    A 320
      S=SI(I)                                                            A 321
      CL=TP*DIL                                                          A 322
      CK=TP*DIK                                                          A 323
      SINL=SIN(CL)                                                       A 324
      COSL=COS(CL)                                                       A 325
      SINK=SIN(CK)                                                       A 326
      COSK=COS(CK)                                                       A 327
      SILK=SIN(CL+CK)                                                    A 328
      CELLO=SINL*SINK-SILK                                               A 329
      IF (JCO1) 37,42,43                                                 A 330
   37 CRLO=0.0                                                           A 331
      CILO=0.0                                                           A 332
      IF (NCIX.LT.1) GO TO 39                                            A 333
      DO 38 K=1,NCIX                                                     A 334
      JIXK=JIX(K)                                                        A 335
      CRLO=CRLO+CURR(JIXK)                                               A 336
   38 CILO=CILO+CURI(JIXK)                                               A 337
   39 CONTINUE                                                           A 338
      IF (NCOX.LT.1) GO TO 41                                            A 339
      DO 40 K=1,NCOX                                                     A 340
      JOXK=JOX(K)                                                        A 341
      CRLO=CRLO-CURR(JOXK)                                               A 342
   40 CILO=CILO-CURI(JOXK)                                               A 343
   41 CONTINUE                                                           A 344
      GO TO 44                                                           A 345
   42 CRLO=0.0                                                           A 346
      CILO=0.0                                                           A 347
      GO TO 44                                                           A 348
   43 CRLO=CURR(JCO1)                                                    A 349
      CILO=CURI(JCO1)                                                    A 350
   44 CRLL=CURR(I)                                                       A 351
      CILL=CURI(I)                                                       A 352
      IF (JCO2) 45,50,51                                                 A 353
   45 CRLY=0.0                                                           A 354
      CILY=0.0                                                           A 355
      IF (NCOZ.LT.1) GO TO 47                                            A 356
      DO 46 K=1,NCOZ                                                     A 357
      JOZK=JOZ(K)                                                        A 358
      CRLY=CRLY+CURR(JOZK)                                               A 359
   46 CILY=CILY+CURI(JOZK)                                               A 360
   47 CONTINUE                                                           A 361
      IF (NCIZ.LT.1) GO TO 49                                            A 362
      DO 48 K=1,NCIZ                                                     A 363
      JIZK=JIZ(K)                                                        A 364
      CRLY=CRLY-CURR(JIZK)                                               A 365
   48 CILY=CILY-CURI(JIZK)                                               A 366
   49 CONTINUE                                                           A 367
      GO TO 52                                                           A 368
   50 CRLY=0.0                                                           A 369
      CILY=0.0                                                           A 370
      GO TO 52                                                           A 371
   51 CRLY=CURR(JCO2)                                                    A 372
      CILY=CURI(JCO2)                                                    A 373
   52 AIR(I)=(CRLO*SINK-CRLL*SILK+CRLY*SINL)/CELLO                       A 374
      AII(I)=(CILO*SINK-CILL*SILK+CILY*SINL)/CELLO                       A 375
      BIR(I)=(CRLO*(COSK-1.)+CRLL*(COSL-COSK)+CRLY*(1.-COSL))/CELLO      A 376
      BII(I)=(CILO*(COSK-1.0)+CILL*(COSL-COSK)+CILY*(1.0-COSL))/CELLO    A 377
      CIR(I)=-(CRLO*SINK-CRLL*(SINL+SINK)+CRLY*SINL)/CELLO               A 378
      CII(I)=-(CILO*SINK-CILL*(SINL+SINK)+CILY*SINL)/CELLO               A 379
      IF (NPRINT) 54,54,53                                               A 380
   53 WRITE (61,95) I,AIR(I),AII(I),BIR(I),BII(I),CIR(I),CII(I)          A 381
   54 CONTINUE                                                           A 382
    C ..............................                                     A 383
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C                                                                       A 384
C     IF NPWR=1  NORMALIZE THE ANTENNA'S INPUT POWER TO A REFERENCE     A 385
C     1-WATT INPUT.                                                     A 386
C                                                                       A 387
C     . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .   A 388
      IF (NPWR.EQ.0) GO TO 57                                           A 389
      PWRSUM=0.                                                         A 390
      DO 55 I=1,ISEGL                                                   A 391
      IEXCIT=ISEG(I)                                                    A 392
      PWR=0.5*REAL((ENCR(I)+FJ*ENCI(I))*(CURR(IEXCIT)-FJ*CURI(IEXCIT))) A 393
      PWRSUM=PWRSUM+PWR                                                 A 394
   55 CONTINUE                                                          A 395
      WATTI=SQRT(1./PWRSUM)                                             A 396
      WRITE (61,96) WATTI                                               A 397
      DO 56 I=1,N                                                       A 398
C                                                                       A 399
C     NORMALIZE THE ANTENNA CURRENTS TO AN EQUIAVLENT 1 WATT DRIVE FOR  A 400
C     FIELD CALCULATIONS.                                               A 401
C                                                                       A 402
      AIR(I)=AIR(I)*WATTI                                               A 403
      AII(I)=AII(I)*WATTI                                               A 404
      BIR(I)=BIR(I)*WATTI                                               A 405
      BII(I)=BII(I)*WATTI                                               A 406
      CIR(I)=CIR(I)*WATTI                                               A 407
      CII(I)=CII(I)*WATTI                                               A 408
   56 CONTINUE                                                          A 409
   57 CONTINUE                                                          A 410
C                                                                       A 411
C     **********NEAR FIELD CALCULATIONS**********                      A 412
C                                                                       A 413
      IF (INEAR.EQ.1) CALL NEFLD (AIR,AII,BIR,BII,CIR,CII,ZRATI,KSYMP)  A 414
C                                                                       A 415
C                                                                       A 416
C     **********FAR FIELD CALCULATIONS**********                       A 417
C                                                                       A 418
      K=0                                                               A 419
      IF (IFAR.EQ.0) GO TO 63                                           A 420
   58 K=K+1                                                             A 421
C                                                                       A 422
C     FAR FIELD INPUT SELECTIONS--UP TO 5 CARDS MAY BE USED             A 423
C       THETR  = INITIAL THETA COORDINATE--DEGREES                      A 424
C       PHYR   = INITIAL PHI COORDINATE--DEGREES                        A 425
C       ETAR   = ETA ANGLE--DEGREES                                     A 426
C       DTHR   = DELTA THETA STEP--DEG                                  A 427
C       DPHR   = DELTA PHI STEP--DEG                                    A 428
C       NTHR   = NUMBER OF THETA STEPS                                  A 429
C       NPHR   = NUMBER OF PHI STEPS                                    A 430
C       NFLD   = =0 IF NO MORE FAR-FIELD CARDS, =1 FOR MORE INPUT       A 431
C       NEWSIG = =1 IF FAR FIELD CALC OVER DIFFERENT MEDIA, =0 IF NOT   A 432
C       SIGFF  = CONDUCTIVITY OF FAR-FIELD MEDIA--MHOS/METER            A 433
C       EPSFF  = RELATIVE DIELECTRIC CONSTANT OF FAR-FIELD MEDIA        A 434
C                                                                       A 435
      READ (60,84) THETR(K),PHYR(K),ETAR(K),DTHR(K),DPHR(K),NTHR(K),NPHR A 436
     1(K),NFLD,NEWSIG,SIGFF,EPSFF                                       A 437
      IF (NFLD.NE.0) GO TO 58                                           A 438
      KMR=K                                                             A 439
      IP=NRPAGE                                                         A 440
      DO 62 KR=1,KMR                                                    A 441
      DPHRK=DPHR(KR)                                                    A 442
      NPHRK=NPHR(KR)                                                    A 443
      THRO=THETR(KR)                                                    A 444
      DTHRK=DTHR(KR)                                                    A 445
      NTHRK=NTHR(KR)                                                    A 446
      SETA=SIN(ETAR(KR)*TA)                                             A 447
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      CETA=COS(ETAR(KR)*TA)                                              A 448
      PHRK=PHYR(KR)-DPHRK                                                A 449
C                                                                        A 450
C     LOOP THROUGH THE PHI ANGLES                                        A 451
C                                                                        A 452
      DO 62 KP=1,NPHRK                                                   A 453
      PHRK=PHRK+DPHRK                                                    A 454
      PHRKA=PHRK*TA                                                      A 455
      SPHI=SIN(PHRKA)                                                    A 456
      CPHI=COS(PHRKA)                                                    A 457
      THRK=THR0-DTHRK                                                    A 458
      PKX=-SPHI                                                          A 459
      PKY=CPHI                                                           A 460
C                                                                        A 461
C     LOOP THROUGH THE THETA ANGLES                                      A 462
C                                                                        A 463
      DO 62 KT=1,NTHRK                                                   A 464
      THRK=THRK+DTHRK                                                    A 465
      THRKA=THRK*TA                                                      A 466
      STHET=SIN(THRKA)                                                   A 467
      ROX=STHET*CPHI                                                     A 468
      ROY=STHET*SPHI                                                     A 469
      ROZ=COS(THRKA)                                                     A 470
      EIXR=CETA*ROZ*CPHI-SETA*SPHI                                       A 471
      EIYR=CETA*ROZ*SPHI+SETA*CPHI                                       A 472
      EIZR=-CETA*STHET                                                   A 473
      IP=IP+1                                                            A 474
      CIX=CMPLX(0.,0.)                                                   A 475
      CIY=CMPLX(0.,0.)                                                   A 476
      CIZ=CMPLX(0.,0.)                                                   A 477
C                                                                        A 478
C     IF YOU WANT TO CALCULATE THE FAR FIELD RADIATION PATTERN OVER A    A 479
C     MEDIA WHICH IS DIFFERENT THAN THE NEAR FIELD, SET NEWSIG=1 AND     A 480
C     READ IN THE NEW GROUND PARAMETERS ON THE FAR-FIELD CARD.           A 481
C                                                                        A 482
      IF (NEWSIG.EQ.1) ZRATI=CSQRT(1./(EPSFF-FJ*SIGFF*COLAM*59.92))     A 483
      ZRSIN=+CSQRT(1.-ZRATI*ZRATI*STHET*STHET                            A 484
      RRV=(ROZ-ZRATI*ZRSIN)/(ROZ+ZRATI*ZRSIN)                            A 485
      RRH=-(ZRATI*ROZ-ZRSIN)/(ZRATI*ROZ+ZRSIN)                           A 486
      RRD=RRH-RRV                                                        A 487
      DO 60 I=1,N                                                        A 488
      CABI=CAB(I)                                                        A 489
      SABI=SAB(I)                                                        A 490
      SALPI=SALP(I)                                                      A 491
      RFL=-1.                                                            A 492
      DO 60 K=1,KSYMP                                                    A 493
      RFL=-RFL                                                           A 494
      ARG=X(I)*ROX+Y(I)*ROY+Z(I)*ROZ*RFL                                 A 495
      CARG=COS(TP*ARG)                                                   A 496
      SARG=SIN(TP*ARG)                                                   A 497
      EXA=CMPLX(CSARG,SARG)                                              A 498
      DODEL=ROX*CABI*ROY*SABI+ROZ*SALPI*RFL                              A 499
      XODEL=CABI-ROX*DODEL                                               A 500
      YODEL=SABI-ROY*DODEL                                               A 501
      ZODEL=SALPI*RFL-ROZ*DODEL                                          A 502
      OMEGA=-DODEL                                                       A 503
      EL=PI*SI(I)                                                        A 504
      SILL=OMEGA*EL                                                      A 505
      TOP=EL+SILL                                                        A 506
      BOT=EL-SILL                                                        A 507
      A=(2.0-OMEGA*OMEGA*EL*EL/3.0)*EL                                   A 508
      IF (ABS(OMEGA).GE.1.E-7) A=2.*SIN(SILL)/OMEGA                      A 509
      TOO=1.0-TOP*TOP/6.0                                                A 510
      IF (ABS(TOP).GE.1.E-9) TOO=SIN(TOP)/TOP                            A 511
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      BOO=1.0-BOT*BOT/6.0                                                A 512
      IF (ABS(BOT).GE.1.E-9) BOO=SIN(BOT)/BOT                            A 513
      B=EL*(BOO-TOO)                                                     A 514
      C=EL*(BOO+TOO)                                                     A 515
      RR=A*AIR(I)+B*BII(I)+C*CIR(I)                                      A 516
      RI=A*AII(I)-B*BIR(I)+C*CII(I)                                      A 517
      RRX=RR*XODEL                                                       A 518
      RRY=RR*YODEL                                                       A 519
      RRZ=RR*ZODEL                                                       A 520
      RIX=RI*XODEL                                                       A 521
      RIY=RI*YODEL                                                       A 522
      RIZ=RI*ZODEL                                                       A 523
      ERX=CMPLX(RRX,RIX)                                                 A 524
      ERY=CMPLX(RRY,RIY)                                                 A 525
      ERZ=CMPLX(RRZ,RIZ)                                                 A 526
      IF (K.NE.2) GO TO 59                                               A 527
      EPY=PKX*ERX+PKY*ERY                                                A 528
      EPX=PKX*EPY                                                        A 529
      EPY=PKY*EPY                                                        A 530
      ERX=-(RRV*ERX+RRD*EPX)                                             A 531
      ERY=-(RRV*ERY+RRD*EPY)                                             A 532
      ERZ=-RRV*ERZ                                                       A 533
   59 CIX=CIX+ERX*EXA                                                    A 534
      CIY=CIY+ERY*EXA                                                    A 535
   60 CIZ=CIZ+ERZ*EXA                                                    A 536
      ERX=CONST*CIX                                                      A 537
      ERY=CONST*CIY                                                      A 538
      ERZ=CONST*CIZ                                                      A 539
      ERC=ERX*EIXR+ERY*EIYR+ERZ*EIZR                                     A 540
      ER=REAL(ERC)                                                       A 541
      EI=AIMAG(ERC)                                                      A 542
      ERAD=CABS(ERX*STHET*CPHI+ERY*STHET*SPHI+ERZ*ROZ)                   A 543
      ETHETA=CABS(ERX*ROZ*CPHI+ERY*ROZ*SPHI-ERZ*STHET)                   A 544
      EPHI=CABS(-ERX*SPHI+ERY*CPHI)                                      A 545
      PHAZE=TD*AATAN2(EI,ER)                                             A 546
      ERMAG=SQRT(ERAD**2+ETHETA**2+EPHI**2)                              A 547
      IF (IP.LE.NRPAGE) GO TO 61                                         A 548
      WRITE (61,97) (COM(I),I=1,10)                                      A 549
      IF (NEWSIG.EQ.1) WRITE (61,98) EPSFF,SIGFF                         A 550
      WRITE (61,99)                                                      A 551
      IP=1                                                               A 552
   61 WRITE (61,100) THRK,PHRK,ERAD,ETHETA,EPHI,ERMAG,PHAZE              A 553
   62 CONTINUE                                                           A 554
   63 CONTINUE                                                           A 555
      GO TO 1                                                            A 556
   64 WRITE (61,101) IERR                                                A 557
   65 CONTINUE                                                           A 558
      STOP                                                               A 559
C                                                                        A 560
C                                                                        A 561
C                                                                        A 562
   66 FORMAT (//33H ANTENNA IS MODELED IN FREE SPACE//)                  A 563
   67 FORMAT (21HI FREQUENCY IN GHZ = ,F12.8,//,6X,4HX(I),6X,4HY(I),6X,4 A 564
     1HZ(I),5X,5HSI(I),5X,5HBI(I))                                       A 565
   68 FORMAT (10A8)                                                      A 566
   69 FORMAT (1815)                                                      A 567
   70 FORMAT (2F10.5,215,2F10.5)                                         A 568
   71 FORMAT (///,30HI**************************)                       A 569
   72 FORMAT (/,30H WIRE ANTENNA MODELING PROGRAM,/)                     A 570
   73 FORMAT (30H **************************)                          A 571
   74 FORMAT (///,1X,10A8/)                                              A 572
   75 FORMAT (/1X,9HFREQUENCY(2X,1H=E13.5/1X,22HFREQUENCY INCREMENT  =E1 A 573
     13.5/1X,22HNO. FREQUENCY STEPS  =I4/1X,22HWAVELENGTH  (METERS) =E13 A 574
     2.5//)                                                              A 575
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 76   FORMAT (1X,22HGROUND PLANE AT Z = 0./1X,22HDIELECTRIC CONSTANT =E   A 576
     113.5/1X,12HCONDUCTIVITY9X,1H=E13.5/)                               A 577
 77   FORMAT (//1X,22HNUMBER OF SEGMENTS   =I4/1X,22HNO. SEG. IN A SECTO  A 578
     1R =I4/,1X,31HNO. SEG. ON AXIS OF ROTATION = ,I4)                   A 579
 78   FORMAT (49H1 STRUCTURE GEOMETRY  (DIMENSIONS IN WAVELENGTHS)//2X,6  A 580
     13HCOORDINATES OF SEG. CENTER     SEG.      WIRE    ORIENTATION AN2  A 581
     22HOLES   CONNECTION DATA  /6X33HX          Y          Z       LENGTH  A 582
     38H    RADIUS     ALPHA      BETA     I-     I    I+     )          A 583
 79   FORMAT (4F10.5,F10.7,2F10.3,3I5)                                    A 584
 80   FORMAT (30H NEGATIVE SEGMENT LENGTH.    I=I5)                       A 585
 81   FORMAT (/23H TOTAL WIRE LENGTH     =E18 11)                         A 586
 82   FORMAT (//29H ANTENNA SOURCE DISTRIBUTIONS/24H   SEG.          VOLTAG  A 587
     1E   /26H   NO.      MAG.       PHASE)                              A 588
 83   FORMAT (I5,2F10.5,I5)                                               A 589
 84   FORMAT (5F10.5,4I5,2F5.1)                                           A 590
 85   FORMAT (3E10.3,3I5)                                                 A 591
 86   FORMAT (9H SEGMENTS,I4,5H THRU,I4,12H LOADED WITH,E10 3,16H OHMS R  A 592
     1ESISTANCE,E10.3,23H HENRIES INDUCTANCE AND,E10 3,20H FARADS CAPACI  A 593
     2TANCE.)                                                            A 594
 87   FORMAT (8F10.5)                                                     A 595
 88   FORMAT (/14,3H I=I3/(1X,10E11 3))                                   A 596
 89   FORMAT (/1X,I5,5X,E11.3,3X,E11.3)                                   A 597
 90   FORMAT (44H1 SEGMENT EXCITATION (VOLTS/WAVELENGTH)      /41H SEG NU  A 598
     1MBER   REAL PART    IMAGINARY PART )                               A 599
 91   FORMAT (5H1SEG.3X,8HCURRENT-,48X,4HSEG 4X,9HCURRENT -/1X,3HNO 5X,4  A 600
     1HREAL.63H          IMAGINARY   MAGNITUDE        PHASE              NO.  A 601
     2     RE43HAL          IMAGINARY    MAGNITUDE      PHASE       )    A 602
 92   FORMAT (1X,I4,E13.4,E12.4,E16.8,F9.3,9X,I4,E13 4,E12 4,E16.8,F9.3)  A 603
 93   FORMAT (4X,8HADMIT=2E12.4,10X,5HZPED=2E12.4/6XE10.4,2XF10.3,18X,E1  A 604
     10.4,2X,F10.3)                                                      A 605
 94   FORMAT (4H1  16X,2HAR10X,2HAI11X,2HBR10X,2HBI11X,2HCR10X,2HCI)      A 606
 95   FORMAT (1X,I4,3(1X,2E12.4))                                         A 607
 96   FORMAT (39H1 * * * * * * * * * * * * * * * * * * * *,//,40H   VOLTAG  A 608
     1E TO DRIVE ANTENNA AT 1-WATT = ,F12 5,//,50H      ALL FIELDS ARE NO  A 609
     2RMALIZED TO THIS INPUT POWER//41H* * * * * * * * * * * * * * * * *  A 610
     3 * * * )                                                           A 611
 97   FORMAT (2H1 ,10A8/)                                                 A 612
 98   FORMAT (22HDIELECTRIC CONSTANT = ,E12 4,20H AND CONDUCTIVITY = ,E1  A 613
     12.4,29H FOR FAR FIELD CALCULATIONS. //)                            A 614
 99   FORMAT (41H  OBSERVATION ANGLES     ELECTRIC FIELD    /4X,5HTHETA,5X  A 615
     1,3HPHI,13X,11HR-COMPONENT,7X,15HTHETA-COMPONENT,6X,13HPHI-COMPONEN  A 616
     2T10X,9HMAGNITUDE,10X,6H PHASE)                                     A 617
100   FORMAT (2(1X,F8.3),12X,4(E12 4,8X),F10 4)                           A 618
101   FORMAT (17H STOP   ERROR NO.I5)                                     A 619
102   FORMAT (32H A PERFECT GROUND PLANE AT Z 0  )                        A 620
      END                                                                 A 621
```

```
      FUNCTION AATAN2 (Y,X)
C                                                                       0   1
C     THIS FUNCTION CORRECTLY COMPUTES THE ARC TANGENT FOR ALL INPUT     0   2
C     ARGUMENTS AND RETURNS AN ANSWER IN THE RANGE OF +- PI/2           0   3
C                                                                       0   4
C     TEST INPUT ARGUMENTS                                              0   5
C                                                                       0   6
      PIO2=1.570796327                                                  0   7
      IF (Y.EQ.0.) GO TO 1                                              0   8
      IF (X.EQ.0.) GO TO 2                                              0   9
      AATAN2=ATAN2(Y,X)                                                 0  10
      RETURN                                                            0  11
1     AATAN2=0.                                                         0  12
      IF (X.LT.0.) AATAN2=2.*PIO2                                       0  13
      RETURN                                                            0  14
2     AATAN2=SIGN(PIO2,Y)                                               0  15
      RETURN                                                            0  16
      END                                                               0  17
                                                                        0  18-
```

```
      SUBROUTINE CMSETUP (ZRATI,KSYMP,IPGND,IGSCRN)                      C   1
C                                                                        C   2
C     SUBROUTINE CMSETUP IS USED TO SETUP THE COMPLEX IMPEDANCE MATRIX   C   3
C     CM.                                                                C   4
C                                                                        C   5
      COMMON /1/ N,NP,X(100),Y(100),Z(100),SI(100),BI(100),ALP(100),BET(  C   6
     1100),ICON1(100),ICON2(100),COLAM,NX                                C   7
      INTEGER P                                                          C   8
      COMPLEX ZRATI,REFS,REFPS,ZRSIN                                     C   9
      COMPLEX ZRATIS,ZSCRN,ZFACT                                         C  10
      COMPLEX FJ,CM,EINC                                                 C  11
      COMMON /2/ CM(22,100),EINC(100),P(100)                             C  12
      COMMON /3/ CAB(100),SAB(100),SALP(100)                             C  13
      COMMON /4/ NCOX,JOX(25),NCIX,JIX(25),NCOZ,JOZ(25),NCIZ,JIZ(25)     C  14
      COMMON /REFL/ RHOX,RHOY,RHOZ,CABJ,SABJ,SALPR,PX,PY,REFS,REFPS      C  15
      DIMENSION ETR(3), ETI(3)                                           C  16
      FJ=CMPLX(0.,1.)                                                    C  17
      PI=3.14159265                                                      C  18
      SIGN=-1.                                                           C  19
      NR=NP*NX                                                           C  20
      NSYM=N-NR                                                          C  21
      ZRATIS=ZRATI                                                       C  22
      IF (IGSCRN EQ.0) GO TO 1                                           C  23
C                                                                        C  24
C     IF IGSCRN INPUT IN THE MAIN PROGRAM = 1, A RADIAL WIRE GROUND      C  25
C     SCREEN IS SELECTED.  YOU WILL BE REQUIRED TO READ IN THE NUMBER OF C  26
C     OF WIRES---NWIRES AND THE RADIUS OF THE RADIAL WIRES FOR EACH PASS C  27
C     THROUGH THE FREQUENCY DO LOOP.                                     C  28
C                                                                        C  29
      READ (60,19) NWIRES,COH                                            C  30
C                                                                        C  31
C     IF A RADIAL GROUND IS SELECTED, COMPUTE SOME PARAMETERS FROM THE   C  32
C     NUMBER OF RADIAL WIRES--NWIRES, AND FROM THE RADIUS--COH (METERS)  C  33
C                                                                        C  34
      COH=COH/COLAM                                                      C  35
      FLWIRE=NWIRES                                                      C  36
      SNFACT=FLWIRE*COH                                                  C  37
      W=2.*PI*0.299793*1.E+9/COLAM                                       C  38
      U0=4.*PI*1.E-7                                                     C  39
      ZFACT=FJ*U0*W*COLAM/FLWIRE                                         C  40
      ETA0=120.*PI                                                       C  41
      WRITE (61,20) NWIRES,COH                                           C  42
    1 CONTINUE                                                           C  43
      DO 2 I=1,NR                                                        C  44
      DO 2 J=1,N                                                         C  45
    2 CM(I,J)=CMPLX(0.,0.)                                               C  46
C                                                                        C  47
C     J--SOURCE LOOP INDEX                                               C  48
C                                                                        C  49
      DO 18 J=1,N                                                        C  50
      CALL TRIO (J,JCO1,JCO2,DIL,DIK)                                    C  51
      S=SI(J)                                                            C  52
      B=BI(J)                                                            C  53
      XJ=X(J)                                                            C  54
      YJ=Y(J)                                                            C  55
      ZJ=Z(J)                                                            C  56
      CABJ=CAB(J)                                                        C  57
      SABJ=SAB(J)                                                        C  58
      SALPJ=SALP(J)                                                      C  59
      DO 18 I=1,NR                                                       C  60
C                                                                        C  61
C     I--OSERVATION LOOP INDEX                                           C  62
C                                                                        C  63
      IX=I                                                               C  64
```

```
      IF (I.GT.NP) IX=I-NSYM                                              C  65
      XIJ=X(IX)-XJ                                                        C  66
      YIJ=Y(IX)-YJ                                                        C  67
      IJ=IX-J                                                             C  68
      CABI=CAB(IX)                                                        C  69
      SABI=SAB(IX)                                                        C  70
      SALPI=SALP(IX)                                                      C  71
      RFL=-1.                                                             C  72
      DO 10 IP=1,KSYMP                                                    C  73
C                                                                         C  74
C     KSYMP LOOP--WHEN IP=1 DO FREE SPACE, IP=2 DO GROUND IMAGE CALC      C  75
C                                                                         C  76
      RFL=-RFL                                                            C  77
C                                                                         C  78
C     ZP = DISTANCE FROM SOURCE SEGMENT TO OBSERVATION POINT MEAS         C  79
C     ALONG THE AXIS OF THE SOURCE SEGMENT AND A LINE PERPENDICULAR       C  80
C     TO THE AXIS AND THE OBSERVATION POINT                               C  81
C                                                                         C  82
C     RS = SQUARE OF THE DISTANCE BETWEEN THE SOURCE AND THE OBSERVATION  C  83
C     POINT.                                                              C  84
C                                                                         C  85
C     RH = PERPENDICULAR DISTANCE BETWEEN OBSERVATION POINT AND AXIS OF   C  86
C     SEGMENT.                                                            C  87
C                                                                         C  88
      ZIJ=Z(IX)-RFL*ZJ                                                    C  89
      Q1=CABI*CABJ+SABI*SABJ+SALPI*SALPJ*RFL                              C  90
      Q2=XIJ*CABI+YIJ*SABI+ZIJ*SALPI                                      C  91
      ZP=XIJ*CABJ+YIJ*SABJ+ZIJ*SALPJ*RFL                                  C  92
      RS=XIJ*XIJ+YIJ*YIJ+ZIJ*ZIJ                                          C  93
      RH2=RS-ZP*ZP                                                        C  94
      IF (RH2.LT.1.E-20) GO TO 3                                          C  95
      RH=SQRT(RH2)                                                        C  96
      QP2=(Q2-ZP*Q1)/RH                                                   C  97
      GO TO 4                                                             C  98
 3    QP2=0.                                                              C  99
      RH=0.                                                               C 100
 4    CONTINUE                                                            C 101
C                                                                         C 102
C     SKIP OVER THE GROUND IMAGE STUFF IF DOING A FREE SPACE CALC.        C 103
C                                                                         C 104
      IF (IP.NE.2) GO TO 10                                               C 105
      SALPR=SALPJ*RFL                                                     C 106
      RHOX=XIJ-CABJ*ZP                                                    C 107
      RHOY=YIJ-SABJ*ZP                                                    C 108
      RHOZ=ZIJ-SALPJ*ZP*RFL                                               C 109
      RMAG=SQRT(RHOX*RHOX+RHOY*RHOY+RHOZ*RHOZ)                            C 110
      IF (RMAG.GT.1.E-6) GO TO 5                                          C 111
      RHOX=0.                                                             C 112
      RHOY=0.                                                             C 113
      RHOZ=0.                                                             C 114
      GO TO 6                                                             C 115
 5    RHOX=RHOX/RMAG                                                      C 116
      RHOY=RHOY/RMAG                                                      C 117
      RHOZ=RHOZ/RMAG                                                      C 118
 6    RMAG=SQRT(YIJ*YIJ+XIJ*XIJ)                                          C 119
C                                                                         C 120
C     MODIFY THE GROUND IMPEDANCE -- ZRAT1 -- BY THE RADIAL GROUND        C 121
C     SCREEN IMPEDANCE IN PARALLEL WITH THE GROUND IMPEDANCE.             C 122
C                                                                         C 123
      IF (IGSCRN.EQ.0) GO TO 7                                            C 124
      XSPEC=(X(IX)*ZJ+Z(IX)*XJ)/(Z(IX)+ZJ)                               C 125
      YSPEC=(Y(IX)*ZJ+Z(IX)*YJ)/(Z(IX)+ZJ)                               C 126
      RHOSPC=SQRT(XSPEC*XSPEC+YSPEC*YSPEC+SNFACT*SNFACT)                  C 127
      ZSCRN=ZFACT*RHOSPC*ALOG(RHOSPC/SNFACT)                              C 128
```

```
      ZRATI=(ZRATIS*ZSCRN)/(ETA0*ZRATIS+ZSCRN)                          C 129
    7 CONTINUE                                                          C 130
      IF (RMAG.GT.1.E-6) GO TO 8                                        C 131
      PX=0.                                                             C 132
      PY=0.                                                             C 133
      CTH=1.                                                            C 134
      ZRSIN=CMPLX(1.,0.)                                                C 135
      GO TO 9                                                           C 136
    8 PX=YIJ/RMAG                                                       C 137
      PY=-XIJ/RMAG                                                      C 138
      CTH=ZIJ/SQRT(RS)                                                  C 139
      ZRSIN=+CSQRT(1.-ZRATI*ZRATI*(1.-CTH*CTH))                         C 140
    9 REFS=(CTH-ZRATI*ZRSIN)/(CTH+ZRATI*ZRSIN)                          C 141
      REFPS=-(ZRATI*CTH-ZRSIN)/(ZRATI*CTH+ZRSIN)                        C 142
      REFPS=REFPS-REFS                                                  C 143
C                                                                       C 144
C     IF IPGND = 1, A PERFECT GROUND IS MODELED BY FIXING THE REFLECTION C 145
C     COEFFICIENTS AS FOLLOWS                                           C 146
C                                                                       C 147
      IF (IPGND.EQ.0) GO TO 10                                          C 148
      ZRSIN=CMPLX(1.,0.)                                                C 149
      REFS=CMPLX(1.,0.)                                                 C 150
      REFPS=CMPLX(0.,0.)                                                C 151
   10 CONTINUE                                                          C 152
C                                                                       C 153
C     INTEGRATE THE E-FIELD AT OBS POINT DUE TO THE SOURCE SEGMENT      C 154
C                                                                       C 155
      CALL INTG (B,S,RH,ZP,QI,QP2,ETR,ETI,DIL,DIK,IJ,IP)                C 156
      IJ=1                                                              C 157
      IF (IP.NE.2) GO TO 12                                             C 158
      DO 11 IC=1,3                                                      C 159
      ETR(IC)=SIGN*ETR(IC)                                              C 160
   11 ETI(IC)=SIGN*ETI(IC)                                              C 161
   12 IF (JCO1) 13,15,14                                                C 162
   13 CALL JMELS (ETR(1),ETI(1),NCIX,JIX,NCOX,JOX,1)                    C 163
      GO TO 15                                                          C 164
   14 CM(I,JCO1)=CM(I,JCO1)+ETR(1)+FJ*ETI(1)                            C 165
   15 CM(I,J)=CM(I,J)+ETR(2)+FJ*ETI(2)                                  C 166
      IF (JCO2) 16,18,17                                                C 167
   16 CALL JMELS (ETR(3),ETI(3),NCOZ,JOZ,NCIZ,JIZ,1)                    C 168
      GO TO 18                                                          C 169
   17 CM(I,JCO2)=CM(I,JCO2)+ETR(3)+FJ*ETI(3)                            C 170
   18 CONTINUE                                                          C 171
      ZRATI=ZRATIS                                                      C 172
      RETURN                                                            C 173
C                                                                       C 174
C                                                                       C 175
C                                                                       C 176
   19 FORMAT (I5,E10.5)                                                 C 177
   20 FORMAT (///27H A RADIAL GROUND SCREEN OF ,I5,31H RADIALS WITH A WI C 178
     1RE RADIUS OF ,E12.4,21H WAVELENGTH WAS USED ///)                  C 179
      END                                                               C 180-
```

```
      SUBROUTINE DATAGN                                                 D   1
      COMMON /1/ N,NP,X(100),Y(100),Z(100),SI(100),BI(100),ALP(100),BET(  D   2
     1100),ICONI(100),ICON2(100),COLAM,NX                               D   3
      FACTOR=1./COLAM                                                   D   4
      ISEG=1                                                            D   5
C                                                                       D   6
C     READ IN 2 DATA CARDS FOR EACH LINE ELEMENT USED                   D   7
C     TO MODEL THE ANTENNA.  THE FIRST CARD CONTAINS THE END POINT      D   8
C     COORDINATES (IN METERS) AND THE INTERCONNECTION DATA FOR THE LINE D   9
C     ENDS.  THE SECOND CARD SPECIFIES THE NUMBER OF SEGMENTS TO USE TO  D  10
C     MODEL THE LINE ELEMENT, THE WIRE RADIUS USED FOR THE ELEMENT AND I D  11
C     DESIRED YOU CAN SPECIFY THAT A CATENARY BE MODELED BY GIVING THE  D  12
C     WIRE WEIGHT/METER AND THE WIRE TENSION .  IF AN INCREASING LENGTH  D  13
C     SEGMENT LINE IS DESIRED, SPECIFY THE LENGTH EXPANSION FACTOR TAU.  D  14
C                                                                       D  15
      WRITE (61,4)                                                      D  16
C                                                                       D  17
C      DATA GENERATOR INPUTS:                                           D  18
C                                                                       D  19
C       X1,Y1,Z1 AND X2,Y2,Z2 ARE THE CARTESIAN COORDINATES OF THE TWO   D  20
C         END POINTS OF THE LINE ELEMENT                                D  21
C       NCON1 = END CONNECTION VALUE OF THE NEGATIVE END OF THE LINE (1) D  22
C       NCON2 = END CONNECTION VALUE OF THE POSITIVE END OF THE LINE (2) D  23
C       WIRERAD = WIRE RADIUS IN METERS                                 D  24
C       WT = WIRE WEIGHT IN POUNDS PER METER---NEEDED ONLY FOR CATENARY  D  25
C       TENS = WIRE TENSION IN POUNDS---SET=0. IF NO CATENARY           D  26
C       TAU = SEGMENT LENGTH EXPANSION FACTOR---SET=0. IF EQUAL LTH SEGS D  27
C                                                                       D  28
    1 READ (60,2) X1,Y1,Z1,NCON1,X2,Y2,Z2,NCON2                        D  29
      READ (60,3) NSEGS,WIRERAD,WT,TENS,TAU                             D  30
C                                                                       D  31
      WRITE (61,5) X1,Y1,Z1,NCON1,X2,Y2,Z2,NCON2                        D  32
      WRITE (61,3) NSEGS,WIRERAD,WT,TENS,TAU                            D  33
C                                                                       D  34
C     CONVERT THE INPUT UNITS IN METERS TO WAVELENGTHS FOR WAAP         D  35
C                                                                       D  36
      X1=X1*FACTOR                                                      D  37
      Y1=Y1*FACTOR                                                      D  38
      Z1=Z1*FACTOR                                                      D  39
      X2=X2*FACTOR                                                      D  40
      Y2=Y2*FACTOR                                                      D  41
      Z2=Z2*FACTOR                                                      D  42
      WIRERAD=WIRERAD*FACTOR                                            D  43
      NSEGS=IABS(NSEGS)                                                 D  44
      CALL LINE (ISEG,NSEGS,TAU,WT,TENS,WIRERAD,X1,Y1,Z1,X2,Y2,Z2)      D  45
      ICONI(ISEG)=NCON1                                                 D  46
      ISEG=ISEG+NSEGS                                                   D  47
      ICON2(ISEG-1)=NCON2                                               D  48
      N=ISEG-1                                                          D  49
      IF (NSEGS.LT.0) RETURN                                            D  50
      GO TO 1                                                           D  51
C                                                                       D  52
C                                                                       D  53
C                                                                       D  54
    2 FORMAT (3F10.5,I5,3F10.5,I5)                                      D  55
    3 FORMAT (I5,4F10.5)                                                D  56
    4 FORMAT (//,33HI DATA GENERATOR INPUT DATA CARDS,//)               D  57
    5 FORMAT (1X,3F10.4,I5,3F10.4,I5)                                   D  58
      END                                                               D  59-
```

```
      SUBROUTINE EFLD (B,S,RH,ZP,IJ,EZRS,EZIS,ERRS,ERIS,EZRC,EZIC,ERRC,E  E   1
     1RIC,EZRK,EZIK,ERRK,ERIK)
C                                                                         E   2
C     SUBROUTINE EFLD COMPUTES THE AXIAL AND RADIAL ELECTRIC FIELDS REF   E   3
C     TO THE SOURCE SEGMENT AT A SPECIFIED OBSERVATION POINT.             E   4
C                                                                         E   5
C     INPUTS:                                                             E   6
C       B = SOURCE RADIUS                                                 E   7
C       S = SOURCE LENGTH                                                 E   8
C       RH = PERPENDICULAR DISTANCE BETWEEN OBS PT AND SOURCE SEG AXIS    E   9
C            AXIS.                                                        E  10
C       ZP = AXIAL DISTANCE BETWEEN SOURCE SEG AND RH MEASURED ALONG      E  11
C            SOURCE AXIS.                                                 E  12
C       IJ = OBSERVATION SEG NUMBER - SOURCE SEG NUMBER                   E  13
C     OUTPUTS:                                                            E  14
C       EZRS = AXIAL FIELD DUE TO SIN TERM--REAL PART                     E  15
C       EZIS = IMAGINARY PART                                             E  16
C       ERRS = RADIAL FIELD DUE TO SIN TERM--REAL PART                    E  17
C       ERIS = IMAGINARY PART                                             E  18
C                                                                         E  19
C       EZRC = AXIAL FIELD DUE TO COS TERM--REAL PART                     E  20
C       EZIC = IMAGINARY PART                                             E  21
C       ERRC = RADIAL FIELD DUE TO COS TERM--REAL PART                    E  22
C       ERIC = IMAGINARY PART                                             E  23
C                                                                         E  24
C       EZRK = AXIAL FIELD DUE TO CONSTANT TERM--REAL PART                E  25
C       EZIK = IMAGINARY PART                                             E  26
C       ERRK = RADIAL FIELD DUE TO CONSTANT TERM--REAL PART               E  27
C       ERIK = IMAGINARY PART                                             E  28
C                                                                         E  29
      COMMON /TMI/ ZPK,RKB2,IJX                                           E  30
      DATA ZZ,TP,TP2/189.363635,6.283185308,39.4784176/                   E  31
      IJX=IJ                                                              E  32
      RHK=RH*TP                                                           E  33
      ZPK=ZP*TP                                                           E  34
      BK=B*TP                                                             E  35
      RKB2=RHK*RHK+BK*BK                                                  E  36
      RKB=SQRT(RKB2)                                                      E  37
      COINC=RHK/RKB                                                       E  38
      SKT=TP*S*0.5                                                        E  39
      ZD2=ZPK-SKT                                                         E  40
      ZD1=ZPK+SKT                                                         E  41
      R2KS=RKB2+ZD2*ZD2                                                   E  42
      R2K=SQRT(R2KS)                                                      E  43
      R1KS=RKB2+ZD1*ZD1                                                   E  44
      R1K=SQRT(R1KS)                                                      E  45
      SR2=SIN(R2K)/R2K*ZZ                                                 E  46
      CR2=COS(R2K)/R2K*ZZ                                                 E  47
      SR1=SIN(R1K)/R1K*ZZ                                                 E  48
      CR1=COS(R1K)/R1K*ZZ                                                 E  49
      SR2R=SR2/R2K                                                        E  50
      SR2RR=SR2/R2KS                                                      E  51
      CR2R=CR2/R2K                                                        E  52
      CR2RR=CR2/R2KS                                                      E  53
      SR1R=SR1/R1K                                                        E  54
      SR1RR=SR1/R1KS                                                      E  55
      CR1R=CR1/R1K                                                        E  56
      CR1RR=CR1/R1KS                                                      E  57
      CST=COS(SKT)                                                        E  58
      SST=SIN(SKT)                                                        E  59
      T1=(CR2R-SR2RR)*ZD2                                                 E  60
      T2=(CR1R-SR1RR)*ZD1                                                 E  61
      T3=(SR2R+CR2RR)*ZD2                                                 E  62
      T4=(SR1R+CR1RR)*ZD1                                                 E  63
                                                                          E  64
```

```
      T1S=T1*SST                                                        E  65
      T2S=-T2*SST                                                       E  66
      T3S=T3*SST                                                        E  67
      T4S=-T4*SST                                                       E  68
      EZRS=(SR2-SR1)*CST+T1S-T2S                                        E  69
      EZIS=(CR2-CR1)*CST-T3S+T4S                                        E  70
      ERRS=-((SR2*ZD2-SR1*ZD1)*CST+(SR2+SR1)*SST+T1S*ZD2-T2S*ZD1)/RKB*CO E  71
     1INC                                                               E  72
      ERIS=-((CR2*ZD2-CR1*ZD1)*CST+(CR2+CR1)*SST-T3S*ZD2+T4S*ZD1)/RKB*CO E  73
     1INC                                                               E  74
      T1S=T1*CST                                                        E  75
      T2S=T2*CST                                                        E  76
      T3S=T3*CST                                                        E  77
      T4S=T4*CST                                                        E  78
      EZRC=(-(SR2+SR1)*SST+T1S-T2S)                                     E  79
      EZIC=(-(CR2+CR1)*SST-T3S+T4S)                                     E  80
      ERRC=-(-(SR2*ZD2+SR1*ZD1)*SST+(SR2-SR1)*CST+T1S*ZD2-T2S*ZD1)/RKB*C E  81
     1OINC                                                              E  82
      ERIC=-(-(CR2*ZD2+CR1*ZD1)*SST+(CR2-CR1)*CST-T3S*ZD2+T4S*ZD1)/RKB*C E  83
     1OINC                                                              E  84
      ERRK=RKB*(CR2R-SR2RR-CR1R+SR1RR)*COINC                            E  85
      ERIK=-RKB*(SR2R+CR2RR-SR1R-CR1RR)*COINC                           E  86
C                                                                       E  87
C     ONLY THE AXIAL FIELD DUE TO THE CONSTANT CURRENT TERM MUST BE     E  88
C     INTEGRATED NUMERICALLY                                            E  89
C                                                                       E  90
      CALL INTX (-SXT,SXT,RKB2,ZPK,BK,IJ,CINT,SINT)                     E  91
      EZRK=-ZZ*SINT+T1-T2                                               E  92
      EZIK=-ZZ*CINT-T3+T4                                               E  93
      RETURN                                                            E  94
      END                                                               E  95-
```

```
      SUBROUTINE FACTOR (N,A,P,NDIM)                                    F   1
C                                                                       F   2
C     SUBROUTINE TO FACTOR A MATRIX INTO A UNIT LOWER TRIANGULAR MATRIX  F   3
C     UPPER TRIANGULAR MATRIX USING THE GAUSS-DOOLITTLE ALGORITHM PRESEN F   4
C     PAGES 411-416 OF A. RALSTON--A FIRST COURSE IN NUMERICAL ANALYSIS. F   5
C     BELOW REFER TO COMMENTS IN RALSTONS TEXT.                         F   6
C                                                                       F   7
      COMPLEX A,D,DETER                                                 F   8
      INTEGER R,P,RM1,RP1,PJ,PR                                         F   9
      DIMENSION A(NDIM,NDIM), P(NDIM)                                   F  10
      COMMON /SCRATM/ D(100)                                            F  11
      IFLG=0                                                            F  12
      DO 9 R=1,N                                                        F  13
C                                                                       F  14
C     STEP 1                                                            F  15
C                                                                       F  16
      DO 1 K=1,N                                                        F  17
      D(K)=A(K,R)                                                       F  18
    1 CONTINUE                                                          F  19
C                                                                       F  20
C     STEPS 2 AND 3                                                     F  21
C                                                                       F  22
      RM1=R-1                                                           F  23
      IF (RM1.LT.1) GO TO 4                                             F  24
      DO 3 J=1,RM1                                                      F  25
      PJ=P(J)                                                           F  26
      A(J,R)=D(PJ)                                                      F  27
      D(PJ)=D(J)                                                        F  28
      JP1=J+1                                                           F  29
      DO 2 I=JP1,N                                                      F  30
      D(I)=D(I)-A(I,J)*A(J,R)                                           F  31
    2 CONTINUE                                                          F  32
    3 CONTINUE                                                          F  33
    4 CONTINUE                                                          F  34
C                                                                       F  35
C     STEP 4                                                            F  36
C                                                                       F  37
      DMAX=D(R)*CONJG(D(R))                                             F  38
      P(R)=R                                                            F  39
      RP1=R+1                                                           F  40
      IF (RP1.GT.N) GO TO 6                                             F  41
      DO 5 I=RP1,N                                                      F  42
      ELMAG=D(I)*CONJG(D(I))                                            F  43
      IF (ELMAG.LT.DMAX) GO TO 5                                        F  44
      DMAX=ELMAG                                                        F  45
      P(R)=I                                                            F  46
    5 CONTINUE                                                          F  47
    6 CONTINUE                                                          F  48
      IF (DMAX.LT.1.E-10) IFLG=1                                        F  49
      PR=P(R)                                                           F  50
      A(R,R)=D(PR)                                                      F  51
      D(PR)=D(R)                                                        F  52
C                                                                       F  53
C     STEP 5                                                            F  54
C                                                                       F  55
      IF (RP1.GT.N) GO TO 8                                             F  56
      DO 7 I=RP1,N                                                      F  57
      A(I,R)=D(I)/A(R,R)                                                F  58
    7 CONTINUE                                                          F  59
    8 CONTINUE                                                          F  60
      IF (IFLG.EQ.0) GO TO 9                                            F  61
      WRITE (61,10) R,DMAX                                              F  62
      IFLG=0                                                            F  63
    9 CONTINUE                                                          F  64
```

```
      RETURN                                                            F  65
C                                                                       F  66
C                                                                       F  67
C                                                                       F  68
 10   FORMAT (7H PIVOT(,I3,2H)=,E16.8)                                  F  69
      END                                                               F  70-
```

```
      SUBROUTINE FACTORS (N,NOP,A,P,NROW,NCOL)                          G   1
C                                                                       G   2
C     SUBROUTINE FACTORS IS USED TO SET-UP THE FACTORIZATION OF THE     G   3
C     SYMMETRIC PART OF THE IMPEDANCE MATRIX                            G   4
C                                                                       G   5
      COMPLEX A,D,DETER,S                                               G   6
      INTEGER P                                                         G   7
      COMMON /SMAT/ S(12,12)                                            G   8
      DIMENSION A(NROW,NCOL), P(NCOL)                                   G   9
      COMMON /SCRATH/ D(100)                                            G  10
      IF (NOP.EQ.1) GO TO 6                                             G  11
      PHAZ=6.2831853072/NOP                                             G  12
      DO 1 I=2,NOP                                                      G  13
      DO 1 J=1,NOP                                                      G  14
      ARG=PHAZ*(I-1)*(J-1)                                              G  15
      XXX=COS(ARG)                                                      G  16
      YYY=SIN(ARG)                                                      G  17
      S(I,J)=CMPLX(XXX,YYY)                                             G  18
1     S(J,I)=S(I,J)                                                     G  19
      DO 5 I=1,N                                                        G  20
      DO 5 J=1,N                                                        G  21
      DO 2 K=1,NOP                                                      G  22
      KA=J+(K-1)*N                                                      G  23
      D(K)=A(I,KA)                                                      G  24
2     CONTINUE                                                          G  25
      DETER=D(1)                                                        G  26
      DO 3 KK=2,NOP                                                     G  27
3     DETER=DETER+D(KK)                                                 G  28
      A(I,J)=DETER                                                      G  29
      DO 5 K=2,NOP                                                      G  30
      KA=J+(K-1)*N                                                      G  31
      DETER=D(1)                                                        G  32
      DO 4 KK=2,NOP                                                     G  33
4     DETER=DETER+D(KK)*S(K,KK)                                         G  34
5     A(I,KA)=DETER                                                     G  35
6     DO 7 KK=1,NOP                                                     G  36
      KA=(KK-1)*N+1                                                     G  37
      CALL FACTOR (N,A(1,KA),P(KA),NROW)                                G  38
7     CONTINUE                                                          G  39
      RETURN                                                            G  40
      END                                                               G  41-
```

```
      SUBROUTINE FACTRCS (N,NOP,M,A,P,NROW,NCOL,MODE)                    M   1
C                                                                        M   2
C     SUBROUTINE FACTRCS TAKES CARE OF FACTORIZATION OF MATRICIES        M   3
C     WITH SEGMENTS ON AXIS OF ROTATION                                  M   4
C                                                                        M   5
      COMPLEX A,SUM                                                      M   6
      INTEGER P                                                          M   7
      DIMENSION A(NROW,NCOL), P(NCOL)                                    M   8
      NA=N*NOP                                                           M   9
      NAP=NA+1                                                           M  10
      NT=NA+M                                                            M  11
      FNOP=NOP                                                           M  12
      GO TO (1,2,4), MODE                                                M  13
1     CALL FACTORS (N,NOP,A,P,NROW,NCOL)                                 M  14
      IF (M.EQ.0) GO TO 7                                                M  15
2     DO 3 I=1,M                                                         M  16
      NAI=NA+I                                                           M  17
3     CALL SOLVE (N,A,P,A(1,NAI),NROW)                                   M  18
4     DO 6 I=1,M                                                         M  19
      IND=I+N                                                            M  20
      DO 6 J=1,M                                                         M  21
      JND=J+NA                                                           M  22
      SUM=CMPLX(0.,0.)                                                   M  23
      DO 5 K=1,N                                                         M  24
5     SUM=SUM+A(IND,K)*A(K,JND)                                          M  25
6     A(IND,JND)=A(IND,JND)-SUM*FNOP                                     M  26
      CALL FACTOR (M,A(N+1,NAP),P(NAP),NROW)                             M  27
7     CONTINUE                                                           M  28
      RETURN                                                             M  29
      END                                                                M  30-
```

```
      SUBROUTINE GF (ZK,CO,SI)                                          |   1
C                                                                       |   2
C     SUBROUTINE GF PROVIDES THE FUNCTION TO BE NUMERICALLY INTEGRATED  |   3
C     BY INTX.  THE FORM IS: EXP(I*K*R)/K*R.  THE REAL PART IS RETURNED |   4
C     THROUGH CO AND THE IMAGINARY PART OF THE INTEGRAND IS SI.         |   5
C                                                                       |   6
      COMMON /THI/ ZPK,RKB2,IJ                                          |   7
      ZDK=ZK-ZPK                                                        |   8
      RK=SQRT(RKB2+ZDK*ZDK)                                             |   9
      SI=SIN(RK)/RK                                                     |  10
      IF (IJ) 1,2,1                                                     |  11
    1 CO=COS(RK)/RK                                                     |  12
      RETURN                                                            |  13
C                                                                       |  14
C     WHEN I=J, SUBTRACT OUT A SINGULAR (1/RK) POINT--IT WILL BE        |  15
C     INCLUDED AT A LATER POINT IN SUBROUTINE INTX                      |  16
C                                                                       |  17
    2 CO=(COS(RK)-1.)/RK                                                |  18
      RETURN                                                            |  19
      END                                                               |  20-
```

```
      SUBROUTINE ON (EZR,EZI,ERR,ERI)                                    1
C                                                                        2
C     SUBROUTINE ON MODIFIES THE PERFECT IMIAGE FIELDS BY THE            3
C     APPROPRIATE REFLECTION COEFFICIENTS EVALUATED AT THE SPECULAR      4
C     POINTS.                                                            5
C                                                                        6
      COMPLEX EZ,ER,ERX,ERY,ERZ,EPX,EPY,REFS,REFPS                       7
      COMMON /REFL/ RHOX,RHOY,RHOZ,CABJ,SABJ,SALPR,PX,PY,REFS,REFPS      8
      EZ=CMPLX(EZR,EZI)                                                  9
      ER=CMPLX(ERR,ERI)                                                  10
      ERX=RHOX*ER+CABJ*EZ                                                11
      ERY=RHOY*ER+SABJ*EZ                                                12
      ERZ=RHOZ*ER+SALPR*EZ                                               13
      EPY=PX*ERX+PY*ERY                                                  14
      EPX=PX*EPY                                                         15
      EPY=PY*EPY                                                         16
      ERX=REFS*ERX+REFPS*EPX                                             17
      ERY=REFS*ERY+REFPS*EPY                                             18
      ERZ=REFS*ERZ                                                       19
      EZ=ERX*CABJ+ERY*SABJ+ERZ*SALPR                                     20
      ER=ERX*RHOX+ERY*RHOY+ERZ*RHOZ                                      21
      EZR=REAL(EZ)                                                       22
      EZI=AIMAG(EZ)                                                      23
      ERR=REAL(ER)                                                       24
      ERI=AIMAG(ER)                                                      25
      RETURN                                                             26
      END                                                                27
```

```
      SUBROUTINE INTG (B,S,RH,ZP,Q1,QP2,ETR,ETI,DIL,DIK,IJ,IP)          K   1
C                                                                       K   2
C     SUBROUTINE INTG IS USED IN COMPUTING THE ENTRIES FOR THE CM MATRIX K   3
C     IT COMPUTES THE E-FIELD AT AN OBSERVATION SEGMENT DUE TO A UNIT   K   4
C     CURRENT ON THE SOURCE SEGMENT.  THE SUBROUTINE RETURNS THE        K   5
C     INTERPOLATED TANGENTIAL FIELDS FOR THE SEGMENTS AS FOLLOWS:       K   6
C       ETR(1) AND ETI(1) ARE THE FIELDS FOR SEGMENTS CONNECTED TO THE  K   7
C         NEGATIVE END OF THE SOURCE SEGMENT.                           K   8
C       ETR(2) AND ETI(2) ARE THE FIELDS FOR THE OBSERVATION POINT SEG  K   9
C       ETR(3) AND ETI(3) ARE THE FIELDS FOR SEGMENTS CONNECTED TO THE  K  10
C         POSITIVE END OF THE SOURCE SEGMENT.                           K  11
C                                                                       K  12
      DIMENSION ETR(3), ETI(3)                                          K  13
      DATA TP/6.283185308/                                              K  14
C                                                                       K  15
C      COMPUTE THE E-FIELDS REFERENCED TO THE SOURCE SEGMENT.           K  16
C                                                                       K  17
      CALL EFLD (B,S,RH,ZP,IJ,EZRS,EZIS,ERRS,ERIS,EZRC,EZIC,ERRC,ERIC,EZ K  18
     1RK,EZIK,ERRK,ERIK)                                                K  19
      IF (IP.NE.2) GO TO 1                                              K  20
C                                                                       K  21
C     IF COMPUTATION IS PERFORMED FOR THE IMIAGE FIELDS, MODIFY THE     K  22
C     PERFECT GROUND IMIAGE FIELDS BY THE APPROPRIATE REFLECTION COEFF  K  23
C                                                                       K  24
      CALL GN (EZRS,EZIS,ERRS,ERIS)                                     K  25
      CALL GN (EZRC,EZIC,ERRC,ERIC)                                     K  26
      CALL GN (EZRK,EZIK,ERRK,ERIK)                                     K  27
C                                                                       K  28
C     TAKE A DOT PRODUCT OF THE SOURCE FIELDS TO COMPUTE THE TANGENTAL  K  29
C     FIELDS AT THE OBSERVATION POINT.                                  K  30
C                                                                       K  31
    1 ETRS=EZRS*Q1+ERRS*QP2                                             K  32
      ETIS=EZIS*Q1+ERIS*QP2                                             K  33
      ETRC=EZRC*Q1+ERRC*QP2                                             K  34
      ETIC=EZIC*Q1+ERIC*QP2                                             K  35
      ETRK=EZRK*Q1+ERRK*QP2                                             K  36
      ETIK=EZIK*Q1+ERIK*QP2                                             K  37
      CL=TP*DIL                                                         K  38
      CK=TP*DIK                                                         K  39
      SINL=SIN(CL)                                                      K  40
      COSL=COS(CL)                                                      K  41
      SINK=SIN(CK)                                                      K  42
      COSK=COS(CK)                                                      K  43
      SILK=SIN(CL+CK)                                                   K  44
      CONS=SINL*SINK-SILK                                               K  45
      ETR(1)=(SINK*ETRK+(COSK-1.)*ETRS-SINK*ETRC)/CONS                  K  46
      ETI(1)=(SINK*ETIK+(COSK-1.)*ETIS-SINK*ETIC)/CONS                  K  47
      ETR(2)=(-SILK*ETRK+(COSL-COSK)*ETRS+(SINL+SINK)*ETRC)/CONS        K  48
      ETI(2)=(-SILK*ETIK+(COSL-COSK)*ETIS+(SINL+SINK)*ETIC)/CONS        K  49
      ETR(3)=(SINL*ETRK+(1.-COSL)*ETRS-SINL*ETRC)/CONS                  K  50
      ETI(3)=(SINL*ETIK+(1.-COSL)*ETIS-SINL*ETIC)/CONS                  K  51
      RETURN                                                            K  52
      END                                                               K  53-
```

```
      SUBROUTINE INTX (EL1,EL2,RKB2,ZPK,B,IJ,SGR,SGI)                    L   1
C                                                                        L   2
C     INTX IS AN ADAPTIVE RHOMBERG INTEGRATION SCHEME                    L   3
C                                                                        L   4
C                                                                        L   5
C     REFERENCE:  JOURNAL OF COMPUTATIONAL PHYSICS  5, PP 265-279        L   6
C     1970-- A VARIABLE INTERVAL WIDTH QUADRATURE TECHNIQUE BASED ON     L   7
C     RHOMBERG'S METHOD , E. K. MILLER, ET AL                            L   8
C                                                                        L   9
      DATA NX,NM,NTS,RX/1.65536,4,1.E-4/                                 L  10
      Z=EL1                                                              L  11
      ZE=EL2                                                             L  12
      IF (IJ.EQ 0) ZE=0.                                                 L  13
      S=ZE-Z                                                             L  14
      EP=10*NM                                                           L  15
      EP=S/EP                                                            L  16
      ZEND=ZE-EP                                                         L  17
      SGR=0 0                                                            L  18
      SGI=0.0                                                            L  19
      NS=NX                                                              L  20
      NT=0                                                               L  21
C                                                                        L  22
C     GF IS THE FUNCTION TO BE NUMERICALLY INTEGRATED                    L  23
C                                                                        L  24
      CALL GF (Z,G1R,G1I)                                                L  25
    1 DZ=S/NS                                                            L  26
      DZOT=DZ*0.5                                                        L  27
      ZP=Z+DZ                                                            L  28
      IF (ZP-ZE) 3,3,2                                                   L  29
    2 DZ=ZE-Z                                                            L  30
      IF (ABS(DZ)-EP) 17,17,3                                            L  31
    3 DZOT=DZ/2.                                                         L  32
      ZP=Z+DZOT                                                          L  33
      CALL GF (ZP,G3R,G3I)                                               L  34
      ZP=Z+DZ                                                            L  35
      CALL GF (ZP,G5R,G5I)                                               L  36
    4 T00R=(G1R+G5R)*DZOT                                                L  37
      T00I=(G1I+G5I)*DZOT                                                L  38
      T01R=(T00R+DZ*G3R)*0.5                                             L  39
      T01I=(T00I+DZ*G3I)*0.5                                             L  40
      T10R=(4.0*T01R-T00R)/3.0                                           L  41
      T10I=(4.0*T01I-T00I)/3 0                                           L  42
      TE1R=TEST(T01R,T10R)                                               L  43
      TE1I=TEST(T01I,T10I)                                               L  44
      IF (TE1I-RX) 5,5,6                                                 L  45
    5 IF (TE1R-RX) 8,8,6                                                 L  46
    6 ZP=Z+DZ*0.25                                                       L  47
      CALL GF (ZP,G2R,G2I)                                               L  48
      ZP=Z+DZ*0.75                                                       L  49
      CALL GF (ZP,G4R,G4I)                                               L  50
      T02R=(T01R+DZOT*(G2R+G4R))*0.5                                     L  51
      T02I=(T01I+DZOT*(G2I+G4I))*0.5                                     L  52
      T11R=(4.0*T02R-T01R)/3.0                                           L  53
      T11I=(4.0*T02I-T01I)/3.0                                           L  54
      T20R=(16.0*T11R-T10R)/15.0                                         L  55
      T20I=(16.0*T11I-T10I)/15.0                                         L  56
      TE2R=TEST(T11R,T20R)                                               L  57
      TE2I=TEST(T11I,T20I)                                               L  58
      IF (TE2I-RX) 7,7,14                                                L  59
    7 IF (TE2R-RX) 9,9,14                                                L  60
    8 SGR=SGR+T10R                                                       L  61
      SGI=SGI+T10I                                                       L  62
      NT=NT+2                                                            L  63
      GO TO 10                                                           L  64
```

```
    9   SQR=SQR+T20R                                                    L  65
        SQI=SQI+T20I                                                    L  66
        NT=NT+1                                                         L  67
   10   Z=Z+DZ                                                          L  68
        IF (Z-ZEND) 11,17,17                                            L  69
   11   G1R=G5R                                                         L  70
        G1I=G5I                                                         L  71
        IF (NT-NTS) 1,12,12                                             L  72
   12   IF (NS-NX) 1,1,13                                               L  73
   13   NS=NS/2                                                         L  74
        NT=1                                                            L  75
        GO TO 1                                                         L  76
   14   NT=0                                                            L  77
        IF (NS-NM) 16,15,15                                             L  78
   15   WRITE (61,20) Z                                                 L  79
        GO TO 9                                                         L  80
   16   NS=NS*2                                                         L  81
        DZ=S/NS                                                         L  82
        DZOT=DZ*0.5                                                     L  83
        G5R=G3R                                                         L  84
        G5I=G3I                                                         L  85
        G3R=G2R                                                         L  86
        G3I=G2I                                                         L  87
        GO TO 4                                                         L  88
   17   CONTINUE                                                        L  89
C                                                                       L  90
C       IF I=J AN ANALYTIC DIFFERENCE TERM IN THE INTEGRAND             L  91
C       IS NOW INCLUDED IN THE CONTRIBUTION                             L  92
C                                                                       L  93
        IF (IJ) 19,18,19                                                L  94
   18   SQR=2.*(SQR+ALOG((SQRT(B*B+S*S)+S)/B))                          L  95
        SQI=2.*SQI                                                      L  96
   19   CONTINUE                                                        L  97
        RETURN                                                          L  98
C                                                                       L  99
C                                                                       L 100
C                                                                       L 101
   20   FORMAT (24H STEP SIZE LIMITED AT Z=F10.5)                       L 102
        END                                                             L 103-
```

```
      SUBROUTINE JMELS (ETR,ETI,NCP,JP,NCM,JM,I)                        M   1
C                                                                       M   2
C     JMELS HANDLES THE STUFFING OF THE COMPLEX IMPEDANCE MATRIX--CM.   M   3
C     THE SUBROUTINE IS CALLED ONLY WHEN AN ICON VALUE IS NEGATIVE--    M   4
C     INDICATING EITHER A MULTIPLE JUNCTION OR A CHANGE IN REF POLARITY.M   5
C                                                                       M   6
C     INPUTS:                                                           M   7
C       I   = OBSERVATION POINT SEGMENT                                 M   8
C       ETR = TANGENTIAL ELECTRIC FIELD (REAL) AT SEGMENT I             M   9
C       ETI = TANGENTIAL ELECTRIC FIELD (IMAG) AT SEGMENT I             M  10
C       NCP = NUMBER OF SEGMENTS CONNECTED TO POSITIVE END OF JTH SEG   M  11
C       JP  = ARRAY OF SEGMENT NUMBERS CONNECTED TO POS END OF JTH SEG  M  12
C       NCM = NUMBER OF SEGMENTS CONNECTED TO NEGATIVE END OF JTH SEG   M  13
C       JM  = ARRAY OF SEGMENT NUMBERS CONNECTED TO NEG END OF JTH SEG  M  14
C                                                                       M  15
      INTEGER P                                                         M  16
      COMPLEX CM,FJ,EINC                                                M  17
      COMMON /2/ CM(22,100),EINC(100),P(100)                            M  18
      DIMENSION JP(25), JM(25)                                          M  19
      FJ=CMPLX(0.,1.)                                                   M  20
      IF (NCP.LT.1) GO TO 2                                             M  21
      DO 1 J=1,NCP                                                      M  22
      JPJ=JP(J)                                                         M  23
    1 CM(I,JPJ)=CM(I,JPJ)+ETR+FJ*ETI                                   M  24
    2 CONTINUE                                                          M  25
      IF (NCM.LT.1) GO TO 4                                             M  26
      DO 3 J=1,NCM                                                      M  27
      JMJ=JM(J)                                                         M  28
    3 CM(I,JMJ)=CM(I,JMJ)-ETR-FJ*ETI                                   M  29
    4 CONTINUE                                                          M  30
      RETURN                                                            M  31
      END                                                               M  32-
```

```
      SUBROUTINE JUNC (J,JNO,NC1,NSEG1,NC2,NSEG2,D)                      N   1
C                                                                        N   2
C     SUBROUTINE JUNC IS USED TO CHECK SEGMENT ENDS FOR MULTIPLE         N   3
C     JUNCTIONS.  THIS SUBR IS ONLY CALLED IF AN ICON VALUE IS NEGATIVE. N   4
C      INPUTS:                                                           N   5
C        J     = SEGMENT NUMBER TO BE TESTED                            N   6
C        JNO   = ICON VALUE OF J-TH SEGMENT TO BE CHECKED               N   7
C      OUTPUTS:                                                          N   8
C        NC1   = NUMBER OF SEGMENTS WHOSE NEG END IS CONNECTED TO JNO   N   9
C        NC2   = NUMBER OF SEGMENTS WHOSE POS END IS CONNECTED TO JNO   N  10
C        NSEG1 = ARRAY OF SEG NUMBERS WHOSE NEG END IS CONNECTED TO JNO N  11
C        NSEG2 = ARRAY OF SEG NUMBERS WHOSE POS END IS CONNEC ED TO JNO N  12
C        D     = AVG LENGTH OF J-TH SEG AND AVG OF ALL OTHER CONN SEGS. N  13
C                                                                        N  14
      COMMON /1/ N,NP,X(100),Y(100),Z(100),SI(100),BI(100),ALP(100),BET( N  15
     1100),ICON1(100),ICON2(100),COLAM,NX                                N  16
      DIMENSION NSEG1(25), NSEG2(25)                                     N  17
      NC1=0                                                              N  18
      NC2=0                                                              N  19
      SNC=0.0                                                            N  20
C                                                                        N  21
C     CHECK FOR NEG ENDS CONNECTED TO JNO                                N  22
C                                                                        N  23
      DO 4 I=1,N                                                         N  24
      IF (ICON1(I)-JNO) 2,1,2                                            N  25
    1 IF (I.EQ.J) GO TO 2                                                N  26
      NC1=NC1+1                                                          N  27
      IF (NC1.GT.25) GO TO 5                                             N  28
      NSEG1(NC1)=I                                                       N  29
      SNC=SNC+SI(I)                                                      N  30
C                                                                        N  31
C     CHECK FOR POS ENDS CONNECTED TO JNO                                N  32
C                                                                        N  33
    2 IF (ICON2(I)-JNO) 4,3,4                                            N  34
    3 IF (I.EQ.J) GO TO 4                                                N  35
      NC2=NC2+1                                                          N  36
      IF (NC2.GT.25) GO TO 5                                             N  37
      NSEG2(NC2)=I                                                       N  38
      SNC=SNC+SI(I)                                                      N  39
    4 CONTINUE                                                           N  40
      FC=NC1+NC2                                                         N  41
C                                                                        N  42
C     COMPUTE AN AVERAGE SEGMENT LENGTH FOR THE MULTIPLE JUNCTION        N  43
C                                                                        N  44
      D=(SI(J)+SNC/FC)/2.0                                               N  45
      RETURN                                                             N  46
    5 WRITE (61,6) JNO                                                   N  47
      STOP                                                               N  48
C                                                                        N  49
C                                                                        N  50
C                                                                        N  51
    6 FORMAT (41H ERROR - TOO MANY CONNECTIONS TO JUNCTION(I4)            N  52
      END                                                                N  53-
```

```
      SUBROUTINE LINE (I,NS,TAU,WT,TENS,HRAD,X1,Y1,Z1,X2,Y2,Z2)                 0   1
      COMMON /1/ N,NP,X(100),Y(100),Z(100),SI(100),BI(100),ALP(100),BET(        0   2
     1100),ICON1(100),ICON2(100),COLAM,NX                                       0   3
C                                                                               0   4
C     THIS SUBROUTINE IS USED TO CALCULATE THE GEOMETRIC COORDINATES OF         0   5
C     EACH MAJOR ANTENNA ARM.  THE DATA GENERATED BY THIS SUBROUTINE IS         0   6
C     X,Y,Z COORDINATE OF THE CENTER OF A SEGMENT PLUS THE ALPHA AND BET        0   7
C     ORIENTATION ANGLES OF EACH POINT.  INTERCONNECTION DATA IS ALSO GE        0   8
C     EACH OF THE SEGMENTS.  BY SPECIFYING THE PROPER PARAMETERS IN THE         0   9
C     CALL ONE HAS THE CHOICE OF USING A TAPERED SEGMENT LENGTH WITH  A         0  10
C     CATENARY FORM OR A LINEAR FORM.                                           0  11
C                                                                               0  12
C     IF TENS =0. THEN DONT MODEL A CATENARY                                    0  13
      IF (TENS.LE 1.) TENS=1.E100                                               0  14
      XINC=X2-X1                                                                0  15
      YINC=Y2-Y1                                                                0  16
      ZINC=Z2-Z1                                                                0  17
      RHO=SQRT(XINC**2+YINC**2+ZINC**2)                                         0  18
      RHOXY=SQRT(XINC**2+YINC**2)                                               0  19
      BETA=AATAN2(YINC,XINC)                                                    0  20
      EXPSUM=0.                                                                 0  21
      NEXP=-1                                                                   0  22
C                                                                               0  23
C     CALCULATE SEGMENT LENGTH SLO   IF TAPERED SEG IS USED SPECIFY TA          0  24
C                                                                               0  25
      DO 1 LS=1,NS                                                              0  26
    1 EXPSUM=EXPSUM+(1.+TAU)**(LS-1)                                            0  27
      SLO=RHO/EXPSUM                                                            0  28
C                                                                               0  29
C     CALC AN APPROX VALUE FOR THE ALPHA ANGLE USING ST LINE SEG   ALFA         0  30
C     WILL BE USED TO DETERMINE THE INCREMENTAL X AND Y STEP                    0  31
C                                                                               0  32
      ALFA=AATAN2(ZINC,RHOXY)                                                   0  33
      CA=COS(ALFA)                                                              0  34
      SA=SIN(ALFA)                                                              0  35
      CAB=CA*COS(BETA)                                                          0  36
      SAB=CA*SIN(BETA)                                                          0  37
C                                                                               0  38
C     SET UP SEGMENT PARAMETERS   IF WIRE WEIGHT IS SPECIFIED, CATENARY         0  39
C     BE CALCULATED   FOR VERTICAL ELEMENTS NO CATENARY WILL BE USED            0  40
C                                                                               0  41
      NEND=NS+1-1                                                               0  42
      XX1=X1                                                                    0  43
      YY1=Y1                                                                    0  44
      ZZ1=Z1                                                                    0  45
      CAT=WT*COLAM/(2.*TENS)                                                    0  46
      DO 4 M=1,NEND                                                             0  47
      NEXP=NEXP+1                                                               0  48
      SL=SLO*(1.+TAU)**NEXP                                                     0  49
      SLX=SL*CAB                                                                0  50
      SLY=SL*SAB                                                                0  51
      XX2=XX1+SLX                                                               0  52
      YY2=YY1+SLY                                                               0  53
      XPRIME=SQRT((XX2-X1)**2+(YY2-Y1)**2)                                      0  54
      IF (ABS(ALFA).LE.1.5) GO TO 2                                             0  55
      ZZ2=ZZ1+SL*SA                                                             0  56
      GO TO 3                                                                   0  57
    2 ZZ2=Z2-(RHOXY-XPRIME)*(CAT*XPRIME*ZINC/RHOXY)                             0  58
    3 XY=SQRT(SLX**2+SLY**2)                                                    0  59
      ALPHA=AATAN2((ZZ2-ZZ1),XY)                                                0  60
      X(M)=(XX1+XX2)/2.                                                         0  61
      Y(M)=(YY1+YY2)/2.                                                         0  62
      Z(M)=(ZZ1+ZZ2)/2.                                                         0  63
      SI(M)=SQRT(XY**2+(ZZ2-ZZ1)**2)                                            0  64
```

```
      BI(M)=MRAD                                                    0  65
      ALP(M)=ALPHA                                                  0  66
      BET(M)=BETA                                                   0  67
      ICON1(M)=M-1                                                  0  68
      ICON2(M)=M+1                                                  0  69
      XX1=XX2                                                       0  70
      YY1=YY2                                                       0  71
      ZZ1=ZZ2                                                       0  72
    4 CONTINUE                                                      0  73
      RETURN                                                        0  74
      END                                                           0  75-
```

```
      SUBROUTINE NEFLD (AIR,AII,BIR,BII,CIR,CII,ZRATI,KSYMP)                P   1
C                                                                           P   2
C     SUBROUTINE NEFLD IS USED TO CALCULATE THE NEAR ELECTRIC FIELD         P   3
C     AT A SELECTION OF OBSERVATION POINTS.  THE INPUTS ARE THE INITIAL     P   4
C     POINT: XO,YO,AND ZO AND THE FINAL POINT XI,YI AND ZI. NXY+1 POINTS    P   5
C     ARE EVALUATED, AND AN INTEGRAL OF THE TANGENTIAL E-FIELD IS EVALUA    P   6
C     TO GIVE A VOLTAGE DROP ALONG THE PATH.  INPUT POSITIONS ARE GIVEN     P   7
C     IN METERS AND THE FIELD VALUES ARE RETURNED IN VOLTS/METER.           P   8
C                                                                           P   9
      COMMON /1/ N,NP,X(100),Y(100),Z(100),SI(100),BI(100),ALP(100),BET(    P  10
     1100),ICONI(100),ICON2(100),COLAM,NX                                   P  11
      COMPLEX ZRATI,REFS,REFPS,ZRSIN                                        P  12
      COMMON /3/ CAB(100),SAB(100),SALP(100)                                P  13
      COMMON /REFL/ RHOX,RHOY,RHOZ,CABJ,SABJ,SALPR,PX,PY,REFS,REFPS         P  14
      DIMENSION AIR(100), AII(100), BIR(100), BII(100), CIR(100), CII(10    P  15
     10)                                                                    P  16
      COMPLEX FJ,EZP,ERHO,EX,EY,EZ,EP,SUM,ET                                P  17
      FJ=CMPLX(0.,1.)                                                       P  18
      PI=3.141592654                                                        P  19
      TP=2.*PI                                                              P  20
      TA=PI/180.                                                            P  21
      FACTOR=1./COLAM                                                       P  22
C                                                                           P  23
C     READ IN INITIAL AND FINAL POINT COORDINATES---DIM ARE IN METERS       P  24
C                                                                           P  25
    1 READ (60,15) XO,YO,ZO,XI,YI,ZI,NXY,NFLD                               P  26
      WRITE (61,16) XO,YO,ZO,XI,YI,ZI                                       P  27
      WRITE (61,17)                                                         P  28
C                                                                           P  29
C     CALCULATE DIRECTION COSINES FOR OBSERVATION VECTOR                    P  30
C                                                                           P  31
      RHOXY=SQRT((XI-XO)**2+(YI-YO)**2)                                     P  32
      RHOXYZ=SQRT(RHOXY**2+(ZI-ZO)**2)                                      P  33
      BETA=AATAN2((YI-YO),(XI-XO))                                          P  34
      ALPHA=AATAN2((ZI-ZO),RHOXY)                                           P  35
      COSALPO=COS(ALPHA)                                                    P  36
      SALPO=SIN(ALPHA)                                                      P  37
      CABO=COSALPO*COS(BETA)                                                P  38
      SABO=COSALPO*SIN(BETA)                                                P  39
C                                                                           P  40
C     CONVERT DIMENSIONS FROM METERS TO WAVELENGTHS FOR THE PROGRAM         P  41
C                                                                           P  42
      DX=FACTOR*(XI-XO)/NXY                                                 P  43
      DY=FACTOR*(YI-YO)/NXY                                                 P  44
      DZ=FACTOR*(ZI-ZO)/NXY                                                 P  45
      XOB=XO*FACTOR                                                         P  46
      YOB=YO*FACTOR                                                         P  47
      ZOB=ZO*FACTOR                                                         P  48
      DRHOXYZ=RHOXYZ/NXY                                                    P  49
      PATH=0.                                                               P  50
      SUM=CMPLX(0.,0.)                                                      P  51
C                                                                           P  52
C     MAIN LOOP TO CALC NEAR FIELDS ALONG SPECIFIED PATH                    P  53
C                                                                           P  54
      NXY=NXY+1                                                             P  55
      DO 14 I=1,NXY                                                         P  56
      EX=CMPLX(0.,0.)                                                       P  57
      EY=CMPLX(0.,0.)                                                       P  58
      EZ=CMPLX(0.,0.)                                                       P  59
      DO 11 J=1,N                                                           P  60
      S=SI(J)                                                               P  61
      B=0.                                                                  P  62
      XJ=X(J)                                                               P  63
      YJ=Y(J)                                                               P  64
```

```
      ZJ=Z(J)                                                          P  65
      CABJ=CAB(J)                                                      P  66
      SABJ=SAB(J)                                                      P  67
      SALPJ=SALP(J)                                                    P  68
      XIJ=XOB-XJ                                                       P  69
      YIJ=YOB-YJ                                                       P  70
      RFL=-1.                                                          P  71
      DO 11 IP=1,KSYMP                                                 P  72
      RFL=-RFL                                                         P  73
      ZIJ=ZOB-ZJ*RFL                                                   P  74
      ZP=XIJ*CABJ+YIJ*SABJ+ZIJ*SALPJ*RFL                               P  75
      RS=XIJ*XIJ+YIJ*YIJ+ZIJ*ZIJ                                       P  76
      RH2=RS-ZP*ZP                                                     P  77
      IF (RH2.LT.1.E-20) GO TO 2                                       P  78
      RH=SQRT(RH2)                                                     P  79
      GO TO 3                                                          P  80
2     RH=0.                                                            P  81
3     CONTINUE                                                         P  82
      SALPR=SALPJ*RFL                                                  P  83
      RHOX=XIJ-CABJ*ZP                                                 P  84
      RHOY=YIJ-SABJ*ZP                                                 P  85
      RHOZ=ZIJ-SALPJ*ZP*RFL                                            P  86
      RMAG=SQ\T((RHOX*RHOX+RHOY*RHOY+RHOZ*RHOZ)                        P  87
      IF (RMAG.GT.1.E-6) GO TO 4                                       P  88
      RHOX=0.                                                          P  89
      RHOY=0.                                                          P  90
      RHOZ=0.                                                          P  91
      GO TO 5                                                          P  92
4     RHOX=RHOX/RMAG                                                   P  93
      RHOY=RHOY/RMAG                                                   P  94
      RHOZ=RHOZ/RMAG                                                   P  95
5     RMAG=SQRT(YIJ*YIJ+XIJ*XIJ)                                       P  96
      IF (IP.NE.2) GO TO 8                                             P  97
      IF (RMAG.GT.1.E-6) GO TO 6                                       P  98
      PX=0.                                                            P  99
      PY=0.                                                            P 100
      CTH=1.                                                           P 101
      ZRSIN=CMPLX(1.,0.)                                               P 102
      GO TO 7                                                          P 103
6     PX=YIJ/RMAG                                                      P 104
      PY=-XIJ/RMAG                                                     P 105
      CTH=ZIJ/SQRT(RS)                                                 P 106
      ZRSIN=+CSQRT(1.-ZRATI*ZRATI*(1.-CTH*CTH))                        P 107
7     REFS=(CTH-ZRATI*ZRSIN)/(CTH+ZRATI*ZRSIN)                         P 108
      REFPS=-(ZRATI*CTH-ZRSIN)/(ZRATI*CTH+ZRSIN)                       P 109
      REFPS=REFPS-REFS                                                 P 110
8     CONTINUE                                                         P 111
      CALL EFLD (0,S,RH,ZP,1.,EZRS,EZIS,ERRS,ERIS,EZRC,EZIC,ERRC,ERIC,EZR  P 112
     1K,EZIK,ERRK,ERIK)                                                P 113
      IF (IP.NE.2) GO TO 9                                             P 114
      CALL GN (EZRS,EZIS,ERRS,ERIS)                                    P 115
      CALL GN (EZRC,EZIC,ERRC,ERIC)                                    P 116
      CALL GN (EZRK,EZIK,ERRK,ERIK)                                    P 117
9     EZP=EZRK*AIR(J)-EZIK*AII(J)+EZRS*BIR(J)-EZIS*BII(J)+EZRC*CIR(J)-EZ   P 118
     1IC*CII(J)+FJ*(EZRK*AII(J)+EZIK*AIR(J)+EZRS*BII(J)+EZIS*BIR(J)+EZRC   P 119
     2*CII(J)+EZIC*CIR(J))                                             P 120
      ERHO=ERRK*AIR(J)-ERIK*AII(J)+ERRS*BIR(J)-ERIS*BII(J)+ERRC*CIR(J)-E   P 121
     1RIC*CII(J)+FJ*(ERRK*AII(J)+ERIK*AIR(J)+ERRS*BII(J)+ERIS*BIR(J)+ERR  P 122
     2C*CII(J)+ERIC*CIR(J))                                            P 123
      IF (IP.NE.2) GO TO 10                                            P  24
      EZP=-EZP                                                         P 125
      ERHO=-ERHO                                                       P 126
10    EX=EX+EZP*CABJ+ERHO*RHOX                                         P 127
      EY=EY+EZP*SABJ+ERHO*RHOY                                         P 128
```

```
      EZ=EZ+EZP*SALPJ*RFL*ERHO*RHOZ                                     P 129
   11 CONTINUE                                                          P 130
C                                                                       P 131
C     EX,EY AND EZ ARE THE COMPLEX E-FIELDS IN THE CARTESIAN            P 132
C     COORDINATE DIRECTIONS AT THE OBSERVATION POINT.                   P 133
C                                                                       P 134
      ETOTAL=SQRT(CABS(EX)**2+CABS(EY)**2+CABS(EZ)**2)/COLAM            P 135
      ET=(EX*CABO+EY*SABO+EZ*SALPO)/COLAM                               P 136
      ETANG=CABS(ET)                                                    P 137
      IF (I.EQ.1) GO TO 12                                              P 138
      IF (I.EQ.NXY) GO TO 12                                            P 139
      SUM=SUM+ET                                                        P 140
      GO TO 13                                                          P 141
   12 SUM=SUM+ET/2.                                                     P 142
   13 CONTINUE                                                          P 143
      XOB=XOB+DX                                                        P 144
      YOB=YOB+DY                                                        P 145
      ZOB=ZOB+DZ                                                        P 146
      WRITE (61,18) PATH,ETANG,ETOTAL                                   P 147
      PATH=PATH+DRHOXYZ                                                 P 148
   14 CONTINUE                                                          P 149
C                                                                       P 150
C     THE TANGENTIAL E-FIELD IS INTEGRATED VIA THE TRAPEZOIDAL          P 151
C     RULE TO COMPUTE THE VOLTAGE DROP ALONG THE SPECIFIED PATH         P 152
C                                                                       P 153
      VDROP=CABS(SUM)*DRHOXYZ                                           P 154
      WRITE (61,19) VDROP,NXY                                           P 155
      IF (NFLD.NE.0) GO TO 1                                            P 156
      RETURN                                                            P 157
C                                                                       P 158
C                                                                       P 159
   15 FORMAT (6F10.4,2I5)                                               P 160
   16 FORMAT (16H1  E-FIELD FROM ,3F10.4,11H METERS TO ,3F10.4,7H METERS P 161
     1)                                                                 P 162
   17 FORMAT (///,46H POSITION ON PATH (METERS)      E-TANGENT (V/M),24H P 163
     1   TOTAL E-FIELD (V/M),///)                                       P 164
   18 FORMAT (3E20.5)                                                   P 165
   19 FORMAT (///,50H THE INTEGRAL OF THE E-FLD TANGENT TO THE PATH IS ,E P 166
     115.5,7H VOLTS.,I5,34H POINTS USED TO EVALUATE INTEGRAL.,//)       P 167
      END                                                               P 168-
```

```
      SUBROUTINE SOLVE (N,A,P,B,NDIM)                                    Q   1
C                                                                        Q   2
C     SUBROUTINE TO SOLVE THE MATRIX EQUATION LU*X=B WHERE L IS A UNIT L Q   3
C     TRIANGULAR MATRIX AND U IS AN UPPER TRIANGULAR MATRIX BOTH OF WHIC Q   4
C     IN A.  THE RHS VECTOR B IS INPUT AND THE SOLUTION IS RETURNED THRO Q   5
C                                                                        Q   6
      COMPLEX A,B,Y,SUM                                                  Q   7
      INTEGER P,PI                                                       Q   8
      DIMENSION A(NDIM,NDIM), P(NDIM), B(NDIM)                           Q   9
      COMMON /SCRATM/ Y(100)                                             Q  10
C                                                                        Q  11
C     FORWARD SUBSTITUTION                                               Q  12
C                                                                        Q  13
      DO 3 I=1,N                                                         Q  14
      PI=P(I)                                                            Q  15
      Y(I)=B(PI)                                                         Q  16
      B(PI)=B(I)                                                         Q  17
      IP1=I+1                                                            Q  18
      IF (IP1.GT.N) GO TO 2                                              Q  19
      DO 1 J=IP1,N                                                       Q  20
      B(J)=B(J)-A(J,I)*Y(I)                                              Q  21
1     CONTINUE                                                           Q  22
2     CONTINUE                                                           Q  23
3     CONTINUE                                                           Q  24
C                                                                        Q  25
C     BACKWARD SUBSTITUTION                                              Q  26
C                                                                        Q  27
      DO 6 K=1,N                                                         Q  28
      I=N-K+1                                                            Q  29
      SUM=CMPLX(0.,0.)                                                   Q  30
      IP1=I+1                                                            Q  31
      IF (IP1.GT.N) GO TO 5                                              Q  32
      DO 4 J=IP1,N                                                       Q  33
      SUM=SUM+A(I,J)*B(J)                                                Q  34
4     CONTINUE                                                           Q  35
5     CONTINUE                                                           Q  36
      B(I)=(Y(I)-SUM)/A(I,I)                                             Q  37
6     CONTINUE                                                           Q  38
      RETURN                                                             Q  39
      END                                                                Q  40-
```

```
      SUBROUTINE SOLVECS (N,NOP,M,A,P,B,NROW,NCOL)                          R   1
C     SUBROUTINE SOLVECS TAKES CARE OF SOLUTION OF PROBLEMS WITH SEGMENT    R   2
C     ON AXIS OF ROTATION                                                   R   3
C                                                                           R   4
      COMPLEX A,B,SUM                                                       R   5
      INTEGER P                                                             R   6
      DIMENSION A(NROW,NCOL), P(NCOL), B(NCOL)                              R   7
      NA=N*NOP                                                              R   8
      NAP=NA+1                                                              R   9
      NT=NA+M                                                               R  10
      CALL SOLVES (N,NOP,A,P,B,NROW,NCOL)                                   R  11
      IF (M.EQ.0) GO TO 6                                                   R  12
      DO 2 I=1,M                                                            R  13
      IND=I+N                                                               R  14
      INDX=I+NA                                                             R  15
      SUM=CMPLX(0.,0.)                                                      R  16
      DO 1 K=1,NA                                                           R  17
1     SUM=SUM+A(IND,K)*B(K)                                                 R  18
2     B(INDX)=B(INDX)-SUM                                                   R  19
      CALL SOLVE (M,A(N+1,NAP),P(NAP),B(NAP),NROW)                          R  20
      DO 5 I=1,N                                                            R  21
      SUM=CMPLX(0.,0.)                                                      R  22
      DO 3 K=NAP,NT                                                         R  23
3     SUM=SUM+A(I,K)*B(K)                                                   R  24
      DO 4 K=1,NOP                                                          R  25
      IND=I+(K-1)*N                                                         R  26
4     B(IND)=B(IND)-SUM                                                     R  27
5     CONTINUE                                                              R  28
6     CONTINUE                                                              R  29
      RETURN                                                                R  30
      END                                                                   R  31-
```

```
      SUBROUTINE SOLVES (N,NOP,A,P,B,NROW,NCOL)                          S   1
C                                                                        S   2
C     SUBROUTINE SOLVES SOLVES ROTATIONALLY SYMMETRIC MATRICIES          S   3
C                                                                        S   4
      COMPLEX A,B,Y,SUM,S                                                S   5
      INTEGER P                                                          S   6
      COMMON /SMAT/ S(12,12)                                             S   7
      DIMENSION A(NROW,NCOL), P(NCOL), B(NCOL)                           S   8
      COMMON /SCRATM/ Y(100)                                             S   9
      IF (NOP.EQ.1) GO TO 5                                              S  10
      FNORM=1./NOP                                                       S  11
      DO 4 I=1,N                                                         S  12
      DO 1 K=1,NOP                                                       S  13
      IA=I+(K-1)*N                                                       S  14
    1 Y(K)=B(IA)                                                         S  15
      SUM=Y(1)                                                           S  16
      DO 2 K=2,NOP                                                       S  17
    2 SUM=SUM+Y(K)                                                       S  18
      B(I)=SUM*FNORM                                                     S  19
      DO 4 K=2,NOP                                                       S  20
      IA=I+(K-1)*N                                                       S  21
      SUM=Y(1)                                                           S  22
      DO 3 J=2,NOP                                                       S  23
    3 SUM=SUM+Y(J)*CONJG(S(K,J))                                         S  24
    4 B(IA)=SUM*FNORM                                                    S  25
    5 DO 6 KK=1,NOP                                                      S  26
      IA=(KK-1)*N+1                                                      S  27
      CALL SOLVE (N,A(1,IA),P(IA),B(IA),NROW)                            S  28
    6 CONTINUE                                                           S  29
      IF (NOP.EQ.1) RETURN                                               S  30
      DO 10 I=1,N                                                        S  31
      DO 7 K=1,NOP                                                       S  32
      IA=I+(K-1)*N                                                       S  33
    7 Y(K)=B(IA)                                                         S  34
      SUM=Y(1)                                                           S  35
      DO 8 K=2,NOP                                                       S  36
    8 SUM=SUM+Y(K)                                                       S  37
      B(I)=SUM                                                           S  38
      DO 10 K=2,NOP                                                      S  39
      IA=I+(K-1)*N                                                       S  40
      SUM=Y(1)                                                           S  41
      DO 9 J=2,NOP                                                       S  42
    9 SUM=SUM+Y(J)*S(K,J)                                                S  43
   10 B(IA)=SUM                                                          S  44
      RETURN                                                             S  45
      END                                                                S  46
```

```
      FUNCTION TEST (F1,F2)                                                 T   1
C                                                                           T   2
C     FUNCTION TEST IS USED BY INTX TO COMPUTE THE RELATIVE ERROR OF THE    T   3
C     NUMERICAL SUB INTEGRATION.                                            T   4
C                                                                           T   5
      IF (ABS(F2)-1.0E-40) 2,2,1                                            T   6
    1 TEST=ABS((F1-F2)/F2)                                                  T   7
      RETURN                                                                T   8
    2 TEST=0.                                                               T   9
      RETURN                                                                T  10
      END                                                                   T  11-
```

```
      SUBROUTINE TRIO (J,JCO1,JCO2,DIL,DIK)                                 U   1
C                                                                           U   2
C     SUBROUTINE TRIO IS USED TO DETERMINE THE TYPE OF JUNCTION USED AT     U   3
C     THE SEGMENT ENDS.  THREE TYPES OF SEGMENT END JUNCTIONS ARE ALLOW     U   4
C     --IF ICON IS 0, SEGMENT END IS OPEN--IF ICON EQUALS SEGMENT NUMBER    U   5
C     THEN SEG END IS GROUNDED--IF ICON IS NEG THEN A CHECK IS MADE FOR     U   6
C     MULTIPLE JUNCTIONS.  TRIO RETURNS AN EQUIVALENT DISTANCE (DIL,DIK)    U   7
C     WHICH IS USED FOR INTERPOLATING CURRENTS FROM 1 SEG TO THE NEXT.      U   8
C      INPUTS:                                                              U   9
C        J      = SEGMENT NUMBER TO BE CHECKED                              U  10
C      OUTPUTS:                                                             U  11
C        JCO1   = ICON VALUE OF J-TH SEG NEG END                           U  12
C        JCO2   = ICON VALUE OF J-TH SEG POS END                           U  13
C        DIL    = AVG DISTANCE FOR CURRENT INTERPOLATION ON SEG NEG END     U  14
C        DIK    = AVG DISTANCE FOR CURRENT INTERPOLATION ON SEG POS END     U  15
C                                                                           U  16
      COMMON /1/ N,NP,X(100),Y(100),Z(100),S1(100),B1(100),ALP(100),BET(    U  17
     1100),ICON1(100),ICON2(100),COLAM,NX                                   U  18
      COMMON /4/ NCOX,JOX(25),NCIX,JIX(25),NCOZ,JOZ(25),NCIZ,JIZ(25)        U  19
      S=S1(J)                                                               U  20
      JCO1=ICON1(J)                                                         U  21
      JCO2=ICON2(J)                                                         U  22
C                                                                           U  23
C     **********CHECK SEGMENT NEGATIVE END**********                       U  24
C                                                                           U  25
      IF (JCO1) 1,2,3                                                       U  26
C                                                                           U  27
C     MULTIPLE JUNCTION                                                     U  28
C                                                                           U  29
    1 CALL JUNC (J,JCO1,NCOX,JOX,NCIX,JIX,DIL)                              U  30
      GO TO 4                                                               U  31
C                                                                           U  32
C     OPEN CIRCUIT--FREE END -- INTERPOLATE ONLY TO END OF SEGMENT          U  33
C                                                                           U  34
    2 DIL=S/2.0                                                             U  35
      GO TO 4                                                               U  36
C                                                                           U  37
C     NORMAL JUNCTION CONNECTION--SIMPLE JUNCTION OR GROUNDED SEGMENT       U  38
C                                                                           U  39
    3 DIL=(S1(JCO1)+S)/2.0                                                  U  40
C                                                                           U  41
C     **********CHECK SEGMENT POSITIVE END**********                       U  42
C                                                                           U  43
    4 IF (JCO2) 5,6,7                                                       U  44
C                                                                           U  45
C     MULTIPLE JUNCTION                                                     U  46
C                                                                           U  47
    5 CALL JUNC (J,JCO2,NCOZ,JOZ,NCIZ,JIZ,DIK)                              U  48
      GO TO 8                                                               U  49
C                                                                           U  50
C     OPEN CIRCUIT--FREE END                                                U  51
C                                                                           U  52
    6 DIK=S/2.0                                                             U  53
      GO TO 8                                                               U  54
C                                                                           U  55
C     NORMAL JUNCTION CONNECTION--SIMPLE JUNCTION OR GROUNDED SEGMENT       U  56
C                                                                           U  57
    7 DIK=(S1(JCO2)+S)/2.0                                                  U  58
    8 CONTINUE                                                              U  59
      RETURN                                                                U  60
      END                                                                   U  61
```

APPENDIX B TABLE I SEGMENT EXPANSION COEFFICIENTS (TAU)

NUMBER OF SEGMENTS--N

L/LO	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	0	- 39	-.46	-.49	- 50	- 50	- 50	- 50	- 50	- 50	- 50	50	- 50	50	50	50	50	50	50
3	1 00	0	- 19	-.26	- 30	- 31	- 32	- 33	- 33	- 33	- 34	- 34	- 34	34	34	34	34	34	34
4	2.00	.30	0	- 12	- 17	- 20	- 22	- 23	- 24	24	- 25	25	25	25	25	25	25	25	25
5	3 00	56	15	0	- 08	- 12	- 15	16	- 17	- 18	- 19	- 19	- 19	20	20	20	20	20	20
6	4 00	79	28	09	0	- 06	- 09	- 11	13	- 14	- 14	15	15	16	16	16	16	17	17
7	5 00	1.00	39	17	06	0	- 04	- 07	- 09	- 10	- 11	- 12	12	13	13	13	14	14	14
8	6 00	1.19	49	24	11	04	0	- 03	06	- 07	- 08	09	10	10	11	11	11	12	12
9	7 00	1 37	58	30	16	08	03	0	- 03	- 05	- 06	07	08	08	09	09	10	10	10
10	8 00	1 54	66	35	20	12	06	03	0	- 02	- 04	05	06	07	07	08	08	08	09
11	9 00	1.70	74	40	24	15	09	05	02	0	- 02	03	04	05	06	06	07	07	07
12	10 00	1 85	81	45	28	18	11	07	04	02	0	02	03	04	04	05	06	06	06
13	11 00	2 00	88	49	31	20	14	09	06	03	01	0	02	03	03	04	05	05	05
14	12 00	2 14	94	53	34	23	16	11	07	05	03	01	0	01	02	03	04	04	04
15	13.00	2 27	1 00	.57	37	25	17	12	09	06	04	02	01	0	01	02	03	04	04
16	14 00	2 41	1 06	61	39	27	19	14	10	07	05	03	02	01	0	01	02	03	03
17	15 00	2 53	1 11	64	42	29	21	15	11	08	06	04	03	02	01	0	01	02	02
18	16 00	2 65	1 16	67	44	31	22	17	13	09	07	05	04	03	02	01	0	01	02
19	17 00	2.77	1 22	70	46	33	24	18	14	10	08	06	05	03	02	01	01	0	01
20	18 00	2 89	1 26	73	48	34	25	19	15	11	09	07	05	04	03	02	01	01	0
21	19 00	3 00	1 31	76	50	36	27	20	16	12	10	08	06	05	04	03	02	01	01
22	20 00	3 11	1 36	79	52	37	28	21	17	13	10	08	07	05	04	03	02	02	01
23	21 00	3.22	1 40	.82	.54	39	29	22	18	14	11	09	07	06	05	04	03	02	01
24	22.00	3.32	1.44	.84	56	40	30	23	19	15	12	10	08	06	05	04	03	02	01
25	23 00	3.42	1.48	.87	58	.42	31	24	19	15	13	10	08	07	06	05	04	03	02
26	24 00	3.52	1 53	.89	60	43	.32	25	20	16	13	11	09	07	06	05	04	03	02
27	25.00	3.62	1.56	.91	61	44	33	26	21	17	14	11	10	08	07	06	05	04	03
28	26.00	3.72	1 60	.94	63	.45	34	27	22	18	14	12	10	08	07	06	05	04	03
29	27.00	3.82	1.64	96	.64	.47	35	28	22	18	15	13	10	09	07	06	05	04	.03
30	28 00	3.91	1 68	.98	66	48	36	28	23	19	16	13	11	09	08	.07	06	05	04
31	29.00	4.00	1.71	1.00	67	.49	.37	29	24	19	16	13	11	09	08	.07	06	05	04
32	30 00	4.09	1 75	1.02	69	50	38	30	24	20	17	14	12	.10	.08	07	06	05	.04
33	31 00	4.18	1 78	1 04	.70	.51	39	31	25	.20	17	14	12	.10	09	07	06	05	05
34	32 00	4.27	1.81	1.06	71	52	40	31	.25	.21	18	15	13	11	.09	.08	07	.06	.05
35	33 00	4 35	1.85	1 08	73	53	40	32	26	22	18	15	13	11	09	.08	07	06	.05
36	34.00	4.44	1.88	1.10	74	.54	41	33	27	.22	18	15	13	11	10	08	07	06	.06
37	35 00	4.52	1.91	1 11	75	.55	42	33	27	23	19	16	13	.12	10	09	08	07	.06
38	36.00	4.60	1.94	1.13	76	56	43	.34	.28	.23	19	16	14	12	10	.09	08	07	.06
39	37.00	4.68	1.97	1.15	77	.57	.43	.35	28	.23	20	17	14	.12	11	09	08	07	.06
40	38 00	4.76	2 00	1 17	.79	.57	.44	35	29	.24	.20	17	15	13	.11	.10	.08	07	07
41	39.00	4 84	2 03	1 18	.80	58	45	36	29	.24	21	.18	15	13	.11	10	.09	.08	.07
42	40 00	4.92	2.06	1.20	.81	.59	.46	.36	.30	.25	21	18	15	13	.12	10	.09	.08	.07
43	41.00	5.00	2.09	1.21	.82	.60	46	.37	30	.25	21	.18	15	13	.12	.10	09	.08	.07
44	42.00	5.08	2.11	1.23	.83	.61	.47	.37	31	.26	22	.19	16	.14	.12	11	09	08	.07
45	43.00	5.15	2.14	1.24	84	.62	.47	.38	31	.26	22	19	16	.14	.12	11	10	09	08
46	44.00	5.23	2.17	1.26	.85	.62	.48	38	32	26	22	19	16	.14	13	.11	10	09	.08
47	45.00	5.30	2.19	1.27	.86	.63	49	39	.32	27	23	.19	.17	15	13	11	10	.09	.08
48	46.00	5.37	2.22	1 29	87	.64	49	.39	.32	.27	23	.20	17	15	13	12	10	09	08
49	47.00	5.45	2.25	1.30	.88	.65	.50	.40	.33	.28	.23	.20	17	.15	13	.12	11	.09	08
50	48.00	5.52	2.27	1.32	.89	.65	.50	.40	.33	.28	24	.20	.18	.16	14	12	11	10	.09