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NUMERICAL PARAMETRIC STUDY OF ELECTROMAGNETIC WAVE SCATTERING BY BURIED DIELECTRIC LAND MINES

BY

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FEB 25 1983
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A FINAL REPORT SUBMITTED TO
U.S. ARMY MOBILITY EQUIPMENT RESEARCH
AND DEVELOPMENT COMMAND
FORT BELVOIR, VIRGINIA 22060

UNDER CONTRACT NO. DAAK-70-80-C-0039

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The views, opinions, and/or findings contained in the report are those of the authors and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

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ABSTRACT

The unimoment method is applied to solve the electromagnetic scattering by a buried dielectric finite cylinder simulating a land mine. Computed results are reported at frequencies from 400 MHz to 1400 MHz at 100 MHz intervals. The dielectric constants of the ground are considered to be dispersive which simulates soil with 5%, 10% and 20% water content. Results are computed for the scattered electric and magnetic fields which are presented in terms of the cylindrical components of $\overline{E}$ and $\eta_0\overline{H}$ at a distance of 1" to 4" above the ground at 1" intervals. The numerical results are computed along the positive x-axis for each azimuthal mode. The fields at points on the positive x-axis may be obtained by summing the modal fields directly. Fields at points other than the positive x-axis may be obtained by summing the modal fields mutiplied by the proper azimuthal function $e^{jm\phi}$. Sample results are given in the report and the complete data are stored on magnetic tape. This report includes documentation for the tapes.

I. INTRODUCTION

Land mines made of plastic or other dielectric material have caused many casualties during recent conflicts. They are continuously causing more casualties many years after the conflicts, because these mines are difficult to detect and complete clearing of such mines is almost impossible. One of the reasons that an effective detection system for dielectric land mines has not yet been developed is the lack of theoretical data for the electromagnetic scattering by buried dielectric bodies.

In order to generate data usable for the design of mine detection systems, this investigation has successfully applied the unimoment method [1] to compute scattering by a buried dielectric finite cylinder which simulates a dielectric land mine. The computation uses the Finite Element Method (FEM) to treat the boundary conditions of the mine. The solution of FEM is terminated at a mathematical sphere by a set of analytical expansions which satisfy the continuity conditions of the tangential components of E and H fields on the air-ground interface. Owing to the versatility of the FEM in matching the mine surface and the fast convergence of the analytical expansions, we are able to compute the scattering by the buried dielectric land mines efficiently.

This report provides the computational results for eleven different frequencies: 400 HMz to 1400 MHz at 100 MHz interval. Five different incident angles, each with two different polarizations, are considered for the incident plane wave. Field components are calculated on the horizontal planes at four different altitude levels, i.e., 1"-4" above ground at 1" interval. The dielectric constants are assumed to be dispersive using the formulas offered by Von Hippel, simulating silt loam with 5%, 10% and 20% water.

Results are computed for the ρ, ϕ, z components of both scattered electric and magnetic fields for each azimuthal mode on the positive x-axis at 1 cm intervals up to 15 cms. The total scattered fields on the positive x-axis can be obtained by directly summing the modal components. The scattered fields at locations other than the positive x-axis may be obtained by summing the modal fields multiplied

by the corresponding $e^{jm\phi}$ factor. Therefore, we are able to obtain 2-dimensional data from a one dimensional data set, which results in great savings in data handling.

Due to the massive amount of data involved, it is not feasible to present all of them graphically. The data is stored in magnetic tapes. This report also contains documentation for the tapes so that a specific data set can be conveniently fetched.

Examples are given of how to use the data to compute the total and scattered electric and magnetic fields. Typical data sets of azimuthal coefficients are given in Chapter VIII. Appendix I gives examples of using the data to calculate the scattered and total fields. Appendix II gives a listing of program PCOEF, which is to be used to read selected portions of the data from the magnetic tapes. Appendix III gives a table of the various symbols used in this report and their meanings.

II. THE UNIMOMENT METHOD

The unimoment method was first published in 1974 [1] to generalize the moment method for the radiation and scattering problems involving material bodies. It was then applied to the inhomogeneously loaded biconical antennas [2], the scattering by two dimensional dielectric cylinders [3], and by axially symmetric dielectrical bodies [4, 5]. Recent discovery of the generalizations of Sommerfeld integrals and a new type of field expansions in two medium half spaces [6] have made possible the extension of the method to the electromagnetic scattering by buried dielectric land mines [7].

The basic idea of the unimoment method is to combine the Finite Element Method (FEM) with the analytic solutions so that the maximum advantages are obtained from both. The analytic solutions are usually expressed in terms of truncated series expansions. Although analytic expansions usually represent the fields of a vast region in space, they are only applicable to simply shaped objects such as spheres. The FEM has been noted for its flexibility in fitting boudaries with general shapes. For scattering problems which involve an infinite - space, it is impractical to use the FEM for the entire space. To minimize the number of unknowns, the FEM is terminated at two spheres; one encloses the entire mine, and the other is imbedded in the mine. Spherical vector wave expansions represent the fields in the interior of the sphere inside the mine. In the exterior of the outer sphere, complications of the analytic expansions occur due to the presence of the air-ground interface. The computation in this report has employed a special type of vector wave expansion incorporated with the generalized Sommerfeld integrals to satisfy the air-ground boundary conditions. The coefficients of the analytical expansions are obtained by enforcing the continuity conditons on the spheres. The scattered fields can then be calculated from the coefficients and the modal fields.

We shall now briefly describe the procedures of the unimoment method in the following steps:

(1) Draw a mathematical sphere S_1 to enclose the entire land mine as shown in Figure 1.

The sphere mathematically separates the space into two parts. The interior of the sphere (Region III) contains the land mine. The exterior of the sphere (Regions I and II) involves the lossy ground and the air. For efficiency and convenience, the sphere should be as small as possible to reduce the FEM calculation, and large enough to enclose the entire mine.

(2) Draw a supplemental mathematical sphere S_2 in the interior of the land mine as shown in Figure 2.

The supplemental sphere is drawn to reduce the region of FEM further. The sphere S_2 mathematically separates the region inside S_1 into two parts. Region IV is the interior of S_2 and Region III is the area between spheres S_1 and S_2. For efficiency and convenience S_2 should be as large as possible but small enough to be completely inside the mine.

(3) Solve the Maxwell's equations for Region III between S_1 and S_2 using FEM.

The original Maxwell's equations has six vector components in 3-dimensions. Because of axial symmetry of the geometry, it is possible to reduce the six unknowns to two coupled azimuthal potentials $\psi_1 = k_0 \rho E_\phi$ and $\psi_2 = k_0 \rho H_\phi$ for each azimuthal Fourier series mode with $e^{jm\phi}$ variations. All other components of $\overline{E}$ and $\overline{H}$ fields can be directly obtained from these potentials. The potentials satisfy two coupled differential equations in Region III including the boundary of the mine.

By using the Fourier series of $e^{jm\phi}$ and the coupled azimuthal potentials we are able to reduce the original three dimensional problem into many much smaller two dimensional problems. The amount of computer time can thus be greatly reduced.

The differential equations are then changed to their corresponding variational integrals. The functions of the potentials which

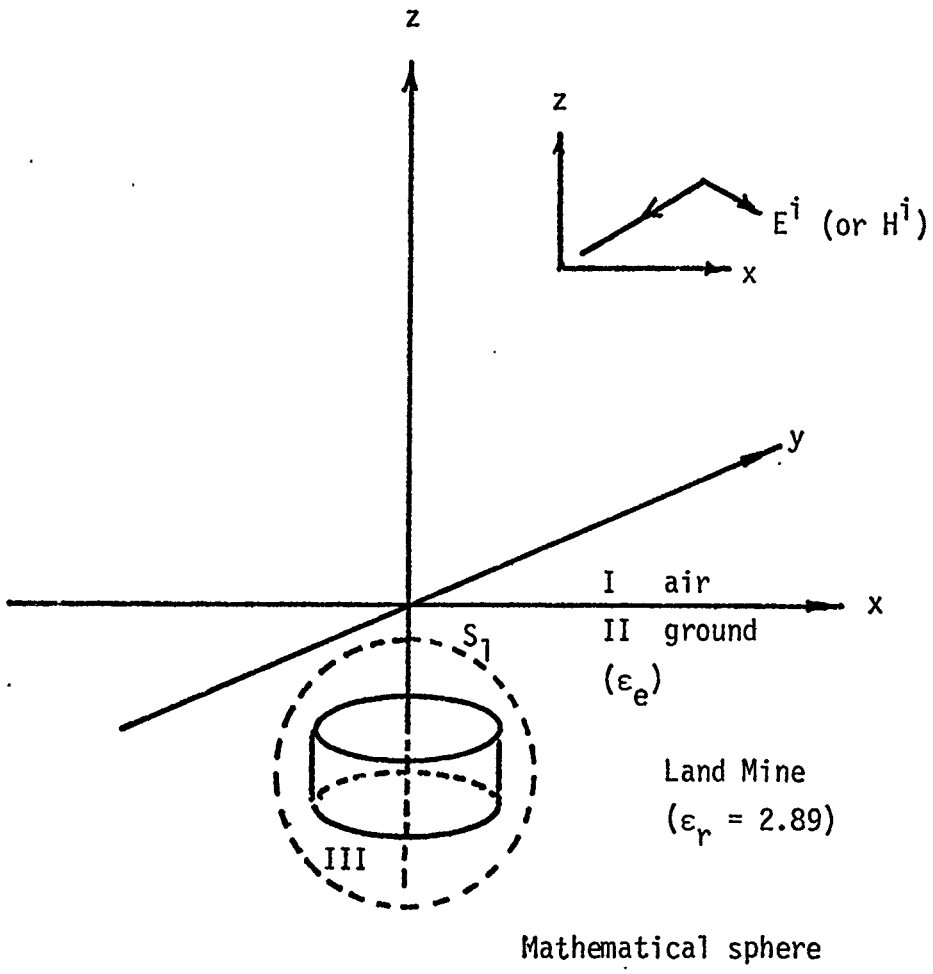


Figure 1. The illustration of the buried dielectric land mine and the mathematical sphere

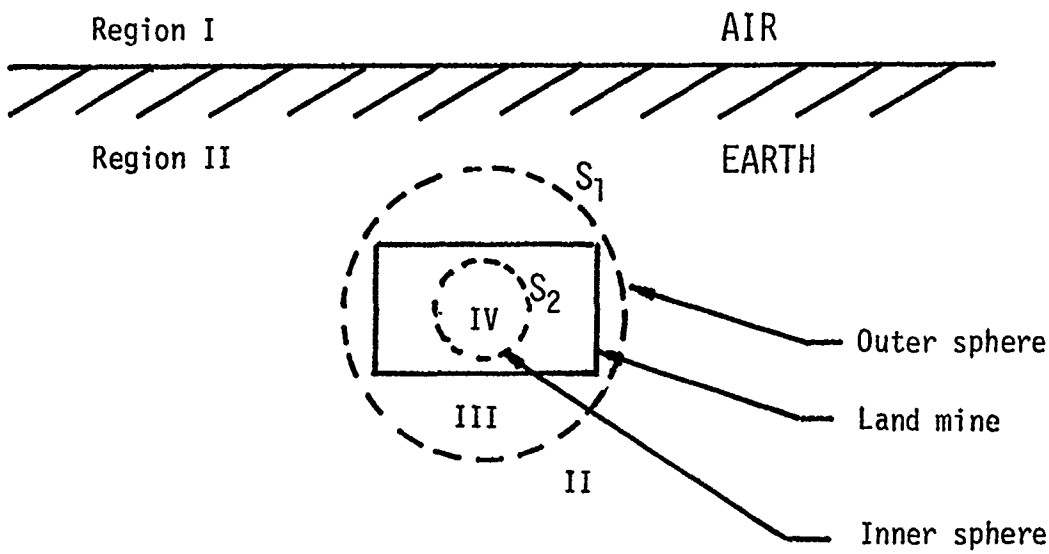


Figure 2. Minimization of FEM region III by a supplemental inner sphere S_2

render stationary the variational integral are also the solutions of the differential equations. The basic idea of FEM is to approximate the potentials by piecewise polynomials so that the variational integrals can be evaluated analytically.

In the FEM, we first divide the entire Region III into many small trianglar elements such as those shown in Figure 3. The triangles conform with the surfaces of the mine, the inner sphere, and the outer sphere. The elements inside the mine have relative dielectric constant $\varepsilon_m = 2.89$ and those outside the mine have ε_e. The subscripts m and e denote mine and earth respectively.

The potentials in each triangle are then represented by interpolating polynomials passing through each nodal value. The variational integral is obtained by summing up the element integrations over all elements in Region III. The variational formulation is stationary if its differentiation with respect to nodal values is zero. This leads to a set of linear equations which can be used to solve for the fields in Region III. The matrix involved in these equations is a banded sparse matrix which can be solved efficiently by a special sparse matrix algorithm.

Since the boundary values on the spheres are not specified, the solutions of Region III are in general not unique. In fact they result in a set of linearly independent solutions.

(4) Expand the field in Region IV inside the sphere S_2 by using the conventional spherical vector waves.

The field in Region IV is expanded analytically by the conventional spherical vector waves. Since the origin of the coordinate is included in this region, only the spherical Bessel functions of the first kind $j_n(kr)$ is required as the radial functions

(5) Represent the field in Region I and II outside the sphere S_1 by mutipole expansions which satisfy the air-ground boundary conditions.

The fields in Regions I and II are decomposed into incident and scattered fields. The scattered fields in Region II (the earth) are further decomposed into direct and secondary waves.

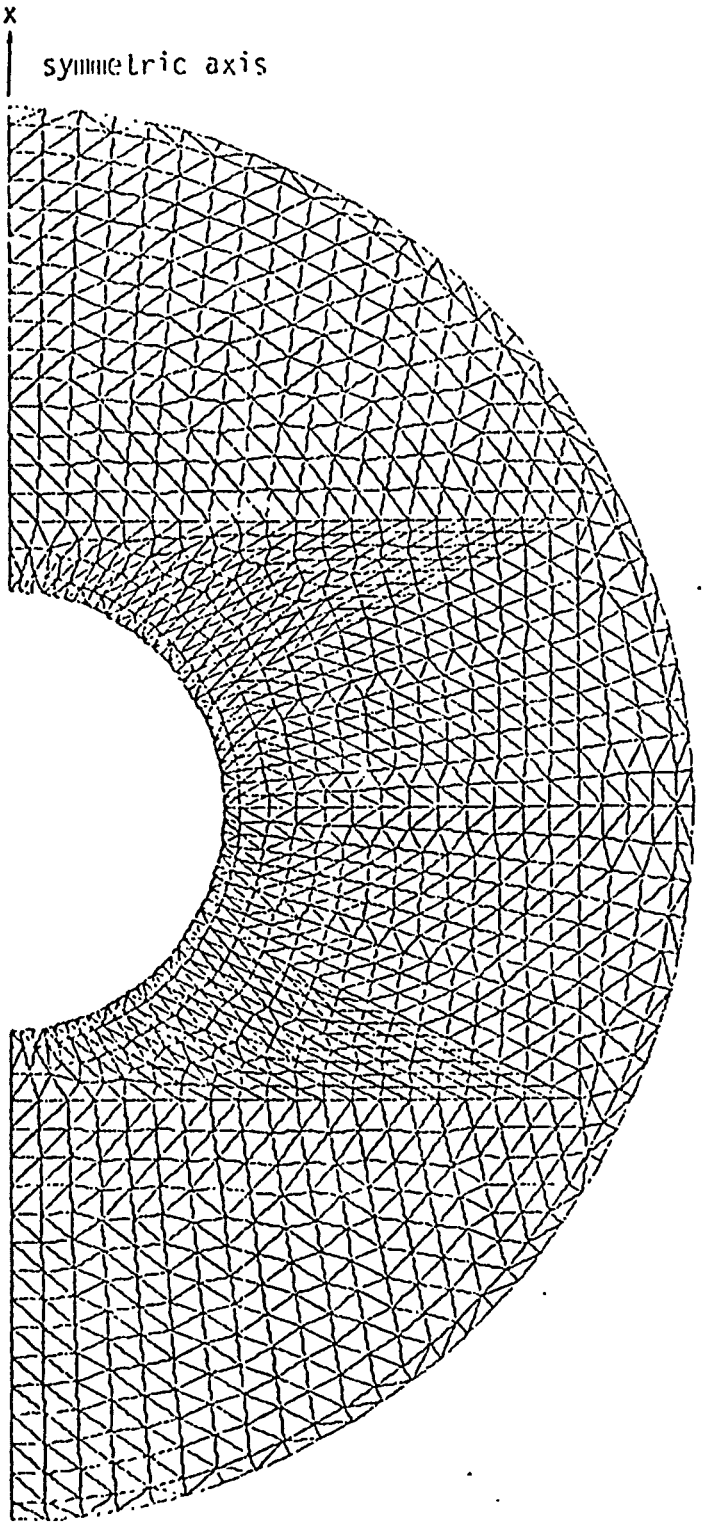


Figure 3. The construction of the triangular elements in the meridianal plane

The direct field is represented in terms of multipole expansions as if the scatterer is in an infinite medium. The secondary fields are represented in generalized Sommerfeld's integrals. The sum of the direct and secondary fields satisfies the air-ground interface boundary conditions. The rectilinear spherical vector waves, in which the rectangular vectors and the spherical harmonics are combined, form the vector potentials. This type of combination was introduced to reduce the complexities in enforcing both the spherical and planar boundary conditions on the mathematical sphere and on the earth surface. Supplemental terms using horizontal rotating multipoles have been discovered and added to the direct field expansions to speed up the convergence [6].

The direct fields are then transformed into cylindrical harmonics by using the Fourier-Bessel integrals which replace the spherical-Hankel-Lengendre functions. By enforcing the continuity conditions of the tangential E and H fields on the air-ground interface, the secondary fields in Region II and the scattered field in Region I are found to be in the form of "Generalized Sommerfeld integrals" [6]. The expansions with the generalized Sommerfeld integrals satisfy the air-ground boundary condition term-by-term.

The analysis has thus yielded a converging multipole expansion technique for the fields in two-medium half spaces. The same set of expansion coefficients are used in both Regions I and II.

(6) Solve the expansion coefficients by enforcing the continuity conditions on both the outer sphere S_1 and the inner sphere S_2.

The three sets of solutions in Regions II, III, and IV are solved individually by the previously described methods. We then couple all the solutions on the mathematical spheres S_1 and S_2 by using the continuity conditions of tangential electric and magnetic fields. The incident waves are the driving fields for the calculations.

(7) Calculate scattered fields in Region I (the air) by using the coefficients and modal fields.

The final step of the unimoment method is to generate the required scattered electromagnetic fields by a buried land mine. The fields on planes parallel to the ground at different heights above the ground are calculated.

III. GROUND PARAMETERS

In an earlier computation, [8], the relative dielectric constant of the ground was assumed to be constant at $\varepsilon_e = 9\text{-}j7$ for all frequencies. This unrealistic assumption has been corrected in this report. The complex dielectric permittivities are now considered to be functions of frequencies as given by Falls and Mittleman [10].

In this report, we consider three types of soil conditions, i.e., silt loam with 5%, 10% and 20% water. The real part of ε_r and the attenuation parameter, α , for the soil are given in Table I.

The conversion from ε_r and α to ε_r and ε_i (real and imaginary part of ε_e) is, (eq. 3.38 in ref. [9]),

$$\tan \delta = \varepsilon_i/\varepsilon_r = \left\{ \left[\frac{2\alpha^2\lambda_o^2}{(2\pi)^2\varepsilon_r} + 1\right]^2 - 1 \right\}^{1/2} \qquad (1)$$

The real and imaginary part of ε_e which are used in the computations for this report are tabulated in Table II. In equation (1), $\tan \delta$ is called the loss tangent and λ_o is the free space wavelength.

TABLE 1

DIELECTRIC CONSTANTS [SILT LOAM]

Frequency	5% Water		10% Water		20% Water	
[Mega Hertz]	α [db/meter]	ε_r	α [db/meter]	ε_r	α [db/meter]	ε_r
400	15.5	5.2	27.0	7.8	30.0	17.6
500	19.0	5.1	33.0	7.6	34.0	17.0
600	20.2	5.0	35.0	7.6	37.5	16.8
700	22.0	4.9	38.0	7.7	40.5	16.6
800	23.8	4.8	40.5	7.8	43.5	16.4
900	25.5	4.8	43.0	7.8	46.5	16.2
1000	27.0	4.7	45.5	7.8	49.2	16.0
1100	29.2	4.6	48.0	7.8	52.0	15.9
1200	31.8	4.6	50.7	7.7	54.9	15.8
1300	34.0	4.5	53.0	7.6	57.5	15.7
1400	36.5	4.5	56.0	7.6	60.2	15.6

TABLE II

DIELECTRIC CONSTANTS [SILT LOAM]

SILT LOAM
TYPE 5 PER CENT WATER

FREQUENCY (MEGA HERTZ)	LOSS (DB/METER)	REAL PART OF THE RELATIVE PERMITTIVITY	LOSS TANGENT	IMAGINARY PART OF THE RELATIVE PERMITTIVITY
400.00	15.50	5.20	.1875E+00	-.9750E+00
500.00	19.00	5.10	.1857E+00	-.9468E+00
600.00	20.20	5.00	.1600E+00	-.8299E+00
700.00	22.00	4.90	.1565E+00	-.7666E+00
800.00	23.80	4.80	.1496E+00	-.7181E+00
900.00	25.50	4.80	.1424E+00	-.6837E+00
1000.00	27.00	4.70	.1371E+00	-.6446E+00
1100.00	29.20	4.60	.1363E+00	-.6269E+00
1200.00	31.80	4.60	.1361E+00	-.6259E+00
1300.00	34.00	4.50	.1358E+00	-.6109E+00
1400.00	36.50	4.50	.1353E+00	-.6090E+00

SILT LOAM
TYPE 10 PER CENT WATER

FREQUENCY (MEGA HERTZ)	LOSS (DB/METER)	REAL PART OF THE RELATIVE PERMITTIVITY	LOSS TANGENT	IMAGINARY PART OF THE RELATIVE PERMITTIVITY
400.00	27.00	7.80	.2679E+00	-.2089E+01
500.00	33.00	7.60	.2653E+00	-.2016E+01
600.00	35.00	7.60	.2340E+00	-.1779E+01
700.00	38.00	7.70	.2162E+00	-.1664E+01
800.00	40.50	7.80	.2001E+00	-.1561E+01
900.00	43.00	7.80	.1888E+00	-.1472E+01
1000.00	45.50	7.80	.1797E+00	-.1402E+01
1100.00	48.00	7.80	.1723E+00	-.1344E+01
1200.00	50.70	7.70	.1679E+00	-.1293E+01
1300.00	53.00	7.60	.1630E+00	-.1239E+01
1400.00	56.00	7.60	.1595E+00	-.1215E+01

SILT LOAM
TYPE 20 PER CENT WATER

FREQUENCY (MEGA HERTZ)	LOSS (DB/METER)	REAL PART OF THE RELATIVE PERMITTIVITY	LOSS TANGENT	IMAGINARY PART OF THE RELATIVE PERMITTIVITY
400.00	30.00	17.60	.1974E+00	-.3473E+01
500.00	34.00	17.00	.1819E+00	-.3093E+01
600.00	37.50	16.80	.1681E+00	-.2824E+01
700.00	40.50	16.60	.1565E+00	-.2598E+01
800.00	43.50	16.40	.1479E+00	-.2426E+01
900.00	46.50	16.20	.1414E+00	-.2290E+01
1000.00	49.20	16.00	.1354E+00	-.2167E+01
1100.00	52.00	15.90	.1305E+00	-.2075E+01
1200.00	54.90	15.80	.1267E+00	-.2002E+01
1300.00	57.50	15.70	.1229E+00	-.1929E+01
1400.00	60.20	15.60	.1198E+00	-.1869E+01

IV. NUMERICAL RESULTS

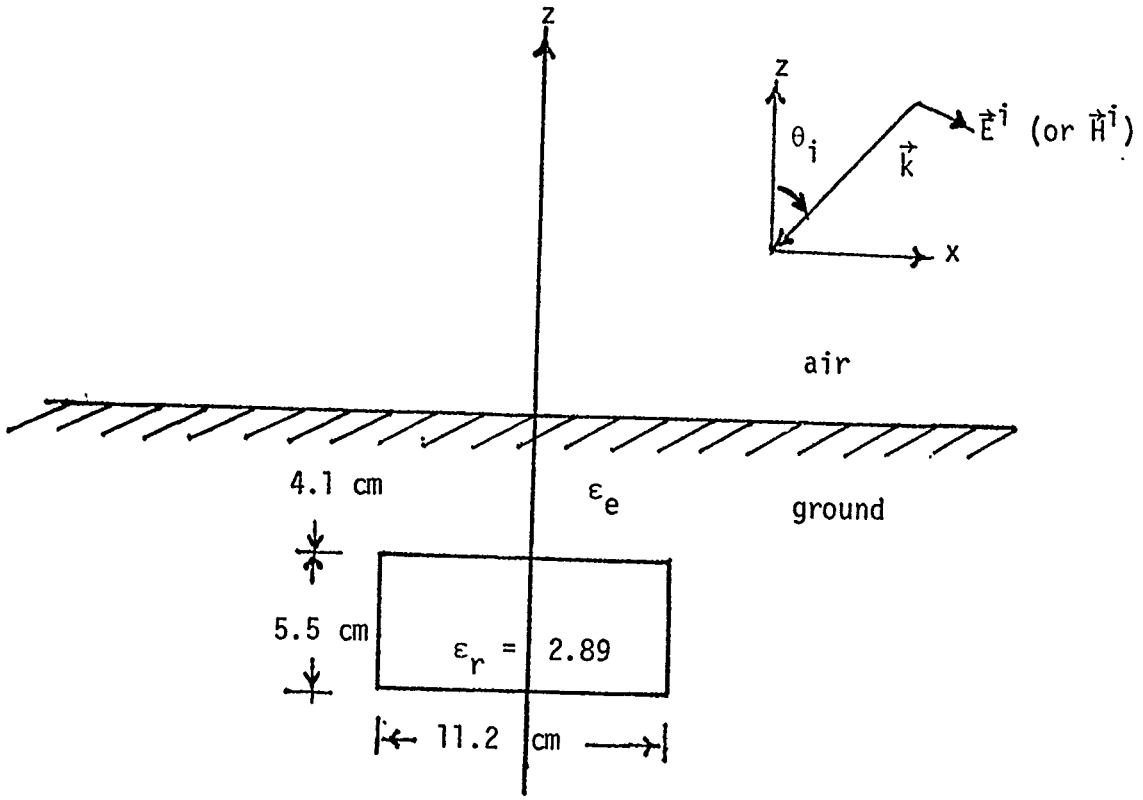
Using the unimoment method described in Chapter II, this investigation has successfully computed the scattering of electromagnetic waves from a buried object which is electrically very similar to an antipersonnel dielectric land mine. The geometrical configuration of the proposed computation is shown in Figure 4. The buried target is a finite cylinder which is 5.5 cm high and 11.2 cm in diameter. The dimensions approximate those of an antipersonnel land mine. The relative dielectric constant of the target is $\varepsilon_r = 2.89$, which is that of TNT. The relative dielectric constant of the ground ε_e as functions of frequency are given in Tables I and II. The top edge of the mine is buried 4.1 cm under the surface of the ground. This configuration is believed to be close to the actual situation.

The scattering configuration involves plane waves incident at $\theta_i = 0°, 30°, 45°, 60°, 75°$ with respect to the z-axis. The frequencies considered are at 400 MHz to 1400 MHz at 100 MHz interval. The scattered electric fields are computed on the planes parallel to the ground at z = 1" (2.5 cm), 2" (5.08 cm), 3" (7.62 cm), and 4" (10.16 cm).

The x and z axes are defined so that the x-z plane is the plane of incidence. The plane of incidence is defined to be the plane which contains the propagation vector $\bar{k}$. Two different kinds of polarizations are considered for each incident angle. They are $\vec{E}^i$ in the x-z plane (or H-Y incidence) and $\vec{H}^i$ in the x-z plane (or E-Y incidence). Owing to their basic differences in refraction and scattering, the two polarizations should result in quite different scattered field patterns except for the symmetric case when $\theta_i = 0°$. In all the computations shown in this report, the original incident plane waves (before reflection and refraction from the ground) are considered to have an amplitude of 1 volt/meter, i.e.,

$$|\vec{E}^i| = \eta_0 |\vec{H}^i| = 1$$

The computation involves 5 incident angles each with 2 polarizations at 11 frequencies. For each case, the scattered fields are given in ρ, ϕ, z components at 4 different parallel planes above ground. The total number of data cases to be presented are 5 x 2 x 11 x 3 x 4 = 1,320.



Incident angles θ_i = 0°, 30°, 45°, 60°, 75°

Incident polarizations = $\vec{E}^i$ or $\vec{H}^i$

Frequencies F = 400 to 1,400 MHz at 100 MHz interval

Field computed at z = 1" (2.54 cm), 2" (5.08 cm),
3" (7.62 cm), 4" (10.16 cm)

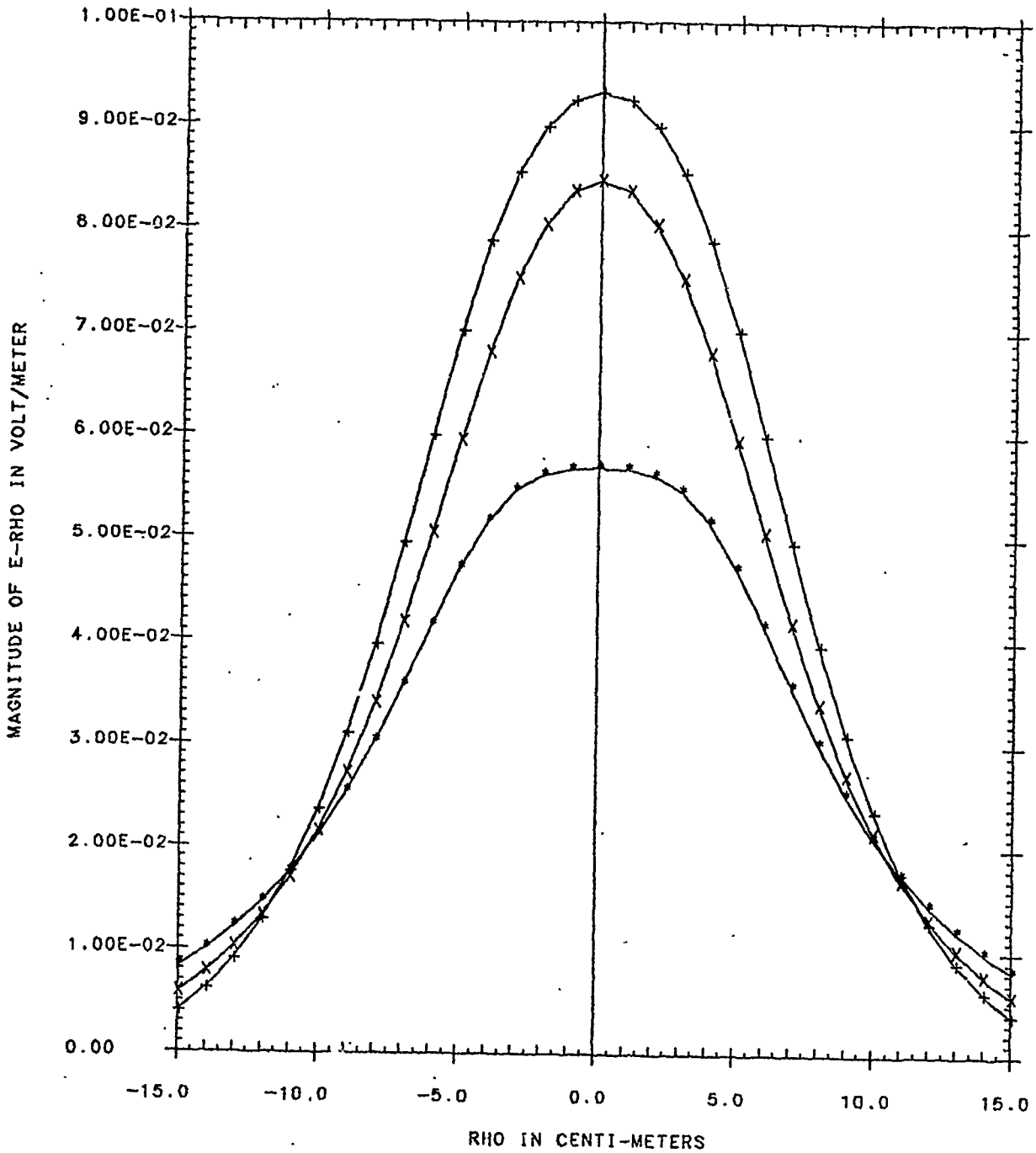
Figure 4. The scattering configurations and computational parameters

Because of the vast amount of data involved, it is impractical to present all the data in graphic form. They are recorded on magnetic tapes so that MERADCOM engineers may recall the data at their convenience. The documentation of the tapes are in Chapters VI and VII of this report.

In Figures 5 - 10, the typical computed results are shown for 600 MHz, 1000 MHz and 1400 MHz.

It is noticed in Figures 8 - 10, where the soil has a 20% water content, that the scattered fields for 1000 MHz is higher than both 600 MHz and 1400 MHz. This phenomenon reverses the trend of previous computations [8], which indicates the scattered fields to be higher at lower frequencies. Since the previous computations were based on an unrealistic assumption that the ground parameter was independent of frequencies, the present results are definitely more reliable.

ANGLE OF INCIDENCE IS 0. WITH H POLARIZED IN THE -Y DIRECTION.

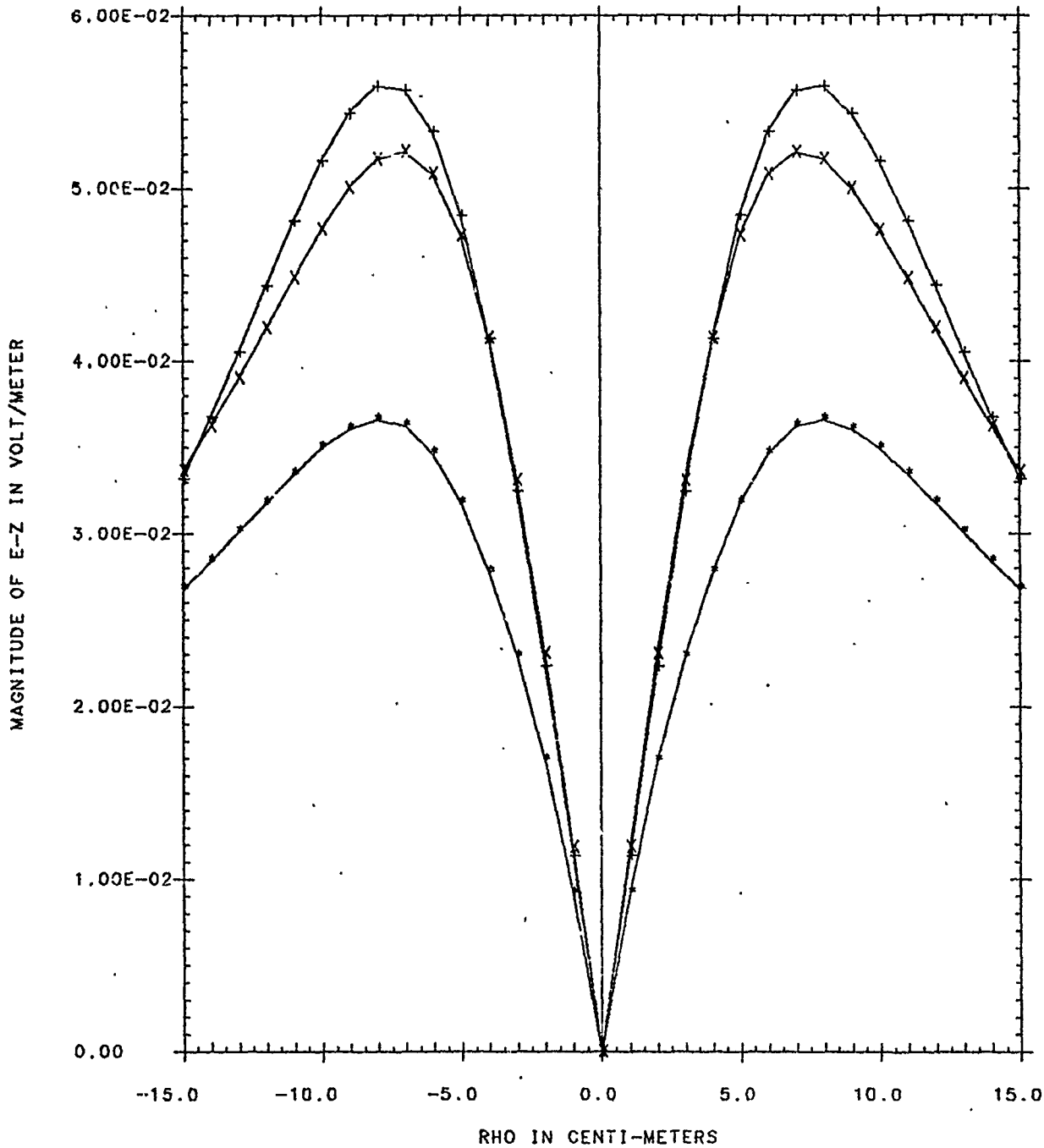


PHI CUT OF 180 - 0 DEGREES IS USED.
AT 1.0 INCH ABOVE THE GROUND
* SILT LOAM WITH 5.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.
X SILT LOAM WITH 10.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.
+ SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.

Figure 5 .

Curves show that 1 inch above the ground the magnitude of E_ρ^s generally increases with increased water content.

ANGLE OF INCIDENCE IS 0. WITH H POLARIZED IN THE -Y DIRECTION.

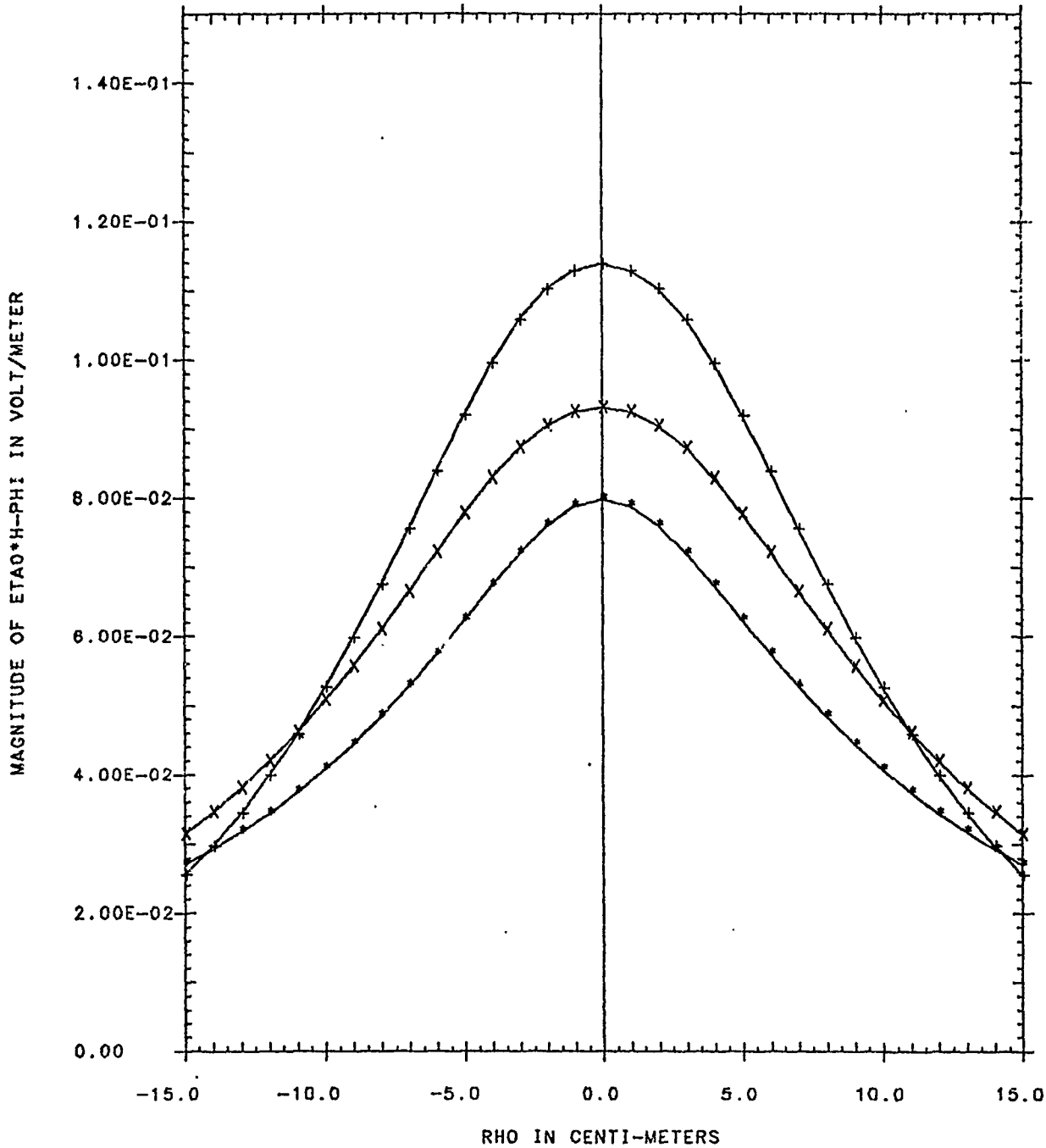


PHI CUT OF 180 -- 0 DEGREES IS USED.
AT 1.0 INCH ABOVE THE GROUND
* SILT LOAM WITH 5.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.
X SILT LOAM WITH 10.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.
+ SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.

Figure 6

Curves show that 1 inch above the ground the magnitude of E_z generally increases with increased water content.

ANGLE OF INCIDENCE IS 0. WITH H POLARIZED IN THE -Y DIRECTION.

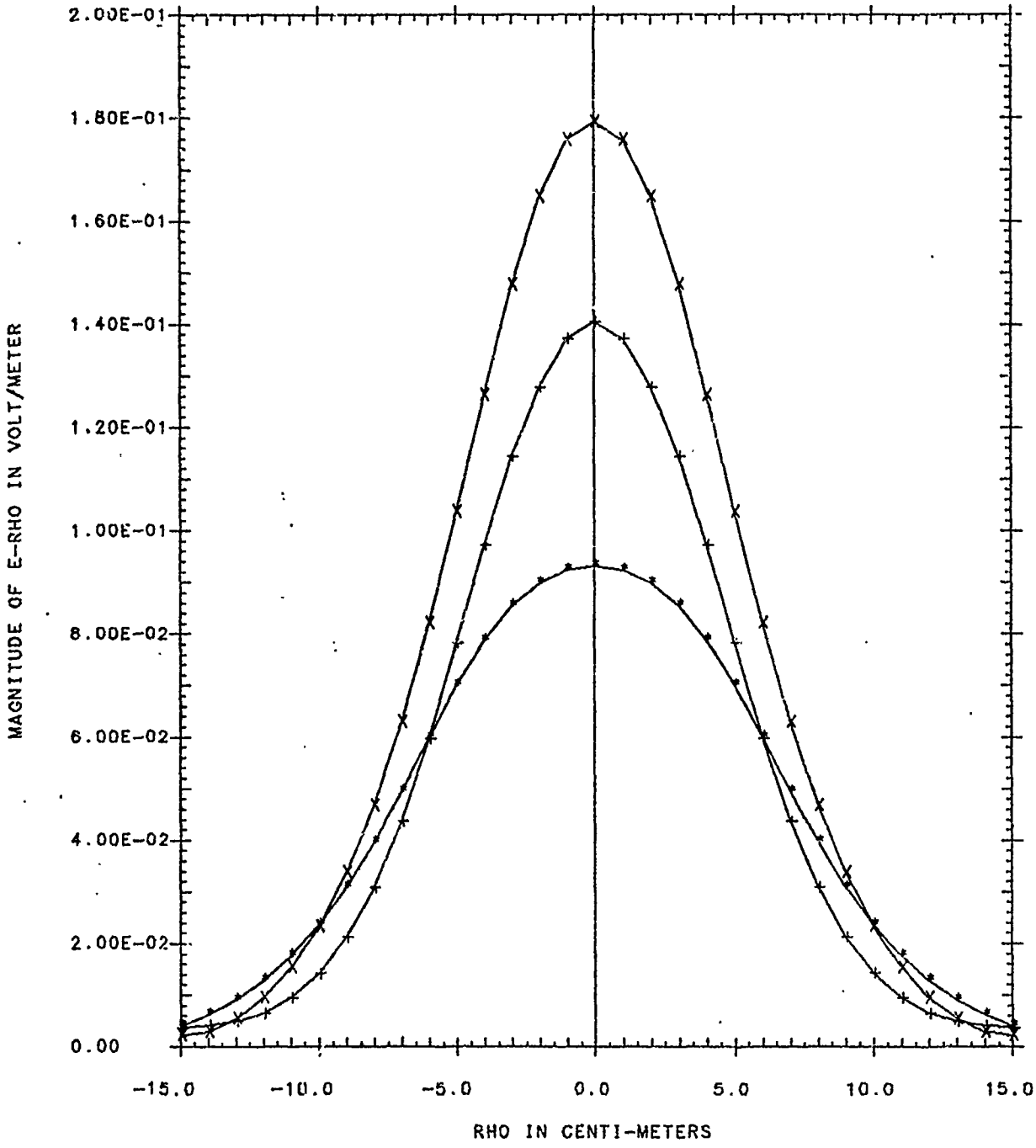


PHI CUT OF 180 - 0 DEGREES IS USED.
AT 1.0 INCH ABOVE THE GROUND
* SILT LOAM WITH 5.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.
X SILT LOAM WITH 10.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.
+ SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.

Figure 7

Curves show that 1 inch above the ground the magnitude of H_ϕ^s generally increases with increased water content at 600 MHz.

ANGLE OF INCIDENCE IS 0. WITH H POLARIZED IN THE -Y DIRECTION.

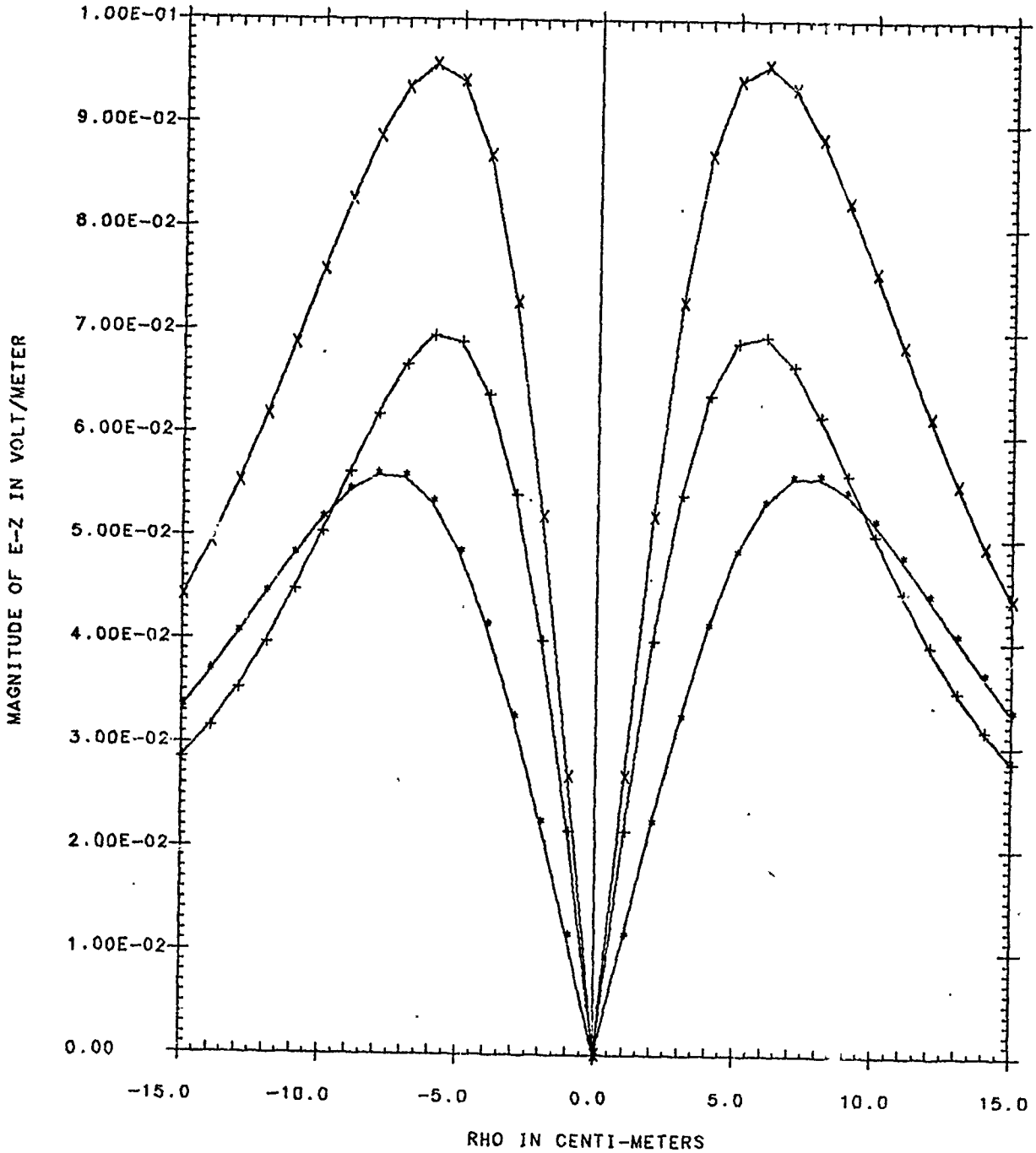


PHI CUT OF 180 - 0 DEGREES IS USED.
AT 1.0 INCH ABOVE THE GROUND
* SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.
X SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 1000. MEGA HERTZ.
+ SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 1400. MEGA HERTZ.

Figure 8

Curves show that 1 inch above the ground the magnitude of E_ρ^s is generally larger at 1000 MHz than at either 600 or 1400 MHz for silt loam having a 20% water content.

ANGLE OF INCIDENCE IS 0. WITH H POLARIZED IN THE -Y DIRECTION.

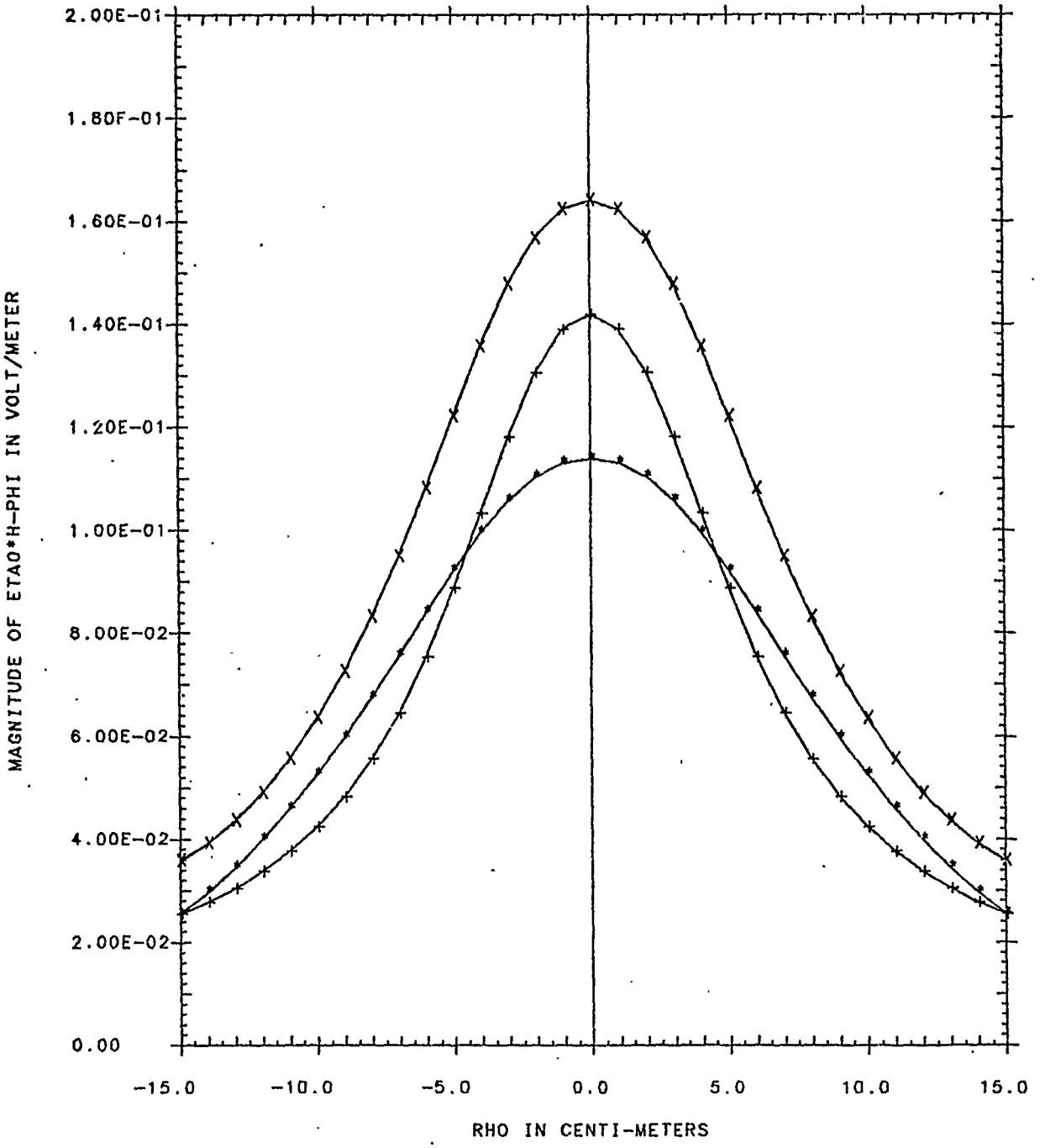


PHI CUT OF 180 - 0 DEGREES IS USED.
AT 1.0 INCH ABOVE THE GROUND
* SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.
X SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 1000. MEGA HERTZ.
+ SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 1400. MEGA HERTZ.

Figure 9

Curves show that 1 inch above the ground the magnitude of E_z is generally larger at 1000 MHz than at either 600 or 1400 MHz for silt loam having a 20% water content.

ANGLE OF INCIDENCE IS 0. WITH H POLARIZED IN THE -Y DIRECTION.



PHI CUT OF 180 - 0 DEGREES IS USED.
AT 1.0 INCH ABOVE THE GROUND
* SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 600.0 MEGA HERTZ.
X SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 1000. MEGA HERTZ.
+ SILT LOAM WITH 20.0 PER CENT WATER FREQUENCY 1400. MEGA HERTZ.

Figure 10

Curves show that 1 inch above the ground the magnitude of H_ρ^s is generally larger at 1000 MHz than at either 600 or 1400 MHZ for silt loam having a 20% water content.

V. DATA PRESENTATION

The data for the scattered fields are presented in such a way as to give the maximum information with the minimum data set and easiest access. The fields are decomposed in their cylindrical components E_ρ^s, E_ϕ^s, E_z^s and $\eta_o H_\rho^s$, $\eta_o H_\phi^s$, $\eta_o H_z^s$. For a particular incident angle, polarization, and ρ, a field location, the fields are given in terms of their "Azimuthal Coefficients" For example:

$$E_\zeta^s = \sum_{-M}^{M} a_m e^{jm\phi} \qquad \zeta = \rho, \phi \text{ or } z$$

where a_m's are the "Azimuthal Coefficients". Therefore, along the positive x-axis, E_ρ^s which equals E_x^s is as shown below

$$E_\rho^s = E_x^s = \sum_{-M}^{M} a_m$$

And, along the negative x-axis, E_ρ^s which equals $-E_x^s$ is as shown below,

$$E_\rho^s = -E_x^s = \sum_{-M}^{M} a_m e^{jm\pi}$$

The field at any other azimuthal angles can be found accordingly.

In this report, the "Azimuthal Coefficients" are computed for ρ from 0 to 15 cm at 1 cm interval, and for z from 1-4" at 1" interval. Therefore, by proper summation of the "Azimuthal Coefficients" fields within circles of 15 cm radius at 4 different height can be obtained.

The "Azimuthal Coefficients" are presented in tapes, the documentation of which is in the next two chapters. Samples of the information on the tapes are given in Chapter VIII.

VI. Description of the Program PCOEF (sent via nine track tape)

1. A complete listing of the Fortran Source of the program PCOEF is in Appendix II.

2. Here at Berkeley the MNF4 compiler was used. The input consists of the file of coefficients to be read, TAPE 18, and the instructions by the user which are in the file input which has been made equivalent to TAPE 10, by the Program statement in the main part of the Program.

3. TAPE 18 should be positioned at its beginning.

4. Below is a typical input for TAPE 10:

```
     500.0      05.0      30.0      00.0      2.0         2.
 ETAØ*HPHI EZEE
12345678901234567890123456789012345678901234567890123456789 0
         1111111111222222222233333333334444444444555555555556
```

5. The input, TAPE 10, is read by subroutine READIN. The reader should refer to that subroutine now. The first logical record contains the desired frequency (in Mega Hertz), the per cent water content of the soil, the angle of incidence in degrees, the angle of polarization in degrees, the height in inches, and the number of components desired. The above example in Item 4 indicates 500 MHz, 5% water, 30° incident angle, 0° polarization, 2 inches above the ground and 2 field components. Subroutine READIN will then call subroutine RCNAME; it reads the names of the components in the order they are to be printed. Note the names must be exactly as listed in array ACOMP, which is set by the third data statement in the main part of the program. Again, for the sake of clarification, the names must be the same as the elements in array ACOMP, such as ETAØ*HPHI for $\eta_o H_\phi$, EZEE for E_z etc., but any order is allowed. Note, the first character of each element of ACOMP is a blank.

6. The subroutine READIN uses subroutine EOFILE to be sure the input which is TAPE 10 will be positioned at the start of the next file. A user at a computer center other than LBL's may have to change EOFILE, since it calls EOF.

7. This program has been successfully run here at Berkeley.

VII. Description of the files Containing Azimuthal Coefficients sent ia the nine track tapes

1. The tapes were written by using LBL's ENCODE. A record length of 80 characters and a blocking factor of 45 was used. The tapes are written in ASCII.

2. Each file containing azimuthal coefficients is for a mine buried in silt loam having either 5%, 10% or 20% water content. The frequency of the incident fields is one of the following: 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, or 1400 Mega Hertz.

3. The air-ground interface is taken to be the xy plane, with the mine being buried and centered on the negative z axis. The incident planar field's Poynting vector is taken to always lie in the xz plane. Incident angles are with respect to the vertical axis (the z axis). Plane waves whose incident angles are 0, 30, 45, 60, and 75 degrees were used. Note that an incident angle of 0 degrees corresponds to a planar wave whose Poynting vector is in the negative z direction. For each incident angle, two polarizations are considered. The polarizations are defined by a polarization angle. The angles of 0 and 90 degrees were used. A polarization angle of 0 degrees means that the incident H field is polarized in the -y direction. A polarization angle of 90 degrees means that the incident E field is polarized in the +y direction.

4. To obtain the total fields, add the incident field and the field scattered by the air-ground interface to that defined by the azimuthal coefficients. The magnitudes are normalized so that the electric field of the incident plane wave has a value of 1 volt per meter. The azimuthal coefficients for the phi, rho, and zee components of the electric field are given in units of volts per meter. Azimuthal coefficients for the phi, rho, and zee components of the magnetic field are given in $\eta_0 H$, ($\eta_0 = 377\Omega$). These coefficients are also in units of volts per meter.

5. The files containing the azimuthal coefficients, when printed, can be read by a human being, although this would certainly be a tedious task. The results are grouped by incident plane wave. For each incident plane wave, the results are grouped by a particular height above the air-ground interface. For each particular height above the air-ground interface, the results are grouped by field components. For each field component, the results are grouped by a particular value of rho. For each value of rho, the most negative azimuthal order appears first.

6. What now follows is a line by line description of such a file. The reader may now wish to refer to a listing of TAPE 18. The first part of Chapter VIII of this report contains a listing of the first part of one of the files.

7. First appears a heading. The first line of this eight line heading is as shown directly below:

FREQMH,PCENT,ZINCH,AOFI,AOFP,MM3,NPTU

FREQMH	indicates frequency in Mega Hertz
PCENT	indicates per cent water content of the soil
ZINCH	indicates height above the air-ground interface in inches
AOFI	indicates angle of incidence in degrees
AOFP	indicates angle of polarization in degrees. (As stated above, there are only two values used. 0 corresponds to the incident H field polarized in the -y direction; 90 indicates the incident E field is polarized in the +y direction.
MM3	indicates the total number of azimuthal coefficients. This number is always a positive odd integer, since the absolute value of the most negative azimuthal order used equals the value of the largest, with all azimuthal orders lying between these limits being used as well.
NPTU	indicates the number of rho values used for the height. The number used is always 16.

8. The second line of the heading lists the values of the first line, in the order of the first line. Referring to the first heading of the file shown in Chapter VIII, we have freq. = 1400 MHz, 20% water, 1 inch above ground, 0° incident, 0° polarization, MM3 = 11, NPTU = 16. The third line prints the format to be used to read the first three lines of the heading.

9. The next line is as shown below:

(RHO(I),J=1,NPTU,1) --- IN FORMAT(4(1X,E10.4))

RHO indicates the rho values used in centimeters. The format is the format used to read the next four lines, which contain the various rho values used. The rho values used are always the same 0 through 15 centimeters in increments of 1 centimeter.

10. These first eight lines then are what are referred to as the heading. A heading then always appears before the results for each particular height.

11. Following the heading are two lines. These two lines indicate the field component and the format to use to read these two lines. Following this is a line shown below:

((WAVEH(IROW,ICOL), IROW=1,MM3,1),JCOL=1NPTU,1) --- IN FORMAT((6(1X,E10.4))

11. (cont.)

This indicates that the two dimensional array for storing the azimuthal coefficients are written out in groups of MM3(=11 in the example shown in Chapter VIII) complex numbers, (22 real numbers). The first block of coefficients refers to JCOL=1, which represents EPHI at $\rho = 0$. The first two numbers in JCOL=1, represents the real and Imaginary part of the most negative azimuthal order, i.e., M=-5 for MM3=11. The next two numbers correspond to M=-4, etc, and the last two numbers corresponds to M=5. The next block of numbers, JCOL=2, represents EPHI at $\rho = 1$ cm, and each subsequent blocks represents the field at 1 cm increment in ρ.

12. Following these coefficients are two lines which indicate the next field component, which are in turn followed by its azimuthal coefficients. This pattern is then repeated throughout the tape.

13. Appendix I illustrates the application of the data base to compute scattered and total fields on planes above the ground.

VIII. Typical Portions of the data Base of Azimuthal Coefficients

The incident field in this report refers to the incident plane wave. The primary field refers to the incident field plus the reflected field from the interface without the buried object. The scattered field is meant to be the total field less the primary field. The azimuthal coefficients are for the scattered fields. To obtain the total fields, add the primary field to that defined by the azimuthal coefficients. The magnitudes are normalized so that the electric field of the incident plane wave has a value of 1 volt per meter. The azimuthal coefficients for the phi, rho, and zee components of the electric field are given in units of volts per meter. Azimuthal coefficients for the phi, rho, and zee components of the magnetic field are given in $\eta_o H$, ($\eta_o = 377\Omega$). These coefficients are also in units of volts per meter.

The coefficients shown are from the beginning of a file where the Incident field's frequency is 1400 Mega Hertz and the soil is Silt Loam having a 20% water content. The near field is for a distance of 1 inch above the air-ground interface. Coefficients in Set I are for 0° incidence and those of Set II are for 30° incidence. Both sets of data are for polarization angle of zero degree.

Data Set I

```
FREQMH,PCENT,ZINCH,ADFI,ADFP,MM3,NPTU
 .1400E+04  .2000E+02  .1000E+01 0.          0.                  11          16
IN FORMAT(38X,/,5(1X,E10.4),2(1X,I10),/,45X)
(RHO(I),I=1,NPTU,1) --- IN FORMAT(4(1X,E10.4))
0.          .1000E+01  .2000E+01  .3000E+01
 .4000E+01  .5000E+01  .6000E+01  .7000E+01
 .8000E+01  .9000E+01  .1000E+02  .1100E+02
 .1200E+02  .1300E+02  .1400E+02  .1500E+02
THE NEAR FIELD COMPONENT IS EPHI
IN FORMAT(29X,A10,/,25X)
((WAVEEH(IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.          .2202E-01   .6676E-01   0.          0.
-.2202E-01  -.6676E-01  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .2340E-01   .6498E-01  0.          0.          -.2340E-01  -.6498E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .2693E-01   .5928E-01
0.          0.          -.2693E-01  -.5928E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          .3095E-01   .4944E-01   0.          0.
-.3095E-01  -.4944E-01  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .3348E-01   .3664E-01  0.          0.          -.3348E-01  -.3664E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .3326E-01   .2318E-01
0.          0.          -.3326E-01  -.2318E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          .3025E-01   .1122E-01   0.          0.
-.3025E-01  -.1122E-01  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .2527E-01   .2013E-02  0.          0.          -.2527E-01  -.2013E-02
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .1940E-01  -.4148E-02
0.          0.          -.1940E-01   .4148E-02  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          .1355E-01  -.7547E-02  0.          0.
-.1355E-01   .7547E-02  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .8404E-02  -.8742E-02  0.          0.          -.8404E-02   .8742E-02
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .4389E-02  -.8432E-02
0.          0.          -.4389E-02   .8432E-02  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          .1612E-02  -.7365E-02  0.          0.
-.1612E-02   .7365E-02  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.1600E-03  -.6150E-02  0.          0.          .1600E-03   .6150E-02
0.          0.          0.          0.          0.          0.
```

← JCOL=1

← JCOL=2

```
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.1346E-02  -.5071E-02
0.          0.          .1346E-02   .5071E-02   0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          -.2280E-02  -.4071E-02  0.          0.
 .2280E-02  .4071E-02   0.          0.          0.          0.
0.          0.          0.          0.
THE NEAR FIELD COMPONENT IS ERHO
IN FORMAT(29X,A10,/,25X)
((WAVEERH(IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.          -.6676E-01  .2202E-01   0.          0.
-.6676E-01  .2202E-01   0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.6495E-01  .2210E-01   0.          0.          -.6495E-01  .2210E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.5994E-01  .2243E-01
0.          0.          -.5994E-01  .2243E-01   0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.5236E-01  .2305E-01   -.5236E-01  .2305E-01   0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.4264E-01  .2348E-01   0.          0.          -.4264E-01  .2348E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.3173E-01  .2300E-01
0.          0.          -.3173E-01  .2300E-01   0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.2114E-01  .2118E-01   -.2114E-01  .2118E-01   0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.1223E-01  .1813E-01   0.          0.          -.1223E-01  .1813E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.5681E-02  .1437E-01
0.          0.          -.5681E-02  .1437E-01   0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.1549E-02  .1050E-01   -.1549E-02  .1050E-01   0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .5347E-03  .7103E-02   0.          0.          .5347E-03   .7103E-02
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .1206E-02   .4586E-02
0.          0.          .1206E-02   .4586E-02   0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .1190E-02  .3040E-02   .1190E-02   .3040E-02   0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .1070E-02  .2229E-02   0.          0.          .1070E-02   .2229E-02
0.          0.          0.          0.          0.          0.
```

```
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .1100E-02   .1757E-02
0.          0.          .1100E-02   .1757E-02   0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          .1224E-02   .1314E-02   0.          0.
 .1224E-02   .1314E-02   0.          0.          0.          0.
0.          0.          0.          0.
THE NEAR FIELD COMPONENT IS EZEE
IN FORMAT(29X,A10,/,25X)
((WAVEEN(IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .7497E-02  -.7796E-02  0.          0.          .7497E-02   -.7796E-02
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .1345E-01   -.1482E-01
0.          0.          .1345E-01   -.1482E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          .1730E-01   -.2081E-01  0.          0.
 .1730E-01  -.2081E-01  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .1872E-01  -.2585E-01  0.          0.          .1872E-01   -.2585E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .1726E-01   -.2982E-01
0.          0.          .1726E-01   -.2982E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          .1291E-01   -.3227E-01  0.          0.
 .1291E-01  -.3227E-01  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .6492E-02  -.3270E-01  0.          0.          .6492E-02   -.3270E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.7437E-03  -.3092E-01
0.          0.          -.7437E-03  -.3092E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          -.7575E-02  -.2706E-01  0.          0.
-.7575E-02  -.2706E-01  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.1302E-01  -.2158E-01  0.          0.          -.1302E-01  -.2158E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.1649E-01  -.1521E-01
0.          0.          -.1649E-01  -.1521E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          -.1783E-01  -.8784E-02  0.          0.
-.1783E-01  -.8784E-02  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.1737E-01  -.3026E-02  0.          0.          -.1737E-01  -.3026E-02
0.          0.          0.          0.          0.          0.
```

```
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.1567E-01  .1694E-02
0.          0.          -.1367E-01  .1694E-02  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          -.1321E-01  .5344E-02  0.          0.
-.1321E-01  .5344E-02   0.          0.          0.          0.
0.          0.          0.          0.
THE NEAR FIELD COMPONENT IS HPHI
IN FORMAT(29X,A10,/,25X)
((WAVEEH(IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.          -.6440E-01  .2979E-01  0.          0.
-.6440E-01  .2979E-01   0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.6225E-01  .3092E-01   0.          0.          -.6225E-01  .3092E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.5615E-01  .3342E-01
0.          0.          -.5615E-01  .3342E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.4720E-01  .3554E-01   0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.3683E-01  .3631E-01   0.          0.          -.3683E-01  .3631E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.2633E-01  .3569E-01
0.          0.          -.2633E-01  .3569E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.1649E-01  .3396E-01   -.1649E-01  .3396E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.7702E-02  .3131E-01   0.          0.          -.7702E-02  .3131E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          -.1684E-03  .2779E-01  -.1684E-03  .2779E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          .5945E-02   .2346E-01  0.          0.
.5945E-02   .2346E-01   0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
.1049E-01   .1851E-01   0.          0.          .1049E-01   .1851E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .1340E-01   .1328E-01
0.          0.          .1340E-01   .1328E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
.1479E-01   .8124E-02   .1479E-01   .8124E-02  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
.1485E-01   .3364E-02   0.          0.          .1485E-01   .3364E-02
0.          0.          0.          0.          0.          0.
```

```
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .1386E-01  -.8125E-03
0.          0.          .1386E-01  -.8125E-03  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          .1203E-01  -.4294E-02  0.          0.
 .1203E-01  -.4294E-02  0.          0.          0.          0.
0.          0.          0.          0.
THE NEAR FIELD COMPONENT IS HRHO
IN FORMAT(29X,A10,/,25X)
((WAVEHK IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.          -.2979E-01 -.6440E-01  0.          0.
 .2979E-01  .6440E-01   0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.3082E-01 -.6028E-01   0.          0.          .3082E-01   .6028E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          .3066E-01   .4935E-01  -.3066E-01  -.4935E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          -.2486E-01 -.3580E-01  0.          0.
 .2486E-01  .3580E-01   0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.1445E-01 -.2472E-01   0.          0.          .1445E-01   .2472E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.4268E-02 -.1877E-01
0.          0.          .4268E-02   .1877E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.1972E-02  .1717E-01   .1972E-02  -.1717E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .3636E-02 -.1755E-01   0.          0.          -.3636E-02  .1755E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .2021E-02  -.1793E-01
0.          0.          -.2021E-02  .1793E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .1299E-02  .1737E-01   -.1299E-02 -.1737E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.5176E-02 -.1555E-01   0.          0.          .5176E-02   .1555E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.8698E-02 -.1233E-01
0.          0.          .8698E-02   .1233E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .1094E-01  .7952E-02   -.1094E-01 -.7952E-02  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.1125E-01 -.3251E-02   0.          0.          .1125E-01   .3251E-02
0.          0.          0.          0.          0.          0.
```

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0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.9716E-02  .5949E-03
0.          0.           .9716E-02 -.5949E-03 0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          -.7304E-02  .2824E-02 0.          0.
 .7304E-02 -.2824E-02 0.          0.          0.          0.
0.          0.          0.          0.
THE NEAR FIELD COMPONENT IS HZEE
IN FORMAT(29X,A10,/,25X)
((WAVEEHK IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .1228E-01  .1351E-01 0.          0.          -.1228E-01 -.1351E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.           .2783E-01  .2168E-01
0.          0.          -.2783E-01 -.2168E-01 0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.           .4300E-01  .2115E-01 0.          0.
-.4300E-01 -.2115E-01 0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .5126E-01  .1282E-01 0.          0.          -.5126E-01 -.1282E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.           .5016E-01  .1198E-02
0.          0.          -.5016E-01 -.1198E-02 0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.           .4211E-01 -.9058E-02 0.          0.
-.4211E-01  .9058E-02 0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .3112E-01 -.1560E-01 0.          0.          -.3112E-01  .1560E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.           .2022E-01 -.1829E-01
0.          0.          -.2022E-01  .1829E-01 0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.           .1091E-01 -.1789E-01 0.          0.
-.1091E-01  .1789E-01 0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .3880E-02 -.1532E-01 0.          0.          -.3880E-02  .1532E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.5178E-03 -.1159E-01
0.          0.           .5178E-03  .1159E-01 0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          -.2405E-02 -.7946E-02 0.          0.
 .2405E-02  .7946E-02 0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
-.2629E-02 -.5420E-02 0.          0.           .2629E-02  .5420E-02
0.          0.          0.          0.          0.          0.
```

```
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          -.2472E-02  -.4247E-02
0.          0.           .2472E-02   .4247E-02  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          -.2853E-02  -.3725E-02  0.          0.
 .2853E-02   .3725E-02  0.          0.          0.          0.
0.          0.          0.          0.
FREQMH,PCENT,ZINCH,AOFI,AOFP,MM3,NPTU
 .1400E+04   .2000E+02   .2000E+01  0.          0.                      11          16
IN FORMAT(38X,/,5(1X,E10.4),2(1X,I10),/,45X)
(RHO(I),I=1,NPTU,1) --- IN FORMAT(4(1X,E10.4))
0.          .1000E+01   .2000E+01   .3000E+01
 .4000E+01   .5000E+01   .6000E+01   .7000E+01
 .8000E+01   .9000E+01   .1000E+02   .1100E+02
 .1200E+02   .1300E+02   .1400E+02   .1500E+02
THE NEAR FIELD COMPONENT IS EPHI
IN FORMAT(29X,A10,/,25X)
((WAVEHM(IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.           .3730E-01   .2949E-01  0.          0.
-.3730E-01  -.2949E-01  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .3728E-01   .2840E-01  0.          0.          -.3728E-01  -.2840E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.           .3710E-01   .2526E-01
0.          0.          -.3710E-01  -.2526E-01  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.           .3647E-01   .2039E-01  0.          0.
-.3647E-01  -.2039E-01  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .3505E-01   .1438E-01  0.          0.          -.3505E-01  -.1438E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.           .3263E-01   .7943E-02
0.          0.          -.3263E-01  -.7943E-02  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.           .2919E-01   .1817E-02  0.          0.
-.2919E-01  -.1817E-02  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .2493E-01  -.3421E-02  0.          0.          -.2493E-01   .3421E-02
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.           .2016E-01  -.7418E-02
0.          0.          -.2016E-01   .7418E-02  0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.           .1526E-01  -.1005E-01  0.          0.
-.1526E-01   .1005E-01  0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .1059E-01  -.1139E-01  0.          0.          -.1059E-01   .1139E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.           .6390E-02  -.1164E-01
0.          0.          -.6390E-02   .1164E-01  0.          0.
```

Data Set II

```
 .1470E-02 -.8727E-02 0.          0.          0.          0.
0.          0.          0.          0.
FREQMN,PCENT,ZINCH,AOFI,AOFP,MM3,NPTU
 .1400E+04  .2000E+02  .1000E+01  .3000E+02 0.                    11          16
IN FORMAT(38X,/,5(1X,E10.4),2(1X,I10),/,45X)
(RHO(I),I=1,NPTU,1) --- IN FORMAT(4(1X,E10.4))
0.          .1000E+01  .2000E+01  .3000E+01
 .4000E+01  .5000E+01  .6000E+01  .7000E+01
 .8000E+01  .9000E+01  .1000E+02  .1100E+02
 .1200E+02  .1300E+02  .1400E+02  .1500E+02
THE NEAR FIELD COMPONENT IS EPHI
IN FORMAT(29X,A10,/,25X)
((WAVEFM(IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.          .1663E-01  .5757E-01 0.          0.
-.1663E-01 -.5757E-01 0.          0.          0.          0.
0.          0.          0.          0.         -.7005E-09  .1122E-07
 .2098E-06  .1158E-05  .1166E-03 -.3785E-04 -.2997E-02 -.2090E-02
 .1775E-01  .5615E-01 0.          0.         -.1775E-01 -.5615E-01
 .2997E-02  .2090E-02 -.1166E-03  .3785E-04 -.2098E-06 -.1158E-05
 .7005E-09 -.1122E-07 -.1579E-08  .1217E-06  .1272E-05  .7168E-05
 .3722E-03 -.1511E-03 -.5814E-02 -.3334E-02  .2065E-01  .5155E-01
0.          0.         -.2065E-01 -.5155E-01  .5814E-02  .3334E-02
-.3722E-03  .1511E-03 -.1272E-05 -.7168E-05  .1579E-08 -.1217E-06
 .1342E-07  .3156E-06  .2936E-05  .1665E-04  .5879E-03 -.3262E-03
-.8056E-02 -.3271E-02  .2411E-01  .4354E-01 0.          0.
-.2411E-01 -.4354E-01  .8056E-02  .3271E-02 -.5879E-03  .3262E-03
-.2936E-05 -.1665E-04 -.1342E-07 -.3156E-06 -.4151E-08  .3663E-06
 .5293E-05  .2569E-04  .6548E-03 -.5272E-03 -.9279E-02 -.1984E-02
 .2657E-01  .3299E-01 0.          0.         -.2657E-01 -.3299E-01
 .9279E-02  .1984E-02 -.6548E-03  .5272E-03 -.5293E-05 -.2569E-04
 .4151E-08 -.3663E-06 -.1967E-06  .2196E-06  .1022E-04  .3185E-04
 .5605E-03 -.7052E-03 -.9271E-02  .2647E-04  .2691E-01  .2169E-01
0.          0.         -.2691E-01 -.2169E-01  .9271E-02 -.2647E-04
-.5605E-03  .7052E-03 -.1022E-04 -.3185E-04  .1967E-06 -.2196E-06
-.5675E-06  .1508E-06  .1920E-04  .3263E-04  .3430E-03 -.8092E-03
-.8120E-02  .2114E-02  .2494E-01  .1143E-01 0.          0.
-.2494E-01 -.1143E-01  .8120E-02 -.2114E-02 -.3430E-03  .8092E-03
-.1920E-04 -.3263E-04  .5675E-06 -.1508E-06 -.8381E-06  .3938E-06
 .2971E-04  .2526E-04  .6639E-04 -.7962E-03 -.6152E-02  .3709E-02
 .2122E-01  .3349E-02 0.          0.         -.2122E-01 -.3349E-02
 .6152E-02 -.3709E-02 -.6639E-04  .7962E-03 -.2971E-04 -.2526E-04
 .8381E-06 -.3938E-06 -.6979E-06  .8028E-06  .3550E-04  .1016E-04
-.1864E-03 -.6544E-03 -.3837E-02  .4459E-02  .1659E-01 -.2209E-02
0.          0.         -.1659E-01  .2209E-02  .3837E-02 -.4459E-02
 .1864E-03  .6544E-03 -.3550E-04 -.1016E-04  .6979E-06 -.8028E-06
-.1610E-06  .9832E-06  .3156E-04 -.6935E-05 -.3378E-03 -.4229E-03
-.1689E-02  .4305E-02  .1185E-01 -.5421E-02 0.          0.
-.1185E-01  .5421E-02  .1689E-02 -.4305E-02  .3378E-03  .4229E-03
-.3156E-04  .6935E-05  .1610E-06 -.9832E-06  .4032E-06  .7045E-06
 .1881E-04 -.1810E-04 -.3540E-03 -.1821E-03 -.1233E-03  .3484E-02
 .7612E-02 -.6737E-02 0.          0.         -.7612E-02  .6737E-02
 .1233E-03 -.3484E-02  .3540E-03  .1821E-03 -.1881E-04  .1810E-04
-.4032E-06 -.7045E-06  .5964E-06  .1333E-06  .3941E-05 -.1890E-04
-.2647E-03 -.1261E-04  .6946E-03  .2425E-02  .4242E-02 -.6740E-02
0.          0.         -.4242E-02  .6740E-02 -.6946E-03 -.2425E-02
 .2647E-03  .1261E-04 -.3941E-05  .1890E-04 -.5964E-06 -.1333E-06
 .3366E-06 -.3255E-06 -.5610E-05 -.1156E-04 -.1434E-03  .5114E-04
 .8990E-03  .1531E-02  .1852E-02 -.6045E-02 0.          0.
-.1852E-02  .6045E-02 -.8990E-03 -.1531E-02  .1434E-03 -.5114E-04
 .5610E-05  .1156E-04 -.3366E-06  .3255E-06 -.1030E-06 -.3896E-06
-.6935E-05 -.2631E-05 -.5924E-04  .3435E-04  .8115E-03  .9948E-03
```

JCOL=1

JCOL=2

```
 .2791E-03 -.5158E-02 0.         0.         -.2791E-03  .5158E-02
-.8115E-03 -.9948E-03  .5924E-04 -.3435E-04  .6935E-05  .2631E-05
 .1030E-06  .3896E-06 -.3610E-06 -.1144E-06 -.2850E-05  .2190E-05
-.3736E-04 -.4721E-05  .7302E-03  .7485E-03 -.7982E-03 -.4334E-02
0.         0.          .7982E-03  .4334E-02 -.7302E-03 -.7485E-03
 .3736E-04  .4721E-05  .2850E-05 -.2190E-05  .3610E-06  .1144E-06
-.2879E-06  .2054E-06  .1402E-05  .1758E-05 -.5534E-04 -.1905E-04
 .7681E-03  .5896E-03 -.1651E-02 -.3549E-02 0.         0.
 .1651E-02  .3549E-02 -.7681E-03 -.5896E-03  .5534E-04  .1905E-04
-.1402E-05 -.1758E-05  .2879E-06 -.2054E-06
THE NEAR FIELD COMPONENT IS ERHO
IN FORMAT(29X,A10,/,25X)
((WAVEEHK IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.         0.         0.         0.         0.         0.
0.         0.         -.5757E-01  .1663E-01 0.         0.
-.5757E-01  .1663E-01 0.         0.         0.         0.
0.         0.         0.         0.         -.1089E-07  .2090E-09
-.1112E-05  .2407E-06  .3791E-04  .1173E-03  .2173E-02 -.2951E-02
-.5611E-01  .1683E-01 -.1336E-02 -.3225E-02 -.5611E-01  .1683E-01
 .2173E-02 -.2951E-02  .3791E-04  .1173E-03 -.1112E-05  .2407E-06
-.1089E-07  .2090E-09 -.1032E-06  .4021E-07 -.6016E-05  .1859E-05
 .1469E-03  .3787E-03  .3861E-02 -.5512E-02 -.5191E-01  .1732E-01
-.2467E-02 -.5678E-02 -.5191E-01  .1732E-01  .3861E-02 -.5512E-02
 .1469E-03  .3787E-03 -.6016E-05  .1859E-05 -.1032E-06  .4021E-07
-.1536E-06  .2905E-06 -.1086E-04  .4469E-05  .2837E-03  .6003E-03
 .4548E-02 -.7296E-02 -.4528E-01  .1785E-01 -.3328E-02 -.7006E-02
-.4528E-01  .1785E-01  .4548E-02 -.7296E-02  .2837E-03  .6003E-03
-.1086E-04  .4469E-05 -.1536E-06  .2905E-06  .2472E-06  .7334E-06
-.1210E-04  .4511E-05  .3745E-03  .6730E-03  .4079E-02 -.8040E-02
-.3673E-01  .1809E-01 -.3973E-02 -.7181E-02 -.3673E-01  .1809E-01
 .4079E-02 -.8040E-02  .3745E-03  .6730E-03 -.1210E-04  .4511E-05
 .2472E-06  .7334E-06  .1160E-05  .8585E-06 -.1284E-04  .4564E-06
 .3902E-03  .6205E-03  .2829E-02 -.7772E-02 -.2729.-01  .1763E-01
-.4428E-02 -.6344E-02 -.2729E-01  .1763E-01  .2829E-02 -.7772E-02
 .3902E-03  .6205E-03 -.1284E-04  .4564E-06  .1160E-05  .8585E-06
 .1965E-05  .2355E-06 -.1672E-04 -.3313E-05  .3654E-03  .5143E-03
 .1359E-02 -.6784E-02 -.1832E-01  .1622E-01 -.4615E-02 -.4795E-02
-.1832E-01  .1622E-01  .1359E-02 -.6784E-02  .3654E-03  .5143E-03
-.1672E-04 -.3313E-05  .1965E-05  .2355E-06  .1951E-05 -.8395E-06
-.2158E-04 -.1567E-05  .3412E-03  .3922E-03  .8312E-04 -.5429E-02
-.1089E-01  .1393E-01 -.4405E-02 -.2943E-02 -.1089E-01  .1393E-01
 .8312E-04 -.5429E-02  .3412E-03  .3922E-03 -.2158E-04 -.1567E-05
 .1951E-05 -.8395E-06  .1052E-05 -.1581E-05 -.2209E-04  .5438E-05
 .3208E-03  .2597E-03 -.7983E-03 -.3979E-02 -.5467E-02  .1113E-01
-.3734E-02 -.1224E-02 -.5467E-02  .1113E-01 -.7983E-03 -.3979E-02
 .3208E-03  .2597E-03 -.2209E-04  .5438E-05  .1052E-05 -.1581E-05
-.1009E-06 -.1475E-05 -.1598E-04  .1234E-04  .2812E-03  .1282E-03
-.1224E-02 -.2627E-02 -.2010E-02  .8266E-02 -.2717E-02  .4793E-05
-.2010E-02  .8266E-02 -.12[illegible]9E-02 -.2627E-02  .2812E-03  .1282E-03
-.1598E-04  .1234E-04 -.1009E-06 -.1475E-05 -.7652E-06 -.7008E-06
-.6340E-05  .1404E-04  .2104E-03  .2529E-04 -.1240E-02 -.1530E-02
-.1703E-03  .5748E-02 -.1638E-02  .5891E-03 -.1703E-03  .5748E-02
-.1240E-02 -.1530E-02  .2104E-03  .2529E-04 -.6340E-05  .1404E-04
-.7652E-06 -.7008E-06 -.6791E-06  .1107E-06  .1344E-05  .9966E-05
 .1257E-03 -.2497E-04 -.9907E-03 -.7892E-03  .5611E-03  .3853E-02
-.7982E-03  .6409E-03  .5611E-03  .3853E-02 -.9907E-03 -.7892E-03
 .1257E-03 -.2497E-04  .1344E-05  .9966E-05 -.6791E-06  .1107E-06
-.1620E-06  .4448E-06  .3815E-05  .3749E-05  .5928E-04 -.2506E-04
-.6716E-03 -.4071E-03  .7220E-03  .2640E-02 -.3319E-03  .4403E-03
 .7220E-03  .2640E-02 -.6716E-03 -.4071E-03  .5928E-04 -.2506E-04
 .3815E-05  .3749E-05 -.1620E-06  .4448E-06  .2607E-06  .2642E-06
 .1971E-05 -.4148E-06  .3078E-04 -.3015E-05 -.4382E-03 -.2773E-03
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 .7365E-03  .1956E-02 -.1669E-03  .2452E-03  .7365E-03  .1956E-02
-.9382E-03 -.2773E-03  .3078E-04 -.3015E-05  .1971E-05 -.4148E-06
 .2607E-06  .2642E-06  .3053E-06 -.8806E-07 -.8330E-06 -.9838E-06
 .3258E-04  .1029E-04 -.3413E-03 -.2466E-03  .8085E-03  .1538E-02
-.1309E-03  .1612E-03  .8085E-03  .1538E-02 -.3413E-03 -.2466E-03
 .3258E-04  .1029E-04 -.8330E-06 -.9838E-06  .3053E-06 -.8806E-07
 .7443E-07 -.2591E-06 -.1924E-05  .5828E-06  .4041E-04  .3402E-05
-.3318E-03 -.2021E-03  .9271E-03  .1168E-02 -.9365E-04  .1529E-03
 .9271E-03  .1168E-02 -.3318E-03 -.2021E-03  .4041E-04  .3402E-05
-.1924E-05  .5828E-06  .7443E-07 -.2591E-06
THE NEAR FIELD COMPONENT IS EZEE
IN FORMAT(29X,A10,/,25X)
((WAVEEHK(IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.         -.1440E-01 -.1186E-01
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .3715E-08  .3755E-08
 .3592E-06  .3414E-07 -.6589E-05 -.1609E-04 -.1448E-04  .5238E-03
 .6790E-02 -.6392E-02 -.1396E-01 -.1085E-01  .6790E-02 -.6392E-02
-.1448E-04  .5238E-03 -.6589E-05 -.1609E-04  .3592E-06  .3414E-07
 .3715E-08  .3755E-08  .9094E-07  .7753E-07  .4249E-05 -.5067E-07
-.6001E-04 -.1077E-03 -.1429E-03  .1957E-02  .1247E-01 -.1248E-01
-.1272E-01 -.8203E-02  .1247E-01 -.1248E-01 -.1429E-03  .1957E-02
-.6001E-04 -.1077E-03  .4249E-05 -.5067E-07  .9094E-07  .7753E-07
 .4392E-06  .2751E-06  .1317E-04 -.2420E-05 -.2061E-03 -.2636E-03
-.3563E-03  .3916E-02  .1631E-01 -.1792E-01 -.1094E-01 -.4660E-02
 .1631E-01 -.1792E-01 -.3563E-03  .3916E-02 -.2061E-03 -.2636E-03
 .1317E-04 -.2420E-05  .4392E-06  .2751E-06  .9644E-06  .3452E-06
 .2145E-04 -.8981E-05 -.4243E-03 -.3882E-03 -.3163E-03  .5847E-02
 .1774E-01 -.2245E-01 -.8800E-02 -.9509E-03  .1774E-01 -.2245E-01
-.3163E-03  .5847E-02 -.4243E-03 -.3882E-03  .2145E-04 -.8981E-05
 .9644E-06  .3452E-06  .1208E-05  .5004E-07  .2334E-04 -.1687E-04
-.6240E-03 -.4022E-03  .2654E-03  .7210E-02  .1634E-01 -.2585E-01
-.6367E-02  .2295E-02  .1634E-01 -.2585E-01  .2654E-03  .7210E-02
-.6240E-03 -.4022E-03  .2334E-04 -.1687E-04  .1208E-05  .5004E-07
 .8523E-06 -.3572E-06  .1960E-04 -.2151E-04 -.7286E-03 -.3126E-03
 .1331E-02  .7708E-02  .1235E-01 -.2782E-01 -.3721E-02  .4582E-02
 .1235E-01 -.2782E-01  .1331E-02  .7708E-02 -.7286E-03 -.3126E-03
 .1960E-04 -.2151E-04  .8523E-06 -.3572E-06  .1339E-06 -.4060E-06
 .1452E-04 -.2205E-04 -.7303E-03 -.1798E-03  .2594E-02  .7355E-02
 .6623E-02 -.2805E-01 -.1045E-02  .5641E-02  .6623E-02 -.2805E-01
 .2594E-02  .7355E-02 -.7303E-03 -.1798E-03  .1452E-04 -.2205E-04
 .1339E-06 -.4060E-06 -.3858E-06  .1353E-07  .1051E-04 -.2093E-04
-.6677E-03 -.5251E-04  .3762E-02  .6351E-02  .3052E-03 -.2644E-01
 .1338E-02  .5477E-02  .3052E-03 -.2644E-01  .3762E-02  .6351E-02
-.6677E-03 -.5251E-04  .1051E-04 -.2093E-04 -.3858E-06  .1353E-07
-.3650E-06  .5428E-06  .6869E-05 -.2012E-04 -.5791E-03  .5370E-04
 .4635E-02  .4932E-02 -.5578E-02 -.2317E-01  .3078E-02  .4373E-02
-.5578E-02 -.2317E-01  .4635E-02  .4932E-02 -.5791E-03  .5370E-04
 .6869E-05 -.2012E-04 -.3650E-06  .5428E-06  .5209E-07  .7443E-06
 .2347E-05 -.1916E-04 -.4805E-03  .1397E-03  .5095E-02  .3319E-02
-.1027E-01 -.1863E-01  .3977E-02  .2810E-02 -.1027E-01 -.1863E-01
 .5095E-02  .3319E-02 -.4805E-03  .1397E-03  .2347E-05 -.1916E-04
 .5209E-07  .7443E-06  .4378E-06  .5048E-06 -.2641E-05 -.1656E-04
-.3746E-03  .2028E-03  .5103E-02  .1722E-02 -.1333E-01 -.1339E-01
 .4111E-02  .1275E-02 -.1333E-01 -.1339E-01  .5103E-02  .1722E-02
-.3746E-03  .2028E-03 -.2641E-05 -.1656E-04  .4378E-06  .5048E-06
 .4861E-06  .8302E-07 -.6254E-05 -.1197E-04 -.2676E-03  .2352E-03
 .4716E-02  .3229E-03 -.1468E-01 -.8079E-02  .3762E-02  .5651E-04
-.1468E-01 -.8079E-02  .4716E-02  .3229E-03 -.2676E-03  .2352E-03
-.6254E-05 -.1197E-04  .4861E-06  .8302E-07  .2362E-06 -.1740E-06
-.7111E-05 -.6652E-05 -.1740E-03  .2361E-03  .4064E-02 -.7675E-03
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-.1454E-01 -.3242E-02  .3219E-02 -.8069E-03 -.1454E-01 -.3242E-02
 .4064E-02 -.7675E-03 -.1740E-03  .2361E-03 -.7111E-05 -.6852E-05
 .2362E-06 -.1740E-06 -.3837E-07 -.1337E-06 -.5624E-05 -.3216E-05
-.1059E-03  .2180E-03  .3300E-02 -.1535E-02 -.1332E-01  .8195E-03
 .2635E-02 -.1428E-02 -.1332E-01  .8195E-03  .3300E-02 -.1535E-02
-.1059E-03  .2180E-03 -.5624E-05 -.3216E-05 -.3837E-07 -.1337E-06
-.1132E-06  .6253E-07 -.3581E-05 -.1909E-05 -.6163E-04  .1991E-03
 .2525E-02 -.2038E-02 -.1140E-01  .4032E-02  .2022E-02 -.1894E-02
-.1140E-01  .4032E-02  .2525E-02 -.2038E-02 -.6163E-04  .1991E-03
-.3581E-05 -.1909E-05 -.1132E-06  .6253E-07
THE NEAR FIELD COMPONENT IS HPHI
IN FORMAT(29X,A10,/,25X)
((WAVEEHK IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.         -.5482E-01  .2175E-01  0.          0.
-.5482E-01  .2175E-01  0.          0.          0.          0.
0.          0.          0.          0.          .4833E-07  .1453E-08
 .1073E-05 -.1826E-06  .1737E-03  .2961E-04  .9984E-03 -.4612E-02
-.5320E-01  .2275E-01  .1665E-02 -.2080E-02 -.5320E-01  .2275E-01
 .9984E-03 -.4612E-02  .1737E-03  .2961E-04  .1073E-05 -.1826E-06
 .4833E-07  .1453E-08  .5895E-06 -.4728E-07  .4591E-05 -.1671E-05
 .5532E-03  .1157E-03  .1260E-02 -.8150E-02 -.4852E-01  .2506E-01
 .2921E-02 -.3973E-02 -.4852E-01  .2506E-01  .1260E-02 -.8150E-02
 .5532E-03  .1157E-03  .4591E-05 -.1671E-05  .5895E-06 -.4728E-07
 .1890E-05 -.5190E-06  .2350E-05 -.4306E-05  .8986E-03  .2294E-03
 .5981E-03 -.1011E-01 -.4138E-01  .2734E-01  .3501E-02 -.5536E-02
-.4138E-01  .2734E-01  .5981E-03 -.1011E-01  .8986E-03  .2294E-03
 .2350E-05 -.4306E-05  .1890E-05 -.5190E-06  .3077E-05 -.1838E-05
-.1229E-04 -.2445E-05  .1111E-02  .2991E-03 -.6969E-03 -.1058E-01
-.3281E-01  .2870E-01  .3320E-02 -.6680E-02 -.3281E-01  .2870E-01
-.6969E-03 -.1058E-01  .1111E-02  .2991E-03 -.1229E-04 -.2445E-05
 .3077E-05 -.1838E-05  .2907E-05 -.3617E-05 -.3139E-04  .1073E-04
 .1204E-02  .2496E-03 -.2209E-02 -.9912E-02 -.2387E-01  .2890E-01
 .2446E-02 -.7340E-02 -.2387E-01  .2890E-01 -.2209E-02 -.9912E-02
 .1204E-02  .2496E-03 -.3139E-04  .1073E-04  .2907E-05 -.3617E-05
 .1147E-05 -.4698E-05 -.3933E-04  .3330E-04  .1186E-02  .6762E-04
-.3579E-02 -.8472E-02 -.1534E-01  .2803E-01  .1079E-02 -.7466E-02
-.1534E-01  .2803E-01 -.3579E-02 -.8472E-02  .1186E-02  .6762E-04
-.3933E-04  .3330E-04  .1147E-05 -.4698E-05 -.1172E-05 -.4221E-05
-.2817E-04  .5353E-04  .1043E-02 -.1783E-03 -.4542E-02 -.6603E-02
-.7661E-02  .2620E-01 -.5007E-03 -.7037E-02 -.7661E-02  .2620E-01
-.4542E-02 -.6603E-02  .1043E-02 -.1783E-03 -.2817E-04  .5353E-04
-.1172E-05 -.4221E-05 -.2687E-05 -.2394E-05 -.3920E-05  .5924E-04
 .7879E-03 -.3820E-03 -.4966E-02 -.4638E-02 -.1078E-02  .2349E-01
-.1993E-02 -.6099E-02 -.1078E-02  .2349E-01 -.4966E-02 -.4638E-02
 .7879E-03 -.3820E-03 -.3920E-05  .5924E-04 -.2687E-05 -.2394E-05
-.2720E-05 -.2742E-06  .1941E-04  .4733E-04  .4889E-03 -.4668E-03
-.4880E-02 -.2868E-02  .4263E-02  .2001E-01 -.3150E-02 -.4786E-02
 .4263E-02  .2001E-01 -.4880E-02 -.2868E-02  .4889E-03 -.4668E-03
 .1941E-04  .4733E-04 -.2720E-05 -.2742E-06 -.1609E-05  .1072E-05
 .3042E-04  .2523E-04  .2328E-03 -.4254E-03 -.4450E-02 -.1475E-02
 .8258E-02  .1597E-01 -.3837E-02 -.3302E-02  .8258E-02  .1597E-01
-.4450E-02 -.1475E-02  .2328E-03 -.4254E-03  .3042E-04  .2523E-04
-.1609E-05  .1072E-05 -.2681E-06  .1252E-05  .2700E-04  .4713E-05
 .7741E-04 -.3116E-03 -.3892E-02 -.4882E-03  .1089E-01  .1163E-01
-.4051E-02 -.1854E-02  .1089E-01  .1166E-01 -.3892E-02 -.4882E-03
 .7741E-04 -.3116E-03  .2700E-04  .4713E-05 -.2681E-06  .1252E-05
 .5220E-06  .6330E-06  .1546E-04 -.6143E-05  .2497E-04 -.1985E-03
-.3368E-02  .1939E-03  .1223E-01  .7369E-02 -.3889E-02 -.5859E-03
 .1223E-01  .7369E-02 -.3368E-02  .1939E-03  .2497E-04 -.1985E-03
 .1546E-04 -.6143E-05  .5220E-06  .6330E-06  .5546E-06 -.9384E-07
 .4524E-05 -.6770E-05  .3310E-04 -.1337E-03 -.2924E-02  .7208E-03
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 .1246E-01  .3356E-02 -.3475E-02  .4449E-03  .1246E-01  .3356E-02
-.2924E-02  .7208E-03  .3310E-04 -.1337E-03  .4524E-05 -.6770E-05
 .5546E-06 -.9384E-07  .1445E-06 -.4319E-06 -.6488E-06 -.2193E-05
 .4947E-04 -.1219E-03 -.2508E-02  .1196E-02  .1178E-01 -.2140E-03
-.2905E-02  .1241E-02  .1178E-01 -.2140E-03 -.2508E-02  .1196E-02
 .4947E-04 -.1219E-03 -.6488E-06 -.2193E-05  .1445E-06 -.4319E-06
-.2435E-06 -.3211E-06 -.3041E-06  .1882E-05  .4266E-04 -.1371E-03
-.2035E-02  .1629E-02  .1035E-01 -.3231E-02 -.2237E-02  .1816E-02
 .1035E-01 -.3231E-02 -.2035E-02  .1629E-02  .4266E-04 -.1371E-03
-.3041E-06  .1882E-05 -.2435E-06 -.3211E-06
THE NEAR FIELD COMPONENT IS HRHO
IN FORMAT(29X,A10,/,25X)
((WAVEEHK(IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.         -.2175E-01 -.5482E-01  0.          0.
 .2175E-01  .5482E-01  0.          0.          0.          0.
0.          0.          0.          0.         -.4798E-09  .4681E-07
 .2193E-06  .9743E-06 -.3026E-04  .1628E-03  .4413E-02  .9340E-03
-.2262E-01 -.5186E-01  0.          0.          .2262E-01  .5186E-01
-.4413E-02 -.9340E-03  .3026E-04 -.1628E-03 -.2193E-06 -.9743E-06
 .4798E-09 -.4681E-07  .8627E-07  .5131E-06  .2279E-05  .2422E-05
-.1226E-03  .4264E-03  .6807E-02  .9835E-03 -.2275E-01 -.4373E-01
0.          0.          .2275E-01  .4373E-01 -.6807E-02 -.9835E-03
 .1226E-03 -.4264E-03 -.2279E-05 -.2422E-05 -.8627E-07 -.5131E-06
 .7025E-06  .1310E-05  .5302E-05 -.6270E-05 -.2432E-03  .5032E-03
 .6647E-02  .4509E-03 -.1870E-01 -.3302E-01  0.          0.
 .1870E-01  .3302E-01 -.6647E-02 -.4509E-03  .2432E-03 -.5032E-03
-.5302E-05  .6270E-05 -.7025E-06 -.1310E-05  .1957E-05  .1229E-05
 .5896E-07 -.2508E-04 -.2914E-03  .4157E-03  .4780E-02  .1419E-03
-.1099E-01 -.2348E-01  0.          0.          .1099E-01  .2348E-01
-.4780E-02 -.1419E-03  .2914E-03 -.4157E-03 -.5896E-07  .2508E-04
-.1957E-05 -.1229E-05  .2716E-05 -.4530E-06 -.1813E-04 -.3394E-04
-.1868E-03  .2711E-03  .2370E-02  .4504E-03 -.3164E-02 -.1762E-01
0.          0.          .3164E-02  .1762E-01 -.2370E-02 -.4504E-03
 .1868E-03 -.2711E-03  .1813E-04  .3394E-04 -.2716E-05  .4530E-06
 .1679E-05 -.2632E-05 -.3539E-04 -.1708E-04  .1134E-04  .5403E-04
 .2761E-03  .1393E-02  .1883E-02 -.1538E-01  0.          0.
-.1883E-02  .1538E-01 -.2761E-03 -.1393E-02 -.1134E-04 -.5403E-04
 .3539E-04  .1708E-04 -.1679E-05  .2632E-05 -.8944E-06 -.3359E-05
-.3122E-04  .1614E-04  .1244E-03 -.2568E-03 -.9325E-03  .2823E-02
 .3403E-02 -.1515E-01  0.          0.         -.3403E-02  .1515E-01
 .9325E-03 -.2823E-02 -.1244E-03  .2568E-03  .3122E-04 -.1614E-04
 .8944E-06  .3359E-05 -.3191E-05 -.1808E-05 -.1496E-05  .3922E-04
 .9808E-05 -.5554E-03 -.9024E-03  .4367E-02  .2195E-02 -.1528E-01
0.          0.         -.2195E-02  .1528E-01  .9024E-03 -.4367E-02
-.9808E-05  .5554E-03  .1496E-05 -.3922E-04  .3191E-05  .1808E-05
-.3501E-05  .9427E-06  .3521E-04  .3296E-04 -.3039E-03 -.6632E-03
 .3548E-03  .5393E-02 -.5394E-03 -.1481E-01  0.          0.
 .5394E-03  .1481E-01 -.3548E-03 -.5393E-02  .3039E-03  .6632E-03
-.3521E-04 -.3296E-04  .3501E-05 -.9427E-06 -.1698E-05  .2894E-05
 .5339E-04  .1782E-05 -.6277E-03 -.4891E-03  .2302E-02  .5290E-02
-.3808E-02 -.1334E-01  0.          0.          .3808E-02  .1334E-01
-.2302E-02 -.5290E-02  .6277E-03  .4891E-03 -.5339E-04 -.1782E-05
 .1698E-05 -.2894E-05  .7510E-06  .2812E-05  .4188E-04 -.3128E-04
-.7561E-03 -.1212E-03  .4024E-02  .3910E-02 -.6819E-02 -.1072E-01
0.          0.          .6819E-02  .1072E-01 -.4024E-02 -.3910E-02
 .7561E-03  .1212E-03 -.4188E-04  .3128E-04 -.7510E-06 -.2812E-05
 .2103E-05  .1106E-05  .1170E-04 -.4428E-04 -.6215E-03  .2324E-03
 .4720E-02  .1772E-02 -.8819E-02 -.7157E-02  0.          0.
 .8819E-02  .7157E-02 -.4720E-02 -.1772E-02  .6215E-03 -.2324E-03
-.1170E-04  .4428E-04 -.2103E-05 -.1106E-05  .1707E-05 -.7191E-06
-.1497E-04 -.3285E-04 -.3315E-03  .3976E-03  .4200E-02 -.2231E-03
```

```
-.9263E-02 -.3275E-02 0.          0.          .9263E-02  .3275E-02
-.4200E-02  .2231E-03  .3315E-03 -.3976E-03  .1497E-04  .3285E-04
-.1707E-05  .7191E-06  .3026E-06 -.1392E-05 -.2306E-04 -.1042E-04
-.7017E-04  .3496E-03  .2960E-02 -.1376E-02 -.8189E-02 -.5768E-05
0.          0.         .8189E-02  .5768E-05 -.2960E-02  .1376E-02
 .7017E-04 -.3496E-03  .2306E-04  .1042E-04 -.3026E-06  .1392E-05
-.8213E-06 -.7808E-06 -.1420E-04  .5476E-05  .4391E-04  .2009E-03
 .1766E-02 -.1613E-02 -.6303E-02  .1998E-02 0.          0.
 .6303E-02 -.1998E-02 -.1766E-02  .1613E-02 -.4391E-04 -.2009E-03
 .1420E-04 -.5476E-05  .8213E-06  .7808E-06
THE NEAR FIELD COMPONENT IS HZEE
IN FORMAT(29X,A10,/,25X)
((WAVEEHK IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          .4132E-08 -.1352E-07
 .7842E-07 -.5590E-06  .2873E-06 -.6904E-04 -.1600E-02 -.1649E-03
 .9836E-02  .1047E-01 0.          0.         -.9836E-02 -.1047E-01
 .1600E-02  .1649E-03 -.2873E-06  .6904E-04 -.7842E-07  .5590E-06
-.4132E-08  .1352E-07  .5965E-07 -.3285E-06  .9142E-07 -.5519E-05
 .1254E-04 -.4054E-03 -.5358E-02 -.1555E-04  .2221E-01  .1739E-01
0.          0.         -.2221E-01 -.1739E-01  .5358E-02  .1555E-04
-.1254E-04  .4054E-03 -.9142E-07  .5519E-05 -.5965E-07  .3285E-06
-.3506E-07 -.1572E-05 -.2966E-05 -.1069E-04  .7043E-04 -.8663E-03
-.9113E-02  .1311E-02  .3444E-01  .1803E-01 0.          0.
-.3444E-01 -.1803E-01  .9113E-02 -.1311E-02 -.7043E-04  .8663E-03
 .2966E-05  .1069E-04  .3506E-07  .1572E-05 -.1119E-05 -.3409E-05
-.7668E-05  .1278E-06  .1667E-03 -.1222E-02 -.1124E-01  .3693E-02
 .4157E-01  .1238E-01 0.          0.         -.4157E-01 -.1238E-01
 .1124E-01 -.3693E-02 -.1667E-03  .1222E-02  .7668E-05 -.1278E-06
 .1119E-05  .3409E-05 -.3533E-05 -.4104E-05 -.2677E-06  .2943E-04
 .1918E-03 -.1448E-02 -.1122E-01  .6379E-02  .4143E-01  .3412E-02
0.          0.         -.4143E-01 -.3412E-02  .1122E-01 -.6379E-02
-.1918E-03  .1448E-02  .2677E-06 -.2943E-04  .3533E-05  .4104E-05
-.5925E-05 -.2299E-05  .2954E-04  .5449E-04  .1070E-04 -.1567E-02
-.9295E-02  .8643E-02  .3556E-01 -.5194E-02 0.          0.
-.3556E-01  .5194E-02  .9295E-02 -.8643E-02 -.1070E-04  .1567E-02
-.2954E-04 -.5449E-04  .5925E-05  .2299E-05 -.6249E-05  .1300E-05
 .6981E-04  .4919E-04 -.3810E-03 -.1492E-02 -.6007E-02  .9884E-02
 .2693E-01 -.1118E-01 0.          0.         -.2693E-01  .1118E-01
 .6007E-02 -.9884E-02  .3810E-03  .1492E-02 -.6981E-04 -.4919E-04
 .6249E-05 -.1300E-05 -.3812E-05  .4356E-05  .9268E-04  .1051E-04
-.8046E-03 -.1136E-02 -.2177E-02  .9645E-02  .1801E-01 -.1404E-01
0.          0.         -.1801E-01  .1404E-01  .2177E-02 -.9645E-02
 .8046E-03  .1136E-02 -.9268E-04 -.1051E-04  .3812E-05 -.4356E-05
-.3624E-07  .4875E-05  .7911E-04 -.3771E-04 -.1016E-02 -.5605E-03
 .1167E-02  .7857E-02  .1023E-01 -.1422E-01 0.          0.
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-.7911E-04  .3771E-04  .3624E-07 -.4875E-05  .2713E-05  .2785E-05
 .3589E-04 -.6452E-04 -.8889E-03  .1207E-04  .3123E-02  .5068E-02
 .4249E-02 -.1248E-01 0.          0.         -.4249E-02  .1248E-01
-.3123E-02 -.5068E-02  .8889E-03 -.1207E-04 -.3589E-04  .6452E-04
-.2713E-05 -.2785E-05  .3002E-05 -.1720E-06 -.9970E-05 -.5612E-04
-.5121E-03  .3465E-03  .3376E-02  .2295E-02  .3973E-03 -.9676E-02
0.          0.         -.3973E-03  .9676E-02 -.3376E-02 -.2295E-02
 .5121E-03 -.3465E-03  .9970E-05  .5612E-04 -.3002E-05  .1720E-06
 .1285E-05 -.1949E-05 -.3288E-04 -.2424E-04 -.1164E-03  .3603E-03
 .2413E-02  .4848E-03 -.1412E-02 -.6819E-02 0.          0.
 .1412E-02  .6819E-02 -.2413E-02 -.4848E-03  .1164E-03 -.3603E-03
 .3288E-04  .2424E-04 -.1285E-05  .1949E-05 -.7263E-06 -.1732E-05
-.2694E-04  .6153E-05  .9665E-04  .1663E-03  .1204E-02 -.5656E-04
```

```
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-.1204E-02  .5656E-04 -.9665E-04 -.1663E-03  .2694E-04 -.6153E-05
 .7263E-06  .1732E-05 -.1547E-05 -.2908E-06 -.6416E-05  .1731E-04
 .8543E-04 -.3222E-04  .5545E-03  .2224E-03 -.1812E-02 -.3754E-02
0.          0.          .1812E-02  .3754E-02 -.5545E-03 -.2224E-03
-.8543E-04  .3222E-04  .6416E-05 -.1731E-04  .1547E-05  .2908E-06
-.9489E-06  .9477E-06  .9136E-05  .9729E-05 -.3830E-04 -.9682E-04
 .6221E-03  .5495E-03 -.2172E-02 -.3302E-02 0.          0.
 .2172E-02  .3302E-02 -.6221E-03 -.5495E-03  .3830E-04  .9682E-04
-.9136E-05 -.9729E-05  .9489E-06 -.9477E-06
FREQMH,PCENT,ZINCH,AOFI,AOFP,MM3,NPTU
 .1400E+04  .2000E+02  .2000E+01  .3000E+02 0.                  11          16
IN FORMAT(38X,/,5(1X,E10.4),2(1X,I10),/,45X)
(RHO(I),I=1,NPTU,1) --- IN FORMAT(4(1X,E10.4))
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 .4000E+01  .5000E+01  .6000E+01  .7000E+01
 .8000E+01  .9000E+01  .1000E+02  .1100E+02
 .1200E+02  .1300E+02  .1400E+02  .1500E+02
THE NEAR FIELD COMPONENT IS EPHI
IN FORMAT(29X,A10,/,25X)
((WAVEEH(IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1) --- IN FORMAT(6(1X,E10.4))
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0.          0.          .3065E-01  .2680E-01 0.          0.
-.3065E-01 -.2680E-01 0.          0.          0.          0.
0.          0.          0.          0.          .1298E-09  .3098E-10
 .3759E-07  .1052E-06  .1820E-04 -.1501E-04 -.1514E-02 -.2220E-03
 .3065E-01  .2589E-01 0.          0.          -.3065E-01 -.2589E-01
 .1514E-02  .2220E-03 -.1820E-04  .1501E-04 -.3759E-07 -.1052E-06
-.1298E-09 -.3098E-10  .1236E-08 -.7036E-10  .2831E-06  .7486E-06
 .6282E-04 -.5740E-04 -.2866E-02 -.2635E-03  .3056E-01  .2324E-01
0.          0.          -.3056E-01 -.2324E-01  .2866E-02  .2635E-03
-.6282E-04  .5740E-04 -.2831E-06 -.7486E-06 -.1236E-08  .7036E-10
 .9913E-09 -.2751E-08  .8913E-06  .2091E-05  .1103E-03 -.1194E-03
-.3906E-02 -.1561E-04  .3015E-01  .1913E-01 0.          0.
-.3015E-01 -.1913E-01  .3906E-02  .1561E-04 -.1103E-03  .1194E-03
-.8913E-06 -.2091E-05 -.9913E-09  .2751E-08 -.1081E-07 -.1028E-07
 .1991E-05  .3819E-05  .1369E-03 -.1891E-03 -.4516E-02  .5216E-03
 .2914E-01  .1402E-01 0.          0.          -.2914E-01 -.1402E-01
 .4516E-02 -.5216E-03 -.1369E-03  .1891E-03 -.1991E-05 -.3819E-05
 .1081E-07  .1028E-07 -.4412E-07 -.1504E-07  .3664E-05  .5288E-05
 .1294E-03 -.2520E-03 -.4642E-02  .1248E-02  .2734E-01  .8502E-02
0.          0.          -.2734E-01 -.8502E-02  .4642E-02 -.1248E-02
-.1294E-03  .2520E-03 -.3664E-05 -.5288E-05  .4412E-07  .1504E-07
-.9191E-07  .2645E-09  .5772E-05  .5776E-05  .8833E-04 -.2941E-03
-.4308E-02  .2004E-02  .2468E-01  .3180E-02 0.          0.
-.2468E-01 -.3180E-02  .4308E-02 -.2004E-02 -.8833E-04  .2941E-03
-.5772E-05 -.5776E-05  .9191E-07 -.2645E-09 -.1265E-06  .4413E-07
 .7784E-05  .4823E-05  .2560E-04 -.3052E-03  .3610E-02  .2633E-02
 .2132E-01 -.1449E-02 0.          0.          -.2132E-01  .1449E-02
 .3610E-02 -.2633E-02 -.2560E-04  .3052E-03 -.7784E-05 -.4823E-05
 .1265E-06 -.4413E-07 -.1201E-06  .9952E-07  .8922E-05  .2559E-05
-.4079E-04 -.2834E-03 -.2697E-02  .3019E-02  .1749E-01 -.5069E-02
0.          0.          -.1749E-01  .5069E-02  .2697E-02 -.3019E-02
 .4079E-04  .2834E-03 -.8922E-05 -.2559E-05  .1201E-06 -.9952E-07
-.7115E-07  .1323E-06  .8614E-05 -.2460E-06 -.9382E-04 -.2357E-03
-.1729E-02  .3120E-02  .1349E-01 -.7557E-02 0.          0.
-.1349E-01  .7557E-02  .1729E-02 -.3120E-02  .9382E-04  .2357E-03
-.8614E-05  .2460E-06  .7115E-07 -.1323E-06 -.9523E-08  .1197E-06
 .6924E-05 -.2556E-05 -.1237E-03 -.1761E-03 -.8454E-03  .2967E-02
 .9619E-02 -.8947E-02 0.          0.          -.9619E-02  .8949E-02
 .8454E-03 -.2967E-02  .1237E-03  .1761E-03 -.6924E-05  .2556E-05
 .9523E-08 -.1197E-06  .2678E-07  .7127E-07  .4561E-05 -.3660E-05
```

IX. MICROFICHE OF THE LISTING OF THE FORTRAN SOURCE OF PROGRAM PCOEF AND LISTINGS OF THE AZIMUTHAL COEFFICIENTS

The microfiche is 48X. There are a total of thirty-four fiches. Thirty-three are listings of the azimuthal coefficients that were written on the nine track tapes. The other fiche is the Fortran Source listing of the Program PCOEF. Program PCOEF's source was also included on one of the nine track tapes. It can be used to read the azimuthal coefficients from the tapes.

The azimuthal coefficients are for a mine buried in one of three soil types (silt loam either at 5%, 10% or 20% water content) where eleven frequencies are used for the incident field (400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300 and 1400 Mega Hertz). Each fiche contains the listing of the azimuthal coefficients for one of the thirty-three combinations of soil type and frequency.

Each fiche comes in its own package. All packages are labeled as well as each fiche.

The package, for the fiche containing the Fortran Source listing of the Program PCOEF, is labeled "SOURCE". The fiche is labeled "SOURCE OF PCOEF".

The label on the package for the fiche containing the azimuthal coefficients consists of the letter "C" followed by six digits. The first four digits are the frequency in Mega Hertz. The last two digits are the water content in percent for the soil. Thus, the label "C040005" is for 400 Mega Hertz silt loam having 5% water content. While the label "C130020" is for 1300 Mega Hertz silt loam having 20% water content. The fiche containing the azimuthal coefficients is labeled with the frequency and the water content in percent. For example the fiche for the azimuthal coefficients corresponding to an incident field of 400 Mega Hertz for silt loam having 5 percent water content is labeled "400 MHZ 05 PERCENT"; while the one for 1300 Mega Hertz 20% water content is labeled "1300 MHZ 20 PERCENT".

For a detailed description of the azimuthal coefficients see Chapter VII "Description of the files containing Azimuthal Coefficients (sent via the nine track tapes)". For a description of the Program PCOEF see Chapter VI "Description of the Program PCOEF (sent via nine track tape)".

X. CONCLUSION AND RECOMMENDATION

The Unimoment method was used previously to calculate the scattered fields by a buried land mine [8]. There was some doubt on the credibility of the results because scattered fields were found to be stronger at lower frequencies, contrary to the experiences of MERADCOM scientists. By using a more realistic model of the ground parameters, we have indeed discovered that the scattered fields of the dielectric mine buried in silt loam having a water content of 20% are stronger at 1000 MHz than at either 600 or 1400 MHz which is consistent with the experiences of MERADCOM scientists. This result suggests that the operating frequency of the existing mine detectors have been appropriately chosen.

The massive amount of calculated results obtained in this work deserves attention, since it contains information that may be useful for the improvement of mine detectors. We recommend: 1) that a program to study these results be initiated to utilize it for engineering purposes and 2) that an experimental program to verify the data be initiated.

The present results are limited to mines which are buried at least 1.6" deep. In warfare, antipersonnel land mines are buried almost flush. The Unimoment method may be modified to compute flush buried land mines. It is expected that a shallow buried land mine will yield greater scattering than a deeply buried mine, thus enhancing the probability of detection from shallowly buried mines. A third recommendation is that the present computer program should be generalized to compute electromagnetic scattering from flush buried antipersonnel land mines.

XI. REFERENCES

1. K.K. Mei, "Unimoment Method of Solving Antenna and Scattering Problems," IEE Transactions on Antennas and Propagation, AP-22, pp. 760-766, November 1974.

2. R.E. Stovall and K.K. Mei, "Application of a Unimoment Technique to a Biconical Antenna with Inhomogeneous Dielectric Loading," IEEE Trans. on Antennas and Propagation, Vol. AP-23, No. 3, 335-342, May 1975.

3. S.K. Chang and K.K. Mei, "Application of the Unimoment Method to Electromagnetic Scattering of Dielectric Cylinders," IEEE Trans. on Antennas and Propagation, AP-24, No. 1, 35-42, January 1976.

4. M.A. Morgan and K.K. Mei "Finite-Element Computation of Scattering by Inhomogeneous Penetrable Bodies of Revolution," URSI International Electromagnetic Symposium, Palo Alto, CA, June 1977.

5. K.K. Mei, M.A. Morgan, and S.K. Chang, "Finite Methods in Electromagnetic Scattering," Chapter 10 in Electromagnetic Scattering, edited by P.L.E. Uslenghi, Academic Press, 1978.

6. S.K. Chang and K.K. Mei, "Generalization of Sommerfeld Integrals and Field Expansions in Two-Medium Half Spaces," Submitted to IEEE Trans. on Antennas and Propagation for publication in 1979.

7. S.K. Chang, "On Electromagnetic Wave Scattering by Buried Obstacles," Ph.D. Dissertation, June 1977.

8. S.K. Chang, "Scattering by Buried Finite Cylindrical Dielectric Land Mines," Final Report, U.S. Army Mobility Equipment Research and Development Command, Fort Belvoir, Contract No. DAAK70-78-C-0168, March 1979.

9. Von Hippel, Dielectric Material, MIT, 1954.

10. R.A. Falls, and L. Mittleman, "Forecasting of the Electromagnetic and Thermal Properties of Soils by the Study of Their Climatological Environment" U.S. Army MERADCOM Report 2259 (1978).

11. Simon Ramo and John R. Whinnery, FIELDS AND WAVES IN MODERN RADIO, 2nd Edition, John Wiley and Sons, Inc.

Appendix I

A. Computation of Primary Fields

A primary field is defined as the sum of the incident field and the reflected field from the interface, without the scatterer. Well known formulas of primary fields are available (for example pages 299-301 of reference [11]). For the sake of completeness we list the fields of both polarizations in MKS units as follows:

(i) The case of magnetic field perpendicular to the plane of incidence, (0° polarization angle):

Referring to Figure I-1, the incident field is

$$H_y^{inc} = \frac{-1}{\eta_o} \quad e^{j\beta_x x} \quad e^{j\beta_z z} \tag{A1}$$

where $\beta_x = k_o \sin\theta$, $\beta_z = k_o \cos\theta$, $k_o = \frac{2\pi}{\lambda_o}$,

$\lambda_o = \frac{c}{f}$, $c = 2.99793 \times 10^8$ meters/sec

The primary fields for $z \geq 0$ are:

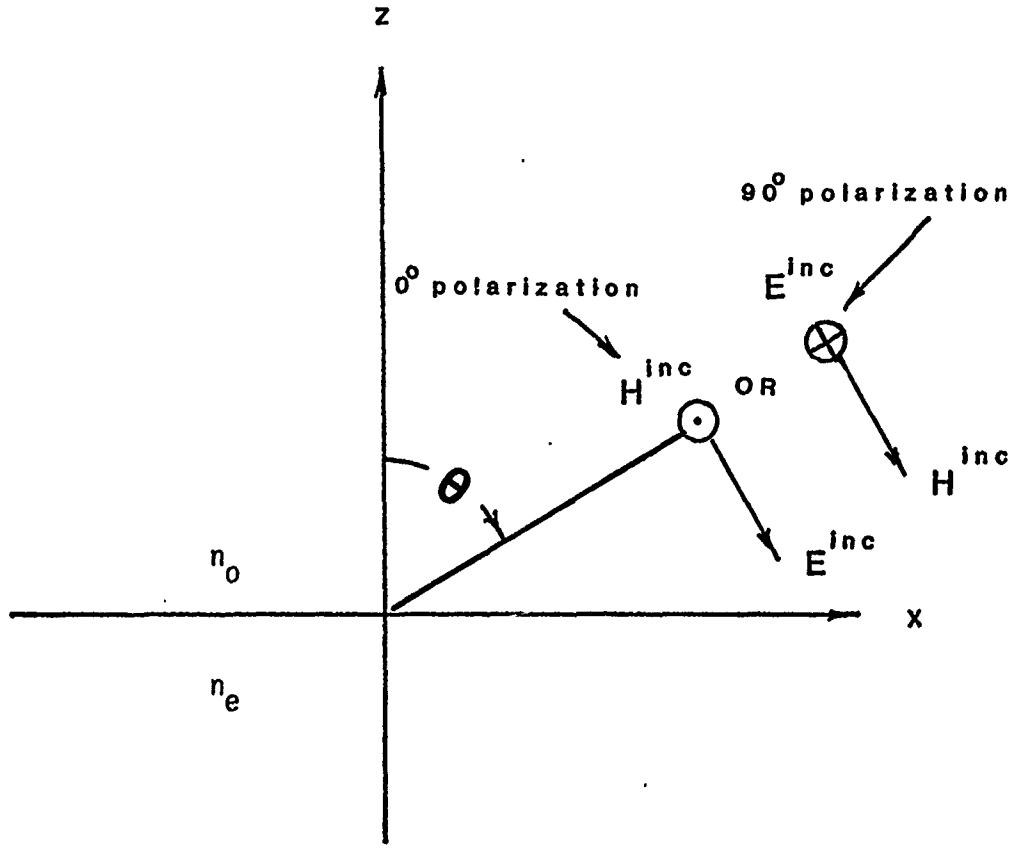
$$E_x^p = \cos\theta \; e^{j\beta_x x} \left[e^{j\beta_z z} + \rho e^{-j\beta_z z} \right] \tag{A2}$$

$$H_y^p = \frac{-1}{\eta_o} \left[e^{j\beta_z z} - \rho e^{-j\beta_z z} \right] \tag{A3}$$

$$E_z^p = \sin\theta \; e^{j\beta_x x} \left[-e^{j\beta_z z} + \rho e^{-j\beta_z z} \right] \tag{A4}$$

$$E_y^p = H_x^p = H_z^p = 0$$

$$\rho = \frac{Z_L - Z_o}{Z_L + Z_o}, \quad Z_L = \eta_e \left[1 - \left(\frac{\eta_e}{\eta_o} \right) \sin^2\theta \right]^{1/2}$$



⊙ Vector points out of page

⊗ Vector points into page

The y axis points into the page and so the coordinate system is right handed.

Figure I-1

Field orientations of 0° and 90° Polarization incident waves

$$Z_o = \eta_o \cos\theta, \quad \eta_e = \eta_o/\sqrt{\varepsilon_e}$$

$$\eta_o = \sqrt{\frac{\mu_o}{\varepsilon_o}} \approx 376.73 \text{ ohms}$$

$$E_\rho^p = E_x^p \cos\phi \tag{A5}$$

$$E_\phi^p = -E_x^p \sin\phi \tag{A6}$$

$$H_\rho^p = H_y^p \sin\phi \tag{A7}$$

$$H_\phi^p = H_y^p \cos\phi \tag{A8}$$

(ii) The case of electric field perpendicular to the plane of incidence, (90° polarization angle):

Referring to Figure I-1 , the incident field is,

$$E_y^{inc} = e^{j\beta_x x} e^{j\beta_z z} \tag{A9}$$

where $\beta_x = k_o \sin\theta, \quad \beta_z = k_o \cos\theta$

The primary fields for $z \geq 0$ are:

$$E_y^p = e^{j\beta_x x} \left[e^{j\beta_z z} + \rho e^{-j\beta_z z} \right] \tag{A10}$$

$$H_x^p = \frac{1}{\eta_o} \cos\theta \; e^{j\beta_x x} \left[e^{j\beta_z z} - \rho e^{-j\beta_z z} \right] \tag{A11}$$

$$H_z^p = -\frac{1}{\eta_o} \; e^{j\beta_x x} \left[e^{j\beta_z z} + \rho e^{-j\beta_z z} \right] \tag{A12}$$

$$E_x^p = E_z^p = H_y^p = 0$$

$$Z_o = \eta_o/\cos\theta$$

$$Z_L = \eta_e \left[1 - \left(\frac{\eta_e}{\eta_o}\right)^2 \sin^2\theta \right]^{-1/2}$$

$$\rho = \frac{Z_L - Z_o}{Z_L + Z_o},$$

$$\eta_e = \eta_o/\sqrt{\varepsilon_e}$$

$$\eta_o = \sqrt{\frac{\mu_o}{\varepsilon_o}} \approx 376.73\Omega.$$

$$E_\rho^p = E_y^p \sin\phi \tag{A13}$$

$$E_\phi^p = E_y^p \cos\phi \tag{A14}$$

$$H_\rho^p = H_x^p \cos\phi \tag{A15}$$

$$H_\phi^p = -H_x^p \sin\phi \tag{A16}$$

(iii) The primary field for the case of $\theta = 0°$, polarization angle = 0°, for 1400 MHz, at $Z = 1$ in. when the soil is silt loam having a water content of 20% as used in the sample data, may be found as follows:

$$\varepsilon_e = 15.6 - j1.869 \quad \text{(From Table 2 on page 12)}$$

$$k_o = 29.34 \qquad k_o Z = .7453 \quad \text{(in MKS units)}$$

$$\eta_e = 95.043\, e^{j.0596} \quad \text{ohms}$$

$$\rho = .5977\, e^{j3.110}$$

$$E_\phi^p = -E_x^p \sin\phi = (-.3089 - j1.0974) \sin\phi$$

$$= -(1.140\, e^{j1.296}) \sin\phi \qquad \text{for } \theta = 0° \tag{A17}$$

(iv) The primary field for $\theta = 30°$ of the same case as in (iii) we have

$$E_x^p = \cos 30°\, e^{j\beta_x x} \left[e^{j\beta_z z} + \rho e^{-j\beta_z z} \right]$$

where $\beta_x = k_o \sin 30° = 14.671 \quad [\text{meter}^{-1}]$

$\beta_z = k_o \cos 30° = 25.410 \quad [\text{meter}^{-1}]$

$\beta_z Z = .64541$

$$Z_L = \eta_e \left[1 - \left(\frac{\eta_e}{\eta_o}\right)^2 \sin^2\theta\right]^{1/2}$$

$$= 95.0 \cdot 3\ e^{j.0596} \left[.98416 - j.0016\right]^{1/2}$$

$$= 95.043\ e^{j.0596} \left(.99204\ e^{-j.0008}\right)$$

$$= 94.29\ e^{j.0587}$$

$$Z_o = \eta_o \cos\theta \approx 376.73 \cos 30° \approx 326.27$$

$$\rho = \frac{Z_L - Z_o}{Z_L + Z_o} = \frac{94.29\ e^{j.0587} - 326.27}{94.29\ e^{j.0587} + 326.27}$$

$$= \frac{-232.13 + j5.527}{420.38 + j5.527} = \frac{232.20\ e^{j3.118}}{420.42\ e^{j.01315}}$$

$$= .5523^{j3.105}$$

$$E_x^p = .866\ e^{j14.671x} \left[e^{j.64543} + .5523\ e^{j3.105}\ e^{-j.64543}\right]$$

$$= e^{j14.671x}\ .866 \left[(.7988 + j.6015) + (-.4286 + j.3483)\right]$$

$$= (.3206 + j.8226)\ e^{j14.671x} = .8828\ e^{j1.199}\ e^{j14.671x}$$

$$E_\phi^p = -E_x^p \sin\phi = -.8828 e^{j[1.1991 + 14.671x]} \sin\phi$$

for $\theta = 30°$. (A18)

B. Example of Computing the Scattered Fields for 0° Incidence

Using Set I of the file in Chapter VIII (polarization angle 0°) EPHI component at $Z = 1$ in. can be computed as follows:

(i) To compute EPHI for $\phi = 0°$, (positive x-axis) at $\rho = 0$, add the 11 complex numbers in block labeled JCOL = 1. The summation of the block labeled JCOL = 2, gives EPHI for $\phi = 0°$, $\rho = 1$ cm, etc. For this particular incident plane wave polarization, EPHI = 0 on the x-axis as to be expected.

(ii) To compute the same field for $\phi \neq 0°$, say $\phi = 30°$, we use the formula,

$$E_\phi^s = \sum_{-M}^{M} a_m \, e^{jm\phi}$$

Since this is the case of 0° incidence, only a_m with $m = \pm 1$ are non-zero,

For $\rho = 0$,

$$E_\phi^s = a_{-1} \, e^{-j30°} + a_{+1} e^{j30°}$$

$$= (.02202 + j.06676)\, e^{-j30°} - (.02202 + j.06676)\, e^{j30°}$$

$$= -2j(.02202 + j.06676) \sin 30°$$

$$= .06676 - j.02202, \text{ for } \theta = 0°, \ \phi = 30°, \ \rho = 0° \quad \text{(B1)}$$

For $\rho = 1$ cm,

$$E_\phi^s = (.02340 + j.06498)\, e^{-j30°} - (.02340 + j.06498)\, e^{j30°}$$

$$= .06498 - j.02340, \quad \text{for } \theta = 0°,\ \phi = 30°,$$

$$\rho = 1\text{cm} \tag{B2}$$

C. Example of Computing the Scattered Fields for 30° Incidence

Using Set II of the file in Chapter VIII, the scattered EPHI component can be computed as follows:

(i) To compute EPHI for $\phi = 0°$, (positive x-axis) at $\rho = 0$, add the 11 complex numbers in block labeled JCOL = 1. The summation of the block labeled JCOL = 2 gives EPHI for $\phi = 0°$, $\rho = 1$ cm etc. For this particular incident plane wave polarization, EPHI = 0 on the x-axis as to be expected.

(ii) To compute the same field for $\phi = 0°$, say $\phi = 30°$, we use the formula

$$E_\phi^s = \sum_{-M}^{M} a_m e^{jm\phi}$$

for $\rho = 0$, (only a_m with $m = \pm 1$ are non-zero)

$$E_\phi^s = a_{-1} e^{-j30°} + a_{+1} e^{j30°}$$

$$= (.01663 + j.05757)\, e^{-j30°} - (.01663 + j.05757)\, e^{j30°}$$

$$= -2j(.01663 + j.05757) \sin 30°$$

$$= .05757 - j.01663 \text{ for } \theta = 30°, \phi = 30°, \rho = 0 \qquad \text{(C1)}$$

for $\rho = 1$ cm (use data in block JCOL = 2 in set II)

$$
\begin{aligned}
E_\phi^s = {} & (-.7005 \times 10^{-9} + j.1122 \times 10^{-7})\, e^{-j5 \times 30^\circ} \\
& + (.2098 \times 10^{-6} + j.1158 \times 10^{-5})\, e^{-j4 \times 30^\circ} \\
& + (.1166 \times 10^{-3} - j.3785 \times 10^{-4})\, e^{-j3 \times 30^\circ} \\
& + (-.2997 \times 10^{-2} - j.2090 \times 10^{-2})\, e^{-j2 \times 30^\circ} \\
& + (.1775 \times 10^{-1} + j.5615 \times 10^{-1})\, e^{-j30^\circ} \\
& + 0 \\
& - (.1775 \times 10^{-1} + j.5615 \times 10^{-1})\, e^{j30^\circ} \\
& - (-.2997 \times 10^{-2} - j.2090 \times 10^{-2})\, e^{j2 \times 30^\circ} \\
& - (.1166 \times 10^{-3} - j.3785 \times 10^{-4})\, e^{j3 \times 30^\circ} \\
& - (.2098 \times 10^{-6} + j.1158 \times 10^{-5})\, e^{j4 \times 30^\circ} \\
& - (-.7005 \times 10^{-9} + j.1122 \times 10^{-7})\, e^{j5 \times 30^\circ}
\end{aligned}
$$

Since the coefficients for $m \geq 4$ are negligible in comparison to the lower order ones, we shall omit them in the following summation, which gives:

$$E_\phi^s = -\Big[2j(.1166 \times 10^{-3} - j.3785 \times 10^{-4}) \sin 90^\circ$$

$$+ \; 2j(-.2997 \times 10^{-2} - j.2090 \times 10^{-2}) \sin 60^\circ$$

$$+ \; 2j(.1775 \times 10^{-1} + j.5615 \times 10^{-1}) \sin 30^\circ \Big]$$

$$= -\Big[(.0000757 + j.0002332) + (.003619 - j.005190)$$

$$+ \; (-.05615 + j.01775)\Big] = .05245 - j.01279$$

$$\text{for} \quad \theta = 30^\circ, \quad \phi = 30^\circ, \quad \rho = 1 \text{ cm} \qquad \text{(C2)}$$

D. Example of Computing Total Fields for 0° Incidence

Using the file of Chapter VIII, the total EPHI component at $z = 1$ in. can be computed as follows:

(i) To compute total EPHI for $\phi = 0°$, (positive x-axis) at $\rho = 0$, simply add the primary field to the scattered field computed in (B). Using formula (A6) at $\phi = 0°$, we find EPHI primary to be zero. From Section B(i) the scattered field for this component is zero. Thus, as expected, the PHI component of the total electric field is zero along the x-axis.

(ii) To compute the same field for $\phi \neq 0°$, say $\phi = 30°$, we add the primary field to the scattered field already computed in (B). Using the formula (A2), (A6) and (A17),

$$E_\phi^p = (-.3089 - j1.0974)\sin\phi$$

$$= -.1545 - j.5487 \quad \text{for} \quad \theta = 0°, \quad \phi = 30° \qquad \text{(D1)}$$

The primary field is independent of ρ because

$\theta = 0°$.

Using B1, we find the total field is

$$E_\phi = E_\phi^s + E_\phi^p = (.06676 - j.02202) + (-.1545 - j.5487)$$

so

$$E_\phi = -.08774 - j.5702 = .5769\, e^{-j1.723}$$

$$\text{for} \quad \theta = 0°, \quad \phi = 30°, \quad \rho = 0° \qquad \text{(D2)}$$

In the time domain

$$E_\phi(t) = R_e\left\{.5769e^{-j1.723}\ e^{j\omega t}\right\} = .5769 \cos\ (\omega t - 1.723)$$

for $\theta = 0°$, $\phi = 30°$, $\rho = 0°$ (D3)

Using (D1) and (B2) we find

$$E_\phi = E_\phi^s + E_\phi^p = (.06498 - j.02340) + (-.1545 - j.5487)$$

$$= -\ .08952 - j.57210 = .5791e^{-j1.7260}$$

for $\theta = 0°$, $\phi = 30°$, $\rho = 1$ cm (D4)

In the time domain

$$E_\phi(t) = R_e\left\{.5791e^{-j1.7260}\ e^{j\omega t}\right\} = .5791 \cos\ (\omega t - 1.7260)$$

for $\theta = 0°$, $\phi = 30°$, $\rho = 1$ cm (D5)

E. Example of Computing Total Fields for 30° Incidence

The total EPHI component at Z = 1 in. at 30° incidence can be computed as follows:

(i) To compute total EPHI for $\phi = 0°$, (positive axis) at $\rho = 0$, simply add the primary field to the scattered field computed in (C). Using formula (A6) at $\phi = 0°$, we find EPHI primary to be zero. From section C(i), the scattered field for this component is zero. Thus, the PHI component of the total electric field is zero along the x-axis.

(ii) To compute the same field for $\phi \neq 0°$, say $\phi = 30°$, we add the primary to the scattered field already computed in (C). Using the formulas (A2), (A6), and (A18),

$$E_\phi^p = -.8828\, e^{j[1.1991 + 14.671x]} \sin\phi$$

and since $x = 0$ at $\rho = 0$

$$E_\phi^p = -(.3206 + j.8226) \sin 30° = -.1603 - j.4113 = -.4414 e^{j1.1991}$$

for $\theta = 30°$, $\phi = 30°$, $\rho = 0$ (E1)

for $\rho \neq 0$, we use $x = \rho \cos\phi$

$$E_\phi^p = -.8828\, e^{[j1.1991 + j14.671(\rho \cos 30°)]} \sin 30°$$

$$= -.8828\, e^{j(1.1991 + .1271)} \sin 30°$$

$$= -.8828\, e^{j1.3262} \sin 30° = -.1069 - j.4283$$

for $\theta = 30°$, $\phi = 30°$, $\rho = 1$ cm (E2)

Using (C1) and (E1) we find that the total field

$$E_\phi = E_\phi^s + E_\phi^p = (.05757 - j.01663) - (.1603 + j.4113)$$

$$= -.1027 - j.4279 = .4401e^{-j1.806}$$

for $\theta = 30°$, $\phi = 30°$, $\rho = 0$ (E3)

In the time domain

$$E_\phi(t) = R_e\left\{.4401e^{-j1.806}\ e^{j\omega t}\right\} = .4401\ \cos(\omega t - 1.806)$$

for $\theta = 30°$, $\phi = 30°$, $\rho = 0$ (E4)

Using (C2) and (E2) we calculate for the total field

$$E_\phi = E_\phi^s + E_\phi^p = (.05245 - j.01279) - (.1069 + j.4283)$$

$$= -.05445 - j.4411 = .4444e^{-j1.694}$$

for $\theta = 30°$, $\phi = 30°$, $\rho = 1$ cm (E5)

In the time domain

$$E_\phi(t) = R_e\left\{.4444e^{-j1.694}\ e^{j\omega t}\right\} = .4444\ \cos(\omega t - 1.694)$$

for $\theta = 30°$, $\phi = 30°$, $\rho = 1$ cm (E6)

Appendix II

Source of PCOEF

```
      PROGRAM FCOEF(INPUT,TAPE10=INPUT,TAPE18,
     1              OUTPUT,TAPE16=OUTPUT)
C
C
C     THE PURPOSE OF THIS PROGRAM IS TO PRINT THE AZIMUTHAL COEFFICIENTS
C     THAT ARE GOING TO BE DELIVERED TO THE ARMY.
C
C
C     THE MAIN PART OF THIS PROGRAM WAS LAST CHANGED ON
C                   -  14 JANUARY 1982  -
C
C
      COMPLEX AZIC(15,16,6)
C
C
      DIMENSION RHO(16),RHOC(16),ACOMP(6),WCOMP(6),RCOMP(6),M(15)
C
C
C     NOTE ONLY UP TO THE FIRST 15 AZIMUTHAL COEFFICIENTS FOR EACH
C     COMPONENT AT EACH RHO Z POINT PAIR CAN BE USED. ALSO NOTE THAT
C     THAT TAPE, ITAPEI, MUST HAVE EXACTLY 16 RHO VALUES FOR EACH Z.
C     FURTHER MORE THEY MUST BE APPROXIMATELY AS LISTED IN THE ARRAY,
C     RHOC.
C
      DATA IR/1/,ITAPEI/18/,MDIM/15/,MAXPTS/16/,NPTSC/16/,IFLAGE/1/
C
      DATA RHOC/0.,1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,13.,14.,15./
C
C     THE ALLOWED NAMES OF THE FIELD COMPONENTS WILL NOW BE SET.
C
      DATA ACOMP/10H EPHI     ,10H ERHO     ,10H EZEE     ,
     1           10H ETA0*HPHI,10H ETA0*HRHO,10H ETA0*HZEE/
C
C     THE NAMES OF THE FIELD COMPONENTS WHICH WILL BE USED BY
C     SUBROUTINE WAZIC IN WRITING THE RESULTS IN A HUMAN READABLE
C     FORM WILL NOW BE SET.
C
      DATA WCOMP/10H EPHI     ,10H ERHO     ,10H EZEE     ,
     1           10H HPHI     ,10H HRHO     ,10H HZEE     /
C
      DATA IUNITR/10/,IUNITE/16/,IUNITO/16/
C
      DATA ISET/0/
C
C
    1 CONTINUE
C
C     THE DESIRED COEFFICIENTS HAVE BEEN OBTAINED FLAG WILL BE UNSET.
C
      IFDES=ISET+1
C
C     SUBROUTINE READIN READS THE INPUT FILE. THE INPUT FILE
C     HAS THE INFORMATION CONCERNING THE FREQUENCY IN MEGA HERTZ,
C     THE WATER CONTENT OF THE SOIL IN PER CENT, THE ANGLE OF INCIDENCE
C     IN DEGREES OF THE INCIDENT PLANE WAVE, AS WELL AS THE ANGLE OF
C     POLARIZATION IN DEGREES OF THE INCIDENT PLANE WAVE. ALSO, THE
C     DISTANCE IN INCHES ABOVE THE GROUND WHERE THE NEAR FIELDS ARE
C     EVALUATED IS READ. SUBROUTINE READIN READS THE NUMBER OF DIFFERENT
C     COMPONENTS OF THE NEAR FIELD THAT ARE TO BE PRINTED IN ADDITION TO
C     THE NAMES OF THE COMPONENTS IN THE ORDER THEY ARE TO BE PRINTED.
C
```

```
      CALL READIN(IUNITE,IUNITR,
     1            FMHZW,PCENTW,AOFIW,AOFPW,ZINCHW,NCOMP,RCOMP)
C
C     SUBROUTINE COMCHK CHECKS TO BE SURE THE COMPONENT NAMES ARE
C     ALLOWED.
C
      CALL COMCHK(IUNITE,ACOMP,NCOMP,RCOMP)
C
C     SUBROUTINE RW1W1Z MAKES THE FIRST READ TO TAPEI, THE TAPE WHERE
C     THE AZIMUTHAL COEFFICIENTS ARE STORED. SUBROUTINE RW1W1Z WILL
C     READ IN THE AZIMUTHAL COEFFICIENTS OF THE NEAR FIELDS THAT
C     CORRESPOND TO ONE INCIDENT PLANE WAVE.
C
      CALL RW1W1Z(IR,ITAPEI,IUNITE,
     1            MAXPTS,FREQMH,PCENT,ZINCH,AOFI,AOFP,
     2            MUSED,NPTSU,RHO,MDIM,AZIC)
C
C     SUBROUTINE TCHECK MAKES SURE THAT THE USER HAS SPECIFIED A
C     FREQUENCY AND A PERCENTAGE WHICH IS IN THE FILE.
C
      CALL TCHECK(IUNITE,FMHZW,FREQMH,PCENTW,PCENT)
    2 CONTINUE
C
C     SUBROUTINE IPZCHK DETERMINES IF THE LAST READ OF TAPE, TAPEI,
C     READ THE DESIRED COEFFICIENTS.
C
      CALL IPZCHK(AOFIW,AOFI,AOFPW,AOFP,ZINCHW,ZINCH,
     1            ISET,IFDES)
C
C     IF IFDES IS SET THEN THE LAST READ DID OBTAIN THE DESIRED
C     COEFFICIENTS.
C
      IF(IFDES .EQ. ISET) GO TO 4
    3 CONTINUE
C
C     THE LAST READ WAS NOT FOR THE DESIRED COEFFICENTS.
C     SO ONE MORE READ WILL BE ATTEMPTED.
C
      CALL RW1W1Z(IR,ITAPEI,IUNITE,
     1            MAXPTS,FREQMH,PCENT,ZINCH,AOFI,AOFP,
     2            MUSED,NPTSU,RHO,MDIM,AZIC)
      GO TO 2
    4 CONTINUE
C
C     THE LAST READ WAS FOR THE DESIRED COEFFICIENTS.
C
C     SUBROUTINE RHOCHK MAKES SURE THAT THE RHO VALUES ARE
C     AT LEAST APPROXIMATELY AS EXPECTED.
C
      CALL RHOCHK(IUNITE,NPTSU,RHO,NPTSC,RHOC)
C
C     SUBROUTINE LOADM LOADS THE ARRAY M WITH THE AZIMUTHAL ORDERS
C     OF THE COEFFICIENTS.
C
      CALL LOADM(IUNITE,MUSED,M)
C
C     EACH LOOP TO 5 CONTINUE WILL PRINT THE AZIMUTHAL COEFFICIENTS
C     OF THE SERIES WHICH REPRESENTS ONE OF THE COMPONENTS OF THE
C     SCATTERED FIELD.
C
      DO 5 I=1,NCOMP,1
      RCOMPE=RCOMP(I)
```

```
C
C     SUBROUTINE CNUMB WILL RETURN THE COMPONENT INDEX.
C
      CALL CNUMB(IUNITE,RCOMPE,ACOMP,ICOMP)
C
C     SUBROUTINE WAZIC WILL PRINT THE COEFFICIENTS.
C
                          IFLAG=IFLAGE
      IF(ICOMP .GT. 3) IFLAG=IFLAG+1
      CALL WAZIC(IUNITO,MDIM,RHO,IFLAG,MUSED,
     1           M,AOFI,AOFP,ZINCH,RCOMPE,WCCMP(ICOMP),AZIC(1,1,ICOMP))
    5 CONTINUE
    6 CONTINUE
      STOP
      END
```

```
      SUBROUTINE CNUMB(IUNITE,RCOMPE,ACOMP,ICOMP)
C
C
C     THIS SUBROUTINE SETS ICOMP EQUAL TO THE INDEX NUMBER OF
C     THE ELEMENT OF ARRAY, ACOMP, THAT IS EQUAL TO RCOMPE.
C     IF RCOMPE IS NOT EQUAL TO ANY OF THE ARRAY ELEMENTS THEN
C     THE USER IS SO INFORMED AND THE PROGRAM IS STOPPED.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 5 NOVEMBER 1981.
C
C
      DIMENSION ACOMP(6)
C
C
    1 CONTINUE
C
C     FOR THE SAKE OF EFFICIENCY SOME LOCAL VARIABLES WILL BE SET EQUAL
C     TO SOME OF THE PARAMETERS.
C
      IUNIT=IUNITE
      RCLOC=RCOMPE
      DO 2 I=1,6,1
      INDEX=I
      IF(RCLOC .EQ. ACOMP(I)) GO TO 3
    2 CONTINUE
C
C     RCOMPE DOES NOT MATCH ANY OF THE ALLOWED VALUES.
C
      WRITE(IUNIT,1002)(ACOMP(I),I=1,6,1),RCLOC
 1002 FORMAT(1H1,
     11H ,25HTHIS IS SUBROUTINE CNUMB.,/,
     21H ,29HAN ERROR HAS BEEN DISCOVERED.,/,
     31H ,48HRCOMPE DOES NOT EQUAL ANY OF THE ALLOWED VALUES.,2(1H ,/),
     41H ,11HACOMP(1) = ,A10,13H  ACOMP(2) = ,A10,13H  ACOMP(3) = ,A10
     5   ,/,
     61H ,11HACOMP(4) = ,A10,13H  ACOMP(5) = ,A10,13H  ACOMP(6) = ,A10
     7   ,/,
     81H ,11H  RCOMPE = ,A10,2(1H ,/),
     91H ,43HTHIS SUBROUTINE WILL NEXT STOP THE PROGRAM.)
      STOP
    3 CONTINUE
      ICOMP=INDEX
      RETURN
      END
```

```
      SUBROUTINE COMCHK(IUNITE,ACOMP,NCOMP,RCOMP)
C
C
C     THIS SUBROUTINE CHECKS THE FIRST NCOMP ELEMENTS OF THE ARRAY,
C     RCOMP, COMPARING THEM TO THE ALLOWABLE SETINGS. IF EACH OF THE
C     FIRST NCOMP ELEMENTS EQUAL ONE OF THE ALLOWABLE VALUES THEN THIS
C     SUBROUTINE TAKES NO FUTHER ACTION. IF JUST ONE OF THE FIRST
C     NCOMP ELEMENTS OF RCOMP DOES NOT EQUAL ANY OF THE ALLOWABLE VALUES
C     THIS SUBROUTINE SO INFORMS THE USER AND THEN STOPS THE PROGRAM.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 5 NOVEMBER 1981.
C
C
      DIMENSION RCOMP(NCOMP),ACOMP(6)
C
C
    1 CONTINUE
C
C     FOR THE SAKE OF EFFICIENCY SOME LOCAL VARIABLES WILL BE SET EQUAL
C     TO SOME OF THE PARAMETERS.
C
      IUNIT=IUNITE
       NUMB=NCOMP
C
C     EACH OF THE FIRST NCOMP ELEMENTS OF RCOMP WILL NOW BE CHECKED.
C
      DO 7 I=1,NUMB,1
      RCOMPI=RCOMP(I)
      DO 2 J=1,6,1
      ACOMPJ=ACOMP(J)
      IF(RCOMPI .EQ. ACOMPJ) GO TO 6
    2 CONTINUE
    3 CONTINUE
C
C     THE ITH ELEMENT OF THE ARRAY, RCOMP, DOES NOT EQUAL
C     ANY OF THE ELEMENTS OF THE ARRAY, ACOMP.
C
      WRITE(IUNIT,1003) I,(ACOMP(K),K=1,6,1)
 1003 FORMAT(1H1,
     11H ,26HTHIS IS SUBROUTINE COMCHK.,/,
     21H ,29HAN ERROR HAS BEEN DISCOVERED.,/,
     31H ,19HTHE ELEMENT NUMBER ,I1,26H OF ARRAY, RCOMP, DOES NOT,/,
     41H ,55HEQUAL ANY OF THE ALLOWED VALUES PASSED IN ARRAY, ACOMP.,
     5     2(1H ,/),
     61H ,11HACOMP(1) = ,A10,13H  ACOMP(2) = ,A10,13H  ACOMP(3) = ,A10
     7   ,/,
     81H ,11HACOMP(4) = ,A10,13H  ACOMP(5) = ,A10,13H  ACOMP(6) = ,A10)
    4 CONTINUE
      DO 5 K=1,NUMB,1
      WRITE(IUNIT,1004) K,RCOMP(K)
 1004 FORMAT(
     11H , 6HRCOMP(,I1, 4H) = ,A10)
    5 CONTINUE
      WRITE(IUNIT,1005)
 1005 FORMAT(1H ,/,
     11H ,43HTHIS SUBROUTINE WILL NEXT STOP THE PROGRAM.)
      STOP
    6 CONTINUE
C
C     THE ITH ELEMENT OF THE ARRAY, RCOMP, EQUALS THE JTH
```

```
C       ELEMENT OF THE ARRAY, ACOMP.
C
      7 CONTINUE
C
C       EACH OF THE FIRST NCOMP ELEMENTS OF THE ARRAY, RCOMP,
C       EQUAL ONE OF THE ALLOWABLE VALUES.
C
        RETURN
        END
```

```
      SUBROUTINE EOFILE(IUNIT,ISET,IENDF)
C
C
C     THIS SUBROUTINE DETERMINES IF ON A PREVIOUS READ OF UNIT, IUNIT,
C     THE END OF THE FILE WAS REACHED.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 24 JANUARY 1981.
C
C
    1 CONTINUE
      IF(EOF(IUNIT)) 2,3,2
    2 CONTINUE
C
C     PREVIOUS READ ENCOUNTERED THE END OF THE FILE.
C
      IENDF=ISET
    3 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE IPZCHK(AOFIW,AOFIG,AOFPW,AOFPG,ZINCHW,ZINCHG,
     1                  ISET,IFLAG)
C
C
C     THIS SUBROUTINE COMPARES AOFIW TO AOFIG, AOFPW TO AOFPG, AND
C     ZINCHW TO ZINCHG. IF ALL COMPARISONS ARE CLOSE THEN IFLAG IS
C     SET EQUAL TO ISET. OTHERWISE THE VALUE OF IFLAG IS NOT CHANGED.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 5 NOVEMBER 1981.
C
C
      DATA SMALL/1.E-3/
C
C
    1 CONTINUE
      ABSID=ABS(AOFIW-AOFIG)
      IF(ABSID .GT. SMALL) GO TO 5
    2 CONTINUE
      ABSPD=ABS(AOFPW-AOFPG)
      IF(ABSPD .GT. SMALL) GO TO 5
    3 CONTINUE
      ABSZD=ABS(ZINCHW-ZINCHG)
      IF(ABSZD .GT. SMALL) GO TO 5
    4 CONTINUE
C
C     ALL COMPARISONS ARE CLOSE.
C
      IFLAG=ISET
    5 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE LOADM(IUNITE,MUSED,M)
C
C
C     THIS SUBROUTINE SETS THE ELEMENTS OF THE ARRAY M TO THE AZIMUTHAL
C     ORDERS OF THE COEFFICIENTS THAT WILL BE PRINTED. THEY WILL BE IN
C     THE ORDER THEY ARE TO BE PRINTED.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 17 NOVEMBER 1981.
C
C
      DIMENSION M(MUSED)
C
C
    1 CONTINUE
C
C     FOR THE SAKE OF EFFICIENCY SOME LOCAL VARIABLES WILL BE SET EQUAL
C     TO SOME OF THE PARAMETERS.
C
       IUNIT=IUNITE
      MTOTAL=MUSED
C
C     MUSED IS THE NUMBER AZIMUTHAL ORDERS USED. THIS NUMBER SHOULD BE
C     ODD SINCE IT IS ASSUMED THAT THE SMALLEST ORDER USED IS THE
C     NEGATIVE OF THE LARGEST ONE USED AND THAT THE ALL THE ONES IN
C     THESE LIMITS ARE USED AS WELL. IT IS ALSO ASSUMED THAT THE
C     AZIMUTHAL ORDERS ARE IN ASCENDING ORDER.
C
        MPOS=MTOTAL/2
      MCHECK=MTOTAL-(2*MPOS)
      IF(MTOTAL .GT. 0 .AND. MCHECK .EQ. 1) GO TO 3
    2 CONTINUE
      WRITE(IUNIT,1002) MTOTAL
 1002 FORMAT(1H1,
     11H ,25HTHIS IS SUBROUTINE LOADM.,/,
     21H ,29HAN ERROR HAS BEEN DISCOVERED.,/,
     31H ,39HMUSED SHOULD BE A POSITIVE ODD INTEGER.,2(1H ,/),
     41H , 9H MUSED = ,I10,2(1H ,/),
     51H ,43HTHIS SUBROUTINE WILL NEXT STOP THE PROGRAM.)
      STOP
    3 CONTINUE
      MVALUE=-MPOS
      DO 4 IM=1,MTOTAL,1
       M(IM)=MVALUE
      MVALUE=MVALUE+1
    4 CONTINUE
    5 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE RCNAME(IUNITR,NUM,RCOMP)
C
C
C     THIS SUBROUTINE READS FROM UNIT, IUNITR, THE NAMES OF THE
C     COMPONENTS TO BE PRINTED.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 18 NOVEMBER 1981.
C
C
      DIMENSION RCOMP(6)
C
C
    1 CONTINUE
C
C     FOR THE SAKE OF EFFICIENCY THE UNIT NUMBER PASSED AS A PARAMETER
C     WILL BE SET TO A LOCAL VARIABLE.
C
      IUNIT=IUNITR
      READ(IUNIT,1001) (RCOMP(I),I=1,NUM,1)
 1001 FORMAT(6A10)
    2 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE READIN(IUNITE,IUNITR,
     1                  FREQMH,PCENT,AOFI,AOFP,ZINCH,NCOMP,RCOMP)
C
C
C     THIS SUBROUTINE READS FROM UNIT, IUNITR, THE INFORMATION NEEDED
C     TO SPECIFY WHAT THE USER WANTS PRINTED. THE INFORMATION IS THE
C     FREQUENCY IN MEGA HERTZ, THE PERCENTAGE OF THE WATER CONTENT THAT
C     IS IN THE SOIL, THE HEIGHT ABOVE THE GROUND IN INCHES THAT THE
C     NEAR FIELDS ARE TO BE PRINTED, THE NUMBER OF DIFFERENT COMPONENTS
C     TO BE PRINTED, AND THE NAMES OF THE COMPONENTS TO BE PLOTTED.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 18 NOVEMBER 1981.
C
C
      DIMENSION RCOMP(6)
C
C
      DATA ISET/0/,IUNSET/1/
C
C
    1 CONTINUE
C
C     FOR THE SAKE OF EFFICIENCY THE UNIT NUMBERS PASSED AS PARAMETERS
C     WILL BE SET TO LOCAL VARIABLES.
C
       IERR=IUNITE
      IREAD=IUNITR
C
C     THE FOUND END OF FILE FLAG WILL NOW BE UNSET.
C
      IENDF=IUNSET
C
C     THE FIRST READ OF UNIT, IUNITR, WILL NOW BE DONE.
C
      READ(IREAD,1001) FMHZ,PC,AI,AP,Z,RNUM
 1001 FORMAT(1X,F9.4,5F10.4)
C
C     IF THE END OF FILE MARK WAS READ BY THE LAST READ A SERIOUS ERROR
C     HAS BEEN DISCOVERED. SUBROUTINE EOFILE DETERMINES IF THE PREVIOUS
C     READ OF UNIT, IUNITR, ENCOUNTERED THE END OF FILE MARK.
C
      CALL EOFILE(IREAD,ISET,IENDF)
      IF(ISET .NE. IENDF) GO TO 3
    2 CONTINUE
C
C     THE END OF FILE MARK WAS ENCOUNTERED DURING THE FIRST READ
C     OF UNIT, IUNITR, THE USER WILL BE SO INFORMED AND THEN THE
C     PROGRAM WILL BE STOPPED.
C
      WRITE(IERR,1002)IREAD
 1002 FORMAT(1H1,
     11H ,26HTHIS IS SUBROUTINE READIN.,/,
     21H ,29HAN ERROR HAS BEEN DISCOVERED.,/,
     31H ,38HREACHED THE END OF THE FILE ON UNIT = ,I3,/,
     41H ,25HAFTER ONLY THE FIRST READ.,/,
     51H ,43HTHIS SUBROUTINE WILL NEXT STOP THE PROGRAM.)
      STOP
    3 CONTINUE
      NUM=IFIX(RNUM+.5)
C
```

```
C     NUM SHOULD BE A POSITIVE INTEGER LESS THAN OR EQUAL TO 6.
C
      IF(0 .LT. NUM .AND. NUM .LE. 6) GO TO 5
    4 CONTINUE
C
C     AN ERROR HAS BEEN DISCOVERED.
C
      WRITE(IERR,1004) RNUM,NUM,FMHZ,PC,AI,AP,Z
 1004 FORMAT(1H1,
     11H ,26HTHIS IS SUBROUTINE READIN.,/,
     21H ,29HAN ERROR HAS BEEN DISCOVERED.,/,
     31H ,58HRCOMP SHOULD BE A POSITIVE NUMBER LESS THAN OR EQUAL TO 6.
     4   ,2(1H ,/),
     51H , 9H  RNUM = ,E10.4,11X, 9H NCOMP = ,I10  ,/,
     61H , 9HFREQMH = ,E10.4,11X, 9H PCENT = ,E10.4,/,
     71H , 9H  AOFI = ,E10.4,11X, 9H  AOFP = ,E10.4,/,
     81H , 9H ZINCH = ,E10.4,2(1H ,/),
     91H ,29HNCCMP WILL BE SET EQUAL TO 1.)
      NUM=1
    5 CONTINUE
C
C     SUBROUTINE RCNAME WILL NOW READ FROM UNIT, IUNITR, THE FIELD
C     COMPONENTS THE USER WANTS PRINTED.
C
      CALL RCNAME(IREAD,NUM,RCCMP)
C
C     IF ON THE LAST READ OF THE UNIT, IUNITR, THE END OF FILE MARK WAS
C     READ THEN A SERIOUS MISTAKE HAS OCCURED. SUBROUTINE EOFILE
C     DETERMINES IF THE PREVIOUS READ OF UNIT, IUNITR, ENCOUNTERED THE
C     END OF FILE MARK.
C
      CALL EOFILE(IREAD,ISET,IENDF)
      IF(ISET .NE. IENDF) GO TO 7
    6 CONTINUE
C
C     THE END OF FILE MARK WAS ENCOUNTERED DURING THE SECOND READ
C     OF UNIT, IUNITR, THE USER WILL BE SO INFORMED AND THEN THE
C     PROGRAM WILL BE STOPPED.
C
      WRITE(IERR,1006)IREAD
 1006 FORMAT(1H1,
     11H ,26HTHIS IS SUBROUTINE READIN.,/,
     21H ,29HAN ERROR HAS BEEN DISCOVERED.,/,
     31H ,38HREACHED THE END OF THE FILE ON UNIT = ,I3,/,
     41H ,27HAFTER ONLY THE SECOND READ.,/,
     51H ,43HTHIS SUBROUTINE WILL NEXT STOP THE PROGRAM.)
      STOP
    7 CONTINUE
C
C     DEMONSTRATE THAT NOTHING ELSE READ FROM THE UNIT, IUNITR, IS USED.
C
    8 CONTINUE
C
C     THE LAST READ DID NOT ENCOUNTER THE END OF THE FILE.
C
      READ(IREAD,1008)DUMMY
 1008 FORMAT(A10)
C
C     CHECK TO DETERMINE IF THE PREVIOUS READ OF UNIT, IUNITR,
C     ENCOUNTERED THE END OF THE FILE. SUBROUTINE EOFILE PERFORMS
C     THIS TASK.
C
```

```
      CALL EOFILE(IREAD,ISET,IENDF)
      IF(ISET .EQ. IENDF) GO TO 10
    9 CONTINUE
      GO TO 8
   10 CONTINUE
C
C     AT END OF FILE
C
C     BEFORE RETURNING SEVERAL OF THE PARAMETERS WILL NOW BE SET.
C
      FREQMH=FMHZ
       PCENT=PC
        AOFI=AI
        AOFP=AF
       ZINCH=Z
       NCOMP=NLM
C
      RETURN
      END
```

```
      SUBROUTINE RHOCHK(IUNITE,NPTSU,RHO,NPTSC,RHOC)
C
C
C     THIS SUBROUTINE DETERMINES IF THE RHO ARRAY IS CORRECT.
C     IF IT IS NOT THE USER IS SO INFORMED AND THE PROGRAM IS STOPPED.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 5 NOVEMBER 1981.
C
C
      DIMENSION RHO(NPTSU),RHOC(NPTSC)
C
C
      DATA SMALL/1.E-3/
C
C
    1 CONTINUE
C
C     FOR THE SAKE OF EFFICIENCY SOME LOCAL VARIABLES WILL BE SET EQUAL
C     TO SOME OF THE PARAMETERS.
C
       IUNIT=IUNITE
      NPTSUL=NPTSU
      NPTSCL=NPTSC
C
C     NPTSU SHOULD BE POSITIVE AND EQUAL TO NPTSC.
C
      IF(NPTSUL .LT. 0 .OR. NPTSUL .NE. NPTSCL) GO TO 4
    2 CONTINUE
      DO 3 I=1,NPTSUL,1
        RHOI=RHO (I)
       RHOCI=RHOC(I)
      RCHECK=ABS(RHOI-RHOCI)
      IF(RCHECK .GT. SMALL) GO TO 4
    3 CONTINUE
C
C     ALL THE RHO VALUES AGREE WITH THE CORRECT VALUES.
C
      GO TO 7
    4 CONTINUE
      WRITE(IUNIT,1004) NPTSUL,NPTSCL
 1004 FORMAT(1H1,
     11H ,26HTHIS IS SUBROUTINE RHOCHK.,/,
     21H ,29HAN ERROR HAS BEEN DISCOVERED.,/,
     31H ,57HTHE VARIABLES WHICH DEFINE THE RHO ARRAY ARE NOT CORRECT.
     4   ,2(1H /),
     51H , 9H NPTSU = ,I10,11X, 9H NPTSC = ,I10,2(1H ,/),
     61H , 3H I ,1X,4X,3HRHO,5X,11X,4X,4HRHOC)
    5 CONTINUE
                                NLIMIT=NPTSUL
      IF(NLIMIT .LT. NPTSCL) NLIMIT=NPTSCL
      IF(NLIMIT .LT.       1) NLIMIT=1
      DO 6 N=1,NLIMIT,1
      WRITE(IUNIT,1005)N,RHO(N),RHOC(N)
 1005 FORMAT(1H ,I3,1X,E12.5,11X,E12.6)
    6 CONTINUE
      WRITE(IUNIT,1006)
 1006 FORMAT(1H ,/,
     11H ,43HTHIS SUBROUTINE WILL NEXT STOP THE PROGRAM.)
      STOP
    7 CONTINUE
```

```
RETURN
END
```

```
      SUBROUTINE RWCOMP(IRW,ITAPEN,COMP,MDIM,MAXPTS,MM3,NPTU,
     1                  WAVEEH)
C
C
C     THIS SUBROUTINE READS OR WRITES THE AZIMUTHAL COEFFICIENTS
C     FOR ALL THE RHO VALUES AT ONE Z LEVEL FOR ONE FIELD COMPONENT.
C     IF IRW EQUALS TWO THEN A WRITE WILL TAKE PLACE, OTHERWISE A
C     READ IS MADE. FOR THE SAKE OF STYLE AND POSSIBLE FUTURE REVISION
C     WHEN A READ OPERATION IS DESIRED CALL THIS SUBROUTINE WITH IRW
C     EQUAL TO ONE.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 23 OCTOBER 1981.
C
C
      COMPLEX WAVEEH(MDIM,MAXPTS)
C
C
    1 CONTINUE
C
C     FOR THE SAKE OF EFFICIENCY SOME LOCAL VARIABLES WILL BE SET EQUAL
C     TO SOME OF THE PARAMETERS.
C
       IRWL=IRW
      ITAPE=ITAPEN
       MM3L=MM3
        NPT=NPTU
C
C     NOW A TEST WILL BE DONE TO DETERMINE IF A READ OF A WRITE
C     HAS BEEN REQUESTED.
C
      IF(IRWL .EQ. 2) GO TO 12
    2 CONTINUE
C
C     A READ IS REQUESTED
C
      READ(ITAPE,1002) COMP
 1002 FORMAT(29X,A10,/,25X)
    3 CONTINUE
      READ(ITAPE,1003)
 1003 FORMAT(76X)
    4 CONTINUE
      READ(ITAPE,1004)((WAVEEH(IROW,JCOL),IROW=1,MM3L,1),JCOL=1,NPT,1)
 1004 FORMAT(6(1X,E10.4))
      GO TO 15
   12 CONTINUE
C
C     A WRITE IS REQUESTED
C
      WRITE(ITAPE,1012) COMP
 1012 FORMAT(
     11H ,28HTHE NEAR FIELD COMPONENT IS ,A10,/,
     21H ,24HIN FORMAT(29X,A10,/,25X)              )
   13 CONTINUE
      WRITE(ITAPE,1013)
 1013 FORMAT(
     11H ,48H((WAVEEH(IROW,JCOL),IROW=1,MM3,1),JCOL=1,NPTU,1),
     2    27H --- IN FORMAT(6(1X,E10.4)) )
   14 CONTINUE
      WRITE(ITAPE,1014)((WAVEEH(IROW,JCOL),IROW=1,MM3L,1),JCOL=1,NPT,1)
 1014 FORMAT(6(1H ,E10.4))
```

```
15 CONTINUE
   RETURN
   END
```

```
      SUBROUTINE RWHEAD(IRW,ITAPEN,IUNITE,
     1                  MAXPTS,FREQMH,PCENT,ZINCH,AOFI,AOFP,
     2                  MM3,NPTU,RHO)
C
C
C     THIS SUBROUTINE READS OR WRITES THE HEADER TO TAPE,ITAPEN.
C     IF IRW EQUALS TWO THEN A WRITE WILL TAKE PLACE, OTHERWISE
C     A READ IS MADE. FOR THE SAKE OF STYLE AND POSSIBLE FUTURE
C     REVISIONS, WHEN A READ OPERATION IS DESIRED A CALL THIS
C     SUBROUTINE WITH IRW EQUAL TO ONE.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 27 OCTOBER 1981.
C
C
      DIMENSION RHO(MAXPTS)
C
C
    1 CONTINUE
C
C     FOR THE SAKE OF EFFICIENCY SOME LOCAL VARIABLES WILL BE SET EQUAL
C     TO SOME OF THE PARAMETERS.
C
       IRWL=IRW
      ITAPE=ITAPEN
      IUNIT=IUNITE
       MPTS=MAXPTS
       FMHZ=FREQMH
         PC=PCENT
         ZI=ZINCH
         AI=AOFI
         AP=AOFP
       MM3L=MM3
        NPT=NPTU
C
C     DETERMINE IF A READ OR WRITE OPERATION IS REQUESTED.
C
      IF(IRWL .EQ. 2) GO TO 12
    2 CONTINUE
C
C     A READ OPERATION IS REQUESTED.
C
      READ(ITAPE,1002) FMHZ,PC,ZI,AI,AP,MM3L,NPT
 1002 FORMAT(38X,/,5(1X,E10.4),2(1X,I10),/,45X)
C
C     A TEST WILL BE MADE TO BE SURE THAT THE ARRAY, RHO, WILL NOT
C     BE CLOBBERED BY THE NEXT READ.
C
      IF(MPTS .LT. NPT) GO TO 5
    3 CONTINUE
      READ(ITAPE,1003)
 1003 FORMAT(47X)
    5 CONTINUE
      READ(ITAPE,1004)(RHO(I),I=1,NPT,1)
 1004 FORMAT(4(1X,E10.4))
C
C     BEFORE THIS SUBROUTINE RETURNS THE PARAMETERS FREQMH, PCENT,
C     ZINCH, AOFI, AOFP, MM3, AND NPTU WILL BE SET EQUAL TO THE
C     VALUES READ FOR FMHZ, PC, ZI, AI, AP, MM3L, AND NPT RESPECTIVELY.
C
      FREQMH=FMHZ
```

```
      PCENT=PC
      ZINCH=ZI
       AOFI=AI
       AOFP=AP
        MM3=MM3L
       NPTU=NPT
     GO TO 15
   5 CONTINUE
C
C     AN ERROR HAS BEEN DISCOVERED.
C
      WRITE(IUNIT,1005) IRWL,FMHZ,PC,ZI,AI,AP,MM3L,NPTS,NPT
 1005 FORMAT(1H1,2(1H ,/),
     11H ,26HTHIS IS SUBROUTINE RWHEAD.,/,
     21H ,29HAN ERROR HAS BEEN DISCOVERED.,/,
     31H ,55HTHE NUMBER OF RHO POINTS IS LARGER THAN THE ARRAY, RHO.,
     4   2(1H ,/),
     51H ,9H  IRWL = ,I15  ,/,
     61H ,9HFREQMH = ,E15.9,5X,9H PCENT = ,E15.9,/,
     71H ,9H ZINCH = ,E15.9,/,
     81H ,9H  AOFI = ,E15.9,5X,9H  AOFP = ,E15.9,/,
     91H ,9H    MM3 = ,I15  ,5X,9HMAXPTS = ,I15  ,/,
     01H ,9H    NPT = ,I15  ,2(1H ,/),
     11H ,42HTHIS SUBROUTINE WILL NOW STOP THE PROGRAM.)
      STOP
   12 CONTINUE
C
C     A WRITE OPERATION IS REQUESTED.
C
      WRITE(ITAPE,1012) FMHZ,PC,ZI,AI,AP,MM3L,NPT
 1012 FORMAT(
     11H ,37HFREQMH,PCENT,ZINCH,AOFI,AOFP,MM3,NPTU,/,
     2    5(1H ,E10.4),2(1H ,I10),/,
     31H ,44HIN FORMAT(38X,/,5(1X,E10.4),2(1X,I10),/,45X)     )
   13 CONTINUE
      WRITE(ITAPE,1013)
 1013 FORMAT(
     11H ,46H(RHO(I),I=1,NPTU,1) --- IN FORMAT(4(1X,E10.4)) )
   14 CONTINUE
      WRITE(ITAPE,1014) (RHO(I),I=1,NPT,1)
 1014 FORMAT(4(1H ,E10.4))
   15 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE RW1W2Z(IRW,ITAPEN,IUNITE,
     1                  MAXPTS,FREQMH,PCENT,ZINCH,AOFI,AOFP,
     2                  MM3,NPTU,RHO,MDIM,WAVEEH)
C
C
C     THIS SUBROUTINE ALONG WITH ITS TREE READS OR WRITES THE
C     INFORMATION ON TAPE, ITAPEN, CONCERNING THE INCIDENT PLANE
C     WAVE AND THE AZIMUTHAL COEFFICIENTS FOR ALL THE RHO VALUES
C     AT THE Z ZLEVEL, ZINCH. IF IRW EQUALS TWO THEN A WRITE WILL
C     TAKE PLACE, OTHERWISE A READ IS MADE. FOR THE SAKE OF STYLE
C     AND POSSIBLE FUTURE REVISION WHEN A READ OPERATION IS DESIRED
C     CALL THIS SUBROUTINE WITH IRW EQUAL TO ONE.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 26 OCTOBER 1981.
C
C
      COMPLEX WAVEEH(MDIM,MAXPTS,6)
C
C
      DIMENSION RHO(MAXPTS),COMPEN(6),COMPWN(6)
C
C
C     THE ELEMENTS OF THE ARRAY COMPWN STORE THE NAME OF EACH FIELD
C     COMPONENT.
C
      DATA COMPWN/10HEPHI      ,10HERHO      ,10HEZEE      ,
     1            10HHPHI      ,10HHRHO      ,10HHZEE      /
C
C
    1 CONTINUE
C
C     FOR THE SAKE OF EFFICIENCY SOME LOCAL VARIABLES WILL BE SET EQUAL
C     TO SOME OF THE PARAMETERS.
C
       IRWL=IRW
      ITAPE=ITAPEN
      IUNIT=IUNITE
       MPTS=MAXPTS
        FMH=FREQMH
         PC=PCENT
       ZINL=ZINCH
         AI=AOFI
         AP=AOFP
       MM3L=MM3
      NPTUL=NPTU
      MDIML=MDIM
    2 CONTINUE
C
C     THE HEADING WILL NOW BE READ OR WRITTEN. SUBROUTINE RWHEAD
C     WILL PERFORM THIS TASK.
C
      CALL RWHEAD(IRWL,ITAPE,IUNIT,
     1            MPTS,FMH,PC,ZINL,AI,AP,
     2            MM3L,NPTUL,RHO)
C
C     A TEST WILL BE DONE TO BE SURE THAT THE FIRST DIMENSION OF
C     THE ARRAY, WAVEEH, IS LARGE ENOUGH.
C
      IF(MM3L .GT. 0 .AND. MM3L .LE. MDIML) GO TO 4
    3 CONTINUE
```

```
C
C     AN ERROR HAS BEEN DISCOVERED, SO THE USER WILL BE INFORMED
C     AND THE PROGRAM STOPPED.
C
      WRITE(IUNIT,1003) IRWL,ITAPE,MPTS,NPTUL,FMH,PC,AI,AP,ZINL,
     1                  MM3L,MDIML
 1003 FORMAT(1H1,2(1H ,/),
     11H ,26HTHIS IS SUBROUTINE RW1W1Z.,/,
     21H ,52HTHE NUMBER OF AZIMUTHAL COEFFICIENTS FOR THE CURRENT,/,
     31H ,52HZ LEVEL SHOULD BE POSITIVE BUT LESS THAN OR EQUAL TO,/,
     41H ,53HTHE FIRST DIMENSION OF THE ARRAY, WAVEEH. THIS IS NOT,/,
     51H , 9HTHE CASE.,2(1H ,/),
     61H , 9H   IRW = ,I10  ,11X, 9HITAPEN = ,I10  ,/,
     71H , 9HMAXPTS = ,I10  ,11X, 9H  NPTU = ,I10  ,/,
     81H , 9HFREQMH = ,E10.4,11X, 9H PCENT = ,E10.4,/,
     91H , 9H  AOFI = ,E10.4,11X, 9H  AOFP = ,E10.4,/,
     01H , 9H ZINCH = ,E10.4,                        /,
     11H , 9H   MM3 = ,I10  ,11X, 9H  MDIM = ,I10  ,2(1H ,/),
     21H ,42HTHIS SUBROUTINE WILL NOW STOP THE PROGRAM.)
      STOP
    4 CONTINUE
C
C     A TEST WILL BE DONE TO DETERMINE IF A READ OR A WRITE
C     HAS BEEN REQUESTED.
C
      IF(IRWL .EQ. 2) GO TO 15
    5 CONTINUE
C
C     A READ OPERATION HAS BEEN REQUESTED.
C
C     NOW THE AZIMUTHAL COEFFICIENTS FOR EACH COMPONENT OF THE
C     NEAR FIELD WILL BE READ. THE REPEATED CALLS TO SUBROUTINE
C     RWCOMP PERFORMS THIS TASK.
C
      DO 6 ICOMP=1,6,1
      CALL RWCOMP(IRWL,ITAPE,COMPRN(ICOMP),MDIML,MPTS,MM3L,NPTUL,
     1            WAVEEH(1,1,ICOMP))
    6 CONTINUE
C
C     THE COMPONENTS SHOULD HAVE BEEN READ IN THE ORDER THAT THEY
C     ARE LISTED IN THE ARRAY, COMPWN.
C
      DO 7 ICOMP=1,6,1
      IF(COMPRN(ICOMP) .NE. COMPWN(ICOMP)) GO TO 8
    7 CONTINUE
C
C     THE PARAMETERS FREQMH,PCENT,ZINCH,AOFI,AOFP,MM3,AND NPTU WILL BE
C     SET EQUAL TO THE VALUES READ FOR MPTS,FMH,PC,ZINL,AI,AP,MM3L, AND
C     NPTUL RESPECTIVELY.
C
      FREQMH=FMH
       PCENT=PC
       ZINCH=ZINL
        AOFI=AI
        AOFP=AP
         MM3=MM3L
        NPTU=NPTUL
      GO TO 17
    8 CONTINUE
C
C     AN ERROR HAS BEEN DISCOVERED. THE COMPONENTS WERE NOT READ
C     IN THE ORDER EXPECTED. THE USER WILL BE SO INFORMED AND THEN
```

```
C     THE PROGRAM STOPPED.
C
      WRITE(IUNIT,1008) IRWL,ITAPE,MPTS,NPTUL,FMH,FC,AI,AP,ZINL,
     1                  MM3L,MDIML
 1008 FORMAT(1H1,2(1H ,/),
     11H ,26HTHIS IS SUBROUTINE RW1W1Z.,/,
     21H ,51HTHE COMPONENTS WERE NOT READ IN THE EXPECTED ORDER.,
     3    2(1H ,/),
     41H , 9H   IRW = ,I10  ,11X, 9HITAPEN = ,I10  ,/,
     51H , 9HMAXPTS = ,I10  ,11X, 9H  NPTU = ,I10  ,/,
     61H , 9HFREQMH = ,E10.4,11X, 9H PCENT = ,E10.4,/,
     71H , 9H  AOFI = ,E10.4,11X, 9H  AOFP = ,E10.4,/,
     81H , 9H ZINCH = ,E10.4,                        /,
     01H , 9H   MM3 = ,I10  ,11X, 9H  MDIM = ,I10  ,2(1H ,/),
     11H , 3H I ,1X,14HEXPECTED ORDER,1X,10HORDER READ)
    9 CONTINUE
      DO 10 I=1,6,1
      WRITE(IUNIT,1009) I,COMPWN(I),COMPRN(I)
 1009 FORMAT(1H ,1X,I1,1X,1X,2X,A10,2X,1X,A10)
   10 CONTINUE
      WRITE(IUNIT,1010)
 1010 FORMAT(2(1H ,/),
     11H ,42HTHIS SUBROUTINE WILL NOW STOP THE PROGRAM.)
      STOP
   15 CONTINUE
C
C     A WRITE OPERATION WAS REQUESTED.
C
      DO 16 ICOMP=1,6,1
      CALL RWCOMP(IRWL,ITAPE,COMPWN(ICOMP),MDIML,MPTS,MM3L,NPTUL,
     1            WAVEEH(1,1,ICOMP))
   16 CONTINUE
   17 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TCHECK(IUNITE,FMHZW,FMHZG,PCENTW,PCENTG)
C
C
C     THIS SUBROUTINE COMPARES FMHZW TO FMHZG, AND PCENTW TO PCENTG.
C     IF BOTH COMPARISONS ARE CLOSE THEN THIS SUBROUTINE RETURNS TO
C     THE CALLING SUBPROGRAM. OTHERWISE IT SO INFORMS THE USER AND
C     THEN STOPS THE PROGRAM.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 5 NOVEMBER 1981.
C
C
      DATA SMALL/1.E-3/
C
C
    1 CONTINUE
C
C     FOR THE SAKE OF EFFICIENCY SOME LOCAL VARIABLES WILL BE SET EQUAL
C     TO SOME OF THE PARAMETERS.
C
      IUNIT=IUNITE
         FW=FMHZW
         FG=FMHZG
        PCW=PCENTW
        PCG=PCENTG
    2 CONTINUE
C
C     NOW THE COMPARISIONS WILL BE MADE.
C
       ABSFD=ABS(FW-FG)
      IF( ABSFD .GT. SMALL) GO TO 5
    3 CONTINUE
      ABSPCD=ABS(PCW-PCG)
      IF(ABSPCD .GT. SMALL) GO TO 5
    4 CONTINUE
      GO TO 6
    5 CONTINUE
      WRITE(IUNIT,1005)FW,PCW,FG,PCG
 1005 FORMAT(1H1,/,
     11H ,26HTHIS IS SUBROUTINE TCHECK.,/,
     21H ,29HAN ERROR HAS BEEN DISCOVERED.,/,
     31H ,47HTHE FREQUENCY OF THE INCIDENT PLANE WAVE OR THE,/,
     41H ,49HPERCENTAGE OF WATER CONTENT IN THE SOIL READ FROM,/,
     51H ,51HTHE FILE WITH THE AZIMUTHAL COEFFICIENTS IS NOT THE,/,
     61H ,45HSAME AS WHAT THE USER SPECIFIED IN THE INPUT.,2(1H ,/),
     71H ,17X,2X,2(,12HFREQUENCY IN,2X,2X,1X,13HPERCENTAGE OF,/,
     81H ,17X,2X,3X,10HMEGA HERTZ,3X,2X,1X,13HWATER CONTENT,/,
     91H ,17HSPECIFIED BY USER,2X,1X,E14.6,1X,2X,1X,E14.8,/,
     01H ,17H    IN THE FILE    ,2X,1X,E14.8,1X,2X,1X,E14.8,2(1H ,/),
     11H ,43HTHIS SUBROUTINE WILL NEXT STOP THE PROGRAM.)
      STOP
    6 CONTINUE
C
C     THE FREQUENCY AND THE PERCENTAGE ARE AS DESIRED.
C
      RETURN
      END
```

```
      SUBROUTINE WAZIC(IUNITO,MDIM,RHO,IFLAG,MUSED,
     1                 M,AOFI,AOFP,ZINCH,COMPN1,COMPN2,AZIC)
C
C
C     THIS SUBROUTINE WRITES TO UNIT, IUNITO, FOR ALL THE RHO VALUES,
C     ONE OF THE USER SPECIFIED SETS OF AZIMUTHAL COEFFICIENTS. IF
C     IFLAG EQUALS ONE THE COEFFICIENTS ARE OF ONE OF THE COMPONENTS
C     OF THE SCATTERED ELECTRIC FIELD. IF IFLAG DOES NOT EQUAL ONE THEN
C     THE COEFFICIENTS ARE OF THE PRODUCT OF ETA0 AND ONE OF THE
C     COMPONENTS OF THE SCATTERED MAGNETIC FIELD.
C
C     THE CALLING SUBPROGRAM IS RESPONSIBLE FOR A CONSISTENT SETTING OF
C     THE PARAMETERS IFLAG, COMPN1, AND COMPN2.
C
C     NOTE NO ERROR CHECKING IS PERFORMED.
C
C     THE OUTPUT TO UNIT, IUNITO, WRITTEN BY THIS SUBROUTINE
C     IS SUITABLE TO BE PRINTED ON A LINE PRINTER.
C
C
C     THIS SUBROUTINE WAS LAST CHANGED ON 14 JANUARY 1982.
C
C
      COMPLEX AZIC(MDIM,16)
C
C
      DIMENSION RHO(16),M(MUSED)
C
C
    1 CONTINUE
C
C     FOR THE SAKE OF EFFICIENCY SOME LOCAL VARIABLES WILL BE SET EQUAL
C     TO SOME OF THE PARAMETERS.
C
       IUNIT=IUNITO
      IFLAGL=IFLAG
      MTOTAL=MUSED
      CNAME1=COMPN1
      CNAME2=COMPN2
C
      IF(IFLAGL .NE. 1) GO TO 3
C
    2 CONTINUE
C
      WRITE(IUNIT,1002) CNAME1
 1002 FORMAT(1H1,/,1H ,57X,A5)
C
      GO TO 4
C
    3 CONTINUE
C
      WRITE(IUNIT,1003) CNAME1
 1003 FORMAT(1H1,/,1H ,54X,A10)
C
    4 CONTINUE
C
      WRITE(IUNIT,1004) AOFI,AOFP,ZINCH
 1004 FORMAT(
     11H ,30X,51HTHE ANGLE OF INCIDENCE OF THE PLANE WAVE IN DEGREES,
     2          4H IS ,F4.1,/,
     31H ,30X,51HTHE POLARIZATION ANGLE OF THE PLANE WAVE IN DEGREES,
```

```
     4          4H IS ,F4.1,/,
     51H ,21X,51HTHE SCATTERED FIELD IS EVALUATED ABOVE THE GROUND A,
     6         23H DISTANCE IN INCHES OF ,F3.1,2(1H ,/))
C
      IF(IFLAGL .NE. 1) GO TO 6
C
    5 CONTINUE
C
      WRITE(IUNIT,1005) CNAME2,CNAME2,CNAME2,CNAME2
 1005 FORMAT(
     11H ,33HTHE AZIMUTHAL COEFFICIENTS OF THE,A6,12HCOMPONENT OF,
     2     43H THE SCATTERED FIELD ARE LISTED UNDER THEIR,
     3     23H CORRESPONDING VALUE OF,/,
     41H ,46HRHO IN UNITS OF VOLTS PER METER. TO OBTAIN THE,A6,
     5     35HCOMPONENT OF THE TOTAL FIELD ADD THE,A6,12HCOMPONENT OF,
     6     13H THE INCIDENT,/,
     71H ,13HFIELD AND THE,A6,35HCOMPONENT OF THE FIELD SCATTERED BY,
     8     50H THE AIR GROUND INTERFACE TO THE SUM OF THE SERIES,
     9     11H DEFINED BY,/,
     01H ,56HTHESE AZIMUTHAL COEFFICIENTS. THE MAGNITUDE WILL THEN BE,
     1     57H NORMALIZED FOR AN INCIDENT PLANE WAVE HAVING AN ELECTRIC.
     2      6H FIELD,/,
     31H ,22HOF ONE VOLT PER METER.)
C
      GO TO 7
C
    6 CONTINUE
C
      WRITE(IUNIT,1006) CNAME2,CNAME2,CNAME2,CNAME2
 1006 FORMAT(
     11H ,53HTHE AZIMUTHAL COEFFICIENTS OF THE PRODUCT OF ETA0 (IN,
     2     14H OHMS) AND THE,A6,36HCOMPONENT OF THE SCATTERED FIELD ARE,
     3      7H LISTED,/,
     41H ,56HUNDER THEIR CORRESPONDING VALUE OF RHO IN UNITS OF VOLTS,
     5     25H PER METER. TO OBTAIN THE,A6,22HCOMPONENT OF THE TOTAL,
     6     10H FIELD ADD,/,
     71H , 3HTHE,A6,39HCOMPONENT OF THE INCIDENT FIELD AND THE,A6,
     8     50HCOMPONENT OF THE FIELD SCATTERED BY THE AIR GROUND,
     9     13H INTERFACE TO,/,
     01H ,51HTHE RATIO OF THE SUM OF THE SERIES DEFINED BY THESE,
     1     57H AZIMUTHAL COEFFICIENTS AND ETA0 (IN OHMS). THE MAGNITUDE,
     2     10H WILL THEN,/,
     31H ,50HBE NORMALIZED FOR AN INCIDENT PLANE WAVE HAVING AN,
     4     38H ELECTRIC FIELD OF ONE VOLT PER METER.)
C
    7 CONTINUE
C
      DO 10 I=1,4,1
        II=(4*(I-1))+1
      IIP1=II+1
      IIP2=II+2
      IIP3=II+3
      WRITE(IUNIT,1007) RHO(II),RHO(IIP1),RHO(IIP2),RHO(IIP3)
 1007 FORMAT(2(1H ,/,),
     11H , 7X,9HAZIMUTHAL,4(2X,6HRHO = ,F4.1,12H CENTIMETERS),/,
     21H , 7X,9H  ORDER  ,4(2X,3X,4HREAL,3X,1X,10HIMAGINARY ,1X))
C
    8 CONTINUE
C
      DO 9 IM=1,NTOTAL,1
      WRITE(IUNIT,1008) M(IM),AZIC(IM,II  ),AZIC(IM,IIP1),AZIC(IM,IIP2),
     1                  AZIC(IM,IIP3)
```

```
 1008 FORMAT(1H ,7X,3X,I2,4X,4(2X,2(E10.4,1X)))
C
    9 CONTINUE
C
   10 CONTINUE
C
      RETURN
      END
```

THE END

Appendix III

Table of Symbols

$\overline{E}^i$	Electric field vector of the incident plane wave
E_j^i	j component of the electric field of the incident plane wave, where j = x, y or z
$\overline{H}^i$	Magnetic field vector of the incident plane wave
H_j^i	j component of the magnetic field of the incident plane wave, where j = x, y or z
$\overline{E}^p$	Electric field vector of the primary field
E_ζ^p	ζ component of the primary electric field, where ζ = x, y, z, ρ or ϕ
$\overline{H}^p$	Magnetic field vector of the primary field
H_ζ^p	ζ component of the primary magnetic field, where ζ = x, y, z, ρ or ϕ
$\overline{E}^s$	Scattered electric field vector
E_ζ^s	ζ component of the scattered electric field, where ζ = x, y, z, ρ or ϕ
$\overline{H}^s$	Scattered magnetic field vector
H_ζ^s	ζ component of the scattered magnetic field, where ζ = x, y, z, ρ or ϕ
$\overline{E}$	total electric field vector
E_ζ	ζ component of the total electric field ζ - x, y, z, ρ or ϕ
$\overline{H}$	total magnetic field vector
H_ζ	ζ component of the total magnetic field ζ = x. y, z, ρ or ϕ
ψ_1	First Azimuthal potential
ψ_2	Second Azimuthal potential
e	base of natural logarithm

ε_o permittivity of free space

ε_e Relative dielectric constant of earth

ε_m Relative dielectric constant of land mine

ε_i imaginary part of a relative dielectric constant

ε_r real part of a relative dielectric constant

$\tan\delta$ Loss tangent of a dielectric material

α attenuation constant of a dielectric medium

k_o wave number of free space

$\vec{k}$ propagation vector

η_o,ETAO intrinsic impedance of free space

λ_o free space wave length

f frequency

c speed of light

ρ reflection coefficient, parameter of cylinderical coordinate system

Z_L analogue for earth of transmission line load impedance

Z_o analogue for earth of intrinsic transmission line impedance

$R_e\{\cdot\}$ real part of the bracketed expression

$I_m\{\cdot\}$ imaginary part of the bracketed expression