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A PROGRAM TO COMPUTE ELF/VLF EARTH-IONOSPHERE MODAL HEIGHT GAIN--ETC(U)

SEP 81 R A PAPPERT, L R HITNEY

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Technical Report 724

A PROGRAM TO COMPUTE ELF/VLF EARTH-IONOSPHERE MODAL HEIGHT GAINS VIA WKB METHODS UP TO SATELLITE ALTITUDES

RA Pappert
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EM Propagation Division

September 1981

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Released by
JH Richter, Head
EM Propagation Division

Under authority of
JD Hightower, Head
Environmental Sciences Department

METRIC CONVERSION

<u>To convert from</u>	<u>To</u>	<u>Multiply by</u>
gauss	tesla (T)	10^{-4}
degree (angle)	radian (rad)	1.75×10^{-2}

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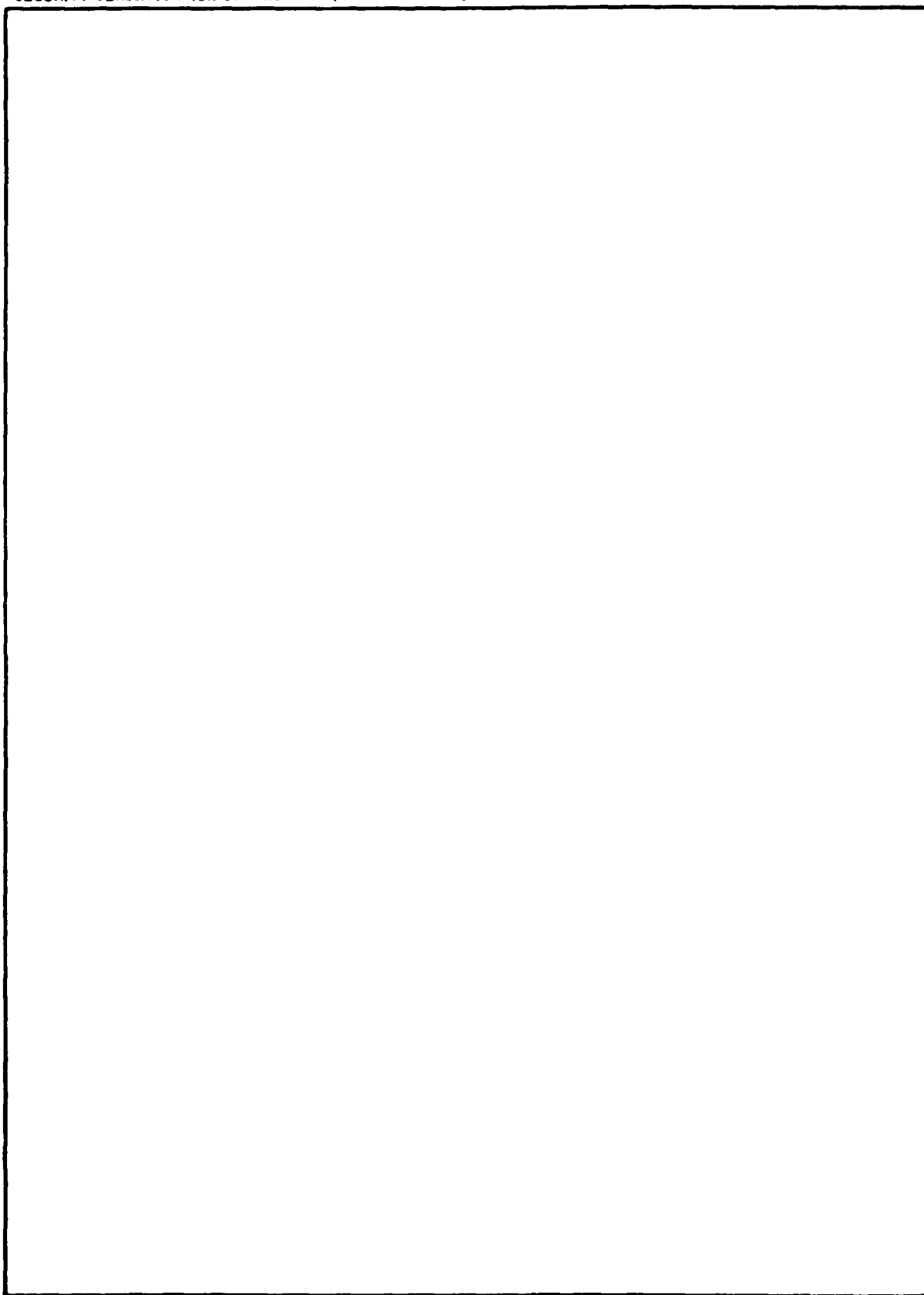
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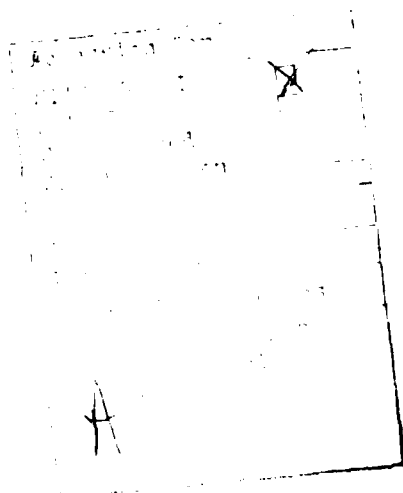
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ABSTRACT

This report presents a variation of an earlier program [2] for computing ELF/VLF earth-ionosphere waveguide modal height gains. In particular, WKB formalism developed by Budden [1] is used to speed up calculation of height gains in the ionosphere up to satellite altitudes. All quantities needed to calculate mode sums at those altitudes for all field components produced by sub-ionospheric electric dipole sources can be generated with the present program.



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I. INTRODUCTION

This report represents the implementation of WKB methods [1] for extending ELF/VLF modal height gains in the ionosphere up to satellite heights. In past works [2,3] this extension has been accomplished by carrying out full-wave integrations up to the satellite altitude. For altitudes sufficiently high in the ionosphere (ie, ≥ 110 km for VLF, ≥ 150 km for ELF under daytime ionospheres and ≥ 250 km for ELF under nighttime ionospheres) the electromagnetic field is in the outgoing whistler mode and the ionospheric gradients are sufficiently weak to justify use of the WKB method. It has been our experience that in carrying fields up to altitudes ≥ 500 km, the WKB method will reduce the computer cost (Univac 1100) by about a factor of 1/3 in the lower ELF band (≈ 75 Hz) and by more than an order of magnitude in the VLF band. Thus, with this cost improvement, it seems quite possible that case studies of satellite reception of VLF signals using waveguide concepts such as reported in reference 4 could be extended to global coverage studies.

Implementation of the WKB theory involves no more than modifications of a full-wave fields program [2] developed originally for the purpose of calculating mode conversion coefficients associated with horizontal inhomogeneities in the earth ionosphere waveguide [5]. One departure of the present fields program from that discussed in reference [2] relates to the replacement of the Inoue-Horowitz [6] integration algorithm by the Runge-Kutta algorithm. This change along with the capability to iterate the mode equation and calculate excitation factors was implemented by CH Shellman, of the NOSC EM Propagation Technology Division, in unpublished work. The Runge-Kutta numerical integration of the field equations together with the Gram-Schmidt orthogonalization procedure and normalization of solutions is a procedure first described by Pitteway [7]. The remaining modifications are related specifically to the field matching required to implement the formulas given in [1]. The essence of the method is to calculate via full-wave Runge-Kutta integration the fields up to an altitude called TOPHT. At TOPHT the outgoing whistler mode (or the outgoing wave with minimum attenuation) is extracted from the set of four magneto-ionic modes and then matched to the corresponding full-wave field components. The WKB fields are then propagated to higher altitude using a Simpson rule integration routine which adjusts the step size in order to maintain precision.

Budden's WKB formulas [1] are summarized in section II. Excitation factors, useful if mode sums are ultimately the goal, and WKB mode summing formulas are summarized in section III. Flow of the program and subroutine descriptions are given in section IV. Section V contains a discussion of card deck arrangement for input along with discussion of a sample output. In section VI WKB height gain results are compared with full-wave Runge-Kutta results, and the appendix contains a program listing.

II. SUMMARY OF WKB FORMULAS

For plane wave incidence of an rf wave on the ionosphere, Maxwell's equations can be written as [8]

$$e' = -iT e \quad (1)$$

where the prime denotes $(k^{-1} \partial / \partial z)$, with k the free space wave number, T a 4×4 matrix given by Budden [1], and e a column matrix composed of components of the electric ($\vec{E}$) and magnetic ($\vec{H}$) fields of the rf wave. The transpose of e is

$$e^T = (E_x, -E_y, Z_0 H_x, Z_0 H_y) \quad (2)$$

where Z_0 is the free space impedance. Henceforth the notation $H_x = Z_0^{-1} H_x$, $H_y = Z_0^{-1} H_y$ and $H_z = Z_0^{-1} H_z$ will be used.

The matrix T has four characteristic roots or eigenvalues, q_i ($i = 1, 2, 3, 4$), which satisfy the characteristic equation

$$\det (T - qI) = 0 \quad (3)$$

where I is the unit 4×4 matrix. This equation is the Booker quartic. Corresponding to any root q_i there is an eigencolumn $P = s^{(i)}$ which satisfies

$$T s^{(i)} = q_i s^{(i)} \quad (4)$$

Let S be the 4×4 matrix whose columns are $s^{(i)}$. For points where S is non-singular, the column matrix f can be defined as

$$e = S f \text{ or } f = S^{-1} e \quad (5)$$

and it can be shown [8] that the elements of f satisfy

$$f'_k = -i q_k f_k + \sum_j \Gamma_{kj} f_j \quad ; j, k = 1, 4 \quad (6)$$

where

$$\Gamma = -S^{-1}S' \quad (7)$$

The preceding transformation can be carried out only when S is non-singular. When two roots of the Booker quartic are equal, two of the columns $S^{(i)}$ are usually multiples of each other, and then S is singular. Near such points some of the coupling coefficients Γ_{kj} are very large and the points may be points of reflection or points where coupling between two upgoing (or downgoing) waves is very strong. The present program cannot be used in such circumstances.

When the species densities and collision frequencies vary slowly enough with height and where no two of the q_j become nearly equal, the terms of Γ are small quantities and there is an approximate solution for which the non-diagonal elements of Γ are ignored. This solution is associated with one particular root q_j of the Booker quartic. It is [1]

$$f_j = \exp(-ik \int^z q_j dz + k \int^z \Gamma_{jj} dz) \quad (8)$$

and the corresponding field components [in Budden's notation] are

$$(E_x, E_y, H_x, H_y) = (A_j F_j)^{-1/2} (a_3 q_j + a_4, -A_j, q_j A_j, a_5 q_j + a_6) \\ \times \exp(-ik \int^z q_j dz + k \int^z \Gamma_{jj} dz) \quad (9)$$

where

$$\begin{aligned} a_1 &= -(T_{11} + T_{44}) & a_4 &= T_{14} T_{42} - T_{12} T_{44} \\ a_2 &= T_{11} T_{44} - T_{14} T_{41} & a_5 &= T_{42} \end{aligned} \quad (10)$$

$$a_3 = T_{12} \quad a_6 = T_{41} T_{12} - T_{11} T_{42}$$

$$A_j = q_j^2 + a_1 q_j + a_2 \quad (12)$$

$$F_j = 2q_j A_j + (q_j^2 - T_{32})(2q_j + a_1) - (a_3 b_5 + b_3 a_5) \quad (13)$$

$$\begin{aligned}
2\Gamma_{jj} = & (A_j F_j)^{-1} \{ q_j^2 (a_3' b_5' - a_3' b_5 + a_5' b_3' - a_5' b_3) \\
& + a_4' b_6' - a_4' b_6 + a_6' b_4' - a_6' b_4 + q_j (a_3' b_6' - a_3' b_6 + a_4' b_5' - a_4' b_5 + a_5' b_4' \\
& - a_5' b_4 + a_6' b_3' - a_6' b_3) \}
\end{aligned} \tag{14}$$

In these equations the T_{ij} 's are the elements of the T matrix given by Budden p 389.

The essence of the program documented in this report is the implementation of equation (9) for altitudes exceeding a height termed TOPHT. The mode extracted from the magneto-ionic set is the least attenuated outgoing wave. Full-wave Runge-Kutta integrations are used to calculate the rf field components up to TOPHT. The full-wave solutions at TOPHT are then matched to the corresponding WKB components and the fields carried to higher altitudes via equation (9).

III. EXCITATION FACTORS AND MODE SUMS

Available as output from the present program are excitation factors for sub-ionospheric electric point dipole excitation of electric and magnetic modal fields. They are defined as follows:

$$\text{EXC}(i,j) = \begin{matrix} & \begin{matrix} i \backslash j \rightarrow \\ \downarrow \end{matrix} & \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{vmatrix} A_1 & -A_2 & A_1 \\ -A_3 & A_4 & -A_3 \\ -A_1 & A_2 & -A_1 \end{vmatrix} \end{matrix} \quad (15)$$

$$\text{MEXC}(i,j) = \begin{vmatrix} 1 & 2 & 3 \\ -A_2 & A_1 & -A_2 \\ A_4 & -A_3 & A_4 \\ A_2 & -A_1 & A_2 \end{vmatrix} \quad (16)$$

where

$$\begin{aligned} A_1 &= \frac{S^{5/2} (1 - \perp R_{\perp \perp} \bar{R}_{\perp})}{(dF/d\theta) \perp R_{\perp}}; & A_2 &= \frac{S^{3/2} \perp R_{\perp}}{(dF/d\theta)} \\ A_3 &= \frac{S^{3/2} \perp R_{\perp}}{(dF/d\theta)}; & A_4 &= \frac{S^{1/2} (1 - \perp R_{\perp \perp} \bar{R}_{\perp})}{(dF/d\theta) \perp \bar{R}_{\perp}} \end{aligned} \quad (17)$$

In these equations F is the modal function

$$F = (1 - R_{11} R_{11}) (1 - R_{11} R_{11}) - R_{11} R_{11} R_{11} R_{11} \quad (18)$$

and $dF/d\theta$ its derivative with respect to the plane wave angle θ . R and $\bar{R}$ are plane wave reflection coefficients of the ionosphere and ground respectively referenced to level d . Consistent with usual notation, the first subscript refers to the polarization (1 for vertical and 1 for horizontal) of the incident wave, and the second subscript applies to the polarization of the reflected wave.

For the purpose of defining field components and mode sums an x, y, z Cartesian coordinate system is assumed with positive z directed vertically upwards into the ionosphere and x measured horizontally, x - z being the plane of incidence. Correspondence between the i, j indices (see equations 15 and 16) and the x, y, z coordinate system is:

$$\begin{aligned} i = j &= 1 \rightarrow z \\ i = j &= 2 \rightarrow y \\ i = j &= 3 \rightarrow x \end{aligned} \quad (19)$$

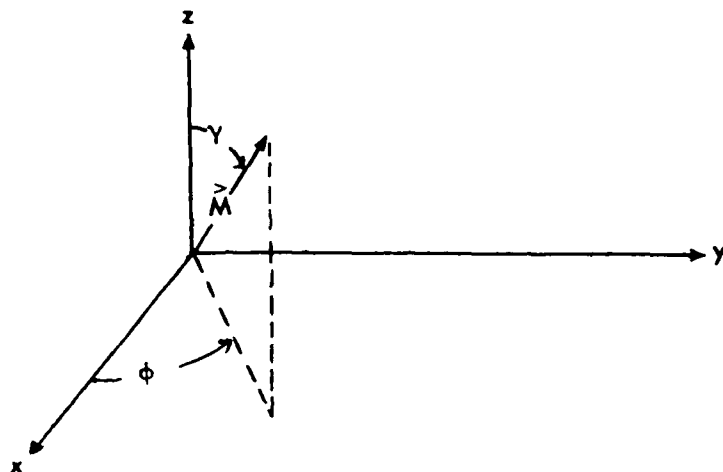
In terms of the excitation factors ($EXC(i, j)$) the adiabatic (or WKB) mode sums for the total electric field component E_j may be written as

$$\begin{aligned} E_j(x, 0, z_R) = & \frac{Q_e}{[\sin(x/a)]^{1/2}} \sum_n \{ (EXC(1, j))^T EXC(1, j)^R \}_n^{1/2} \cos(\gamma) e_{1n}^T(z_T) \\ & + (EXC(2, j))^T EXC(2, j)^R \}_n^{1/2} \sin(\gamma) \sin(\phi) e_{2n}^T(z_T) \\ & + (EXC(3, j))^T EXC(3, j)^R \}_n^{1/2} \sin(\gamma) \cos(\phi) e_{3n}^T(z_T) \} \\ & e_{jn}^R(z_R) e^{-ik(Sn-1)x} \end{aligned} \quad (20)$$

where the subscript n denotes the mode index, a the earth's radius, k the free space wave number and S the sine of the ground eigenangle. The transmitter is at $(0, 0, z_T)$ and the receiver is at $(x, 0, z_R)$. The components of the electric field height gain are denoted by the e_j 's and the superscripts T and R signify that the quantities are to be evaluated for the transmitter or receiver regions respectively. With the frequency f in kHz, the radiated power P in kW and

$$Q_e = 6.803 \times 10^2 (f_{\text{kHz}} P_{\text{kW}})^{1/2} \quad (21)$$

the total field component, E_j , is in units of $\mu\text{V/m}$. The angles γ and ϕ measure the orientation of the transmitting dipole relative to the x , y , z coordinate system as shown



In similar fashion the mode sums for the components of the total magnetic induction, B_j , may be written as follows

$$B_j(x, 0, z_R) = \frac{Q_b}{[\sin(x/a)]^{1/2}} \sum_n \{ (\text{MEXC}(1, j)^T \text{MEXC}(1, j)^R)^{1/2} \cos \gamma e_{1n}^T(z_T) \\ + (\text{MEXC}(2, j)^T \text{MEXC}(2, j)^R)^{1/2} \sin \gamma \sin \phi e_{2n}^T(z_T) + (\text{MEXC}(3, j)^T \\ \text{MEXC}(3, j)^R)^{1/2} \sin \gamma \sin \phi e_{3n}^T(z_T) \} h_{jn}^R(z_R) e^{-ik(S_n - 1)x} \quad (22)$$

The components of the magnetic field height gain are denoted by the h_j 's. With

$$Q_b = 7.176 \times 10^{-2} (f_{\text{kHz}} P_{\text{kW}})^{1/2} \quad (23)$$

the total field component, B_j , is in units of γ ($1\gamma = 10^{-5} \text{ gauss} = 10^{-9} \text{ W/m}^2$).

Although the transmitter altitude z_T must be in the isotropic portion of the guide beneath the ionosphere, the receiver altitude z_R in equation (20) or (22) can be within the earth-ionosphere waveguide or within the ionosphere itself. The program can, then, be used to generate required inputs for studies such as satellite reception of ground based VLF transmission using waveguide concepts [4]. Apart from impedance considerations the program can be used in conjunction with general magneto-ionic reciprocity theory [9] to estimate fields radiated into the earth-ionosphere waveguide by satellite-borne sources. However, more direct means are available for making that type of calculation [3] and it is recommended that the WKB method employed here be implemented directly into the program of reference [3].

In past work [2] the electric and magnetic field modal height gains have been normalized by equating the y component of the magnetic field to unity at the ground. We will denote the electric and magnetic field components so normalized by $\bar{e}_i$ and $\bar{h}_i$. These quantities are printed out in the current program under the listing "HEIGHT GAINS WITH HY NORMALIZED TO UNITY AT THE GROUND." The height gains e_i and h_i entering equations (20) and (22) are related to $\bar{e}_i$ and $\bar{h}_i$ as follows:

$$e_1 = (1 + \bar{R}_1) \bar{e}_1 / \bar{e}_1(d)$$

$$e_2 = (1 + \bar{R}_1) \bar{e}_2 / \bar{e}_2(d)$$

$$e_3 = (1 + \bar{R}_1) \bar{e}_3 / \bar{e}_1(d)$$

; barred quantities are height gain components normalized with

$$\bar{h}_2 = \bar{h}_y = 1 \text{ at the ground.} \quad (24)$$

$$h_1 = (1 + \bar{R}_1) \bar{h}_1 / \bar{e}_2(d)$$

$$h_2 = (1 + \bar{R}_1) \bar{h}_2 / \bar{e}_1(d)$$

$$h_3 = (1 + \bar{R}_1) \bar{h}_3 / \bar{e}_2(d)$$

The height gains e_i and h_i are calculated and printed when excitation factor data are requested (ie, when IEXC.NE.0). They are printed out under the label "HEIGHT GAINS NORMALIZED FOR USE WITH WKB MODE SUMMING FORMULAS."

It is these unbarred height gains which must be used in conjunction with the excitation factors defined by equations (15) and (16) in the mode summing formulas (20) and (22). The level d in equation (24) is the level where the mode equation is evaluated and is equivalent in the program to LWSTHT.

IV. PROGRAM DESCRIPTION

This section describes the subroutines in the WKBHTG program listed in the appendix. Many of the subroutines are only slight modifications of those given in reference [2]. The subroutines WKBVAR, QGAMMA and DDKXMT have been added for the purpose of implementing the WKB formalism. Principal output of the program is height gain functions. Height gains with two different normalizations are available. The first, which is always calculated, printed and plotted, is printed under the heading "HEIGHT GAINS NORMALIZED WITH HY EQUAL TO UNITY AT THE GROUND." This normalization is consistent with past works [2,3,5]. The second set of height gains is calculated and printed only when excitation factor data are requested (ie, when IEXC .NE. 0). This second set of height gains is printed out under the heading "HEIGHT GAINS NORMALIZED FOR USE WITH WKB MODE SUMMING FORMULAS," and defined by equations (24) of section III. Also printed out when IEXC .NE. 0 are the excitation factors defined by equations (15), (16) and (17) of section III. The second set of height gains must be used in conjunction with the excitation factors when implementing the WKB mode summing formulas (20) and (22). A chart showing the essential structure of the WKB height gain program follows on pages 19 through 22.

SUBROUTINE MAIN

MAIN calls for the input of ionic species data in XINPUT and for computation of height gain field components via WAVFLD. After executing WAVFLD, height gains are available in the arrays EX, EY, EZ, HX, HY, and HZ at DELHT intervals between the ground and WKBHT. If IEXC .EQ. 0, the height gains available in the arrays are those associated with HY normalized to unity at the ground. Otherwise the height gains available in the arrays are those renormalized according to equations (24).

SUBROUTINE XINPUT (ISTART, ISTOP)

XINPUT controls read-in of input parameters via NAMELIST statements and ionic species densities and collision frequencies as a function of altitude. Common areas are set up as required. ISTART is set to 1 before the first call to XINPUT and to 0 upon subsequent calls. ISTART = 1 implies all necessary data are to be read in and ISTART = 0 signals that previously read data are to be updated, with all unspecified parameters remaining unchanged. If a value ISTOP = 0 is returned by XINPUT, then more input data are specified in the data deck for subsequent calls to WAVFLD, whereas if a value ISTOP = 1 is returned, the data read were the last data in the data deck, so that XINPUT should not be called again.

The data deck is divided into several parts, each of which is marked by an identifier card with the identifier DATUMFOL, SPECIE, PROFILE, COLLFREQ, QUIT or STOP. Each of these identifiers is described in the following section.

SUBROUTINE WAVFLD (EX, EY, EZ, HX, HY, HZ)

WAVFLD calls for Runge-Kutta integration of the field equations from TOPHT to LWSTHT at DELHT equally spaced increments and for combining the solutions at LWSTHT so that they satisfy the proper modal polarization condition. It performs the back substitution of normalizing values (saved as data in WFSTOR). It also calls for calculation of height gains between the ground and LWSTHT at DELHT increments via modified Hankel functions of order one-third as well as the extension of height gain functions from TOPHT to WKBHT via Budden's WKB formalism (these height gains are normalized with $HY = 1$ at the ground and are always printed out). If $IEXC.NE.0$ it also calls for calculation of the excitation factors defined in section III and renormalization of the height gains according to equations (24). Upon exiting, WAVFLD places the field strengths in the arrays EX, EY, EZ, HX, HY, HZ at DELHT intervals between the ground and WKBHT. If $IEXC.EQ.0$, the height gains available in the arrays are those associated with HY normalized to unity at the ground. Otherwise the height gains in the arrays are those renormalized according to equations (24).

SUBROUTINE ITRATE

ITRATE is the control routine for finding an angle, theta, which satisfies the modal equation. It calls for integration through the ionosphere (WFINTG), and for R , $\bar{R}$ and modal function evaluations a variable number of times depending upon whether iteration of the input angle is desired (ie, ITR.NE.0) and whether excitation factors are desired (ie, IEXC.NE.0).

SUBROUTINE WFINTG (TOPHT, LWSTHT, DELHT, IFLAG)

WFINTG performs the Runge-Kutta integration of the two solution vectors in P down through the ionosphere. Numerical solutions are obtained at all height increments of DELHT between TOPHT and LWSTHT. Accuracy is maintained by continually adjusting the step size used in the numerical integration. The current step size (call it h) is used to obtain an estimate of P , and then a better estimate is obtained by using two integrations with step size $h/2$. If the two solutions agree within an error of PRECSN (an input parameter normally set to 3.D-5), the better estimate is accepted. The step size is automatically decreased to $h/2$ if the two estimates differ by more than PRECSN, and the integration is repeated. If the error is significantly greater than PRECSN, a step size $h/2$ is used. If the error is significantly less than PRECSN, the step size $2h$ is used if it also yields an error less than PRECSN. These tests thus form an automatic step-size correction. IFLAG is an internally controlled flag. If IFLAG = 0 the integration is performed for THETA only, if IFLAG = 1 the integration is performed for THETA and THETA-DTHETA where DTHETA is internally set to (5.D-2, 1.D-2).

ENTRY INIT T

INIT T is an entry in subroutine TMTRX. Sets up height independent values to be used in T matrix calculation. These include the internally set flag ISO (ISO = 1 for isotropic calculation, 0 otherwise). Also set are the angular radio frequency, the wave number, direction cosines of the geomagnetic field, the complex sine and cosine of THETA and THETA-DTHETA.

SUBROUTINE TMTRX(HT)

TMTRX computes the value of the T matrix at a specific height HT. The T matrix depends upon input ionospheric parameters (species density, collision frequency, angle of propagation, magnetic field, etc). The susceptibility

matrix, M, for each species in the ionosphere is computed, the effect of earth curvature is included and the T matrix is computed from the susceptibility matrix elements. The equations used to evaluate the M and T are given in Clemmow and Heading [8] and by Budden [1].

SUBROUTINE WFDENS

WFDENS (HT, EN, COLL) computes the species density (returned in EN) and collision frequencies (returned in COLL) at height HT for up to five species in the ionosphere. EN and COLL are determined from corresponding profiles in the common field WFPF. LHT and MHT are integer values which indicate which profile values are to be interpolated to find values at the height HT. The EN (or COLL) values are given by logarithmic interpolation of the profile values at heights ENHT(LHT + 1) and ENHT(LHT) or (COLLHT(MHT + 1) and COLLHT(MHT),).

SUBROUTINE WF INIT(P)

WF INIT computes the two starting field vectors in P at TOPHT subject to the condition of outgoing wave. This is done by making use of Booker quartic solutions for a homogeneous anisotropic medium.

SUBROUTINE QUARTC (FOUR B3, SIX B2, FOURB1, B0,Q)

QUARTC computes the four roots of the polynomial $Q^4 + \text{FOURB3} \cdot Q^3 + \text{SIXB2} \cdot Q^2 + \text{FOURB1} \cdot Q + B0$ in closed form [10]. Up to ten applications of Newton's iteration are then performed to improve the accuracy of the roots, if necessary.

SUBROUTINE PDERIV(P,DPDH)

PDERIV computes the height derivatives of the two field vectors in P according to Clemmow and Heading [8]. The derivative is returned in DPDH.

ENTRY TI MTRX

This is an entry in TMTRX which calculates T matrix elements for the incremental plane wave angle THETA-DTHETA.

SUBROUTINE XFER (A,B,N)

Transfers the N element array A into B.

ENTRY WF STOR

WF STOR is an entry in WFSCAL where certain values obtained during integration through the ionosphere are saved for later use. The solution matrix P, the height for which P is a solution and a height integer index are saved along with orthogonalization and normalization values OSUM, APROD and BPROD. In addition, values of the susceptibility matrix elements M31, M32 and M33, which are needed to compute the EZ component of the electric field, are saved at each height.

SUBROUTINE WF STEP (P,DPDH, HT, DELHT, IFLAG)

WF STEP numerically advances the solution matrix P, using the derivative DPDH, from HT to HT-DELHT by the Runge-Kutta method. IFLAG, set internally, controls the calculations at intermediate points between HT and HT-DELHT at which evaluations are required for comparison of the second and fourth order Runge-Kutta integrations.

SUBROUTINE WF SCAL (PP, IFLAG)

WF SCAL normalizes and orthogonalizes the solution vector PP according to the formulas of reference [2]. This scaling must later be removed to yield correct unscaled solutions. Control for calculating the quantities needed for removal of the scaling is the internally set IFLAG. The quantities OSUM, APROD and BPROD needed in the backward substitution (or equivalently for removing the scalings) are calculated for IFLAG = 0.

ENTRY FFCT (PP, C, S, F)

This is an entry in WF BNDY which evaluates the mode function:

$$F = (1 - R_{11} \bar{R}_1) (1 - R_{11} \bar{R}_1) - R_{11} R_{11} \bar{R}_1 \bar{R}_1$$

The two field solution vectors given in PP along with cosine (C) and sine (S) of the plane wave incident angle THETA are used in computing the reflection coefficients by plane wave decomposition at LWSTHT.

SUBROUTINE RMTRX (P, COSN, R)

RMTRX computes the 2 x 2 ionospheric reflection coefficient matrix (returned in R) from the two solution vectors given in P. The two solutions at LWSTHT are transformed into upgoing and downgoing components and the ratio of these components determines the reflection coefficients.

SUBROUTINE RBARS(C,S,RBAR11, RBAR22, EY, HY)

RBARS calculates the plane wave reflection coefficients (returned in RBAR11 and RBAR22) looking towards the ground from LWSTHT. Evaluations are in terms of modified Hankel functions of order 1/3. The cosine (C) and sine (S) of the plane wave angle THETA are used in the R determination. Note that $RBAR11 \neq \bar{R}_1$ and $RBAR22 \neq \bar{R}_1$.

SUBROUTINE MDHKNL (Z, H1, H2, H1PRME, H2PRME)

MDHKNL calculates for argument Z two independent solutions (H1 and H2) and their derivatives (H1PRME, H2PRME) of Stokes' equation by methods described in reference [11].

SUBROUTINE WF BNDY(B)

WF BNDY computes the coefficients B_1, B_2 (in B) which are used to linearly combine the two solutions in P to form the unique solution which satisfies the boundary condition on the modal polarization at LWSTHT and the normalization condition $HY = 1$ at $Z = 0$. The polarization condition is:

$$EY/HY = \frac{1 + \bar{R}_1}{1 + \bar{R}_1} \frac{(1 - \bar{R}_1 \bar{R}_1)}{\bar{R}_1 \bar{R}_1} = \frac{1 + \bar{R}_1}{1 + \bar{R}_1} \frac{\bar{R}_1 \bar{R}_1}{1 - \bar{R}_1 \bar{R}_1}$$

where all reflection coefficients are referenced to LWSTHT.

ENTRY HT GAIN (ALTT, EX, EY, EZ, HX, HY, HZ)

HT GAIN is an entry in RBARS where the field height gains at heights ALTT between the ground and LWSTHT are calculated at DELHT intervals using modified Hankel functions of order 1/3.

ENTRY WF LOAD

WF LOAD is an entry in WFSCAL which transfers normalizing and orthogonalizing values saved in WFSTOR for the purpose of unscaling the two solutions in P starting from LWSTHT and proceeding to TOPHT at DELHT intervals.

SUBROUTINE WKBVAR (EX, EY, EZ, HX, HY, HZ)

WKBVAR extends calculation of the field equations from TOPHT to WKBHT by means of the formulas in section II. Integration of the phase factors q_j and r_{jj} (j index for least attenuated outgoing mode) is performed by a Simpson rule routine which maintains precision by adjustment of the step size much like the Runge-Kutta step size adjustment in WFINTG.

ENTRY INITDT

This is an entry in DDKXMT where all height independent quantities are initialized before extending field calculations from TOPHT to WKBHT via the WKB method.

SUBROUTINE Q GAMMA (HT, DELHT, TOPHT, Q, GAMMA)

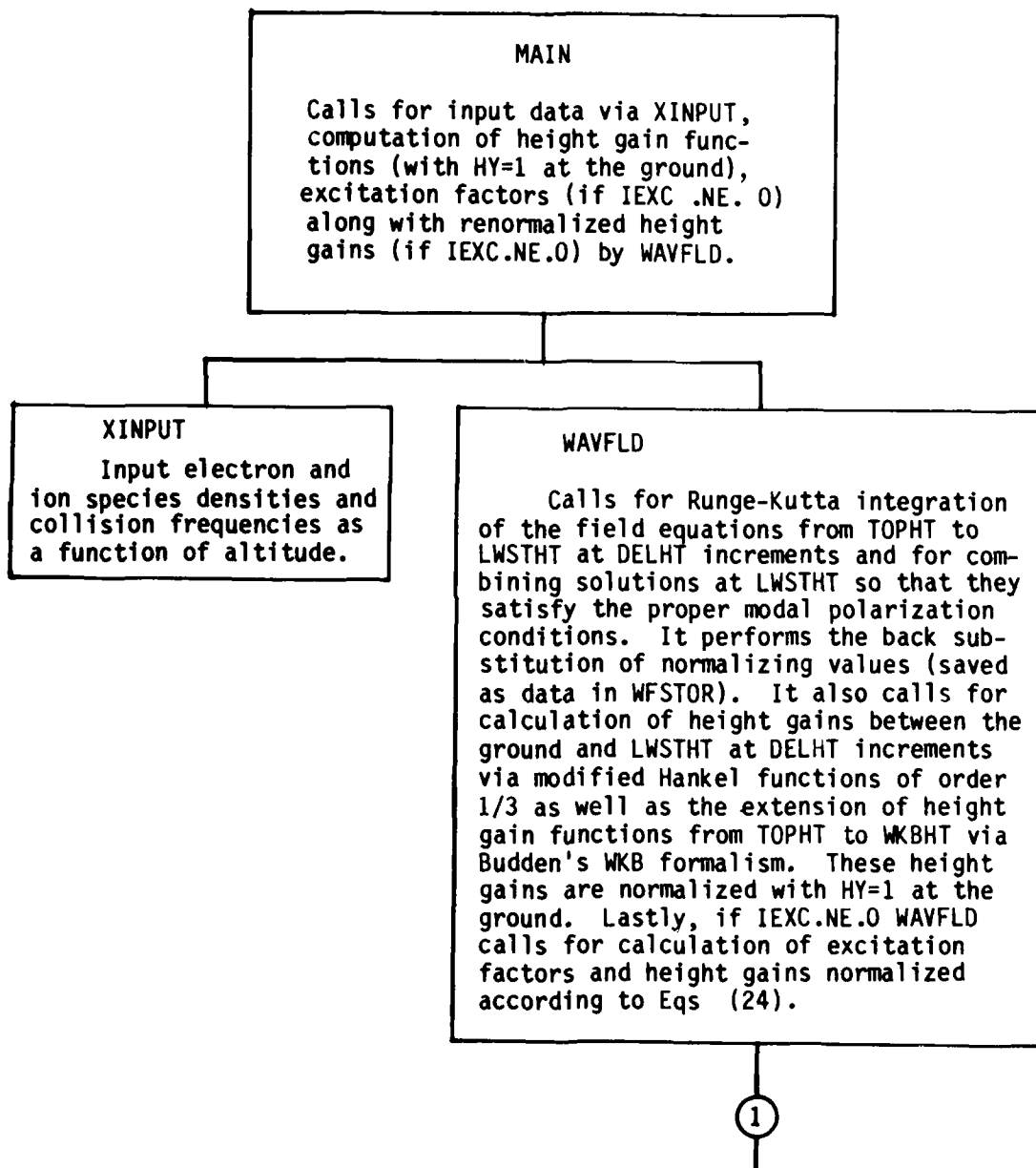
Q GAMMA determines the Booker quartic solution for the least attenuated outgoing magneto-ionic component at TOPHT and computes the a_i 's, b_i 's, a_i 's, b_i 's, A_i , F_i and r_{ii} according to formulas of section II. Full-wave solutions are matched at TOPHT to the WKB solutions. At other heights and up to WKBHT coefficients of the exponentials in equation (9) of section II are calculated along with coefficients for HZ and EZ.

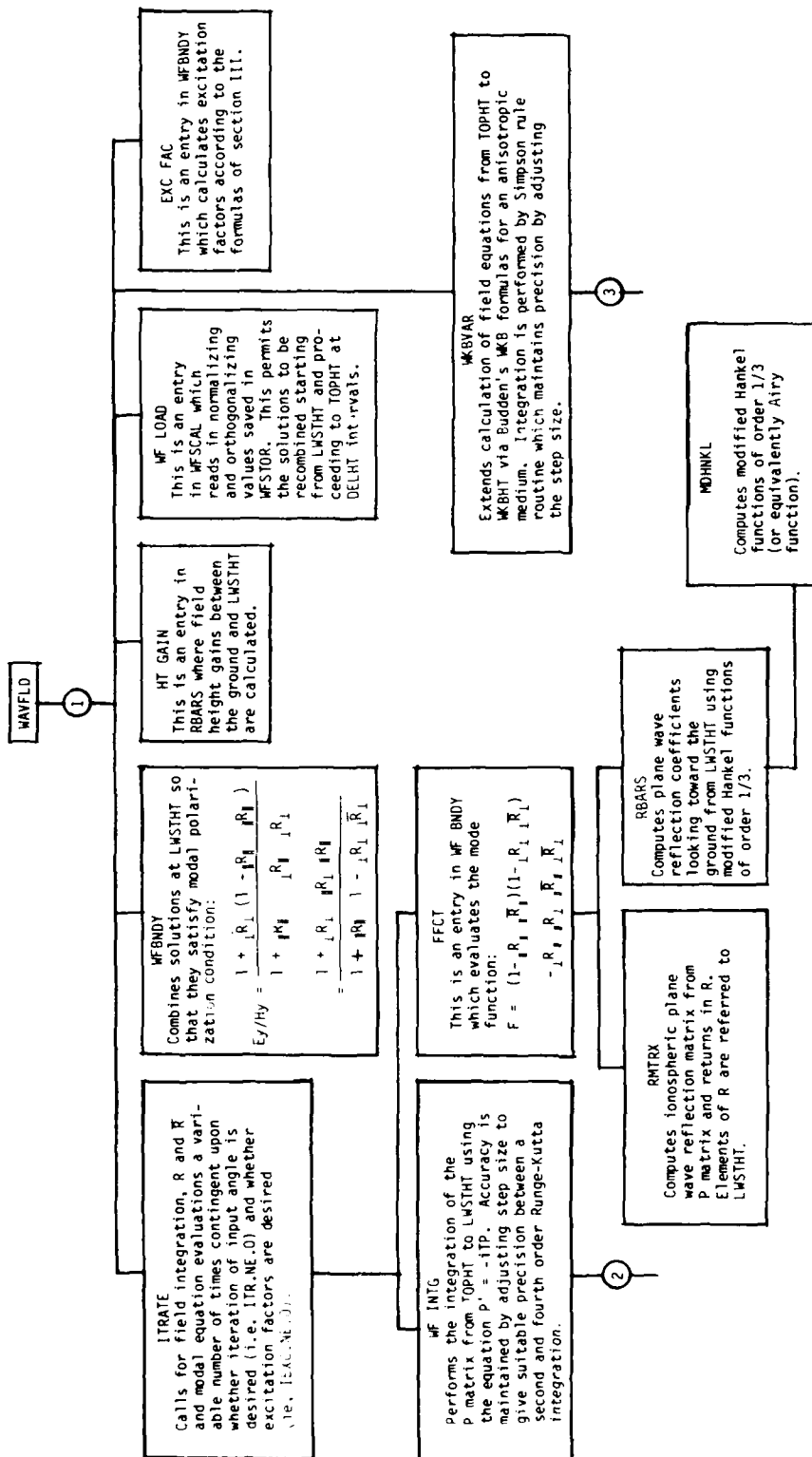
SUBROUTINE DDKXMT

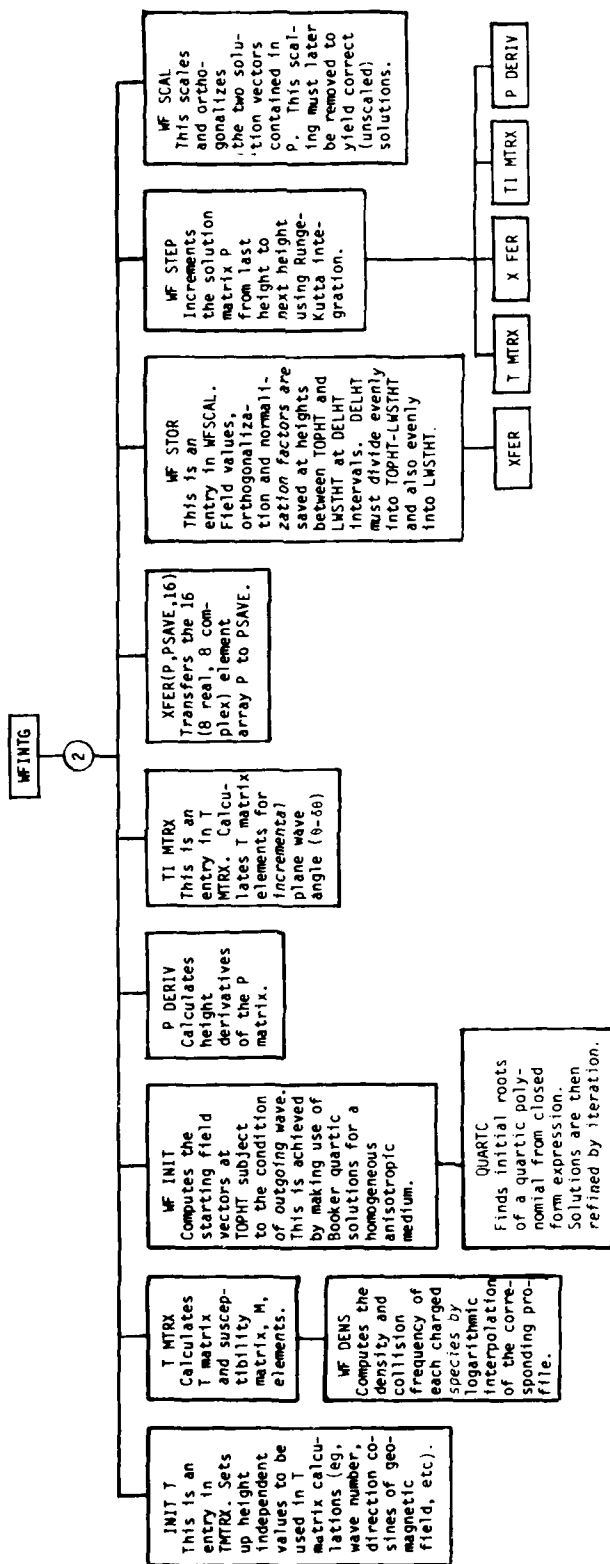
DDKXMT calculates susceptibility matrix elements, M, the T matrix elements and their derivatives with respect to height in the height range $TOPHT \leq Z \leq WKBHT$.

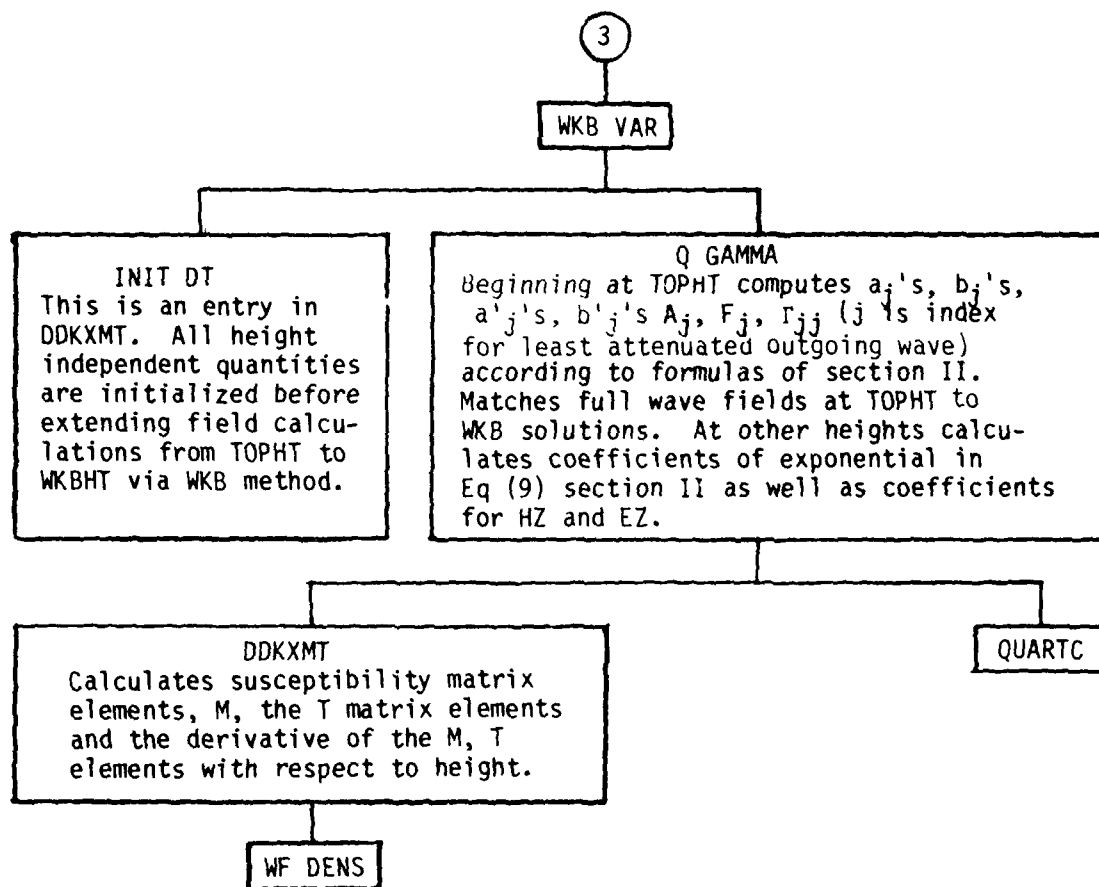
ENTRY EXCFAC(S)

EXCFAC is an entry in WFBNDY where the excitation factors for the sine (S) of the plane wave eigenangle THETA are calculated according to the formulas of section III.









V. SAMPLE INPUT AND OUTPUT

A. INPUT

Altitude independent parameters, species densities and collision frequencies as a function of altitude are supplied via an input data deck on a standard input unit. Read-in occurs in the subroutine XINPUT. The data deck is divided into several parts, each of which is marked by control cards DATUMFOL, SPECIE, PROFILE, COLLFREQ, QUIT, or STOP. Each of these control cards is described below:

1) DATUMFOL

DATUMFOL - is a control card signifying that input for the namelist DATUM follows.

&DATUM - initiates reading of altitude independent input data in namelist input format. These data are:

THETA - complex angle of incidence in degrees as measured at H. THETA must be an eigenangle if ITR = 0.

FREQ - frequency in kHz.

IDBG - integer flag controlling auxiliary printout. If IDBG.GE.1, the R matrix elements, $\bar{R}_{\parallel}$ and $\bar{R}_{\perp}$, are printed. If IDBG.GE.2 the solution vectors (P) at TOPHT and LWSTHT are printed along with the Booker quartic solution at TOPHT and the combining coefficients (B(1), B(2)) of the two independent solution vectors contained in P at LWSTHT.

TOPHT - starting height for full-wave integration (km).

LWSTHT - lowest height for full-wave integration (km).
Also equivalent to level D where mode equation is
evaluated.

WKBHT - altitude in km to which height gains are extended
beyond TOPHT via WKB formulas.

DELHT - height increment in km at which height gains are
printed.

PRECSN - accuracy to be maintained locally in the numerical
integrations. Usually taken to be the default
value of $3.0E-5$.

AZIM - azimuth of propagation path in degrees, measured
clockwise from geomagnetic north.

CODIP - codip of geomagnetic field in degrees

MAGFLD - geomagnetic field strength in webers/square meter

COEFNU(5)
- coefficient and exponent of exponential form of
EXPNU(5) collision frequency (if not specified by profile).
Up to five values may be specified, one for each
species.

ALPHA - earth curvature coefficient in inverse km.
Default is $3.14E-4$.

SIGMA - ground conductivity in siemens/meter. Default
value is the seawater value of 4.64.

EPSLON - ground permittivity in farads/meter. Default
value is $7.172015D-10$. This corresponds to a

dielectric constant of 81 for seawater.

ISO - flag signaling whether calculations are to be performed for isotropic or anisotropic ionosphere. ISO.NE.0 signals isotropy.

ITR - integer flag which calls for modal equation iteration when ITR .NE. 0.

H - altitude in km at which modified refractive index is unity. Eigenangles are referenced to this altitude.

&END - signifies end of the DATUM namelist input.

ii) SPECIE

SPECIE - is a control card signifying that input for namelist SPECIE follows.

&SPECIE - initiates reading of altitude independent species data. These data are:

NRSPEC - number (integer) of species in the ionosphere. Can take on values up to 5. Default value is 1.

CHARGE(5) - sign of charge of each species in proton units. For an electron, the CHARGE is -1.0. Default values are -1.0, 1.0, -1.0, 1.0, -1.0).

RAT10M(5) - mass of each species relative to mass of an electron. Default values are (1.0, 5.8D4, 5.8D4, 5.8D4, 5.8D4).

&END - signifies the end of the SPECIE namelist input.

iii) PROFILE

PROFILE - is a control card initiating reading of the ionospheric profile cards. The control card PROFILE is followed by an alpha-numeric card which is used to identify the profile. The profile is input starting at the top of the ionosphere. The cards must be input in descending order by height. The profile cards contain the height in kilometers and the species densities in particles per cubic centimeter. A maximum of five species can be specified. In the special case of three species, only two are specified on the card. The first is assumed to be electrons and the second is positive ions. The third species, negative ions, is calculated by subtracting the electron density from the positive ion density. All three species are listed on the computer printout. If the value of any species density is less than or equal to zero, it is set in the program to $1.0E-40$. The heights are punched in the form XXX.XX with the decimal point in column 5, and the densities are punched in the form X.XXD±XX with the decimal points in column 15, 25, etc. All species data must be specified except for the special case discussed above. The end of the profile is indicated by a dummy height of 999.99.

iv) COLLFREQ

COLLFREQ - is a control card initiating reading of the collision frequency profile. This allows using non-exponential collision frequencies. A strictly exponential collision frequency may be specified in namelist input by the variables COEFNU and EXPNU.

If a profile deck is used it overrides COEFNU and EXPNU. Collision frequencies for all species must be input. The card preparation is just as above with species density values replaced by collision frequency values (in collisions/s) on the cards.

v) QUIT

QUIT - is a card control which indicates the end of input data for a call to WAVFLD. After calling WAVFLD, XINPUT can be read and used as data for a subsequent call to WAVFLD. This allows several runs to be made with one input deck. Note that only those data which are changed need be specified after the card QUIT.

vi) STOP

STOP - control card which indicates that there are no more input data and that the run is to be terminated after the next call to WAVFLD. Note that if QUIT is encountered ISTOP is set to zero, but if STOP is encountered ISTOP is set to one.

A schematic of an input deck is shown on page 30 , and an actual sample input is shown on pages 31 and 32.

B. OUTPUT

The output corresponding to the input is shown on pages 33 through 51. The output corresponds to the flag settings ITR .EQ. 1 and IEXC .EQ. 1.

First come NAMELIST and profile printouts followed by output, which gives the number of Runge-Kutta integration steps used in WAVFLD during the course of integrating from TOPHT to LWSTHT. This is followed by the modal equation values for the input eigenangle THETA shown on page 35. Since ITR.EQ.1 an

iteration is performed and the iterated value of THETA is shown as NEW THETA on the output. The process of integration from TOPHT to LWSTHT is repeated for this NEW THETA. Again the number of integration steps and modal equation value is shown. The iteration stops because the change in the absolute value of the real part of the eigenangle is $.LE. 5.D-2$ and the change in the absolute value of the imaginary part is $.LE. 5.D-3$.

The first set of field strengths at 50.0 km (LWSTHT) is calculated using ground boundary conditions and modified Hankel functions of order one-third to extend the calculations to 50. km. The second set is calculated from the Runge-Kutta field integration. Together the two sets of field strengths give an alternative check of how well the modal condition is satisfied. This alternative check is particularly useful when ITR $.NE. 0$ and eigenangles are input from another program such as the waveguide program of reference [12]. It has been our experience that a good eigenangle will cause the two sets of field values to agree to better than one percent.

Since IEXC $.EQ. 1$ the excitation factors $EXC(I,J)$ and $MFXC(I,J)$ defined in section III are calculated and printed. The rows correspond respectively to electric dipole excitation produced by a vertical (V), horizontal broadside (HB), and horizontal end-on (HE) oriented dipole. The columns are for excitation of the EZ (or HZ), EY (or HY) and EX (or HX) components. That is to say $EXC(I,J)$ and $MEXC(I,J)$ are to be combined with height gain components according to the mode summing formulas of section III.

Following the excitation factors come the height gains calculated at DELHT intervals up to WKBHT. They are normalized with $HY = 1$ at the ground. This is consistent with past work [2,5]. The magnitudes of these height gains are also plotted and the plot is shown on page 52. The rapid change in the slope of the EY, EZ, and HZ plots is quite surprising. An immediate reaction might be that this is where the full-wave and WKB fields are matched. However, though unexplained, the break (~ 94 km) is much too low (TOPHT = 120 km) and totally unrelated to field matching at TOPHT. Consistency of the full-wave calculations, as indicated by the modal function evaluation and the continuity of the field components at LWSTHT along with the fact that, as indicated in the following section, the fullwave and WKB methods yield nearly identical results for fields above TOPHT, points towards the accuracy of the full-wave methods. It is clear that very little of the EY, EZ and HZ

components penetrate the ionosphere for the first order mode used for the sample input. Penetration is greater the higher the order of the mode. Finally, the large value of the relative fields within the guide is peculiar to the low conductivity (10^{-5} S/M) indicated in the sample input. Because IEXC .ME. 0 a second set of height gains normalized according to Equations (24) are calculated. These are the height gains that are to be used in conjunction with the excitation factors EXC(I,J) and MEXC(I,J) in the WKB mode summing formulas (20) and (22).

EXAMPLE OF INPUT DECK

DATUMFØL

&DATUM
(input data)
&END

SPECIE

&SPECIE
(input specie data)
>END

PRØFILE

(profile cards for each specie)

999.99

CØLLFREQ

(coll. frequency cards for each specie)

999.99

QUIT (end of input for this run)

DATUMFØL

&DATUM
(changes in input data)
&END

PRØFILE

(specify entire new profile deck)

999.99

QUIT (end of input for this run)

DATUMFØL

&DATUM
(changes in input data)
&END

STØP (end of data deck)

SAMPLE INPUT

1	DATUMFOL	
2	&DATUM	
3	FREQ = 17.8,	
4	CCFNU = .1816012, EXPNU = -.15D-3,	
5	AZIM = 87.801, CODIP = 6.593, MAGFLD = .5222D-4,	
6	SIGMA = 1.D-5, EPSLON = .442717D-10,	
7	ALPHA = 3.14D-4,	
8	PRECSN = 3.D-5,	
9	THETA = (89.89694661, -4.96306701),	
10	ITR = 1,	
11	IEXC = 1,	
12	TOPHT = 120., LWSTHT = 50., MKBHT = 500., DELHT = 5.,	
13	&END	
14	PROFILE 1	
15	GLOBAL NIGHTTIME IONOSPHERE(SAT. NIGHT ABOVE 99, H' = 87 BELOW 99)	
16	500.00	2.00+005
17	400.00	4.00+005
18	370.00	4.30+005
19	350.00	4.40+005
20	330.00	4.30+005
21	250.00	1.00+005
22	225.00	5.00+003
23	220.00	3.20+003
24	210.00	1.68+003
25	200.00	1.00+003
26	190.00	6.50+002
27	180.00	4.60+002
28	170.00	3.45+002
29	160.00	2.82+002
30	155.00	2.60+002
31	150.00	2.50+002
32	145.00	2.55+002
33	140.00	2.80+002
34	130.00	3.70+002
35	120.00	5.80+002
36	112.00	1.10+003
37	110.00	1.30+003
38	106.00	1.70+003
39	104.00	1.90+003
40	102.00	1.98+003
41	100.00	2.00+003
42	99.00	1.95+003
43	.00	1.83-012
44	999.99	
45	COLLFREQ	
46	500.00	2.00+002
47	400.00	3.80+002
48	370.00	3.90+002
49	350.00	3.80+002
50	330.00	3.50+002
51	300.00	2.80+002
52	250.00	1.05+002
53	225.00	3.50+001
54	220.00	3.00+001

SAMPLE INPUT

55	210.00	3.30+001
56	200.00	4.50+001
57	150.00	1.60+003
58	120.00	1.00+004
59	104.00	3.00+004
60	0.00	1.82+011
61	999.99	
62	STOP	

SAMPLE OUTPUT

```

DATUMFOL
$DATUM
THETA = (.898969466100000000+002,-.496306700999999999+001).FREQ = .178000000000000000+002.IDBG =
TOPHT = .120000000000000000+003.LWSTHT = .500000000000000000+002.WKBHT = .500000000000000000+003.DELHT = .500000000000000000+001.
PRECEN = .300000000000000000-004.AZIM = .878009999999999999+002.CODIP = .659300000000000000+001.MAGFLD = .522199999999999999-004.
COEFNU = .181600000000000000+012,.000000000000000000 ,.000000000000000000 ,.000000000000000000 ,.000000000000000000
EXPNU = -.150000000000000000-003,.000000000000000000 ,.000000000000000000 ,.000000000000000000 ,.000000000000000000
ALPHA = .314000000000000000-003.SIGMA = .100000000000000000-004.EPSLON = .442716999999999999-010.ISO =
IEXC = 1.IIR = 1.H = .000000000000000000
$SEND
PROFILE 1
GLOBAL NIGHTTIME IONOSPHERE(SAT. NIGHT ABOVE 99, H' = 87 BELOW 99)
500.00 2.00+005
400.00 4.00+005
370.00 4.30+005
350.00 4.40+005
330.00 4.30+005
250.00 1.00+005
225.00 5.00+003
220.00 3.20+003
210.00 1.68+003
200.00 1.00+003
190.00 8.50+002
180.00 4.60+002
170.00 3.45+002
160.00 2.82+002
155.00 2.60+002
150.00 2.50+002
145.00 2.55+002
140.00 2.80+002
130.00 3.70+002
120.00 5.80+002
112.00 1.10+003
110.00 1.30+003
108.00 1.70+003
104.00 1.90+003
102.00 1.98+003
100.00 2.00+003
99.00 1.95+003
.00 1.83-012
999.99
COLLFREQ
500.00 2.00+002
400.00 3.80+002
370.00 3.90+002
350.00 3.80+002
330.00 3.50+002
300.00 2.80+002
250.00 1.05+002
225.00 3.50+001
220.00 3.00+001
210.00 3.30+001
200.00 4.50+001
150.00 1.60+003

```

SAMPLE OUTPUT

1.00+004
3.00+004
1.82+011

120.00
104.00
.00
999.99
STOP

SAMPLE OUTPUT

199 INTEGRATION STEPS USED IN WAVFLD

MODAL EQN. VALUE = -.85624-003 -.47601-003
 NEW THETA = 89.89689024 -4.96334525
 199 INTEGRATION STEPS USED IN WAVFLD
 MODAL EQN. VALUE = -.22750-004 .59081-004

ALTERNATIVE CHECK OF HOW WELL BOUNDARY CONDITIONS ARE SATISFIED

FIELD STRENGTHS AT HT = 50.0000			
EX = -.1228028+000	-.7505839-001	EY =	.7157429+001
HX = -.9115202+000	-.1299195+000	HY =	-.1182348+001
			-.3547941+002
		EZ =	.1167723+001
		HZ =	.7178751+001
			-.4617074+001
			-.3561367+002
FIELD STRENGTHS AT HT = 50.0000			
EX = -.1227217+000	-.7493293-001	EY =	.7157429+001
HX = -.9115218+000	-.1299023+000	HY =	-.1182348+001
			-.3547941+002
		EZ =	.1167723+001
		HZ =	.7178751+001
			-.4617074+001
			-.3561367+002

SAMPLE OUTPUT

ELECTRIC DIPOLE XMTR-ELECTRIC DIPOLE RCVR-EXC(I,J)

	EZ MAG	EZ ANG	EY MAG	EY ANG	EX MAG	EX ANG
V	.101366-002	1.743	.758462-002	1.694	.101366-002	1.743
HB	.765577-002	1.699	.573130-001	1.650	.765577-002	1.699
HE	.101366-002	-1.398	.758462-002	-1.447	.101366-002	-1.398

ELECTRIC DIPOLE XMTR-MAGNETIC DIPOLE RCVR-MEXC(I,J)

	HZ MAG	HZ ANG	HY MAG	HY ANG	HX MAG	HX ANG
V	.758462-002	1.694	.101366-002	1.743	.758462-002	1.694
HB	.573130-001	1.650	.765577-002	1.699	.573130-001	1.650
HE	.758462-002	-1.447	.101366-002	-1.398	.758462-002	-1.447

HEIGHT GAINS WITH HY NORMALIZED TO UNITY AT THE GROUND

FIELD STRENGTHS AT HT = .0000					
EX =	-.2546609+000	-.1437555+000	EY =	-.3997266+000	-.4401592+000
HX =	-.1904790+001	-.4587942+000	HY =	.1000000+001	.0000000
EZ = -.1003753+001					
HZ = -.4012954+000					
EZ = -.4417487+000					
FIELD STRENGTHS AT HT = 5.0000					
EX =	-.2570230+000	-.1326362+000	EY =	.4536456+000	-.4012360+001
HX =	-.1931847+001	-.4576281+000	HY =	.7428811+000	.4767521+000
EZ = -.7445745+000					
HZ = .4547218+000					
EZ = -.4027489+001					
FIELD STRENGTHS AT HT = 10.0000					
EX =	-.2634507+000	-.1261878+000	EY =	.1311257+001	-.7664975+001
HX =	-.1987635+001	-.4625051+000	HY =	.5015237+000	.9628957+000
EZ = -.5019799+000					
HZ = .1314982+001					
EZ = -.9634059+000					
HZ = -.7693944+001					
FIELD STRENGTHS AT HT = 15.0000					
EX =	-.2712007+000	-.1228573+000	EY =	.2179711+001	-.1143259+002
HX =	-.2051695+001	-.4684154+000	HY =	.2687141+000	.1463508+001
EZ = -.2686855+000					
HZ = .2186107+001					
EZ = -.1462072+001					
HZ = -.1147584+002					
FIELD STRENGTHS AT HT = 20.0000					
EX =	-.2774484+000	-.1212240+000	EY =	.3056212+001	-.1531096+002
HX =	-.2102748+001	-.4702764+000	HY =	.3997936-001	.1978480+001
EZ = -.4018585-001					
HZ = .3065291+001					
EZ = -.1973506+001					
HZ = -.1536890+002					
FIELD STRENGTHS AT HT = 25.0000					
EX =	-.2792537+000	-.1199322+000	EY =	.3928397+001	-.1925516+002
HX =	-.2118484+001	-.4629261+000	HY =	-.1865745+000	.2502288+001
EZ = .1854285+000					
HZ = .3940134+001					
EZ = -.2492144+001					
HZ = -.1932804+002					
FIELD STRENGTHS AT HT = 30.0000					
EX =	-.2736040+000	-.1176619+000	EY =	.4774243+001	-.2317792+002
HX =	-.2075919+001	-.4412553+000	HY =	-.4103348+000	.3023766+001
EZ = .4075635+000					
HZ = .4788593+001					
EZ = -.3006854+001					
HZ = -.2326565+002					
FIELD STRENGTHS AT HT = 35.0000					

SAMPLE OUTPUT

EX =	-.2575379+000	-.1131359+000	EY =	-.5562651+001	-.2694920+002	EZ =	-.6231941+000	-.3500902+001
HX =	-.1952385+001	-.4004821+000	HY =	-.6282358+000	.3526046+001	HZ =	.5579321+001	-.2705121+002
FIELD STRENGTHS AT HT = 40.0000								
EX =	-.2283502+000	-.1051681+000	EY =	.6253912+001	-.3039816+002	EZ =	.8269856+000	-.3952245+001
HX =	-.1727129+001	-.3365579+000	HY =	-.8348618+000	.3986793+001	HZ =	.6272636+001	-.3051322+002
FIELD STRENGTHS AT HT = 45.0000								
EX =	-.1838708+000	-.9272881-001	EY =	.6802044+001	-.3331868+002	EZ =	.1011525+001	-.4334262+001
HX =	-.1383487+001	-.2466874+000	HY =	-.1022664+001	.4378912+001	HZ =	.6822370+001	-.3344478+002
FIELD STRENGTHS AT HT = 50.0000								
EX =	-.1228028+000	-.7505839-001	EY =	.7157429+001	-.3547941+002	EZ =	.1167723+001	-.4617074+001
HX =	-.9115202+000	-.1293195+000	HY =	-.1182348+001	.4671845+001	HZ =	.7178751+001	-.3561367+002
FIELD STRENGTHS AT HT = 55.0000								
EX =	-.4501075-001	-.5165826-001	EY =	.7270833+001	-.3663894+002	EZ =	.1285186+001	-.4769374+001
HX =	-.3108883+000	.1226794-001	HY =	-.1303244+001	.4833399+001	HZ =	.7292400+001	-.3677758+002
FIELD STRENGTHS AT HT = 60.0000								
EX =	.4779607-001	-.2292963-001	EY =	.7098594+001	-.3656639+002	EZ =	.1353793+001	-.4761566+001
HX =	.4063804+000	.1753233+000	HY =	-.1374880+001	.4832926+001	HZ =	.7119526+001	-.3670472+002
FIELD STRENGTHS AT HT = 65.0000								
EX =	.1522890+000	.1041943-001	EY =	.6608826+001	-.3506660+002	EZ =	.1364214+001	-.4568887+001
HX =	.1213677+001	.3509884+000	HY =	-.1387470+001	.4644529+001	HZ =	.6628155+001	-.3519923+002
FIELD STRENGTHS AT HT = 70.0000								
EX =	.2632274+000	.4655638-001	EY =	.5789450+001	-.3200861+002	EZ =	.1310407+001	-.4177960+001
HX =	.2068753+001	.5260520+000	HY =	-.1334253+001	.4253967+001	HZ =	.5806181+001	-.3212964+002
FIELD STRENGTHS AT HT = 75.0000								
EX =	.3754899+000	.8133256-001	EY =	.4658211+001	-.2735475+002	EZ =	.1196444+001	-.3602136+001
HX =	.2913923+001	.6818943+000	HY =	-.1216904+001	.3676554+001	HZ =	.4671423+001	-.2745814+002
FIELD STRENGTHS AT HT = 80.0000								
EX =	.5051596+000	.9284751-001	EY =	.3271048+001	-.2118964+002	EZ =	.1080754+001	-.2900346+001
HX =	.3674882+001	.7970680+000	HY =	-.1067631+001	.3004038+001	HZ =	.3280016+001	-.2126967+002
FIELD STRENGTHS AT HT = 85.0000								
EX =	.1051623+001	-.1036718+000	EY =	.1711966+001	-.1377765+002	EZ =	.1231454+001	-.1554639+001
HX =	.4205467+001	.8699483+000	HY =	-.11115539+001	.2365336+001	HZ =	.1716240+001	-.1382963+002
FIELD STRENGTHS AT HT = 90.0000								
EX =	.2500770+001	.1056639+001	EY =	.2309829+000	-.6001358+001	EZ =	.1572671-001	-.6073145+000
HX =	.3942202+001	.5876019+000	HY =	-.6951899+000	.6684161+000	HZ =	.2309130+000	-.6023916+001
FIELD STRENGTHS AT HT = 95.0000								
EX =	.1666843+001	.3154096+000	EY =	.1575048+000	-.4586697+000	EZ =	.2936326-001	-.6765647-001
HX =	.1396176+001	-.5553139+000	HY =	.1215235+001	-.9191051+000	HZ =	.1580242+000	-.4604156+000
FIELD STRENGTHS AT HT = 100.0000								
EX =	-.3897804+000	.2767017+000	EY =	-.2633607+000	-.4027665+000	EZ =	-.3490241-001	-.4326486-001
HX =	.7890973+000	.9587099+000	HY =	-.1032869+001	.7026058+000	HZ =	-.2694307+000	-.4042361+000
FIELD STRENGTHS AT HT = 105.0000								
EX =	-.3314287+000	-.3769999+000	EY =	.3295788+000	-.3186358+000	EZ =	.3463264-001	-.4083927-001

SAMPLE OUTPUT

HX =	-.8571831+000	.7856211+000	HY =	-.8488067+000	-.9447479+000	HZ =	.3307659+000	-.3198830+000
FIELD STRENGTHS AT HT = 110.0000								
EX =	.5219873+000	-.1919426+000	EY =	.1901460+000	.4501960+000	EZ =	.2792488-001	.5003454-001
HX =	-.3988290+000	-.9564429+000	HY =	.1085675+001	-.4360712+000	HZ =	.1909299+000	.4518558+000
FIELD STRENGTHS AT HT = 115.0000								
EX =	-.3763528+000	.4847217+000	EY =	-.4146503+000	-.2901294+000	EZ =	-.5303552-001	-.2731933-001
HX =	.7659905+000	.5185262+000	HY =	-.6407850+000	.9066123+000	HZ =	-.4162517+000	-.2911535+000
FIELD STRENGTHS AT HT = 120.0000								
EX =	.4176959+000	-.5450113+000	EY =	.4301032+000	.2810752+000	EZ =	.5638134-001	.2433900-001
HX =	-.6913764+000	-.4404731+000	HY =	.5985464+000	-.8668926+000	HZ =	.4317611+000	.2820629+000
FIELD STRENGTHS AT HT = 125.0000								
EX =	-.6077898+000	.4047983+000	EY =	-.3204241+000	-.3974325+000	EZ =	-.4763372-001	-.3944930-001
HX =	.4803184+000	.5819914+000	HY =	-.8314939+000	.6161311+000	HZ =	-.3216886+000	-.3988740+000
FIELD STRENGTHS AT HT = 130.0000								
EX =	.7745365+000	-.4705109-001	EY =	.8501502-001	.4921004+000	EZ =	.2464032-001	.5659289-001
HX =	-.1250385+000	-.6778183+000	HY =	.1017060+001	-.1124439+000	HZ =	.8541088-001	.4939339+000
FIELD STRENGTHS AT HT = 135.0000								
EX =	-.6641921+000	-.4540883+000	EY =	.2231033+000	-.4338606+000	EZ =	.1252387-001	-.6013030-001
HX =	-.2899626+000	.5798535+000	HY =	-.8680126+000	-.5338321+000	HZ =	.2238729+000	-.4355237+000
FIELD STRENGTHS AT HT = 140.0000								
EX =	.1840429+000	.8126564+000	EY =	-.4418743+000	.1682432+000	EZ =	-.4781950-001	.3783052-001
HX =	.5650004+000	-.2224647+000	HY =	.2706357+000	.9803989+000	HZ =	-.4435063+000	.1689435+000
FIELD STRENGTHS AT HT = 145.0000								
EX =	.4734980+000	-.7083891+000	EY =	.4176169+000	.1944457+000	EZ =	.6033767-001	.6227270-002
HX =	-.5280528+000	-.2387344+000	HY =	.5262568+000	-.8700153+000	HZ =	.4192145+000	.1951102+000
FIELD STRENGTHS AT HT = 150.0000								
EX =	-.8468589+000	.1221692+000	EY =	-.1350939+000	-.4373043+000	EZ =	-.3611925-001	-.4869217-001
HX =	.1753931+000	.5461651+000	HY =	-.9988627+000	.1901954+000	HZ =	-.1356692+000	-.4389244+000
FIELD STRENGTHS AT HT = 155.0000								
EX =	.6545869+000	.5377594+000	EY =	-.2365730+000	.3977262+000	EZ =	-.1273424-001	.5946912-001
HX =	.2936002+000	-.5062666+000	HY =	.8141803+000	.0089797+000	HZ =	-.2373987+000	.3992557+000
FIELD STRENGTHS AT HT = 160.0000								
EX =	-.7079927-001	-.8269487+000	EY =	.4606290+000	-.1059928+000	EZ =	.5283730-001	-.3078602-001
HX =	-.5921832+000	.1431606+000	HY =	-.1339852+000	-.1008126+001	HZ =	.4623411+000	-.1064624+000
FIELD STRENGTHS AT HT = 165.0000								
EX =	-.4954733+000	.6390216+000	EY =	-.4168838+000	-.2445993+000	EZ =	-.5951377-001	-.1557687-001
HX =	.5545932+000	.3172421+000	HY =	-.5845856+000	.8335973+000	HZ =	-.4184864+000	-.2454521+000
FIELD STRENGTHS AT HT = 170.0000								
EX =	.7665408+000	-.1793103+000	EY =	.1678178+000	.4626601+000	EZ =	.3485012-001	.5104889-001
HX =	-.2348198+000	-.6258253+000	HY =	.9809830+000	-.2806841+000	HZ =	.1685198+000	.4643702+000
FIELD STRENGTHS AT HT = 175.0000								
EX =	-.7071289+000	-.2704195+000	EY =	.1293394+000	-.4846202+000	EZ =	.2391026-002	-.6201061-001
HX =	-.1755678+000	.6880864+000	HY =	-.9747462+000	-.3181816+000	HZ =	.1297491+000	-.4864591+000

SAMPLE OUTPUT

FIELD STRENGTHS AT HT = 180.0000			
EX =	.4813082+000	.5455196+000	EY =
HX =	.5091623+000	-.5526553+000	HY =
FIELD STRENGTHS AT HT = 185.0000			
EX =	-.2578454+000	-.6433489+000	EY =
HX =	-.7131548+000	.3640285+000	HY =
FIELD STRENGTHS AT HT = 190.0000			
EX =	.7393562+000	.6453035+000	EY =
HX =	.8136408+000	-.2450945+000	HY =
FIELD STRENGTHS AT HT = 195.0000			
EX =	-.1640093+000	-.5994212+000	EY =
HX =	-.8602790+000	.2998283+000	HY =
FIELD STRENGTHS AT HT = 200.0000			
EX =	.3320104+000	.4820073+000	EY =
HX =	.7677427+000	-.5978275+000	HY =
FIELD STRENGTHS AT HT = 205.0000			
EX =	-.5249506+000	-.1464840+000	EY =
HX =	-.2328071+000	.1023311+001	HY =
FIELD STRENGTHS AT HT = 210.0000			
EX =	.3248527+000	-.3905831+000	EY =
HX =	-.8958775+000	-.6863565+000	HY =
FIELD STRENGTHS AT HT = 215.0000			
EX =	.4051137+000	.2308825+000	EY =
HX =	.5755821+000	-.1088922+001	HY =
FIELD STRENGTHS AT HT = 220.0000			
EX =	.1823947+000	.3875730+000	EY =
HX =	.1199446+001	-.6004509+000	HY =
FIELD STRENGTHS AT HT = 225.0000			
EX =	.3127993+000	.2185256+000	EY =
HX =	.8422145+000	-.1248611+001	HY =
FIELD STRENGTHS AT HT = 230.0000			
EX =	-.9798832+001	-.3123709+000	EY =
HX =	-.1670263+001	.5394126+000	HY =
FIELD STRENGTHS AT HT = 235.0000			
EX =	.1368368+000	-.2457652+000	EY =
HX =	-.1786987+001	-.9888567+000	HY =
FIELD STRENGTHS AT HT = 240.0000			
EX =	-.9698682+001	.2215930+000	EY =
HX =	.2173689+001	.9556404+000	HY =
FIELD STRENGTHS AT HT = 245.0000			
EX =	.1875522+000	-.9015362+001	EY =
HX =	-.1183548+001	-.2492635+001	HY =
FIELD STRENGTHS AT HT = 250.0000			
EX =	.3693935+000	.3693935+000	EY =
HZ =	-.3242237+001	-.3491465+000	HY =
FIELD STRENGTHS AT HT = 255.0000			
EX =	.4971528+001	.4585922+000	EY =
HZ =	.4585922+000	-.2269430+000	HY =
FIELD STRENGTHS AT HT = 260.0000			
EX =	-.5541371+001	.1414023+000	EY =
HZ =	-.4905872+000	.1025529+001	HY =
FIELD STRENGTHS AT HT = 265.0000			
EX =	.5373794+001	-.1601410+000	EY =
HZ =	.4780013+000	-.1034190+001	HY =
FIELD STRENGTHS AT HT = 270.0000			
EX =	-.4189300+001	.2979983+000	EY =
HZ =	-.3929085+000	.8926001+000	HY =
FIELD STRENGTHS AT HT = 275.0000			
EX =	.7153658+002	-.4625156+000	EY =
HZ =	.1109212+000	-.2674828+000	HY =
FIELD STRENGTHS AT HT = 280.0000			
EX =	.4537994+001	.2814606+000	EY =
HZ =	.3605337+000	-.9643783+000	HY =
FIELD STRENGTHS AT HT = 285.0000			
EX =	-.2027326+001	.3780958+000	EY =
HZ =	-.2059094+000	.6055305+000	HY =
FIELD STRENGTHS AT HT = 290.0000			
EX =	-.4087045+001	.1764813+000	EY =
HZ =	-.3637602+000	.1237119+001	HY =
FIELD STRENGTHS AT HT = 295.0000			
EX =	-.2192427+001	.3010437+000	EY =
HZ =	-.2086428+000	.8491308+000	HY =
FIELD STRENGTHS AT HT = 300.0000			
EX =	.3492691+001	-.9459052+001	EY =
HZ =	.3054178+000	-.1667711+001	HY =
FIELD STRENGTHS AT HT = 305.0000			
EX =	.2893579+001	.1363189+000	EY =
HZ =	.2409995+000	-.1779190+001	HY =
FIELD STRENGTHS AT HT = 310.0000			
EX =	-.2597318+001	-.9838300+001	EY =
HZ =	-.2180966+000	.2153724+001	HY =
FIELD STRENGTHS AT HT = 315.0000			
EX =	.1110444+001	.1867843+000	EY =
HZ =	.8653726+001	-.1181854+001	HY =

SAMPLE OUTPUT

FIELD STRENGTHS AT HT = 250.0000			
EX =	-.1173625+000	EY =	-.1317511+000
HY =	.2406096+001	HV =	-.2071046+001
HX =	.2118230+001	EZ =	-.1602092-001
		HZ =	-.1322640+000
FIELD STRENGTHS AT HT = 255.0000			
EX =	.1697581+000	EY =	.3892107-001
HY =	-.7717258+000	HV =	.3132704+001
HX =	-.3186882+001	EZ =	.5432867-002
		HZ =	.3909348-001
FIELD STRENGTHS AT HT = 260.0000			
EX =	-.5969734-001	EY =	-.1575393+000
HY =	.3133784+001	HV =	-.1157283-001
HX =	.1194977+001	EZ =	-.1873198-001
		HZ =	-.1581402+000
FIELD STRENGTHS AT HT = 265.0000			
EX =	-.1282451+000	EY =	-.1036527+000
HY =	.2177974+001	HV =	-.2595259+001
HX =	.2650249+001	EZ =	-.1278017-001
		HZ =	-.1040619+000
FIELD STRENGTHS AT HT = 270.0000			
EX =	.5414179-001	EY =	-.1535657+000
HY =	.3319321+001	HV =	.1138360+001
HX =	-.1136277+001	EZ =	-.1768260-001
		HZ =	-.1541341+000
FIELD STRENGTHS AT HT = 275.0000			
EX =	-.3505591-001	EY =	.1548096+000
HY =	-.3506893+001	HV =	-.7680524+000
HX =	.7589106+000	EZ =	.1792637-001
		HZ =	.1553856+000
FIELD STRENGTHS AT HT = 280.0000			
EX =	.1416041+000	EY =	.6174899-001
HY =	-.1504256+001	HV =	.3283956+001
HX =	-.3346796+001	EZ =	.7937231-002
		HZ =	.6200282-001
FIELD STRENGTHS AT HT = 285.0000			
EX =	.7509848-001	EY =	.1297448+000
HY =	-.3247632+001	HV =	.1829197-001
HX =	-.1879199+001	EZ =	.1555100-001
		HZ =	.1302437+000
FIELD STRENGTHS AT HT = 290.0000			
EX =	-.1214485+000	EY =	-.8267545-001
HY =	.2186752+001	HV =	-.3087982+001
HX =	.3152312+001	EZ =	-.1027700-001
		HZ =	-.8300077-001
FIELD STRENGTHS AT HT = 295.0000			
EX =	-.1022178+000	EY =	.1043738+000
HY =	-.2813383+001	HV =	-.2705858+001
HX =	.2733252+001	EZ =	.1169606-001
		HZ =	.1047501+000
FIELD STRENGTHS AT HT = 300.0000			
EX =	-.1414699+000	EY =	-.8343060-002
HY =	.2819087+000	HV =	-.3932998+001
HX =	.4000007+001	EZ =	-.1678605-002
		HZ =	-.8396285-002
FIELD STRENGTHS AT HT = 305.0000			
EX =	.1360729+000	EY =	.2334127-001
HY =	-.7408053+000	HV =	.3960917+001
HX =	-.4031442+001	EZ =	.3403092-002
		HZ =	.2345000-001
FIELD STRENGTHS AT HT = 310.0000			
EX =	.1273986+000	EY =	-.4794580-001
HY =	.1454178+001	HV =	.3873466+001
HX =	-.3929195+001	EZ =	-.4978840-002
		HZ =	-.4810617-001
FIELD STRENGTHS AT HT = 315.0000			
EX =	-.2091740-001	EY =	.1297639+000
HY =	-.4234640+001	HV =	-.6504125+000
HX =	.6351865+000	EZ =	.1507238-001
		HZ =	.1302481+000
FIELD STRENGTHS AT HT = 320.0000			

SAMPLE OUTPUT

EX = .1249436+000	-.3230590-001	EY =	.293889-001	.1244998+000	EZ =	.4048558-002	.1440134-001
HX = -.1052180+001	-.4247647+001	HY =	.4171115+001	-.1060573+001	HZ =	.2951861-001	.1249624+000
FIELD STRENGTHS AT HT = 325.0000							
EX = -.8206323-002	-.1257274+000	EY =	.1247764+000	-.5470277-002	EZ =	.1455178-001	-.1253218-002
HX = -.4464959+001	.2450244+000	HY =	-.2680579+000	-.4389567+001	HZ =	.1252438+000	-.5510282-002
FIELD STRENGTHS AT HT = 330.0000							
EX = .1185025+000	.3294663-001	EY =	-.3518034-001	.1167443+000	EZ =	-.3537702-002	.1381276-001
HX = .1270032+001	-.4388887+001	HY =	.4323796+001	.1222337+001	HZ =	-.3529414-001	.1171879+000
FIELD STRENGTHS AT HT = 335.0000							
EX = .1053917+000	.6274437-001	EY =	-.6443416-001	.1031145+000	EZ =	-.7022613-002	.1236373-001
HX = .2378609+001	-.3901447+001	HY =	.3851159+001	.2315479+001	HZ =	-.6465987-001	.1035116+000
FIELD STRENGTHS AT HT = 340.0000							
EX = .1006192+000	.6953792-001	EY =	-.7105646-001	.9823913-001	EZ =	-.7821513-002	.1182656-001
HX = .2637416+001	-.3731693+001	HY =	.3685783+001	.2571017+001	HZ =	-.7131783-001	.9861890-001
FIELD STRENGTHS AT HT = 345.0000							
EX = .1085255+000	.5565010-001	EY =	-.5747215-001	.1063712+000	EZ =	-.6193393-002	.1270997-001
HX = .2127833+001	-.4044115+001	HY =	.3989922+001	.2067990+001	HZ =	-.5767123-001	.1067794+000
FIELD STRENGTHS AT HT = 350.0000							
EX = .1203573+000	.1741548-001	EY =	-.1983163-001	.1189142+000	EZ =	-.1734158-002	.1399090-001
HX = .7020383+000	-.4515455+001	HY =	.4444781+001	.6629915+000	HZ =	-.1988749-001	.1193636+000
FIELD STRENGTHS AT HT = 355.0000							
EX = .1194996+000	-.2254267-001	EY =	.1979032-001	.1189173+000	EZ =	.2895321-002	.1379701-001
HX = -.7974512+000	-.4486133+001	HY =	.4406856+001	-.8114378+000	HZ =	.1988315-001	.1193605+000
FIELD STRENGTHS AT HT = 360.0000							
EX = .1155265+000	-.3795977-001	EY =	.3515599-001	.1153082+000	EZ =	.4673035-002	.1329996-001
HX = -.1372733+001	-.4330880+001	HY =	.4250698+001	-.1376235+001	HZ =	.3530593-001	.1157355+000
FIELD STRENGTHS AT HT = 365.0000							
EX = .1178206+000	-.3007432-001	EY =	.2729278-001	.1174131+000	EZ =	.3764756-002	.1358442-001
HX = -.1074188+001	-.4400809+001	HY =	.4321288+001	-.1083069+001	HZ =	.2741353-001	.1178494+000
FIELD STRENGTHS AT HT = 370.0000							
EX = .1215781+000	.1899670-002	EY =	-.4475526-002	.1204547+000	EZ =	.6805474-004	.1409563-001
HX = .1179911+000	-.4515268+001	HY =	.4441090+001	.8863884-001	HZ =	-.4473520-002	.1209074+000
FIELD STRENGTHS AT HT = 375.0000							
EX = .1014215+000	.6740977-001	EY =	-.6895995-001	.9908127-001	EZ =	-.7572004-002	.1191498-001
HX = .2528137+001	-.3718559+001	HY =	.3672235+001	.2463653+001	HZ =	-.6921332-001	.9946387-001
FIELD STRENGTHS AT HT = 380.0000							
EX = .1968299-003	.1219692+000	EY =	-.1208857+000	-.2401342-002	EZ =	-.1413585-001	.3130102-003
HX = .4476318+001	.3961456-001	HY =	-.1179923-001	.4402350+001	HZ =	-.1213398+000	-.2391485-002
FIELD STRENGTHS AT HT = 385.0000							
EX = -.1201715+000	.2195589-001	EY =	-.1920418-001	-.1195663+000	EZ =	-.2831129-002	-.1387557-001
HX = .7551482+000	.4392127+001	HY =	-.4314752+001	.7692803+000	HZ =	-.1929491-001	-.1200120+000
FIELD STRENGTHS AT HT = 390.0000							
EX = .5730440-002	-.1222201+000	EY =	.1210072+000	.8276269-002	EZ =	.1417894-001	.3723061-003

SAMPLE OUTPUT

HX =	-.4429529+001	-.2539850+000	HY =	.2229022+000	-.4357677+001	HZ =	.1214626+000	.8288441-002
FIELD STRENGTHS AT HT = 395.0000								
EX =	.9539693-001	.7692805-001	EY =	-.7826604-001	.9291170-001	EZ =	-.8687671-002	.1124044-001
HX =	.2898420+001	-.3409451+001	HY =	.3370014+001	.2741215+001	HZ =	-.7854526-001	.9327260-001
FIELD STRENGTHS AT HT = 400.0000								
EX =	-.1215227+000	-.1729859-001	EY =	.1972135-001	-.1200697+000	EZ =	.1713633-002	-.1412575-001
HX =	-.6649430+000	.4347168+001	HY =	-.4279214+001	-.6275572+000	HZ =	.1977662-001	-.1205234+000
FIELD STRENGTHS AT HT = 405.0000								
EX =	.1150483+000	.4530701-001	EY =	-.4733480-001	.1130600+000	EZ =	-.4973750-002	.1344288-001
HX =	.1637088+001	-.4034349+001	HY =	.3977528+001	.1585524+001	HZ =	-.4749480-001	.1134916+000
FIELD STRENGTHS AT HT = 410.0000								
EX =	.2067978-001	-.1228345+000	EY =	.1212966+000	.2309523-001	EZ =	.1428599-001	.2099155-002
HX =	-.4243302+001	-.7592724+000	HY =	.7209764+000	-.4177758+001	HZ =	.1217554+000	.2315293-001
FIELD STRENGTHS AT HT = 415.0000								
EX =	-.6050604-001	-.1099430+000	EY =	.1102278+000	-.5764995-001	EZ =	.1259430-001	-.7279984-002
HX =	-.3760177+001	.2019632+001	HY =	-.2009085+001	-.3685815+001	HZ =	.1106325+000	-.5788351-001
FIELD STRENGTHS AT HT = 420.0000								
EX =	-.1045706-001	-.1260039+000	EY =	.1250889+000	-.7720329-002	EZ =	.1457715-001	-.1520425-002
HX =	-.4215297+001	.3067812+000	HY =	-.3272914+000	-.4143874+001	HZ =	.1255571+000	-.7768826-002
FIELD STRENGTHS AT HT = 425.0000								
EX =	.1257310+000	-.2052726-001	EY =	.1771301-001	.1250262+000	EZ =	.2688475-002	.1452034-001
HX =	-.6326709+000	-.4137207+001	HY =	.4065160+001	-.6473388+000	HZ =	.1779900-001	.1254926+000
FIELD STRENGTHS AT HT = 430.0000								
EX =	-.9316709-001	.8830822-001	EY =	-.8556781-001	-.9416612-001	EZ =	-.1048450-001	-.1057823-001
HX =	.2821007+001	.3036633+001	HY =	-.2969504+001	.2792965+001	HZ =	-.8590363-001	-.9450615-001
FIELD STRENGTHS AT HT = 435.0000								
EX =	.1227686+000	-.4075126-001	EY =	.3783062-001	.1225037+000	EZ =	.5028191-002	.1412559-001
HX =	-.1254293+001	-.3908539+001	HY =	.3836619+001	-.1257366+001	HZ =	.3799171-001	.1229576+000
FIELD STRENGTHS AT HT = 440.0000								
EX =	-.5505286-001	-.1181605+000	EY =	.1182288+000	-.5210510-001	EZ =	.1355493-001	-.6675638-002
HX =	-.3701991+001	.1680422+001	HY =	-.1675259+001	-.3630950+001	HZ =	.1186644+000	-.5231909-001
FIELD STRENGTHS AT HT = 445.0000								
EX =	-.1183996+000	-.5691972-001	EY =	.5884725-001	-.161472+000	EZ =	.6297641-002	-.1386364-001
HX =	-.1780294+001	.3611839+001	HY =	-.3563337+001	-.1729155+001	HZ =	.5904997-001	-.1165922+000
FIELD STRENGTHS AT HT = 450.0000								
EX =	-.9742170-001	-.8965842-001	EY =	.9084652-001	-.9468797-001	EZ =	.1014262-001	-.1151629-001
HX =	-.2729495+001	.2908319+001	HY =	-.2877179+001	-.2667090+001	HZ =	.9117267-001	-.9505750-001
FIELD STRENGTHS AT HT = 455.0000								
EX =	.5617343-001	-.1210423+000	EY =	.1187838+000	.5814352-001	EZ =	.1416312-001	.6200608-002
HX =	-.3567438+001	-.1697816+001	HY =	.1648366+001	-.3519300+001	HZ =	.1192387+000	.5834318-001
FIELD STRENGTHS AT HT = 460.0000								
EX =	.6409747-001	.1182418+000	EY =	-.1184693+000	.6109272-001	EZ =	-.1353674-001	.7730455-002
HX =	.3458445+001	-.1831924+001	HY =	.1822930+001	.3390751+001	HZ =	-.1189044+000	.6134048-001

SAMPLE OUTPUT

FIELD STRENGTHS AT HT = 465.0000			
EX =	-.6444014-001	-.1192723+000	
HX =	-.3428441+001	.1810195+001	
EY =		.1194902+000	-.6141817-001
HY =		-.1801411+001	-.3361440+001
EZ =			.1365396-001
HZ =			.1199290+000
FIELD STRENGTHS AT HT = 470.0000			
EX =	-.5605294-001	.1246246+000	
HX =	.3487691+001	.1608618+001	
EY =		-.1223392+000	-.5806722-001
HY =		-.1561214+001	.3440533+001
EZ =			-.1458559-001
HZ =			-.1228074+000
FIELD STRENGTHS AT HT = 475.0000			
EX =	.1079057+000	.8561790-001	
HX =	.2393027+001	-.2958358+001	
EY =		-.8701052-001	.1051776+000
HY =		.2924660+001	.2336086+001
EZ =			-.9638285-002
HZ =			-.8732064-001
FIELD STRENGTHS AT HT = 480.0000			
EX =	.1350923+000	.3211100-001	
HX =	.9059823+000	-.3659298+001	
EY =		-.3453658-001	.1331947+000
HY =		.3605243+001	.8690463+000
EZ =			-.3365316-002
HZ =			-.3464540-001
FIELD STRENGTHS AT HT = 485.0000			
EX =	.1100544+000	.8649992-001	
HX =	.2335103+001	-.2914992+001	
EY =		-.8790681-001	.1072961+000
HY =		.2881785+001	.2279480+001
EZ =			-.9730696-002
HZ =			-.8821996-001
FIELD STRENGTHS AT HT = 490.0000			
EX =	-.5277033-001	.1308777+000	
HX =	.3419224+001	.1415287+001	
EY =		-.1286038+000	-.5489683-001
HY =		-.1371589+001	.3372328+001
EZ =			-.1530362-001
HZ =			-.1290950+000
FIELD STRENGTHS AT HT = 495.0000			
EX =	-.8380777-001	-.1149598+000	
HX =	-.2988280+001	.2132894+001	
EY =		.1155561+000	-.8073495-001
HY =		-.2116426+001	-.2921132+001
EZ =			.1309390-001
HZ =			.1159772+000
FIELD STRENGTHS AT HT = 500.0000			
EX =	.1045865+000	.9815013-001	
HX =	.2509929+001	-.2626607+001	
EY =		-.9930609-001	.1016594+000
HY =		.2599344+001	.2453407+001
EZ =			-.1108856-001
HZ =			-.9966290-001

SAMPLE OUTPUT

HEIGHT GAINS NORMALIZED FOR USE WITH WKB MODE SUMMING FORMULAS

FIELD STRENGTHS AT HT = .0000								
EX=	.7445885-001	-.1639185+000	EY=	.2697037-001	-.3783949-001	EZ=	-.5411622-001	-.6155869+000
HX=	.3383116-002	-.1530835+000	HY=	.5381852-001	.6132937+000	HZ=	.2706568-001	-.3798571-001
FIELD STRENGTHS AT HT = 5.0000								
EX=	.6751233-001	-.1647689+000	EY=	.3139428+000	-.3203252-001	EZ=	.2528834+000	-.4823506+000
HX=	.2844433-002	-.1551304+000	HY=	-.2524083+000	.4812624+000	HZ=	.3151160+000	-.3220174-001
FIELD STRENGTHS AT HT = 10.0000								
EX=	.6321165-001	-.1683639+000	EY=	.6071264+000	-.2723809-001	EZ=	.5638349+000	-.3597102+000
HX=	.2289814-002	-.1594717+000	HY=	-.5635486+000	.3594030+000	HZ=	.6094006+000	-.2743507-001
FIELD STRENGTHS AT HT = 15.0000								
EX=	.6075196-001	-.1729377+000	EY=	.9092726+000	-.2352671-001	EZ=	.8822194+000	-.2434697+000
HX=	.1676648-002	-.1644618+000	HY=	-.8830985+000	.2435645+000	HZ=	.9126813+000	-.2375693-001
FIELD STRENGTHS AT HT = 20.0000								
EX=	.5941406-001	-.1766815+000	EY=	.1220010+001	-.2104130-001	EZ=	.1208176+001	-.1308569+000
HX=	.9703836-003	-.1683914+000	HY=	-.1211238+001	.1309980+000	HZ=	.1224585+001	-.2131069-001
FIELD STRENGTHS AT HT = 25.0000								
EX=	.5852467-001	-.1777191+000	EY=	.1535703+001	-.1997935-001	EZ=	.1538396+001	-.2040138-001
HX=	.1475938-003	-.1694709+000	HY=	-.1544678+001	.2024445-001	HZ=	.1541463+001	-.2029405-001
FIELD STRENGTHS AT HT = 30.0000								
EX=	.5743637-001	-.1741320+000	EY=	.1849321+001	-.2056867-001	EZ=	.1866019+001	.8813169-001
HX=	-.7999739-003	-.1658603+000	HY=	-.1876540+001	-.8892109-001	HZ=	.1856258+001	-.2093452-001
FIELD STRENGTHS AT HT = 35.0000								
EX=	.5552586-001	-.1640352+000	EY=	.2150416+001	-.2303468-001	EZ=	.2180620+001	.1937877+000
HX=	-.1860817-002	-.1557491+000	HY=	-.2196313+001	-.1955264+000	HZ=	.2158483+001	-.2345678-001
FIELD STRENGTHS AT HT = 40.0000								
EX=	.5220943-001	-.1457058+000	EY=	.2425283+001	-.2755943-001	EZ=	.2468394+001	.2944811+000
HX=	-.2999208-002	-.1374851+000	HY=	-.2490006+001	-.2974521+000	HZ=	.2434380+001	-.2804142-001
FIELD STRENGTHS AT HT = 45.0000								
EX=	.4697434-001	-.1177574+000	EY=	.2657418+001	-.3423292-001	EZ=	.2712614+001	.3870985+000
HX=	-.4151725-002	-.1097495+000	HY=	-.2740597+001	-.3915266+000	HZ=	.2667385+001	-.3477618-001
FIELD STRENGTHS AT HT = 50.0000								
EX=	.3942377-001	-.7935373-001	EY=	.2828327+001	-.4299968-001	EZ=	.2894467+001	.4676728+000
HX=	-.5225834-002	-.7176728-001	HY=	-.2928845+001	-.4736947+000	HZ=	.2838935+001	-.4360252-001
FIELD STRENGTHS AT HT = 55.0000								
EX=	.2925927-001	-.3038498-001	EY=	.2918760+001	-.5360808-001	EZ=	.2994194+001	.5315156+000
HX=	-.6103015-002	-.2353716-001	HY=	-.3034432+001	-.5391452+000	HZ=	.2929705+001	-.5426485-001
FIELD STRENGTHS AT HT = 60.0000								
EX=	.1663491-001	.2807899-001	EY=	.2910357+001	-.6555540-001	EZ=	.2993097+001	.5740122+000
HX=	-.8663557-002	.3394671-001	HY=	-.3037997+001	-.5831046+000	HZ=	.2921269+001	-.6825569-001

FIELD STRENGTHS AT HT = 65.0000	EX=	.1805796-002	.9395864-001	EZ=	.2875490+001	.5907729+000
	HY=	-.6635047-002	.9851510-001	HZ=	.2798136+001	-.7876184-001
	HX=					
FIELD STRENGTHS AT HT = 70.0000	EX=	-.1438623-001	.1639413+000	EZ=	.2632841+001	.5788129+000
	HY=	-.5794604-002	.1667222+000	HZ=	.2550068+001	-.9052321-001
	HX=					
FIELD STRENGTHS AT HT = 75.0000	EX=	-.2967243-001	.2346628+000	EZ=	.2273558+001	.5399100+000
	HY=	-.3650947-002	.2338534+000	HZ=	.2174471+001	-.9955067-001
	HX=					
FIELD STRENGTHS AT HT = 80.0000	EX=	-.2975585-001	.3148081+000	EZ=	.1835928+001	.5067273+000
	HY=	.1989978-003	.2938780+000	HZ=	.1678766+001	-.1029690+000
	HX=					
FIELD STRENGTHS AT HT = 85.0000	EX=	.1201780+000	.6393743+000	EZ=	.1019725+001	.6715747+000
	HY=	.3450460-002	.3356073+000	HZ=	.1084621+001	-.9875235-001
	HX=					
FIELD STRENGTHS AT HT = 90.0000	EX=	-.5134425+000	.1590573+001	EZ=	.3733086+000	-.2303968-001
	HY=	.2063709-001	.3108112+000	HZ=	.4638543+000	-.8246847-001
	HX=					
FIELD STRENGTHS AT HT = 95.0000	EX=	-.1037317+000	.1039239+001	EZ=	.4307358-001	.1436713-001
	HY=	.6560750-001	.9739121-001	HZ=	.3778565-001	.4416604-002
	HX=					
FIELD STRENGTHS AT HT = 100.0000	EX=	-.1906768+000	-.2241582+000	EZ=	.2465567-001	-.2373388-001
	HY=	-.6009920-001	.7619082-001	HZ=	.2639229-001	-.2729248-001
	HX=					
FIELD STRENGTHS AT HT = 105.0000	EX=	.213747+000	-.2235527+000	EZ=	.2691035-001	.1904207-001
	HY=	-.7423825-001	-.5240387-001	HZ=	.2992439-001	.1994333-001
	HX=					
FIELD STRENGTHS AT HT = 110.0000	EX=	.1458098+000	.3098015+000	EZ=	-.2918299-001	.1981894-001
	HY=	.6641135-001	-.4635027-001	HZ=	-.3133325-001	.2208908-001
	HX=					
FIELD STRENGTHS AT HT = 115.0000	EX=	-.3175315+000	-.2042728+000	EZ=	.1390048-001	-.3399664-001
	HY=	-.2686850-001	.6711154-001	HZ=	.1531693-001	-.3662534-001
	HX=					
FIELD STRENGTHS AT HT = 120.0000	EX=	.3567317+000	.2268386+000	EZ=	-.1189260-001	.3588821-001
	HY=	.2214786-001	-.6011658-001	HZ=	-.1436500-001	.3765866-001
	HX=					
FIELD STRENGTHS AT HT = 125.0000	EX=	-.2809706+000	-.3509680+000	EZ=	.2163043-001	-.3133856-001
	HY=	-.3646217-001	.4635078-001	HZ=	.2511441-001	-.3119406-001
	HX=					
FIELD STRENGTHS AT HT = 130.0000	EX=	.7054055-001	.4724861+000	EZ=	-.3338196-001	.1815750-001
	HY=	.4968385-001	-.2081220-001	HZ=	-.3630001-001	.1473034-001
	HX=					

SAMPLE OUTPUT

FIELD STRENGTHS AT HT = 135.0000									
EX=	.2427436+000								
HX=	-.4909902-001								
EY=	.3683923-001		.9827651-002		.3755155-001		.4444688-002		
HY=	.2806807+000		-.5610767+000		.3697901-001		.9858782-002		
FIELD STRENGTHS AT HT = 140.0000									
EX=	-.4884921+000								
HX=	.2637283-001								
EY=	-.2019074-001		-.3094801-001		-.2577480-001		-.2729141-001		
HY=	-.5867073+000		.2187428+000		-.2027134-001		-.3106100-001		
FIELD STRENGTHS AT HT = 145.0000									
EX=	.4599336+000								
HX=	.9456087-002								
EY=	-.7909139-002		.3512256-001		-.5718610-003		.3733986-001		
HY=	.5618973+000		.2759270+000		-.7933338-002		.3525560-001		
FIELD STRENGTHS AT HT = 150.0000									
EX=	-.1205023+000								
HX=	-.3879337-001								
EY=	.3114988-001		-.1758335-001		.2791871-001		-.2477225-001		
HY=	-.1704029+000		-.6023601+000		.3126403-001		-.1765420-001		
FIELD STRENGTHS AT HT = 155.0000									
EX=	-.2945755+000								
HX=	.4354000-001								
EY=	-.3430365-001		-.1145672-001		-.3715737-001		-.4609286-002		
HY=	-.3296654+000		.5321060+000		-.3443417-001		-.1149436-001		
FIELD STRENGTHS AT HT = 160.0000									
EX=	.5033521+000								
HX=	-.2077306-001								
EY=	.1574863-001		.3341465-001		.2172450-001		.3074793-001		
HY=	.6110667+000		-.1364281+000		.1581295-001		.3353759-001		
FIELD STRENGTHS AT HT = 165.0000									
EX=	-.4185735+000								
HX=	-.1501030-001								
EY=	.1175130-001		-.3589999-001		.6350256-002		-.3733774-001		
HY=	-.5427015+000		-.3136597+000		.1178980-001		-.3603655-001		
FIELD STRENGTHS AT HT = 170.0000									
EX=	.1512240+000								
HX=	.4388911-001								
EY=	-.3254239-001		.2050366-001		-.2943238-001		.2412074-001		
HY=	.2249368+000		.5865247+000		-.3266131-001		.2058568-001		
FIELD STRENGTHS AT HT = 175.0000									
EX=	.1277899+000								
HX=	-.5546329-001								
EY=	.3915737-001		.1823863-002		.3815940-001		-.1870919-002		
HY=	.1426793+000		-.6149298+000		.3930460-001		.1824595-002		
FIELD STRENGTHS AT HT = 180.0000									
EX=	-.3086604+000								
HX=	.5066457-001								
EY=	-.3398997-001		-.2042893-001		-.3407964-001		-.1729416-001		
HY=	-.4146337+000		.4821025+000		-.3412072-001		-.2050029-001		
FIELD STRENGTHS AT HT = 185.0000									
EX=	.3806850+000								
HX=	-.3964990-001								
EY=	.2492326-001		.3112099-001		.2517268-001		.2851588-001		
HY=	.5589830+000		-.3188535+000		.2502165-001		.3123389-001		
FIELD STRENGTHS AT HT = 190.0000									
EX=	-.3882606+000								
HX=	.3223731-001								
EY=	-.1892040-001		-.3497561-001		-.1886365-001		-.3259124-001		
HY=	-.6141886+000		.2234156+000		-.1895687-001		-.3510392-001		
FIELD STRENGTHS AT HT = 195.0000									
EX=	.3587945+000								
HX=	-.3719207-001								
EY=	.2014307-001		.3370691-001		.1925656-001		.3152110-001		
HY=	.6162037+000		-.2614447+000		.2022392-001		.3383026-001		
FIELD STRENGTHS AT HT = 200.0000									
EX=	-.2777437+000								
HX=	.5841110-001								
EY=	-.2926218-001		-.2494389-001		-.2727209-001		-.2349735-001		
HY=	-.5111177+000		.4617925+000		-.2937589-001		-.2503293-001		
FIELD STRENGTHS AT HT = 205.0000									

SAMPLE OUTPUT

EX=	.6158562-001	-.3298325+000	EY=	.3715759-001	.7584995-003	EZ=	.3462601-001	.1382533-002
HX=	-.8201394-001	-.7735078-003	HY=	.1030471+000	-.7095081+000	HZ=	.3729716-001	.7555462-003
FIELD STRENGTHS AT HT = 210.0000								
EX=	.2570252+000	.1782095+000	EY=	-.1552574-001	.3210307-001	EZ=	-.1534170-001	.2939183-001
HX=	.3752649-001	-.7931929-001	HY=	.6315108+000	.4046482+000	HZ=	-.1557900-001	.3222597-001
FIELD STRENGTHS AT HT = 215.0000								
EX=	-.1196735+000	.2608687+000	EY=	-.3228320-001	-.9387004-002	EZ=	-.2955477-001	-.9935679-002
HX=	.9272034-001	.2585929-001	HY=	-.3097117+000	.7351997+000	HZ=	-.3240582-001	-.9417193-002
FIELD STRENGTHS AT HT = 220.0000								
EX=	-.2278799+000	.1327201+000	EY=	-.1949964-001	-.2474415-001	EZ=	-.1689421-001	-.2377609-001
HX=	.6578525-001	.8161789-001	HY=	-.7251930+000	.4486107+000	HZ=	-.1957668-001	-.2483397-001
FIELD STRENGTHS AT HT = 225.0000								
EX=	-.1171860+000	.2035985+000	EY=	-.2644416-001	-.1087445-001	EZ=	-.2381528-001	-.1145969-001
HX=	.1093458+000	.4356707-001	HY=	-.4524020+000	.8247531+000	HZ=	-.2654510-001	-.1091114-001
FIELD STRENGTHS AT HT = 230.0000								
EX=	.1863015+000	-.7690695-001	EY=	.1227995-001	.2166533-001	EZ=	.9978815-002	.2070973-001
HX=	-.6894783-001	-.1185862+000	HY=	.9932797+000	-.4261190+000	HZ=	.1232942-001	.2174472-001
FIELD STRENGTHS AT HT = 235.0000								
EX=	.1580906+000	.7069440-001	EY=	-.6420534-002	.2059880-001	EZ=	-.7281075-002	.1852173-001
HX=	.4581898-001	-.1528957+000	HY=	.1143426+001	.4997726+000	HZ=	-.6441414-002	.2067711-001
FIELD STRENGTHS AT HT = 240.0000								
EX=	-.1411213+000	-.4755560-001	EY=	.3902623-002	-.1822641-001	EZ=	.4871776-002	-.1647937-001
HX=	-.3685641-001	.1818743+000	HY=	-.1370992+001	-.4553111+000	HZ=	.3914424-002	-.1829542-001
FIELD STRENGTHS AT HT = 245.0000								
EX=	.6538443-001	.1101727+000	EY=	-.1283164-001	.9685382-002	EZ=	-.1249760-001	.7959430-002
HX=	.1706828+000	-.1318029+000	HY=	.8566944+000	.1439140+001	HZ=	-.1287828-001	.9723733-002
FIELD STRENGTHS AT HT = 250.0000								
EX=	-.8925430-001	-.6469959-001	EY=	.6866415-002	-.1203177-001	EZ=	.7210145-002	-.1053391-001
HX=	-.1217757+000	.2189414+000	HY=	-.1572246+001	-.1141971+001	HZ=	.6890305-002	-.1207800-001
FIELD STRENGTHS AT HT = 255.0000								
EX=	.3516311-001	.1018276+000	EY=	-.1224532-001	.5717599-002	EZ=	-.1168103-001	.4382650-002
HX=	.2305425+000	-.1118908+000	HY=	.6463766+000	.1879341+001	HZ=	-.1229037-001	.5801192-002
FIELD STRENGTHS AT HT = 260.0000								
EX=	-.1014834+000	-.2798843-001	EY=	.2121772-002	-.1306189-001	EZ=	.2936289-002	-.1183434-001
HX=	-.3917903-001	.2591693+000	HY=	-.1958562+001	-.5433499+000	HZ=	.2127696-002	-.1311124-001
FIELD STRENGTHS AT HT = 265.0000								
EX=	-.7259076-001	-.7288750-001	EY=	.8128315-002	-.1005903-001	EZ=	.8226988-002	-.8620301-002
HX=	-.1661942+000	.2103616+000	HY=	-.1464196+001	-.1475425+001	HZ=	.8157249-002	-.1009805-001
FIELD STRENGTHS AT HT = 270.0000								
EX=	-.9155189-001	.4149449-001	EY=	-.6422732-002	-.1088474-001	EZ=	-.5069533-002	-.1048327-001
HX=	.1419306+000	.2345983+000	HY=	-.1937919+001	.8735838+000	HZ=	-.6448534-002	-.1092459-001
FIELD STRENGTHS AT HT = 275.0000								
EX=	.9355891-001	-.2987523-001	EY=	.4995080-002	.1129490-001	EZ=	.3724921-002	.1075191-001

SAMPLE OUTPUT

HX=	-.1162299+000	-.2551931+000	HY=	.2072260+001	-.6565166+000	HZ=	.5015589-002	.1133651-001
FIELD STRENGTHS AT HT = 280.0000								
EX=	.4756315-001	.8333984-001	EY=	-.9781690-002	.7057304-002	EZ=	-.9521614-002	.5740892-002
HX=	.2305815+000	-.1704879+000	HY=	.1096925+001	.1933280+001	HZ=	-.9817296-002	.7095353-002
FIELD STRENGTHS AT HT = 285.0000								
EX=	.8528553-001	.3892183-001	EY=	-.3723541-002	.1118740-001	EZ=	-.4276305-002	.9986032-002
HX=	.8953788-001	-.2792333+000	HY=	.2065060+001	.9492573+000	HZ=	-.3735768-002	.1122997-001
FIELD STRENGTHS AT HT = 290.0000								
EX=	-.5921654-001	-.6986073-001	EY=	.7944690-002	-.8341286-002	EZ=	.7934925-002	-.7047672-002
HX=	-.2043884+000	.2193750+000	HY=	-.1497309+001	-.1777030+001	HZ=	.7973203-002	-.8373829-002
FIELD STRENGTHS AT HT = 295.0000								
EX=	.5783543-001	-.6824754-001	EY=	.9309225-002	.6322204-002	EZ=	.8059660-002	.6521093-002
HX=	-.2554764+000	-.1694246+000	HY=	.1541573+001	-.1807543+001	HZ=	.9345147-002	.6344477-002
FIELD STRENGTHS AT HT = 300.0000								
EX=	-.1455784-001	-.8615321-001	EY=	.1058291-001	-.2970186-002	EZ=	.9944759-002	-.1910091-002
HX=	-.3007764+000	.8799793-001	HY=	-.3966182+000	-.2395853+001	HZ=	.1062217-001	-.2982985-002
FIELD STRENGTHS AT HT = 305.0000								
EX=	.2349791-001	.8203325-001	EY=	-.9949692-002	.4031968-002	EZ=	-.9445741-002	.2932062-002
HX=	.2955496+000	-.1235716+000	HY=	.6751185+000	.2388668+001	HZ=	-.9986402-002	.4048652-002
FIELD STRENGTHS AT HT = 310.0000								
EX=	-.2118663-001	.8059360-001	EY=	-.1036492-001	-.1579299-002	EZ=	-.9392550-002	-.2252778-002
HX=	.3242182+000	.4575527-001	HY=	-.6541045+000	.2451266+001	HZ=	-.1040406-001	-.1583608-002
FIELD STRENGTHS AT HT = 315.0000								
EX=	.7891314-001	-.1985218-001	EY=	.3531379-002	.9610224-002	EZ=	.2495803-002	.9095961-002
HX=	-.1188750+000	-.3128236+000	HY=	.2516927+001	-.6228342+000	HZ=	.3546132-002	.9645738-002
FIELD STRENGTHS AT HT = 320.0000								
EX=	.2653729-001	.7488848-001	EY=	-.9019071-002	.4313155-002	EZ=	-.8614361-002	.3258014-002
HX=	.3068875+000	-.1509349+000	HY=	.8749282+000	.2501040+001	HZ=	-.9052245-002	.4330749-002
FIELD STRENGTHS AT HT = 325.0000								
EX=	.7666616-001	-.1179935-001	EY=	.2491205-002	.9437662-002	EZ=	.1551746-002	.8857071-002
HX=	-.9290758-001	-.3368954+000	HY=	.2677667+001	-.4006382+000	HZ=	.2502027-002	.9472691-002
FIELD STRENGTHS AT HT = 330.0000								
EX=	-.1382833-001	.7444995-001	EY=	-.9499797-002	-.7465580-003	EZ=	-.8661671-002	-.1426268-002
HX=	.3562626+000	.2405397-001	HY=	-.5169515+000	.2717541+001	HZ=	-.9535565-002	-.7478769-003
FIELD STRENGTHS AT HT = 335.0000								
EX=	-.3290870-001	.6801290-001	EY=	-.8945085-002	-.3207021-002	EZ=	-.7960544-002	-.3641528-002
HX=	.3374609+000	.1168106+000	HY=	-.1212805+001	.2486507+001	HZ=	-.8979155-002	-.3217660-002
FIELD STRENGTHS AT HT = 340.0000								
EX=	-.3723199-001	.6575154-001	EY=	-.8682987-002	-.3794514-002	EZ=	-.7674096-002	-.4160397-002
HX=	.3287983+000	.1393953+000	HY=	-.1378425+001	.2398836+001	HZ=	-.8716165-002	-.3807399-002
FIELD STRENGTHS AT HT = 345.0000								
EX=	-.2828917-001	.6955299-001	EY=	-.9078089-002	-.2621248-002	EZ=	-.8128265-002	-.3114337-002
HX=	.3441885+000	.9528934-001	HY=	-.1053553+001	.2558290+001	HZ=	-.9112567-002	-.2629669-002

SAMPLE OUTPUT

FIELD STRENGTHS AT HT = 350.0000			
EX=	-.4203357-002	.7475162-001	EY=
HX=	.3564893+000	-.2142414-001	HY=
FIELD STRENGTHS AT HT = 355.0000			
EX=	-.2025657-001	.7207513-001	EY=
HX=	.3293324+000	-.1354456+000	HY=
FIELD STRENGTHS AT HT = 360.0000			
EX=	.2949796-001	.6880876-001	EY=
HX=	.3079168+000	-.1767972+000	HY=
FIELD STRENGTHS AT HT = 365.0000			
EX=	.2478532-001	.7064010-001	EY=
HX=	.3182181+000	-.1551607+000	HY=
FIELD STRENGTHS AT HT = 370.0000			
EX=	.5378100-002	.7466534-001	EY=
HX=	.5467697+000	-.6602186-001	HY=
FIELD STRENGTHS AT HT = 375.0000			
EX=	-.3588363-001	.6582904-001	EY=
HX=	.3259794+000	.1312685+000	HY=
FIELD STRENGTHS AT HT = 380.0000			
EX=	-.7479235-001	.6684917-002	EY=
HX=	.7135984-001	.3424928+000	HY=
FIELD STRENGTHS AT HT = 385.0000			
EX=	-.1993286-001	-.7251880-001	EY=
HX=	-.3228566+000	.1306530+000	HY=
FIELD STRENGTHS AT HT = 390.0000			
EX=	.7526519-001	-.3063261-002	EY=
HX=	-.5421191-001	-.3424821+000	HY=
FIELD STRENGTHS AT HT = 395.0000			
EX=	-.4204536-001	.6264649-001	EY=
HX=	.3070319+000	.1578089+000	HY=
FIELD STRENGTHS AT HT = 400.0000			
EX=	.4068940-002	-.7546010-001	EY=
HX=	-.3430216+000	.2146042-001	HY=
FIELD STRENGTHS AT HT = 405.0000			
EX=	-.2159477-001	.7299675-001	EY=
HX=	.3352878+000	.5797578-001	HY=
FIELD STRENGTHS AT HT = 410.0000			
EX=	.7644657-001	.6072010-002	EY=
HX=	-.1253096-001	-.3366574+000	HY=
FIELD STRENGTHS AT HT = 415.0000			
EX=	.6417102-001	-.4302494-001	EY=
HX=	-.2167140+000	-.2535852+000	HY=
FIELD STRENGTHS AT HT = 350.0000			
EX=	-.8673860-002	.4616074-003	EY=
HZ=	-.9445693-002	.2761637+001	HY=
FIELD STRENGTHS AT HT = 355.0000			
EX=	-.8305800-002	.3487393-002	EY=
HZ=	-.8784571-002	.2659027+001	HY=
FIELD STRENGTHS AT HT = 360.0000			
EX=	-.7905287-002	.4600821-002	EY=
HZ=	-.8251458-002	.2532859+001	HY=
FIELD STRENGTHS AT HT = 365.0000			
EX=	-.8128627-002	.4035323-002	EY=
HZ=	-.8544041-002	.2591929+001	HY=
FIELD STRENGTHS AT HT = 370.0000			
EX=	-.8641100-002	.1659876-002	EY=
HZ=	-.9307446-002	.2728463+001	HY=
FIELD STRENGTHS AT HT = 375.0000			
EX=	-.7714894-002	-.3620420-002	EY=
HZ=	-.8745719-002	.2384749+001	HY=
FIELD STRENGTHS AT HT = 380.0000			
EX=	-.9527378-003	-.9271358-002	EY=
HZ=	-.1833733-002	.2296916+000	HY=
FIELD STRENGTHS AT HT = 385.0000			
EX=	.8357430-002	-.3453417-002	EY=
HZ=	.8844096-002	-.2604809+001	HY=
FIELD STRENGTHS AT HT = 390.0000			
EX=	.5347566-003	.9378258-002	EY=
HZ=	.1385451-002	-.9781920-001	HY=
FIELD STRENGTHS AT HT = 395.0000			
EX=	-.7361251-002	-.4432839-002	EY=
HZ=	-.8427995-002	.2214336+001	HY=
FIELD STRENGTHS AT HT = 400.0000			
EX=	.8755460-002	-.4892300-003	EY=
HZ=	.9532418-002	-.2658189+001	HY=
FIELD STRENGTHS AT HT = 405.0000			
EX=	-.8512114-002	-.1735959-002	EY=
HZ=	-.9456045-002	.2524723+001	HY=
FIELD STRENGTHS AT HT = 410.0000			
EX=	-.5185476-003	.9646448-002	EY=
HZ=	.2551896-003	.2173296+000	HY=
FIELD STRENGTHS AT HT = 415.0000			
EX=	.5142575-002	.7459563-002	EY=
HZ=	.6258711-002	-.1430524+001	HY=

SAMPLE OUTPUT

FIELD STRENGTHS AT HT = 420.0000									
EX=	.7671460-001	-.1319459-001	EY=	.2668223-002	.9424136-002	EZ=	.1716987-002	.8856247-002	
HX=	-.9347490-001	-.3168037+000	HY=	.2523797+001	-.4237429+000	HZ=	.2679707-002	.9459087-002	
FIELD STRENGTHS AT HT = 425.0000									
EX=	.1935590-001	.7600526-001	EY=	-.9253293-002	.3430273-002	EZ=	-.8760543-002	.2430288-002	
HX=	.3054249+000	-.1170638+000	HY=	.6157897+000	.2458298+001	HZ=	-.9287484-002	.3444591-002	
FIELD STRENGTHS AT HT = 430.0000									
EX=	-.5917299-001	-.5238617-001	EY=	.5769087-002	-.8099197-002	EZ=	.5924376-002	-.6987116-002	
HX=	-.1850149+000	.2658877+000	HY=	-.1872722+001	-.1670865+001	HZ=	.5789473-002	-.8130493-002	
FIELD STRENGTHS AT HT = 435.0000									
EX=	.3159972-001	.7310003-001	EY=	-.8726364-002	.4924640-002	EZ=	-.8392528-002	.3843977-002	
HX=	.2776328+000	-.1607342+000	HY=	.9776156+000	.2285305+001	HZ=	-.8758344-002	.4944484-002	
FIELD STRENGTHS AT HT = 440.0000									
EX=	.6950425-001	-.4012280-001	EY=	.5943674-002	.8162702-002	EZ=	.4823633-002	.7953881-002	
HX=	-.1898433+000	-.2547786+000	HY=	.2136679+001	-.1222838+001	HZ=	.5967253-002	.8192407-002	
FIELD STRENGTHS AT HT = 445.0000									
EX=	.2853641-001	-.7567706-001	EY=	.9847484-002	.2563807-002	EZ=	.8841415-002	.3116183-002	
HX=	-.3054024+000	-.7593276-001	HY=	.8687060+000	-.2278433+001	HZ=	.9884840-002	.2571891-002	
FIELD STRENGTHS AT HT = 450.0000									
EX=	.4974385-001	-.6457340-001	EY=	.8740496-002	.5364032-002	EZ=	.7608728-002	.5600617-002	
HX=	-.2674513+000	-.1601093+000	HY=	.1480864+001	-.1908095+001	HZ=	.8774135-002	.5382798-002	
FIELD STRENGTHS AT HT = 455.0000									
EX=	.7725765-001	.2793649-001	EY=	-.2466252-002	.1003714-001	EZ=	-.3040233-002	.9023539-002	
HX=	.7037215-001	-.3006412+000	HY=	.2247077+001	.8215287+000	HZ=	-.2473940-002	.1007519-001	
FIELD STRENGTHS AT HT = 460.0000									
EX=	-.6936730-001	.4567417-001	EY=	-.6634011-002	-.8031718-002	EZ=	-.5469566-002	-.7885953-002	
HX=	.1973657+000	.2336527+000	HY=	-.1981419+001	.1300477+001	HZ=	-.6660161-002	-.8060824-002	
FIELD STRENGTHS AT HT = 465.0000									
EX=	.6968090-001	-.4593979-001	EY=	.6675828-002	.8104266-002	EZ=	.5502893-002	.7955473-002	
HX=	-.1952077+000	-.2317324+000	HY=	.1964601+001	-.1285702+001	HZ=	.6702146-002	.8133638-002	
FIELD STRENGTHS AT HT = 470.0000									
EX=	-.7944816-001	-.2766980-001	EY=	.2401343-002	-.1030738-001	EZ=	.2999794-002	-.9277379-002	
HX=	-.6488572-001	.2930690+000	HY=	-.2194079+001	-.7723183+000	HZ=	.2408746-002	-.1034643-001	
FIELD STRENGTHS AT HT = 475.0000									
EX=	-.4670159-001	.7078572-001	EY=	-.9477796-002	-.4896783-002	EZ=	-.8323650-002	-.5226191-002	
HX=	.2656813+000	.1335834+000	HY=	-.1275306+001	.1919400+001	HZ=	-.9514129-002	-.4913681-002	
FIELD STRENGTHS AT HT = 480.0000									
EX=	-.1242301-001	.8457940-001	EY=	-.1074534-001	-.4240328-003	EZ=	-.9832280-002	-.1217006-002	
HX=	.2944979+000	.8377210-002	HY=	-.3389518+000	.2257844+001	HZ=	-.1078573-001	-.4239469-003	
FIELD STRENGTHS AT HT = 485.0000									
EX=	-.4712689-001	.7215098-001	EY=	-.9654465-002	-.4930025-002	EZ=	-.8484105-002	-.5269222-002	
HX=	.2614072+000	.1298807+000	HY=	-.1242897+001	.1890059+001	HZ=	-.9691466-002	-.4947020-002	
FIELD STRENGTHS AT HT = 490.0000									

SAMPLE OUTPUT

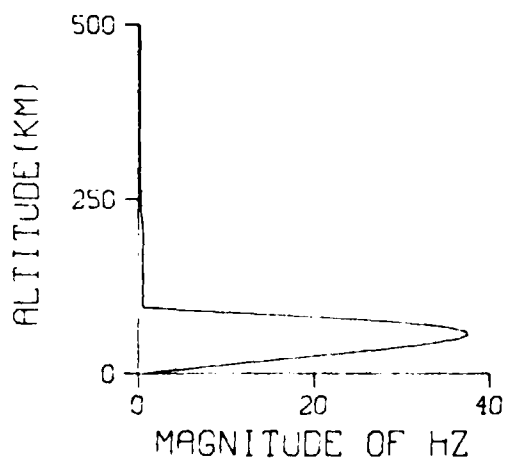
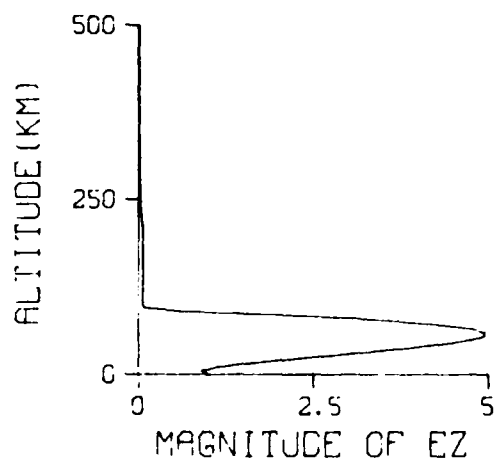
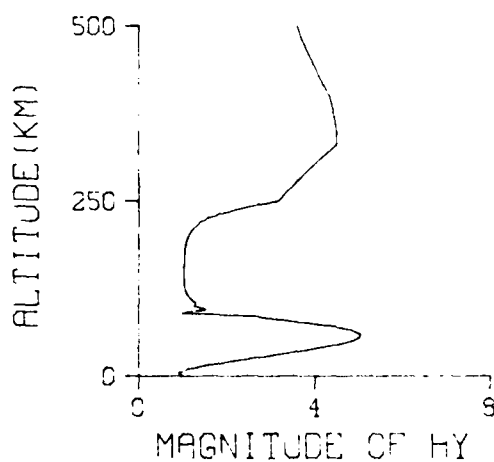
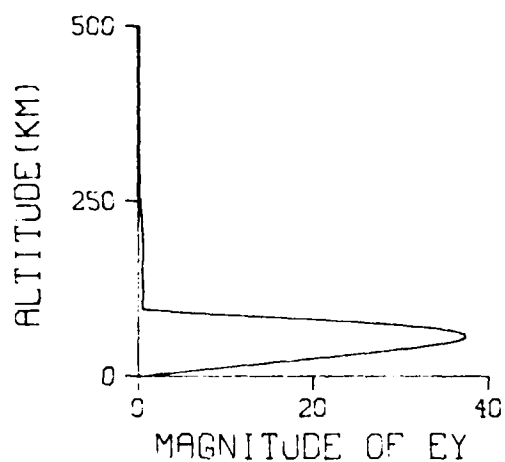
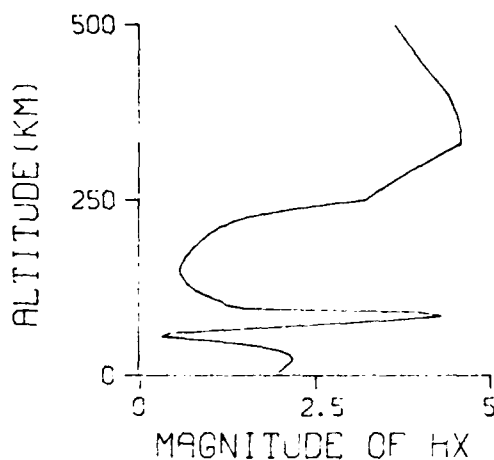
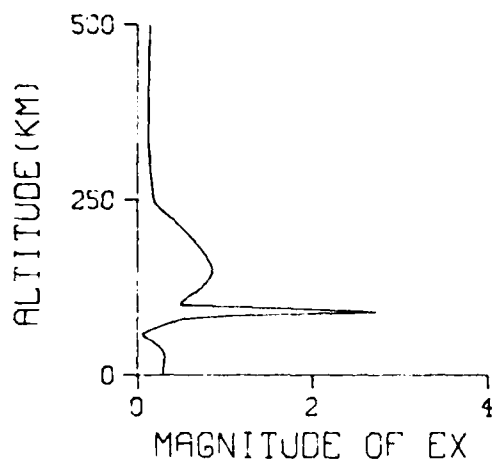
EX=	-.8310647-001	-.2532007-001	EY=	.2055134-002	-.1073309-001	EZ=	.2712196-002	-.9695892-002
HX=	-.5125973-001	.2846279+000	HY=	-.2142045+001	-.6596929+000	HZ=	.2061171-002	-.1077369-001
FIELD STRENGTHS AT HT = 495.0000								
EX=	.6599372-001	-.5758574-001	EY=	.8085582-002	.7482845-002	EZ=	.6848420-002	.7491271-002
HX=	-.2124382+000	-.1923065+000	HY=	.1677609+001	-.1455201+001	HZ=	.8117094-002	.7509664-002
FIELD STRENGTHS AT HT = 500.0000								
EX=	-.5456617-001	.6942453-001	EY=	-.9412146-002	-.5894200-002	EZ=	-.8190101-002	-.8134202-002
HX=	.2422898+000	.1480235+000	HY=	-.1364766+001	.1726200+001	HZ=	-.9449693-002	-.5914851-002

PROGRAM VERIFICATION

A variety of comparisons were made between the WKB extended height gains and the full-wave Runge-Kutta results. Two representative examples of the comparisons are given in tables 1 and 2.

Table 1 shows comparison between the full-wave calculated field components and the WKB calculations for the parameters given in the sample input of the previous section. Given in the table are all six field components at 250,350 and 500 km. Five sets of WKB results are given. These correspond to TOPHT settings of 100, 110, 120, 130 and 150 km. Though there is a reasonable improvement between the results for TOPHT $\geq$ 110 Km and those for TOPHT = 100 Km, the improvement with increasing TOPHT to 150 Km is at best very minor. This is probably because some residual reflection occurs at altitudes greater than 150 Km. For TOPHT $\geq$ 110 Km most of the comparisons agree to better than 2%. There are a couple of cases where the smaller of the Re and Im parts differ from the fullwave calculation by about 10%. In view of path and ionospheric uncertainties this difference would be of no significance in any practical applications. Even with TOPHT=150 Km, the cost savings over the full wave integration was more than an order of magnitude on the Univac 1100/82 system.

GLOBAL NIGHTTIME IONOSPHERE (SAT. NIGHT ABOVE 99, H_i=87 BELOW 99)
 AZIM=87.8 DEG, CODIP=6.6 DEG, MAGFLD=5.2×10⁻¹ GAUSS
 FREQ=17.8 KHZ, SIGMA=10.0×10⁻⁶ S/M, EPSLON=4.4×10⁻¹¹ F/M
 HY NORMALIZED TO 1 AT THE GROUND



PROGRAM VERIFICATION

A variety of comparisons were made between the WKB extended height gains and the full-wave Runge-Kutta results. Two representative examples of the comparisons are given in tables 1 and 2.

Table 1 shows comparison between the full-wave calculated field components and the WKB calculations for the parameters given in the sample input of the previous section. Given in the table are all six field components at 250, 350 and 500 km. Five sets of WKB results are given. These correspond to TOPHT settings of 100, 110, 120, 130 and 150 km. Though there is a reasonable improvement between the results for TOPHT $\geq$ 110 Km and those for TOPHT = 100 Km, the improvement with increasing TOPHT to 150 km is at best very minor. This is probably because some residual reflection occurs at altitudes greater than 150 Km. For TOPHT $\geq$ 110 Km most of the comparisons agree to better than 2%. There are a couple of cases where the smaller of the Re and Im parts differ from the fullwave calculation by about 10%. In view of path and ionospheric uncertainties this difference would be of no significance in any practical applications. Even with TOPHT=150 Km, the cost savings over the full wave integration was more than an order of magnitude on the Univac 1100/82 system.

Table 1 presented results in the VLF band at 17.8 kHz. Table 2 shows results at lower ELF (75 Hz) for the electron and ion density profiles and collision frequency profiles shown below:

SATELLITE NIGHT AMBIENT PROFILE			
800.00	5.00+004	5.00+004	1.00-040
700.00	7.00+004	7.00+004	1.00-040
600.00	1.10+005	1.10+005	1.00-040
500.00	2.00+005	2.00+005	1.00-040
400.00	4.00+005	4.00+005	1.00-040
370.00	4.30+005	4.30+005	1.00-040
350.00	4.40+005	4.40+005	1.00-040
330.00	4.50+005	4.50+005	1.00-040
300.00	5.00+005	5.00+005	1.00-040
270.00	5.00+005	5.00+005	1.00-040
250.00	5.00+005	5.00+005	1.00-040
220.00	1.40+003	1.40+003	1.00-040
210.00	1.60+003	1.60+003	1.00-040
200.00	1.00+003	1.00+003	1.00-040
190.00	6.50+002	6.50+002	1.00-040
180.00	4.60+002	4.60+002	1.00-040
170.00	3.40+002	3.40+002	1.00-040
160.00	2.80+002	2.80+002	1.00-040
150.00	2.60+002	2.60+002	1.00-040
140.00	2.50+002	2.50+002	1.00-040
130.00	2.50+002	2.50+002	1.00-040
120.00	2.50+002	2.50+002	1.00-040
110.00	1.80+002	1.80+002	1.00-040
100.00	1.10+003	1.10+003	1.00-040
90.00	1.30+003	1.30+003	1.00-040
80.00	1.70+003	1.70+003	1.00-040
70.00	1.90+003	1.90+003	1.00-040
60.00	2.90+003	2.90+003	1.00-040
50.00	1.90+003	1.90+003	1.00-040
40.00	1.80+003	1.80+003	1.00-040
30.00	1.80+003	1.80+003	1.00-040
20.00	1.80+003	1.80+003	1.00-040
10.00	1.80+003	1.80+003	1.00-040
0.00	1.80+003	1.80+003	1.00-040
800.00	5.00+001	7.00-004	2.00-004
700.00	7.00+001	7.00-004	2.00-004
600.00	1.10+002	1.00-002	1.00-002
500.00	2.00+002	2.00-002	1.00-002
400.00	3.80+002	1.80-002	1.00-002
370.00	3.90+002	1.90-002	1.00-002
350.00	4.00+002	2.00-002	1.00-002
330.00	4.10+002	2.10-002	1.00-002
300.00	4.20+002	2.20-002	1.00-002
270.00	4.30+002	2.30-002	1.00-002
250.00	4.40+002	2.40-002	1.00-002
220.00	4.50+002	2.50-002	1.00-002
210.00	4.60+002	2.60-002	1.00-002
200.00	4.70+002	2.70-002	1.00-002
190.00	4.80+002	2.80-002	1.00-002
180.00	4.90+002	2.90-002	1.00-002
170.00	5.00+002	3.00-002	1.00-002
160.00	5.10+002	3.10-002	1.00-002
150.00	5.20+002	3.20-002	1.00-002
140.00	5.30+002	3.30-002	1.00-002
130.00	5.40+002	3.40-002	1.00-002
120.00	5.50+002	3.50-002	1.00-002
110.00	5.60+002	3.60-002	1.00-002
100.00	5.70+002	3.70-002	1.00-002
90.00	5.80+002	3.80-002	1.00-002
80.00	5.90+002	3.90-002	1.00-002
70.00	6.00+002	4.00-002	1.00-002
60.00	6.10+002	4.10-002	1.00-002
50.00	6.20+002	4.20-002	1.00-002
40.00	6.30+002	4.30-002	1.00-002
30.00	6.40+002	4.40-002	1.00-002
20.00	6.50+002	4.50-002	1.00-002
10.00	6.60+002	4.60-002	1.00-002
0.00	6.70+002	4.70-002	1.00-002
800.00	5.00+001	7.00-004	2.00-004
700.00	7.00+001	7.00-004	2.00-004
600.00	1.10+002	1.00-002	1.00-002
500.00	2.00+002	2.00-002	1.00-002
400.00	3.80+002	1.80-002	1.00-002
370.00	3.90+002	1.90-002	1.00-002
350.00	4.00+002	2.00-002	1.00-002
330.00	4.10+002	2.10-002	1.00-002
300.00	4.20+002	2.20-002	1.00-002
270.00	4.30+002	2.30-002	1.00-002
250.00	4.40+002	2.40-002	1.00-002
220.00	4.50+002	2.50-002	1.00-002
210.00	4.60+002	2.60-002	1.00-002
200.00	4.70+002	2.70-002	1.00-002
190.00	4.80+002	2.80-002	1.00-002
180.00	4.90+002	2.90-002	1.00-002
170.00	5.00+002	3.00-002	1.00-002
160.00	5.10+002	3.10-002	1.00-002
150.00	5.20+002	3.20-002	1.00-002
140.00	5.30+002	3.30-002	1.00-002
130.00	5.40+002	3.40-002	1.00-002
120.00	5.50+002	3.50-002	1.00-002
110.00	5.60+002	3.60-002	1.00-002
100.00	5.70+002	3.70-002	1.00-002
90.00	5.80+002	3.80-002	1.00-002
80.00	5.90+002	3.90-002	1.00-002
70.00	6.00+002	4.00-002	1.00-002
60.00	6.10+002	4.10-002	1.00-002
50.00	6.20+002	4.20-002	1.00-002
40.00	6.30+002	4.30-002	1.00-002
30.00	6.40+002	4.40-002	1.00-002
20.00	6.50+002	4.50-002	1.00-002
10.00	6.60+002	4.60-002	1.00-002
0.00	6.70+002	4.70-002	1.00-002

The comparison between the full wave calculated field components and the WKB calculations are for the parameters included as part of the Table legend. Given in the table are all six field components at 400,600 and 800 km. The WKB result is for TOPHT = 250 km and the agreement is good to about 1% in this case which is typical of the lower ELF band.

Field + Height Km	E _x		E _y		E _z		H _x		H _y		H _z	
	Re	Im	Re	Im	Re	Im	Re	Im	Re	Im	Re	Im
FULL WAVE TOPHT = 500 Km	-119	.132	-.133	-.118	-.016	-.013	2.362	2.100	-2.104	2.365	-.133	-.119
	.119	.020	-.019	.129	-.002	.014	.723	-4.449	4.450	.723	-.019	-.120
	.102	.100	-.099	.102	-.011	.012	2.496	-2.571	2.573	2.498	-.100	.103
WKB TOPHT = 100 Km	-108	.131	-.136	-.129	-.016	-.014	2.568	2.062	-2.116	2.226	-.136	-.129
	.115	.014	-.024	.125	-.002	.015	.511	-4.668	4.292	.836	-.024	.125
	.102	.091	-.108	.104	-.012	.013	2.454	-2.813	2.421	2.497	-.108	.105
WKB TOPHT = 110 Km	-119	.134	-.134	-.118	-.016	-.013	2.395	2.110	-2.098	2.389	-.134	-.119
	.120	.019	-.019	.120	-.002	.014	.701	-4.496	4.474	.690	-.019	-.120
	.104	.099	-.099	.103	.011	.013	2.501	-2.614	2.606	2.484	-.100	.104
WKB TOPHT = 120 Km	-117	.135	-.132	-.118	-.016	-.013	2.406	2.118	-2.071	2.382	-.132	-.119
	.120	.017	-.020	-.119	.002	-.014	.702	-4.515	4.445	.663	-.020	.119
	.105	.098	-.099	.102	.011	.012	2.510	-2.627	2.599	2.453	-.100	.102
WKB TOPHT = 130 Km	-118	.135	-.130	-.119	-.016	-.013	2.395	2.137	-2.088	2.382	-.131	-.119
	.121	.018	-.021	.118	-.002	.014	.734	-4.517	4.457	.683	-.021	.119
	.104	.099	-.100	.101	-.011	.012	2.531	-2.613	2.598	2.472	-.100	.101
WKB TOPHT = 150 Km	-119	.133	-.134	-.117	-.016	-.013	2.380	2.090	-2.092	2.389	-.134	-.117
	.120	.019	-.018	.119	-.002	.014	.688	-4.463	4.469	.682	-.018	-.120
	.103	.099	-.098	.103	-.011	.013	2.477	-2.598	2.606	2.477	-.098	.104

TABLE 1. HEIGHT GAIN COMPARISONS FOR "GLOBAL NIGHTTIME IONOSPHERE" AT 17.8 KHZ.
(See sample input for geomagnetic and ground parameters.)

Field + Height Km	E _x		E _y		E _z		H _x		H _y		H _z	
	Re(10 ⁻²)	Im(10 ⁻²)	Re(10 ⁻²)	Im(10 ⁻²)	Re(10 ⁻²)	Im(10 ⁻²)	Re(10 ⁻²)	Im(10 ⁻²)	Re(10 ⁻²)	Im(10 ⁻²)	Re(10 ⁻²)	Im(10 ⁻²)
FULL WAVE TOPHT = 800 Km	400	.212	.057	.055	.203	.032	-.117	.286	-1.055	1.105	.300	-.052
	600	.095	.289	-.276	.090	.159	-.052	.746	-.245	.256	.782	-.316
	800	.228	.291	-.279	.217	.161	-.125	.510	-.396	.414	.534	-.312
WKB TOPHT = 250 Km	400	.212	.057	-.055	.203	.032	-.117	.286	-1.048	1.098	.297	-.052
	600	.095	.287	-.274	.090	.158	-.052	.744	-.244	.256	.779	-.315
	800	.227	.290	-.277	.216	.160	-.125	.507	-.395	.413	.531	-.311

TABLE 2. HEIGHT GAIN COMPARISONS FOR "SATELLITE NIGHT AMBIENT PROFILE" AT 75 HZ.
 (Geomagnetic field = $.5 \times 10^{-4}$ w/m², AZIM = 270°, DIP = 60°,
 ground conductivity = 3 siemens/m,
 ground permittivity = $.7172 \times 10^{-9}$ farads/m,
 ground eigenangle: 84.295°, -33.075°).

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APPENDIX:

WKBHTG PROGRAM LISTING

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1  C
2  C PROGRAM DRIVER
3  C THE DRIVER PROGRAM ALTERNATELY CALLS
4  C FOR THE INPUT OF DATA ON THE STANDARD
5  C INPUT UNIT AND CALLS FOR THE COMPUTATION
6  C OF HEIGHT GAIN FUNCTIONS BY WAVFLD.
7
8  C
9  C IMPLICIT REAL*8 (A-H,O-Z)
10 C COMPLEX*16 EX(129), EY(129), EZ(129),
11 C HX(129), HY(129), HZ(129)
12 C $,THETA
13 C REAL*8 MAGFLD,LWSTHT
14
15 C COMMON/WFINPT/THETA,FREQ,AZIM,CODIP,MAGFLD,COEFNU(5),EXPNU(5),
16 C STOPTHT,LWSTHT,WKBHT,DELHT,H,ALPHA,SIGMA,EPSILON
17 C COMMON/EXC IN/IEXC
18
19 C ISTART = 1
20 C 100 CALL XINPUT (ISTART, ISTOP)
21 C ISTART = 0
22 C DO 200 J=1,129
23 C EX(J) = 0.0
24 C EY(J) = 0.0
25 C EZ(J) = 0.0
26 C HX(J) = 0.0
27 C HY(J) = 0.0
28 C HZ(J) = 0.0
29 C CALL WAVFLD(EX,EY,EZ,HX,HY,HZ)
30 C IF(IEXC .EQ. 0)GO TO 250
31 C JHT = WKBHT/DELHT+1.01
32 C HT = 0.
33 C PRINT 176
34 C PRINT 174
35 C DO 300 IHT = 1,JHT
36 C PRINT 175,HT,EX(IHT),EY(IHT),EZ(IHT),HX(IHT),HY(IHT),HZ(IHT)
37 C HT = HT+DELHT
38 C 300 CONTINUE
39 C IF(ISTOP .EQ. 0)GO TO 100
40 C 174 FORMAT(//,' HEIGHT GAINS NORMALIZED FOR USE WITH WKB MODE SUMMING
41 C $FORMULAS',/)
42 C 175 FORMAT(//,' FIELD STRENGTHS AT HT =',F10.4,/,
43 C $, EX=',E17.7,E15.7,5X,' EY=',E17.7,E15.7,5X,
44 C $, EZ=',E17.7,E15.7,/, HX=',E17.7,E15.7,5X,
45 C $, HY=',E17.7,E15.7,5X,' HZ=',E17.7,E15.7)
46 C 176 FORMAT('1')
47 C END

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1  SUBROUTINE XINPUT (ISTART, ISTOP)
2
3  C XINPUT READS IN IONOSPHERIC INPUT
4  C DATA (VIA NAMELIST). AS WELL AS
5  C ELECTRON OR ION DENSITY AND
6  C COLLISION FREQUENCY PROFILES. THIS
7  C ROUTINE SHOULD BE CALLED PRIOR TO
8  C CALLING WAVFLD. ISTART = 1 INDICATES
9  C THAT A NEW SET OF INPUT DATA IS TO BE
10 C READ. ISTART = 0 INDICATES AN UPDATE
11 C OF EXISTING DATA. ISTOP = 1 INDICATES
12 C THE END OF INPUT DATA FOR THIS JOB.
13 C ISTOP = 0 INDICATES MORE INPUT DATA
14 C APPEARS IN THE DATA DECK.
15 C
16
17 C IMPLICIT REAL *8 (A-H,O-Z)
18 C DIMENSION ED(5),COLL(5)
19 C CHARACTER*4 BCD(20)
20 C CHARACTER*4 LABEL2(20)
21 C COMMON/WFLABL/LABEL2
22 C COMMON/WFINPT/THETA,FREQ,AZIM,CODIP,MAGFLD,COEFNU(5),EXPNU(5),
23 C $STOPHT,LWSTHT,WKBHT,DELHT,H,ALPHA,SIGMA,EPSLON
24 C COMMON/WF FLAG/PRECSN,ISO,IDBG
25 C $COMMON/WFPROF/ENHT(100),ENLOG(100,5),COLLHT(25),COLLFR(25,5),
26 C $LHT,MHT,CHARGE(5),RAT10M(5),NRSPEC
27 C COMMON/EXC IN/IEXC
28 C COMMON/ITRAT/ITR
29 C REAL*8 MAGFLD,LWSTHT
30 C COMPLEX*16 THETA
31
32 C
33 C NAMELIST/DATUM/THETA,FREQ,IDBG,STOPHT,LWSTHT,WKBHT,DELHT,PRECSN,
34 C $AZIM,CODIP,MAGFLD,COEFNU,EXPNU,ALPHA,SIGMA,EPSLON,ISO,
35 C $IEXC,ITR,H
36 C NAMELIST /SPECIE/ NRSPEC, CHARGE, RAT10M
37 C
38
39 C
40 C IDAT = 0
41 C ISTOP = 1
42 C ICOLL = 1
43 C IF (ISTART.NE.0) ICOLL = 0
44
45 C
46 C PRINT 904
47 C 100 READ 900, BCD
48 C PRINT 901, BCD
49 C IF(BCD(1)).EQ. 'DATU') GO TO 200
50 C IF(BCD(1)).EQ. 'SPEC') GO TO 300
51 C IF(BCD(1)).EQ. 'COLL') GO TO 400
52 C IF(BCD(1)).EQ. 'PROF') GO TO 500
53 C PRINT 904
54 C IF(BCD(1)).EQ. 'STOP') GO TO 120
55 C IF(BCD(1)).NE. 'QUIT') GO TO 800
56 C ISTOP = 0
57 C 120 IF (IDAT.EQ.0.AND.ISTART.NE.0) GO TO 800

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55 IF (ICOLL.NE.0) RETURN
56 COLLHT(1) = TOPHT
57 COLLHT(2) = 0.0
58 DO 150 J = 1,NRSPEC
59 COLLFR(2,J) = DLOG (COEFNU(J))
60 COLLFR(1,J) = COLLFR(2,J) + 1000.0 * TOPHT * EXPNU(J)
61
62 150 CONTINUE
63 RETURN
64
65 C
66 200 IF (BCD(2) .NE. 'MFOL') GO TO 800
67 IDAT = 1
68 PREVNU = COEFNU(1)
69 COEFNU(1) = 0.0
70 READ (5, DATUM)
71 IF (COEFNU(1).NE.0.0) ICOLL = 0
72 IF (COEFNU(1).EQ.0.0) COEFNU(1) = PREVNU
73 249 WRITE (6, DATUM)
74 GO TO 100
75
76 C
77 300 READ (5, SPECIE)
78 WRITE (6, SPECIE)
79 GO TO 100
80
81 C
82 400 IF (BCD(2) .NE. 'FREQ') GO TO 800
83 ICOLL = 1
84 L = 1
85 410 READ 902, HT, COLL
86 IF (DABS(HT-999.99).LT.0.01) GO TO 430
87 IF (L.GT.25) GO TO 800
88 IF (L.NE.1 .AND. HT .GE. COLLHT(L-1)) GO TO 800
89 DO 411 M=1,NRSPEC
90 IF (COLL(M) .LE. 0.0) COLL(M)=1.0D-40
91 CONTINUE
92 PRINT 903,HT,(COLL(M),M=1,NRSPEC)
93 COLLHT(L) = HT
94 DO 415 M=1,NRSPEC
95 COLLFR(L,M)=DLOG(COLL(M))
96 L = L + 1
97 GO TO 410
98 PRINT 903,HT
99 GO TO 100
100
101 C
102 500 IF (BCD(2) .NE. 'ILE ') GO TO 800
103 READ 900, LABEL2
104 PRINT 901,LABEL2
105 L=1
106 510 READ 902,HT,ED
107 IF (DABS(HT-999.99).LT. 0.01) GO TO 530
108 IF (L.GT.100) GO TO 800
109 IF (L.NE.1 .AND. HT .GE. ENHT(L-1)) GO TO 800
110 ENHT(L) = HT
111 IF (NRSPEC .EQ. 3) ED(3) = ED(2)-ED(1)
112 DO 511 M=1,NRSPEC
113 IF (ED(M) .LE. 0.0) ED(M)=1.0D-40
114 CONTINUE
115 PRINT 903,HT,(ED(M),M=1,NRSPEC)
116 DO 515 M=1,NRSPEC

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112      ENLOG(L,M) = DLOG(ED(M))
113      L = L+1
114      GO TO 510
115      PRINT 903,HT
116      GO TO 100
117      C
118      C      ERROR EXIT
119      C      800 PRINT 910
120      STOP
121      FORMAT (20A4)
122      FORMAT (1X,20A4)
123      FORMAT(F7.2,4X,5(1X,E9.2))
124      FORMAT(1X,F7.2,5X,5(1PE9.2,6X))
125      FORMAT(' ',//)
126      FORMAT ('ERROR IN DATA DECK DETECTED'./.)
127      $ IN SUBROUTINE XINPUT'
128      END

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SUBROUTINE WF DENS (HT, EN, COLL)
C
C WF DENS COMPUTES THE ION DENSITY
C AND COLLISION FREQUENCY FOR EACH
C SPECIE BY LOGARITHMIC INTERPOLATION
C OF THE CORRESPONDING PROFILES.
C PROFILE VALUES ARE INTERPOLATED BETWEEN
C ENTRIES MHT AND MHT+1 (LHT AND LHT+1).
C
IMPLICIT REAL *B (A-H,O-Z)
COMMON/WFPROF/ENHT(100),ENLOG(100,5),COLLHT(25),COLLFR(25,5),
$      LHT,MHT,CHARGE(5),RAT10M(5),NRSPEC
DIMENSION EN(5), COLL(5), DELE(5), DELC(5)
COMMON/PRIMES/DELE,DELC
DATA EPSHT/5.0-4/
C
LUCKY=0
MUCKY=0
IF (LHT.EQ.0) LHT=1
IF (MHT.EQ.0) MHT=1
C
10 IF (HT.GE.ENHT(LHT+1)-EPSHT .AND. HT.LT.ENHT(LHT)+EPSHT) GO TO 20
IF (LUCKY.EQ.1) GO TO 30
LHT=LHT-1
IF (LHT.EQ.0) LHT=1
IF (LHT.EQ.1) LUCKY=1
GO TO 10
30 LHT=LHT+1
IF (LHT.GT.101) GO TO 899
GO TO 10
C
20 IF (HT.GE.COLLHT(MHT+1)-EPSHT.AND.HT.LT.COLLHT(MHT)+EPSHT)GOTO 100
IF (MUCKY.EQ.1) GO TO 40
MHT=MHT-1
IF (MHT.EQ.0) MHT=1
IF (MHT.EQ.1) MUCKY=1
GO TO 20
40 MHT=MHT+1
IF (MHT.GT. 26) GO TO 899
GO TO 20
C
100 IF (LHT.EQ.LSAVE) GO TO 200
DO 150 K = 1,NRSPEC
DELE(K) = (ENLOG(LHT+1,K) - ENLOG(LHT,K))
$ / (ENHT(LHT+1) - ENHT(LHT))
150 CONTINUE
LSAVE = LHT
C
200 IF (MHT.EQ.MSAVE) GO TO 300
DO 250 K = 1,NRSPEC
DELC(K) = (COLLFR(MHT+1,K) - COLLFR(MHT,K))
$ / (COLLHT(MHT+1) - COLLHT(MHT))
250 CONTINUE
MSAVE = MHT

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55 300 DH = HT - ENHT(LHT)
56 DC = HT - COLLHT(MHT)
57 DO 500 K = 1, NRSPEC
58 EN(K) = DEXP (ENLOG(LHT,K) + DH * DELE(K))
59 COLL(K) = DEXP (COLLFR(MHT,K) + DC * DELC(K))
60 500 CONTINUE
61 RETURN
62 899 PRINT 900
63 900 FORMAT (' ERROR IN PROFILE INTERPOLATION')
64 STOP
65 END

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1  SUBROUTINE WAVFLD(EX,EY,EZ,HX,HY,HZ)
2
3  C  WAVFLD CALLS FOR THE DOWNWARD
4  C  INTEGRATION, AND THEN PERFORMS THE
5  C  BACK SUBSTITUTION OF NORMALIZING
6  C  VALUES (SAVED AS DATA BY WFSTOR).
7  C  FIELD STRENGTHS ARE COMPUTED AT
8  C  HEIGHTS FROM TOPHT TO LWSTHT AT
9  C  DELHT INCREMENTS, AND ARE RETURNED
10 C  IN THE LISTS EX, EY, EZ, HX, HY, HZ.
11 C
12
13  IMPLICIT REAL *8 (A-H,O-Z)
14  CHARACTER*4 LABEL2(20)
15  COMMON/WFLABL/LABEL2
16  COMMON/START/INEX, INEY, INHX, INHY
17  COMMON/WF FLAG/PRECSN, ISO, IDBG
18  COMMON/WF SAVE/P(4,2), M31, M32, M33, ORTHO, ANORM, BNORM, HT, LEVL
19  COMMON/CS/C,S,CI,SI
20  COMMON /WFINPT/ THETA, FREQ.
21  $AZNUTH, CODIP, MAGFLD, COEFNU(5), EXPNU(5),
22  $ TOPHT, LWSTHT, WKBHT, DELHT, H,
23  $ ALPHA, SIGMA, EPSLON
24  COMMON/EXC IN/IEXC
25  COMMON/D RX TX/EYD, EZD, RBAR11, RBAR22
26  REAL*8 MAGFLD, LWSTHT
27  COMPLEX*16 EX(1), EY(1), EZ(1),
28  $ HX(1), HY(1), HZ(1),
29  $ P, M31, M32, M33, ORTHO,
30  $ C,S,CI,SI,
31  $ THETA,
32  $ EYD,EZD,
33  $ INEX, INEY, INHX, INHY,
34  $ B(2), W(4), O SUM
35  $ .EXSTOR, EYSTOR, EZSTOR, HXSTOR, HYSTOR, HZSTOR
36  $ .RBAR11, RBAR22
37  REAL*4 XARRAY(6,129), YARRAY(129), XARRAY(129), XMIN, XMAX, XOR, XSTEP,
38  $ XAXIS, YOR, YSTEP, YAXIS
39  REAL*4 PORX(6)/3+1.5, 3*5.0/
40  REAL*4 PORY(6)/7.0, 4.0, 1.0, 0.7, 0.4, 0.1, 0.0/
41  CHARACTER*15 LABEL(6) /'MAGNITUDE OF EX', 'MAGNITUDE OF EY',
42  $ /'MAGNITUDE OF EZ', 'MAGNITUDE OF HX',
43  $ /'MAGNITUDE OF HY', 'MAGNITUDE OF HZ'/
44  EQUIVALENCE(LWSTHT, O)
45
46  C
47  C
48  JHT = TOPHT/DELHT+1.01
49  TEST = (JHT-1)*DELHT-TOPHT
50  IF(DABS(TEST) .GT. 0.0001) GO TO 800
51  MHT = LWSTHT/DELHT+1.01
52  TEST = (MHT-1)*DELHT-LWSTHT
53  IF(DABS(TEST) .GT. 0.0001) GO TO 800
54  CALL ITRATE
55  C  ITERATION TO SATISFY MODAL EQUATION
56  CALL ITRATE

```

```

55 C
56 C COMBINE SOLUTIONS AT GROUND SO THAT
57 C THEY SATISFY BOUNDARY CONDITION.
58 C CALL WF BNDY(B)
59 C
60 C HT GAINS BELOW IONOSPHERE
61 C WFHT = 0.0
62 C DO 15 IHT=1,MHT
63 C CALL HT GAIN(WFHT,EX(IHT),EY(IHT),EZ(IHT),
64 C HX(IHT),HY(IHT),HZ(IHT))
65 C $ IF(DABS(WFHT-D) .GT. .001)GO TO 10
66 C PRINTB99
67 C PRINT 901,WFHT,EX(IHT),EY(IHT),EZ(IHT),HX(IHT),HY(IHT),HZ(IHT)
68 C EXSTOR = EX(IHT)
69 C EYSTOR = EY(IHT)
70 C EZSTOR = EZ(IHT)
71 C HXSTOR = HX(IHT)
72 C HYSTOR = HY(IHT)
73 C HZSTOR = HZ(IHT)
74 C 10 CONTINUE
75 C 15 WFHT = WFHT+DELHT
76 C
77 C PERFORM BACK SUBSTITUTION OF
78 C NORMALIZING VALUES.
79 C O SUM = 0.0
80 C PRODA = 1.0
81 C PRODB = 1.0
82 C IHT = MHT
83 C CALL WF LOAD
84 C GO TO 25
85 C
86 C 21 O SUM = O SUM+ANORM/BNORM+ORTHO
87 C PRODA = PRODA * ANORM
88 C IF(PRODA .LT. 1.0D-30) PRODA = 0.0
89 C PRODB = PRODB * BNORM
90 C CALL WF LOAD
91 C DO 23 J=1,4
92 C P(J,2) = (P(J,2)-O SUM*P(J,1))*PRODB
93 C 23 P(J,1) = P(J,1) * PRODA
94 C
95 C COMPUTE FIELD STRENGTHS
96 C AT PROFILE HEIGHTS.
97 C 25 DO 26 J=1,4
98 C 26 W(J) = P(J,1) * B(1) + P(J,2) * B(2)
99 C EX(IHT) = W(1)
100 C EY(IHT) = -W(2)
101 C EZ(IHT) = -(S *W(4)+M31*W(1)-M32*W(2))/(1.0-M33)
102 C HX(IHT) = W(3)
103 C HY(IHT) = W(4)
104 C HZ(IHT) = -S*W(2)
105 C IF(DABS(HT-D) .LT. .001)PRINT901, HT,EX(IHT)
106 C $,EY(IHT),EZ(IHT),HX(IHT),HY(IHT),HZ(IHT)
107 C
108 C IF(DABS(HT-D) .GT. 0.001) GO TO 41
109 C EX(IHT) = EXSTOR
110 C EY(IHT) = EYSTOR
111 C EZ(IHT) = EZSTOR

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112 HX(IHT) = HXSTOR
113 HY(IHT) = HYSTOR
114 HZ(IHT) = HZSTOR
115 EY D = EY(IHT)
116 EZ D = EZ(IHT)
117 41 CONTINUE
118
119 C
120 IHT = IHT + 1
121 IF (IHT.LE.JHT) GO TO 21
122 INEX=EX(IHT-1)
123 INEY=EY(IHT-1)
124 INHX=HX(IHT-1)
125 INHY=HY(IHT-1)
126 IF (LEVL .NE. 0) PRINT 903,LEVL
127 CALL WKBVAR(EX,EY,EZ,HX,HY,HZ)
128
129 C C COMPUTE AND PRINT EXCITATION FACTORS
130 IF (IEXC .NE. 0) CALL EXC FAC(S)
131 JHT = WKBHT/DELHT+1.01
132 HT = 0.
133 PRINT 898
134 DO 48 IHT = 1,JHT
135 PRINT 901,HT,EX(IHT),EY(IHT),EZ(IHT),HX(IHT),HY(IHT),HZ(IHT)
136 XARAY(1,IHT) = CDABS(EX(IHT))
137 XARAY(2,IHT) = CDABS(EY(IHT))
138 XARAY(3,IHT) = CDABS(EZ(IHT))
139 XARAY(4,IHT) = CDABS(HX(IHT))
140 XARAY(5,IHT) = CDABS(HY(IHT))
141 XARAY(6,IHT) = CDABS(HZ(IHT))
142 XARAY(IHT) = HT
143 48 HT = HT+DELHT
144 CALL BGNPL(1)
145 CALL INTAXS
146 CALL YAXANG(0.)
147 CALL AXSPLT(0.,SNGL(WKBHT),2.0,YOR,YSTEP,YAXIS)
148 DO 44 J=1,6
149 CALL PHYSOR(PORX(J),PORY(J))
150 XMIN = XARAY(J,1)
151 XMAX = XARAY(J,1)
152 XARRAY(1) = XARAY(J,1)
153 DO 42 K=2,JHT
154 IF (XARAY(J,K) .LT. XMIN) XMIN=XARAY(J,K)
155 IF (XARAY(J,K) .GT. XMAX) XMAX=XARAY(J,K)
156 XARRAY(K) = XARAY(J,K)
157 42 CONTINUE
158 CALL AXSP-T(XMIN,XMAX,2.5,XOR,XSTEP,XAXIS)
159 CALL TITLE(0,0,LABEL(J),15,'ALTITUDE(KM)',12,XAXIS,YAXIS)
160 CALL GRAPH(XOR,XSTEP,YOR,YSTEP)
161 CALL CURVE(XARRAY,YARRAY,JHT,0)
162 CALL ENDGR(J)
163 44 CONTINUE
164 CALL PHYSOR(0.,0.)
165 CALL TITLE(0,0,0,0,0,1,1,1)
166 CALL MESSAGE(LABEL2,80,0,8,10,1)
167 CALL MESSAGE('AZIM= DEG.COIP= DEG.MAGFLD= GAUSS',
168 $ 48,1,5,9,8)

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169 CALL REALN(SNGL(AZMUTH),1,2,0,9,8)
170 CALL REALN(SNGL(CODIP),1,3,8,9,8)
171 CALL REALN(SNGL(MAGFLD*1.0E4),-1,5,6,9,8) F/M',
172 CALL MESSAGE('FREQ= KHZ,SIGMA= S/M,EPSLON=
173 $ 51,1,5,9,5)
174 CALL REALN(SNGL(FREQ),1,2,0,9,5)
175 CALL REALN(SNGL(SIGMA),-1,3,9,9,5)
176 CALL REALN(SNGL(EPSLON),-1,6,2,9,5)
177 CALL MESSAGE('HY NORMALIZED TO 1 AT THE GROUND',.32,2,5,9,2)
178 CALL ENDFL(0)
179 IF(IEXC.EQ. 0)GO TO 47
180 HT = 0.
181 DO 49 IHT = 1,JHT
182 EX(IHT) = (1.+RBAR11)*EX(IHT)/EZO
183 EY(IHT) = (1.+RBAR22)*EY(IHT)/EYO
184 EZ(IHT) = (1.+RBAR11)*EZ(IHT)/EZO
185 HX(IHT) = (1.+RBAR22)*HX(IHT)/EYO
186 HY(IHT) = (1.+RBAR11)*HY(IHT)/EZO
187 HZ(IHT) = (1.+RBAR22)*HZ(IHT)/EYO
188 49 HT = HT+DELHT
189 47 CONTINUE
190 RETURN
191
192 C 800 PRINT 902
193 STOP
194
195 C 898 FORMAT('1')
196 899 FORMAT('/',) ALTERNATIVE CHECK OF HOW WELL BOUNDARY CONDITIONS ARE
197 $SATISFIED',/)
198 900 FORMAT('/',) HEIGHT GAINS WITH HY NORMALIZED TO UNITY AT THE GROUND
199 $',/)
200 901 FORMAT('/',) FIELD STRENGTHS AT HT =',F10,4,/,
201 $ EX =',E17,7,E15,7,5X,' EY =',E17,7,E15,7,
202 $ 5X,' EZ =',E17,7,E15,7,/, ' HX =',E17,7,E15,7,
203 $ 5X,' HY =',E17,7,E15,7,5X,' HZ =',E17,7,E15,7)
204 902 FORMAT(' ERROR IN WAVFLD',/)
205 $ DELHT DOES NOT DIVIDE TOPHT-LWSTHT EVENLY')
206 903 FORMAT(' ',LEVL NOT ZERO. LEVL = ',I3)
207 END

```



```

1 SUBROUTINE WF INTG(TOPHT,LWSTHT,DELHT,IFLAG)
2
3 WF INTG PERFORMS THE INTEGRATION OF
4 THE P MATRIX DOWN THROUGH THE
5 IONOSPHERE, USING THE TECHNIQUES
6 GIVEN BY PITTEWAY.
7 ACCURACY IS MAINTAINED BY ADJUSTING
8 THE STEPSIZE SO THAT THE P MATRIX
9 IS COMPUTED WITH SUFFICIENT ACCURACY.
10
11 C IFLAG=0 INTEG FOR THETA ONLY
12 C IFLAG=1 INTEG FOR THETA AND THETA-DTHETA
13 C
14
15 IMPLICIT REAL *8 (A-H,O-Z)
16 COMMON/WF FLAG/PRECSN,ISO,IDBG
17 COMMON/P MTX/P(16),PI(16)
18 COMMON/WF SAVE/P SAVE(16),M31 SAV,M32 SAV,M33 SAV,
19 $ ORTHO,ANORM,BNORM,MT,LEVL
20 COMMON/M MTX/M(3,3)
21 COMMON/WF PROF/ENHT(100),ENLOG(100,5),COLLHT(25),COLLFR(25,5),
22 $ LHT,MHT,CHARGE(5),RAT10M(5),NRSPEC
23
24 INTEGER SVFLAG
25 REAL*8 LWSTHT
26 COMPLEX*16 M31 SAV,M32 SAV,M33 SAV,ORTH0,M
27 DIMENSION PREVP(16),TEMPP(16),DPDH(16),PV DPH(16),DPIDH(16)
28 DATA EPSHT/5.0D-04/
29 DATA DHMIN/1.0D-03/
30 MINIMUM STEP-SIZE ALLOWED
31
32 C
33 C
34 C
35 C
36 C
37 C
38 C
39 C
40 C
41
42 CALL INIT T
43 CALL T MTRX(TOP HT)
44 CALL WF INIT(P)
45 CALL P DERIV(P,DPDH)
46 IF(IFLAG.EQ. 0) GO TO 11
47 CALL TI MTRX
48 CALL WF INIT(P1)
49 CALL P DERIV(P1,DPIDH)
50
51 11 CONTINUE
52
53 C
54
55 ISTEPS = 0
56 KMAX = 0
57 LEVL = 0
58 HT = TOPHT
59 CALL XFER(P,P SAVE,16)
60 M31 SAV = M(3,1)
61 M32 SAV = M(3,2)
62 M33 SAV = M(3,3)
63 CALL WF STOR
64 WFHT = TOPHT - DELHT
65 DELH2 = 0.125D0*DELHT
66 SVFLAG=0
67
68 C DETERMINE NEXT STEPSIZE TO USE.

```

```

55 10 IF (SVFLAG.EQ.1) DELH2=SAVDH2
56 40 SVFLAG=0
57 NODBL = 0
58 HTO=HT
59 CALL XFER(P,PREVP,16)
60 CALL XFER(DPDH,PV DPDH,16)
61 HTLIM = WFHT
62 IF (ENHT(LHT+1).GT.HTLIM+EPSHT)
63 $ HTLIM = ENHT(LHT+1)
64 IF (COLLHT(MHT+1).GT.HTLIM+EPSHT)
65 $ HTLIM = COLLHT(MHT+1)
66 IF (HTO-DELH2.GE.HTLIM+EPSHT) GO TO 50
67 SAVDH2 = DELH2
68 SVFLAG = 1
69 DELH2 = HTO - HTLIM
70
71 C
72 C PERFORM NEXT INTEGRATION STEP.
73 50 CALL WF STEP(P,DPDH,HT,DELH2,0)
74 CALL XFER(P,TEMPP,16)
75 M31 SAV = M(3,1)
76 M32 SAV = M(3,2)
77 M33 SAV = M(3,3)
78 HT=HTO
79 CALL XFER(PREVP,P,16)
80 CALL XFER(PV DPDH,DPDH,16)
81 DELH=0.5*DELH2
82 CALL WF STEP(P,DPDH,HT,DELH,1)
83 CALL P DERIV(P,DPDH)
84 CALL WF STEP(P,DPDH,HT,DELH,2)
85 C CHECK ACCURACY OF RESULT.
86 PMAX = 0.0
87 DO 85 J=1,16
88 PABS = DABS(P(J)-TEMPP(J))
89 IF (P(J).NE.0.) PABS=DABS((P(J)-TEMPP(J))/P(J))
90 IF (PMAX.LT. PABS) PMAX = PABS
91 85 CONTINUE
92 C ADJUST STEPSIZE IF NECESSARY.
93 IF (PMAX.LT.PRECSN) GO TO 100
94 C
95 IF (DELH.GT.DHMIN) GO TO 95
96 IF (KMAX.EQ.0) PRINT 900, HT
97 KMAX = 1
98 GO TO 100
99 95 CONTINUE
100 DELH2 = 0.5 * DELH2
101 NODBL = 1
102 IF (PMAX.LT.10.0*PRECSN) GO TO 99
103 DELH2 = 0.25 * DELH2
104 NODBL = 0
105 99 CONTINUE
106 HT=HTO
107 CALL XFER(PREVP,P,16)
108 CALL XFER(PV DPDH,DPDH,16)
109 SVFLAG=0
110 GO TO 50
111 C
112 100 CALL WF SCAL(P,0)

```

```

112 CALL XFER(P,P,SAVE,16)
113 IF (HT.LT.WFHT+EPSHT) CALL WF STOR
114 CALL P DERIV(P,DPOH)
115 IF (IFLAG.EQ. 0) GO TO 72
116 HT = HTO
117 CALL WF STEP(PI,DPOH,HT,DELM,3)
118 CALL P DERIV(PI,DPOH)
119 CALL WF STEP(PI,DPOH,HT,DELM,4)
120 CALL WF SCAL(PI,1)
121 CALL P DERIV(PI,DPOH)
122 72 CONTINUE
123 C
124 ISTEPS = ISTEPS+1
125 IF (IDBG.EQ. 0) GO TO 73
126 IDIV = ISTEPS/50
127 IF (ISTEPS.EQ. 50*IDIV) PRINT 902,ISTEPS,HT
128 73 CONTINUE
129 IF (NO DBL.EQ. 0 .AND. PMAX.LT. 0.5*PRECSN) DELH2 = 2.0*DELH2
130 C
131 C CHECK INTEGRATION AND PROFILE HEIGHTS
132 IF (HT.LT.LWSTHT+EPSHT) GO TO 80
133 IF (HT.LT.WFHT+EPSHT) WFHT = WFHT - DELHT
134 IF (HT.LT.ENHT(LHT+1)+EPSHT) LHT=LHT+1
135 IF (HT.LT.COLLHT(MHT+1)+EPSHT) MHT=MHT+1
136 GO TO 10
137 C
138 80 PRINT 901,ISTEPS
139 RETURN
140 C
141 900 FORMAT (' MINIMUM STEPSIZE USED AT HT =',D14.5)
142 901 FORMAT (1X,13,' INTEGRATION STEPS USED IN WAVFLO',/)
143 902 FORMAT (1X,14,' INTEGRATION STEPS, HT =',F9.4)
144 END

```

```

1  SUBROUTINE WF STEP(P,DPDH,HT,DELH,IFLAG)
2
3  C WF STEP INCREMENTS THE SOLUTION OF P
4  C FROM HT TO HT-DELH, USING
5  C RUNGE-KUTTA INTEGRATION
6
7  C
8  C IFLAG=0 ONE LARGE STEP, THETA
9  C IFLAG=1 FIRST SMALL STEP, THETA
10 C IFLAG=2 SECOND SMALL STEP, THETA
11 C IFLAG=3 FIRST SMALL STEP, THETA-DTHETA
12 C IFLAG=4 SECOND SMALL STEP, THETA-DTHETA
13 C
14
15 C IMPLICIT REAL*8 (A-H,O-Z)
16 C COMMON/WF CON/OMEGA,WAVE NR
17 C COMMON/WF FLAG/PRECSN,ISO,IDBG
18 C COMMON/T MTX/T(18)
19 C COMMON/TM MTX/TM(18)
20 C DIMENSION P(16),DPDH(16),PO(16),
21 C $ HDELP0(16),DELP1(16),DELP2(16)
22 C $ DIMENSION T SAVE1(18),T SAVE2(18),
23 C $ TM SAV1(18),TM SAV2(18),TM SAV3(18),TM SAV4(18)
24 C
25
26 C HT0 = HT
27 C DELH K = DELH*WAVE NR
28 C HDELH K = DELH K*0.5
29 C DO 11 J=1,16
30 C PO(J) = P(J)
31 C HDELP0(J) = -DPDH(J)*HDELH K
32 C 11 P(J) = P0(J)+HDELP0(J)
33 C
34 C HT = HT0-0.5*DELH
35 C IF(IFLAG.LE. 2) CALL T MTRX(HT)
36 C IF(IFLAG.EQ. 0) CALL XFER(T,T SAVE1,18)
37 C IF(IFLAG.EQ. 0) CALL XFER(TM,TM SAV2,18)
38 C IF(IFLAG.EQ. 1) CALL XFER(TM,TM SAV1,18)
39 C IF(IFLAG.EQ. 2) CALL XFER(TM,TM SAV3,18)
40 C IF(IFLAG.EQ. 3) CALL XFER(TM SAV1,TM,18)
41 C IF(IFLAG.EQ. 4) CALL XFER(TM SAV3,TM,18)
42 C IF(IFLAG.GE. 3) CALL TI MTRX
43 C
44 C CALL P DERIV(P,DPDH)
45 C DO 12 J=1,16
46 C DELP1(J) = -DPDH(J)*DELH K
47 C 12 P(J) = P0(J)+0.5*DELP1(J)
48 C
49 C CALL P DERIV(P,DPDH)
50 C DO 13 J=1,16
51 C DELP2(J) = -DPDH(J)*DELH K
52 C 13 P(J) = P0(J)+DELP2(J)
53 C
54 C HT = HT0-DELH
55 C IF(IFLAG.EQ. 0) CALL T MTRX(HT)

```

```

55 IF(IFLAG.EQ. 0) CALL XFER(T,T,SAVE2,18)
56 IF(IFLAG.EQ. 1) CALL XFER(T,SAVE1,T,18)
57 IF(IFLAG.EQ. 2) CALL XFER(T,SAVE2,T,18)
58 IF(IFLAG.EQ. 0) CALL XFER(TM,TM,SAV4,18)
59 IF(IFLAG.EQ. 3) CALL XFER(TM,SAV2,TM,18)
60 IF(IFLAG.EQ. 4) CALL XFER(TM,SAV4,TM,18)
61 IF(IFLAG.EQ. 3) CALL TI MTRX
62
63 CALL P DERIV(P,DPDH)
64 THIRD = 1.000/3.000
65 DO 14 J=1,16
66 DELP4 = (HDELP0(J)+DELP1(J)+DELP2(J)-DPDH(J)*HDELM K)*THIRD
67 14 P(J) = P0(J)+DELP4
68 RETURN
69
70 C
END

```



```

55 Q TEMP = Q(J2)
56 Q(1) = Q(J1)
57 Q(2) = Q TEMP
58
59 C
60 DO 31 J=1,2
61 DET = (T11-Q(J))*(T44-Q(J))-T14*T41
62 P(1,J) = (T12*Q(J)-(T12*T44-T14*T42))/DET
63 P(2,J) = 1.0
64 P(3,J) = Q(J)
65 31 P(4,J) = (T42*Q(J)+(T12*T41-T11*T42))/DET
66
67 C
68 40 IF(DBG .LT. 2) RETURN
69 PRINT 902,Q
70 RETURN
71
72 C
73 50 B1 = (T11+T44)*0.5
74 B0 = T11*T44-T14*T41
75 SQR00T = CDSORT(B1**2-B0)
76 Q(1) = B1+SQR00T
77 Q(4) = B1-SQR00T
78 SQR00T = CDSORT(T32)
79 Q(2) = +SQR00T
80 Q(3) = -SQR00T
81
82 C
83 DO 51 J=1,4
84 Q ABS = CDABS(Q(J))
85 IF(Q ABS .GT. Q MAX) IFAIL = 1
86 51 CONTINUE
87 IF(IFAIL .NE. 0) GO TO 80
88
89 C
90 Q1 TEST = Q(1)+I*Q(1)
91 Q4 TEST = Q(4)+I*Q(4)
92 IF(Q4 TEST .GT. Q1 TEST) Q(1) = Q(4)
93 Q2 TEST = Q(2)+I*Q(2)
94 Q3 TEST = Q(3)+I*Q(3)
95 IF(Q3 TEST .GT. Q2 TEST) Q(2) = Q(3)
96
97 C
98 P(1,1) = T14
99 P(2,1) = 0.0
100 P(3,1) = 0.0
101 P(4,1) = -(T11-Q(1))
102
103 C
104 P(1,2) = 0.0
105 P(2,2) = 1.0
106 P(3,2) = Q(2)
107 P(4,2) = 0.0
108 GO TO 40
109
110 C
111 80 PRINT 900,Q
112 STOP
113
114 C
115 900 FORMAT(' ','ERROR IN WF INIT, Q VALUES TOO LARGE OR DO NOT SORT'
116 $ /,' Q = ',4(E15.5,E13.5),//)
117 901 FORMAT(' ','P VALUES = ',/,
118 $ 4(E15.5,E13.5),/,4(E15.5,E13.5))
119 902 FORMAT(' ','INITIAL VALUES FROM WF INIT',/,

```

112 ' 0 VALUES =',/.2(E15.5,E13.5))

113 \$

114 C

END


```

1  SUBROUTINE T MTRX(HT)
2
3  C T MTRX COMPUTES THE MATRICES
4  C M- THE SUSCEPTIBILITY TENSOR
5  C T- THE COEFFICIENT MATRIX OF
6  C THE LINEAR SYSTEM OF O.D.E.
7  C DP/DZ = -IK*T*P. CALL TO
8  C NOTE THAT ON
9  C ENTRY INIT T, VARIOUS
10 C IONOSPHERIC CONSTANTS ARE COMPUTED.
11 C
12 C IMPLICIT REAL *8 (A-H,O-Z)
13 C COMMON/WF FLAG/PRECSN,ISO,IDBG
14 C COMMON/M MTX/M11,M21,M31,M12,M22,M32,M13,M23,M33
15 C COMMON/T MTX/ T11,T31,T41,T12,T32,T42,T14,T34,T44
16 C COMMON/TA MTX/TA11,TA31,TA41,TA12,TA32,TA42,TA14,TA34,TA44
17 C COMMON/CS/C,S,CI,SI
18 C COMMON /WFINPT/ THETA, FREQ.
19 C $ AZMUTH, CODIP, MAGFLD, CEFFNU(5), EXPNU(5),
20 C $ TOPHT, LWSTHT, WKBHT,DELHT, H,
21 C $ ALPHA,SIGMA,EPSLON
22 C COMMON/WF CON/OMEGA,WAVE NR
23 C COMMON/WFPROF/ENHT(100),ENLOG(100,5),COLLHT(25),COLLFR(25,5),
24 C $ LHT,MHT,CHARGE(5),RATON(5),NRSPEC
25 C $ REAL*8 MAGFLD, LWSTHT,
26 C $ LSQSQ, MSQSQ, NSQSQ,
27 C $ LMYSQ, LNYSQ, MNYSQ, NU,
28 C $ LY,MY,NY
29 C $ COMPLEX*16 M(3,3),
30 C $ M11,M21,M31,M12,M22,M32,M13,M23,M33,
31 C $ T11,T31,T41,T12,T32,T42,T14,T34,T44,
32 C $ TM11,TM31,TM41,TM12,TM32,TM42,TM14,TM34,TM44,
33 C $ C,S,CI,SI,CSQ,SSQ,CSQI,SSQI,
34 C $ THETA,DTHETA,
35 C $ D,M13D,M23D,
36 C $ U,USQ,DD,I,IUD,TA,TB
37 C $ DIMENSION Y(5),YSQ(5),LY(5),MY(5),
38 C $ NY(5),LMYSQ(5),LNYSQ(5),MNYSQ(5),EN(5),NU(5),
39 C $ LSQSQ(5),MSQSQ(5),NSQSQ(5),
40 C $ COEF EN(5)
41 C $ EQUIVALENCE(M11,M)
42 C
43 C DATA PI/3.141592653D0/
44 C DATA DTR/1.745329252D-02/
45 C DATA COEFFX/3.182357D03/,COEFFY/1.758796D011/
46 C DATA I/10.0D0,1.0D0//
47 C DATA VELLT/2.997928D05/
48 C DATA DTHETA/(5.0D-02,1.0D-02)/
49 C
50 C
51 C CALCULATE THE MATRIX M.
52 C M(1,1) = 0.0
53 C M(1,2) = 0.0
54 C M(1,3) = 0.0

```

```

55 M(2,1) = 0.0
56 M(2,2) = 0.0
57 M(2,3) = 0.0
58 M(3,1) = 0.0
59 M(3,2) = 0.0
60 M(3,3) = 0.0
61
62 CALL WF DENS (HT, EN, NU)
63 NFLAG = 0
64 DO 20 K=1,NRSPEC
65 C ADD IN THE CONTRIBUTIONS TO THE
66 C SUSCEPTIBILITY TENSOR M FOR EACH
67 C SPECIE IN THE IONOSPHERE.
68 IF(EN(K) .LT. 1.0E-3) GO TO 20
69 NFLAG = 1
70 X = COEF EN(K)*EN(K)
71 Z = NU(K)*DV OMGA
72 U=1.0-I*Z
73 USQ=U*U
74 DD = -X / (U * (USQ - YSQ(K)))
75 IUD = (Z+I)*DD
76 TA = USQ * DD
77 M(1,1) = M(1,1) + TA
78 M(2,2) = M(2,2) + TA
79 M(3,3) = M(3,3) + TA
80 M(2,2) = M(2,2) - MSQSQ(K) * DD
81 TA = MY(K)*IUD
82 TB = LMSQ(K) * DD
83 M(1,3) = M(1,3) + TA - TB
84 M(3,1) = M(3,1) - TA - TB
85 IF (ISO.NE.0) GO TO 20
86 M(1,1) = M(1,1) - LSQSQ(K) * DD
87 M(3,3) = M(3,3) - NSQSQ(K) * DD
88 TA = MY(K)*IUD
89 TB = LMSQ(K) * DD
90 M(2,1) = M(2,1) + TA - TB
91 M(1,2) = M(1,2) - TA - TB
92 TA = LY(K)*IUD
93 TB = MMSQ(K) * DD
94 M(3,2) = M(3,2) + TA - TB
95 M(2,3) = M(2,3) - TA - TB
96
97 20 CONTINUE
98
99 C CRVTRM=ALPHA*(H-HT)
100 M(1,1) = M(1,1) - CRVTRM
101 M(2,2) = M(2,2) - CRVTRM
102 M(3,3) = M(3,3) - CRVTRM
103
104 C CALCULATE THE MATRIX T.
105 D = 1.0/(1.0+M33)
106 TM41 = 1.0*M11
107 TM32 = M22
108 TM14 = D
109 IF(NFLAG .EQ. 0) GO TO 40
110 M13D = M13*D
111 M23D = M23*D
112 TM41 = TM41-M31*M13D

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112 TM11 = M31*D
113 TM44 = M13D
114 IF(ISO .NE. 0) GO TO 40
115 TM32 = TM32-M32*M23D
116 TM31 = M31*M23D-M21
117 TM12 = M32*D
118 TM42 = M32*M13D-M12
119 TM34 = M23D
120
121 C
122 40 T41 = TM41
123 T32 = CSQ+TM32
124 T14 = 1.0-SSQ+TM14
125 IF(INFLAG.EQ. 0) GO TO 70
126 T11 = -S*TM11
127 T44 = -S*TM44
128 IF(ISO .NE. 0) RETURN
129 T31 = TM31
130 T12 = S*TM12
131 T42 = TM42
132 T34 = S*TM34
133 RETURN
134
135 C
136 ENTRY TJ MTRX
137 T41 = TM41
138 T32 = CSQI+TM32
139 T14 = 1.0-SSQI+TM14
140 T11 = -SI*TM11
141 T44 = -SI*TM44
142 IF(ISO .NE. 0) RETURN
143 T31 = TM31
144 T12 = SI*TM12
145 T42 = TM42
146 T34 = SI*TM34
147 RETURN
148
149 C
150 ENTRY INIT T
151 COMPUTE VARIOUS QUANTITIES
152 WHICH DO NOT VARY WITH HEIGHT.
153 LHT = 0
154 ISO=0
155 IF(MAGFLD.EQ. 0.0) GO TO 250
156 IF (DABS(CODIP-90.0).GE.0.15) GO TO 300
157 IF (DABS(AZMUTH-90.0).LT.0.15) GO TO 250
158 IF (DABS(AZMUTH-270.0).GE.0.15) GO TO 300
159 ISO = 1
160 250 ISO = 1
161 300 OMEGA = 2000.0 * PI * FREQ
162 OV OMEGA = 1.0/OMEGA
163 WAVENR=OMEGA/VELLT
164 SINDIP = DSIN (CODIP*DTR)
165 DRCOSL = SINDIP * DCOS (AZMUTH * DTR)
166 DRCOSM = SINDIP * DSIN (AZMUTH * DTR)
167 DRCOSN = - DCOS (CODIP * DTR)
168 DO 60 K=1,NRSPEC
169 COEF EN(K) = COEFFX*1.0E6*CHARGE(K)*2/(OMEGA**2*RATION(K))
170 Y(K) = COEFFY * CHARGE(K) * MAGFLD

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169      $ / (OMEGA * RATION(K))
170      YSQ(K)=Y(K)**2
171      LY(K) = DRCOSL*Y(K)
172      MY(K) = DRCOSM*Y(K)
173      NY(K) = DRCOSN*Y(K)
174      LSOYSQ(K)=DRCOSL**2*YSQ(K)
175      MSOYSQ(K)=DRCOSM**2*YSQ(K)
176      NSOYSQ(K)=DRCOSN**2*YSQ(K)
177      LMYSQ(K)=DRCOSL*DRCOSM*YSQ(K)
178      LMYSQ(K)=DRCOSL*DRCOSN*YSQ(K)
179      MMYSQ(K)=DRCOSM*DRCOSN*YSQ(K)
180      80 CONTINUE
181      C = CDCOS(THETA*DTR)
182      S = CDSIN(THETA*DTR)
183      CSQ = C**2
184      SSQ = S**2
185      CI = CDCOS((THETA-DTHETA)*DTR)
186      SI = CDSIN((THETA-DTHETA)*DTR)
187      CSQI = CI**2
188      SSQI = SI**2
189
190      70 T11 = 0.0
191      T31 = 0.0
192      T12 = 0.0
193      T42 = 0.0
194      T34 = 0.0
195      T44 = 0.0
196      RETURN
197      END

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SUBROUTINE WF BNDY(B)
C
C WF BNDY COMPUTES THE VECTOR B,
C WHICH DETERMINES HOW TO COMBINE
C THE SOLUTION VECTORS IN ORDER TO
C SATISFY THE BOUNDARY CONDITIONS.
C THIS ROUTINE IS VALID ONLY FOR
C EIGENANGLES OF THE MODAL EQUATION, AND
C IS USED TO COMPUTE HEIGHT GAIN FUNCTIONS.
C
C
C IMPLICIT REAL*8 (A-H,O-Z)
C COMMON/WF FLAG/PRECSN,ISO,IOBG
C COMMON/P MTX/P(4,2),PI(16)
C COMMON/EY GRND/EYG,HYG
C COMMON/DERIV F/DFDT
C COMMON/D RX TX/EYD,EZD,RBAR11,RBAR22
C REAL*4 EOUT
C COMPLEX*16 P,B(2),R(2,2),F,
C RBAR11, RBAR22, NURMF, DENMF,
C $ EX1, EX2, EY1, EY2, HX1, HX2, HY1, HY2,
C $ EY,HY,EYG,HYG,
C $ C.S.
C $ DFDT,
C $ EYD,EZD,
C $ FOFR, NUMA, DENA, A, HYSUM, ABPARL, ABPERP,
C $ CTEMP,EXC(3,3),MEXC(3,3)
C DIMENSION PR(16),
C LABEL(3),EOUT(6)
C DATA DTR/1.745329252D-02/
C DATA LABEL/'V','E','B'/
C
C IF (IOBG.GT.1) PRINT 902, P
C
C EX1=P(1,1)
C EX2=P(1,2)
C EY1=-P(2,1)
C EY2=-P(2,2)
C HX1=P(3,1)
C HX2=P(3,2)
C HY1=P(4,1)
C HY2=P(4,2)
C
C IF (ISO.NE.0) GO TO 500
C COMPUTE B, NON-ISOTROPIC CASE.
C (FROM POLARIZATION EY/HY, SEE BUDDEN).
C NURMF = R(2,1) * (1.0 + RBAR22) * RBAR11
C DENMF = (1.0 + RBAR11) * (1.0 - RBAR22 * R(2,2))
C F OF R=NURMF/DENMF
C NUMA=-(EY1-FOFR*HY1)
C DENA=EY2-FOFR*HY2
C A=NUMA/DENA
C HYSUM=HY1+A*HY2
C B(1) = 1.0 / HYSUM*HY
C B(2) = A / HYSUM*HY
C EYG = (EY1*B(1)+EY2*B(2))/EY

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55 GO TO 820
56
57 C COMPUTE B. ISOTROPIC CASE.
58 C (CHOOSE CORRECTLY POLARIZED SOLUTION).
59 500 ABPARL = 1.0 - RBAR11 * R(1,1)
60 ABPERP = 1.0 - RBAR22 * R(2,2)
61 TEMP A = CDABS (ABPERP)
62 TEMP B = CDABS (ABPARL)
63 TEMP = TEMP A / TEMP B
64 IF (TEMP.LT.1.0D0) GO TO 600
65 B(1) = 1.0/HY1*HY
66 B(2) = 0.0
67 EYG = 0.0
68 GO TO 700
69 600 B(1) = 0.0
70 B(2) = 1.0/EY2*EY
71 HYG = 0.0
72 IF (TEMP.LT.10.0D0) GO TO 800
73 IF (TEMP.GT.0.1D0) GO TO 800
74 IF (TEMP.B.GT.0.1D0) GO TO 800
75 IF (TEMP.A.GT.0.1D0) GO TO 800
76 800 PRINT 900, ABPARL, ABPERP
77
78 C
79 820 CONTINUE
80 IF (IDBG.GE.2) PRINT 905, B
81 RETURN
82
83 C
84 C
85 ENTRY FFCT(PP,C,S,F,JJ)
86 CALL R MTRX(PP,C,R)
87 CALL RBARS(C,S,RBAR11,RBAR22,EY,HY)
88 IF (IDBG .GE. 1)PRINT 904,R,RBAR11,RBAR22
89
90 C
91 C COMPUTE MODAL EQN. VALUE
92 A = (1.0 - R(1,1) * RBAR11)
93 A = A * (1.0 - R(2,2) * RBAR22)
94 F = A - R(1,2) * R(2,1) * RBAR11 * RBAR22
95 IF (JJ .EQ. 0)PRINT901,F
96 RETURN
97
98 C
99 C ENTRY EXC FAC(S)
100 C COMPUTE EXCITATION FACTORS.
101 A = S**2*CDSORT(S)/DFDT*DTR
102 CTEMP = A*(1.0+RBAR11)**2*(1.0-RBAR22*R(2,2))/RBAR11
103 EXC(1,1) = CTEMP
104 EXC(3,1) = -CTEMP
105 EXC(1,3) = CTEMP
106 EXC(3,3) = -CTEMP
107 MEXC(1,2) = CTEMP
108 MEXC(3,2) = -CTEMP
109 CTEMP = A/S*R(2,1)*(1.0+RBAR11)*(1.0+RBAR22)
110 EXC(1,2) = -CTEMP
111 EXC(3,2) = CTEMP
112 MEXC(1,1) = -CTEMP
113 MEXC(3,1) = CTEMP
114 MEXC(1,3) = -CTEMP
115 MEXC(3,3) = CTEMP

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112 MEXC(3,3) = CTEMP
113 CTEMP = A/S*R(1,2)*(1.0+RBAR22)*(1.0+RBAR11)
114 EXC(2,1) = -CTEMP
115 EXC(2,3) = -CTEMP
116 MEXC(2,2) = -CTEMP
117 CTEMP = A/S**2*(1.0+RBAR22)**2*(1.0-RBAR11*R(1,1))/RBAR22
118 EXC(2,2) = CTEMP
119 MEXC(2,1) = CTEMP
120 MEXC(2,3) = CTEMP
121
122 C
123
124 PRINT 920
125 PRINT 922
126 CALL MA3(EXC(1,1),EXC(1,2),EXC(1,3),EOUT)
127 PRINT 923,(EOUT(K),K=1,6)
128 CALL MA3(EXC(2,1),EXC(2,2),EXC(2,3),EOUT)
129 PRINT 924,(EOUT(K),K=1,6)
130 CALL MA3(EXC(3,1),EXC(3,2),EXC(3,3),EOUT)
131 PRINT 925,(EOUT(K),K=1,6)
132
133 C
134
135 PRINT 930
136 PRINT 932
137 CALL MA3(MEXC(1,1),MEXC(1,2),MEXC(1,3),EOUT)
138 PRINT 933,(EOUT(K),K=1,6)
139 CALL MA3(MEXC(2,1),MEXC(2,2),MEXC(2,3),EOUT)
140 PRINT 934,(EOUT(K),K=1,6)
141 CALL MA3(MEXC(3,1),MEXC(3,2),MEXC(3,3),EOUT)
142 PRINT 935,(EOUT(K),K=1,6)
143 RETURN
144
145 C
146
147 900 FORMAT (' POLARIZATION VALUES',/,)
148 $ ' ABPARL =',(D15.5,D13.5), ' ABPERP =',(D15.5,D13.5),/
149 901 FORMAT (' MODAL EON. VALUE =',(D15.5,D13.5))
150 902 FORMAT (' P VALUES ON ENTRY TO WF BNDY',/,)
151 $ 4(E15.5,E13.5),/,4(E15.5,E13.5))
152 904 FORMAT (' R =',2(D15.5,D13.5),/,5X,
153 $ 2(D15.5,D13.5),/, ' RBAR =',2(D15.5,D13.5))
154 905 FORMAT (' SOLUTION COMBINATION FACTORS',/,)
155 $ ' B1 =',E15.5,E13.5, ' B2 =',E15.5,E13.5)
156 920 FORMAT('1',14X,'ELECTRIC DIPOLE XMTR-ELECTRIC DIPOLE RCVR-EXC(1,J)
157 $',/,)
158 922 FORMAT('1',24X,'EZ MAG',4X,'EZ ANG',10X,'EY MAG',4X,'EY ANG',10X,
159 $ 'EX MAG',4X,'EX ANG',/)
160 923 FORMAT('1',14X,'V',4X,3(E13.6,2X,F6.3,5X)/)
161 924 FORMAT('1',13X,'HB',4X,3(E13.6,2X,F6.3,5X)/)
162 925 FORMAT('1',13X,'HE',4X,3(E13.6,2X,F6.3,5X)/)
163 930 FORMAT('1',14X,'ELECTRIC DIPOLE XMTR-MAGNETIC DIPOLE RECVR-MEXC(1,
164 $J)',/,)
165 932 FORMAT('1',24X,'HZ MAG',4X,'HZ ANG',10X,'HY MAG',4X,'HY ANG',10X,
166 $ 'HX MAG',4X,'HX ANG',/)
167 933 FORMAT('1',14X,'V',4X,3(E13.6,2X,F6.3,5X)/)
168 934 FORMAT('1',13X,'HB',4X,3(E13.6,2X,F6.3,5X)/)
169 935 FORMAT('1',13X,'HE',4X,3(E13.6,2X,F6.3,5X)/)
170
171 C
172 END

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SUBROUTINE WF SCAL(PP,IFLAG)
C
C WFSAL SCALES AND ORTHOGONALIZES THE SOLUTION
C VECTORS P. THIS SCALING MUST LATER BE
C REMOVED TO YIELD CORRECT (UNSCALED) SOLUTIONS.
C
IMPLICIT REAL*8 (A-H,O-Z)
COMMON/WF SAVE/P SAVE(16),M31 SAV,M32 SAV,M33 SAV,
$ O SUM,APROD,BPROD,HT,LEVL
COMMON/SAVE/P ETC(27,129)
COMPLEX*16 P(4,2),
$ M31 SAV,M32 SAV,M33 SAV,O SUM,ORTHO
DIMENSION PR(8,2),PP(16)
EQUIVALENCE (P,PR)
C
C CALL XFER(PP,P,16)
ANORM = 0.0
DO 11 J=1,8
11 ANORM = ANORM+PR(J,1)**2
ORTHO = 0.0
DO 12 J=1,4
12 ORTHO = ORTHO+DCONJG(P(J,1))*P(J,2)
ORTHO = ORTHO/ANORM
C
DO 13 J=1,4
13 P(J,2) = P(J,2)-ORTHOP(J,1)
BNORM = 0.0
DO 14 J=1,8
14 BNORM = BNORM+PR(J,2)**2
ANORM = 1.0/DSQRT(ANORM)
BNORM = 1.0/DSQRT(BNORM)
DO 15 J=1,8
PR(J,1) = PR(J,1)*ANORM
PR(J,2) = PR(J,2)*BNORM
15 CALL XFER(P,PP,16)
IF(IFLAG.NE. 0) RETURN
C
O SUM = O SUM+ORTHOP/APROD/BPROD
APROD = APROD*ANORM
BPROD = BPROD*BNORM
RETURN
C
C ENTRY WF STOR
LEVL = LEVL+1
CALL XFER(P SAVE,P ETC(1,LEVL),27)
O SUM = 0.0
A PROD = 1.0
B PROD = 1.0
RETURN
C
C

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ENTRY WF LOAD
CALL XFER(P,ETC(1,LEVL),P,SAVE,27)
LEVL = LEVL-1
RETURN
END

C

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1  SUBROUTINE QUARTC (FOURB3, SIXB2, FOURB1, B0, Q)
2
3  QUARTC FINDS THE ROOTS OF A QUARTIC
4  POLYNOMIAL, FROM THE CLOSED FORM.
5
6  IMPLICIT REAL *8 (A-H,O-Z)
7  COMPLEX*16
8
9  $ B3=B3,B1,B0,Q,FOURB3,SIXB2,FOURB1,B3SQ,H,I,G,HPRIME,GPRIME
10  1,SQROOT,PPLUS,P,LOGD,CBERT0,CBERT1,CBERT2,OMEGA1,OMEGA2,ROOTP,ROOT
11  2Q,ROOTR,FUNCTION,CPLXI,CLSQR,CPLXGF,CPLKPF
12  REAL*8 MGPLUS,MGMNUS,MAGF
13  DIMENSION Q(4), PRI(2), FNCTN(4)
14  EQUIVALENCE (P,PRI)
15  DATA CPLXI/(0.000,1.000)/
16  DATA OMEGA1/(-5.0D-1, 8.660254038D-1)/
17  DATA OMEGA2/(-5.0D-1,-8.660254038D-1)/
18  DATA PRECSN /1.0D-10/
19
20  B3=FOURB3*0.25
21  B2=SIXB2/6.0
22  B1=FOURB1*0.25
23  B3SQ=B3**2
24  H=B2-B3SQ
25  I=B0-4.0*B3*B1+3.0*B2**2
26  G=B1+B3*(-3.0*B2+2.0*B3SQ)
27  HPRIME=-I/12.0
28  GPRIME=-G**2/4.0-H*(H**2+3.0*HPRIME)
29  SQROOT = CDSQRT (GPRIME**2 + 4.0 * HPRIME**3)
30  P=(-GPRIME+SQROOT)*0.5
31  MGPLUS=DABS(PRI(1))+DABS(PRI(2))
32  PPLUS=P
33  P=(-GPRIME-SQROOT)*0.5
34  MGMNUS=DABS(PRI(1))+DABS(PRI(2))
35  IF (MGPLUS.GT.MGMNUS) P=PPLUS
36  LOGP = CLOG (P)
37  CBERT0 = CDEXP (LOGP / 3.0)
38  CBERT1=OMEGA1*CBERT0
39  CBERT2=OMEGA2*CBERT0
40  ROOTP = CDSQRT (CBERT0 - HPRIME / CBERT0 - H)
41  ROOTQ = CDSQRT (CBERT1 - HPRIME / CBERT1 - H)
42  ROOTR = CDSQRT (CBERT2 - HPRIME / CBERT2 - H)
43  IF (CDABS(G) .LE. 1.0D-50) GO TO 5
44  SIGN=-ROOTP*ROOTQ*ROOTR*2.0/G
45  IF (SIGN.LT.0.0) ROOTR=-ROOTR
46  Q(1)=+ROOTP+ROOTQ+ROOTR-B3
47  Q(2)=+ROOTP-ROOTQ-ROOTR-B3
48  Q(3)=-ROOTP+ROOTQ-ROOTR-B3
49  Q(4)=-ROOTP-ROOTQ+ROOTR-B3
50  DO 20 N=1,4
51  ITER = 0
52  200 CONTINUE
53  ROOTP = Q(N)**4 + FOURB3 * Q(N)**3 + SIXB2 * Q(N)**2
54  $ + FOURB1 * Q(N) + B0

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55      ROOTQ = 4.0 * Q(N)**3 + 3.0 * FOURB3 * Q(N)**2
56      $ + 2.0 * SIXB2 * Q(N) + FOURB1
57      ROOTR = ROOTP / ROOTQ
58      Q(N) = Q(N) - ROOTR
59      IF (CDABS (ROOTR).LT.PRECSN) GO TO 20
60      ITER = ITER + 1
61      IF (ITER.LT.10) GO TO 200
62      PRINT 900, ITER, Q(N)
63      20 CONTINUE
64      RETURN
65      900 FORMAT (13,' ITERATIONS, Q = ',
66      $E15.5,E13.5,' FAILS TO CONVERGE')
67      END

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SUBROUTINE R MTRX(P,COSN,R)
C
C R MTRX COMPUTES REFLECTION
C COEFFICIENT MATRIX FROM P MATRIX
C AND RETURNS IT IN R.
C
C
C IMPLICIT REAL *8 (A-H,O-Z)
C COMPLEX*16 P(4,2),COSN,R(2,2),
C $ G12, G13, G14, G23, G24, G34,
C $ D00, D11, D22, D12, D21
C
C
C G12=P(1,1)*P(2,2)-P(1,2)*P(2,1)
C G13=P(1,1)*P(3,2)-P(1,2)*P(3,1)
C G14=P(1,1)*P(4,2)-P(1,2)*P(4,1)
C G23=P(2,1)*P(3,2)-P(2,2)*P(3,1)
C G24=P(2,1)*P(4,2)-P(2,2)*P(4,1)
C G34=P(3,1)*P(4,2)-P(3,2)*P(4,1)
C
C D00 = - G13 + COSN * (G34 - G12 + COSN * G24)
C D11 = G13 + COSN * (G34 + G12 + COSN * G24)
C D22 = G13 + COSN * (- G34 - G12 + COSN * G24)
C D12 = 2.0 * COSN * G14
C D21 = 2.0 * COSN * G23
C
C R(1,1) = D11 / D00
C R(2,2) = D22 / D00
C R(1,2) = D12 / D00
C R(2,1) = D21 / D00
C
C RETURN
C END

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AD-A107 517

NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA

F/G 20/14

A PROGRAM TO COMPUTE ELF/VLF EARTH-IONOSPHERE MODAL HEIGHT GAIN--ETC(U)

SEP 81 R A PAPPERT, L R HITNEY

UNCLASSIFIED

NOSC/TK-724

NL

2 OF 2

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1  SUBROUTINE RBARS(C,S,RBAR11,RBAR22,EY,HY)
2  IMPLICIT REAL *B (A-H,O-Z)
3  COMMON/WFINPT/THETA,FREQ,AZMUTH,CODIP,MAGFLD,CEFFNU(5),EXPNU(5),
4  $ TOPHT, LWSTHT, WK8HT,DELHT, H,
5  $ ALPHA,SIGMA,EPSLON
6  COMMON/WF CON/OMEGA,K
7  COMMON/EY GRND/EYG,HYG
8  COMPLEX *16 THETA,I,NGSQ,C,S,SSQ,SOROOT,RTIORT,IMC,
9  $ PO,H10,H20,H1PRMO,H2PRMO,CAPH10,CAPH20,
10 $ PD,H1D,H2D,H1PRMD,H2PRMD,
11 $ PZ,H1Z,H2Z,H1PRMZ,H2PRMZ,
12 $ A1ST,A2ND,A3RD,A4TH,A1,A2,A3,A4,
13 $ EXD,EXDSQ,EXZ,EXZSQ,
14 $ RBAR11,RBAR22,Z1,Z2,
15 $ DEN12,DEN34,
16 $ EYG,HYG,
17 $ EX,EY,EZ,HX,HY,HZ
18 REAL *8 K,KVRAOT,KVRATT,NOSQ,NDSQ,NZSQ,MAGFLD,LWSTHT
19 EQUIVALENCE(PZ,PD),(H1Z,H1D),(H2Z,H2D),(H1PRMZ,H1PRMD),
20 $ (H2PRMZ,H2PRMD),(EXD,EXZ),(EXDSQ,EXZSQ)
21 DATA 1/(0.000,1.000)/
22 DATA TSTTHM/1.0001/
23 DATA EPSLNO/8.85434D-12/
24
25 C
26 C
27 EYG = 1.0
28 HYG = 1.0
29 ALT = LWSTHT
30 D = LWSTHT
31 SSQ=S*S
32 NGSQ = (EPSLON-I*SIGMA/OMEGA)/EPSLNO
33 SOROOT=CDROOT(NGSQ-SSQ)
34 THTIM=I*THETA
35 IF(THTIM.GT. TSTTHM) GO TO 10
36
37 C
38 KVRAOT=DEXP(DLOG(K/ALPHA)/3.0)
39 KVRATT=KVRAOT**2
40 AVRKOT=1.0/KVRAOT
41 AVRKTT=AVRKT**2*0.5
42 NOSQ=1.0-ALPHA*H
43 PO=KVRAIT*(NOSQ-SSQ)
44 RTIORT=NOSQ/NGSQ*SOROOT
45 CALL MOHNKL (PO,H10,H20,H1PRMO,H2PRMO)
46 CAPH10=H1PRMO+AVRKT*H10
47 CAPH20=H2PRMO+AVRKT*H20
48 A1ST=CAPH20-I*RTIORT*KVRAOT*H20
49 A2ND=CAPH10-I*RTIORT*KVRAOT*H10
50 A3RD=H2PRMO-I*KVRAOT*SOROOT*H20
51 A4TH=H1PRMO-I*KVRAOT*SOROOT*H10
52 DEN12 = H20*A2ND-H10*A1ST
53 DEN34 = H20*A4TH-H10*A3RD
54 IF(D.EQ. 0.0) GO TO 10

```

```

55 NDSQ=1.0-ALPHA*(H-D)
56 PD=KVRATT*(NDSQ-SSQ)
57 CALL MDHKKL (PD,H1D,H2D,H1PRMD,H2PRMD)
58 CAPH1D=H1PRMD+AVRKT*H1D
59 CAPH2D=H2PRMD+AVRKT*H2D
60
61 C
62 A1 = C*NDSQ*(H2D-A2ND-H1D-A1ST)
63 A2=1-AVRKOT*(CAPH1D-A1ST-CAPH2D-A2ND)
64 A3=1-AVRKOT*(H2PRMD-A4TH-H1PRMD-A3RD)
65 A4 = C*(H2D-A4TH-H1D-A3RD)
66 RBAR11=(A1-A2)/(A1+A2)
67 RBAR22=(A3+A4)/(A4-A3)
68 GO TO 40
69
70 C
71 FLAT EARTH
72 10 IKC = I*K*C
73 EXD = CDEXP(-IKC*D)
74 EXDSQ = EXD**2
75 Z1=(NGSQ*C-SQROOT)/(NGSQ*C+SQROOT)
76 Z2=(C-SQROOT)/(C+SQROOT)
77 RBAR11=Z1*EXDSQ
78 RBAR22=Z2*EXDSQ
79 GO TO 40
80
81 C
82 ENTRY HT GAIN(ALT,EX,EY,EZ,HX,HY,HZ)
83 ALT = ALT
84 IF(THTIM .GT. TSTTHM) GO TO 50
85 NDSQ = 1.0-ALPHA*(H-ALT)
86 PZ = KVRATT*(NDSQ-SSQ)
87 CALL MDHKKL(PZ,H1Z,H2Z,H1PRMZ,H2PRMZ)
88 EXPON = DEXP(0.5*ALPHA*ALT)
89 HY = (H2Z-A2ND-H1Z-A1ST)*EXPON/DEN12*HYG
90 EY = (H2Z-A4TH-H1Z-A3RD)/DEN34*EYG
91 EX = I-AVRKOT*((H2PRMZ-A2ND-H1PRMZ-A1ST)/DEN12*HYG
92 $ *EXPON+AVRKT*HY)/NDSQ
93 EZ = -S/NZSQ*HY
94 HZ = S*EY
95 HX = AVRKOT/I*(H2PRMZ-A4TH-H1PRMZ-A3RD)/DEN34*EYG
96 RETURN
97
98 C
99 FLAT EARTH
100 50 EXZ = CDEXP(-IKC*ALT)
101 EXZSQ = EXZ**2
102 HY = (1.0+Z1*EXZSQ)/(1.0+Z1)/EX2*HYG
103 EY = (1.0+Z2*EXZSQ)/(1.0+Z2)/EX2*EYG
104 EX = -C*(1.0-Z1*EXZSQ)/(1.0+Z1)/EXZ*HYG
105 EZ = -S*HY
106 HZ = S*EY
107 HX = C*(1.0-Z2*EXZSQ)/(1.0+Z2)/EXZ*EYG
108 RETURN
109 C
110 END

```

```

1 :
2 SUBROUTINE MDHKL (Z,H1,H2,H1PRME,H2PRME)
3 IMPLICIT REAL *8 (A-H,O-Z)
4 COMPLEX*16 Z,H1,H2,H1PRME,H2PRME,ZPOWER,TERM1,TERM2,
5 TERM3,ZTERM,TERM,SUM1,SUM2,SUM3,SUM4,SQRTZB,
6 EXP1,EXP2,EXP3,EXP4,EXP5,GM2F,GM2FP,MPower,BETA,RTZ,
7 CONST1,CONST2,CONST3,CONST4
8 DIMENSION A(23),B(23),C(23),D(23),CAP(14)
9 DATA A/
10 9.30436716930000D-01,3.10145572309700D 01,2.06763714873160D 02,
11 5.74343652425450D 02,8.70217655190080D 02,8.28778719228640D 02,
12 5.41685437404340D 02,2.57945446383020D 02,9.34584950663100D 01,
13 2.66263518707400D 01,6.12100043005600D 00,1.15928038448000D 00,
14 1.84012759441000D-01,2.48330309640000D-02,2.88420801000000D-03,
15 2.91334142000000D-04,2.58274950000000D-05,2.02568600000000D-06,
16 1.41557000000000D-07,8.87000000000000D-09,5.01000000000000D-10,
17 2.60000000000000D-11,1.00000000000000D-12/
18 DATA B/
19 6.78298725140000D-01,1.13049787524000D 01,5.38332321543100D 01,
20 1.19629404787350D 02,1.53371031778650D 02,1.27809193148880D 02,
21 7.47422182157200D 01,3.2359386215200D 01,1.07853128738400D 01,
22 2.85325737403000D 00,6.13603736351000D-01,1.09376780098000D-01,
23 1.64229395500000D-02,2.10505122000000D-03,2.33167788000000D-04,
24 2.25282890000000D-05,1.91567100000000D-06,1.44470000000000D-07,
25 9.72900000000000D-09,5.89000000000000D-10,3.20000000000000D-11,
26 2.00000000000000D-12,0.00000000000000D 00/
27 DATA C/
28 4.65218358460000D-01,6.20291144619000D 00,2.58454643591500D 01,
29 5.22130593114000D 01,6.21584039421500D 01,4.87516893663900D 01,
30 2.70842718702200D 01,1.12150194079600D 01,3.59455750255000D 00,
31 9.18150064510000D-01,1.91281263439000D-01,3.31222966990000D-02,
32 4.84244103800000D-03,6.05683682000000D-04,6.55501820000000D-05,
33 1.98599000000000D-06,5.16550000000000D-07,3.82200000000000D-08,
34 2.52800000000000D-09,1.50000000000000D-10,8.00000000000000D-12,
35 0.00000000000000D 00,0.00000000000000D 00/
36 DATA D/
37 6.78298725140000D-01,4.52199150096200D 01,3.76832625080150D 02,
38 1.19629404787350D 03,1.99382341312250D 03,2.04494709038206D 03,
39 1.42010214609865D 03,7.11830549673510D 02,2.69632821846030D 02,
40 7.98912064729000D 01,1.90217158268800D 01,3.71881052333900D 00,
41 6.07648778323000D-01,8.42202048960000D-02,1.00262148690000D-02,
42 1.03630127800000D-03,9.38678690000000D-05,7.51243500000000D-06,
43 5.35074000000000D-07,3.41350000000000D-08,1.96200000000000D-09,
44 1.02000000000000D-10,5.00000000000000D-12/
45 DATA CAP/
46 1.04166666666667D-01,8.35503472222222D-02,1.28226574556327D-01,
47 2.91849026464140D-01,8.81627267437580D-01,3.32140828186277D 00,
48 1.49957629868626D 01,7.89230130115870D 01,4.74451538868000D 02,
49 3.20749009100000D 03,2.40865496000000D 04,1.98923120000000D 05,
50 1.79190200000000D 06,1.74843770000000D 07/
51 DATA I/(0.00D,1.00D)/
52 DATA ROOT3/1.73205080756888D 00/
53 DATA ALPHA/8.53667218838951D-01/
54 DATA CONST1/( 2.58819045102522D-01,-9.65925826289067D-01)/

```

C

```

55 DATA CONST2/( 2.58819045102522D-01, 9.65925826289067D-01)/
56 DATA CONST3/(-9.65925826289067D-01, 2.58819045102522D-01)/
57 DATA CONST4/(-9.65925826289067D-01,-2.58819045102522D-01)/
58
59 C
60 ZPOWER=1.0
61 SUM3=0.0
62 SUM4=0.0
63 ZMAG=CDABS(Z)
64 IF(ZMAG .GT. 4.2) GO TO 70
65 IF(ZMAG .GE. 3.2) GO TO 10
66 N=12
67 GO TO 30
68
69 10 IF(ZMAG .GE. 4.1) GO TO 20
70 N=15
71 GO TO 30
72
73 20 N=23
74 GO TO 30
75
76 30 SUM1=0.
77 SUM2=0.
78 ZTERM=-Z**3/200.0
79 DO 50 M=1,N
80 SUM1=SUM1+A(M)*ZPOWER
81 SUM2=SUM2+B(M)*ZPOWER
82 SUM3=SUM3+C(M)*ZPOWER
83 SUM4=SUM4+D(M)*ZPOWER
84 ZPOWER=ZPOWER*ZTERM
85 IF(CDABS(ZPOWER) .LE. 1.0D-30) GO TO 60
86 CONTINUE
87 GM2F=1*(Z*SUM2-2.*SUM1)/ROOT3
88 GPMFP=1*(SUM4+2.*Z*SUM3)/ROOT3
89 H1=Z*SUM2+GM2F
90 H2=H1-2.0*GM2F
91 H1PRME=SUM4+GPMFP
92 H2PRME=H1PRME-2.0*GPMFP
93 RETURN
94
95 C
96 70 SUM1=1.0
97 SUM2=1.0
98 RTZ=CDSQRT(Z)
99 SQTZB=RTZ*Z
100 ZTERM=1/SQTZB
101 MPOWER=1.0
102 TERM=-1.5/Z
103 DO 80 M=1,14
104 ZPOWER=ZPOWER*ZTERM
105 MPOWER=MPOWER*(-ZTERM)
106 TERM1=CAP(N)*ZPOWER
107 TERM2=CAP(N)*MPOWER
108 SUM1=SUM1+TERM1
109 SUM2=SUM2+TERM2
110 SUM3=SUM3+N*TERM1
111 SUM4=SUM4+N*TERM2
112 CONTINUE
113 SUM3=SUM3*TERM
114 SUM4=SUM4*TERM
115 EXP1=CDEXP(2.*1*SQTZB/3.)
116 EXP2=EXP1*CONST1
117 EXP3=CONST2/EXP1

```

```

112 EXP4=CONST3*EXP1
113 EXP5=CONST4/EXP1
114 BETA=ALPHA/CDSQRT(RTZ)
115 ZREAL=Z
116 ZIMAG=-I*Z
117 IF (ZREAL.GE.0.0.OR.ZIMAG.GE.0.0)GO TO 90
118 H1=BETA*(EXP2*SUM2+EXP5*SUM1)
119 H1PRME=BETA*(EXP2*(SUM2*(-0.25/Z+I*RTZ)+SUM4)+EXP5*(SUM1*(-0.25/Z
120 $ -I*RTZ)+SUM3))
121 GO TO 110
122 90 H1=BETA*EXP2*SUM2
123 H1PRME=BETA*EXP2*(SUM2*(-0.25/Z+I*RTZ)+SUM4)
124 110 IF (ZREAL.GE.0.0.OR.ZIMAG.LT.0.0)GO TO 120
125 H2=BETA*(EXP3*SUM1+EXP4*SUM2)
126 H2PRME=BETA*(EXP3*(SUM1*(-0.25/Z-I*RTZ)+SUM3)+EXP4*(SUM2*(-0.25/Z
127 $ +I*RTZ)+SUM4))
128 RETURN
129 H2=BETA*EXP3*SUM1
130 H2PRME=BETA*EXP3*(SUM1*(-0.25/Z-I*RTZ)+SUM3)
131 RETURN
132 END

```

```

SUBROUTINE XFER(A,B,N)
REAL*8 A,B
DIMENSION A(1),B(1)
DO 11 J=1,N
11 B(J)=A(J)
RETURN
END

```

```

1
2
3
4
5
6
7

```

```

SUBROUTINE MA3(Z1,Z2,Z3,OUT)
COMPLEX*16 Z1,Z2,Z3
REAL*8 CDANG
DIMENSION OUT(6)
OUT(1)=CDABS(Z1)
OUT(3)=CDABS(Z2)
OUT(5)=CDABS(Z3)
OUT(2)=CDANG(Z1)
OUT(4)=CDANG(Z2)
OUT(6)=CDANG(Z3)
RETURN
END

```

```

1
2
3
4
5
6
7
8
9
10
11
12

```

1	FUNCTION CDANG(ARG)
2	IMPLICIT REAL*8 (A-H,O-Z)
3	COMPLEX*16 ARG,ARG PRT
4	DIMENSION PARTS(2)
5	EQUIVALENCE (ARG PRT,PARTS)
6	
7	ARG PRT = ARG
8	ARG RL = PARTS(1)
9	ARG IM = PARTS(2)
10	CDANG = DATAN2(ARG IM,ARG RL)
11	RETURN
12	END

```

1 SUBROUTINE WKBVAR(EX,EY,EZ,HX,HY,HZ)
2 IMPLICIT REAL*8(A-H,O-Z)
3 INTEGER SVFLAG
4 REAL*8 MAGFLD,LWSTHT
5 COMPLEX*16 I,THETA,Q,GAMMA,INTGRQ,INTGAM,SUMQ,SUMGAM,EXPO,OSAV,
6 $PARTEX,PARTEX,PARTZ,PARTHX,PARTHY,PARTHZ,EX(1),EY(1),EZ(1),HX(1),
7 $HY(1),HZ(1)
8 COMMON /WFINPT/ THETA, FREQ,
9 $ AZMUTH, CODIP, MAGFLD, CEFFNU(5), EXPNU(5),
10 $ TOPHT, LWSTHT, WKBHT,DELHT, M,
11 $ ALPHA,SIGMA,EPSLON
12 COMMON/ANSWER/PARTEX,PARTY,PARTZ,PARTHX,PARTHY,PARTHZ
13 COMMON/WFCON/OMEGA,WAVENR
14 COMMON/WFFLAG/PRECSN,ISO,IDBUG
15 DATA EPSHT/5.D-4/
16 DATA DHMIN/1.D-3/
17 DATA I/(0.000,1.000)/
18
19 IF (WKBHT.LE.TOPHT) RETURN
20 JHT = TOPHT/DELHT+1.01
21 JHT = JHT+1
22 CALL INIT DT
23 SUMQ=(0.000,0.000)
24 SUNGAM=(0.000,0.000)
25 HT=TOPHT
26 WFHT=TOPHT+DELHT
27 DELH2=DELHT/8.
28
29 10 IF (SVFLAG.EQ.1) DELH2=SAVDH2
30 SVFLAG=0
31 HTLIM=WFHT
32 NODBL=0
33 IF (HT+DELH2.LE.HTLIM+EPSHT) GO TO 50
34 SAVDH2=DELH2
35 SVFLAG=1
36 DELH2=HTLIM-HT
37
38 50 LFLAG=0
39 60 INTGRQ=(0.,0.)
40 INTGAM=(0.,0.)
41 DO 30 M=1,3
42 CALL QGAMMA(HT,DELHT,TOPTHT,Q,GAMMA)
43 IF (M.EQ.2) GO TO 110
44 INTGRQ=DELH2*Q/6. + INTGRQ
45 INTGAM=DELH2*GAMMA/6. + INTGAM
46 GO TO 30
47 110 INTGRQ=2.*DELH2*Q/3. + INTGRQ
48 INTGAM=2.*DELH2*GAMMA/3. + INTGAM
49 30 IF (M.NE.3) HT=HT+DELH2/2.
50
51 LFLAG=LFLAG+1
52 IF(LFLAG.EQ.3) GO TO 70
53 IF (LFLAG.EQ.2) GO TO 65
54 QSAV=INTGRQ

```

```

55 HT=HT-DELM2
56 DELH2=DELM2/2.
57 GO TO 60
58
59 70 DELH2=DELM2*2.
60 QABS=CDABS(QSAV-INTGRQ)
61 IF (CDABS(INTGRQ).NE.0.) QABS=QABS/CDABS(INTGRQ)
62 IF (QABS.LT.PRECSN) GO TO 100
63 IF (DELM2.GT.DHMIN) GO TO 95
64 IF (KMAX.EQ.0) PRINT 900,HT
65 900 FORMAT (' MINIMUM STEP SIZE USED FIRST AT HT =',D14.5)
66 KMAX=1
67 GO TO 100
68
69 95 HT=HT-DELM2
70 DELH2=DELM2/2.
71 NODBL=1
72 IF (QABS.LT.10.*PRECSN) GO TO 99
73 DELH2=DELM2/4.
74 NODBL=0
75 SVFLAG=0
76 GO TO 50
77
78 100 IF (NODBL.EQ.0 .AND. QABS.LT.PRECSN/3.) DELH2=2.*DELM2
79 120 SUMQ=SUMQ+INTGRQ
80 SUMGAM=SUMGAM+INTGAM
81 IF (HT.LT.WFHT-EPSHT) GO TO 10
82 WFHT=WFHT+DELM2
83 EXPO=CDEXP(WAVENR*(-SUMQ*1 + SUMGAM))
84 EX(IHT) = PARTEY*EXPO
85 EY(IHT) = PARTEY*EXPO
86 EZ(IHT) = PARTEZ*EXPO
87 HX(IHT) = PARTHX*EXPO
88 HY(IHT) = PARTHY*EXPO
89 HZ(IHT) = PARTHZ*EXPO
90 IHT = IHT+1
91 IF (HT.LT.WKBHT-EPSHT) GO TO 10
92 RETURN
93 END

```

```

1  SUBROUTINE QGAMMA(HT,DELHT, TOPHT,Q,GAMMA)
2  IMPLICIT REAL*8(A-H,O-Z)
3  COMPLEX*16 C,S,CI,SI,I,QI(4),Q,GAMMA,AJ,FJ,F,DERIVF,
4  $ M(3,3),T(4,4),MPRIME(3,3),TPRIME(4,4),
5  $ COEFFB,COEFFC,COEFFD,COEFFE,
6  $ A1,A2,A3,A4,A5,A6,B3,B4,B5,B6,
7  $ A3PRIM,A4PRIM,A5PRIM,A6PRIM,
8  $ B3PRIM,B4PRIM,B5PRIM,B6PRIM,
9  $ COEFFC,COEFF1,COEFF2,INEX,INEY,INHX,INHY,
10 $ PARTEX,PARTEY,PARTEZ,PARTHX,PARTHY,PARTHZ,
11 $ HXNORM,HYNORM,EXNORM,EYNORM
12 $ COMMON/CS/C,S,CI,SI
13 COMMON/START/INEX, INEY, INHX, INHY
14 COMMON/ANSWER/PARTEX,PARTEY,PARTEZ,PARTHX,PARTHY,PARTHZ
15 DATA I/(0.0D0,1.0D0)/
16
17 CALL DDKXMT(HT,M,T,MPRIME,TPRIME)
18 COEFFA = 1.0D0
19 COEFFB = -(T(1,1)+T(4,4))
20 COEFFC = T(1,1)*T(4,4) - T(1,4)*T(4,1) - T(3,2)
21 COEFFD = T(3,2)*(T(1,1)+T(4,4)) - T(1,2)*T(3,1) - T(3,4)*T(4,2)
22 COEFFE = T(1,1)*(T(3,4)*T(4,2) - T(3,2)*T(4,4)) +
23 $ T(1,2)*(T(3,1)*T(4,4) - T(3,4)*T(4,1)) +
24 $ T(1,4)*(T(3,2)*T(4,1) - T(3,1)*T(4,2))
25
26 JJ=7
27 IF (HT.GT.TOPHT) GO TO 400
28
29 10 CALL QUARTC (COEFFB,COEFFC,COEFFD,COEFFE,QQ)
30 QR MAX=QQ(1)
31 J2=1
32 DO 23 J=2,4
33 QREAL=QQ(J)
34 IF (QREAL.LT.QR MAX) GO TO 23
35 QRMAX=QREAL
36 J2=J
37 23 CONTINUE
38 Q=QQ(J2)
39
400 K=1
41 500 CONTINUE
42 IF (K.GT.21 ) GO TO 510
43 F = Q**4*COEFFA + Q**3*COEFFB + Q**2*COEFFC + Q*COEFFD + COEFFE
44 DERIVF=4.0D0*Q**3*COEFFA + 3.0D0*Q**2*COEFFB + 2.0D0*Q*COEFFC +COEFFD
45 REAL=F/DERIVF
46 GINARY=-I*F/DERIVF
47 IF ((REAL**2.LE.1.D-20).AND.(GINARY**2.LE.1.D-30)) GO TO 530
48 Q=Q-F/DERIVF
49 K=K+1
50 GO TO 500
51 510 IF (JJ.EQ.7) GO TO 570
52 PRINT 520,HT
53 520 FORMAT (10X,'DOES NOT CONVERGE AFTER 20 ITERATIONS AT HEIGHT=',
54 $ F10.5/)
55 530 CONTINUE

```

```

55 REAL=Q
56 GINARY=-I*Q
57 IF (REAL**2 .GT. GINARY**2 .AND. REAL.GT.0.) GO TO 540
58 IF (JJ.EQ.13) GO TO 550
59 JJ=13
60 GO TO 10
61
62 550 PRINT 560, HT
63 560 FORMAT (10X, 'DOES NOT CONVERGE TO THE PROPER Q AT HEIGHT=', F10.5/)
64 540 CONTINUE
65
66 A1=-(T(1,1)+T(4,4))
67 A2=T(1,1)*T(4,4) - T(1,4)*T(4,1)
68 A3=T(1,2)
69 A4=T(1,4)*T(4,2) - T(1,2)*T(4,4)
70 A5=T(4,2)
71 A6=T(4,1)*T(1,2) - T(1,1)*T(4,2)
72 B3=T(3,4)
73 B4=T(1,4)*T(3,1) - T(3,4)*T(1,1)
74 B5=T(3,1)
75 B6=T(4,1)*T(3,4) - T(4,4)*T(3,1)
76 A3PRIM=TPRIME(1,2)
77 A4PRIM=TPRIME(1,4)*T(4,2)+T(1,4)*TPRIME(4,2) -
78 TPRIME(1,2)*T(4,4)-T(1,2)*TPRIME(4,4)
79 A5PRIM=TPRIME(4,2)
80 A6PRIM=TPRIME(4,1)*T(1,2)+T(4,1)*TPRIME(1,2) -
81 TPRIME(1,1)*T(4,2)-T(1,1)*TPRIME(4,2)
82 B3PRIM=TPRIME(3,4)
83 B4PRIM=TPRIME(1,4)*T(3,1)+T(1,4)*TPRIME(3,1) -
84 TPRIME(3,4)*T(1,1)-T(3,4)*TPRIME(1,1)
85 B5PRIM=TPRIME(3,1)
86 B6PRIM=TPRIME(4,1)*T(3,4)+T(4,1)*TPRIME(3,4) -
87 TPRIME(4,4)*T(3,1)-T(4,4)*TPRIME(3,1)
88 AJ=Q*Q+A1*Q+A2
89 FJ=2.000*Q*AJ + (Q*Q-T(3,2))*(2.000*Q+A1) - (A3*B5+B3*A5)
90 COEFF0=A4*B6PRIM-A4PRIM*B6+A6*B4PRIM-A6PRIM*B4
91 COEFF1=A3*B6PRIM-A3PRIM*B6+A4*B5PRIM-A4PRIM*B5+A5*B4PRIM-
92 A5PRIM*B4+A6*B3PRIM-A6PRIM*B3
93 COEFF2=A3*B5PRIM-A3PRIM*B5+A5*B3PRIM-A5PRIM*B3
94 GAMMA=(Q*Q*COEFF2 + Q*COEFF1 + COEFF0)/(2.00*AJ*FJ)
95
96 NICE=(HT-TOPHT)/DELHT
97 IF ( (HT-TOPHT)/DELHT - NICE .NE. 0.0) RETURN
98 IF (HT.NE.TOPHT) GO TO 605
99 HXNORM=INHX*CDSORT(AJ*FJ)/(Q*AJ)
100 HYNORM=INHY*CDSORT(AJ*FJ)/(Q*A5+A6)
101 EXNORM=INEX*CDSORT(AJ*FJ)/(Q*A3+A4)
102 EYNORM=INEY*CDSORT(AJ*FJ)/(-AJ)
103 PARTHX=HXNORM/CDSORT(AJ*FJ)*(Q*AJ)
104 PARTHY=HYNORM/CDSORT(AJ*FJ)*(Q*A5+A6)
105 PARTEX=EXNORM/CDSORT(AJ*FJ)*(Q*A3+A4)
106 PARTEY=EYNORM/CDSORT(AJ*FJ)*(-AJ)
107 PARTHZ=PARTEY*S
108 PARTEZ=-(S*PARTHY + M(3,1)*PARTEX + M(3,2)*PARTEY)/(1.+M(3,3))
109 RETURN
110 END

```

```

1  SUBROUTINE DDXMT(HT,M,T,MPRIME,TPRIME)
2  IMPLICIT REAL *8 (A-H,O-Z)
3  COMMON/PRIMES/DELE,DELC
4  COMMON/WF FLAG/PRECSN,ISO,IDBG
5  COMMON /WFINTP/ THETA, FREQ,
6  $ AZMUTH, CODIP, MAGFLD, CEFFNU(5), EXPNU(5),
7  $ TOPHT, LWSTHT, WKBHT, DELHT, H,
8  $ ALPHA,SIGMA,EPSLON
9  COMMON/WF CON/OMEGA,WAVE NR
10 COMMON/WFPROF/ENHT(100),ENLOG(100,5),COLLHT(25),COLLFR(25,5),
11 $ LHT,MHT,CHARGE(5),RATON(5),NRSPEC
12 $ COMMON/CS/C,S,CI,SI
13 REAL*8 MAGFLD, LWSTHT,
14 $ LSQYSQ, MSQYSQ, NSQYSQ,
15 $ LMYSQ, LNYSQ, MNYSQ, NU, NUPRIM,
16 $ LY,MY,NY
17 $ COMPLEX*16 M(3,3),
18 $ T(4,4),
19 $ MPRIME(3,3),TPRIME(4,4),XPRIME,UPRIME,ODPRIM,IUDPRI,M331,
20 $ TAPRIM,TBPRIM,
21 $ C,S,CI,SI,CSQ,SSQ,CSQI,SSQI,
22 $ THETA,DTHETA,
23 $ U,USQ,OD,I,IUD,TA,TB
24 $ DIMENSION DELE(5),DELC(5),ENPRIM(5),NUPRIM(5)
25 $ DIMENSION Y(5),YSQ(5),LY(5),MY(5),
26 $ NY(5),LMYSQ(5),LNYSQ(5),MNYSQ(5),EN(5),NU(5),
27 $ LSQYSQ(5),MSQYSQ(5),NSQYSQ(5),
28 $ COEF EN(5)
29
30 DATA PI/3.141592653D0/
31 DATA DTR/1.745329252D-02/
32 DATA COEFFX/3.182357D03/,COEFFY/1.758796D11/
33 DATA I/(0.000,1.000)/
34 DATA VELLT/2.997928D05/
35 DATA DTHETA/(5.0D-02,1.0D-02)/
36
37 C
38 CALCULATE THE MATRIX M.
39 M(1,1) = 0.0
40 M(1,2) = 0.0
41 M(1,3) = 0.0
42 M(2,1) = 0.0
43 M(2,2) = 0.0
44 M(2,3) = 0.0
45 M(3,1) = 0.0
46 M(3,2) = 0.0
47 M(3,3) = 0.0
48 MPRIME(1,1)=0.0
49 MPRIME(1,2)=0.0
50 MPRIME(1,3)=0.0
51 MPRIME(2,1)=0.0
52 MPRIME(2,2)=0.0
53 MPRIME(2,3)=0.0
54 MPRIME(3,1)=0.0
55 MPRIME(3,2)=0.0

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55 MPRIME(3,3)=0.0
56
57 C
58 CALL WF DENS (HT, EN, NU)
59 DO 10 K=1,NRSPEC
60 ENPRIM(K)=EN(K)*DELE(K)
61 NUPRIM(K)=NU(K)*DELC(K)
62 10 CONTINUE
63
64 C
65 NFLAG = 0
66 DO 20 K=1,NKSPEC
67 ADD IN THE CONTRIBUTIONS TO THE
68 SUSCEPTIBILITY TENSOR M FOR EACH
69 SPECIE IN THE IONOSPHERE.
70 IF(EN(K) .LT. 1.0E-3) GO TO 20
71 NFLAG = 1
72 X = COEF EN(K)*EN(K)
73 XPRIME=COEFEN(K)*ENPRIM(K)/WAVENR
74 IF(NGLECT .NE. 0) X = -X
75 Z = NU(K)*OV OMGA
76 IF(NGLECT .NE. 0) Z = -Z
77 U=1.0-1*Z
78 UPRIME=-1*NUPRIM(K)*OV OMGA/WAVENR
79 USQ=U*U
80 DD = -X / (U * (USQ - YSQ(K)))
81 ODDPRIM=(X*(3.00*USQ*UPRIME-YSQ(K)*UPRIME) -
82 XPRIME*(U*(USQ-YSQ(K))))/(U*(USQ-YSQ(K)))*2
83 IUD = (Z+1)*DD
84 IUDPRI=NUPRIM(K)*OV OMGA/WAVENR*DD + (Z+1)*DDPRIM
85
86 TA = USQ * DD
87 M(1,1) = M(1,1) + TA
88 M(2,2) = M(2,2) + TA
89 M(3,3) = M(3,3) + TA
90 M(2,2) = M(2,2) - MSQSQ(K) * DD
91 TAPRIM=2.00*U*UPRIME*DD + USQ*DDPRIM
92 MPRIME(1,1)=MPRIME(1,1) + TAPRIM
93 MPRIME(2,2)=MPRIME(2,2) + TAPRIM
94 MPRIME(3,3)=MPRIME(3,3) + TAPRIM
95 MPRIME(2,2)=MPRIME(2,2) - MSQSQ(K) * DDPRIM
96
97 TA = MY(K)*IUD
98 TB = LNYSQ(K) * DD
99 M(1,3) = M(1,3) + TA - TB
100 M(3,1) = M(3,1) - TA - TB
101 TAPRIM=MY(K)*IUDPRI
102 TBPRIM=LNYSQ(K)*DDPRIM
103 MPRIME(1,3)=MPRIME(1,3) + TAPRIM - TBPRIM
104 MPRIME(3,1)=MPRIME(3,1) - TAPRIM - TBPRIM
105
106 IF (ISO.NE.0) GO TO 20
107 M(1,1) = M(1,1) - LSQSQ(K) * DD
108 M(3,3) = M(3,3) - NSQSQ(K) * DD
109 MPRIME(1,1)=MPRIME(1,1) - LSQSQ(K)*DDPRIM
110 MPRIME(3,3)=MPRIME(3,3) - NSQSQ(K)*DDPRIM
111 TA = NY(K)*IUD
112 TB = LMYSQ(K) * DD
113 M(2,1) = M(2,1) + TA - TB

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112 M(1,2) = M(1,2) - TA - TB
113 TAPRIM=NY(K)*IUDPRI
114 TBPRI=LMSQ(K)*DDPRIM
115 MPRIME(2,1)=MPRIME(2,1) + TAPRIM - TBPRI
116 MPRIME(1,2)=MPRIME(1,2) - TAPRIM - TBPRI
117 TA = LY(K)*IUD
118 TB = MYSQ(K) * DD
119 M(3,2) = M(3,2) + TA - TB
120 M(2,3) = M(2,3) - TA - TB
121 TAPRIM=LY(K)*IUDPRI
122 TBPRI=MYSQ(K)*DDPRIM
123 MPRIME(3,2)=MPRIME(3,2) + TAPRIM -TBPRI
124 MPRIME(2,3)=MPRIME(2,3) - TAPRIM -TBPRI
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168
20 CONTINUE
C
CRVTRM=ALPHA*(H-HT)
M(1,1) = M(1,1) - CRVTRM
M(2,2) = M(2,2) - CRVTRM
M(3,3) = M(3,3) - CRVTRM
CURVPR=ALPHA/VAENR
MPRIME(1,1)=MPRIME(1,1) + CURVPR
MPRIME(2,2)=MPRIME(2,2) + CURVPR
MPRIME(3,3)=MPRIME(3,3) + CURVPR
C
C CALCULATE THE MATRIX T.
T(1,1)=-S*M(3,1)/(1.0D0+M(3,3))
T(4,4)=-S*M(1,3)/(1.0D0+M(3,3))
T(1,2)= S*M(3,2)/(1.0D0+M(3,3))
T(3,4)= S*M(2,3)/(1.0D0+M(3,3))
T(1,3)=0.0D0
T(2,4)=0.0D0
T(1,4)=(C+C*M(3,3))/(1.0D0+M(3,3))
T(2,1)=0.0D0
T(4,3)=0.0D0
T(2,2)=0.0D0
T(3,3)=0.0D0
T(2,3)=1.0D0
T(3,1)=M(2,3)*M(3,1)/(1.0D0+M(3,3)) - M(2,1)
T(4,2)=M(3,2)*M(1,3)/(1.0D0+M(3,3)) - M(1,2)
T(3,2)= C+C + M(2,2) - M(2,3)*M(3,2)/(1.0D0+M(3,3))
T(4,1)=1.0D + M(1,1) - M(1,3)*M(3,1)/(1.0D0+M(3,3))
M331=1.0D0+M(3,3)
TPRIME(1,1)=(-S*MPRIME(3,1)+M331*S*M(3,1)+MPRIME(3,3))/M331**2
TPRIME(4,4)=(-S*MPRIME(1,3)+M331*S*M(1,3)+MPRIME(3,3))/M331**2
TPRIME(1,2)=(-S*MPRIME(3,2)+M331*S*M(3,2)+MPRIME(3,3))/M331**2
TPRIME(3,4)=(-S*MPRIME(2,3)+M331*S*M(2,3)+MPRIME(3,3))/M331**2
TPRIME(1,3)=0.0D0
TPRIME(2,4)=0.0D0
TPRIME(1,4)=( MPRIME(3,3)*M331 - MPRIME(3,3)*(C+C*M(3,3)))/M331**2
TPRIME(2,1)=0.0D0
TPRIME(4,3)=0.0D0
TPRIME(2,2)=0.0D0
TPRIME(3,3)=0.0D0
TPRIME(2,3)=0.0D0
TPRIME(3,1)=(- M(2,3)*MPRIME(3,1)+M331*MPRIME(2,3)+M(3,1)*M331 -

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169      MPRIME(3,3)*M(2,3)*M(3,1)/M331**2 - MPRIME(2,1)
170      TPRIME(4,2)=( M(3,2)*MPRIME(1,3)*M331+MPRIME(3,2)*M(1,3)*M331 -
171      MPRIME(3,3)*M(3,2)*M(1,3)/M331**2 - MPRIME(1,2)
172      TPRIME(3,2)=MPRIME(2,2) - (MPRIME(2,3)*M(3,2)*M331+
173      M(2,3)*MPRIME(3,2)*M331-MPRIME(3,3)*M(2,3)*M(3,2) )/
174      M331**2
175      TPRIME(4,1)=MPRIME(1,1) - (MPRIME(1,3)*M(3,1)*M331+
176      M(1,3)*MPRIME(3,1)*M331-MPRIME(3,3)*M(1,3)*M(3,1) )/
177      M331**2
178      RETURN
179
180      ENTRY INIT DT
181      ISO=0
182      IF (MAGFLD .EQ. 0.0) GO TO 250
183      IF (DABS(CODIP-90.0).GE.0.15) GO TO 300
184      IF (DABS(AZMUTH-90.0).LT.0.15) GO TO 250
185      IF (DABS(AZMUTH-270.0).GE.0.15) GO TO 300
186
187      ISO = 1
188      OMEGA = 2000.0 * PI * FREQ
189      OV OMEGA = 1.0/OMEGA
190      WAVENR=OMEGA/VELLT
191      SINDIP = DSIN (CODIP*DTR)
192      DRCOSL = SINDIP * DCOS (AZMUTH * DTR)
193      DRCOSM = SINDIP * DSIN (AZMUTH * DTR)
194      DRCOSN = - DCOS (CODIP * DTR)
195      DO 60 K=1,NRSPEC
196      CDEF EN(K) = COEFFX*1.0E6*CHARGE(K)**2/(OMEGA**2*RATIOM(K))
197      Y(K) = COEFFY * CHARGE(K) * MAGFLD
198      $ / (OMEGA * RATIOM(K))
199      YSQ(K)=Y(K)**2
200      LY(K) = DRCOSL*Y(K)
201      MY(K) = DRCOSM*Y(K)
202      NY(K) = DRCOSN*Y(K)
203      LSOYSQ(K)=DRCOSL**2*YSQ(K)
204      MSOYSQ(K)=DRCOSM**2*YSQ(K)
205      NSOYSQ(K)=DRCOSN**2*YSQ(K)
206      LMYSQ(K)=DRCOSL*DRCOSM*YSQ(K)
207      LMYSQ(K)=DRCOSL*DRCOSN*YSQ(K)
208      MMYSQ(K)=DRCOSM*DRCOSN*YSQ(K)
209      60 CONTINUE
210      C = CDCOS(THETA*DTR)
211      S = CDSIN(THETA*DTR)
212      CSQ = C**2
213      SSQ = S**2
214      CI = CDCOS((THETA-DTHETA)*DTR)
215      SI = CDSIN((THETA-DTHETA)*DTR)
216      CSQI = CI**2
217      SSQI = SI**2
218      RETURN
219      END

```

C

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