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Addendum 1
Technical Report 208

HF CHANNEL SIMULATOR FOR WIDEBAND SIGNALS

Deviative Absorption and Groundwave Attenuation in the HF Channel

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6 November 1978

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Prepared for
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In NOSC TR 208, of 31 March 1978, a mathematical model of the wideband HF channel ~~was~~ has been developed and a software version of the model ~~was~~ presented. This addendum augments that model by including deviative absorption loss for the skywave returns and by providing for automatic calculation of the groundwave attenuation. With these additions, the model more accurately portrays the HF channel and has increased utility. A software version of the revised channel model is implemented and a listing of the program is appended.

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I. INTRODUCTION

This addendum augments NOSC TR 208 (ref. 1) and should be read in conjunction with that report. In the report, a mathematical model of the wideband HF channel was developed and used for computer simulation of the channel. The purpose of this addendum is to augment the existing channel model by adding (1) a deviative absorption term for the skywave returns, and (2) an attenuation term for the groundwave. With these additions the mathematical model will more accurately portray the HF channel and its utility will be considerably enhanced.

In the following sections the two additions are described and a FORTRAN listing of the revised simulator is provided. Notations and definitions used are, wherever possible, identical to those appearing in the report.

II. DEVIATIVE ABSORPTION

The earlier channel model incorporated only three sources of attenuation for the skywave returns. These were nondeviative absorption, antenna gain and spreading ($1/r^2$) loss. Several less-important sources of attenuation, such as polarization mismatch, focusing and deviative absorption, were not included. While the losses due to these other sources are relatively small, one of them – deviative absorption – plays an important role in signal analysis applications. Both the deviative absorption loss and the signal distortion are greater for high-angle returns than they are for low-angle returns. If deviative absorption is not included in the model, the high-angle returns will have an exaggerated effect on the overall received signal, and this may lead to a more pessimistic evaluation of the channel than is warranted.

In what follows, a tractable approximation for the deviative absorption loss is described and sample calculations using this approximation are presented. We begin with some notation and assumptions; all of which have been discussed in greater detail in (ref. 1).

The electron density profile is assumed to have a parabolic shape in the E and F regions; no provision has been made for daytime splitting of the F region into distinct F_1 and F_2 regions. The nighttime electron density profile is given by

$$N(h) = \begin{cases} 0 & , \quad h < h_E - 2H_E \\ N_E\left[1 - \left(\dfrac{h - h_E}{2H_E}\right)^2\right], & h_E - 2H_E \leq h \leq h_E + 2H_E \\ 0 & , \quad h_E + 2H_E < h < h_F - 2H_F \\ N_F\left[1 - \left(\dfrac{h - h_F}{2H_F}\right)^2\right], & h_F - 2H_F \leq h \leq h_F + 2H_F \\ 0 & , \quad h_F + 2H_F < h \end{cases} \qquad (1)$$

Here, N_E is the peak electron density (free electrons per m^3) of the E region while h_E is the height of the peak electron density in the E region in km, and $2H_E$ is the semithickness of the E region parabola in km. Similar definitions apply to the F region parameters N_F, h_F and $2H_F$.

1. NOSC TR 208, HF Channel Simulator for Wideband Signals (U), by R Lugannani and HG Booker, Unclassified, 31 March 1978.

For the daytime electron density profile, allowance is made for ionization between the E and F regions. Between these regions the electron density is assumed to be constant and equal to N_E. For the daytime profile we have,

$$N(h) = \begin{cases} 0 & , \quad h < h_E - 2H_E \\ N_E\left[1 - \left(\frac{h - h_E}{2H_E}\right)^2\right], & h - 2H_E \leq h \leq h_E \\ N_E & , \quad h_E < h < h_F + 2H_F\left(1 - \frac{N_E}{N_F}\right)^{1/2} \\ N_F\left[1 - \left(\frac{h - h_F}{2H_F}\right)^2\right], & h_F + 2H_F\left(1 - \frac{N_E}{N_F}\right)^{1/2} \leq h \leq h_F + 2H_F \\ 0 & , \quad h_F + 2H_F < h \end{cases} \tag{2}$$

The constants appearing in equation (2) are defined in the same manner as they were for the nighttime case, except that their values will be different because of the different heights and ionization densities in the daytime ionosphere.

In the absence of a magnetic field, the refractive index is given by,

$$\mu^2 = \mu^2(h) = 1 - K\,\frac{N(h)}{f^2} \tag{3}$$

where f is the frequency in Hz, N(h) is given by either equation (1) or (2), and,

$$K = \frac{e^2}{4\pi^2 \epsilon_o m} \cong 80.5. \tag{4}$$

The penetration frequency for each region is defined as the plasma frequency at the peak electron density. For the E and F regions, these are given by,

$$f_{pE}^2 = KN_E \tag{5a}$$

$$f_{pF}^2 = KN_F \tag{5b}$$

with f_{pE} and f_{pF} in Hz.

For vertical incidence in the absence of a magnetic field, the following expression will be used for the deviative absorption loss (ref. 2)

$$L_{dev}^{(vert)}(f) = \left(\frac{8.686}{c}\right) \int_0^{h_r} \nu \cdot \left[\frac{1}{\mu} - \mu\right] dh. \tag{6}$$

2. Davies, K. Ionospheric Radio Propagation, in National Bureau of Standards Monograph 80, U. S. Government Printing Office, 1965.

Here, $L_{dev}^{(vert)}(f)$ is the attenuation in decibels per hop, $\nu = \nu(h)$ is the collision frequency in Hz, c is the velocity of light in km/sec and h_r is the height at which $\mu = 0$. In the case of oblique incidence the deviative loss is obtained from (6) by means of the relationship

$$L_{dev} = L_{dev}(f) = \frac{1}{\cos\theta} L_{dev}^{(vert)}(f \cdot \cos\theta) \tag{7}$$

where θ is the ray angle measured from the vertical.

The integration in equation (6) is difficult to perform because of the presence of the collision frequency in the integrand. To overcome this difficulty the integrand will be simplified by taking the collision frequency to be constant in the E and F regions and allowing it to decrease exponentially between the two regions. Thus, for the nighttime collision frequency, we will use,

$$\nu(h) = \begin{cases} 0, & h < h_E - 2H_E \\ \nu_E, & h_E - 2H_E \leq h \leq h_E + 2H_E \\ 0, & h_E + 2H_E < h < h_F - 2H_F \\ \nu_F, & h_F - 2H_F \leq h \leq h_F + 2H_F \\ 0, & h_F + 2H_F < h, \end{cases} \tag{8}$$

and for the daytime collision frequency,

$$\nu(h) = \begin{cases} 0 , & h < h_E - 2H_E \\ \nu_E , & h_E - 2H_E \leq h \leq h_E \\ \nu_E \exp\left[-\left(\frac{h - h_E}{2H_E}\right)\right], & h_E < h < h_F + 2H_F\left(1 - \frac{N_E}{N_F}\right)^{1/2} \\ \nu_F , & h_F + 2H_F\left(1 - \frac{N_E}{N_F}\right)^{1/2} \leq h \leq h_F + 2H_F \\ 0 , & h_F + 2H_F < h \end{cases} \tag{9}$$

where

$$\nu_E = \nu(h_E) \tag{10a}$$

$$\nu_F = \nu(h_F) \tag{10b}$$

Substituting equations (8) and (9) into (6), performing the integration and using (7) we obtain for the deviative absorption loss:

Nighttime

$$L_{dev} = \begin{cases} 8.686\left(\frac{\nu_E \cdot H_E}{2c \cdot x}\right)\left[\left(\hat{f}_E x + \frac{1}{\hat{f}_E x}\right)\ln\left(\frac{1+\hat{f}_E x}{1-\hat{f}_E x}\right) - 2\right], & \hat{f}_E x \leqslant 1 \\ 8.686\left(\frac{\nu_E \cdot H_E}{c \cdot x}\right)\left[\left(\hat{f}_E x + \frac{1}{\hat{f}_E x}\right)\ln\left(\frac{\hat{f}_E x + 1}{\hat{f}_E x - 1}\right) - 2\right], & \hat{f}_E x > 1 \\ \quad + 8.686\left(\frac{\nu_F \cdot H_F}{2c \cdot x}\right)\left[\left(\hat{f}_F x + \frac{1}{\hat{f}_F x}\right)\ln\left(\frac{1+\hat{f}_F x}{1-\hat{f}_F x}\right)\right] & \end{cases} \tag{11}$$

Daytime

$$L_{dev} = \begin{cases} 8.686\left(\frac{\nu_E \cdot H_E}{2c \cdot x}\right)\left[\left(\hat{f}_E x + \frac{1}{\hat{f}_E x}\right)\ln\left(\frac{1+\hat{f}_E x}{1-\hat{f}_E x}\right) - 2\right], & \hat{f}_E x \leqslant 1 \\ 8.686\left(\frac{\nu_E \cdot H_E}{2c \cdot x}\right)\left[\left(\hat{f}_E x + \frac{1}{\hat{f}_E x}\right)\ln\left(\frac{\hat{f}_E x + 1}{\hat{f}_E x - 1}\right) - 2\right], & \hat{f}_E x > 1 \\ \quad + 8.686\left(\frac{\nu_E \cdot H_E}{c \cdot x}\right)\frac{1}{\hat{f}_E x\,(\hat{f}_E^2 x^2 - 1)^{1/2}} & \\ \quad + 8.686\left(\frac{\nu_F \cdot H_F}{c \cdot x}\right)\cdot\left(\hat{f}_F x + \frac{1}{\hat{f}_F x}\right)\ln\left(\frac{\sqrt{1-r^2}+\sqrt{\hat{f}_F^2 x^2 - r^2}}{\sqrt{1-\hat{f}_F^2 x^2}}\right) & \\ \quad - 8.686\left(\frac{\nu_F \cdot H_F}{c \cdot x}\right)\frac{\sqrt{1-r^2}}{\hat{f}_F x}\sqrt{\hat{f}_F^2 x^2 - r^2} & \end{cases} \tag{12}$$

with,

$$x = \cos\theta \tag{13}$$

$$\hat{f}_E = \frac{f}{f_{pE}} \tag{14a}$$

$$\hat{f}_F = \frac{f}{f_{pF}} \tag{14b}$$

$$r^2 = \frac{f_{pE}^2}{f_{pF}^2} \tag{15}$$

In the foregoing analysis, the effect of the earth's magnetic field has been neglected, but we take this to be an adequate approximation for the ordinary wave. For the extraordinary wave, the penetration frequencies are shifted relative to those for the ordinary wave and it is essential to take this into account. As in (ref. 1) the extraordinary wave penetration, frequencies are obtained using the relationships,

$$f_{pE}^{(x)} = \frac{1}{2} f_{HE} + \left[f_{HE}^2 + 4 \left(f_{pE}^{(0)} \right)^2 \right]^{1/2} \tag{16a}$$

$$f_{pF}^{(x)} = \frac{1}{2} f_{HF} + \left[f_{HF}^2 + 4 \left(f_{pF}^{(0)} \right)^2 \right]^{1/2} . \tag{16b}$$

Here, the superscripts "0" and "x" denote the ordinary and extraordinary waves respectively, with $f_{pE}^{(0)}$ given by (5a) and $f_{pF}^{(0)}$ given by (5b). The frequencies f_{HE} and f_{HF} are the gyrofrequencies associated with the earth's magnetic field at the levels of maximum ionization density in the E and F regions respectively. For the gyrofrequencies we will use the approximate expressions (ref. 2),

$$f_{HE} = 0.87 \left(\frac{6370}{6370 + h_E} \right)^3 [1 + 3 \sin^2 \Phi]^{1/2} \tag{17a}$$

$$f_{HF} = 0.87 \left(\frac{6370}{6370 + h_F} \right)^3 [1 + 3 \sin^2 \Phi]^{1/2} \tag{17b}$$

where f_{HE} and f_{HF} are in MHz, and Φ is the latitude expressed in magnetic coordinates. If ϕ and λ are the respective geographic latitude and longitude, and ϕ_o and λ_o represent the latitude and longitude of the north magnetic pole ($\phi_o \cong 78.3°$N, $\lambda_o \cong 69°$W), then (ref. 2),

$$\sin \Phi = \sin \phi \sin \phi_o + \cos \phi \cdot \cos \phi_o \cdot \cos (\lambda - \lambda_o). \tag{18}$$

We assume that, to calculate deviative absorption for the extraordinary wave, we may use equations (11) and (12), but with $f_{pE}^{(x)}$ and $f_{pF}^{(x)}$ substituted for the ordinary wave penetration frequencies. Otherwise, the calculations for deviative loss take the same form as those for the ordinary wave.

To evaluate L_{dev}, the collision frequency is needed and for this the following approximation will be used,

$$\nu(h) = \exp[12.43 - 0.1773 \cdot (h - 90)] + K \cdot (3.93 \times 10^5) \cdot T^{-3/2} \cdot N(h) \tag{19}$$

Here, T = T(h) is the temperature at height h in degrees Kelvin and *K* is given by equation (4). The first term on the right side of (19) accounts for collisions between electrons and neutral particles; it is based on table 9.4 of (ref. 3). This term is important in the E region but almost negligible in the F region. The second term in (19) accounts for collisions between electrons and ions and has been taken from equation 4.2.10 of reference 4. This term is relatively

3. Banks, PM, and Kockarts, G, Aeronomy, Part A, Academic Press, 1973
4. Ratcliffe, JA, The Magneto-Ionic Theory and its Applications to the Ionosphere, Cambridge University Press, 1959

small in the E region, but it is the dominant term in the F region. For the heights of interest here, equation (19) provides an adequate approximation to the collision frequency.

For the temperature, T(h), we will use the profile appearing in the 1959 ARDC Model Atmosphere (ref. 5). Throughout the range of interest in h, this temperature profile will be approximated by the polynomial,

$$T(h) = b_0 + b_1 h + b_2 h^2 + b_3 h^3. \tag{20}$$

The coefficients have been determined using a combination of least squares and minimax fits. The results are listed in table 1.

The deviative absorption loss has been incorporated into the Fortran version of the simulator and a revised listing of the program is presented in appendix A. The changes appear mainly in the existing subroutine "ATTEN" and in the new subroutines "DEVIAT" and "TEMP."

A synthetic ionogram has been generated, using the revised computer program. The resulting curves are presented in figure 1 and they should be compared with figure 5 of this report (ref. 1). The delays are identical for the two figures, but the increased attenuation of the high-angle return is readily evident.

Table 1. Coefficients for polynomial approximation of temperature profile

Coefficient	100 km $\leq$ h $<$ 210 km	210 km $\leq$ h $\leq$ 600 km
b_0	1.414×10^{3}	1.424×10^{3}
b_1	-4.428×10^{1}	3.990×10^{-2}
b_2	4.217×10^{-1}	-1.040×10^{-3}
b_3	-1.004×10^{-3}	3.000×10^{-6}

5. Minzer, RA, Champion, KSW, and Pond, HL, The ARDC Model Atmosphere: Air Force Surveys in Geophysics, No. 115, 1959.

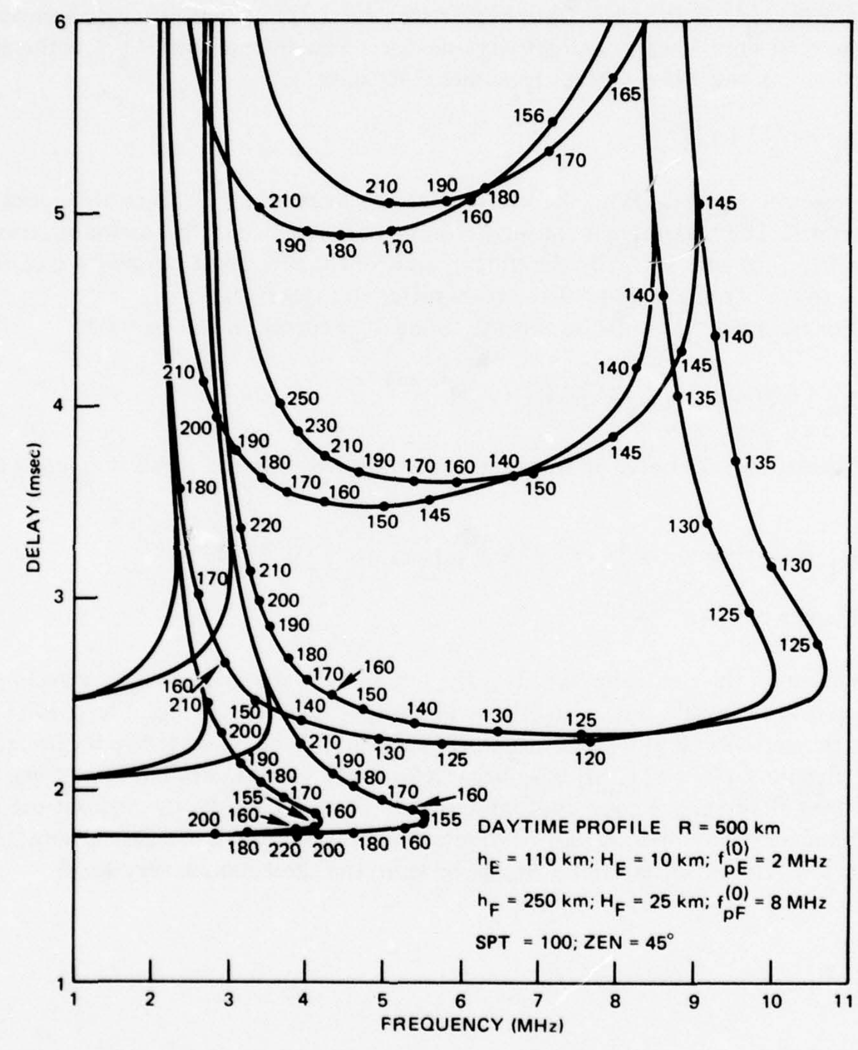

Figure 1. Computed ionosphere returns for one, two, and three hops. (Numbers on curve are attenuation in dB.)

III. GROUNDWAVE ATTENUATION

This section is concerned with the attenuation of a groundwave that has propagated across a rough, curved, lossy ocean surface. Our approach is based on the work of Barrick (ref. 6) and represents an attempt to reduce his expressions to a tractable form for computation. By providing for internal calculation of the groundwave attenuation, the utility of the simulator is increased; since, it is no longer necessary to enter this attenuation as a separate input whenever range, frequency, or sea state change.

Following Barrick, the groundwave loss, L_g, will be written as the sum of two terms. The first term, $L_g^{(1)}$, is the basic transmission loss due to propagation across a smooth, curved, lossy (4 mhos/meter conductivity) surface. The second term, $L_g^{(2)}$, is the additional transmission loss caused by surface roughness. We have

$$L_g = L_g^{(1)} + L_g^{(2)} \tag{21}$$

with all losses in decibels. Both the transmitter and receiver are assumed to be located at the ocean surface. The maximum error incurred as a consequence of this assumption is approximately 3% (ref. 6) and is worth tolerating in view of the attendant simplicity (viz, it is not necessary to specify the heights of the transmitter and receiver).

For the basic transmission loss the following expression will be used,

$$L_g^{(1)} = 20 \log_{10}\left(\frac{2\pi Rf}{0.3}\right) + C_1(f) \cdot R^{C_2(f)} \tag{22}$$

where R is the distance between transmitter and receiver in km, f is the frequency in MHz, and

$$C_1(f) = (1.78 \times 10^{-4}) \cdot f^{2.58} \cdot \exp\left[-(1.40 \times 10^{-8}) \cdot f^5\right] \tag{23}$$

$$C_2(f) = 1.83 \cdot f^{-0.243} \tag{24}$$

The first term on the right side of (22) is the loss the signal experiences by traveling a distance R across a smooth, flat, perfectly conducting surface. The second term is a correction term for the earth's curvature and for a lossy surface; it is based on figure 8 of reference 6. The coefficients $C_1(f)$ and $C_2(f)$ have been determined using a combination of least squares and minimax fits to give a good approximation to Barrick's results throughout the ranges and frequencies of interest. A plot of equation (22) is presented in figure 2 here, together with selected values from Barrick. As can be seen, the agreement is very good.

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6. Battelle Memorial Institute Report, Contract DAAH01-70-C-0312, Theory of Groundwave Propagation Across a Rough Sea at Dekameter Wavelengths, by DE Barrick, 1970.

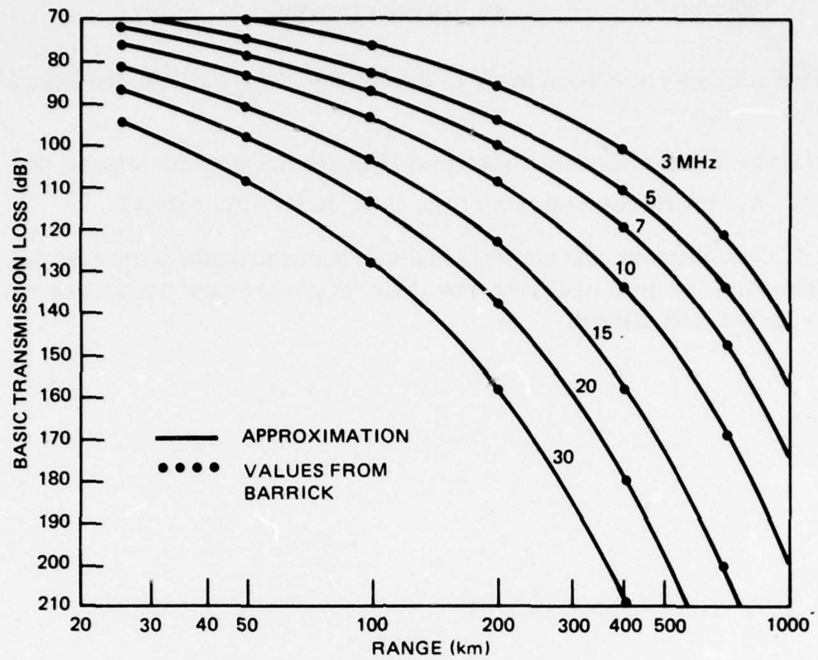

Figure 2. Basic transmission loss for groundwave.

Determination of the additional transmission loss, $L_g^{(2)}$, requires a knowledge of the ocean wave spectrum, which is characterized by specifying the sea state. Two spectra have been considered by Barrick (ref. 6): the Neumann-Pierson spectrum, modified to account for wind direction; and the Phillips spectrum, which is independent of wind direction. The Phillips spectrum was chosen because, as noted by Barrick, it appears to give better agreement with actual observations. Also, the Phillips spectrum results in losses that lie between those obtained for the upwind-downwind and crosswind directions, using the modified Neumann-Pierson spectrum, and it does not require that wind direction be specified as an additional input.

For the additional transmission loss, the dependence on range, frequency, and sea state is complicated and precludes a simple, accurate analytic approximation. However, interpolation can be used to provide good accuracy as well as ease of computation and it is this approach that will be used. The interpolation scheme is linear in both range and frequency, with reference values obtained from figures 25-31 of reference 6. The reference frequencies used are 3, 5, 7, 10, 15, 20 and 30 MHz, while the reference ranges used are 25, 50, 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 km. With these reference points the error attributable to the interpolation is negligible for the ranges and frequencies of interest.

A Fortran version of the calculations necessary to determine the groundwave loss has been incorporated into the simulator; a listing of this program is presented in appendix A of this addendum. The changes consist of a new subroutine "GNDATN" and a statement in the main program that calls this subroutine.

IV. CONCLUSION

Two additions have been made to the HF channel model and the associated simulator. These are:

(1) Inclusion of deviative absorption loss for the skywave returns, and

(2) Automatic computation of the groundwave attenuation.

The first of these improves the accuracy and utility of the mathematical model, while the second eliminates the need to enter a new value for groundwave attenuation whenever range, frequency, or sea state change.

GLOSSARY OF NEW MATHEMATICAL TERMS*

b_j	Coefficients used in the polynomial approximation of the temperature profile
$C_j(f)$	Parameters used in the approximation of $L_g^{(1)}$
L_{dev}	Deviative absorption loss, oblique incidence
$L_{dev}^{(vert)}$	Deviative absorption loss, vertical incidence
L_g	Groundwave loss
$L_g^{(1)}$	Basic transmission loss component of L_g
$L_g^{(2)}$	Additional transmission loss component of L_g
$T = T(h)$	Temperature
$\nu(h)$	Collision frequency
ν_E	Collision frequency at height h_E
ν_F	Collision frequency at height h_F

*This glossary contains only those symbols that are introduced for the first time in this addendum. Other symbols used in the text are listed in the glossary of the report (ref. 1).

APPENDIX A

PROGRAM FOR CALCULATING CHANNEL PARAMETERS

```
      DIMENSION T(48,14),P(4,8),A(3),G(2),TEM(2),CNU(4),F(3)              C  002:000010
      COMMON HE,HEM,HF,HFM,TIME                                             C  002:000010
                                                                            C  002:000010
C          ***** PROGRAM MODIFIED DECEMBER 1977 *****                       C  002:000010
                                                                            C  002:000010
C          THIS PROGRAM COMPUTES CHANNEL PARAMETERS FROM BASIC INPUTS       C  002:000010
                                                                            C  002:000010
C          GLOSSARY OF MOST IMPORTANT VARIABLES                             C  002:000010
C              FC     = CARRIER FREQUENCY (MHZ.)                            C  002:000010
C              BW     = BANDWIDTH (KHZ.)                                    C  002:000010
C              XLONG  = LONGITUDE OF TRANSMITTER (DEGREES) + FOR WEST,      C  002:000010
C                       - FOR EAST)                                         C  002:000010
C              XLAT   = LATITUDE OF TRANSMITTER (DEGREES) + FOR NORTH,      C  002:000010
C                       - FOR SOUTH)                                        C  002:000010
C              R      = DISTANCE BETWEEN TRANSMITTER AND RECEIVER (KM.)     C  002:000010
C              RAG    = DIRECTION FROM TRANSMITTER TO RECEIVER (DEGREES)    C  002:000010
C                       MEASURED IN GEOGRAPHIC COORDINATES)                 C  002:000010
C              RAM    = DIRECTION FROM TRANSMITTER TO RECEIVER (DEGREES)    C  002:000010
C                       MEASURED IN MAGNETIC COORDINATES)                   C  002:000010
C              ISEA   = SEA STATE                                           C  002:000010
C              SPT    = SUNSPOT NUMBER                                      C  002:000010
C              ZEN    = SOLAR ZENITH ANGLE (DEGREES)                        C  002:000010
C              TEM(1)= TEMPERATURE AT HEIGHT HFM (DEG. K)                   C  002:000010
C              TEM(2)= TEMPERATURE AT HEIGHT HFM (DEG. K)                   C  002:000010
C              TIME   = TIME OF DAY ('DAY' OR 'NITE')                       C  002:000010
C              HEM    = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)   C  002:000010
C              4HE    = THICKNESS OF E REGION (KM.)                         C  002:000010
C              HFM    = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.)   C  002:000010
C              4HF    = THICKNESS OF F REGION (KM.)                         C  002:000010
C              FPEO   = PENETRATION FREQ. OF E REGION O-WAVE (MHZ.)         C  002:000010
C              FPFO   = PENETRATION FREQ. OF F REGION O-WAVE (MHZ.)         C  002:000010
C              FPEX   = PENETRATION FREQ. OF E REGION X-WAVE (MHZ.)         C  002:000010
C              FPFX   = PENETRATION FREQ. OF F REGION X-WAVE (MHZ.)         C  002:000010
C              CNU(1)= ADDITIVE TERM IN EXPONENT OF COLLISION FREQ.         C  002:000010
C              CNU(2)= MULTIPL. TERM IN EXPONENT OF COLLISION FREQ.         C  002:000010
C              CNU(3)= SHIFT TERM IN EXPONENT OF COLLISION FREQ.            C  002:000010
C              CNU(4)= MULTIPL. FACTOR IN SECOND TERM OF COLLISION FREQ.    C  002:000010
C              ABSMLT= MULTIPLICATIVE CONST. FOR NONDEVIATIVE ABSORPTION    C  002:000010
C              SPTMLT= SUNSPOT NO. MULTIPLIER FOR NONDEVIATVE ABSORPTION    C  002:000010
C              SOLEXP= SOLAR ZEN. ANG. EXPNT. FOR NONDEVIATVE ABSORPTION    C  002:000010
C              SHIFTE= E REGION REFERENCE DOPPLER SHIFT (HZ.)               C  002:000010
C              EXSHIE= E REGION DOPPLER SHIFT EXPONENT                      C  002:000010
C              SPRDE  = E REGION REFERENCE DOPPLER SPREAD (HZ.)             C  002:000010
C              EXSPRE= E REGION DOPPLER SPREAD EXPONENT                     C  002:000010
C              RFREQE= E REGION DOPPLER REFERENCE FREQ. (MHZ.)              C  002:000010
C              SHIFTF= F REGION REFERENCE DOPPLER SHIFT (HZ.)               C  002:000010
C              EXSHIF= F REGION DOPPLER SHIFT EXPONENT                      C  002:000010
C              SPRDF  = F REGION REFERENCE DOPPLER SPREAD (HZ.)             C  002:000010
C              EXSPRF= F REGION DOPPLER SPREAD EXPONENT                     C  002:000010
C              RFREQF= F REGION DOPPLER REFERENCE FREQ. (MHZ.)              C  002:000010
C              ATT    = ATTENUATION (DB.)                                   C  002:000010
C              ATTDIF= ATTENUATION DIFFERENCE BETWEEN STRONGEST RETURN      C  002:000010
C                       FROM IONOSPHERE AND WEAKEST RETURN RETAINED         C  002:000010
C              NPATH  = NO. OF IONOSPHERE RETURNS RETAINED                  C  002:000010
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C          GDLLAY= GROUNDWAVE DELAY (SEC.)                                    C  002100000I0
C          GATTEN= GROUNDWAVE ATTENUATION (DB)                                C  00210000010
C          IPRINT= PRINT SELECTOR FOR T(I,J) ARRAY ('ALL' OR 'RET')           C  00210000010
C          NPUNCH= PUNCH SELECTOR. PUNCHES DATA CARDS FOR USE IN              C  00210000010
C                  SIGNAL ANALYSIS PART OF SIMULATOR IF NPUNCH=1.             C  00210000010
C                  DOES NOT PUNCH DATA CARDS IF NPUNCH=0.                     C  00210000010
                                                                              C  00210000010
C       ARRAY T(I,J) CONTAINS THE FOLLOWING PARAMETERS                        C  00210000010
C          I = N: INDEX NUMBER FOR PATH                                       C  00210000010
C          J = 1: NUMBER OF HOPS                                              C  00210000010
C            = 2: REGION AND MAGNETOIONIC INDICATOR (EO = E REGION -          C  00210000010
C                 ORDINARY WAVE; SIMILARLY FOR EX, FO, AND FX)                C  00210000010
C            = 3: 'HIGH' (FOR HIGH RAY) OR 'LOW' (FOR LOW RAY)                C  00210000010
C            = 4: SOLUTION INDICATOR (0=NO SOLUTION, 1=SOLUTION)              C  00210000010
C            = 5: THETA = RAY ANGLE MEASURED FROM VERTICAL (DEGREES)          C  00210000010
C            = 6: PATH LENGTH (KM.)                                           C  00210000010
C            = 7: DELAY AT CARRIER FREQUENCY (SEC.)                           C  00210000010
C            = 8: RECEIVED CARRIER PHASE (CYCLES)                             C  00210000010
C            = 9: SIGNAL DELAY (SEC.)                                         C  00210000010
C            =10: AMPLITUDE DISTORTION (SEC/MHZ)                              C  00210000010
C            =11: PHASE DISTORTION (SEC/MHZ**2)                               C  00210000010
C            =12: ATTENUATION (DB.)                                           C  00210000010
C            =13: DOPPLER SHIFT (HZ.)                                         C  00210000010
C            =14: DOPPLER SPREAD (HZ.)                                        C  00210000010
                                                                              C  00210000010
      PI=3.14159265359                                                        C  00210000010
      IN='NITE'                                                               C  00210005010
      PRET='RET'                                                              C  00210007I3
C          READ DATA                                                          C  00210009I3
      READ/,FC,BW                                                             C  00210009I3
                                                                                 FIB IS 0006 LONG
      READ/,XLONG,XLAT                                                        C  00210013I0
      READ/,R                                                                 C  00210010I0
      READ/,RAG                                                               C  00210025I0
      READ/,ISEA                                                              C  00210020I0
      READ/,SPT                                                               C  00210035I0
      READ/,ZEN                                                               C  00210030I0
      READ(5,909)TIME                                                         C  00210045I0
      READ/,HEM,HE,FPEO                                                       C  00210040I2
      READ/,HFM,HF,FPFO                                                       C  0021005AI0
      READ/,CNU(1),CNU(2),CNU(3),CNU(4)                                       C  0021006BI0
      READ/,ABSMLT,SPTMLT,SOLEXP                                              C  0021007BI0
      READ/,SHIFTE,EXSHTE,SPRDE,FXSPRE,RFREQE                                 C  0021008BI0
      READ/,SHIFTF,EXSHTF,SPRDF,FXSPRF,RFREQF                                 C  00210094I0
      READ/,ALTDIF                                                            C  002100A4I0
      READ(5,909)TPRINT                                                       C  002100A0I0
      READ/,NPUNCH                                                            C  002100B3I2
C          END READ DATA                                                      C  002100B0I0
C          COMPUTE PENETRATION FREQUENCIES FOR EXTRAORDINARY WAVES            C  002100B0I0
      CALL GETDMA(XLAT,XLONG,XLATM,XLONGM)                                    C  002100B0I0
      SINPHI=SIN((PI/180.)*XLATM)                                             C  002100B0I4
      XMLAT=.87*SQRT(1.+3.*(SINPHI**2))                                       C  002100C0I1
      FHEX=XMLAT*((6370./(6370.+HEM))**3)                                     C  002100C4I5
      FHFX=XMLAT*((6370./(6370.+HFM))**3)                                     C  002100C8I0
      FPEX=.5*FHEX+SQRT((FPEO**2)+(.25*(FHEX**2)))                            C  002100C0I4
      FPFX=.5*FHFX+SQRT((FPFO**2)+(.25*(FHFX**2)))                            C  002100D3I5
C          END COMPUTATION OF PENETRATION FREQS. FOR EXTRAORDINARY WAVES      C  002100D7I5
C          COMPUTE BEARING OF RECEIVER IN MAGNETIC COORDINATES                C  002100D7I5
      CALL RNGMAG(XLAT,XLONG,R,RAG,RAM)                                       C  002100D7I5
C          END COMPUTATION OF RECEIVER BEARING                                C  002100D0I0
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C          COMPUTE TEMPERATURES AT HEM AND HFM                    C  002:00D8:10
      CALL TEMP(HEM,TEM(1))                                       C  002:00D8:10
      CALL TEMP(HFM,TEM(2))                                       C  002:00DD:11
C          END COMPUTATION OF TEMPERATURES                        C  002:00DF:13
C          COMPUTE GROUNDWAVE DELAY                               C  002:00DF:13
      GDFLAY=R/(3.E+05)                                           C  002:00DF:13
C          END COMPUTATION OF GROUNDWAVE DELAY                    C  002:00E1:14
C          COMPUTE GROUNDWAVE ATTENUATION                         C  002:00E1:14
      CALL GNDATN(FC,ISEA,R,GATTEN)                               C  002:00E1:14
C          END COMPUTATION OF GROUNDWAVE ATTENUATION              C  002:00E4:12
      WRITE(6,910)                                                C  002:00E4:12
                                                                      FIB IS 0006 LONG
      WRITE(6,911)                                                C  002:00E8:12
      WRITE(6,912)FC,BW                                           C  002:00EC:12
      WRITE(6,913)                                                C  002:00F4:12
      WRITE(6,915)XLONG                                           C  002:00F8:12
      WRITE(6,916)XLAT                                            C  002:00FF:12
      WRITE(6,917)R                                               C  002:0106:12
      WRITE(6,918)RAG                                             C  002:010D:12
      WRITE(6,919)                                                C  002:0114:12
      WRITE(6,920)                                                C  002:0118:12
      WRITE(6,921)ISEA                                            C  002:011C:12
      WRITE(6,922)                                                C  002:0123:12
      WRITE(6,923)SPT                                             C  002:0127:12
      IF(ITME.IS.TN)GOTO9                                         C  002:012E:12
      WRITE(6,932)ZEN                                             C  002:013D:10
      GOTO10                                                      C  002:0136:12
 9    WRITE(6,933)                                                C  002:0136:15
10    IF(ITME.IS.TN)GOTO11                                        C  002:0138:12
      WRITE(6,924)                                                C  002:013D:10
      GOTO12                                                      C  002:0141:12
11    WRITE(6,925)                                                C  002:0141:15
12    WRITE(6,926)HEM                                             C  002:0148:12
      SE=2.*HE                                                    C  002:014D:12
      WRITE(6,927)SE                                              C  002:014E:15
      WRITE(6,928)FPED                                            C  002:0155:12
      WRITE(6,930)FPEX                                            C  002:015C:12
      WRITE(6,960)HEM,TEM(1)                                      C  002:0163:12
      WRITE(6,929)HFM                                             C  002:016C:12
      SF=2.*HF                                                    C  002:0173:12
      WRITE(6,927)SF                                              C  002:0175:10
      WRITE(6,928)FPFD                                            C  002:0178:12
      WRITE(6,930)FPFX                                            C  002:0182:12
      WRITE(6,960)HFM,TEM(2)                                      C  002:0189:12
      WRITE(6,961)                                                C  002:0192:12
      WRITE(6,962)CNU(1),GNU(2),CNU(3)                            C  002:0196:12
      WRITE(6,963)CNU(4)                                          C  002:01A0:12
      WRITE(6,953)                                                C  002:01A7:12
      WRITE(6,954)ABSHFT,SPTHLT,SULEXP                            C  002:01A8:12
      WRITE(6,945)                                                C  002:01B5:12
      WRITE(6,946)SHIFTE,EXSHTF,SPRDE,EXSPRE,RFREQE               C  002:01B9:12
      WRITE(6,947)SHIFTF,EXSHTF,SPRDF,EXSPRF,RFREQF               C  002:01C6:12
      WRITE(6,900)                                                C  002:01D3:12
      WRITE(6,934)                                                C  002:01D7:12
      WRITE(6,900)                                                C  002:01D8:12
      WRITE(6,935)GDELAY,GATTEN                                   C  002:01DF:12
      WRITE(6,936)                                                C  002:01E7:12
C          DO 60 COMPUTES THE ARRAY T(I,J)                        C  002:01EB:12
      DO60NHOP=1,6                                                C  002:01E8:12
      XNHOP=FLOAT(NHOP)                                           C  002:01EC:10
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```
      RH=H/XNHOP
      NNHOP=8*(NHOP-1)
      DO35I=1,8
      II=I+NNHOP
      T(II,1)=NHOP
   35 CONTINUE
      I=1+NNHOP
C          ASSIGN LABELS TO EACH TRANSMISSION MODE
      T(I,2)='EO'
      T(I,3)='LOW '
      I=I+1
      T(I,2)='EO'
      T(I,3)='HIGH'
      I=I+1
      T(I,2)='FO'
      T(I,3)='LOW '
      I=I+1
      T(I,2)='FO'
      T(I,3)='HIGH'
      I=I+1
      T(I,2)='EX'
      T(I,3)='LOW '
      I=I+1
      T(I,2)='EX'
      T(I,3)='HIGH'
      I=I+1
      T(I,2)='FX'
      T(I,3)='LOW '
      I=I+1
      T(I,2)='FX'
      T(I,3)='HIGH'
C          END LABEL ASSIGNMENT
C          NMAG = 1 FOR ORDINARY WAVE; NMAG = 2 FOR EXTRAORDINARY WAVE
      DO50NMAG=1,2
      IF(NMAG-1)36,36,37
C          SUBROUTINE 'PATH' RETURNS ARRAY P(I,J) CONTAINING SIGNAL
C          PATH LENGTH, DELAY AND DELAY DERIVATIVES
   36 CALL PATH(RH,FPEO,FPFO,FC,P)
      GOTO38
   37 CALL PATH(RH,FPEX,FPFX,FC,P)
   38 DO40I=1,4
      II=I+4*(NMAG-1)+NNHOP
      T(II,4)=P(I,1)
      T(II,5)=(180./PI)*ARCOS(P(I,3))*P(I,1)
      T(II,6)=XNHOP*P(I,4)
      T(II,7)=P(I,5)*XNHOP
      T(II,8)=FC*P(I,5)*XNHOP*(1.E+06)
      INT=T(II,8)
      T(II,8)=T(II,8)-FLOAT(INT)
      T(II,9)=(P(I,5)+FC*P(I,6))*XNHOP
      T(II,10)=(P(I,6)+.5*FC*P(I,7))*XNHOP
      T(II,11)=((.5*P(I,7))+((FC*P(I,8))/6.))*XNHOP
C          COMPUTE ATTENUATION
      XIND=P(I,1)-(1.E-08)
      IF(XIND)21,21,20
   20 TH=T(II,5)
      DIST=T(II,6)
      XMAG=3.-2.*FLOAT(NMAG)
      A(1)=ABSMLT
      A(2)=SPIMLT
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      A(3)=SOLEXP                                                    C  002:027210
      G(1)=XLATM                                                     C  002:027312
      G(2)=RAM                                                       C  002:027413
      F(1)=FC                                                        C  002:027514
      IF(NMAG-1)41,41,42                                             C  002:027615
 41   F(2)=FPEO                                                      C  002:027810
      F(3)=FPFO                                                      C  002:027911
      GOTO43                                                         C  002:027A13
 42   F(2)=FPEX                                                      C  002:027B10
      F(3)=FPFX                                                      C  002:027C11
 43   CALL ATTEN(G,TH,SPT,ZEN,TFM,CNU,DIST,NHUP,F,XMAG,A,ATT)        C  002:027D13
      T(TI,12)=ATT                                                   C  002:028510
      GOTO22                                                         C  002:028710
 21   T(TI,12)=0.                                                    C  002:028713
C         END COMPUTATION OF ATTENUATION                             C  002:028812
C         COMPUTE DOPPLER SHIFTS AND SPREADS                         C  002:028912
 22   XIND=FLOAT(I)-2.5                                              C  002:028912
      IF(XIND)23,23,24                                               C  002:028B14
 23   T(TI,13)=XNHOP*SHIFTE*((FC/RFREQE)**EXSHTE)*P(I,1)             C  002:028C13
      T(TI,14)=SQRT(XNHOP)*SPRDE*((FC/RFREQE)**EXSPRE)*P(I,1)        C  002:029213
      GOTO25                                                         C  002:029911
 24   T(TI,13)=XNHOP*SHIFTF*((FC/RFREQF)**EXSHTF)*P(I,1)             C  002:029914
      T(TI,14)=SQRT(XNHOP)*SPRDF*((FC/RFREQF)**EXSPRF)*P(I,1)        C  002:029F14
 25   CONTINUE                                                       C  002:02A012
C         END COMPUTATION OF SHIFTS AND SPREADS                      C  002:02A612
 40   CONTINUE                                                       C  002:02A012
 50   CONTINUE                                                       C  002:02A813
 60   CONTINUE                                                       C  002:02AA14
C         DO 70 DETERMINES MINIMUM (NONZERO) ATTENUATION             C  002:02AC15
      ATTMIN=1.E+05                                                  C  002:02AC15
      ATTMAX=0.                                                      C  002:02AE13
      DO70I=1,48                                                     C  002:02AF11
      IF(T(I,12))70,70,61                                            C  002:02B010
 61   ATTMIN=AMIN1(T(I,12),ATTMIN)                                   C  002:02B211
      ATTMAX=AMAX1(T(I,12),ATTMAX)                                   C  002:02B610
 70   CONTINUE                                                       C  002:02B915
      IF(ATTMAX)71,71,72                                             C  002:02BC10
 71   WRITE(6,950)                                                   C  002:02BD11
      NPATH=0                                                        C  002:02C112
      GOTO120                                                        C  002:02C210
 72   WRITE(6,938)                                                   C  002:02C213
      WRITE(6,939)                                                   C  002:02C612
      WRITE(6,940)                                                   C  002:02CA12
      IF(IPRINT.IS.PHET)GOTO101                                      C  002:02CE12
C         DO 100 PRINTS THE COMPLETE ARRAY T(I,J)                    C  002:02CF14
      DO100I=1,48                                                    C  002:02CF14
      IN=I(T,1)+1.E-05                                               C  002:02D110
      WRITE(6,941)IN,T(I,2),T(I,3),T(I,4),T(I,5),T(I,6),T(I,7),T(I,8),T(   C  002:02D415
     1I,9),T(I,10),T(I,11),T(I,12),T(I,13),T(I,14)                   C  002:02EA11
 100  CONTINUE                                                       C  002:02F812
C         DO 110 DETERMINES NPATH AND MODIFIES ARRAY T(I,J) SO THAT  C  002:02FD13
C         IT CONTAINS ONLY THE DESIRED RETURNS                       C  002:02FD13
 101  ATTLIM=ATTMIN+ATTDIF                                           C  002:02FD13
      NPATH=0                                                        C  002:02FE15
      DO110I=1,48                                                    C  002:02FF13
      IF(T(T,12))110,110,102                                         C  002:030110
 102  IF(T(T,12)-ATTLIM)103,103,110                                  C  002:030311
 103  NPATH=NPATH+1                                                  C  002:030513
      DO105J=1,14                                                    C  002:030615
      T(NPATH,J)=T(I,J)                                              C  002:030810
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105  CUNTINUE                                                           C  0021030L14
110  CUNTINUE                                                           C  0021030L15
     IF(IPRINT.IS.PRET)GOTO114                                          C  0021031110
     GOTO115                                                            C  0021031212
C         DO 115 PRINTS THE MODIFIED ARRAY T(I,J)                       C  0021031215
114  DO115I=1,NPATH                                                     C  0021031215
     IN=I(I,1)+1.E-05                                                   C  0021031410
     WRITE(6,951)IN,T(I,2),T(I,3),T(I,5),T(I,6),T(I,7),T(I,8),T(I,9),T( C  0021031715
    1I,10),T(I,11),T(I,12),T(I,13),T(I,14)                              C  0021032U12
115  CUNTINUE                                                           C  0021033U12
     WRITE(6,900)                                                       C  0021033L13
     WRITE(6,952)ALTUDE                                                 C  0021034Z12
120  CUNTINUE                                                           C  0021034V12
C         PUNCH DATA CARDS FUR USE IN SIGNAL ANALYSIS PART OF SIMULATOR C  0021034V12
C         IF NPUNCH=1 (PUNCHES MODIFIED ARRAY T(I,J))                   C  0021034V12
     IF(NPUNCH-1)140,121,140                                            C  0021034V12
121  PUNCH/,FC,RN,R,NPATH                                               C  0021034A13
                                                                           FIB IS 0006 LONG
     PUNCH 909,TIME                                                     C  0021035612
     PUNCH/,GDELAY,GATTEN                                               C  0021035U12
     DO130I=1,NPATH                                                     C  0021036512
     PUNCH 955,(T(I,J),J=1,7)                                           C  0021036610
     PUNCH 956,(T(I,J),J=8,11)                                          C  0021037312
     PUNCH 957,(T(I,J),J=12,14)                                         C  0021038U12
130  CUNTINUE                                                           C  0021038U12
140  CONTINUE                                                           C  0021038F13
C         END PUNCH DATA CARDS                                          C  0021038F13
900  FORMAT(1X)                                                         C  0021033F13
901  FORMAT(1X,/)                                                       C  0021038F13
902  FORMAT(1X,//)                                                      C  0021038F13
903  FURMAT(1X,///)                                                     C  0021038F13
904  FORMAT(1X,////)                                                    C  0021038F13
909  FURMAT(A6)                                                         C  0021038F13
910  FORMAT(46X,'SUMMARY OF TRANSMISSION PARAMETERS'///)                C  0021038F13
911  FURMAT(1X,'SIGNAL PARAMETERS'/)                                    C  0021038F13
912  FORMAT(9X,'CARRIER FREQ. =',F7.3,' MHZ.     BANDWIDTH =',F7.2,' KHZ C  0021038F13
    1.'/)                                                               C  0021038F13
913  FORMAT(1X,'TRANSMITTER/RECEIVER PARAMETERS'/)                      C  0021038F13
915  FORMAT(9X,'LOCATION OF TRANSMITTER: LONGITUDE = ',F7.2,' DEGREES ( C  0021038F13
    1+ FOR WEST, - FOR EAST)')                                          C  0021038F13
916  FURMAT(34X,'LATITUDE  = ',F7.2,' DEGREES (+ FOR NORTH, - FOR SOUTH C  0021038F13
    1)')                                                                C  0021038F13
917  FURMAT(9X,'DISTANCE BETWEEN TRANSMITTER AND RECEIVER =',F8.2,' KM. C  0021038F13
    1')                                                                 C  0021038F13
918  FURMAT(9X,'DIRECTION FROM TRANSMITTER TO RECEIVER =',F6.2,' DEGREE C  0021038F13
    1S (MEASURED FROM TRUE NORTH)')                                     C  0021038F13
919  FORMAT(9X,'TRANSMITTER ANTENNA PATTERN = (3/2)*(SIN(THETA)**2)')   C  0021038F13
920  FURMAT(9X,'RECEIVER ANTENNA PATTERN = (3/2)*(SIN(THETA)**2)')      C  0021038F13
921  FURMAT(9X,'SEA STATE ='I2/)                                        C  0021038F13
922  FORMAT(1X,'IONOSPHERE PARAMETERS'/)                                C  0021038F13
923  FURMAT(9X,'SUNSPOT NUMBER = ',F7.2)                                C  0021038F13
924  FORMAT(9X,'DAYTIME ELECTRON DENSITY PROFILE')                      C  0021038F13
925  FURMAT(9X,'NIGHTTIME ELECTRON DENSITY PROFILE')                    C  0021038F13
926  FURMAT(15X,'F REGION: HEIGHT OF MAX. ELECTRON DENSITY =',F7.2,' KM C  0021038F13
    1.')                                                                C  0021038F13
927  FURMAT(25X,'SEMITHICKNESS OF PARABOLA =',F7.2,' KM.')              C  0021038F13
928  FORMAT(25X,'PENETRATION FREQUENCY, ORDINARY WAVE =',F7.3,' MHZ.')  C  0021038F13
929  FORMAT(15X,'F REGION: HEIGHT OF MAX. ELECTRON DENSITY =',F7.2,' KM C  0021038F13
    1.')                                                                C  0021038F13
930  FURMAT(25X,'PENETRATION FREQUENCY, EXTRAORDINARY WAVE =',F7.3,' MH C  0021038F13
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     1Z.')                                                              C 0021038F13
932  FORMAT(9X,'SOLAR ZENITH ANGLE ='F7.2,' DEGREES')                   C 0021038F13
933  FORMAT(9X,'SOLAR ZENITH ANGLE = NOT APPLICABLE TO NIGHTTIME TRANSM C 0021038F13
    1ISSION')                                                           C 0021038F13
934  FORMAT(1X,'COMPUTED CHANNEL PARAMETERS'/)                          C 0021038F13
935  FORMAT(1X,'GROUNDWAVE:  DELAY = ',1PE10.3,' SEC.    ATTENUATION =  C 0021038F13
    1',E10.3,' DB.')                                                    C 0021038F13
936  FORMAT(1X,'IONOSPHERE RETURNS:'/)                                  C 0021038F13
938  FORMAT( 3X,'MODE',3X,'SOLUTION',3X,'RAY ANGLE',3X,'PATH',4X,'CARRI C 0021038F13
    1ER',4X,'CARRIER',3X,'  SIGNAL   ',1X,'AMPLITUDE',4X,'PHASE',5X,'ATT C 0021038F13
    2ENUATION',2X,'DOPPLER',4X,'DOPPLER')                               C 0021038F13
939  FORMAT(10X,'INDICATOR',2X,'(DEGREES)',2X,'LENGTH',4X,'DELAY',6X,'P C 0021038F13
    1HASE',6X,'DELAY',3X,'DISTORTION',1X,' DISTORTION',5X,'(DB)', 7X,'S C 0021038F13
    2HIFT',5X,'SPREAD')                                                 C 0021038F13
940  FORMAT( 9X,'(O=NO SOLN)',13X,'(KM)',5X,'(SEC)',4X,'(CYCLES)',5X,'( C 0021038F13
    1SEC)',4X,'(SEC/MHZ)',1X,'(SEC/MHZ**2)',15X,'(HZ)', 7X,'(HZ)'/)     C 0021038F13
941  FORMAT(1X,I1,A2,1X,A4,4X,F3.1,7X,F5.2,1X,F9.2,1X,1PE10.3,1X,E10.3, C 0021038F13
    11X,E10.3,1X,E10.3,2X,E10.3,2X,E10.3,1X,E10.3,1X,E10.3)             C 0021038F13
945  FORMAT(9X,'DOPPLER REFERENCE VALUES')                              C 0021038F13
946  FORMAT(15X,'F REGION: SHIFT =',F8.4,' HZ,',1X,'SHIFT EXP. =',F6.3, C 0021038F13
    1'; SPREAD =',F8.4,' HZ,',1X,'SPREAD EXP. =',F6.3,'; REF. FREQ. =', C 0021038F13
    2F7.3,' MHZ.')                                                      C 0021038F13
947  FORMAT(15X,'F REGION: SHIFT =',F8.4,' HZ,',1X,'SHIFT EXP. =',F6.3, C 0021038F13
    1'; SPREAD =',F8.4,' HZ,',1X,'SPREAD EXP. =',F6.3,'; REF. FREQ. =', C 0021038F13
    2F7.3,' MHZ.')                                                      C 0021038F13
950  FORMAT(22X,'***** THERE ARE NO RETURNS FROM THE IONOSPHERE FOR THI C 0021038F13
    1S FREQUENCY AND RANGE *****')                                      C 0021038F13
951  FORMAT(1X,I1,A2,1X,A4,4X,'NA',8X,F5.2,1X,F9.2,1X,1PE10.3,1X,E10.3, C 0021038F13
    11X,E10.3,1X,E10.3,2X,E10.3,2X,E10.3,1X,E10.3,1X,E10.3)             C 0021038F13
952  FORMAT(9X,'ALL IONOSPHERE RETURNS WHOSE ATTENUATION IS GREATER THA C 0021038F13
    1N ',F7.2,' DB. ABOVE THE MINIMUM ATTENUATION ARE IGNORED')         C 0021038F13
953  FORMAT(9X,'NONDEVIATIVE ABSORPTION CONSTANTS')                     C 0021038F13
954  FORMAT(15X,'MULTIPLICATIVE CONSTANT =',F8.2,', SUNSPOT NUMBER MULT C 0021038F13
    1IPLIER =',F9.6,', SOLAR ZENITH ANGLE EXPONENT =',F6.3)             C 0021038F13
955  FORMAT(I1,A2,A4,4E16.9)                                            C 0021038F13
956  FORMAT(4E16.9)                                                     C 0021038F13
957  FORMAT(3E16.9)                                                     C 0021038F13
960  FORMAT(25X,'TEMPERATURE AT',F7.2,' KM. = ',F7.2,' DEG. K')         C 0021038F13
961  FORMAT(9X,'CONSTANTS USED IN DETERMINATION OF COLLISION FREQUENCIE C 0021038F13
    1S')                                                                C 0021038F13
962  FORMAT(15X,'EXPONENT OF FIRST TERM: ADDITIVE CONST. =',F8.4,', MUL C 0021038F13
    1TIPLICATIVE CONST. =',F8.4,', SHIFT CONST. =',F8.4)                C 0021038F13
963  FORMAT(15X,'MULTIPLICATIVE CONST. OF SECOND TERM =',1PE12.4)       C 0021038F13
     STOP                                                               C 0021038F13
     END                                                                C 0021039U12
```

```
      SUBROUTINE BNGMAG(PHIT,XLAMT,R,ANGLEG,ANGLEM)
C         SUBROUTINE COMPUTES BEARING OF THE RECEIVER FROM THE
C         TRANSMITTER IN MAGNETIC COORDINATES
C              PHIT   = GEOGRAPHIC LATITUDE OF TRANSMITTER (DEGREES)
C              XLAMT  = GEOGRAPHIC LONGITUDE OF TRANSMITTER (DEGREES)
C              R      = DISTANCE BETWEEN TRANSMITTER AND RECEIVER (KM.)
C              ANGLEG= BEARING OF RECEIVER IN GEOGRAPHIC COORD.(DEGREES)
C              ANGLEM= BEARING OF RECEIVER IN MAGNETIC COORD. (DEGREES)
      PI=3.14159265359
      CC=PI/180.
      GG=ANGLEG/180.
      IF(GG)6,5,6
5     PHIR=PHIT+(R/(CC*6370.))
      GOTO8
6     IF(GG-1.)10,7,10
7     PHIR=PHIT-(R/(CC*6370.))
8     XLAMR=XLAMT
      GOTO20
10    A=CC*(90.-PHIT)
      B=R/6370.
      G=(CC*ANGLEG)/2.
      D1=(A-B)/2.
      S1=(A+B)/2.
      W1=SIN(D1)/(TAN(G)*SIN(S1))
      W2=COS(D1)/(TAN(G)*COS(S1))
      Z1=ATAN(W1)
      Z2=ATAN(W2)
      W3=(TAN(S1)*COS(Z2))/COS(Z1)
      C=2.*ATAN(W3)
      PHIR=90.-(C/CC)
      XLAMR=XLAMT+((Z2-Z1)/CC)
20    CALL GEIOMA(PHIT,XLAMT,PHITM,XLAMTM)
      CALL GEIOMA(PHIR,XLAMR,PHIRM,XLAMRM)
      D2=(CC/2.)*(PHIRM-PHITM)
      S2=(CC/2.)*(PHIRM+PHITM)
      D=(CC/2.)*(XLAMTM-XLAMRM)
      IF(D)55,50,55
50    IF(PHIRM-PHITM)51,52,52
51    ANGLEM=180.
      GOTO100
52    ANGLEM=0.
      GOTO100
55    W4=SIN(D2)/(TAN(D)*COS(S2))
      W5=COS(D2)/(TAN(D)*SIN(S2))
      Z4=ATAN(W4)
      Z5=ATAN(W5)
      ANGLEM=((Z5-Z4)/CC)
100   RETURN
      END
```

```
      SUBROUTINE ATTEN(G,TH,SPT,ZEN,TEM,CNU,DIST,NHOP,F,XMAG,A,ATT)
      DIMENSION G(2),TEM(2),CNU(4),F(3),A(3),XNU(2)
      COMMON HE,HEM,HF,HFM,TIME
C
C        SUBROUTINE COMPUTES TOTAL ATTENUATION OF IONOSPHERE RETURNS
C
C     ***** PROGRAM MODIFIED DECEMBER 1977 *****
C
C           HE     = THICKNESS OF E REGION (KM.)
C           HEM    = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)
C           F(2)   = PENETRATION FREQUENCY OF E REGION (MHZ.)
C           HF     = THICKNESS OF F REGION (KM.)
C           HFM    = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.)
C           F(3)   = PENETRATION FREQUENCY OF F REGION (MHZ.)
C           G(1)   = MAGNETIC LATITUDE (DEGREES)
C           G(2)   = BEARING OF RECEIVER IN MAGNETIC COORD. (DEGREES)
C           TH     = RAY ANGLE MEASURED FROM VERTICAL (DEGREES)
C           X      = COS(TH)
C           SPT    = SUNSPOT NUMBER
C           ZEN    = SOLAR ZENITH ANGLE (DEGREES)
C           TEM(1)= TEMPERATURE AT HEIGHT HEM (DEG. K)
C           TEM(2)= TEMPERATURE AT HEIGHT HFM (DEG. K)
C           TIME   = TIME OF DAY ('DAY' OR 'NITE')
C           NHOP   = NUMBER OF HOPS
C           DIST   = TOTAL SIGNAL PATH LENGTH (KM.)
C           F(1)   = CARRIER FREQUENCY (MHZ.)
C           XMAG   = INDICATOR (+1 FOR O-WAVE, -1 FOR X-WAVE)
C           A(1)   = MULTIPLICATIVE CONST. FOR NONDEVIATIVE ABSORPTION
C           A(2)   = SUNSPOT NO. MULTIPLIER FOR NONDEVIATVE ABSORPTION
C           A(3)   = SOLAR ZEN. ANG. EXPNT. FOR NONDEVIATVE ABSORPTION
C           CNU(1)= ADDITIVE TERM IN EXPONENT OF COLLISION FREQ.
C           CNU(2)= MULTIPL. TERM IN EXPONENT OF COLLISION FREQ.
C           CNU(3)= SHIFT TERM IN EXPONENT OF COLLISION FREQ.
C           CNU(4)= MULTIPL. FACTOR IN SECOND TERM OF COLLISION FREQ.
C           XNU(1)= COLLISION FREQ. AT HEIGHT HEM (MHZ.)
C           XNU(2)= COLLISION FREQ. AT HEIGHT HFM (MHZ.)
C           DBNOND= NONDEVIATIVE ABSORPTION (DB.)
C           DBDEV  = DEVIATIVE ABSORPTION (DB.)
C           DBR2   = SPREADING (1/R**2) LOSS (DB.)
C           DBANT  = ANTENNA PATTERN LOSS (DB.)
C           ATT    = TOTAL SIGNAL ATTENUATION (DB.)

      PI=3.14159265359
      CC=PI/180.
      TN='NITE'
      XTH=CC*TH
      X=COS(XTH)
C        COMPUTE NONDEVIATIVE ABSORPTION
      IF(TIME.IS.TN)GOTO9
      ANGIND=ATAN(-2.*TAN(CC*G(1)))
      XRAM=CC*G(2)
      XA=SIN(XTH)*COS(XRAM)*COS(ANGIND)
      XB=COS(XTH)*SIN(ANGIND)
      XI=ABS(XA+XB)
      XR=ABS(XA-XB)
      FM=.87*SQRT(1.+3.*((SIN(CC*G(1)))**2))*((6370./6440.)**3)
      B=(A(1)*(1.+A(2)*SPT)*((COS(CC*ZEN))**A(3)))/COS(XTH)
      DBT=B/((F(1)+XMAG*FM*XI)**2)
      DBR=B/((F(1)+XMAG*FM*XR)**2)
```

```
      DBNUND=FLOAT(NHUP)*(DBI+DBR)                                     C  011:0033:1
      GOTO10                                                           C  011:0033:0
9     UBNUNO=0.                                                        C  011:0033:3
10    CONTINUE                                                         C  011:0036:1
C           END COMPUTATION OF NONDEVIATIVE ABSORPTION                 C  011:0036:1
C           COMPUTE DEVIATAVE ABSORPTION                               C  011:0036:1
      XNU(1)=EXP(CNU(1)-CNU(2)*(HEM-CNU(3)))+(CNU(4)*(F(2)**2))/(TEM(1)*  C  011:0036:1
     1*1.5)                                                            C  011:003E:4
      XNU(2)=EXP(CNU(1)-CNU(2)*(HFM-CNU(3)))+(CNU(4)*(F(3)**2))/(TEM(2)*  C  011:0041:3
     1*1.5)                                                            C  011:004A:4
      CALL DEVIAT(F,X,XNU,DBDEV)                                       C  011:0040:3
      DBDEV=FLOAT(NHUP)*DBDEV                                          C  011:0050:4
C           END COMPUTATION OF DEVIATIVE ABSORPTION                    C  011:0052:0
C           COMPUTE 1/R**2 LOSS                                        C  011:0052:0
      DBR2=20.*ALOG10((4.*PI*DIST*F(1))/.3)                            C  011:0052:0
C           END COMPUTATION OF 1/R**2 LOSS                             C  011:0058:0
C           COMPUTE ANTENNA PATTERN LOSS                               C  011:0058:0
      RTH=SQRT(3./2.)                                                  C  011:0058:0
      DBANT=-40.*ALOG10(RTH*SIN(XTH))                                  C  011:005A:0
C           END COMPUTATION OF ANTENNA LOSS                            C  011:0050:2
      ATT=DBNUND+DBDEV+DBR2+DBANT                                      C  011:0050:2
      RETURN                                                           C  011:005F:4
      END                                                              C  011:0060:1
```

```
      SUBROUTINE PATH(R,FPE,FPF,F,P)
      COMMONHE,HEM,HF,HFM,TIME
      DIMENSIONP(4,8)

C         EVALUATES ANGLE, PATH DISTANCE,DELAY AND DELAY DERIVATIVES
C         FOR E REGION AND F REGION
C              4HE = THICKNESS OF E REGION (KM.)
C              HEM = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)
C              FPE = PENETRATION FREQUENCY OF F REGION (MHZ.)
C              4HF = THICKNESS OF F REGION (KM.)
C              HFM = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.)
C              FPF = PENETRATION FREQUENCY OF F REGION (MHZ.)
C              TIME= TIME OF DAY ('DAY' OR 'NITE')
C              R    = LENGTH OF GROUND PATH (KM.)
C              F    = FREQUENCY (MHZ.)
C              X    = COS(THETA): THETA=RAY ANGLE MEASURED FROM VERTICAL
C         SUBROUTINE RETURNS P(I,J)
C              I = 1: LOW  RAY, F REGION
C                = 2: HIGH RAY, F REGION
C                = 3: LOW  RAY, F REGION
C                = 4: HIGH RAY, F REGION
C              J = 1: SOLUTION INDICATOR (0=NO SOLUTION, 1=SOLUTION)
C                = 2: R=LENGTH OF GROUND PATH (KM.)
C                = 3: X=COS(THETA)
C                = 4: U=LENGTH OF SIGNAL PATH (KM.)
C                = 5: T=PATH DELAY (SEC.)
C                = 6: D1T=DERIVATIVE OF DELAY (SEC./MHZ.)
C                = 7: D2T=SECOND DERIVATIVE OF DELAY (SEC./MHZ.**2)
C                = 8: D3T=THIRD DERIVATIVE OF DELAY (SEC./MHZ.**3)

      FNE=F/FPE
      FNF=F/FPF
      IF(FNE-1.)10,10,20
10    XMIN=1.
      DO15J=1,8
      P(2,J)=0.
      P(3,J)=0.
      P(4,J)=0.
15    CONTINUE
      GOTO40

C         DO 30 DETERMINES MINIMUM VALUE OF AF(X)

20    XLAST=1.E-10
      CALL AE(FPE,F,XLAST,ALAST)
      DO30L=1,9
      DIFF=1./(10.**L)
26    XMIN=XLAST+DIFF
      IF(FNE*XMIN-1.)27,29,29
27    CALL AE(FPE,F,XMIN,AMIN)
      IF(AMIN-ALAST)28,29,29
28    XLAST=XMIN
      ALAST=AMIN
      GOTO26
29    IF(L-1)36,36,37
36    XLAST=XMIN-DIFF
      GOTO38
37    XLAST=XMIN-2.*DIFF
38    CALL AF(FPF,F,XLAST,ALAST)
```

```
 30   CONTINUE                                                            C 0141002911
                                                                          C 0141002B12
C          IF MIN. AE(X) .GT. R. THERE ARE NO RETURNS FROM E REGION       C 0141002B12
                                                                          C 0141002B12
      IF(AMIN-R)40,40,31                                                  C 0141002B12
 31   DO35J=1,8                                                           C 0141002C14
      P(1,J)=0.                                                           C 0141002E10
      P(2,J)=0.                                                           C 0141003014
 35   CONTINUE                                                            C 0141003312
      GOTO80                                                              C 0141003513
                                                                          C 0141003610
C          DO 50 DETERMINES X = COS(THETA) FOR E REGION LOW RAY           C 0141003610
                                                                          C 0141003610
 40   XLAST=1.E-10                                                        C 0141003610
      DO50L=1,8                                                           C 0141003813
      DIFF=1./(10.**L)                                                    C 0141003A10
 46   X=XLAST+DIFF                                                        C 0141003C13
      IF(X-XMIN)47,49,49                                                  C 0141003D15
 47   CALL AE(FPE,F,X,A)                                                  C 0141003E15
      IF(A-R)49,49,48                                                     C 0141004113
 48   XLAST=X                                                             C 0141004215
      GOTO46                                                              C 0141004314
 49   XLAST=X-DIFF                                                        C 0141004411
 50   CONTINUE                                                            C 0141004513
      P(1,1)=1.                                                           C 0141004714
      P(1,2)=R                                                            C 0141004815
      X=AMIN1(X,1.)                                                       C 0141004A14
      P(1,3)=X                                                            C 0141004D12
      P(1,4)=R/SQRT(1.-X**2)                                              C 0141004F11
      CALL DELAYE(R,FPE,F,X,T,D1T,D2T,D3T)                                C 0141005215
      P(1,5)=T                                                            C 0141005713
      P(1,6)=D1T                                                          C 0141005912
      P(1,7)=D2T                                                          C 0141005B11
      P(1,8)=D3T                                                          C 0141005D10
      IF(FNE-1.)200,200,60                                                C 0141005E15
                                                                          C 0141006013
C          DO 70 DETERMINES X = COS(THETA) FOR E REGION HIGH RAY          C 0141006013
                                                                          C 0141006013
 60   XLAST=(1./FNE)-1.E-10                                               C 0141006013
      DO70L=1,9                                                           C 0141006314
      DIFF=1./(10.**L)                                                    C 0141006510
 66   X=XLAST-DIFF                                                        C 0141006713
      IF(X-XMIN)69,69,67                                                  C 0141006815
 67   CALL AE(FPE,F,X,A)                                                  C 0141006915
      IF(A-R)69,69,68                                                     C 0141006C13
 68   XLAST=X                                                             C 0141006D15
      GOTO66                                                              C 0141006E14
 69   XLAST=X+DIFF                                                        C 0141006F11
 70   CONTINUE                                                            C 0141007013
      P(2,1)=1.                                                           C 0141007214
      P(2,2)=R                                                            C 0141007411
      X=AMIN1(X,1.)                                                       C 0141007610
      P(2,3)=X                                                            C 0141007814
      P(2,4)=R/SQRT(1.-X**2)                                              C 0141007A13
      CALL DELAYE(R,FPE,F,X,T,D1T,D2T,D3T)                                C 0141007E11
      P(2,5)=T                                                            C 0141008215
      P(2,6)=D1T                                                          C 0141008414
      P(2,7)=D2T                                                          C 0141008613
      P(2,8)=D3T                                                          C 0141008812
 80   IF(FNE-1.)90,90,100                                                 C 0141008A11
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```
90    XMIN=1.
      DO95J=1,8
      P(4,J)=0.
95    CONTINUE
      GOTO120

C          DO 110 DETERMINES MINIMUM VALUE OF AF(X)

100   XLAST=(1./FNF)+1.E-11
      CALL AF(FPE,FPF,F,XLAST,ALAST)
      DO110L=1,10
      DIFF=1./(10.**L)
106   XMIN=XLAST+DIFF
      IF(FNF*XMIN-1.)107,109,109
107   CALL AF(FPE,FPF,F,XMIN,AMIN)
      IF(AMIN-ALAST)108,109,109
108   XLAST=XMIN
      ALAST=AMIN
      GOTO106
109   IF(L-1)116,116,117
116   XLAST=XMIN-DIFF
      GOTO118
117   XLAST=XMIN-2.*DIFF
118   CALL AF(FPE,FPF,F,XLAST,ALAST)
110   CONTINUE

C          IF MIN. AF(X) .GT. R, THERE ARE NO RETURNS FROM F REGION

      IF(AMIN-R)120,120,111
111   DO115J=1,8
      P(3,J)=0.
      P(4,J)=0.
115   CONTINUE
      GOTO200

C          DO 130 DETERMINES X = COS(THETA) FOR F REGION LOW RAY

120   XLAST=(1./FNF)+1.E-11
      DO130L=1,9
      DIFF=1./(10.**L)
126   X=XLAST+DIFF
      IF(X-XMIN)127,129,129
127   CALL AF(FPE,FPF,F,X,A)
      IF(A-R)129,129,128
128   XLAST=X
      GOTO126
129   XLAST=X-DIFF
130   CONTINUE
      P(3,1)=1.
      P(3,2)=R
      X=AMIN1(X,1.)
      P(3,3)=X
      P(3,4)=R/SQRT(1.-X**2)
      CALL DELAYF(R,FPE,FPF,F,X,T,D1T,D2T,D3T)
      P(3,5)=T
      P(3,6)=D1T
      P(3,7)=D2T
      P(3,8)=D3T
      IF(FNF-1.)200,200,140
```

```
C          DO 150 DETERMINES X = COS(THETA) FOR F REGION HIGH RAY           C  014100E010
                                                                            C  014100E010
 140  XLAST=(1./FNF)-1.E-11                                                 C  014100E010
      DO150L=1,10                                                           C  014100E014
      DIFF=1./(10.**L)                                                      C  014100EA10
 146  X=XLAST-DIFF                                                          C  014100EC13
      IF(X-XMIN)149,149,147                                                 C  014100ED15
 147  CALL AF(FPE,FPF,F,X,A)                                                C  014100EE15
      IF(A-R)149,149,148                                                    C  014100F210
 148  XLAST=X                                                               C  014100F312
      GOTO146                                                               C  014100F411
 149  XLAST=X+DIFF                                                          C  014100F414
 150  CONTINUE                                                              C  014100F610
      P(4,1)=1.                                                             C  014100F811
      P(4,2)=H                                                              C  014100F915
      X=AMIN1(X,1.)                                                         C  014100FB14
      P(4,3)=A                                                              C  014100FE12
      P(4,4)=H/SQRT(1.-X**2)                                                C  014101001l
      CALL DELAYF(R,FPE,FPF,F,X,T,D1T,D2T,D3T)                              C  0141010315
      P(4,5)=I                                                              C  0141010910
      P(4,6)=U1T                                                            C  014101OA15
      P(4,7)=U2T                                                            C  014101OC14
      P(4,8)=U3T                                                            C  014101OE13
 200  RETURN                                                                C  0141011012
      END                                                                   C  0141011015


                                                                            START OF SEGMENT 015
      SUBROUTINE AE(FPE,F,X,A)                                              C  015100000010
      COMMONHE,HEM,HF,HFM,TIME                                              C  015100000010
                                                                            C  015100000010
C          EVALUATES A(X)=A FOR THE E REGION                                C  015100000010
C               4HE = THICKNESS OF E REGION (KM.)                           C  015100000010
C               HEM = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)     C  015100000010
C               FPE = PENETRATION FREQUENCY OF F REGION (MHZ.)              C  015100000010
C               X   = COS(THETA)) THETA=RAY ANGLE MEASURED FROM VERTICAL    C  015100000010
C          WARNING: F*X MUST BE LESS THAN FPF                               C  015100000010
                                                                            C  015100000010
      FFE=F*X/FPF                                                           C  015100000010
      A=2.*SQRT((1./X**2)-1.)*(HFM-2.*HE+HE*FFF*ALOG((1.+FFE)/(1.-FFE)))    C  0151000115
      RETURN                                                                C  0151000A11
      END                                                                   C  0151000A14
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      SUBROUTINE AF(FPE,FPF,F,X,A)                                            C  0171000010
      COMMONHE,HEM,HF,HFM,TIME                                                C  0171000010
                                                                              C  0171000010
C         EVALUATES A(X)=A FOR THE F REGION                                   C  0171000010
C             4HE  = THICKNESS OF E REGION (KM.)                              C  0171000010
C             HEM  = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)        C  0171000010
C             FPE  = PENETRATION FREQUENCY OF E REGION (MHZ.)                 C  0171000010
C             4HF  = THICKNESS OF F REGION (KM.)                              C  0171000010
C             HFM  = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.)        C  0171000010
C             FPF  = PENETRATION FREQUENCY OF F REGION (MHZ.)                 C  0171000010
C             TIME= TIME OF DAY ('DAY' OR 'NITE')                             C  0171000010
C             F    = FREQUENCY (MHZ.)                                         C  0171000010
C             X    = COS(THETA); THETA=RAY ANGLE MEASURED FROM VERTICAL       C  0171000010
C         WARNING: F*X MUST BE GREATER THAN FPE AND LESS THAN FPF             C  0171000010
                                                                              C  0171000010
      TN='NITE'                                                               C  0171000010
      FFE=F*X/FPE                                                             C  0171000213
      FFF=F*X/FPF                                                             C  0171000412
      FFF2=FFF**2                                                             C  0171000611
      FPR=(FPE**2)/(FPF**2)                                                   C  0171000710
      IF(TIME.IS.TN)GOTO10                                                    C  0171000910
      A=HEM-2.*HE+HE*FFE*ALOG((FFE+1.)/(FFE-1.))                              C  0171000A14
      A=A+(HFM-HEM-2.*HF*SQRT(1.-FPR))/SQRT(1.-(1./FFE**2))                   C  0171001012
      A=A+2.*HF*FFF*ALOG((SQRT(1.-FPR)+SQRT(FFF2-FPR))/SQRT(1.-FFF2))         C  0171001712
      GOTO20                                                                  C  0171001F10
 10   A=HEM-2.*HE+2.*HE*FFE*ALOG((FFE+1.)/(FFE-1.))                           C  0171001F13
      A=A+HFM-2.*HF-HEM-2.*HE+HF*FFF*ALOG((1.+FFF)/(1.-FFF))                  C  0171002514
 20   A=A+2.*SQRT((1./X**2)-1.)                                               C  0171002015
      RETURN                                                                  C  0171003112
      END                                                                     C  0171003115
```

```
      SUBROUTINE DELAYE(R,FPE,F,X,T,D1T,D2T,D3T)
      COMMONHE,HEM,HF,HFM,TIME
C         EVALUATES DELAY AND DELAY DERIVATIVES FOR E REGION
C               4HE  = THICKNESS OF E REGION (KM.)
C               HEM  = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)
C               FPE  = PENETRATION FREQUENCY OF E REGION (MHZ.)
C               R    = LENGTH OF GROUND PATH (KM.)
C               F    = FREQUENCY (MHZ.)
C               X    = COS(THETA); THETA=RAY ANGLE MEASURED FROM VERTICAL
C               T    = SIGNAL PATH DELAY (SEC.)
C               D1T  = DERIVATIVE OF DELAY (SEC./MHZ.)
C               D2T  = SECOND DERIVATIVE OF DELAY (SEC./MHZ.**2)
C               D3T  = THIRD DERIVATIVE OF DELAY (SEC./MHZ.**3)
      C=3.E+05
      FNE=F/FPE
      FNE2=FNE**2
      FNE4=FNE**4
      FFE=FNE*X
      FFE2=FFE**2
      X2=X**2
      X4=X**4
      V1=X2/(1.-X2)
      V2=V1**.5
      V3=V1**1.5
      V4=1./((1.-X2)**1.5)
      V5=1./((1.-X2)**2.5)
      V6=X2*V5
      W1=1./(1.-FFE2)
      W2=W1**2
      W3=W1**3
      Z1=X/F
      T=R/(C*SQRT(1.-X2))
      T2=T**2
      U1=X*T/(1.-X2)
      U2=(1.+2.*X2)/(X2*T)
      DEN=R*V3+2.*HEM-4.*HE*W1
      DXDF=Z1*(R*V2-2.*HEM+4.*HE*W1)/DEN
      DXDF2=DXDF**2
      D1T=U1*DXDF
      Z2=Z1+DXDF
      Z3=Z2**2
      Z4=1.-3.*X*F*DXDF/(1.-X2)
      D2XDF=(Z1*(R*V4*Z4*DXDF+8.*HE*F*FNE2*W2*Z3))/DEN
      D2XDF=D2XDF+(DXDF2/X)-(DXDF/F)
      D2T=U2*(D1T**2)+U1*D2XDF
      Z5=D2XDF-(DXDF2/X)+(DXDF/F)
      Z6=3.*X*DXDF2+(1.-X2)*D2XDF
      Z7=DXDF2*((1.+X2)/(1.-X2))+Z1*DXDF+X*D2XDF
      Z8=Z1+5.*DXDF+2.*F*D2XDF
      D3XDF=-((DXDF**3)/X2)+(2.*DXDF*D2XDF/X)+(DXDF/(F**2))-(D2XDF/F)-Z5
     1*((Z1-DXDF)/X)-(Z5*(R*DXDF*V6-8.*HE*X*FNE2*Z2*W2)/DEN)
      D3XDF=D3XDF+(Z1/DEN)*(R*V5*Z4*Z6-3.*R*F*DXDF*V5*Z7+32.*HE*X*F*FNE4
     1*W3*(Z2**3)+8.*HE*FNE2*Z2*Z8*W2)
      D3T=-(3.*(1.+X2+2.*X4)*(D1T**3)/(X4*T2))+3.*U2*D1T*D2T+U1*D3XDF
      RETURN
      END
```

```
      SUBROUTINE DELAYF(R,FPE,FPF,F,X,T,D1T,D2T,D3T)
      COMMONHE,HEM,HF,HFM,TIME
C        EVALUATES DELAY AND DELAY DERIVATIVES FOR F REGION
C              4HE = THICKNESS OF E REGION (KM.)
C              HEM = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)
C              FPE = PENETRATION FREQUENCY OF E REGION (MHZ.)
C              4HF = THICKNESS OF F REGION (KM.)
C              HFM = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.)
C              FPF = PENETRATION FREQUENCY OF F REGION (MHZ.)
C              R   = LENGTH OF GROUND PATH (KM.)
C              F   = FREQUENCY (MHZ.)
C              T   = SIGNAL PATH DELAY (SEC.)
C              D1T = DERIVATIVE OF DELAY (SEC./MHZ.)
C              D2T = SECOND DERIVATIVE OF DELAY (SEC./MHZ.**2)
C              D3T = THIRD DERIVATIVE OF DELAY (SEC./MHZ.**3)
      TN='NITE'
      C=3.E+05
      FNE=F/FPE
      FNE2=FNE**2
      FFE=FNE*X
      FFE2=FFE**2
      FNF=F/FPF
      FNF2=FNF**2
      FFF=FNF*X
      FFF2=FFF**2
      FFF3=FFF**3
      FFF4=FFF**4
      FFF5=FFF4*FNF
      FFF6=FFF2*FNF
      FPR=FPE/FPF
      FPR2=FPR**2
      RFPR=SQRT(1.-FPR2)
      X2=X**2
      X4=X**4
      V1=1./SQRT(1.-X2)
      V2=X*V1
      V3=X*X2*(V1**3)
      V4=V1**3
      W1=1./(FFE2-1.)
      W2=W1**2
      W3=W1**3
      W4=(FFE2/(FFE2-1.))**1.5
      W5=W1**2.5
      W6=W1*W5
      W7=1./(1.-FFF2)
      W8=W7**2
      W9=W7**3
      W10=FFF2-FPR2
      W11=SQRT(W10)
      T=R*V1/C
      T2=T**2
      Z1=X/F
      IF(TIME.IS.TN)GOTO8W
      C1=2.*(HFM-HEM-2**HF*RFPR)
      C2=RFPR*W11+W10
      B=2.*HEM+4.*HE*W1+C1*W4-(4.*HF*FF3/C2)-4.*HF*FFF3*W7
      DXDF=Z1*(R*V2-B)/(R*V3+B)
```

```
      GOTO20                                                              C 0191004815
10    B=2.*HFN+8.*HE*W1-4.*HF*W7                                          C 019100 4C12
      DXDF=Z1*(R*V2-B)/(R*V3+B)                                           C 0191005113
20    D1T=X*T*DXDF/(1.-X2)                                                C 0191005512
      Z2=Z1+DXDF                                                          C 0191005810
      DEN=R*V3+B                                                          C 0191005912
      IF(TIME.IS.IN)GOTO30                                                C 0191005D11
      ZD1=2.*(RFPK/W11)                                                   C 0191005C15
      C3=C2**2                                                            C 0191005E14
      FFF6=FFE2*FNE                                                       C 0191005F15
      DBDF=Z2*(8.*HE*X*FNE2*W2-3.*C1*FFE6*W5-(12.*HF*FFF6/C2)+(4.*HF*FFF  C 0191006111
     15*ZD1/C3)-12.*HF*FFF6*W7-8.*HF*FFF5*W8)                             C 0191006913
      D2XDF=(DXDF**2/X)-(DXDF/F)+((R*Z1*DXDF*V4*(1.-(3.*X*F*DXDF/(1.-X2   C 0191007013
     1)))-Z2*DBDF)/DEN)                                                   C 0191007614
      GOTO40                                                              C 0191007915
30    D2XDF=(DXDF**2/X)-(DXDF/F)+Z1*((R*DXDF*V4*(1.-(3.*X*F*DXDF/(1.-X2   C 019100 7A12
     1)))+16.*HE*F*FNE2*W2*(Z2**2)+8.*HF*F*FNF2*W8*(Z2**2))/DEN)          C 0191008012
40    D2T=((D1T**2)*(1.+2.*X2)/(X2*T))+(D2XDF*X*T/(1.-X2))                C 0191008915
      IF(TIME.IS.IN)GOTO50                                                C 019100 8F14
      C4=C2**3                                                            C 0191009112
      ZD2=ZD1**2                                                          C 0191009215
      FFF7=FFF3*FFF2*FNF2                                                 C 0191009410
      FFF8=FFF*FNF2                                                       C 0191009515
      FFF9=FFF3*FNF2                                                      C 0191009711
      W12=1./(W11**3)                                                     C 0191009813
      ZD3=2.*Z1+3.*DXDF                                                   C 019100 9A12
      ZD4=3.*Z1+2.*DXDF                                                   C 019100 9C14
      ZD5=2.*Z1+DXDF                                                      C 019100 9F10
      ZD6=5.*Z1+4.*DXDF                                                   C 019100A015
      ZD7=5.-FFF2                                                         C 019100A311
      ZD8=3.-FFF2                                                         C 019100A413
      ZD9=D2XDF                                                           C 019100A515
      ZD10=3.*ZD4-FFF2*ZD6                                                C 019100A614
      D2BDF=((DXDF-Z1+F*D2XDF)/(F*Z2))*DBDF+Z2*(-8.*HE*FNE2*(FFE2*ZD3+Z   C 019100A910
     1D5)*W3+FFFA*3.*C1*(ZD4+FFE2*ZD3)*W6+(12.*HF*FFF6*(-ZD4+FFF2*Z2*ZD   C 019100AF11
     21)/C2)+(4.*HF*FFF9*ZD6*ZD1/C3)-(4.*HF*FFF7*RFPR*Z2*W12/C3)-(8.*HF   C 019100B015
     3*FFF7*Z2*ZD2/C4)-16.*HF*FFF9*Z2*ZD8*W9-4.*HF*FFF8*ZD10*W8)          C 019100BF15
      DXDF2=DXDF**2                                                       C 019100C915
      D3XDF=-((DXDF**3)/X2)+(2.*DXDF*D2XDF/X)+(DXDF/(F**2))-(D2XDF/F)+(   C 019100CB10
     11./DEN)*(-3.*R*X*DXDF*(V1**5)*(((1.+4.*X2)/(1.-X2))*DXDF2+Z1*DXDF   C 019100D110
     2+3.*X*D2XDF)+(R*V4/F)*(((1.+2.*X2)/(1.-X2))*DXDF2-Z1*DXDF+X*ZD9)-   C 019100D810
     3(1./F)*(2.*DXDF-Z1+Z.*F*D2XDF-(DXDF2/Z1))*DBDF-Z2*D2BDF)            C 019100E013
      GOTO60                                                              C 019100E714
50    DXDF2=DXDF**2                                                       C 019100E811
      ZN1=D2XDF-(DXDF2/X)+(DXDF/F)                                        C 019100E912
      ZN2=Z1+5.*DXDF+2.*F*D2XDF                                           C 019100EC11
      ZN3=V1**5                                                           C 019100EF13
      ZN4=Z2**3                                                           C 019100F112
      ZZ=Z1-DXDF                                                          C 019100F215
      D3XDF=-((DXDF**3)/X2)+(2.*DXDF*D2XDF/X)+(DXDF/(F**2))-(D2XDF/F)-(   C 019100F411
     1ZZ*ZN1/X)-(ZN1/DEN)*(R*3.*X2*DXDF*ZN3-16.*HE*X*FNE2*Z2*W2-8.*HF*X   C 019100FA11
     2*FNF2*Z2*W8)+(Z1/DEN)*(R*ZN3*(1.-(3.*X*F*DXDF/(1.-X2)))*(3.*X*DXD   C 0191010311
     3F2+(1.-X2)*D2XDF)-3.*R*F*DXDF*ZN3*(((1.+X2)/(1.-X2))*DXDF2+Z1*DXD   C 0191010812
     4F+X*D2XDF)-64.*HE*X*F*(FNE2**2)*ZN4*W3+32.*HF*X*F*(FNF2**2)*ZN4*W   C 0191011210
     59+16.*HE*FNE2*Z2*ZN2*W2+8.*HF*FNF2*Z2*ZN2*W8)                       C 0191011613
60    D3T=-(3./(X4*T2))*(1.+X2+2.*X4)*(D1T**3)+(3./(X2*T))*(1.+2.*X2)*D   C 0191012313
     11T*D2T+(X*T/(1.-X2))*D3XDF                                          C 019101 2A14
      RETURN                                                              C 0191012E14
      END                                                                 C 0191012F11
```

```
      SUBROUTINE DEVIAT(F,X,XNU,DBDEV)
      DIMENSION F(3),XNU(4)
      COMMON HE,HEM,HF,HFM,TIME
C
C        ***** PROGRAM WRITTEN DECEMBER 1977 *****
C
C        SUBROUTINE COMPUTES DEVIATIVE ABSORPTION
C
C        GLOSSARY OF MOST IMPORTANT TERMS
C             4HE    = THICKNESS OF E REGION (KM.)
C             HEM    = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)
C             F(2)   = PENETRATION FREQUENCY OF E REGION (MHZ.)
C             4HF    = THICKNESS OF F REGION (KM.)
C             HFM    = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.)
C             F(3)   = PENETRATION FREQUENCY OF F REGION (MHZ.)
C             X      = COS(THETA))THETA=RAY ANGLE MEASURED FROM VERTICAL
C             F(1)   = CARRIER FREQUENCY (MHZ.)
C             TIME   = TIME OF DAY ('DAY' OR 'NITE')
C             C      = VELOCITY OF LIGHT (KM/SEC)
C             XNU(1)= COLLISION FREQ. AT HEIGHT HEM (MHZ.)
C             XNU(2)= COLLISION FREQ. AT HEIGHT HFM (MHZ.)
C             DBDEV  = DEVIATIVE ABSORPTION (DB.)
C
      C=3.E+05
      TN='NITE'
      FNEX=(F(1)*X)/F(2)
      FNFX=(F(1)*X)/F(3)
      SE=FNEX+(1./FNEX)
      IF(FNEX-1.)10,11,12
   10 EE=(1.+FNEX)/(1.-FNEX)
      DBDEV=XNU(1)*HE*(.5*SE*ALOG(EE)-1.)
      GOTO190
   11 DBDEV=2000.
      GOTO200
   12 IF(FNFX-1.)14,13,13
   13 DBDEV=2000.
      GOTO200
   14 SF=FNFX+(1./FNFX)
      R2=(F(2)/F(3))**2
      RR=SQRT(1.-R2)
      EE=(FNEX+1.)/(FNEX-1.)
      IF(TIME.IS.TN)GOTO15
      EF=(RR+SQRT(FNFX**2-R2))/SQRT(1.-FNFX**2)
      EG=(RR+SQRT(FNFX**2-R2))/FNFX
      EH=1./(FNEX*SQRT(FNEX**2-1.))
      DBDEV=XNU(1)*HE*(.5*SE*ALOG(EE)-1.)+XNU(2)*HF*SF*ALOG(EF)+XNU(1)*H
     1E*EH-XNU(2)*HF*EG
      GOTO190
   15 EF=(1.+FNFX)/(1.-FNFX)
      DBDEV=2.*XNU(1)*HE*(.5*SE*ALOG(EE)-1.)+XNU(2)*HF*(.5*SF*ALOG(EF)-1
     1.)
  190 DBDEV=(8.686*DBDEV)/(X*C)
  200 RETURN
      END
```

```
      SUBROUTINE TEMP(H,T)                                              C 01B:000010
                                                                        C 01B:000010
C          SUBROUTINE COMPUTES TEMPERATURE AT HEIGHT H USING POWER       C 01B:000010
C          SERIES FIT TO TABLE IN 1959 ARDC MODEL ATMOSPHERE. TWO        C 01B:000010
C          DIFFERENT SERIES ARE USED; ONE FOR HEIGHTS BETWEEN 100 KM.   C 01B:000010
C          AND 210 KM., AND ANOTHER FOR HEIGHTS BETWEEN 210 KM. AND     C 01B:000010
C          600 KM.                                                       C 01B:000010
                                                                        C 01B:000010
C          ***** PROGRAM WRITTEN JANUARY 1978 *****                      C 01B:000010
                                                                        C 01B:000010
C              H = HEIGHT (KM.)                                          C 01B:000010
C              T = TEMPERATURE (DEG. K)                                  C 01B:000010
                                                                        C 01B:000010
      IF(H-100.)50,5,5                                                  C 01B:000010
5     IF(H-210.)10,15,15                                                C 01B:000112
10    A=1414.                                                           C 01B:000214
      B=-44.28                                                          C 01B:000314
      C=.4217                                                           C 01B:000514
      D=-1.004E-03                                                      C 01B:000713
      GOTO25                                                            C 01B:000914
15    IF(H-600.)20,20,50                                                C 01B:000A11
20    A=1423.7                                                          C 01B:000B14
      B=.0399                                                           C 01B:000D13
      C=-.00104                                                         C 01B:000F13
      D=3.F-06                                                          C 01B:001114
25    T=A+H*(B+H*(C+D*H))                                               C 01B:001313
      GOTO100                                                           C 01B:001712
50    WRITE(6,95)                                                       C 01B:001715
95    FORMAT(1X,'***** WARNING: THE HEIGHT OF THE PEAK ELECTRON DENSITY C 01B:001C12
     1LIES OUTSIDE THE ACCEPTABLE RANGE FOR THE SERIES APPROXIMATIONS US C 01B:001C12
     2ED *****')                                                        C 01B:001C12
100   RETURN                                                            C 01B:001C12
      END                                                               C 01B:001C15
```

```
      SUBROUTINE GNDATN(F,IS,R,GATTEN)                                       C   01C:000010
      DIMENSION XA(6,8,13),FF(8),RR(13)                                      C   01C:000010
C                                                                            C   01C:000010
C         ***** PROGRAM WRITTEN MARCH 1978 *****                             C   01C:000010
C                                                                            C   01C:000010
C         SUBROUTINE COMPUTES ATTENUATION OF GROUNDWAVE. THIS ATTEN-         C   01C:000010
C         UATION CONSISTS OF TWO COMPONENTS--A BASIC LOSS TERM, XLBASC,      C   01C:000010
C         DUE TO THE SPREAD OF SIGNAL ENERGY OVER A CURVED, LOSSY OCEAN      C   01C:000010
C         SURFACE; AND AN ADDED LOSS TERM, XLADD, DUE TO RANDOM              C   01C:000010
C         SURFACE IRREGULARITIES USING THE PHILLIPS ISOTROPIC WAVE           C   01C:000010
C         SPECTRUM. BOTH LOSS TERMS ARE OBTAINED FROM BARRICK (1970).        C   01C:000010
C                                                                            C   01C:000010
C         GLOSSARY OF MOST IMPORTANT TERMS                                   C   01C:000010
C             F      = CARRIER FREQUENCY (MHZ.)                              C   01C:000010
C             R      = GROUND DISTANCE BETWEEN XMTR. AND RCVR. (KM.)         C   01C:000010
C             IS     = SEA STATE                                             C   01C:000010
C             XLBASC= BASIC LOSS (DB.)                                       C   01C:000010
C                      XLBASC=20*ALOG10(2*PI*R*F/.3)+D*(R**E)                C   01C:000010
C                              D=D1*(F**D2)*EXP(D3*(F**5))                   C   01C:000010
C                              E=E1*(F**E2)                                  C   01C:000010
C             XLADD  = ADDED LOSS (DB.)                                      C   01C:000010
C                      ADDED LOSS IS CALCULATED BY INTERPOLATING BETWEEN     C   01C:000010
C                      VALUES FROM BARRICK'S CURVES. THE ARRAY XA            C   01C:000010
C                      CONTAINS THE VALUES FOR THIS INTERPOLATION.           C   01C:000010
                                                                             C   01C:000010
C         THE ARRAY XA(IS,IF,IR) CONTAINS THE FOLLOWING REFERENCE            C   01C:000010
C         VALUES                                                             C   01C:000010
C             IS =    SEA STATE                                              C   01C:000010
C             IF =    1! FREQ. =  3.0 MHZ.                                   C   01C:000010
C                =    2! FREQ. =  5.0 MHZ.                                   C   01C:000010
C                =    3! FREQ. =  7.0 MHZ.                                   C   01C:000010
C                =    4! FREQ. = 10.0 MHZ.                                   C   01C:000010
C                =    5! FREQ. = 15.0 MHZ.                                   C   01C:000010
C                =    6! FREQ. = 20.0 MHZ.                                   C   01C:000010
C                =    7! FREQ. = 30.0 MHZ.                                   C   01C:000010
C             IR =    1! RANGE =   25 KM.                                    C   01C:000010
C                =    2! RANGE =   50 KM.                                    C   01C:000010
C                =    3! RANGE =  100 KM.                                    C   01C:000010
C                =    4! RANGE =  200 KM.                                    C   01C:000010
C                =    5! RANGE =  300 KM.                                    C   01C:000010
C                =    6! RANGE =  400 KM.                                    C   01C:000010
C                =    7! RANGE =  500 KM.                                    C   01C:000010
C                =    8! RANGE =  600 KM.                                    C   01C:000010
C                =    9! RANGE =  700 KM.                                    C   01C:000010
C                =   10! RANGE =  800 KM.                                    C   01C:000010
C                =   11! RANGE =  900 KM.                                    C   01C:000010
C                =   12! RANGE = 1000 KM.                                    C   01C:000010
C                                                                            C   01C:000010
C                                                                            C   01C:000010
C         WARNING: THE RECOMMENDED RANGES AND FREQUENCIES FOR                C   01C:000010
C                  INTERPOLATION LIE BETWEEN 25 KM. - 1000 KM. AND           C   01C:000010
C                  3 MHZ. - 30 MHZ. RESPECTIVELY. IF EITHER THE RANGE        C   01C:000010
C                  OR FREQUENCY LIES OUTSIDE THESE LIMITS, A WARNING         C   01C:000010
C                  STATEMENT IS PRINTED AND THE GROUNDWAVE ATTENUATION       C   01C:000010
C                  IS SET EQUAL TO 1.0E+04.                                  C   01C:000010
C                                                                            C   01C:000010
C                                                                            C   01C:000010
C                                                                            C   01C:000010
      PI=3.14159265359                                                       C   01C:000010
```

```
C        ASSIGN VALUES TO CONSTANTS USED IN XLRASC                              C  01C:000510
      D1=1.78E-04                                                               C  01C:000510
      D2=2.58                                                                   C  01C:000713
      D3=-1.4E-08                                                               C  01C:000913
      E1=1.83                                                                   C  01C:000814
      E2=-.243                                                                  C  01C:000D13
C        END ASSIGNMENT OF VALUES TO CONSTANTS IN XLRASC                        C  01C:000F14
C        ASSIGN REFERENCE FREQUENCY VALUES TO ARRAY FF                          C  01C:000F14
      FF(1)=3.                                                                  C  01C:000F14
      FF(2)=5.                                                                  C  01C:001015
      FF(3)=7.                                                                  C  01C:001210
      FF(4)=10.                                                                 C  01C:001312
      FF(5)=15.                                                                 C  01C:001414
      FF(6)=20.                                                                 C  01C:001610
      FF(7)=30.                                                                 C  01C:001712
C        END ASSIGNMENT OF REFFRENCE FREQUENCIES                                C  01C:001814
C        ASSIGN REFERENCE RANGE VALUES TO ARRAY RR                              C  01C:001814
      RR(1)=25.                                                                 C  01C:001814
      RR(2)=50.                                                                 C  01C:001915
      RR(3)=100.                                                                C  01C:001B10
      RR(4)=200.                                                                C  01C:001C12
      RR(5)=300.                                                                C  01C:001D14
      RR(6)=400.                                                                C  01C:001F11
      RR(7)=500.                                                                C  01C:002014
      RR(8)=600.                                                                C  01C:002211
      RR(9)=700.                                                                C  01C:002314
      RR(10)=800.                                                               C  01C:002511
      RR(11)=900.                                                               C  01C:002614
      RR(12)=1000.                                                              C  01C:002811
C        END ASSIGNMENT OF REFFRENCE RANGES                                     C  01C:002914
C        ASSIGN VALUES TO ARRAY XA                                              C  01C:002914
      XA(1,1, 1)=-.60000E-01                                                    C  01C:002914
      XA(1,1, 2)=-.75000E-01                                                    C  01C:002C12
      XA(1,1, 3)=-.10000E+00                                                    C  01C:002F12
      XA(1,1, 4)=-.15000E+00                                                    C  01C:003212
      XA(1,1, 5)=-.20000E+00                                                    C  01C:003512
      XA(1,1, 6)=-.25000E+00                                                    C  01C:003812
      XA(1,1, 7)=-.30000E+00                                                    C  01C:003B12
      XA(1,1, 8)=-.34000E+00                                                    C  01C:003E12
      XA(1,1, 9)=-.40000E+00                                                    C  01C:004112
      XA(1,1,10)=-.45000E+00                                                    C  01C:004412
      XA(1,1,11)=-.49000E+00                                                    C  01C:004712
      XA(1,1,12)=-.55000E+00                                                    C  01C:004A12
      XA(1,2, 1)=0.                                                             C  01C:004D12
      XA(1,2, 2)=-.60000E-01                                                    C  01C:004E13
      XA(1,2, 3)=-.90000E-01                                                    C  01C:005112
      XA(1,2, 4)=-.12000E+00                                                    C  01C:005412
      XA(1,2, 5)=-.15000E+00                                                    C  01C:005712
      XA(1,2, 6)=-.18000E+00                                                    C  01C:005A12
      XA(1,2, 7)=-.20000E+00                                                    C  01C:005D12
      XA(1,2, 8)=-.24000E+00                                                    C  01C:006012
      XA(1,2, 9)=-.27000E+00                                                    C  01C:006312
      XA(1,2,10)=-.35000E+00                                                    C  01C:006612
      XA(1,2,11)=-.40000E+00                                                    C  01C:006912
      XA(1,2,12)=-.48000E+00                                                    C  01C:006C12
      XA(1,3, 1)=0.                                                             C  01C:006F12
      XA(1,3, 2)=0.                                                             C  01C:007013
      XA(1,3, 3)=-.13000E+00                                                    C  01C:007114
      XA(1,3, 4)=-.15000E+00                                                    C  01C:007412
      XA(1,3, 5)=-.17000E+00                                                    C  01C:007712
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XA(1,3, 6)=-.18000E+00        C    01C1007A12
XA(1,3, 7)=-.19000E+00        C    01C1007D12
XA(1,3, 8)=-.20000E+00        C    01C1008012
XA(1,3, 9)=-.20000E+00        C    01C1008312
XA(1,3,10)=-.22000E+00        C    01C1008612
XA(1,3,11)=-.23000E+00        C    01C1008912
XA(1,3,12)=-.25000E+00        C    01C1008C12
XA(1,4, 1)=0.                 C    01C1008F12
XA(1,4, 2)=0.                 C    01C1009013
XA(1,4, 3)=0.                 C    01C1009114
XA(1,4, 4)=0.                 C    01C1009215
XA(1,4, 5)=0.                 C    01C1009410
XA(1,4, 6)= .12000E+00        C    01C1009511
XA(1,4, 7)= .20000E+00        C    01C1009811
XA(1,4, 8)= .20500E+00        C    01C1009B11
XA(1,4, 9)= .35000E+00        C    01C1009E11
XA(1,4,10)= .45000E+00        C    01C100A111
XA(1,4,11)= .60000E+00        C    01C100A411
XA(1,4,12)= .80000E+00        C    01C100A711
XA(1,5, 1)=0.                 C    01C100AA11
XA(1,5, 2)= .10000E+00        C    01C100AB12
XA(1,5, 3)= .21000E+00        C    01C100AE11
XA(1,5, 4)= .56000E+00        C    01C100B111
XA(1,5, 5)= .85000E+00        C    01C100B411
XA(1,5, 6)= .12000E+01        C    01C100B711
XA(1,5, 7)= .14000E+01        C    01C100BA11
XA(1,5, 8)= .16500E+01        C    01C100BD11
XA(1,5, 9)= .20000E+01        C    01C100C011
XA(1,5,10)= .23000E+01        C    01C100C114
XA(1,5,11)= .25500E+01        C    01C100C411
XA(1,5,12)= .28000E+01        C    01C100C711
XA(1,6, 1)=0.                 C    01C100CA11
XA(1,6, 2)= .30000E+00        C    01C100CB12
XA(1,6, 3)= .80000E+00        C    01C100CE11
XA(1,6, 4)= .12000E+01        C    01C100D111
XA(1,6, 5)= .17000E+01        C    01C100D411
XA(1,6, 6)= .19000E+01        C    01C100D711
XA(1,6, 7)= .23000E+01        C    01C100DA11
XA(1,6, 8)= .27000E+01        C    01C100DD11
XA(1,6, 9)= .32000E+01        C    01C100E011
XA(1,6,10)= .38000E+01        C    01C100E311
XA(1,6,11)= .40500E+01        C    01C100E611
XA(1,6,12)= .46000E+01        C    01C100E911
XA(1,7, 1)= .45000E+00        C    01C100EC11
XA(1,7, 2)= .10000E+01        C    01C100EF11
XA(1,7, 3)= .13000E+01        C    01C100F012
XA(1,7, 4)= .18000E+01        C    01C100F311
XA(1,7, 5)= .20000E+01        C    01C100F611
XA(1,7, 6)= .24000E+01        C    01C100F713
XA(1,7, 7)= .27000E+01        C    01C100FA11
XA(1,7, 8)= .30500E+01        C    01C100FD11
XA(1,7, 9)= .37000E+01        C    01C1010011
XA(1,7,10)= .40000E+01        C    01C1010311
XA(1,7,11)= .44000E+01        C    01C1010414
XA(1,7,12)= .49000E+01        C    01C1010711
XA(2,1, 1)=-.12000E+00        C    01C1010A11
XA(2,1, 2)=-.15000E+00        C    01C1010C12
XA(2,1, 3)=-.20000E+00        C    01C1010F12
XA(2,1, 4)=-.30000E+00        C    01C1011212
XA(2,1, 5)=-.40000E+00        C    01C1011512
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XA(2,1, 6)=-.50000E+00                                          C    01C!0118!2
XA(2,1, 7)=-.60000E+00                                          C    01C!011B!2
XA(2,1, 8)=-.68000E+00                                          C    01C!011E!2
XA(2,1, 9)=-.80000E+00                                          C    01C!0121!2
XA(2,1,10)=-.90000E+00                                          C    01C!0124!2
XA(2,1,11)=-.98000E+00                                          C    01C!0127!2
XA(2,1,12)=-.11000E+01                                          C    01C!012A!2
XA(2,2, 1)=-.25000E+00                                          C    01C!012D!2
XA(2,2, 2)=-.30000E+00                                          C    01C!0130!2
XA(2,2, 3)=-.40000E+00                                          C    01C!0133!2
XA(2,2, 4)=-.55000E+00                                          C    01C!0136!2
XA(2,2, 5)=-.69000E+00                                          C    01C!0139!2
XA(2,2, 6)=-.80000E+00                                          C    01C!013C!2
XA(2,2, 7)=-.95000E+00                                          C    01C!013F!2
XA(2,2, 8)=-.11100E+01                                          C    01C!0142!2
XA(2,2, 9)=-.12700E+01                                          C    01C!0145!2
XA(2,2,10)=-.14200E+01                                          C    01C!0148!2
XA(2,2,11)=-.16000E+01                                          C    01C!014B!2
XA(2,2,12)=-.16200E+01                                          C    01C!014E!2
XA(2,3, 1)=-.30000E+00                                          C    01C!0151!2
XA(2,3, 2)=-.40000E+00                                          C    01C!0154!2
XA(2,3, 3)=-.50000E+00                                          C    01C!0157!2
XA(2,3, 4)=-.62000E+00                                          C    01C!015A!2
XA(2,3, 5)=-.65000E+00                                          C    01C!015D!2
XA(2,3, 6)=-.76000E+00                                          C    01C!0160!2
XA(2,3, 7)=-.85000E+00                                          C    01C!0163!2
XA(2,3, 8)=-.90000E+00                                          C    01C!0166!2
XA(2,3, 9)=-.10000E+01                                          C    01C!0169!2
XA(2,3,10)=-.11500E+01                                          C    01C!016A!5
XA(2,3,11)=-.12000E+01                                          C    01C!016D!2
XA(2,3,12)=-.12500E+01                                          C    01C!0170!2
XA(2,4, 1)=-.40000E+00                                          C    01C!0173!2
XA(2,4, 2)=-.40000E+00                                          C    01C!0176!2
XA(2,4, 3)=-.10000E+00                                          C    01C!0179!2
XA(2,4, 4)= .40000E+00                                          C    01C!017C!2
XA(2,4, 5)= .90000E+00                                          C    01C!017F!1
XA(2,4, 6)= .14000E+01                                          C    01C!0182!1
XA(2,4, 7)= .19000E+01                                          C    01C!0185!1
XA(2,4, 8)= .24000E+01                                          C    01C!0188!1
XA(2,4, 9)= .29000E+01                                          C    01C!018B!1
XA(2,4,10)= .33000E+01                                          C    01C!018E!1
XA(2,4,11)= .37500E+01                                          C    01C!0191!1
XA(2,4,12)= .42000E+01                                          C    01C!0194!1
XA(2,5, 1)= .20000E+00                                          C    01C!0197!1
XA(2,5, 2)= .85000E+00                                          C    01C!019A!1
XA(2,5, 3)= .23000E+01                                          C    01C!019D!1
XA(2,5, 4)= .42000E+01                                          C    01C!01A0!1
XA(2,5, 5)= .57000E+01                                          C    01C!01A3!1
XA(2,5, 6)= .71000E+01                                          C    01C!01A6!1
XA(2,5, 7)= .86000E+01                                          C    01C!01A9!1
XA(2,5, 8)= .99000E+01                                          C    01C!01AC!1
XA(2,5, 9)= .11400E+02                                          C    01C!01AF!1
XA(2,5,10)= .13000E+02                                          C    01C!01B2!1
XA(2,5,11)= .14900E+02                                          C    01C!01B3!4
XA(2,5,12)= .17000E+02                                          C    01C!01B6!1
XA(2,6, 1)= .11500E+01                                          C    01C!01B7!4
XA(2,6, 2)= .26000E+01                                          C    01C!01BA!1
XA(2,6, 3)= .42000E+01                                          C    01C!01BD!1
XA(2,6, 4)= .55000E+01                                          C    01C!01C0!1
XA(2,6, 5)= .68000E+01                                          C    01C!01C3!1
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XA(2,6, 6)= .80000E+01        C   01C101C611
XA(2,6, 7)= .93000E+01        C   01C101C714
XA(2,6, 8)= .10650E+02        C   01C101CA11
XA(2,6, 9)= .12000E+02        C   01C101CD11
XA(2,6,10)= .13300E+02        C   01C101CE14
XA(2,6,11)= .14600E+02        C   01C101D111
XA(2,6,12)= .16000E+02        C   01C101D411
XA(2,7, 1)= .33500E+01        C   01C101D514
XA(2,7, 2)= .42500E+01        C   01C101D811
XA(2,7, 3)= .42500E+01        C   01C101DB11
XA(2,7, 4)= .49000E+01        C   01C101DE11
XA(2,7, 5)= .58000E+01        C   01C101E111
XA(2,7, 6)= .66000E+01        C   01C101E411
XA(2,7, 7)= .77000E+01        C   01C101E711
XA(2,7, 8)= .83500E+01        C   01C101EA11
XA(2,7, 9)= .92000E+01        C   01C101ED11
XA(2,7,10)= .10100E+02        C   01C101F011
XA(2,7,11)= .10950E+02        C   01C101F311
XA(2,7,12)= .11900E+02        C   01C101F611
XA(3,1, 1)=-.24000E+00        C   01C101F911
XA(3,1, 2)=-.32500E+00        C   01C101FC12
XA(3,1, 3)=-.42500E+00        C   01C101FF12
XA(3,1, 4)=-.60000E+00        C   01C1020212
XA(3,1, 5)=-.76000E+00        C   01C1020512
XA(3,1, 6)=-.93500E+00        C   01C1020812
XA(3,1, 7)=-.11150E+01        C   01C1020B12
XA(3,1, 8)=-.12780E+01        C   01C1020E12
XA(3,1, 9)=-.14750E+01        C   01C1021112
XA(3,1,10)=-.16750E+01        C   01C1021412
XA(3,1,11)=-.18550E+01        C   01C1021712
XA(3,1,12)=-.20680E+01        C   01C1021A12
XA(3,2, 1)=-.50000E+00        C   01C1021D12
XA(3,2, 2)=-.53000E+00        C   01C1022012
XA(3,2, 3)=-.67000E+00        C   01C1022312
XA(3,2, 4)=-.78000E+00        C   01C1022612
XA(3,2, 5)=-.90000E+00        C   01C1022912
XA(3,2, 6)=-.10000E+01        C   01C1022C12
XA(3,2, 7)=-.11700E+01        C   01C1022D14
XA(3,2, 8)=-.13000E+01        C   01C1023012
XA(3,2, 9)=-.14700E+01        C   01C1023312
XA(3,2,10)=-.16000E+01        C   01C1023612
XA(3,2,11)=-.18000E+01        C   01C1023912
XA(3,2,12)=-.20000E+01        C   01C1023C12
XA(3,3, 1)=-.30000E+00        C   01C1023E10
XA(3,3, 2)=-.15000E+00        C   01C1024012
XA(3,3, 3)= .20000E+00        C   01C1024312
XA(3,3, 4)= .60000E+00        C   01C1024611
XA(3,3, 5)= .12000E+01        C   01C1024911
XA(3,3, 6)= .16500E+01        C   01C1024C11
XA(3,3, 7)= .21000E+01        C   01C1024F11
XA(3,3, 8)= .25000E+01        C   01C1025211
XA(3,3, 9)= .30500E+01        C   01C1025511
XA(3,3,10)= .38000E+01        C   01C1025811
XA(3,3,11)= .41500E+01        C   01C1025B11
XA(3,3,12)= .48000E+01        C   01C1025E11
XA(3,4, 1)= .20000E+00        C   01C1026111
XA(3,4, 2)= .70000E+00        C   01C1026411
XA(3,4, 3)= .17000E+01        C   01C1026711
XA(3,4, 4)= .36000E+01        C   01C1026A11
XA(3,4, 5)= .52000E+01        C   01C1026D11
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XA(3,4, 6)= .70000E+01     C   01C:0270:11
XA(3,4, 7)= .82000E+01     C   01C:0273:11
XA(3,4, 8)= .96000E+01     C   01C:0276:11
XA(3,4, 9)= .11300E+02     C   01C:0279:11
XA(3,4,10)= .12800E+02     C   01C:027C:11
XA(3,4,11)= .14250E+02     C   01C:027F:11
XA(3,4,12)= .15700E+02     C   01C:0282:11
XA(3,5, 1)= .12000E+01     C   01C:0285:11
XA(3,5, 2)= .28000E+01     C   01C:0288:11
XA(3,5, 3)= .50000E+01     C   01C:028B:11
XA(3,5, 4)= .78000E+01     C   01C:028E:13
XA(3,5, 5)= .99000E+01     C   01C:028F:11
XA(3,5, 6)= .11900E+02     C   01C:0292:11
XA(3,5, 7)= .14100E+02     C   01C:0295:11
XA(3,5, 8)= .16250E+02     C   01C:0298:11
XA(3,5, 9)= .18400E+02     C   01C:029B:11
XA(3,5,10)= .20600E+02     C   01C:029E:11
XA(3,5,11)= .22700E+02     C   01C:02A1:11
XA(3,5,12)= .24900E+02     C   01C:02A4:11
XA(3,6, 1)= .25000E+01     C   01C:02A7:11
XA(3,6, 2)= .48000E+01     C   01C:02AA:11
XA(3,6, 3)= .60000E+01     C   01C:02AD:11
XA(3,6, 4)= .82000E+01     C   01C:02B0:11
XA(3,6, 5)= .99000E+01     C   01C:02B3:11
XA(3,6, 6)= .11600E+02     C   01C:02B6:11
XA(3,6, 7)= .13300E+02     C   01C:02B9:11
XA(3,6, 8)= .14100E+02     C   01C:02BC:11
XA(3,6, 9)= .16800E+02     C   01C:02BF:11
XA(3,6,10)= .18800E+02     C   01C:02C2:11
XA(3,6,11)= .20450E+02     C   01C:02C5:11
XA(3,6,12)= .22300E+02     C   01C:02C8:11
XA(3,7, 1)= .55500E+01     C   01C:02CB:11
XA(3,7, 2)= .62000E+01     C   01C:02CE:11
XA(3,7, 3)= .62000E+01     C   01C:02D1:11
XA(3,7, 4)= .72000E+01     C   01C:02D4:11
XA(3,7, 5)= .82000E+01     C   01C:02D7:11
XA(3,7, 6)= .93000E+01     C   01C:02DA:11
XA(3,7, 7)= .10400E+02     C   01C:02DD:11
XA(3,7, 8)= .11450E+02     C   01C:02E0:11
XA(3,7, 9)= .12600E+02     C   01C:02E3:11
XA(3,7,10)= .13700E+02     C   01C:02E6:11
XA(3,7,11)= .14800E+02     C   01C:02E9:11
XA(3,7,12)= .15900E+02     C   01C:02EC:11
XA(4,1, 1)=-.36000E+00     C   01C:02EF:11
XA(4,1, 2)=-.50000E+00     C   01C:02F2:12
XA(4,1, 3)=-.65000E+00     C   01C:02F5:12
XA(4,1, 4)=-.90000E+00     C   01C:02F8:12
XA(4,1, 5)=-.11200E+01     C   01C:02FB:12
XA(4,1, 6)=-.13700E+01     C   01C:02FE:12
XA(4,1, 7)=-.16300E+01     C   01C:0301:12
XA(4,1, 8)=-.18750E+01     C   01C:0304:12
XA(4,1, 9)=-.21500E+01     C   01C:0307:12
XA(4,1,10)=-.24500E+01     C   01C:030A:12
XA(4,1,11)=-.27300E+01     C   01C:030D:12
XA(4,1,12)=-.30410E+01     C   01C:0310:12
XA(4,2, 1)=-.25000E+00     C   01C:0313:12
XA(4,2, 2)=-.20000E+00     C   01C:0316:12
XA(4,2, 3)= .10000E+00     C   01C:0319:12
XA(4,2, 4)= .35000E+00     C   01C:031C:11
XA(4,2, 5)= .65000E+00     C   01C:031F:11
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XA(4,2, 6)= .90000E+00                                   C    01C1032211
XA(4,2, 7)= .10500E+01                                   C    01C1032511
XA(4,2, 8)= .14000E+01                                   C    01C1032811
XA(4,2, 9)= .16500E+01                                   C    01C1032B11
XA(4,2,10)= .18500E+01                                   C    01C1032E11
XA(4,2,11)= .20800E+01                                   C    01C1033111
XA(4,2,12)= .23000E+01                                   C    01C1033411
XA(4,3, 1)=0.                                            C    01C1033711
XA(4,3, 2)= .40000E+00                                   C    01C1033C12
XA(4,3, 3)= .10000E+01                                   C    01C1033D13
XA(4,3, 4)= .22500E+01                                   C    01C1033G12
XA(4,3, 5)= .34000E+01                                   C    01C1033F11
XA(4,3, 6)= .45000E+01                                   C    01C1034211
XA(4,3, 7)= .55000E+01                                   C    01C1034511
XA(4,3, 8)= .65000E+01                                   C    01C1034811
XA(4,3, 9)= .77000E+01                                   C    01C1034B11
XA(4,3,10)= .86000E+01                                   C    01C1034E11
XA(4,3,11)= .97500E+01                                   C    01C1035111
XA(4,3,12)= .11000E+02                                   C    01C1035411
XA(4,4, 1)= .80000E+00                                   C    01C1035514
XA(4,4, 2)= .16000E+01                                   C    01C1035811
XA(4,4, 3)= .32000E+01                                   C    01C1035B11
XA(4,4, 4)= .59000E+01                                   C    01C1035E11
XA(4,4, 5)= .82000E+01                                   C    01C1036111
XA(4,4, 6)= .10300E+02                                   C    01C1036411
XA(4,4, 7)= .12500E+02                                   C    01C1036711
XA(4,4, 8)= .14700E+02                                   C    01C1036A11
XA(4,4, 9)= .16900E+02                                   C    01C1036D11
XA(4,4,10)= .19200E+02                                   C    01C1037011
XA(4,4,11)= .21300E+02                                   C    01C1037311
XA(4,4,12)= .23500E+02                                   C    01C1037611
XA(4,5, 1)= .19500E+01                                   C    01C1037911
XA(4,5, 2)= .41000E+01                                   C    01C1037C11
XA(4,5, 3)= .70000E+01                                   C    01C1037F11
XA(4,5, 4)= .10200E+02                                   C    01C1038013
XA(4,5, 5)= .12700E+02                                   C    01C1038311
XA(4,5, 6)= .15400E+02                                   C    01C1038611
XA(4,5, 7)= .18000E+02                                   C    01C1038911
XA(4,5, 8)= .20500E+02                                   C    01C1038A14
XA(4,5, 9)= .23200E+02                                   C    01C1038D11
XA(4,5,10)= .25800E+02                                   C    01C1039011
XA(4,5,11)= .28416E+02                                   C    01C1039311
XA(4,5,12)= .31038E+02                                   C    01C1039611
XA(4,6, 1)= .37500E+01                                   C    01C1039911
XA(4,6, 2)= .67000E+01                                   C    01C1039C11
XA(4,6, 3)= .87000E+01                                   C    01C1039F11
XA(4,6, 4)= .10300E+02                                   C    01C103A211
XA(4,6, 5)= .12200E+02                                   C    01C103A511
XA(4,6, 6)= .14300E+02                                   C    01C103A811
XA(4,6, 8)= .18450E+02                                   C    01C103AB11
XA(4,6, 7)= .16400E+02                                   C    01C103AE11
XA(4,6, 9)= .20500E+02                                   C    01C103B111
XA(4,6,10)= .22500E+02                                   C    01C103B411
XA(4,6,11)= .24600E+02                                   C    01C103B711
XA(4,6,12)= .26500E+02                                   C    01C103BA11
XA(4,7, 1)= .77000E+01                                   C    01C103BD11
XA(4,7, 2)= .78000E+01                                   C    01C103C011
XA(4,7, 3)= .78000E+01                                   C    01C103C311
XA(4,7, 4)= .90000E+01                                   C    01C103C611
XA(4,7, 6)= .11700E+02                                   C    01C103C713
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XA(4,7, 7)= .13100E+02                                                    C   01C103CA11
XA(4,7, 8)= .14450E+02                                                    C   01C103CD11
XA(4,7, 9)= .15800E+02                                                    C   01C103D011
XA(4,7,10)= .17100E+02                                                    C   01C103D311
XA(4,7,11)= .18300E+02                                                    C   01C103D611
XA(4,7,12)= .19500E+02                                                    C   01C103D911
XA(5,1, 1)=-.26500E+00                                                    C   01C103DC11
XA(5,1, 2)=-.32500E+00                                                    C   01C103DF12
XA(5,1, 3)=-.37500E+00                                                    C   01C103E212
XA(5,1, 4)=-.45000E+00                                                    C   01C103E512
XA(5,1, 5)=-.52500E+00                                                    C   01C103E812
XA(5,1, 6)=-.63000E+00                                                    C   01C103EB12
XA(5,1, 7)=-.74000E+00                                                    C   01C103EE12
XA(5,1, 8)=-.83800E+00                                                    C   01C103F112
XA(5,1, 9)=-.96000E+00                                                    C   01C103F412
XA(5,1,10)=-.11000E+01                                                    C   01C103F712
XA(5,1,11)=-.12350E+01                                                    C   01C103FA12
XA(5,1,12)=-.15370E+01                                                    C   01C103FD12
XA(5,2, 1)=0.                                                             C   01C1040012
XA(5,2, 2)= .25000E+00                                                    C   01C1040113
XA(5,2, 3)= .60000E+00                                                    C   01C1040411
XA(5,2, 4)= .12500E+01                                                    C   01C1040711
XA(5,2, 5)= .18700E+01                                                    C   01C1040A11
XA(5,2, 6)= .25000E+01                                                    C   01C1040D11
XA(5,2, 7)= .30500E+01                                                    C   01C1041011
XA(5,2, 8)= .36300E+01                                                    C   01C1041311
XA(5,2, 9)= .42000E+01                                                    C   01C1041611
XA(5,2,10)= .47500E+01                                                    C   01C1041911
XA(5,2,11)= .52500E+01                                                    C   01C1041C11
XA(5,2,12)= .58000E+01                                                    C   01C1041F11
XA(5,3, 1)= .45000E+00                                                    C   01C1042211
XA(5,3, 2)= .90000E+00                                                    C   01C1042511
XA(5,3, 3)= .19000E+01                                                    C   01C1042811
XA(5,3, 4)= .37000E+01                                                    C   01C1042B11
XA(5,3, 5)= .53000E+01                                                    C   01C1042E11
XA(5,3, 6)= .69000E+01                                                    C   01C1043111
XA(5,3, 7)= .84000E+01                                                    C   01C1043411
XA(5,3, 8)= .99500E+01                                                    C   01C1043711
XA(5,3, 9)= .11500E+02                                                    C   01C1043A11
XA(5,3,10)= .13200E+02                                                    C   01C1043D11
XA(5,3,11)= .14800E+02                                                    C   01C1044011
XA(5,3,12)= .16600E+02                                                    C   01C1044311
XA(5,4, 1)= .12000E+01                                                    C   01C1044611
XA(5,4, 2)= .23000E+01                                                    C   01C1044911
XA(5,4, 3)= .45000E+01                                                    C   01C1044C11
XA(5,4, 4)= .80000E+01                                                    C   01C1044F11
XA(5,4, 5)= .11000E+02                                                    C   01C1045013
XA(5,4, 6)= .13900E+02                                                    C   01C1045115
XA(5,4, 7)= .16500E+02                                                    C   01C1045411
XA(5,4, 8)= .19300E+02                                                    C   01C1045711
XA(5,4, 9)= .22000E+02                                                    C   01C1045A11
XA(5,4,10)= .24700E+02                                                    C   01C1045B14
XA(5,4,11)= .27455E+02                                                    C   01C1045E11
XA(5,4,12)= .30207E+02                                                    C   01C1046111
XA(5,5, 1)= .27000E+01                                                    C   01C1046411
XA(5,5, 2)= .54000E+01                                                    C   01C1046711
XA(5,5, 3)= .90000E+01                                                    C   01C1046A11
XA(5,5, 4)= .12450E+02                                                    C   01C1046B13
XA(5,5, 5)= .15300E+02                                                    C   01C1046E11
XA(5,5, 6)= .18300E+02                                                    C   01C1047111
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XA(5,5, 7)= .21200E+02                    C   01C:0474:1
XA(5,5, 8)= .24300E+02                    C   01C:047/:1
XA(5,5, 9)= .27300E+02                    C   01C:047A:1
XA(5,5,10)= .30357E+02                    C   01C:047U:1
XA(5,5,11)= .33429E+02                    C   01C:048U:1
XA(5,5,12)= .36523E+02                    C   01C:048J:1
XA(5,6, 1)= .49500E+01                    C   01C:0486:1
XA(5,6, 2)= .85000E+01                    C   01C:048Y:1
XA(5,6, 3)= .10600E+02                    C   01C:048L:1
XA(5,6, 4)= .12400E+02                    C   01C:048F:1
XA(5,6, 5)= .14700E+02                    C   01C:0492:1
XA(5,6, 6)= .17000E+02                    C   01C:0495:1
XA(5,6, 7)= .19400E+02                    C   01C:0496:4
XA(5,6, 8)= .21700E+02                    C   01C:049Y:1
XA(5,6, 9)= .24000E+02                    C   01C:049L:1
XA(5,6,10)= .26224E+02                    C   01C:049U:4
XA(5,6,11)= .28418E+02                    C   01C:04AU:1
XA(5,6,12)= .30579E+02                    C   01C:04A3:1
XA(5,7, 1)= .90500E+01                    C   01C:04A6:1
XA(5,7, 2)= .91500E+01                    C   01C:04AY:1
XA(5,7, 3)= .90000E+01                    C   01C:04AL:1
XA(5,7, 4)= .10400E+02                    C   01C:04AU:3
XA(5,7, 5)= .11900E+02                    C   01C:04BU:1
XA(5,7, 6)= .13300E+02                    C   01C:04B3:1
XA(5,7, 7)= .14800E+02                    C   01C:04B6:1
XA(5,7, 8)= .16300E+02                    C   01C:04B9:1
XA(5,7, 9)= .17700E+02                    C   01C:04BL:1
XA(5,7,10)= .19200E+02                    C   01C:04BF:1
XA(5,7,11)= .20550E+02                    C   01C:04C2:1
XA(5,7,12)= .21900E+02                    C   01C:04C5:1
XA(6,1, 1)=-.17000E+00                    C   01C:04C8:1
XA(6,1, 2)=-.15000E+00                    C   01C:04C8:2
XA(6,1, 3)=-.10000E+00                    C   01C:04CE:2
XA(6,1, 4)=0.                             C   01C:04DA:2
XA(6,1, 5)= .70000E-01                    C   01C:04D2:3
XA(6,1, 6)= .11000E+00                    C   01C:04D5:1
XA(6,1, 7)= .15000E+00                    C   01C:04D8:1
XA(6,1, 8)= .20000E+00                    C   01C:04DB:1
XA(6,1, 9)= .23000E+00                    C   01C:04DE:1
XA(6,1,10)= .25000E+00                    C   01C:04E1:1
XA(6,1,11)= .26000E+00                    C   01C:04E4:1
XA(6,1,12)= .30000E+00                    C   01C:04E/:1
XA(6,2, 1)= .20000E+00                    C   01C:04EA:1
XA(6,2, 2)= .48000E+00                    C   01C:04EU:1
XA(6,2, 3)= .10500E+01                    C   01C:04FU:1
XA(6,2, 4)= .21000E+01                    C   01C:04F3:1
XA(6,2, 5)= .30500E+01                    C   01C:04F6:1
XA(6,2, 6)= .39500E+01                    C   01C:04FY:1
XA(6,2, 7)= .48500E+01                    C   01C:04FL:1
XA(6,2, 8)= .57000E+01                    C   01C:04FF:1
XA(6,2, 9)= .65000E+01                    C   01C:0502:1
XA(6,2,10)= .72000E+01                    C   01C:0505:1
XA(6,2,11)= .79500E+01                    C   01C:0508:1
XA(6,2,12)= .86500E+01                    C   01C:050B:1
XA(6,3, 1)= .70000E+00                    C   01C:050E:1
XA(6,3, 2)= .13000E+01                    C   01C:0511:1
XA(6,3, 3)= .27000E+01                    C   01C:0514:1
XA(6,3, 4)= .51000E+01                    C   01C:051/:1
XA(6,3, 5)= .72000E+01                    C   01C:051A:1
XA(6,3, 6)= .92000E+01                    C   01C:051U:1
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      XA(6,3, 7)= .11100E+02                                          C  01C1052011
      XA(6,3, 8)= .13050E+02                                          C  01C1052311
      XA(6,3, 9)= .15100E+02                                          C  01C1052611
      XA(6,3,10)= .17200E+02                                          C  01C1052911
      XA(6,3,11)= .19300E+02                                          C  01C1052C11
      XA(6,3,12)= .21700E+02                                          C  01C1052F11
      XA(6,4, 1)= .16500E+01                                          C  01C1053211
      XA(6,4, 2)= .31000E+01                                          C  01C1053511
      XA(6,4, 3)= .59000E+01                                          C  01C1053811
      XA(6,4, 4)= .10200E+02                                          C  01C1053B11
      XA(6,4, 5)= .13700E+02                                          C  01C1053E11
      XA(6,4, 6)= .17000E+02                                          C  01C1054111
      XA(6,4, 7)= .20200E+02                                          C  01C1054214
      XA(6,4, 8)= .23300E+02                                          C  01C1054511
      XA(6,4, 9)= .26000E+02                                          C  01C1054811
      XA(6,4,10)= .28907E+02                                          C  01C1054914
      XA(6,4,11)= .31830E+02                                          C  01C1054C11
      XA(6,4,12)= .34775E+02                                          C  01C1054F11
      XA(6,5, 1)= .37000E+01                                          C  01C1055211
      XA(6,5, 2)= .70000E+01                                          C  01C1055511
      XA(6,5, 3)= .10700E+02                                          C  01C1055613
      XA(6,5, 4)= .14400E+02                                          C  01C1055911
      XA(6,5, 5)= .17600E+02                                          C  01C1055C11
      XA(6,5, 6)= .21000E+02                                          C  01C1055F11
      XA(6,5, 7)= .24500E+02                                          C  01C1056014
      XA(6,5, 8)= .27700E+02                                          C  01C1056311
      XA(6,5, 9)= .30843E+02                                          C  01C1056611
      XA(6,5,10)= .33947E+02                                          C  01C1056911
      XA(6,5,11)= .37026E+02                                          C  01C1056C11
      XA(6,5,12)= .40008E+02                                          C  01C1056F11
      XA(6,6, 1)= .63000E+01                                          C  01C1057211
      XA(6,6, 2)= .10000E+02                                          C  01C1057511
      XA(6,6, 3)= .12200E+02                                          C  01C1057613
      XA(6,6, 4)= .14000E+02                                          C  01C1057911
      XA(6,6, 5)= .16500E+02                                          C  01C1057A13
      XA(6,6, 6)= .19100E+02                                          C  01C1057D11
      XA(6,6, 7)= .21600E+02                                          C  01C1058011
      XA(6,6, 8)= .24200E+02                                          C  01C1058311
      XA(6,6, 9)= .26800E+02                                          C  01C1058611
      XA(6,6,10)= .29315E+02                                          C  01C1058911
      XA(6,6,11)= .31794E+02                                          C  01C1058C11
      XA(6,6,12)= .34245E+02                                          C  01C1058F11
      XA(6,7, 1)= .10800E+02                                          C  01C1059211
      XA(6,7, 2)= .10600E+02                                          C  01C1059511
      XA(6,7, 3)= .10800E+02                                          C  01C1059811
      XA(6,7, 4)= .12100E+02                                          C  01C1059B11
      XA(6,7, 5)= .13700E+02                                          C  01C1059E11
      XA(6,7, 6)= .15400E+02                                          C  01C105A111
      XA(6,7, 7)= .17100E+02                                          C  01C105A411
      XA(6,7, 8)= .18800E+02                                          C  01C105A713
      XA(6,7, 9)= .20500E+02                                          C  01C105AA11
      XA(6,7,10)= .22200E+02                                          C  01C105AD11
      XA(6,7,11)= .23700E+02                                          C  01C105B011
      XA(6,7,12)= .25700E+02                                          C  01C105B311
C           END ASSIGNMENT OF VALUES TO ARRAY XA                       C  01C105B611
C           DETERMINE IF (=LARGEST INTEGER SUCH THAT FF(IF) .LE. F)    C  01C105B811
      IF(F-3.)20,21,21                                                C  01C105B811
   20 WRITE(6,101)                                                    C  01C105B713
      WRITE(6,102)F                                                   C  01C105B812
      GOTO199                                                         C  01C105C212
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21    IF(F-5.)22,23,23                                              C  01C105C215
22    IF=1                                                          C  01C105C411
      GOTO35                                                        C  01C105C415
23    IF(F-7.)24,25,25                                              C  01C105C512
24    IF=2                                                          C  01C105C614
      GOTO35                                                        C  01C105C713
25    IF(F-10.)26,27,27                                             C  01C105C810
26    IF=3                                                          C  01C105C912
      GOTO35                                                        C  01C105CA11
27    IF(F-15.)28,29,29                                             C  01C105CA14
28    IF=4                                                          C  01C105CB10
      GOTO35                                                        C  01C105CB15
29    IF(F-20.)30,31,31                                             C  01C105CD12
30    IF=5                                                          C  01C105CE14
      GOTO35                                                        C  01C105CF13
31    IF(F-30.)32,33,34                                             C  01C105D010
32    IF=6                                                          C  01C105D312
      GOTO35                                                        C  01C105D411
33    IF=7                                                          C  01C105D414
      GOTO35                                                        C  01C105D513
34    WRITE(6,101)                                                  C  01C105D610
      WRITE(6,102)F                                                 C  01C105DA12
      GOTO199                                                       C  01C105E112
35    CONTINUE                                                      C  01C105E115
C          END DETERMINATION OF INTEGER IF                          C  01C105E115
C          DETERMINE IR (=LARGEST INTEGER SUCH THAT RR(IR) .LE. R)  C  01C105E115
      IF(R-25.)40,41,41                                             C  01C105E115
40    WRITE(6,101)                                                  C  01C105E311
      WRITE(6,103)R                                                 C  01C105E712
      GOTO199                                                       C  01C105EE12
41    IF(R-50.)42,43,43                                             C  01C105EE15
42    IR=1                                                          C  01C105F011
      GOTO65                                                        C  01C105F015
43    IF(R-100.)44,45,45                                            C  01C105F112
44    IR=2                                                          C  01C105F214
      GOTO65                                                        C  01C105F313
45    IF(R-200.)46,47,47                                            C  01C105F410
46    IR=3                                                          C  01C105F512
      GOTO65                                                        C  01C105F611
47    IF(R-300.)48,49,49                                            C  01C105F614
48    IR=4                                                          C  01C105F811
      GOTO65                                                        C  01C105F910
49    IF(R-400.)50,51,51                                            C  01C105F913
50    IR=5                                                          C  01C105FB10
      GOTO65                                                        C  01C105FB15
51    IF(R-500.)52,53,53                                            C  01C105FC12
52    IR=6                                                          C  01C105FD15
      GOTO65                                                        C  01C105FE14
53    IF(R-600.)54,55,55                                            C  01C105FF11
54    IR=7                                                          C  01C1060014
      GOTO65                                                        C  01C1060113
55    IF(R-700.)56,57,57                                            C  01C1060210
56    IR=8                                                          C  01C1060313
      GOTO65                                                        C  01C1060412
57    IF(R-800.)58,59,59                                            C  01C1060415
58    IR=9                                                          C  01C1060612
      GOTO65                                                        C  01C1060711
59    IF(R-900.)60,61,61                                            C  01C1060714
60    IR=10                                                         C  01C1060914
      GOTO65                                                        C  01C1060A13
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61    IF(R-1000.)62,63,64                                                   C  01C1060010
62    IR=11                                                                 C  01C1060013
      GOTO65                                                                C  01C1060012
63    IR=12                                                                 C  01C1060015
      GOTO65                                                                C  01C1061014
64    WRITE(6,101)                                                          C  01C1061111
      WRITE(6,103)R                                                         C  01C1061512
      GOTO199                                                               C  01C1061612
65    CONTINUE                                                              C  01C1061615
C           END DETERMINATION OF INTEGER IR                                 C  01C1061615
      D=D1*(F**D2)*EXP(D3*(F**5))                                           C  01C1061615
      E=E1*(F**E2)                                                          C  01C1062211
      XLBASC=20.*ALOG10(62.*PI*R*F)/.3)+D*(R**E)                            C  01C1062415
      DIF=1./(FF(IF+1)-FF(IF))                                              C  01C1062612
      DIR=1./(RR(IR+1)-RR(IR))                                              C  01C1062710
      Z1=XA(IS,IF,IR)+DIF*(XA(IS,IF+1,IR)-XA(IS,IF,IR))*(F-FF(IF))          C  01C1063114
      Z2=XA(IS,IF,IR+1)+DIF*(XA(IS,IF+1,IR+1)-XA(IS,IF,IR+1))*(F-FF(IF))    C  01C1063611
      XLADD=Z1+DIR*(Z2-Z1)*(R-RR(IR))                                       C  01C1064A13
      GATTEN=XLBASC+XLADD                                                   C  01C1064L13
      GOTO200                                                               C  01C1064F15
101   FORMAT(1X)                                                            C  01C1065012
102   FORMAT(1X,'*****WARNING: THE FREQUENCY ',F8.4,' MHZ. LIES OUTSIDE     C  01C1065012
     1THE REGION RECOMMENDED FOR INTERPOLATION*****'/)                      C  01C1065012
103   FORMAT(1X,'***** WARNING: THE RANGE',F9.2,' KM. LIES OUTSIDE THE R    C  01C1065012
     1EGION RECOMMENDED FOR INTERPOLATION *****'/)                          C  01C1065012
199   GATTEN=10000.                                                         C  01C1065012
200   RETURN                                                                C  01C1065112
      END                                                                   C  01C1065115
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