

APPENDIX 8. SAMPLE CASE

A sample case is included with the description of the program for three reasons. First, it demonstrates the use of the program. Second, it illustrates the three types of output available (printout, punched cards, and ray path plots). Finally, it serves as a test case to verify that the user's copy of the program is running correctly. This last point is especially important if the user has had to make many modifications in converting the program to run on a computer other than a CDC 3800.

Although the ionospheric models in the sample case demonstrate the use of the program, they don't give realistic absorption for the radio waves. The absorption in the sample case is too low for two reasons. First, although the Chapman layer has a realistic electron density for the F region, it has much too low an electron density for the D region, where most of the absorption occurs. Second, the collision frequency profile in the sample case is designed for use with the Sen-Wyller formula for refractive index rather than the Appleton-Hartree formula used in the sample case. Multiplying the collision frequency profile in the sample case by 2.5 gives an effective collision frequency profile for use with the Appleton-Hartree formula that will give nearly the correct absorption for HF radio waves (Davies, 1965, p. 89).

Appendix 8a. Input Parameter Forms for the Sample Case

Filled-out input parameter forms are included to describe the sample case (i. e., show what ray paths are requested for which ionospheric models and what type of output is wanted). Furthermore, comparing them with Appendix 8b illustrates the relationship between the forms and the input data cards.

INPUT PARAMETER FORM FOR THREE-DIMENSIONAL RAY PATHS

Name _____ Project No. _____ Date _____

Ionospheric ID (3 characters) X01

Title (75 characters) Test Case

Models:	Electron density	<u>CHAPX</u>	
	Perturbation	<u>WAVE</u>	
	Magnetic field	<u>DIPOLY</u>	
	Ordinary	_____	(W1 = + 1.)
	Extraordinary	<input checked="" type="checkbox"/> _____	(W1 = - 1.)
	Collision frequency	<u>EXPZ2</u>	
Transmitter:	Height	<u>0</u>	km, nautical miles, feet (W3)
	Latitude	<u>40</u>	rad, <u>deg</u> km (W4)
	Longitude	<u>-105</u>	rad, <u>deg</u> km (W5)
	Frequency, initial	<u>6</u>	MHz (W7)
	final	_____	(W8)
	step	_____	(W9)
	Azimuth angle, initial	<u>45</u>	rad, <u>deg</u> clockwise of north (W11)
	final	_____	(W12)
	step	_____	(W13)
	Elevation angle, initial	<u>0</u>	rad, <u>deg</u> (W15)
	final	<u>90</u>	(W16)
	step	<u>15</u>	(W17)
Receiver:	Height	<u>200</u>	<u>km</u> , nautical miles, feet (W20)
Penetrating rays:	Wanted	<input checked="" type="checkbox"/> _____	(W21 = 0.)
	Not wanted	_____	(W21 = 1.)
	Maximum number of hops	<u>3</u>	(W22)
	Maximum number of steps per hop	<u>1000</u>	(W23)
	Maximum allowable error per step	<u>10⁻⁴</u>	(W42)
Additional calculations:			= 1. to integrate
			= 2. to integrate and print
	Phase path	<u>2</u>	(W57)
	Absorption	<u>2</u>	(W58)
	Doppler shift	_____	(W59)
	Path length	_____	(W60)
	Other	_____	

Printout: Every 5 steps of the ray trace (W71)

Punched cards (raysets): (W72 = 1.)

INPUT PARAMETER FORM FOR PLOTTING THE PROJECTION
OF THE RAY PATH ON A VERTICAL PLANE

Coordinates of the left edge of the graph:

Latitude = 40. $\frac{\text{rad}}{\text{deg}}$ north (W83)
km

Longitude = -105. $\frac{\text{rad}}{\text{deg}}$ east (W84)
km

Coordinates of the right edge of the graph:

Latitude = 52.12 $\frac{\text{rad}}{\text{deg}}$ north (W85)
km

Longitude = -81.8 $\frac{\text{rad}}{\text{deg}}$ east (W86)
km

Height above the ground of the bottom of the graph = 0. km (W88)

Distance between tic marks = 100. $\frac{\text{rad}}{\text{deg}}$ (W87)
 $\frac{\text{km}}{\text{km}}$

(W81 = 1.)

INPUT PARAMETER FORM FOR PLOTTING THE PROJECTION
OF THE RAY PATH ON THE GROUND

Coordinates of the left edge of the graph:

Latitude = 40. $\frac{\text{rad}}{\text{deg}}$ north (W83)
km

Longitude = -105. $\frac{\text{rad}}{\text{deg}}$ east (W84)
km

Coordinates of the right edge of the graph:

Latitude = 52.12 $\frac{\text{rad}}{\text{deg}}$ north (W85)
km

Longitude = -81.8 $\frac{\text{rad}}{\text{deg}}$ east (W86)
km

Factor to expand lateral deviation scale by = 200. (W82)

Distance between tic marks on range scale = 100. $\frac{\text{rad}}{\text{deg}}$ (W87)
km

(W81 = 2.)

INPUT PARAMETER FORM FOR SUBROUTINE CHAPX

An ionospheric electron density model consisting of a Chapman layer with tilts, ripples, and gradients

$$f_N^2 = f_c^2 \exp\left(\alpha(1-z-e^{-z})\right)$$

$$z = \frac{h - h_{\max}}{H}$$

$$f_c^2 = f_{c0}^2 \left(1 + A \sin\left(2\pi\left(\theta - \frac{\pi}{2}\right)/B\right) + C\left(\theta - \frac{\pi}{2}\right)\right)$$

$$h_{\max} = h_{\max 0} + E\left(\theta - \frac{\pi}{2}\right) R_0$$

f_N is the plasma frequency

h is the height above the ground

R_0 is the radius of the earth in km

and θ is the colatitude in radians.

Specify:

Critical frequency at the equator, $f_{c0} = \underline{6.5}$ MHz (W101)

Height of the maximum electron density at the equator, $h_{\max 0} = \underline{300}$ km (W102)

Scale height, $H = \underline{62.}$ km (W103)

$\alpha = \underline{0.5}$ (W104, 0.5 for an α Chapman layer, 1.0 for a β Chapman layer)

Amplitude of periodic variation of f_c^2 with latitude, $A = \underline{0.}$ (W105)

Period of variation of f_c^2 with latitude, $B = \underline{0.}$ $\frac{\text{rad}}{\text{deg}}$ (W106)
km

Coefficient of linear variation of f_c^2 with latitude, $C = \underline{0.}$ rad^{-1} (W107)

Tilt of the layer, $E = \underline{0.}$ $\frac{\text{rad}}{\text{deg}}$ (W108)

INPUT PARAMETER FORM FOR SUBROUTINE WAVE

A perturbation to an ionospheric electron density model consisting of a "gravity-wave" irregularity traveling from north pole to south pole

$$N = N_0(1 + \Delta)$$

$$\Delta = \delta \exp - [(R - R_0 - z_0)/H]^2 .$$

$$\cos 2\pi \left[t' + (\pi/2 - \theta) \frac{R_0}{\lambda_x} + (R - R_0)/\lambda_z \right]$$

$$\frac{\partial N}{\partial t} = \frac{-2\pi}{\lambda_x} V_x N_0 \delta \exp - [(R - R_0 - z_0)/H]^2 .$$

$$\sin 2\pi \left[t' + (\pi/2 - \theta) \frac{R_0}{\lambda_x} + (R - R_0)/\lambda_z \right]$$

R_0 is the radius of the earth.

R, θ, φ are the spherical (earth-centered) polar coordinates
(Δ is independent of φ).

$N_0(R, \theta, \varphi)$ is any electron density model.

Specify:

the height of maximum wave amplitude, $z_0 = \underline{250.}$ km (W151)

wave-amplitude "scale height," $H = \underline{100.}$ km (W152)

wave perturbation amplitude, $\delta = \underline{0.1}$ [0. to 1.] (W153)

horizontal trace velocity, $V_x = \underline{-}$ km/sec (W154)
(needed only if Doppler shift is calculated)

horizontal wavelength, $\lambda_x = \underline{100.}$ km (W155)

vertical wavelength, $\lambda_z = \underline{100.}$ km (W156)

time in wave periods, $t' = \underline{0.}$ [0. to 1.] (W157)

INPUT PARAMETER FORM FOR SUBROUTINE DIPOLY

An ionospheric model of the earth's magnetic field consisting of an earth centered dipole

The gyrofrequency is given by:

$$f_H = f_{H_0} \left(\frac{R_0 + h}{R_0} \right)^3 \left(1 + 3 \cos^2 \lambda \right)^{\frac{1}{2}}$$

The magnetic dip angle, I, is given by

$$\tan I = 2 \cot \lambda$$

h is the height above the ground

R_0 is the radius of the earth

λ is the geomagnetic colatitude

Specify:

the gyrofrequency at the equator on the ground, $f_{H_0} = \underline{0.8}$ MHz (W20i)

the geographic coordinates of the north magnetic pole

latitude = 78.5 ^{radians} degrees north (W24)

longitude = 291. ^{radians} degrees east (W25)

INPUT PARAMETER FORM FOR SUBROUTINE EXPZ 2

An ionospheric collision frequency model consisting of a double exponential profile

$$\nu = \nu_1 e^{-a_1(h-h_1)} + \nu_2 e^{-a_2(h-h_2)}$$

where h is the height above the ground.

Specify for the first exponential:

Collision frequency at height h_1 , $\nu_1 = \frac{3.65 \times 10^4}{\text{per second (W251)}}$ collisions

Reference height, $h_1 = \underline{100}$ km (W252)

Exponential decrease of ν with height, $a_1 = \underline{0.148}$ km⁻¹ (W253)

Specify for the second exponential:

Collision frequency at height h_2 , $\nu_2 = \frac{30}{\text{per second (W254)}}$ collisions

Reference height, $h_2 = \underline{140}$ km (W255)

Exponential decrease of ν with height, $a_2 = \underline{0.0183}$ km⁻¹ (W256)

Appendix 8b. Listing of Input Cards for the Sample Case

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X01 TEST CASE
1 0. OF DUPLICATE W CARDS, THE LAST ONE DOMINATES
1 -1. EXTRAORDINARY RAY
3 0. TRANSMITTER HEIGHT, KM
4 40. 1 TRANSMITTER LATITUDE, DEG NORTH
5 -105. 1 TRANSMITTER LONGITUDE, DEG EAST
7 6.0 INITIAL FREQUENCY, MC/S
9 0. DONT STEP FREQUENCY
11 45.0 1 INITIAL AZIMUTH ANGLE, DEGS CLOCKWISE FROM NORTH POLE
13 0. DONT STEP AZIMUTH ANGLE
15 0. 1 INITIAL ELEVATION ANGLE, DEG
16 90.0 1 FINAL ELEVATION ANGLE, DEG
17 15.0 1 STEP IN ELEVATION ANGLE, DEG
20 200. RECEIVER HEIGHT ABOVE THE EARTH, KM
22 3. NUMBER OF HOPS
57 2. INTEGRATE AND PRINT PHASE PATH
58 2. INTEGRATE AND PRINT ABSORPTION
71 5.0 NUMBER OF STEPS FOR EACH PRINTING
72 1. PUNCH RAYSETS
81 1. PLOT PROJECTION OF RAY PATH ON A VERTICAL PLANE
83 40.0 1 LEFT LATITUDE OF PLOT, DEG
84 -105. 1 LEFT LONGITUDE OF PLOT, DEG
85 52.12 1 RIGHT LATITUDE OF PLOT, DEG
86 -81.8 1 RIGHT LONGITUDE OF PLOT, DEG
87 100.0 1 DISTANCE BETWEEN TIC MARKS, KM
101 6.5 CRITICAL FREQUENCY, MC/S
102 300.0 HMAX, KM
103 62. SCALE HEIGHT, KM
104 0.5 ALPHA CHAPMAN LAYER
150 1. CALL PERTURBATION SUBROUTINE
151 250. Z0, KM
152 100. SH, SCALE HEIGHT, KM
153 0.1 DELTA
155 100. LAMBDAZ, HORIZONTAL WAVELENGTH, KM
156 100. LAMBDAZ, VERTICAL WAVELENGTH, KM
201 0.8 GYROFREQUENCY ON THE GROUND AT THE EQUATOR, MHZ
24 78.5 1 ACCEPTED STANDARD LAT. OF NORTH MAGNETIC POLE, DEG NORTH
25 291. 1 ACCEPTED STANDARD LONG. OF NORTH MAGNETIC POLE, DEG EAST
251 3.65 E4 COLLISION FREQUENCY AT H1, /SEC
252 100.0 H1, REFERENCE HEIGHT, KM
253 .148 A1, EXPONENTIAL DECREASE OF NU WITH HEIGHT, /KM
254 30. COLLISION FREQUENCY AT H2, /SEC
255 140. H2, REFERENCE HEIGHT, KM
256 .0183 A2, EXPONENTIAL DECREASE OF NU WITH HEIGHT, /KM
(A BLANK IN COL. 1-3 ENDS THE CURRENT W ARRAY)

X01 TEST CASE
71 0. NO PERIODIC PRINTOUT
72 0. DO NOT PUNCH RAYSETS
81 2. PLOT PROJECTION OF RAY PATH ON THE GROUND
82 10.0 LATERAL DEVIATION EXPANSION FACTOR
(A BLANK IN COL. 1-3 ENDS THE CURRENT W ARRAY)

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Col. 1-3 Identification number

Col. 4-17 Data in E14.6 format

Col. 18 A 1 indicates an angle in degrees

Col. 19 A 1 indicates a central earth angle in kilometers

Col. 20 A 1 indicates a distance in nautical miles

Col. 21 A 1 indicates a distance in feet

Col. 22-24 Left for other conversions

Col. 25-80 Description of the data

Appendix 8c. Sample Printout

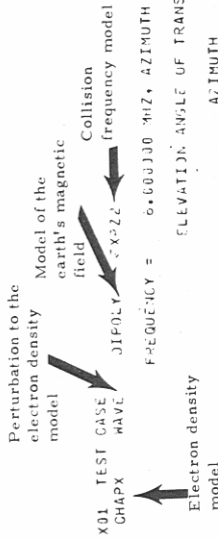
11/05/74

X01 TEST CASE D1POLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS
 CHAPX -- ALL ANGLES IN RADIANS, ONLY NONZERO VALUES PRINTED

INITIAL VALUES FOR THE W ARRAY -- ALL ANGLES IN RADIANS, ONLY NONZERO VALUES PRINTED

1	-1.0000000000+000
2	6.3700000000+003
4	5.98131708003-001
5	-1.83259571460+000
7	6.0000000000+000
11	7.85338153390-001
16	1.57079632679+000
17	2.61799367791-061
20	2.0000000000+002
22	3.0000000000+000
23	1.0000000000+003
24	1.37008346280+000
25	5.0789012331+000
41	3.0000000000+000
42	1.0000000000-004
43	5.0000000000+001
44	1.0000000000+000
45	1.0000000000+002
46	1.0000000000-008
47	5.0000000000-061
57	2.0000000000+000
58	2.0000000000+000
71	5.0000000000+000
72	1.0000000000+000
81	1.0000000000+000
83	6.98131708003-001
84	-1.83259571460+000
85	9.09665606124-001
86	-1.42767932513+000
87	1.55985671273-002
101	6.5000000000+000
102	3.0000000000+002
103	6.13999999995+001
104	5.0000000000-001
150	1.0000000000+000
151	2.5000000000+002
152	1.0000000000+002
153	1.0000000000-001
155	1.0000000000+002
156	1.0000000000+002
201	8.0000000000-001
251	3.6500000000+004
252	1.0000000000+002
253	1.4000000000-001
254	3.0000000000+001
255	1.33999999999+002
256	1.83300000000-002

11/05/74



	HEIGHT KM	RAJGE KM	AZIMUTH		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMPR DEG	LOCAL DEG	XMPR DEG	LOCAL DEG	REAL	IMAG			
0+000 XMPR	0.0000	0.0000	0.000	0.000	-0.000	0.000	0.000	-1.000	0.0000	0.0000	0.0000
-3-011 ENTR ION	52.4737	-18.7210	-0.000	0.000	-0.000	7.364	0.597	-1.427	823.2593	823.2593	0.0000
0+000	59.4425	-56.8820	-0.000	0.000	-0.000	7.797	0.513	-2.072	876.2593	876.2593	0.0000
-3-011	94.3916	565.0962	-0.000	0.000	-0.000	8.150	0.293	-2.886	912.2593	912.2593	0.0000
-3-011	73.7839	345.2593	0.000	0.000	-0.000	8.502	0.141	-2.599	952.2593	952.2593	0.0000
-2-009	85.8755	1628.3470	0.000	0.000	-0.000	9.345	0.021	-3.200	1048.2593	1048.2593	0.0004
-2-008	95.1450	1116.6700	0.000	0.000	-0.000	10.035	0.004	-4.060	1128.2593	1128.2593	0.0014
-9-008	113.8421	1134.0737	0.000	0.000	-0.002	10.683	0.001	-5.656	1208.2593	1208.2467	0.0034
-1-005	126.5479	1271.1132	0.000	0.002	-0.078	9.958	0.001	-7.582	1288.2593	1288.1390	0.0058
-4-006	143.3756	1347.7703	0.001	0.012	-0.269	6.649	0.000	-5.844	1368.2593	1367.5112	0.0076
-7-006	153.8536	1416.4564	0.001	0.051	-0.473	3.399	0.000	-2.083	1440.2593	1437.7718	0.0089
-9-006	177.2033	1454.4623	0.001	0.051	-0.753	0.000	0.000	-2.083	1518.9022	1476.0613	0.0106
-3-011 MIN DIST	156.1469	1491.1961	0.002	-0.029	-0.753	0.000	0.000	-1.720	1512.7786	1512.7786	0.0106
-3-011 MIN DIST	158.1469	1491.1961	0.002	-0.029	-0.753	0.000	0.000	-1.720	1512.7786	1512.7786	0.0106
-6-011 WAVE REV	151.2535	1683.3795	0.000	0.039	-0.746	0.341	0.001	-1.695	1522.9022	1516.5809	0.0126
-2-005	151.2535	1683.3795	0.000	0.028	-1.756	-7.550	0.000	-1.385	1615.9022	1605.6686	0.0144
3-006	153.2035	1059.7028	0.007	0.024	-2.782	-10.288	0.000	-1.318	1695.9022	1684.0907	0.0144
6-006	168.1332	1413.6452	0.000	0.016	-4.796	-10.483	0.000	-1.341	1855.9022	1843.6645	0.0191
8-006	80.8887	1565.0039	0.004	0.015	-6.536	-9.113	0.000	-1.403	2015.9022	2003.6590	0.0218
8-005 EXIT ION	49.2235	2185.5251	0.000	0.013	-8.572	-7.138	0.203	-1.093	2239.9022	2227.6590	0.0220
0+000 GRND REF	0.0000	2900.0492	-0.000	0.000	-13.042	0.738	0.001	-1.000	2955.4929	2943.2497	0.0220
0+000 ENTR ION	52.9830	3540.8051	-0.003	0.008	-15.566	7.401	-0.935	1.636	3700.7907	3688.5475	0.0220
0+000	53.4945	3544.7388	-0.003	0.008	-15.577	7.436	-0.935	1.705	3700.7907	3692.5475	0.0220
0+000	31.1154	3492.1351	-0.003	0.008	-16.214	9.661	-0.004	1.984	3957.7907	3945.5474	0.0227
-1-008 MAX LAT	107.9072	3385.1998	-0.003	0.008	-16.435	10.475	-0.000	1.635	4053.7907	4041.5426	0.0247
-1-008 WAVE REV	107.9072	3385.1398	-0.003	0.008	-16.435	10.475	-0.000	1.635	4053.7907	4041.5426	0.0247
-4-006	119.7975	6145.9652	-0.003	0.008	-16.578	10.307	-0.000	1.765	4117.7907	4105.5117	0.0266
-5-005	140.3009	6185.0264	-0.004	0.031	-16.914	9.243	-0.000	1.868	4261.7907	4248.4412	0.0308
-5-005	150.1106	4251.1682	-0.007	0.047	-17.169	4.188	-0.000	2.901	4341.7907	4325.8067	1.0350
0+000 MIN DIST	157.9616	4305.0842	-0.007	0.076	-17.366	-0.000	-0.000	9.317	4388.0431	4369.8069	3.0330

THIS RAY CALCULATION TOOK 12.382 SEC

Polarization = +i means the electric field vector is rotating counter clockwise when looking along the ray.

Angle of the wave normal with the local horizontal.

Elevation angle of current ray path point at the transmitter.

Azimuth angle of the wave normal in degrees clockwise from great circle between transmitter and ray point.

Azimuth angle of the direction of transmission in degrees clockwise from great circle between transmitter and ray point.

Great circle distance along the ground between the ray point and the transmitter.

Height of ray point above the ground.

V_r / Real part ($\sigma_p - 1$) vector, and n is the magnitude of the wave normal. This quantity would be zero if there were no errors in the numerical integration.

X01 TEST CASE 11/05/74
 CHAPX WAVE APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

DIPOLE EXPZ2 ELEVATION ANGLE OF TRANSMISSION = 45.000000 DEG
 FREQUENCY = 8.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 15.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMITR DEG	LOCAL DEG	XMITR DEG	LOCAL DEG	REAL	IMAG			
0+000 XMITR	0.0000	0.0000	-0.000	-0.000	15.000	15.000	0.001	-1.000	0.0000	0.0000	0.0000
0+000 ENTR ION	52.9852	186.0044	-0.000	-0.000	15.000	16.073	3.113	-3.358	194.1401	194.1401	0.0000
0+000	63.7838	211.6249	-0.000	-0.000	15.000	16.903	2.323	-7.474	221.1401	221.1401	0.0000
0+000	66.6275	230.5627	-0.000	-0.000	15.000	17.074	1.297	-9.793	241.1401	241.1401	0.0000
-5-010	79.6832	272.1042	-0.000	-0.000	15.000	17.447	0.369	-18.918	285.1401	285.1401	0.0001
-7-009	91.7890	309.7220	-0.000	-0.000	15.000	17.765	0.353	-11.019	325.1401	325.1401	0.0004
-2-008	104.1175	347.1979	-0.000	-0.000	15.000	18.116	-0.015	29.112	365.1401	365.1401	0.0011
1-006	126.7922	414.2467	-0.000	-0.000	14.990	18.525	-0.000	10.310	437.1401	437.1401	0.0031
3-005	151.4725	488.2483	-0.000	-0.000	14.941	16.907	-0.000	4.594	517.1401	517.1401	0.0048
-3-006	161.8111	524.9617	-0.001	-0.002	14.959	13.612	0.000	-4.495	557.1401	557.1401	0.0057
-1-005	169.1102	561.6061	0.000	-0.078	14.015	8.649	0.000	-2.160	597.1401	597.1401	0.0079
-7-006	172.1418	598.6253	0.015	0.155	13.155	1.378	0.000	-1.537	637.1401	637.1401	0.0081
-3-011 MIN DIST	172.1332	604.1034	0.015	0.134	12.975	0.000	0.000	-1.481	643.9528	632.4672	0.0081
-3-011 MIN DIST	172.1392	604.1034	0.015	0.184	12.975	0.000	0.000	-1.481	643.9528	632.4672	0.0081
2-010 WAVE REV	172.0655	607.7222	0.015	0.196	12.864	-0.820	0.000	-1.452	647.9528	635.9500	0.0083
-3-005	153.8276	766.9590	0.026	-0.078	8.942	-15.755	0.000	-1.173	756.9528	735.2639	0.0114
-3-005	130.0051	790.9017	0.033	-0.036	5.835	-16.205	0.000	-1.154	836.9528	813.9074	0.0133
-3-005	109.1516	855.5089	0.037	-0.032	3.033	-17.862	0.000	-1.162	916.9528	893.8060	0.0160
-3-005	81.0347	930.6930	0.039	-0.030	0.752	-17.194	0.003	-1.174	996.9528	973.8062	0.0173
-3-005 EXIT ION	48.4333	1036.6769	0.042	-0.027	-1.983	-16.239	0.075	-1.037	1108.9528	1085.8062	0.0174
0+000 GRND REF	0.0000	1212.9251	0.046	-0.023	-5.455	14.366	-0.002	1.000	1292.1934	1269.1468	0.0174
-3-011 ENTR ION	52.9855	1403.0408	0.049	-0.020	-4.165	16.366	-1.305	1.885	1490.3081	1467.2614	0.0174
-3-011	54.1138	1406.8464	0.049	-0.020	-4.142	16.400	-1.305	2.105	1494.3081	1471.2614	0.0174
-9-037	110.0072	1565.1016	0.052	-0.018	-3.213	17.984	-0.000	2.342	1603.3081	1560.2574	0.0191
-1-005	134.9372	1759.5945	0.052	-0.018	-2.890	18.138	-0.000	2.221	1763.3081	1740.0923	0.0214
-1-005	156.1159	1726.0642	0.052	-0.018	-2.698	15.432	-0.000	3.024	1835.3081	1810.6175	0.0228
-1-002	165.2114	1762.7028	0.051	-0.021	-2.675	11.173	-0.000	14.789	1875.3081	1848.1145	0.0237
-7-005	170.7131	1799.2958	0.054	-0.033	-2.779	5.562	0.000	-3.471	1915.3081	1894.3621	0.0248
0+000 MIN DIST	171.9566	1826.6204	0.059	-0.065	-2.959	-0.000	0.000	-1.952	1947.4107	1912.8923	0.0258

THIS RAY CALCULATION TOOK 11.247 SEC

X01 TEST CASE 11/05/74
 CHAPX WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUENCY = 6.000000 MHz, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG
 ELEVATION ANGLE OF TRANSMISSION = 30.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMTR DEG	LOCAL DEG	XMTR DEG	LOCAL DEG	REAL	IMAG			
3-011 XMTR	0.0000	0.0000									
0+000 ENTR ION	52.5739	89.9010	-0.300	-0.000	30.000	30.000	-0.000	1.000	0.0000	0.0000	0.0000
-3-011	60.5694	102.6627	-0.000	-0.000	30.000	30.809	-0.332	1.259	104.6686	104.6686	0.0000
0+000	65.3141	111.1535	-0.000	-0.000	30.000	30.923	-0.213	1.562	119.6686	119.6686	0.0000
-2-010	78.2077	131.4761	-0.000	-0.000	30.000	31.000	-0.110	1.614	129.6686	129.6686	0.0000
-2-009	88.5857	148.3519	-0.000	-0.000	30.000	31.183	-0.017	1.609	153.6686	153.6686	0.0000
-1-007	107.3766	178.5914	-0.000	-0.000	30.000	31.334	-0.004	1.592	173.6686	173.6686	0.0002
-1-006	128.3994	211.9816	-0.000	-0.000	30.000	31.600	-0.000	1.562	209.6686	209.6686	0.0008
-5-006	149.2460	245.1205	-0.000	-0.001	29.998	31.773	-0.000	1.539	249.6686	249.6686	0.0020
-2-005	168.5912	277.9003	-0.302	-0.009	29.935	31.083	-0.000	1.574	289.6686	289.6686	0.0029
-2-005	184.0395	310.3408	-0.311	-0.068	29.657	27.599	-0.000	1.695	329.6686	329.6686	0.0038
1-006	191.3569	342.2014	-0.027	0.444	28.909	19.956	-0.000	7.331	369.6686	360.9884	0.0052
0+000 MIN DIST	191.5641	354.9408	-0.023	0.219	26.398	0.000	0.000	-1.911	409.6686	390.0049	0.0073
0+000 MIN DIST	191.5641	354.9408	-0.023	0.219	26.398	0.000	0.000	-1.530	425.7924	400.9614	0.0082
6-010 WAVE REV	191.4066	358.1065	-0.020	0.137	26.154	-1.395	0.000	-1.475	425.7924	400.9614	0.0082
4-006	172.2684	426.8860	0.135	-0.735	19.783	-23.513	0.000	-1.113	425.7924	403.6919	0.0085
2-005	135.6960	493.7148	0.236	-0.521	12.986	-29.961	0.000	-1.076	514.7924	468.9299	0.0125
2-005	95.7861	561.7275	0.298	-0.455	7.074	-29.718	0.000	-1.080	594.7924	544.6800	0.0147
2-005	56.5019	630.5940	0.348	-0.405	2.257	-29.100	0.039	-1.062	674.7924	624.5459	0.0172
2-005	46.7356	644.4661	0.357	-0.397	1.406	-28.975	0.035	-1.018	754.7924	704.5457	0.0177
-3-011 GRND REF	0.0000	733.6080	0.405	-0.308	-3.299	28.173	-0.000	1.000	770.7924	720.5457	0.0177
0+000 ENTR ION	52.9781	830.3382	0.446	-0.308	-0.104	29.043	-0.277	1.223	872.6950	822.4383	0.0177
-4-007	92.6830	901.1376	0.470	-0.284	1.779	29.671	-0.002	1.497	983.3256	933.0789	0.0177
-2-005	132.5904	968.2234	0.490	-0.266	3.349	30.046	-0.000	1.461	1064.3256	1014.0788	0.0180
-1-005	163.3870	1021.9170	0.501	-0.223	4.356	26.978	-0.000	1.628	1144.3256	1093.9984	0.0201
-2-005	179.0552	1055.0139	0.507	-0.452	4.735	20.718	-0.000	2.556	1208.3256	1156.1125	0.0215
-9-006	188.0742	1087.7704	0.511	0.102	4.734	9.433	0.000	-4.108	1248.3256	1191.4144	0.0228
0+000 MIN DIST	103.8217	1107.5272	0.511	0.454	4.531	0.000	0.000	-1.771	1288.3256	1222.7505	0.0245

THIS RAY CALCULATION TOOK 8.642 SEC

X01 TEST CASE
 CHAPX
 DIPOLY EXPZ2
 APFLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS
 11/05/74

FREQUENCY = 6.600300 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG
 ELEVATION ANGLE OF TRANSMISSION = 45.000000 DEG

	HEIGHT KM	WAVE	XMPR DEG	AZIMUTH DEVIATION		LOCAL DEG	ELEVATION		LOCAL DEG	REAL	IMAG	GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
				XMPR DEG	LOCAL DEG		XMPR DEG	LOCAL DEG						
0+000	0.0000	0.0000	0.000	-0.000	-0.000	45.000	45.000	45.000	1.000	1.000	0.0000	0.0000	0.0000	
0+000	52.3759	52.3246	-0.500	-0.000	-0.000	45.000	45.471	45.000	1.000	1.000	74.6128	74.6128	0.0000	
3-011	61.3530	61.3530	0.000	0.000	0.000	45.000	45.552	45.000	1.207	1.207	87.6128	87.6128	0.0000	
0+000	69.3926	63.2802	-0.300	-0.000	-0.000	45.000	45.614	45.000	1.219	1.219	97.6128	97.6128	0.0000	
-3-109	85.1331	83.4659	-0.300	-0.000	-0.000	45.000	45.751	45.000	1.213	1.213	119.6128	119.6128	0.0001	
-4-038	99.4743	97.2070	-0.300	-0.000	-0.000	45.000	45.873	45.000	1.209	1.209	139.6128	139.6128	0.0004	
-1-037	113.8433	110.8868	-0.300	-0.000	-0.000	45.000	45.986	45.000	1.209	1.209	159.6128	159.6128	0.0009	
5-035	142.5566	138.0459	-0.300	-0.000	-0.000	44.789	43.268	44.789	1.260	1.260	199.6128	199.6128	0.0021	
-2-005	173.1037	164.7826	-0.311	-0.106	-0.106	44.134	34.573	44.134	1.601	1.601	237.3102	237.3102	0.0030	
6-005	193.2703	190.5927	-1.371	0.369	0.369	43.622	28.430	43.622	2.293	2.293	278.4398	278.4398	0.0048	
-3-011	200.0000	200.2014	-0.132	0.607	0.607	40.436	4.776	40.436	0.000	0.000	295.1649	295.1649	0.0058	
2-006	209.8843	233.2999	-0.166	-1.590	-1.590	39.431	3.110	39.431	-1.831	-1.831	348.1649	348.1649	0.0095	
2-006	209.8843	235.8629	-0.166	-1.746	-1.746	39.431	3.110	39.431	-1.831	-1.831	352.1649	352.1649	0.0098	
3-005	209.8360	241.0969	0.021	-1.982	-1.982	36.819	-12.892	36.819	0.000	0.000	310.1892	310.1892	0.0103	
3-037	205.9618	259.5199	0.244	-2.001	-2.001	36.819	-12.892	36.819	0.000	0.000	388.1649	388.1649	0.0122	
3-011	200.0000	274.3788	0.385	-1.415	-1.415	27.233	-23.456	27.233	0.000	0.000	410.8543	410.8543	0.0137	
1-005	172.6329	311.6736	0.547	-0.183	-0.183	16.021	-45.154	16.021	0.000	0.000	467.8543	467.8543	0.0169	
4-006	117.8520	366.4800	0.563	-0.033	-0.033	10.932	-44.327	10.932	0.000	0.000	547.8543	547.8543	0.0193	
6-006	99.5472	396.2849	0.575	-0.030	-0.030	2.978	-44.472	2.978	0.000	0.000	659.8543	659.8543	0.0204	
6-006	38.9026	444.9524	0.574	-0.027	-0.027	2.978	-44.472	2.978	0.000	0.000	715.8543	715.8543	0.0206	
6-005	38.9026	444.9524	0.574	-0.027	-0.027	-2.180	44.114	-2.180	0.000	0.000	622.2214	622.2214	0.0206	
0+000	0.0000	484.7060	0.578	-0.022	-0.022	3.168	44.599	3.168	0.105	0.105	791.3392	791.3392	0.0206	
0+000	52.9777	538.6621	0.578	-0.022	-0.022	7.705	45.103	7.705	0.136	0.136	872.3392	872.3392	0.0214	
-6-007	110.1068	595.3574	0.581	-0.020	-0.020	9.586	45.095	9.586	0.000	0.000	912.3392	912.3392	0.0226	
-6-007	138.4297	622.9739	0.581	-0.016	-0.016	11.199	42.989	11.199	0.000	0.000	857.2445	857.2445	0.0236	
-4-006	165.8750	650.1869	0.579	-0.068	-0.068	12.376	35.811	12.376	0.000	0.000	992.3392	992.3392	0.0252	
7-005	193.5935	676.6832	0.572	0.057	0.057	12.376	35.811	12.376	0.000	0.000	1015.8617	1015.8617	0.0266	
-3-011	200.0000	691.5163	0.546	0.796	0.796	12.679	26.353	12.679	0.000	0.000	905.3752	905.3752	0.0266	

THIS RAY CALCULATION TOOK 10.310 SEC

XJ1 TEST CASE CHAPX WAVE DIPOLE EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS 11/05/74

FREQUENCY = 6.000000 MHz, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 60.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMTR DEG	LOCAL DEG	XMTR DEG	LOCAL DEG	REAL	IMAG			
0+000 XMTR	0.0000	0.0000	-0.000	-0.000	60.000	60.000	-0.000	1.000	0.0000	0.0000	0.0000
0+000 ENTR ION	52.9788	30.2936	-0.000	-0.000	60.000	60.272	-0.053	1.049	61.0908	61.0908	0.0000
0+000	59.9272	34.2236	-0.000	-0.000	60.000	60.308	-0.035	1.092	59.0908	59.0908	0.0000
0+000	67.7470	38.8347	-0.000	-0.000	60.000	60.348	-0.012	1.103	78.0908	78.0908	0.0000
-7-009	85.1354	46.8990	-0.000	-0.000	60.000	60.435	-0.001	1.103	98.0908	98.0908	0.0001
-1-007	102.8587	58.1107	-0.000	-0.000	60.000	60.522	-0.000	1.101	118.0908	118.0908	0.0004
-4-007	119.9525	67.7696	-0.000	-0.000	59.939	60.592	-0.000	1.100	138.0908	138.0820	0.0011
-4-006	154.5342	86.6836	-0.007	-0.005	59.967	60.149	-0.000	1.103	178.0908	177.5563	0.0022
4-005	156.1632	105.2175	-0.094	-0.088	59.597	55.830	-0.000	1.158	218.0908	211.9329	0.0037
9-005	200.0000	114.4162	-0.157	-0.051	59.325	50.578	-0.001	1.250	239.2552	236.8743	0.0050
-1-004	224.6062	137.5936	-0.234	0.797	57.441	24.698	-0.000	5.656	286.2552	248.7596	0.0090
-1-004	225.8332	146.6930	-0.354	5.402	55.872	-5.298	0.000	-2.002	324.2552	253.2681	0.0114
-1-004	225.8332	146.6930	-0.354	5.402	55.872	-5.298	0.000	-2.002	324.2552	253.2681	0.0114
-1-004	221.4155	153.9714	-0.522	9.624	54.028	-33.777	0.000	-1.188	348.2552	257.0925	0.0135
-3-005	204.2335	166.0800	-1.210	16.099	49.687	-60.227	0.000	-1.030	388.2552	269.8039	0.0168
0+000 RCVR	200.0000	166.1639	-1.383	16.976	48.744	-62.499	0.000	-1.025	395.1225	273.3158	0.0173
-1-005	153.9530	185.8715	-3.072	16.994	38.450	-69.419	0.000	-1.013	452.1225	318.1391	0.0201
-4-005	116.7265	198.8446	-4.206	15.804	29.230	-69.701	0.000	-1.013	492.1225	357.6160	0.0213
-2-305	79.2276	212.0602	-5.215	14.796	19.415	-69.586	0.000	-1.013	532.1225	397.6124	0.0223
0+000 EXIT ION	26.7751	236.9190	-6.444	13.564	5.561	-69.441	0.000	-1.000	588.1225	436.6124	0.0223
0+000 GRND REF	0.0000	240.7118	-7.005	13.003	-1.083	69.350	-0.000	1.000	616.7330	482.2229	0.0223
-3-011	52.9836	260.0662	-7.392	12.021	10.239	69.499	-0.025	1.025	673.3376	538.6275	0.0223
-3-011	56.7354	261.4245	-8.556	11.957	11.015	69.511	-0.023	1.038	677.3376	542.6275	0.0223
-3-005	113.9101	281.9769	-8.339	11.075	20.549	69.695	-0.003	1.050	738.3376	603.8243	0.0232
6-005	151.2131	295.2551	-9.446	10.601	25.514	69.477	-0.000	1.051	778.3376	643.4278	0.0244
-4-005	185.7563	308.0424	-9.310	9.231	29.335	66.600	-0.000	1.071	818.3376	678.2033	0.0259
0+000 RCVR	200.0000	313.9111	-10.115	8.555	30.682	63.964	-0.000	1.099	837.7013	691.0808	0.0271

THIS RAY CALCULATION TOOK 8.0004 SEC

X01 TEST CASE 11/05/74
 CHAPX WAVE DIFOLY EXPZZ APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS
 FREQUENCY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG
 ELEVATION ANGLE OF TRANSMISSION = 75.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMTR DEG	LOCAL DEG	XMTR DEG	LOCAL DEG	REAL	IMAG			
0+000 XMTR	0.0000	0.0000	-0.000	-0.000	75.000	75.000	-0.000	1.000	0.0000	0.0000	0.0000
0+000 ENTR ION	52.98646	14.0759	-0.000	-0.000	75.000	75.127	-0.024	1.023	54.8374	54.8374	0.0000
-3-011	60.7168	16.1160	-0.000	-0.000	75.000	75.145	-0.014	1.044	62.8374	62.8374	0.0000
-3-011	65.5499	17.3788	-0.000	-0.000	75.000	75.156	-0.008	1.047	67.8374	67.8374	0.0000
-2-006	87.7850	23.1909	-0.000	-0.000	75.000	75.209	-0.003	1.048	90.8374	90.8374	0.0001
-1-007	137.1237	28.2124	-0.000	-0.000	75.000	75.253	-0.000	1.047	110.8374	110.8374	0.0005
-3-007	125.4556	33.2025	-0.001	-0.000	74.999	75.279	-0.000	1.046	130.8374	130.8374	0.0013
4-007	145.6921	38.1498	-0.007	-0.012	74.994	75.188	-0.000	1.047	150.8374	150.8374	0.0019
3-005	174.7737	46.6081	-0.062	-0.321	74.920	73.849	-0.000	1.057	186.8374	183.5011	0.0030
0+000 RCVR	200.3030	52.6875	-0.362	1.334	74.783	71.857	-0.000	1.087	213.9181	202.1284	0.0046
0+005	224.9440	60.6695	-1.077	1.370	74.879	52.074	-0.000	1.988	266.9161	217.2922	0.0091
1-004	230.7996	66.1625	-1.711	-7.396	73.432	15.969	0.000	-9.825	306.9161	220.4673	0.0127
1-004 APOGEE	230.9183	67.5504	-1.511	-8.853	73.111	8.237	0.000	-3.876	314.9181	220.4673	0.0134
9-003 WAVE REV	230.2593	70.7651	-0.922	-11.181	72.307	-4.474	0.003	-1.950	330.9181	221.5762	0.0167
5-005	222.0226	74.2620	1.343	-14.206	68.508	-29.337	0.000	-1.143	378.9181	228.5798	0.0187
0+000 RCVR	200.0000	106.6257	5.511	-13.543	61.084	-46.475	0.000	-1.024	434.9673	249.2747	0.0232
2-005	161.6693	134.6131	9.542	-11.278	49.256	-55.293	0.000	-1.007	491.9673	291.7804	0.0263
-2-005	129.0135	155.6984	10.092	-9.754	38.661	-56.407	0.000	-1.006	531.9673	330.5977	0.0275
-3-036	95.7332	177.1855	11.265	-8.562	27.405	-56.282	0.003	-1.006	571.9673	370.5601	0.0289
-1-006	62.4374	196.9508	12.222	-7.620	16.463	-56.084	0.001	-1.006	611.9673	410.5600	0.0292
-1-006 EXIT ION	29.3420	220.9903	12.992	-6.356	6.551	-55.885	0.001	-1.000	651.9673	450.5600	0.0292
0+000 GRNG REF	0.0000	240.7569	13.557	-5.291	-1.083	55.706	-0.000	1.000	687.4459	486.0386	0.0292
0+000 ENTR ION	52.9836	276.3463	14.372	-5.473	9.565	56.027	-0.069	1.064	751.4563	550.0469	0.0292
-6-003	37.0257	296.8465	14.784	-5.055	14.785	56.231	-0.001	1.134	792.4563	591.0469	0.0293
-6-006	120.3097	320.5884	15.124	-4.721	18.948	56.406	-0.000	1.130	832.4563	631.0396	0.0303
2-005	153.3776	342.0624	15.423	-4.425	22.353	55.904	-0.000	1.135	872.4563	670.5260	0.0314
4-035	183.9935	362.9372	15.675	-4.214	24.915	51.894	-0.000	1.195	912.4563	705.8795	0.0327
-3-011 RCVR	200.0000	375.3567	15.794	-3.644	25.987	45.376	-0.000	1.374	937.9577	722.8911	0.0343

THIS RAY CALCULATION TOOK 9.624 SEC

FREQUENCY = 6.400000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 90.000000 DEG

MODE	WAVE	HEIGHT KM	RANGE KM	AZIMUTH		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
				XMITR DEG	LOCAL DEG	XMITR DEG	LOCAL DEG	REAL	IMAG			
0+000	XMITR	J.00000	0.00000			90.000	90.000	-0.000	0.000	0.0000	0.0000	0.0000
-3-011	ENTR ION	52.39000	0.00000			90.000	90.000	-0.000	1.000	52.39000	52.39000	0.0000
-3-011	MAX LAT	54.39000	0.00000			90.000	90.000	-0.000	1.012	54.39000	54.39000	0.0000
-6-011	ENTR ION	62.49000	0.00000			90.000	90.000	-0.000	1.014	62.49000	62.49000	0.0000
-6-011	MAX LAT	64.39000	0.00000			90.000	90.000	-0.000	1.018	64.39000	64.39000	0.0000
-6-011	ENTR ION	67.49000	0.00000			90.000	90.000	-0.000	1.013	67.49000	67.49000	0.0000
-6-011	MAX LAT	69.24000	0.00000			90.000	90.000	-0.000	1.019	69.24000	69.24000	0.0000
-6-011	ENTR ION	71.74000	0.00000			90.000	90.000	-0.000	1.019	71.74000	71.74000	0.0000
-6-011	MAX LAT	76.74000	0.00000			90.000	90.000	-0.000	1.019	76.74000	76.74000	0.0000
-9-011	ENTR ION	79.24000	0.00000			90.000	90.000	-0.000	1.019	79.24000	79.24000	0.0000
-9-011	MAX LAT	84.24000	0.00000			90.000	90.000	-0.000	1.019	84.24000	84.24000	0.0000
-2-010	ENTR ION	83.24000	0.00000			90.000	90.000	-0.000	1.019	83.24000	83.24000	0.0000
-2-010	MAX LAT	84.24000	0.00000			90.000	90.000	-0.000	1.018	84.24000	84.24000	0.0000
-3-010	ENTR ION	94.24000	0.00000	-143.742-178.476		90.000	90.000	-0.000	1.018	94.24000	94.24000	0.0000
-3-010	MAX LAT	105.24000	0.00000	-144.362-179.996		90.000	90.000	-0.000	1.018	105.24000	105.24000	0.0000
-2-009	ENTR ION	110.23300	0.00000	-145.186-179.920		90.000	90.000	-0.000	1.018	110.23300	110.23300	0.0000
-2-009	MAX LAT	115.23300	0.00000	-145.276-179.991		90.000	90.000	-0.000	1.018	115.23300	115.23300	0.0000
-3-009	ENTR ION	119.73650	0.00000	-145.262-179.991		90.000	90.000	-0.000	1.018	119.73650	119.73650	0.0000
-3-009	MAX LAT	120.73300	0.00000	-145.262-179.991		90.000	90.000	-0.000	1.018	120.73300	120.73300	0.0000
-4-009	ENTR ION	125.73300	0.00000	-145.262-179.991		90.000	90.000	-0.000	1.018	125.73300	125.73300	0.0000
-4-009	MAX LAT	138.68560	0.00000	-145.262-179.991		90.000	90.000	-0.000	1.018	138.68560	138.68560	0.0000
9-008	ENTR ION	150.57700	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.018	150.57700	150.57700	0.0000
9-008	MAX LAT	154.32720	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.019	154.32720	154.32720	0.0000
3-007	ENTR ION	167.82300	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.020	167.82300	167.82300	0.0000
3-007	MAX LAT	175.15320	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.021	175.15320	175.15320	0.0000
-2-007	ENTR ION	176.92000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.021	176.92000	176.92000	0.0000
-2-007	MAX LAT	182.07750	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.025	182.07750	182.07750	0.0000
4-005	ENTR ION	200.00000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.030	200.00000	200.00000	0.0000
4-005	MAX LAT	218.55300	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.047	218.55300	218.55300	0.0000
3-006	ENTR ION	227.98860	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.054	227.98860	227.98860	0.0000
3-006	MAX LAT	237.36540	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.052	237.36540	237.36540	0.0000
-4-004	ENTR ION	238.23050	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.052	238.23050	238.23050	0.0000
-4-004	MAX LAT	238.23050	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.052	238.23050	238.23050	0.0000
-2-003	ENTR ION	238.23050	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.052	238.23050	238.23050	0.0000
-2-003	MAX LAT	238.23050	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.052	238.23050	238.23050	0.0000
-4-004	ENTR ION	238.23050	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.052	238.23050	238.23050	0.0000
-4-004	MAX LAT	238.23050	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.052	238.23050	238.23050	0.0000
-6-011	ENTR ION	256.67400	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.042	256.67400	256.67400	0.0000
-6-011	MAX LAT	256.67400	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.042	256.67400	256.67400	0.0000
-2-005	ENTR ION	52.39000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.042	52.39000	52.39000	0.0000
-2-005	MAX LAT	54.39000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.042	54.39000	54.39000	0.0000
-1-005	ENTR ION	62.49000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.042	62.49000	62.49000	0.0000
-1-005	MAX LAT	64.39000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.042	64.39000	64.39000	0.0000
-2-006	ENTR ION	72.79360	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.042	72.79360	72.79360	0.0000
-2-006	MAX LAT	74.79360	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.042	74.79360	74.79360	0.0000
-3-011	ENTR ION	84.24000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.006	84.24000	84.24000	0.0000
-3-011	MAX LAT	86.24000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.006	86.24000	86.24000	0.0000
-1-007	ENTR ION	94.24000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.006	94.24000	94.24000	0.0000
-1-007	MAX LAT	96.24000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.006	96.24000	96.24000	0.0000
-3-006	ENTR ION	105.24000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.006	105.24000	105.24000	0.0000
-3-006	MAX LAT	107.24000	0.00000	-145.266-180.000		90.000	90.000	-0.000	1.006	107.24000	107.24000	0.0000
0+000	RCVR	0.00000	0.00000			90.000	90.000	-0.000	1.006	0.00000	0.00000	0.0000

THIS RAY CALCULATION TOOK 13.937 SEC

X01 TEST CASE DIFOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS 11/05/74
 CHAPX WAVE

FREQUENCY = 6.000300 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 0.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMTR DEG	LOCAL DEG	XMTR DEG	LOCAL DEG	REAL	IMAG			
0+000 XMTR	0.0000	0.0000									
-3-011 ENTR ION	52.9737	18.7210	0.000	0.000	-0.000	7.364	0.000	-1.000	0.0000	823.2593	0.0000
-3-011 MIN DIST	158.1465	1.91.1561	0.002	-0.029	-0.753	0.000	0.000	-1.427	1518.9022	1512.7766	0.0106
-3-011 MIN DIST	158.1465	1.91.1561	0.002	-0.029	-0.753	0.000	0.000	-1.720	1518.9022	1512.7766	0.0106
-6-011 WAVE REV	158.1177	1.94.9559	0.003	-0.039	-0.736	-0.341	0.000	-1.695	1522.9022	1516.5809	0.0107
8-005 EXIT ION	49.2239	2188.5251	0.003	0.013	-0.572	-7.138	0.205	-1.093	2239.9022	2227.6590	0.0220
0+000 GRNU REF	0.0000	2900.0482	-0.000	0.010	-13.042	0.738	0.001	-1.000	2955.4929	2943.2497	0.0220
0+000 ENTR ION	52.9830	3.40.8051	-0.003	0.008	-15.566	7.401	-0.933	1.636	3700.7907	3688.5475	0.0220
-1-005 MAX LAT	107.9072	3.85.1958	-0.003	0.008	-16.435	10.475	-0.000	1.635	4053.7907	4041.5426	0.0247
-1-005 WAVE REV	107.9072	3.85.1958	-0.002	0.008	-16.435	10.475	-0.000	1.835	4053.7907	4041.5426	0.0247
0+000 MIN DIST	157.9016	4.305.0842	-0.007	0.076	-17.356	-0.000	-0.000	9.317	4388.0431	4369.8069	0.0330

THIS RAY CALCULATION TOOK 10.723 SEC

ELEVATION ANGLE OF TRANSMISSION = 15.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMTR DEG	LOCAL DEG	XMTR DEG	LOCAL DEG	REAL	IMAG			
0+000 XMTR	0.0000	0.0000									
0+000 ENTR ION	52.9852	186.0044	-0.000	-0.000	15.000	16.673	0.001	-1.000	0.0000	0.0000	0.0000
-3-011 MIN DIST	172.1332	604.1034	0.015	0.184	12.975	0.000	0.000	-1.881	194.1401	194.1401	0.0000
-3-011 MIN DIST	172.1332	604.1034	0.015	0.184	12.975	0.000	0.000	-1.481	643.8528	632.4672	0.0081
-2-010 WAVE REV	172.0659	607.7222	0.015	0.196	12.864	-0.820	0.000	-1.452	643.8528	632.4672	0.0081
-3-005 EXIT ION	48.8383	1036.8769	0.042	-0.027	-1.983	-16.239	0.076	-1.037	1106.8528	1085.8062	0.0174
0+000 GRNU REF	0.0000	1212.9251	0.046	-0.023	-5.455	14.656	-0.002	1.000	1292.1934	1269.1468	0.0174
-3-011 ENTR ION	52.9855	1403.0468	0.049	-0.020	-4.165	16.366	-1.306	1.885	1490.3081	1467.2614	0.0174
0+000 MIN DIST	171.9560	1628.6204	0.059	-0.065	-2.959	-0.000	0.000	-1.952	1947.4107	1912.8923	0.0258

THIS RAY CALCULATION TOOK 10.735 SEC

FREQUENCY = 6.600000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 30.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMTR DEG	LOCAL DEG	XMTR DEG	LOCAL DEG	REAL	IMAG			
3-011 XMTR	0.0000	0.0000	-0.000	-0.000	30.000	30.000	-0.000	1.000	0.0000	0.0000	0.0000
0*000 ENTR ION	52.9739	89.9010	-0.023	0.219	30.609	30.609	-0.332	1.259	104.6686	104.6686	0.0000
0*000 MIN DIST	191.5641	354.9408	-0.023	0.219	26.398	0.000	0.000	-1.530	425.7924	400.9614	0.0082
0*000 MIN DIST	191.5641	354.9408	-0.023	0.219	26.398	0.000	0.000	-1.530	425.7924	400.9614	0.0082
6-010 WAVE REV	191.4066	358.1065	-0.020	0.137	26.154	-1.395	0.000	-1.475	429.7924	403.6919	0.0085
2-005 EXIT ION	48.7358	144.4661	0.357	-0.397	1.406	-28.975	0.035	-1.018	770.7924	720.5457	0.0177
0*000 GRND REF	0.0000	733.6080	0.405	-0.349	-3.299	28.173	-0.000	1.000	872.6850	822.4383	0.0177
0*000 ENTR ION	52.9739	89.9010	0.445	-0.308	-0.104	29.043	-0.277	1.223	983.3256	933.0769	0.0177
0*000 MIN DIST	139.8217	1107.5272	3.514	0.454	4.581	0.000	0.000	-1.771	1312.8736	1240.1070	0.0259

THIS RAY CALCULATION TOOK 8.6113 SEC

ELEVATION ANGLE OF TRANSMISSION = 45.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMTR DEG	LOCAL DEG	XMTR DEG	LOCAL DEG	REAL	IMAG			
0*000 XMTR	0.0000	0.0000	-0.000	-0.000	45.000	45.000	-0.000	1.000	0.0000	0.0000	0.0000
0*000 ENTR ION	52.9739	52.3246	-0.132	0.607	45.471	45.471	-0.113	1.100	74.6128	74.6128	0.0000
-3-011 RCVR	200.0000	200.2014	-0.040	-1.746	28.480	28.480	0.000	2.293	295.1649	278.4398	0.0058
2-005 APOBEE	209.6834	235.8029	0.021	-1.382	39.431	-0.266	0.000	-1.623	352.1649	306.3131	0.0098
3-006 WAVE REV	209.4390	241.0969	0.021	-1.382	39.431	-0.266	0.000	-1.623	352.1649	306.3131	0.0098
3-011 RCVR	200.0000	274.3788	0.389	-1.415	34.427	-23.456	0.000	-1.142	410.8543	336.8372	0.0137
6-005 EXIT ION	38.3020	144.9524	0.574	-0.027	2.978	-44.472	0.004	-1.000	659.8543	566.5130	0.0206
0*000 GRND REF	0.0000	884.7060	0.576	-0.025	-2.140	44.114	-0.000	1.000	715.5626	622.2214	0.0206
0*000 ENTR ION	52.9739	89.9010	0.576	-0.022	3.158	44.599	-0.105	1.094	791.3392	697.9980	0.0206
-3-011 RCVR	200.0000	691.5163	0.544	0.796	12.769	26.953	-0.000	2.159	1015.3617	905.3752	0.0266

THIS RAY CALCULATION TOOK 8.6113 SEC

X01 TEST CASE
 CHAPX DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS 11/05/74
 FREQUENCY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG
 ELEVATION ANGLE OF TRANSMISSION = 60.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMTR DEG	LOCAL DEG	XMTR DEG	LOCAL DEG	REAL	IMAG			
0+000 XMTR	0.0000	0.0000	-0.000	-0.000	50.000	60.000	-0.000	1.000	0.0000	0.0000	0.0000
0+000 ENTR ION	52.9796	30.2935	-0.157	-0.851	59.325	50.578	-0.000	1.049	61.0908	61.0908	0.0000
0+000 RCVR	200.0000	114.4162	-0.354	5.402	55.872	-5.298	0.000	-2.002	239.2552	225.6343	0.0050
-1-004 APOGEE	225.8332	146.6930	-0.354	5.402	55.872	-5.298	0.000	-2.002	324.2552	253.2681	0.0114
-1-004 WAVE REV	200.0000	168.1639	-1.383	16.376	+8.744	-62.499	0.000	-1.025	395.1225	273.3158	0.0114
0+000 RCVR	26.7751	230.9196	-6.447	13.564	5.551	-59.411	0.000	-1.000	588.1225	453.6124	0.0173
-2-005 EXIT ION	0.0000	240.7118	-7.992	12.021	10.239	59.499	-0.026	1.025	616.7330	482.2229	0.0223
0+000 GRND REF	52.9836	266.0662	-7.992	12.021	10.239	59.499	-0.026	1.025	673.3376	538.8275	0.0223
-3-011 ENTR ION	200.0000	313.9111	-10.115	8.555	30.682	93.564	-0.000	1.039	837.7013	691.0808	0.0271
0+000 RCVR											

THIS RAY CALCULATION TOOK 7.518 SEC

ELEVATION ANGLE OF TRANSMISSION = 75.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMTR DEG	LOCAL DEG	XMTR DEG	LOCAL DEG	REAL	IMAG			
0+000 XMTR	0.0000	0.0000	-0.000	-0.000	75.000	75.000	-0.000	1.000	0.0000	0.0000	0.0000
0+000 ENTR ION	52.9846	14.0759	-0.302	1.334	74.783	71.357	-0.024	1.023	54.8374	54.8374	0.0000
0+000 RCVR	200.0000	52.6875	-1.511	-8.853	73.111	8.237	0.000	-3.876	213.9181	202.1284	0.0046
1-004 APOGEE	230.9133	57.5504	-0.322	-11.131	72.307	-4.474	0.000	-1.950	316.9181	220.4673	0.0134
9-005 WAVE REV	230.2533	70.7691	-0.322	-11.131	72.307	-4.474	0.000	-1.950	330.9181	221.5782	0.0147
0+000 RCVR	200.0000	106.6297	5.511	-13.543	61.094	-46.475	0.000	-1.024	434.9673	249.2747	0.0232
-1-006 EXIT ION	29.3420	220.9308	12.392	-6.856	6.551	-55.885	0.000	-1.000	651.9673	450.5600	0.0292
0+000 GRND REF	52.9836	240.7589	13.557	-6.291	-1.033	55.706	-0.000	1.000	687.4459	466.0386	0.0292
0+000 ENTR ION	52.9836	276.3403	14.370	-5.479	9.565	56.027	-0.063	1.064	751.5563	550.0489	0.0292
-3-011 RCVR	200.0000	375.3507	15.794	-3.644	25.987	45.376	-0.000	1.074	937.9577	722.8911	0.0343

THIS RAY CALCULATION TOOK 9.049 SEC

X01 TEST CASE 11/05/74
 CHAPX WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUENCY = 0.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG
 ELEVATION ANGLE OF TRANSMISSION = 90.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION		ELEVATION		POLARIZATION		GROUP PATH KM	PHASE PATH KM	ABSORPTION DB
			XMTR DEG	LOCAL DEG	XMTR DEG	LOCAL DEG	REAL	IMAG			
04-000 XMTR	0.0000	0.0000	0.0000	0.0000	90.0000	90.0000	-0.0000	1.0000	0.0000	0.0000	0.0000
-3-011 ENTR ION	52.9908	0.0000	0.0000	0.0000	90.0000	90.0000	-0.0003	1.0009	52.9908	52.9908	0.0000
-3-011 MAX LAT	54.9908	0.0000	0.0000	0.0000	90.0000	90.0000	-0.0003	1.0112	54.9908	54.9908	0.0000
-6-011 WAVE REV	69.2408	0.0000	0.0000	0.0000	90.0000	90.0000	-0.0002	1.0119	69.2408	69.2408	0.0000
-3-009 WAVE REV	119.7305	0.0003	-145.262	0.004	90.0000	90.0000	-0.0000	1.0118	119.7408	119.7331	0.0010
2-007 WAVE REV	175.1532	0.1157	-145.266-180.000	0.000	89.961	89.993	-0.0003	1.021	176.7408	173.9276	0.0029
0+000 RCVR	203.0070	0.3028	-145.266-180.000	0.000	89.911	88.779	-0.0003	1.030	207.1658	194.9665	0.0047
4-005 WAVE REV	230.2036	0.9913	-145.266	0.000	89.747	89.207	-0.0000	1.052	262.1658	213.5202	0.0089
-3-003 WAVE REV	235.2305	3.6109	-145.266	0.000	89.049	-11.150	-0.0001	4.505	310.1658	215.7522	0.0127
-2-003 APOGEE	238.0007	4.0933	-145.266	-0.000	88.978	-33.291	0.0001	-5.606	318.1658	215.8346	0.0134
-6-011 RCVR	239.0000	15.3973	-145.266	0.000	85.450	-75.213	0.0001	-1.080	411.0570	238.1693	0.0205
-2-005 EXIT ION	25.6746	48.6937	-145.266	0.000	27.535	-76.963	0.0001	-1.000	986.0570	410.5865	0.0252
-3-011 GRND REF	0.0000	53.7019	-145.266	0.000	-0.242	78.918	-0.0003	1.000	622.2176	436.6971	0.0252
-3-011 ENTR ION	52.9956	63.9944	-145.266	0.000	39.224	79.011	-0.0003	1.003	676.2116	430.6911	0.0252
0+000 RCVR	200.0070	92.7180	-145.266	0.000	64.368	77.233	-0.0003	1.006	833.2790	635.5670	0.0300

THIS RAY CALCULATION TOOK 13.161 SEC

Appendix 8d. Listing of Punched Card Output (ray sets)
for Sample Case

```

X01 TEST CASE
CHAPX 6.500+000 3.000+002 6.200+001 5.000-001 0.000+000 0.000+000 0.000+000
WAVE 2.500+002 1.000+002 1.000-001 0.000+000 1.000+002 1.000+002 0.000+000
DIPOLY 8.000-001 0.000+000 0.000+000 0.000+000 0.000+000 0.000+000 0.000+000
EXPZ2 3.650+004 1.000+002 1.480-001 3.000+001 1.400+002 1.830-002 0.000+000
X01X 0 40000255000 2000000 60000 4500000 0 0 -1003T
1581469 14911561 2 -29 0 1514389 4513 -1610 11 0 0 -1721M
1581469 14911561 2 -29 0 1514389 4513 -1610 11 0 0 -1722M
1581469 29000482 -0 10 738 2875068 80425 68182 22 0 0 -1003G
1579016 43050842 -7 76 -0 4278561109482 91246 33 0 -0 9323M
X01X 0 40000255000 2000000 60000 4500000 1500000 0 -1003T
1721392 6041034 15 184 0 635731 8122 -3264 8 0 0 -1481M
1721392 6041034 15 184 0 635731 8122 -3264 8 0 0 -1482M
1721418 12129251 46 -23 14656 1211094 81100 58053 17 0 -0 1003G
1719566 18286204 59 -65 -0 1854769 92641 58123 26 0 0 -1953M
X01X 0 40000255000 2000000 60000 4500000 3000000 -0 1003T
1915641 3549408 -23 219 0 407964 17828 -7003 8 0 0 -1531M
1915641 3549408 -23 219 0 407964 17828 -7003 8 0 0 -1532M
1916346 7336080 405 -349 28173 733203139482 89236 18 0 -0 1003G
1898217 11075272 514 454 0 1138430174444101677 26 0 0 -1773M
X01X 0 40000255000 2000000 60000 4500000 4500000 -0 1003T
0 2002014 -132 607 28480 285194 9971 -6754 6 0 -0 2291R
2096843 2743788 389 -1415-23456 342980 67874 -6143 14 0 0 -1142R
2096843 4847060 576 -25 44114 484589230974137632 21 0 -0 1003G
0 6915163 548 796 26953 729880285982175495 27 0 -0 2163R
X01X 0 40000255000 2000000 60000 4500000 6000000 -0 1003T
0 1144182 -157 -851 50578 231305 7950 -5671 5 0 -0 1251R
2258382 1681639 -1383 16876-62499 262993132130 10323 17 0 0 -1032R
2258382 2407118 -7009 13003 69320 240697376036241525 22 0 -0 1003G
0 3139111-10115 8555 63564 376316461386314765 27 0 -0 1103R
X01X 0 40000255000 2000000 60000 4500000 7500000 -0 1003T
0 526875 -302 1334 71357 207034 6884 -4906 5 0 -0 1091R
2309183 1066297 5511-13543-46475 227435207533 21840 23 0 0 -1022R
2309183 2407589 13557 -6291 55706 240745446701245294 29 0 -0 1003G
0 3753507 15794 -3644 45376 430430507528292462 34 0 -0 1373R
X01X 0 40000255000 2000000 60000 4500000 9000000 -0 1003T
0 3028214734180000 88779 200000 7166 -5034 5 0 -0 1031R
2382305 153973214734 0-75213 200610210447 37559 20 0 0 -1082R
2382305 537019214734 0 78918 53702568516382995 25 0 0 -0 1003G
0 927180214734 0 77233 221057612222414510 30 0 -0 1013R

```

The first card is the title card.
The second card contains the name of the electron density
model plus parameters W101-W107.
The third card contains the name of the perturbation
model plus parameters W151-W157.
The fourth card contains the name of the magnetic field
model plus parameters W201-W207.
The fifth card contains the name of the collision
frequency model plus parameters W251-W257.

For description of remaining cards, see figures 1 and 2.

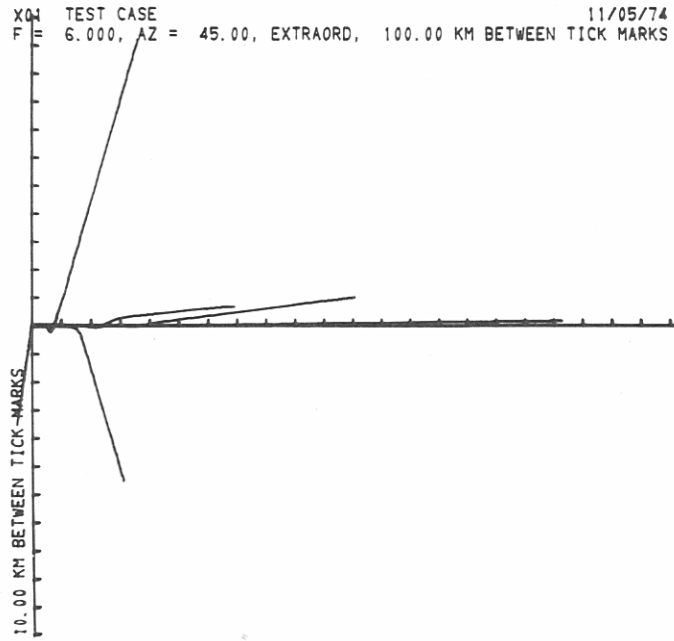
Appendix 8e. Ray Path Plots for Sample Case

Projection of raypath on vertical plane

X01 TEST CASE 11/05/74
F = 6.000, AZ = 45.00, EXTRAORD, 100.00 KM BETWEEN TICK MARKS



Projection of raypath on ground for sample case



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15. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography of literature survey, mention it here.) This report describes an accurate, versatile FORTRAN computer program for tracing rays through an anisotropic medium whose index of refraction varies continuously in three dimensions. Although developed to calculate the propagation of radio waves in the ionosphere, the program can be easily modified to do other types of ray tracing because of its organization into subroutine. The program can represent the refractive index by either the Appleton-Hartree or the Sen-Wyller formula, and has several ionospheric models for electron density perturbations to the electron density (irregularities), the earth's magnetic field and electron collision frequency. For each path, the program can calculate group path length, phase path length, absorption, Doppler shift due to a time-varying ionosphere, and geometrical path length. In addition to printing these parameters and the direction of the wave normal at various points along the ray path, the program can plot the projection of the ray path on any vertical plane or on the ground and punch the main characteristics of each ray path on cards. The documentation includes equations, flow charts, program listings with comments, definitions of program variables, deck set-ups, description of input and output, and a sample case.			
KEY WORDS: Appleton-Hartree formula; computer program; ionosphere; radio waves; ray tracing; Sen-Wyller formula; three-dimensional.			
17. AVAILABILITY STATEMENT <input checked="" type="checkbox"/> UNLIMITED. <input type="checkbox"/> FOR OFFICIAL DISTRIBUTION.		18. Security Class (This report) UNCLASSIFIED	20. Number of pages 197
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