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RUNNING AN IONOSPHERIC RAY TRACING PROGRAM ON THE PDP-11/40 MIN--ETC(U)
APR 79 A SHUVAL, F J GORMAN

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RUNNING AN IONOSPHERIC RAY TRACING PROGRAM ON THE PDP-11/40 MINI-COMPUTER - INSTRUCTION BOOK

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COMMUNICATIONS SYSTEMS CENTER

April 1979

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Locating the source of transmission is one of the tasks of military intelligence. In VHF frequencies and above, this is done by measuring the direction of arrival of the radio waves (DF) by two, three, or more stations, and then pinpointing the source by drawing straight lines on a map.

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Locating the source of transmission is one of the tasks of military intelligence. In VHF frequencies and above, the technique is straight forward.

In HF (2-30 MHz), the situation is different since the main mode of propagation is by reflection from the ionosphere. This enables the use of a different technique where the azimuth and elevation of the incoming wave are measured together with the state of the ionosphere at the time of reception.

All this information is presented as an input to an ionospheric ray tracing program that calculates the ray's trajectory from the reception site to the transmitting point.

The actual system needed is quite complicated and elaborate. Apart from the equipment to measure the direction of the arrival of the incoming wave, there is a requirement to measure in real-time the structure of the ionosphere at the area of interest. It is required, therefore, to measure the electron density profile and the tilts of the ionospheric layers. This can be accomplished by using a Digisonde together with a special "Drift Attachment" equipment that can measure ionospheric tilts by Doppler techniques. This

The report is essentially an instruction book that shows how to run the ray tracing program on the PDP-11/40, and is divided into two main parts. The first part describes generally how to write into the machine, edit, debug, and run a FORTRAN program. The second part depicts the operation of the ray tracing program itself.

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1. INTRODUCTION

Locating the source of transmission is one of the tasks of military intelligence. In VHF frequencies and above, this is done by measuring the direction of arrival of the radio waves (DF) by two, three, or more stations, and then pinpointing the source by drawing straight lines on a map.

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At the Propagation Research Team, Signal Processing Division, Communications Systems Center, CORADCOM, an attempt is made to implement such a system using the existing equipment at the ionospheric station at Naval Ammunition Depot Earle.

At this stage, integration of the Digisonde, Drift Attachment and PDP-11/40 mini-computer is carried on with the intention of adding the DF equipment at a later date; thus actual field measurements in real-time will be possible in order to determine the overall accuracy of the system.

This report covers one important step in the above mentioned process - the computation.

A three dimensional ionospheric ray tracing program was chosen.[1] This FORTRAN program was originally written for a CDC-3800 machine and had to be adapted to the PDP-11/40 mini-computer.

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How to operate the PDP-11/40 computer is described in full in the various manuals of the machine, especially [2], [3]. However, a reader might easily get discouraged because of the volume of material that has to be covered. The first part of this report is an easy,step-by-step procedure. By adhering to it, the reader will be able to operate the PDP-11/40 machine safely and run FORTRAN programs on it. However, it is strongly suggested that the machine manuals be read because the information included in this report is very limited for obvious reasons. The second part describes the ray tracing program that exists in the PDP-11/40. However, it is assumed that the reader is already familiar with the ray tracing program. Therefore, it is necessary to read ref. 1 in advance, especially pp 1-50, which generally describes the theoretical basis and actual structures of the program and pp 161-185, which give the sample case.

2. Operation of the PDP-11/40 Machine

The following instructions are relevant only to our machine and are not intended to be taken as general rules for other PDP-11/40 machines.

Our machine has only one disk (DK) and on Input-Output (I/O) device - the teletype (TT).

2.1 Turning On

Make yourself familiar with the various switches of the machine. Actually, there are three panels to be concerned with:

a. The teletype (TT panel)
b. The main panel of the machine
c. The disk (DK) panel

- Locate the three switches (SW) on the left side of the TT panel. Make sure that POWER SW is pressed on ON, the middle SW on LINE and BAUD RATE is pressed on 300.

- Make sure that ENABLE/HALT SW on the DK panel is pressed to HALT and that the POWER SW (the one with the key) is in OFF position.

- Verify that the RUN/LOAD SW on the DK panel is pressed to LOAD, and that the WTPROT SW is pressed the same way.

- Turn the POWER SW on the main panel to POWER, lights will turn on, and you will hear the ventilators start working. After a few seconds you will hear a mechanical click from the DK section. This will also be signified (in case you miss the click) by the turning on of the LOAD light in the DK panel.

- Turn the LOAD/RUN SW on the DK panel to RUN. The DK will start to revolve. Wait some time until RDY (ready) light on this panel turns on. This signifies that the DK has reached the required RPM.

2.2 Boot-Strap

Now the computer is ready to be activated. The action of interfacing the machine together with the operating system that resides in the DK and thus allows communication with the computer via the TT - is called Boot-Strapping. The action itself involves writing into the computer's memory a short program in machine language. The program is shown in Table 1.

TABLE 1: Boot-Strap Program
(All No. are octal)

Address	Content
001000	012700
001002	177406
001004	012710
001006	177400
001010	012740
001012	000005
001014	105710
001016	100376
001020	005007

Entering the program is performed through the various switches on the main panel. On the lower left side are located 18 SW numbered 0-17 which are divided into groups of three colored by red and purple. Each group of three stands for one octal number which is entered in binary form.

When a SW (one of the eighteen) is in the down position this means binary "0", and when in the up position-binary "1". The position of the groups of three SW corresponded to the position of the octal numbers in Table 1. So, if you want to represent the octal No. 012700, you start from the left (for example):

Take the first group from the left and press the SW down; this represents the octal number 0. Proceeding, you take the next group of three SW (nos. 12-14). In this group, SW number 12 has to be in the up position and the other two down.

In the next group (SW 9-11) only one SW has to be in the up position, SW number 10. This represents the octal number 2. The next number is 7, and is represented by all three SW (nos. 6-8) in the up position, etc. The actual Boot-Strapping is done as follows:

- Write the octal number 0010000.

- Activate the LOAD ADRS (Load Address) SW (on the main panel) and you will see this number appearing on the ADDRESS lights above the eighteen SW (the position of the lights corresponds to the position of the SW).

- Write the content of this address (from Table 1), i.e., 012700.

- Activate the DEP SW (on the main panel) and you will see this number appearing on the DATA lights just below the ADDRESS lights.

- From now on, you will be advanced automatically. So all you have to do is to write the content of Table 1 and activate the DEP SW each time. After each step, check the content by looking at the lights. If you want to examine a former address, write that address and activate the EXAM SW. If the content is in error, load the right one. In any case, whether the content is right or wrong, do not forget to return to your original address.

- After completion of writing Table 1, write again the address 001000 and load it by the LOAD ADRS SW.

- Move ENABLE/HALT SW to ENABLE

- Activate the START SW.

You will see lights flashing on the ADDRESS and DATA lights line and after several seconds the TT will print.

RT 11FB V02 - 01

.

The dot (.) in the left corner of the page signifies that the computer is activated and is now ready to receive instructions, run programs, etc.

In case you do not get this printing, try Boot-Strapping again because it is easy to err. If you are sure of your Boot-Strapping procedure and you still do not get the desired results, it means that something is probably wrong with the computer and expert help is needed.

After Boot-Strapping is completed, it is advisable (but not necessary) to turn the POWER SW on the main panel to LOCK position. This deactivates all the switches on this panel so that accidental change in position of one of them will not harm the operation of computer.

2.3 Turning Off

The turning off procedure is important in order to avoid physical damage to the DK and/or loss of files on the DK.

- If the POWER SW on the main panel is on LOCK position turn it to POWER after verifying that all the SW are in their proper positioning, i.e., that they are in the same position as after Boot-Strapping.

- Verify that the last response of the computer on the TT is (.). This means that the computer is in the KEYBOARD MONITOR (KMON) mode of operation. If not, read further on how to transfer to this mode.

- Change the ENABLE/HALT SW on the main panel to HALT.

-Turn the LOAD/RUN SW of the DK panel to LOAD. The RDY light will go off. After about 15-20 seconds, a mechanical click will be heard and the LOAD light on this panel will be on.

- Shut off the machine by turning the POWER SW in the main panel to OFF.

2.4 Operation and Communication via Teletype

At this stage, the communication with the computer is done through the TT keyboard.

2.4.1 Modes of Operation-General

After Boot-Strapping the computer is in KEYBOARD MONITOR (KMON) mode. This mode is signified by the fact that after each operation the computer responds with a (.) at the left side of the line. In this mode, running programs are possible.

Other modes are FORTRAN, EDIT, LINK, PIP (only modes concerning our purpose were mentioned here - see the computer manuals for further details).

In the EDIT mode, you can type in programs, edit them, and store them on the DK.

In the FORTRAN mode, you can compile FORTRAN programs.

In the LINK mode, compiled FORTRAN programs are translated to machine language.

The PIP stands for Peripheral Interchange Program. In this mode information can be transferred between the various peripheral devices.

Entering into a mode of operation is done from the KMON mode by typing the appropriate statement. For example: To enter the LINK mode type

.R LINK <CR>

The (.) is already there to signify that the computer is in KMON and awaiting further instructions.

You type R (for RUN), leave one space, and then type LINK followed by <CR>. The <CR> stands for Carriage Return and this tells the computer that the statement is completed and that it is its turn to act. This is done by hitting the RETURN key. The carriage will return to the beginning of the line. No character will be printed.

In simple language you told the computer to run the program LINK. This program is a part of the operating system and is already on the DK. Do not forget to leave the required space. Whenever you type wrong statements, the computer types an appropriate message that tells you to correct the last statement.

However, if everything is right then the computer responds with a star (*). The whole procedure looks like:

R LINK <CR>

*

The (*) signifies in this case that the computer is in the LINK mode and it awaits further instructions. In order to return to KMON you have to press two keys together, the CNTRL key and the letter C.

This echoes as ⌒C

The whole procedure looks like

.R LINK <CR>

* ⌒C

.

And now you are back in KMON.

In a similar manner, you can type R FORTRN, R EDIT or R PIP and be in FORTRAN, EDIT or PIP mode respectively. Returning back to KMON form FORTRAN, LINK or PIP modes is done by the ⌒C. Returning from EDIT mode is done differently and will be explained later.

In order to transfer from one mode to another, you have to go through KMON mode. This cannot be done directly.

2.4.2 <u>File Names</u>

The general structure of a file name is fil-nam.ext
where: <u>fil-nam</u> stands for file name - a string of up to six characters (letters and numbers only) beginning with a letter.

<u>ext</u> - stands for extension - a string of 3 characters that is either given by you or by the computer by default.

Suppose you want to create a file by name TAKE1. For this computer you have to add an extension like TAKE1.ABC or TAKE1.003. However, if this file contains a FORTRAN program, the extension has to be FOR (in order to comply with the instructions that you will be given later on; for different instructions see computer manuals) - like TAKE1.FOR.

Extensions given by the computer by default that may concern you are:

OBJ which is given after compilation of a FORTRAN program.

SAV which is given after the link procedure (LINK mode).

BAK which is given if you create a back-up version of your file.

2.4.3 PIP Mode

Again, PIP stands for Peripheral Interchange Program. In this mode transferring information between the various peripheral equipment of the PDP-11/40 system is made possible.

In our particular case, since we have only one DK and on TT, the program uses are somewhat limited although important.

In order to transfer to the PIP mode you have to be in KMON mode and type:

.R PIP <CR>

*

The computer responds with the (*) which signifies that it is in the PIP mode and awaiting further instructions.

2.4.3.1 Viewing List of Files on DK

In order to get a list of all the files that are on the DK, type

*/L <CR>

The (*) was already here signifying that the computer is ready. The (/) means all, and the (L) stands for List. So what you actually said is List All. The <CR> is done by hitting the RETURN key, and this is a sign that your instruction is completed and it is the computer's turn to act.

After this instruction is typed, a complete list of existing files on DK will be typed. When the typing has been completed, a (*) will be typed again to signify the fact that the computer is ready for further instructions.

2.4.3.2 Viewing Content of a File

Suppose you want to examine the content of a file named REACH.FOR, then type:

*TT:=REACH.FOR <CR>

(You should type the complete name including the extension) and the TT will print the content of the file. The action will be ended by (*) as usual.

One important point to remember, however, is that not all the files on the DK are written in the same code. Some of them are in various versions of machine language and trying to print them will yield nonsense.

In particular, all the files having the extension.SAV or .OBJ that were given by the computer after compiling or linking will not be comprehensible.

Only the so-called Source Programs will be comprehensible. So whatever,the file name is, type in its name according to the way shown above and its content will be printed.

If you want to stop the printing while it is still in progress type:

⌒ 0

This is done by pressing simultaneously the CNTRL key and the letter 0 key. The printing will stop immediately and the (*) will be printed.

2.4.3.3 Deleting a File on DK

In order to delete a file type:

*----.----/D <CR>

Which means Delete All of the file whose name is signified here by ----.----. After the instruction has been carried out the (*) will appear.

For example, deletion of the file named RACK.SAV will appear on the paper as:

*RACK.SAV/D

*

Note that although you hit the <CR>, this action does not echo on the paper. The second (*) means that the action is completed.

2.4.4 Edit Mode

As mentioned before, creating and modifying files on the DK in this mode is possible. Entering this mode is made via the KNOM by typing:

.R EDIT <CR>

*

The (*) is the response of the computer.

In this mode there is a special character $ (ESC/SEL). This is the upper left key and it echoes as $. This is not equivalent to the usual dollar sign which is the upper case (shift) of the 4 key, although they appear to be the same in printing.

The role of the $ (ESC/SEL) is dual - firstly, it serves as a delimiter between individual instructions in instruction chains, and secondly, $$ in this mode means what <CR> does in other modes, i.e., the instruction is over and it is the computer's turn to act. After execution of the instruction the computer responds with (*).

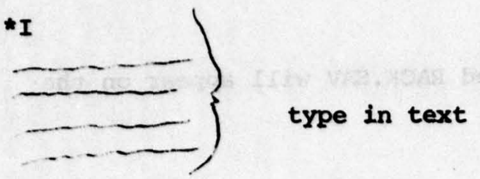
2.4.4.1 Creating a File on DK

Suppose you want to create a file on the DK. Usually you are in KNOM, so in order to create the file you have to type the following sequence:

.R EDIT <CR>

*EWDK:fil-nam.ext$$

```
*I
```




```
$$

*EX$$

.
```

<u>Explanation</u>

The first step is transferring to EDIT mode. The computer responds by (*) and you type EWDK which means Edit Write on DK, a file having the name fil-nam.ext. The $$ means execute. The computer responds with a (*) and you type I (for Insert) and the text. <u>Now remember:</u> Type the text as if you are typing on a regular computer card. If you have a FORTRAN program that you want to type in, be careful to follow the usual FORTRAN coding form, i.e., start with the seventh colum (leave 6 spaces), do not pass the 72nd column, the 6th column is used as a continuation <u>mark, etc. In this machine, however, you do not need line numbers (which are automatically given by the compiler) so do not type them in.</u>

After each line type in <CR>. In this mode it is just another character (but in FORTRAN this means end of computer card).

If in the process of typing you make a mistake and notice it immediately, you can correct the mistake by using the DELETE key. Hitting this key once deletes tye last character printed. Hitting this key twice deletes the last two characters printed, etc. So if the characters are not too far away you can delete them and retype. The whole procedure is shown in the following example:

```
ABC=SQRT(X)*SIM(ALP PLA(MAN(ALPHA)
```

If after reaching the letter P you notice a mistake has just been made, you hit the DELETE key 5 times and the deleted characters are printed in the order of appearance from right to left with the special character (\), i.e., PLA(M. When you start to retype, the second (\) appears to you will know that everything between the two (\)'s has been deleted. The whole new line is now:

```
ABC=SQRT(X )*SIN(ALPHA)
```

The number of times that you can use the DELETE key is unlimited You can even go back to the previous line - this is possible because the whole program is just a long string of characters and the <CR> is the same as any other in this mode. However, going too far back is not worth the effort, so just keep typing and correct the error later by using methods that will be explained further ahead. After you type the whole program, type $$ which tells the computer to store the information on the DK. When this is finished the computer prints (*) and you type EX$$. This stands for Exit. This is the way to leave the EDIT mode and return to KMON.

If however, you want to check yourself then do not type the EX$$ so you are still in the EDIT mode, and you can check and correct your text (using the ways shown later on). After corrections have been made, you then exit.

2.4.4.2 Calling Sequence

Whenever you want to modify a program that exists as a file on the DK, you have to be in the EDIT mode, call the file from the DK to the memory, modify it and store it again on the DK. Suppose you have a file named DEMO.FOR that you want to modify, then type:

```
.R EDIT<CR>
*ERDEMO.FOR$EWDEMO.FOR$R$B$$

   { make changes

*EX$$
```

First you enter the EDIT mode. Then you instruct the computer to Edit and Read a file named DEMO.FOR from the DK (by default since we have only one DK) and Edit and Write on the same DK a file by the same name. Then you make the necessary changes according to the ways that will be explained later on, and you Exit to KMON. Using EX$$ again assures that all the changes will be saved. After exit you are again in KMON which is signified by the (.). Another way is by typing:

```
*EBDEMO.FOR$R$$

 { make changes

*EX$$
```

This also creates a back up version that by default is getting the ext.BAK, i.e., DEMO.BAK

Sometimes it is useful to have a back-up.

2.4.4.3 Copying a File

By the following sequence:

.R EDIT CR

*ERDK:GEO.007$$

*EWDK:ABE.FOR$$

*EX$$

You have entered the EDIT mode, you Edited and Read from the DK (only one in our system) a file named GEO.007 and copied it (Edited and Wrote) on the same DK under the name ABE.FOR, and returned to KMON. The file GEO.007 was not affected by the act of copying. This of course is just an example, but the general rule is clear. If you want to make corrections to the new file, first you have to exit via EX$$ and then enter the EDIT mode again.

2.4.4.4 Controlling the Pointer's Position

Before you modify your text, you have to be sure where the intended modification is to take place. For this purpose there is a pointer. The pointer does nothing but point to the exact place in the string of characters that comprises your program, at that particular moment. For example, whenever you call up a file for editing (by the calling sequence 2.4.4.3), the pointer is initially located at the beginning of the program. Whenever you are not sure where you are, or you want to return to the beginning, type:

*B$$

The (*) was already there as a result of previous operations. The B means Back and the double ESC/SEL means, in this case, execute.

The following is a list of the most important instructions needed. For further details see the computer manuals.

*±nA$$ - Advance the pointer ±n lines from the current position of the pointer. If the pointer is in the middle of the current line it will nevertheless be positioned at the beginning of the appropriate line as though the pointer was originally at the beginning of the current line.

As mentioned before, each line is terminated by hitting the RETURN key. This actually prints two instructions into the memory. First: Carriage Return <CR> and then Line Feed <LF> and not just <CR> as was mentioned earlier, for the sake of simplicity. Now, when modifying the text, care should be taken not to lose any of these instructions.

For example, when you type 2A$$ you mean that you want to advance the pointer by two lines. The pointer is then moved until it encounters the second string of <CR><LF> and then it is stopped. This is of course the beginning of the next line.

You can advance forward or backward (by the (-) sign).

*/A$$ - moves the pointer to the end of the text.

*OA$$ - moves the pointer to the beginning of the current line. (equivalent to OJ$$).

*±NJ$$ - Jump the pointer ±n characters from the current position. The movement is not stopped when an end of the line is encountered but continues to the next line until the number of the required character n is reached.

*OJ$$ - Jump to the beginning of the current line (=OJ$$).

*nGtext$$ - Get the nth occurrence of the specified text. The pointer is placed just after the text string. If n = 1, the 1 can be omitted.

2.4.4.5 Listing of Text

In order to be sure that you are at the right place, it is advisable to print out the text.

*L$$ - List out the text from the current position of the pointer to the end of the line.

*/L$$ - Prints out all the text from the current locations of the pointer to the end of the text.

If, however, you want to see several lines only, the type/L$$ and the printing will begin. When you want to stop the printing, type⌐O (CNTRL O) and the printing will cease. It is important to note that listing does not change the position of the pointer.

2.4.4.6 Changing Characters

This is actually text modifying.

*nctext$$ - Change n characters from pointer with specified text. The pointer is placed just after the change.

Example: Suppose you have a line ABC=X+Y and you want to change the (+) to (-). First bring the pointer to just before the (+) and the type *1C-$$. This means change 1 character immediately after the pointer to -.

*OCtext$$ - Replace characters from the beginning of the current line up to the pointer with specified text.

2.4.4.7 Inserting Text

*Otext$$ - Insert specified text just after the pointer. The use of this statement is straightforward - bring the pointer to the required position and insert the text. The pointer will be just after the insertion. The text can be any legitimate character from a space up to several lines. Of course, when inserting more than one line do not forget to type in the <CR>.

2.4.4.8 Deleting Text

It is possible to delete characters and also lines.

*±nD$$ - Delete ±n characters from the current location of pointer.

*OD$$ - Delete from the beginning of the current line to the pointer.

*/D$$ - Delete from the pointer to the end of the text.

*nK$$ - Delete n lines beginning at the pointer and ending at the nth <CR><LF> (kill n lines).

*OK$$≡OD

*/K$$≡/D

2.4.4.9 Chain of Operations

This feature has the capability to perform chain operations, which makes the actual text editing much easier. This is best explained with an example:

*3A$23J$2CX1$14J$I△2B/L$$

This means - Advance 3 lines

Jump 23 characters

Change 2 characters to X1

Jump 14 characters

Insert △ 2 (the △ here means one space)

Back to the beginning of the program

List the entire program

Each statement is separated by $ (ESC/SEL) and only when $$ occurs, is the chain executed.

From experience, it was found that it is very easy to err, so it is advisable to print before and after the text modification in order to make sure that the new text is the desired one.

2.4.5 Running a FORTRAN Program

In order to run a FORTRAN program you must have a FORTRAN file, i.e., a file written in the FORTRAN language and having the extension .FOR. For example,DEMO.FOR.

This is your source program.

First, you have to compile your program using the FORTRAN mode, and then you have to link it using the LINK mode and finally run it. The whole procedure looks like:

.R FORTRAN <CR>

*DEMO,TT:=DEMO <CR>

List of program including

line no. assigned by the compiler

error messages if any, etc.

*^C

.R LINK <CR>

*DEMO=DEMO/F <CR>

*^C

.R DEMO <CR>

<u>Explanation</u>

You start in KMON as signified by the (.) then you transfer to FORTRAN mode and receive the (*). Then essentially you tell the computer to create (by default) a file named DEMO.OBJ which will be the compiled version of the file DEMO.FOR (also by default). At the same time, you ask for a print-out by the TT of the source file with the line numbers given by the compiler and all the other statistics.

If you want to stop the printing at any time, then type ^O. The printing action will stop but the compilation will continue. When compilation is finished, the (*) will be printed. If no error messages occurred then you can proceed. First you return to KMON by ^C and you get the (.), then you transfer to LINK mode. You then ask the computer to create a file by the name DEMO.SAV. This is done by the linking program. In this way, you get a set of machine instructions from the compiled version. If no error messages occurred during linking, then return to KMON, get the (.), and then run the program.

Actually, R DEMO means by default run the DEMO.SAV. Now, whenever you want to run the program just type:

.R DEMO <CR>

If you do not want to have a printout in the compilation stage (probably to save time and because you are sure of the changes you have done in the text),you can type in the FORTRAN mode.

*DEMO=DEMO <CR>

This is the same action as before except for the printing. If an error message occurs in the compilation or printing processes - correct it accordingly.

Usually, however, a program consists of a main program and several subroutines. So a procedure for running this combination is needed. For example:

We have a file MAIN.FOR which is the main program and two subroutines (also as files) SUB1.FOR and SUB2.FOR. The sequence of instruction is as follows (assuming no error messages)

.R FORTRAN <CR>

*MAIN=MAIN <CR>

*SUB1=SUB1 <CR>

*SUB2=SUB2 <CR>

*^C

.R LINK <CR>

*MAIN=MAIN,SUB1,SUB2/F <CR>

*^C

.R MAIN <CR>

Here of course each file was compiled separately without printing and then they were linked.

It is possible, if wished, to compile them together by the statement:

*MAIN=MAIN,SUB1,SUB2 <CR>

This creates a file - MAIN.OBJ out of the compilation of the three other files, and only it has to be linked.

It should be noted that it was not necessary to name the .OBJ file by the name MAIN but only optional for the sake of convenience. The same rule applies in the LINK procedure.

If printing the program is desired then type

*MAIN,TT:=MAIN,SUB1,SUB2 <CR>

This creates a MAIN.OBJ file and gives a printout with the line numbers memory assignment, etc. If you want to run the program again, all you have to do is type

.R MAIN <CR>

If you want to stop execution of a program in the middle of operation type twice ^C.

3. Running of Ray Tracing Program on the PDP 11/40

As mentioned in the introduction, it is assumed that the reader is already familiar with the ray tracing program as described in (1). In order to prepare the PDP 11/40 for the ray tracing program, you have to type in two statements.

You start from KMON-

```
.SET TTY WIDTH=136 <CR>
.DAT 08-MAR-78 <CR>
```

The first line tells the TT to print lines of 136 characters long (which are needed in our case). The second line is the setting of the date. A nine character string starting with the day no., then a minus sign, the first 3 letters of the month, a minus sign, and the last two no. of the year. In this example, March 10, 1978.
The date is needed for the program.
If you want, you can set the internal clock by typing:

```
.TIM 09:35 <CR>
```

In this example, you set the clock to 9:35 AM.
For 3:24 PM type 15:24.

3.1 General Description

The complete ray tracing program with all the options contains some fifty subroutines. Not all of them were transferred to the PDP 11/40.

List of the subroutines that were chosen together with the reasons is given below:

a. Main body of program includes subroutines

NITIAL, READW, TRACE, BACKUP, REACH

POLCAR, PRINTR, RKAM, HAMLTN.

These were chosen because they are a must, i.e., they are the skeleton on which the various options of ionospheric models are added.

Missing are the subroutines dealing with Plotting since we do not have these facilities.

b. Version of refractive index are

AHWFWC, BQWFWC

These two were included since the proposed system has to function with real ionosphere that includes magnetic field and collisions. The Appleton Hartree formula (AHWFWC) is considered as adequate. The Booker Quartic version (BQWFWC) is included as a backup although its operation on a sample case was not always satisfactory due to machine limitation (as will be explained later).

c. Versions of electron density models are

CHAPX, TABLEX+GAUSEL, TABLE.

CHAPX was included as a part of the sample case (the one in the original version (1)). The sample case as a whole was included in order to facilitate a quick check on the whole program in case of doubt.

Having a Digisonde enables us to measure in realtime the ionospheric conditions. The output of the Digisonde is a table of electron density values vs. height. So, we need subroutine TABLEX (that goes with GAUSEL).

Subroutine TABLE was written especially for our purpose. It performs essentially the same function as TABLEX and GAUSEL, but it is more adapted to our system.

The interpolation law between the points of height in the table of electron density values is parabolic-logarithmic - the same law that is used in the Digisonde's signal processing.

So for normal use TABLE should be chosen (does not need GAUSEL) and TABLEX+GAUSEL serve as a backup.

d. Versions of electron density perturbation models are ELECT1, WAVE, TROUGH.

ELECT1 will serve for the non-perturbation case if so desired.

WAVE can describe a gravity wave irregularity traveling from north to south and is also used in the sample case.

TROUGH was chosen because it seems to be the most suitable version to include tilt of ionospheric layers.

At the time of writing of this report, it is not known whether this subroutine will be adequate or not. The reason is that the transformation between the drift attachment measurement (in the Digisonde) and the ionospheric layers tilts has not yet been completed. So, it is possible that writing a new short subroutine to serve as a perturbation model will be needed.

e. Version of magnetic field are:

DIPOLY, HARMNY

DIPOLY was chosen as a part of the sample case.

HARMNY (in the original version HARMONY) was chosen as the most complete representation of the earth's magnetic field.

f. Versions of collision frequency chosen are:

EXPZ and EXPZ2

EXPZ2 is a part of the sample case.

Listing of all these subroutines appear in APPENDICES 1-22. Each subroutine is written on a separate file having the same name with extension, i.e., subroutine READW is in a file named READW.FOR and so forth.

3.2 Main Changes from the Original Version

In the adaptation process of this program from the original version to the PDP 11/40 machine many changes had to be done. The major ones are mentioned here:

- Variable names are allowed to have up to six characters - so in case of a longer name in the original value the name was shortened. For example, if the original name was HARMONY it was changed to HARMNY, etc.

- Assignment of Alpha-Numeric string of characters as a variable's value (for printing purposes) is possible on this machine only by the use of DATA statement - in contrast to the original version. Furthermore, that string of characters should not be greater than four. Therefore, longer string had to be divided - like a string of eight characters was divided into two strings of four characters each.

- This machine does not recognize the ENTRY point statement which appears in the original version.

- Use of the BLOCK DATA statement was required in order to assign initial values to variables that appear in a COMMON BLOCK.

- The FORTRAN library of this machine does not contain the ACOS(X) function. Instead, the ATAN(X) was used where needed.

- Since our hardware does not include either plotter or card punch machines, these options were omitted.

- The original printout contained azimuth deviation of the ray from the original azimuth of transmission.

For the proposed system real azimuth is more suitable - so it was printed instead.

All the above mentioned changes and more can be seen by comparing the listing of the subroutines that are on the DK (see APPENDICES 1-22, except #15) to the original version in (1).

3.3 Running Sequence

The running sequence is composed of compiling the proper subroutines, linking them and then running. The input data should already be in a special file. This file will be explained later.

As an example, we will take the sample case itself and see how to run it on the PDP 11/40. We need therefore the following files:

NITIAL.FOR, READW.FOR, TRACE.FOR, BACKUP.FOR,REACH.FOR, POLCAR.FOR, PRINTR.FOR, RKAM.FOR, HAMLTN.FOR.

These files comprise the basic program. To them, the following models have to be added - AHWFWC.FOR, CHAPX.FOR, WAVE.FOR, DIPOLY.FOR and EXPZ2. FOR.

The running sequence is as follows:

```
.R FORTRAN <CR>

*PART1=NITIAL,READW,TRACE,BACKUP,REACH <CR>

*PART2=POLCAR,PRINTR,RKAM,HAMLTN <CR>

*PART3=AHWFWC,CHAPX,WAVE <CR>

*PART 4=DIPOLY,EXPZ2 <CR>

*^C
.R LINK <CR>

*RAYTRC=PART1,PART2,PART3,PART4/F <CR>

*^C

.R RAYTRC <CR>
```

This sequence is an extension of similar ones shown in Chapter 2.

The division of the subroutines into the different parts is not obligatory, and you can change it as you wish. However, you cannot compile together all the subroutines (the computer prints an error message), and you cannot link together too many subroutines (depending on their size of course). This division was found to function properly, so it was adopted.

After running the program (R RAYTRC), the computer starts execution and the following message is typed:

ENTER DATA FILE NAME* then

you print the name of the data file and a <CR>. The whole message looks like -

ENTER DATA FILE NAME* TEST1.FOR

By this way, the computer knows where to read data from. The content of TEST1.FOR is shown in APPENDIX 23 (same as the sample case in (1)). Printout of this sample case is shown in APPENDIX 27.

The printout format is explained in Figure 1.

In APPENDIX 28, printout of a different sample case is shown. Use was made of the TABLE subroutine. For this, it was necessary to feed the computer with a table of electron density values vs. height. These values were computed from the same Chapman model that was used in CHAPX for the sample case.

The input data file in this case is TEST3.FOR and is shown in APPENDIX 25.

The running sequence in this case is as follows:

```
.R FORTRAN

*PART1=NITIAL,READW,TRACE,BACKUP,REACH <CR>

*PART2=POLCAR,PRINTR,RKAM,HMLTN <CR>

*PART3=AHWFWC,TABLE,WAVE <CR>

*PART4=DIPOLY,EXPZ2 <CR>

*^C
.R LINK <CR>
```

*RAYTRC=PART1,PART2,PART3,PART4/F <CR>

*^C

.R RAYTRC <CR>

ENTER DATA FILE NAME* TEST3.FOR <CR>

As can be seen, the only differences are in the compilation of PART3 and in the name of the data file. The results are shown in APPENDIX 28. It should be noted that in both cases the running sequence created a file PART3.OBJ. However, there can only be one file by that name on the disk The thing that happened is that when the second time occurred, the new file was overwritten on the old file by that name. The same rule applied to file RAYTRC.SAV created after the linking procedure. If you want to keep the old version just call the new version by a different name.

Two more cases are shown in APPENDICES 29 and 30. In APPENDIX 29, results of the combination of the following subroutines are shown

AHWFWC, CHAPX, WAVE, HARMNY, EXPZ2.

i.e., instead of a magnetic dipol representation of the earth magnetic field (DIPOLY) a more complete model was used.

The input data file is TEST2.FOR, shown in APPENDIX 24.

In APPENDIX 30, results are shown of the following combination:

AHWFWC, TABLE, WAVE, HARMNY, EXPZ2

This case differs from the last one by the fact that the electron density model is given by a form of table.

The input data file is shown in APPENDIX 26. This is the most complicated case for it contains TABLE and HARMNY; and it was important to verify that it works properly.

Another case tested was similar to the one shown in APPENDIX 28, but instead of subroutine TABLE, subroutines TABLEX and GAUSEL were used. The results were similar and therefore, not shown in the report.

3.4 Input Data

As can be seen from APPENDICES 23, 24, 25, and 26, the input data file consists of from 1 - 3 main parts. In every case, the first part is the one that appears in the original program (1). For convenience the rules are copied here:

The data is entered into a linear array W in the program. Each piece of data is stored on one card (one line in the file). The first three columns of the card identify the data. Table 2 defines the identifying numbers that are subscripts for the linear array - W. The last 56 columns of the card are available for comments.

The computer program needs angles in radians, whereas people usually use angles in degrees. The program is set up for angles in radians but putting a "1" in column 18 allows the user to enter the angle in degrees, and have the program make the conversion.

A "1" in column 19 allows the user to enter central earth angles as the great circle distance along the ground in km (the program will calculate the latitude of a transmitter which is 500 km north of the equator, for instance),

the program expects distances in km, A "1" in column 20 indicates a distance in feet.

For clarity, the read statement and format will be given here (from subroutine READW)

```
READ (10, 1100) NW, W (NW), DEG, KM, NM, FEET

1100 FORMAT(I3, E14.7, 4I1)
```

NW - is the identifying number or the subscript.

W(NW) - is the data itself

DEG, KM, NM, FEET - are the conversion factors.

As mentioned earlier, Table 2 explains what to put in. Some values are already initiated in the program and do not have to be entered. However, if different values are required or desired, then the new values entered and read will override the original values that are in the program. W 72 and W 81 - 88 do not have to be entered since we do not have punching and plotting options in the version.

TABLE 2

Description of the Input Data for the W Array

W1	= 1. for ordinary ray
	=-1. for extraordinary ray
W2*	Radius of the earth in km
W3	Height of transmitter above the earth in km
W4	North geographic latitude of the transmitter
W5	East geographic longitude of the transmitter
W7	Initial frequency in MHz
W8	Final frequency in MHz
W9	Step in frequency in MHz (zero for a fixed frequency)
W11	Initial azimuth angle of transmission
W12	Final azimuth angle of transmission
W13	Step in azimuth angle of transmission (zero for a fixed azimuth)
W15	Initial elevation angle of transmission
W16	Final elevation angle of transmission
W17	Step in elevation angle of transmission (zero for a fixed elevation)
W20	Receiver height above the earth in km
W21	Nonzero to skip to the next frequency after the ray has penetrated the ionosphere
W22*	Maximum number of hops
W23*	Maximum number of steps
W24*	North geographic latitude of the north geomagnetic pole
W25*	East geographic longitude of north geomagnetic pole
W41*	=1. for Runge-Kutta integration
	=2. for Adams-Moulton integration without error checking
	=3. for Adams-Moulton integration with relative error check
	=4. for Adams-Moulton integration with absolute error check
W42*	Maximum allowable single step error
W43*	Ratio of maximum single step error to minimum single step error
W44*	Initial integration step size in km (step in group path)
W45*	Maximum step length in km
W46*	Minimum step length in km
W47*	Factor by which to increase or decrease step length
W57	=1. to integrate, =2. to integrate and print phase path
W58	=1. to integrate, =2. to integrate and print absorption
W59	=1. to integrate, =2. to integrate and print doppler shift
W60	=1. to integrate, =2. to integrate and print path length
W71	Number of steps between periodic printout
W81	=0. to not plot ray path
	=1. to plot projection of ray path on a vertical plane
	=2. to plot projection of ray path on the ground
W82-88	Parameters used when plotting
W100-149	Parameters for analytic electron density models
W150-199	Parameters for perturbations to electron density models
W200-249	Parameters for analytic magnetic field models
W250-299	Parameters for analytic collision frequency models

*These values have been initialized in the main program but may be reset by reading them in. See Appendix 1 for initial values.

For further details, see APPENDIX 23, note that the last card (line) is a blank one, to signify the end of this part.

APPENDIX 24 shows the input data file for the case of harmonic representation of the earth's magnetic field (subroutine HARMNY).

The portion after the blank card is the input data for HARMNY. This data is fixed so it should be left untouched (more details in (1)).

APPENDIX 25 shows the input data file in case there is a table of electron density values and a dipole magnetic field representation (the dipole parameters are read in the first part). For more details see below.

APPENDIX 26 shows an input data file similar to the one that will probably be used, for it contains the input for the HARMNY and TABLE subroutines.

The first part is the one described in TABLE 2. The second part is the fixed data for the magnetic field. The third part contains data of electron density values. The second and third parts should not be interchanged. The first line in the third part contains the number of points to be read (31 in Appendix 26), the other line contains the height in km and electron density (in electrons/cm^3). The format is given here (taken from TABLE):

```
READ (10, 1000)  NOP,  ( (HTAB(I), NTAB (I)), I = 1, NOP)

1000 FORMAT (I4/(F8.3.E12.4))
```

Where:

NOP - Number of Points

HTAB - Height of Table in km

NTAB - Electron density (N) of Table in elec/cm^3.

In summary, in order to prepare an input data file, you may copy of of the files in APPENDICES 23-26 (according to your needs) and then modify it. This way a lot of typing can be saved.

Perturbation to the electron density model

Model of the earth's magnetic field

Collision frequency model

DATE (mon, day , yr)

X01 TEST CASE 4 478

CHAPX WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

Electron density model

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 0.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSD RPTN DB
-6.E-08	XMTR	0.0000	0.0007				0.000	0.000	-1.000	0.0000	0.0000	0.0000
-1.E-07	ENTR ION	73.9033	965.6646	45.000	-0.000	-0.000	8.686	0.095	-2.709	973.1300	973.1300	0.0000
-2.E-07		91.9331	1075.7850	45.000	-0.000	0.000	9.675	0.010	-3.547	1086.1300	1086.1299	0.0007
-1.E-07		105.8511	1153.3594	45.000	-0.000	-0.000	10.357	0.002	-4.690	1166.1300	1166.1268	0.0022
-2.E-07		120.6396	1230.5894	45.000	0.000	-0.005	10.908	0.000	-6.775	1246.1300	1246.0909	0.0045
2.E-06		135.8042	1307.4519	45.000	0.003	-0.033	10.787	0.000	-7.845	1326.1300	1325.8309	0.0066
-2.E-06		149.4229	1383.9340	44.999	-0.020	-0.156	8.589	0.000	-4.021	1406.1300	1404.6534	0.0082
-5.E-06		155.2788	1429.6499	44.999	0.036	-0.330	5.618	0.000	-2.535	1454.1300	1451.1095	0.0091
-6.E-06		157.8027	1467.6357	44.999	0.032	-0.565	2.165	0.000	-1.921	1494.1300	1489.2479	0.0100
-1.E-07	MIN DIST	158.1475	1491.1564	44.998	-0.029	-0.753	0.000	0.000	-1.720	1518.9016	1512.7781	0.0105
-1.E-07	MIN DIST	158.1475	1491.1564	44.998	-0.029	-0.753	0.000	0.000	-1.720	1518.9016	1512.7781	0.0105
-5.E-07	WAVE REV	158.1182	1494.9558	44.998	-0.039	-0.786	-0.341	0.000	-1.695	1522.9016	1516.5803	0.0106
-2.E-06		151.2544	1583.3795	44.992	0.028	-1.756	-7.550	0.000	-1.385	1615.9016	1605.6678	0.0126
3.E-06		138.2036	1659.7026	44.993	0.024	-2.782	-10.588	0.000	-1.318	1695.9016	1684.0900	0.0143
5.E-06		108.1387	1813.6451	44.994	0.016	-4.796	-10.484	0.000	-1.341	1855.9016	1843.6638	0.0191
8.E-06		80.8872	1969.0037	44.996	0.015	-6.536	-9.113	0.008	-1.403	2015.9016	2003.6583	0.0217
8.E-06	EXIT ION	71.0610	2031.5000	44.996	0.014	-7.161	-8.551	0.034	-1.430	2079.9016	2067.6582	0.0219
-1.E-07	GRND REF	0.0000	2899.6401	45.000	0.010	-13.041	0.742	0.001	-1.000	2955.0845	2942.8411	0.0229
-6.E-08	ENTR ION	73.8477	3785.9297	45.003	0.008	-15.948	8.714	-0.068	2.218	3848.8345	3836.5911	0.0229
-2.E-07		94.6484	3911.5823	45.003	0.008	-16.259	9.842	-0.002	1.948	3977.8345	3965.5908	0.0238
-1.E-06	MAX LAT	105.8896	3973.6094	45.003	0.008	-16.406	10.385	-0.000	1.850	4041.8345	4029.5876	0.0252
-1.E-06	WAVE REV	105.8896	3973.6094	45.003	0.008	-16.406	10.385	-0.000	1.850	4041.8345	4029.5876	0.0252
-5.E-06		123.7598	4066.2302	45.004	0.009	-16.620	10.986	-0.000	1.750	4137.8345	4125.5269	0.0281
-5.E-06		147.0796	4188.8491	45.004	0.032	-16.923	9.041	-0.000	1.889	4265.8345	4252.3818	0.0313
-4.E-06		156.4619	4264.9683	45.006	0.047	-17.183	3.776	-0.000	3.082	4345.8345	4329.6294	0.0329
-6.E-08	MIN DIST	157.9038	4304.2812	45.007	0.074	-17.362	-0.000	-0.000	9.340	4387.2407	4369.0029	0.0339

v^2/ Real part $(n^2)-1$ where v is the magnitude of the wave normal vector, and n is the complex phase refractive index. This quantity would be zero if there where no errors in the numerical integration.

Height of ray point above the ground

Great circle distance along the ground between the ray point and the transmiter

Azimuth of ray point from transmiter in degrees

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

Elevation angle of the wave normal in point at the transmiter

Elevation angle of current ray path the local horizontal

Elevation angle of the wave normal with

Polarization = +1 means the electric field vector is rotating counter clockwise when looking along the ray

Fig 1: Example of program output

3.5 Explanation of Output Format

When the ray tracing program starts to run, the first printout is a reproduction of the input data as read by the computer. This is done to facilitate easy checks on the input data. Samples of this can be seen in APPENDICES 27, 28, 29, and 30.

APPENDIX 27 is the output of the sample case - the input to it was TEST1.FOR
APPENDIX 28 is the output of the sample case - the input to it was TEST3.FOR
APPENDIX 29 is the output of the sample case - the input to it was TEST2.FOR
APPENDIX 30 is the output of the sample case - the input to it was TEST5.FOR

In the next step, the real calculation begins and a printout of the ray trajectory appears. A sample of this is shown in Figure 1 which is self-explanatory. This differs from the similar figure in (1) (p. 171) in one aspect.

Instead of printing the: "Azimuth angle of the direction of transmission in degrees clockwise from the great circle between transmitter and ray point" as done in the original version, "Azimuth of ray point from transmitter" was printed and the header was changed accordingly. The reason for the change was more compatibility with the proposed system.

The following is a short explanation of the computer messages on special points on the ray's trajectory.

XMTR - at the transmitter

MIN DIS - at the closest approach point (minimum distance).

A little elaboration is required to explain the meaning of this - closest approach point is defined (in the program) as the point where the wave normal is horizontal. It approximates an apogee if it (the min-distance point) is above the receiver's height and approximates a perigee if it is below the receiver's height. This is only an approximation because this condition is found using the wave normal direction which does not necessarily coincide with the ray's direction in the presence of magnetic field. The situation is clarified in Figure 2.

Whenever the ray's point is one of the two described in the two left cases in the figure (and the wave normal is horizontal), the program prints MIN DIS. At the two right cases in Figure 2, the program prints:

APOGEE when at apogee point

PERIGEE when at perigee point

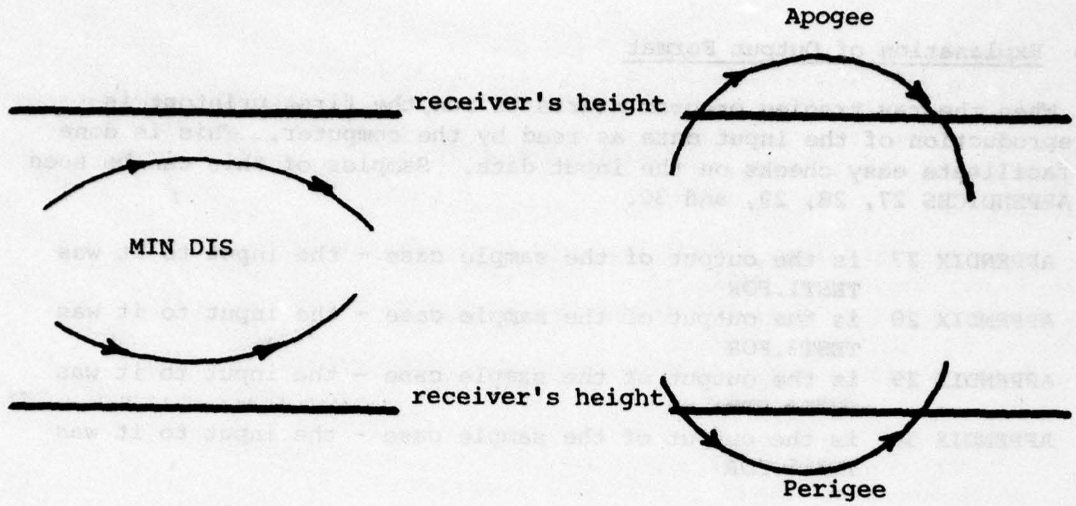


Figure 2: **Explanation of the Minimum Distance Concept**

RCVR	at the receiver's height
GRND REF	ground reflection
STP MAX	exceeded the maximum number of integration steps allowed
PENETRAT	ray penetrated the ionosphere
ENTR ION	ray entered the ionosphere
EXIT ION	ray exited out of the ionosphere

WAVE REV means wave reversal. This also needs further elaboration. The wave normal K is represented in the program in a spherical coordinate system (r, θ, Φ). At each point on the ray's path, the wave normal components K_r, K_θ, K_Φ, are calculated.

The new value is compared to the old one and whenever one of the following three conditions occur:

$(K_r)_{old} \cdot (K_r)_{new} < 0$

$(K_\theta)_{old} \cdot (K_\theta)_{new} < 0$

$(K_\Phi)_{old} \cdot (K_\Phi)_{new} < 0$

the wave reversal message is printed out.

MAX LAT stands for maximum latitude.

MAX LONG stands for maximum longitude.

The variables being integrated in this program are r, θ, Φ, K_r, K_θ, K_Φ, and the independent variable is the group path T. Explicitly two of them, namely $d\theta/dT$ and $d\Phi/dT$, are integrated.

At each step of the numerical integration the new value is compared to the old one and when:

$(d\theta/dT)_{old} \cdot (d\theta/dT)_{new} < 0$ - MAX LAT is printed

$(d\Phi/dT)_{old} \cdot (d\Phi/dT)_{new} < 0$ - MAX LONG is printed

4. Final Remarks

Comparing the results of calculation as they appear in APPENDIX 27 to the original, values show that generally they are very similar. However, there are some differences; these occur because of the differences between the CDC-3800, for which the program was intially written, and the PDP-11/40.

The main difference stems from the fact that a real variable is represented on the PDP-11/40 by 32 bits; whereas it is represented in the CDC by 64 bits or so. This means that on the PDP-11/40 there can be 6 or 7 significant decimal digits compared to 11 or 12 on the CDC. So rounding errors are larger in this case. Notice, however, that on the special points on the ray's trajectory the differences are small.

The results between the special points may differ significantly because the intermediate printing is done every fixed number of steps (5 in our case). Step size may differ between the two computers which actually print from two different points.

The special points however, are very similar and the differences stem from the rounding errors on the PDP-11/40.

Two special points stand out as very different-the point where the ray enters the ionosphere and the point where the ray leaves the ionosphere. The difference stems from the way the logical variable SPACE is calculated in subroutines AHWFWC in the two programs. This logical variable is TRUE when the ray is in free space and accordingly, the calculation is carried out.

In the original version we have:

```
SPACE=REAL(N2).EQ.1..and.ABS(AIMG(N2)).LT.ABSLIM
```

where N2 is the square of the index of refraction and ABSLIM=1.E-5. So in simple words, the program decides that the ray is in free space if, at the same time, the real part of N2 is equal to one and the imaginary part of N2 is smaller than 1.E-5.

On the PDP-11/40 this way did not work so it was written differently.

```
SPACE=ABS(REAL(N2)-1.)LT.0.5E-7.and.ABS(AIMAG(N2).LT.ABSLIM
```

if instead 0.5E-7.0 was written, then the two statements would have been, mathematically speaking, identical.

Again, this was necessary because of rounding errors. (Recall that in any calculations which include addition and subtraction, the smallest meaningful number on the PDP-11/40 is somewhere around E-7.) Even though the calculation is done differently in free space (connecting straight lines) than in the ionosphere, the actual results, although differing at the beginning, quickly converge. This is so because at these heights the deviation of the ray from the straight line is negligible.

Some more statements were changed in the same spirit especially in subroutine PRINTR.

Another example of rounding errors can be seen on the first line of the printout of the ray's trajectory. When the ray is at the transmitter (XMTR) the range should be zero. However, on the PDP-11/40 it is 0.0007KM.

Another kind of limitation encountered, was the reaching of the largest number that can be used in the PDP-11/40. This is basically a hardware limitation that has to deal with the number of binary bits used to represent a real number.

This problem was first encountered while using the AHWFWC subroutine The program stopped and an error message indicating overflow was printed. The problem was solved by changing the representation of the algebraic expressions where the problem occurred.

For example:

Instead of writing A/D**2, A/D/D was written

or instead of (B**2-4.*A*C), (B-2*SQRT(A)*SQRT(C))*(B+2*SQRT(A)*SQRT(C))

was written, etc. For the sample case, this problem was solved as seen in APPENDICES 27-30, and it is hoped that it will not occur again in the future.

The same problem occurred while using the BQWFWC subroutine. In this case, the problem appeared first in one expression. This expression was changed and then the overflow occurred in another expression (the first expression for SCALE in APPENDIX 11). Many ways were tried to write this expression without success. In spite of this the subroutine was left in the DK for two reasons. One is that further work on it may solve the problem and the other is that in real situations the subroutine may work.

REFERENCES

1. R. M. Jones and J. J. Stephenson
   "A Versatile Three Dimensional Ray Tracing Computer Program for Radio Waves in the Ionosphere"
   OTR-75-76 Oct 75
   Office of Telecommunication, Boulder, Colorado
   or - NTIS PB-248 856

2. RT-11 System Reference Manual
   DEC 11-ORUGA-B-D
   Digital Equipment Corporation, Maynard, Massachusetts

3. PDP-11 FORTRAN Language Manual
   DEC-11-FLLRA-A-D
   Digital Equipment Corporation, Maynard, Massachusetts

```
  II:=NITIAL.FOR
CCC     PROGRAM NITIAL
C               SETS THE INITIAL CONDITIONS FOR EACH RAY AND CALLS TRACE
        DIMENSION MFLD(4),MODSAV(2)
        COMMON /CONST/ PI,PIT2,PID2,DEGS,RAD,K,C,LOGTEN
        COMMON /FLG/ NTYP,NEWWR,NEWWP,PENET,LINES,IHOP,HPUNCH
        COMMON /RIN/ MODRIN(7),COLL,FIELD,SPACE,N2,N2I,PNP(10),POLAR,
     1                  LPOLAR,SGN
        COMMON /RK/ N,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART
        COMMON /XX/ MODX(4),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
        COMMON/YY/MODY(2),Y(16)/ ZZ /MODZ(2),Z(4)
        COMMON R(20),T,STP,DRDT(20) /WW/ ID(10),W0,W(400)
        EQUIVALENCE (RAY,W(1)),(EARTHR,W(2)),(XMTRH,W(3)),(TLAT,W(4)),
       1 (TLON,W(5)),(F,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),
       2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),
       3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),
       4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))
       5,(INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),(STEP1,W(44)),
       6 (STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),(SKIP,W(71)),
       7 (RAYSET,W(72)),(PLT,W(81)),(PERT,W(150))
        LOGICAL SPACE,NEWWR,NEWWP,PENET
        REAL N2,N2I,LOGTEN,K,MAXSTP,INTYP,MAXERR,MU,KOLL,MODX,MODY,MODZ,
       1 MFLD,MODSAV,MODRIN,ID
        INTEGER DD,YY
        DATA COLL1/4H  NO/,COLL2/4HWITH/,AB1/4HEXTR/,AB2/4HAORD/,
       1 AB3/4HINAR/,AB4/4HY   /,AB5/4HNO F/,AB6/4HIELD/,AB7/4H    /,
       2 AB8/4HORDI/,AB9/4HNARY/
        COMPLEX PNP,POLAR,LPOLAR
        CALL IDATE(MM,DD,YY)
        KOLL=COLL1
        IF (COLL.NE.0.) KOLL=COLL2
C********* CONSTANTS
        PI=3.1415926536
        PIT2=2.*PI
        PID2=PI/2.
        DEGS=180./PI
        RAD=PI/180.
        C=2.997925E5
        K=80.6523860 5E-6
        LOGTEN=ALOG(10.)
C********* INITIALIZE SOME VARIABLES IN THE W ARRAY
        DO 5 NW=1,400
      5 W(NW)=0.
        PLON=0.
        PLAT=PID2
        EARTHR=6370.
        INTYP=3.
        MAXERR=1.E-4
        ERATIO=50.
        STEP1=1.
        STPMAX=100.
        STPMIN=1.E-8
        FACTR=0.5
        MAXSTP=1000.
        HOP=1.
C********* READ W ARRAY AND PRINT NON-ZERO VALUES
        WRITE(7,73)
     73 FORMAT(1H ,'ENTER DATA FILE NAME ',$)
        CALL ASSIGN (10,NAME,-1)
     10 CALL READ W
```

```
      F=0.
      BETA=0.
      AZ1=0.
      IF (SKIP.EQ.0.) SKIP=MAXSTP
      RAY=SIGN(1.,RAY)
      NTYP=2.+FIELD*RAY
      GO TO (13,14,15), NTYP
   13 MFLD(1)=AB1
      MFLD(2)=AB2
      MFLD(3)=AB3
      MFLD(4)=AB4
      GO TO 16
   14 MFLD(1)=AB5
      MFLD(2)=AB6
      MFLD(3)=AB7
      MFLD(4)=AB7
      GO TO 16
   15 MFLD(1)=AB8
      MFLD(2)=AB9
      MFLD(3)=AB7
      MFLD(4)=AB7
   16 MODSAV(1)=MODX(3)
      MODSAV(2)=MODX(4)
      IF(PERT) 101,100,101
  100 MODX(3)=AB7
      MODX(4)=AB7
  101 WRITE(7,1000) ID,MM,DD,YY,MODX,MODY,MODZ,MODRIN,MFLD,KOLL
 1000 FORMAT(1H1,10A4,60X,3I2//1X,4A3,3X,2A3,3X,2A3,16X,7A4,4A4,1X,A4
     1 ,11H COLLISIONS/)
      WRITE(7, 1050)
 1050 FORMAT(40H INITIAL VALUES FOR THE W ARRAY -- ALL ANGLES IN,
     1 37H RADIANS, ONLY NONZERO VALUES PRINTED/)
      DO 17 NW=1,400
      IF (W(NW).NE.0.) WRITE(7, 1700) NW,W(NW)
 1700 FORMAT (I4,1PE19.11)
   17 CONTINUE
C********* LET SUBROUTINE PRINTR KNOW THERE IS A NEW W ARRAY
      NEWWP=.TRUE.
      NEWWR=.TRUE.
C********* INITIALIZE PARAMETERS FOR INTEGRATION SUBROUTINE RKAM
      N=6
      DO 20 NR=7,20
      IF (W(50+NR).NE.0.) N=N+1
   20 CONTINUE
      MODE=INTYP
      STEP=STEP1
      E1MAX=MAXERR
      E1MIN=MAXERR/ERATIO
      E2MAX=STPMAX
      E2MIN=STPMIN
      FACT=FACTR
C********* DETERMINE TRANSMITTER LOCATION IN COMPUTATIONAL COORDINATE
C********* SYSTEM (GEOMAGNETIC COORDINATES IF DIPOLE FIELD IS USED)
      RO=EARTHR+XMTRH
      SP=SIN (PLAT)
      CP=SIN (PID2-PLAT)
      SDPH=SIN (TLON-PLON)
      CDPH=SIN (PID2-(TLON-PLON))
      SL=SIN (TLAT)
      CL=SIN (PID2-TLAT)
      ALPHA=ATAN2(-SDPH*CP,-CDPH*CP*SL+SP*CL)
      TEMP=CDPH*CP*CL+SP*SL
      THO=ATAN(SQRT(1-TEMP**2)/TEMP)
      PHO=ATAN2(SDPH*CL,CDPH*SP*CL-CP*SL)
C********* LOOP ON FREQUENCY, AZIMUTH ANGLE, AND ELEVATION ANGLE
      NFREQ=1
```

```
      IF (FSTEP.NE.O.) NFREQ=(FEND-FBEG)/FSTEP+1.5
      NAZ=1
      IF (AZSTEP.NE.O.) NAZ=(AZEND-AZBEG)/AZSTEP+1.5
      NBETA=1
      IF (ELSTEP.NE.O.)  NBETA=(ELEND-ELBEG)/ELSTEP+1.5
      DO 50 NF=1,NFREQ
      F=FBEG+(NF-1)*FSTEP
      DO 45 J=1,NAZ
      AZ1=AZBEG+(J-1)*AZSTEP
      AZA=AZ1*DEGS
      GAMMA=PI-AZ1+ALPHA
      SGAMMA=SIN (GAMMA)
      CGAMMA=SIN (PID2-GAMMA)
      DO 40 I=1,NBETA
      BETA=ELBEG+(I-1)*ELSTEP
      EL=BETA*DEGS
      CBETA=SIN (PID2-BETA)
      R(1)=RO
      R(2)=THO
      R(3)=PHO
      R(4)=SIN (BETA)
      R(5)=CBETA*CGAMMA
      R(6)=CBETA*SGAMMA
      T=0.
      RSTART=1.
C     SGN=1.  (NEED FOR RAY TRACING IN COMPLEX SPACE.)
C******** ALLOW IONOSPHERIC MODEL SUBROUTINES TO READ AND PRINT DATA
      CALL RINDEX
      IF (I.NE.1.AND.NPAGE.LT.3.AND.LINES.LE.17), GO TO 25
      NPAGE=0
      LINES=0
      WRITE(7, 1000) ID,MM,DD,YY,MODX,MODY,MODZ,MODRIN,MFLD,KOLL
      WRITE(7, 2400) F,AZA
 2400 FORMAT(18X,10HFREQUECY =,F12.6,19H MHZ, AZIMUTH ANGLE,
     1 18H OF TRANSMISSION =,F12.6,4H DEG)
   25 NPAGE=NPAGE+1
      WRITE(7, 2500) EL
 2500 FORMAT (/31X,33HELEVATION ANGLE OF TRANSMISSION =,F12.6,4H DEG/)
      IF (N2.GT.O.) GO TO 30
      CALL ELECTX
      FN=SIGN (SQRT (ABS (X))*F,X)
      WRITE(7, 2900) FN
 2900 FORMAT (48HOTRANSMITTER IN EVANESCENT REGION, TRANSMISSION ,
     1 10HIMPOSSIBLE/20HPLASMA FREQUENCY = ,E17.10)
      GO TO 45
   30 MU=SQRT (N2/(R(4)**2+R(5)**2+R(6)**2))
      DO 34 NN=4,6
   34 R(NN)=R(NN)*MU
      DO 35 NN=7,N
   35 R(NN)=0.
      CALL TRACE
      IF (PENET.AND.ONLY.NE.O..AND.IHOP.EQ.1) GO TO 45
   40 CONTINUE
   45 CONTINUE
      IF(PENET.AND.ONLY.NE.O..AND.IHOP.EQ.1.AND.NAZ.EQ.1.AND.NBETA.EQ.1)
     1 GO TO 55
   50 CONTINUE
   55 MODX(3)=MODSAV(1)
      MODX(4)=MODSAV(2)
      GO TO 10
         END
 *
```

```
TT:=READW.FOR
      SUBROUTINE READ W
C                               READS W ARRAY
C     A 1 IN THE FOLLOWING COLUMNS WILL MAKE THE DESCRIBED CONVERTIONS
COL 18    DEGREES TO RADIANS
COL 19    GREAT CIRCLE DISTANCE IN KM TO RADIANS
COL 20    NAUTICAL MILES TO KM
COL 21    FEET TO KM
      COMMON /CONST/ PI,PIT2,PID2,DEGS,RAD,DUM(3)
      COMMON /WW/ ID(10),W0,W(400)
      EQUIVALENCE (EARTHR,W(2))
      INTEGER DEG,FEET
      REAL ID
      READ(10,1000,END=3) ID
 1000 FORMAT(10A4)
    4 READ(10,1100) NW,W(NW),DEG,KM,NM,FEET
 1100 FORMAT(I3,E14.7,4I1)
      IF (NW.EQ.0) GO TO 10
      IF (NW.GT.0.AND.NW.LE.400) GO TO 5
      WRITE(7,4000) NW
 4000 FORMAT(15H1THE SUBSCRIPT ,I3,32H ON THE W-ARRAY INPUT IS OUT OF ,
     1 45HBOUNDS.   ALLOWABLE VALUES ARE 1 THROUGH 400. )
      CALL EXIT
    5 IF (DEG.NE.0) W(NW)=W(NW)*RAD
      IF (KM.NE.0) W(NW)=W(NW)/EARTHR
      IF (NM.NE.0) W(NW)=W(NW)*1.852
      IF (FEET.NE.0) W(NW)=W(NW)*3.048006096E-4
      GO TO 4
   10 RETURN
    3 CALL EXIT
      END
*
```

```
TT1=TRACE.FOR
      SUBROUTINE TRACE
C           CALCULATES THE RAY PATH
      DIMENSION ROLD(20),DROLD(20)
      COMMON /RK/ N,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART
      COMMON /FLG/ NTYP,NEWWR,NEWWP,PENET,LINES,IHOP,HPUNCH
      COMMON /TRAC/ GROUND,PERIGE,THERE,MINDIS,NEWRAY,SMT
      COMMON /RIN/ MODRIN(7),COLL,FIELD,SPACE,N2,PNP(10),POLAR,LPOLAR
      COMMON /XX/ MODX(4),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
      COMMON R(20),T,STP,DRDT(20) /WW/ ID(10),W0,W(400)
      LOGICAL SPACE,HOME,WASNT,UNDRGD,GROUND,PERIGE,THERE,MINDIS,NEWWR,
     1        NEWWP,PENET,NEWRAY,WAS
      REAL MAXSTP,MODRIN,MODX,ID
      COMPLEX N2,PNP,POLAR,LPOLAR
      EQUIVALENCE (EARTHR,W(2)),(RCVRH,W(20)),(HOP,W(22)),(MAXSTP,W(23))
     1,(SKIP,W(71)),(RAYSET,W(72)),(PLT,W(81))
      NHOP=HOP
      MAX=MAXSTP
      NSKIP=SKIP
      RSTART=1.
      CALL HAMLTN
      HOME=DRDT(1)*(R(1)-EARTHR-RCVRH).GE.0.
C********* IHOP=0 TELLS PRINTR TO PRINT HEADING
      IHOP=0
      CALL PRINTR (4HXMTR,4H    ,0.)
      HTMAX=0.
      NEWRAY=.TRUE.
      THERE=R(1)-EARTHR.EQ.RCVRH
C********* LOOP ON NUMBER OF HOPS
   10 IHOP=IHOP+1
      IF (IHOP.GT.NHOP) RETURN
      PENET=.FALSE.
      APHT=RCVRH
C********* LOOP ON MAXIMUM NUMBER OF STEPS PER HOP
      DO 79 J=1,MAX
      H=R(1)-EARTHR
      IF (ABS(H-RCVRH).GT.ABS(APHT-RCVRH)) APHT=H
      HTMAX=AMAX1(H,HTMAX)
      IF (.NOT.SPACE) GO TO 12
      CALL REACH
      RSTART=1.
      H=R(1)-EARTHR
      IF (ABS(H-RCVRH).GT.ABS(APHT-RCVRH)) APHT=H
      HTMAX=AMAX1(H,HTMAX)
      IF (.NOT.SPACE) GO TO 12
      IF (PERIGE) CALL PRINTR (4HPERI,4HGEE ,0.)
      IF (THERE) GO TO 51
      IF (MINDIS) GO TO 40
      IF (GROUND) GO TO 60
      IF (PERIGE) GO TO 79
   12 DO 13 L=1,N
      ROLD(L)=R(L)
   13 DROLD(L)=DRDT(L)
      TOLD=T
      WAS=THERE
      CALL RKAM
      H=R(1)-EARTHR
      THERE=.FALSE.
      WASNT=.NOT.HOME
      HOME=DRDT(1)*(H-RCVRH).GE.0.
```

```
      TMP=(DRDT(1)-DROLD(1))*(T-TOLD)
      SMT=0.
      IF (TMP.NE.0.) SMT=0.5*(R(1)-ROLD(1)+0.5*TMP)**2/ABS(TMP)
      IF (((H-RCVRH)*(ROLD(1)-EARTHR-RCVRH).LT.0..AND..NOT.WAS).OR.
     1 (WAS.AND.DRDT(1)*DROLD(1).LT.0..AND.HOME)) GO TO 50
      IF (HOME.AND.WASNT) GO TO 30
      IF (H.LT.0..OR.DRDT(1).GT.0..AND.DROLD(1).LT.0..AND.SMT.GT.H)
     1 GO TO 20
      IF(DROLD(1).LT.0..AND.DRDT(1).GT.0.)CALL PRINTR(4HPERI,4HGEE ,0.)
      IF (DROLD(1).GT.0..AND.DRDT(1).LT.0.) CALL PRINTR(4HAPOG,4HEE  ,
     1 0.)
      IF (DROLD(2)*DRDT(2).LT.0.) CALL PRINTR(4HMAX ,4HLAT ,0.)
      IF (DROLD(3)*DRDT(3).LT.0.) CALL PRINTR(4HMAX ,4HLONG,0.)
      DO 14 I=4,6
      IF (ROLD(I)*R(I).LT.0.) CALL PRINTR(4HWAVE,4H REV,0.)
   14 CONTINUE
      GO TO 75
C********* RAY WENT UNDERGROUND
   20 CALL BACK UP ( 0.,0)
      GO TO 60
C********** RAY MAY HAVE MADE A CLOSEST APPROACH
   30 CALL BACK UP(RCVRH,1)
      IF (THERE) GO TO 51
   40 DRDT(1)=0.
      HPUNCH=R(1)-EARTHR
      CALL PRINTR(4HMIN ,4HDIST,RAYSET)
      IF (IHOP.GE.NHOP) RETURN
      IHOP=IHOP+1
      CALL PRINTR (4HMIN ,4HDIST,RAYSET)
      GO TO 89
C********* RAY CROSSED RECEIVER HEIGHT
   50 CALL BACK UP(RCVRH,0)
      THERE=.TRUE.
   51 R(1)=EARTHR+RCVRH
      HTMAX=AMAX1(RCVRH,HTMAX)
      HPUNCH=APHT
      CALL PRINTR(4HRCVR,4H    ,RAYSET)
      IF (RCVRH.NE.0.) GO TO 89
      IF (IHOP.GE.NHOP) RETURN
      IHOP=IHOP+1
      APHT=RCVRH
C********* GROUND REFLECT
   60 R(1)=EARTHR
      IF (ABS(RCVRH).GT.ABS(APHT-RCVRH)) APHT=0.
      R(4)=ABS (R(4))
      DRDT(1)=ABS (DRDT(1))
      RSTART=1.
      HPUNCH=HTMAX
      CALL PRINTR(4HGRND,4H REF,RAYSET)
      HTMAX=0.
      IF (RCVRH.NE.0.) GO TO 65
      THERE=.TRUE.
      HPUNCH=APHT
      CALL PRINTR (4HRCVR,4H    ,RAYSET)
      GO TO 89
   65 H=0.
      THERE=.FALSE.
C*********
   75 IF (H.GT.HMAX.AND.H.GT.RCVRH.AND.DRDT(1).GT.0.) GO TO 90
      IF (MOD(J,NSKIP).EQ.0) CALL PRINTR(4H    ,4H    ,0.)
   79 CONTINUE
C********* EXCEEDED MAXIMUM NUMBER OF STEPS
      HPUNCH=H
      CALL PRINTR(4HSTEP,4H MAX,RAYSET)
      RETURN
C*********
```

```
89 HOME=.TRUE.
   GO TO 10
C********* RAY PENETRATED
90 PENET=.TRUE.
   HPUNCH=H
   CALL PRINTR(4HPENE,4HTRAT,RAYSET)
   RETURN
      END
*
```

```
TT:=BACKUP.FOR
      SUBROUTINE BACK UP(HS,KN)
      COMMON /RK/ N,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART
      COMMON /TRAC/ GROUND,PERIGE,THERE,MINDIS,NEWRAY,SMT
      COMMON R(20),T,STP,DRDT(20) /WW/ ID(10),WO,W(400)
      EQUIVALENCE (EARTHR,W(2)),(INTYP,W(41)),(STEP1,W(44))
      REAL INTYP,ID
      LOGICAL GROUND,PERIGE,THERE,MINDIS,NEWRAY,HOME
      IF (KN.EQ.1) GOTO 100
C********* DIAGNOSTIC PRINTOUT
C          CALL PRINTR (4HBACK,4H UP0,0.)
C********* GOING AWAY FROM THE HEIGHT HS
      HOME=DRDT(1)*(R(1)-EARTHR-HS).GE.0.
      IF (HS.GT.0..AND..NOT.HOME.OR.HS.EQ.0..AND.DRDT(1).GT.0.) GO TO 30
C********* FIND NEAREST INTERSECTION OF RAY WITH THE HEIGHT HS
      DO 10 I=1,10
      STEP=-(R(1)-EARTHR-HS)/DRDT(1)
      STEP=SIGN(AMIN1(ABS(STP),ABS(STEP)),STEP)
      IF (ABS(R(1)-EARTHR-HS).LT..5E-4.AND.ABS(STEP).LT.1.) GO TO 60
C********* DIAGNOSTIC PRINTOUT
C          CALL PRINTR(4HBACK,4H UP1,0.)
      MODE=1
      RSTART=1.
      CALL RKAM
   10 RSTART=1.
C********* FIND NEAREST CLOSEST APPROACH OF RAY TO THE HEIGHT HS
  100 CONTINUE
      THERE=.FALSE.
C********* DIAGNOSTIC PRINTOUT
C          CALL PRINTR (4HGRAZ,4HE 0 ,0.)
      IF (SMT.GT.ABS(R(1)-EARTHR-HS)) GO TO 30
      DO 20 I=1,10
      STEP=-R(4)/DRDT(4)
      STEP=SIGN(AMIN1(ABS(STP),ABS(STEP)),STEP)
      IF (ABS(R(4)).LE.1.E-6.AND.ABS(STEP).LT.1.) GO TO 60
C********* DIAGNOSTIC PRINTOUT
C          CALL PRINTR (4HGRAZ,4HE 1 ,0.)
      MODE=1
      RSTART=1.
      CALL RKAM
      RSTART=1.
      IF (DRDT(4)*(R(1)-EARTHR-HS).LT.0.) GO TO 30
      IF(R(5).EQ.0..AND.R(6).EQ.0.) GO TO 60
   20 CONTINUE
C********* IF A CLOSEST APPROACH COULD NOT BE FOUND IN 10 STEPS, IT
C********* PROBABLY MEANS THAT THE RAY INTERSECTS THE HEIGHT HS
   30 CONTINUE
C********* DIAGNOSTIC PRINTOUT
C          CALL PRINTR (4HBACK,4H UP2,0.)
      MODE=1
C********* ESTIMATE DISTANCE TO NEAREST INTERSECTION OF RAY WITH HEIGHT
C********* HS BEHIND THE PRESENT RAY POINT
      STEP=(-R(4)-SQRT(R(4)**2-2.*(R(1)-EARTHR-HS)*DRDT(4)))/DRDT(4)
      RSTART=1.
      CALL RKAM
      RSTART=1.
C********* FIND NEAREST INTERSECTION OF RAY WITH HEIGHT HS
      DO 40 I=1,10
      STEP=-(R(1)-EARTHR-HS)/DRDT(1)
      STEP=SIGN(AMIN1(ABS(STP),ABS(STEP)),STEP)
```

```
      IF (ABS(R(1)-EARTHR-HS).LT..5E-4.AND.ABS(STEP).LT.1.) GO TO 60
C********* DIAGNOSTIC PRINTOUT
C         CALL PRINTR (4HBACK,4H UP3,0.)
      MODE=1
      RSTART=1.
      CALL RKAM
   40 RSTART=1.
   50 THERE=.TRUE.
C********* RESET STANDARD MODE AND INTEGRATION TYPE
   60 MODE=INTYP
      STEP=STEP1
      RETURN
         END
*
```

```
TT:=REACH.FOR
      SUBROUTINE REACH
C         CALCULATES THE STRAIGHT LINE RAY PATH BETWEEN THE EARTH
C          AND THE IONOSPHERE OR BETWEEN IONOSPHERIC LAYERS
      COMMON /RK/ N,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART
      COMMON /TRAC/ GROUND,PERIGE,THERE,MINDIS,NEWRAY,SMT
      COMMON /COORD/ S
      COMMON /RIN/ MODRIN(7),COLL,FIELD,SPACE,N2,N2I,PNP(10),POLAR,
     1             LPOLAR
      COMMON /XX/ MODX(4),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
      COMMON R(20),T,STP,DRDT(20) /WW/ ID(10),WO,W(400)
      EQUIVALENCE (EARTHR,W(2)),(XMTRH,W(3)),(RCVRH,W(20))
      LOGICAL CROSS,CROSSG,CROSSR,SPACE,GROUND,PERIGE,THERE,MINDIS,
     1        NEWRAY,RSPACE
      REAL N2,N2I,MODRIN,MODX,ID
      COMPLEX PNP,POLAR,LPOLAR
      DATA NSTEP / 500/
      CALL HAMLTN
      H=R(1)-EARTHR
      IF (.NOT.NEWRAY.AND..NOT.RSPACE) CALL PRINTR(4HEXIT,4H ION,0.)
      NEWRAY=.FALSE.
      V=SQRT(R(4)**2+R(5)**2+R(6)**2)
C********** NORMALIZE THE WAVE NORMAL DIRECTION TO ONE
      R(4)=R(4)/V
      R(5)=R(5)/V
      R(6)=R(6)/V
C********** NEGATIVE OF DISTANCE ALONG RAY TO CLOSEST APPROACH TO CENTER
C********** OF EARTH
      UP=R(1)*R(4)
      RADG=EARTHR**2-R(1)**2*(R(5)**2+R(6)**2)
      DISTG=SQRT (AMAX1(0.,RADG))
C********** DISTANCE ALONG RAY TO FIRST INTERSECTION WITH OR CLOSEST
C********** APPROACH TO THE EARTH
      SG=-UP-DISTG
C********** CROSSG IS TRUE IF THE RAY WILL INTERSECT OR TOUCH THE EARTH
      CROSSG=UP.LT.0..AND.RADG.GE.0.
      RADR=(EARTHR+RCVRH)**2-R(1)**2*(R(5)**2+R(6)**2)
      DISTR=SQRT (AMAX1(0.,RADR))
C********** DISTANCE ALONG RAY TO THE FIRST INTERSECTION WITH OR CLOSEST
C********** APPROACH TO THE RECEIVER HEIGHT
      SR=DISTR-UP
      IF (UP.LT.0..AND.DISTR.LT.-UP.AND.R(1).NE.EARTHR+RCVRH) SR=-DISTR
     1 -UP
C********** CROSSR IS TRUE IF THE RAY WILL INTERSECT WITH OR MAKE A
C********** CLOSEST APPROACH TO THE RECEIVER HEIGHT
      CROSSR=R(4).LT.0..OR.R(1).LT.(EARTHR+RCVRH)
      CROSS=CROSSG.OR.CROSSR
C********** MAXIMUM DISTANCE IN WHICH TO LOOK FOR THE IONOSPHERE
      S1=AMIN1(SR,SG)
      IF(.NOT.CROSSG) S1=SR
      IF (UP.GE.0.) GO TO 15
      CROSS=.TRUE.
C********** IF RAY IS GOING DOWN, S1 IS AT MOST THE DISTANCE TO A PERIGEE
      S1=AMIN1(S1,-UP)
C********** CONVERT THE POSITION AND DIRECTION OF THE RAY TO CARTESIAN
C********** COORDINATES
   15 CALL POL CAR(0)
      SSTEP=100.
      S=SSTEP
      DO 20 I=1,NSTEP
```

```
      IF ((S-SSTEP).GT.S1.AND.CROSS) GO TO 25
C********** CONVERT POSITION AND DIRECTION TO SPHERICAL POLAR COORDINATES
C********** AT A DISTANCE S ALONG THE RAY
      CALL POL CAR(1)
      CALL ELECTX
C********** FREE SPACE
      IF (X.EQ.0.) GO TO 20
      CALL RINDEX
C********** EFFECTIVELY FREE SPACE
      IF (SPACE) GO TO 20
      IF (SSTEP.LT.0.5E-1) GO TO 25
C********** RAY IN THE IONOSPHERE.  STEP BACK OUT
      S=S-SSTEP
C********** DECREASE STEP SIZE
      SSTEP=SSTEP/10.
   20 S=S+SSTEP
      WRITE(7, 2000) NSTEP
 2000 FORMAT (9H EXCEEDED,I5,26H STEPS IN SUBROUTINE REACH)
      CALL EXIT
   25 IF(CROSS) S=AMIN1(S,S1)
C********** CONVERT POSITION AND DIRECTION TO SPHERICAL POLAR COORDINATES
C********** AT A DISTANCE S ALONG THE RAY
      CALL POL CAR(1)
C********** AVOID THE RAY BEING SLIGHTLY UNDERGROUND
      R(1)=AMAX1(R(1),EARTHR)
C********** ONE STEP INTEGRATION
      IF (N.LT.7) GO TO 31
      DO 30 NN=7,N
   30 R(NN)=R(NN)+S*DRDT(NN)
   31 T=T+S
      CALL RINDEX
C********** AT A PERIGEE
      PERIGE=S.EQ.(-UP)
C********** CORRECT MINOR ERRORS
      IF (PERIGE) R(4)=0.
C********** KEEP CONSISTENCY AFTER CORRECTING MINOR ERRORS
      DRDT(1)=R(4)
C********** ON THE GROUND
      GROUND=S.EQ.SG.AND.CROSSG
C********** AT THE RECEIVER HEIGHT
      THERE=S.EQ.SR.AND.CROSSR.AND..NOT.PERIGE
C********** AT A CLOSEST APPROACH TO THE RECEIVER HEIGHT
      MINDIS=PERIGE.AND.S.EQ.SR.AND.CROSSR
      RSPACE=SPACE
      V=SQRT(N2/(R(4)**2+R(5)**2+R(6)**2))
C********** RENORMALIZE THE WAVE NORMAL DIRECTION TO = SQRT(REAL(N**2))
      R(4)=R(4)*V
      R(5)=R(5)*V
      R(6)=R(6)*V
      RSTART=1.
      IF (.NOT.SPACE) CALL PRINTR (4HENTR,4H ION,0.)
      RETURN
      END
```

```
TT:=POLCAR.FOR
      SUBROUTINE POL CAR(KN)
      DIMENSION XO(6),X(6),RO(4)
      COMMON R(6) /COORD/ S
      COMMON /CONST/ PI,PIT2,PID2,DUM(5)
      IF(KN.EQ.1) GO TO 10
C          CONVERTS SPHERICAL COORDINATES TO CARTESIAN
      IF (R(5).EQ.0..AND.R(6).EQ.0.) GO TO 1
      VERT=0.
      SINA=SIN(R(2))
      COSA=SIN(PID2-R(2))
      SINP=SIN(R(3))
      COSP=SIN(PID2-R(3))
      XO(1)=R(1)*SINA*COSP
      XO(2)=R(1)*SINA*SINP
      XO(3)=R(1)*COSA
      X(4)=R(4)*SINA*COSP+R(5)*COSA*COSP-R(6)*SINP
      X(5)=R(4)*SINA*SINP+R(5)*COSA*SINP+R(6)*COSP
      X(6)=R(4)*COSA-R(5)*SINA
      RETURN
C          VERVICAL INCIDENCE
    1 VERT=1.
      RO(1)=R(1)
      RO(2)=R(2)
      RO(3)=R(3)
      RO(4)=SIGN (1.,R(4))
      RETURN
C          STEPS THE RAY A DISTANCE S, AND THEN
C          CONVERTS CARTESIAN COORDINATES TO SPHERICAL COORDINATES
   10 CONTINUE
      IF (VERT.NE.0.) GO TO 2
      X(1)=XO(1)+S*X(4)
      X(2)=XO(2)+S*X(5)
      X(3)=XO(3)+S*X(6)
      TEMP=SQRT(X(1)**2+X(2)**2)
      R(1)=SQRT(X(1)**2+X(2)**2+X(3)**2)
      R(2)=ATAN2(TEMP,X(3))
      R(3)=ATAN2(X(2),X(1))
      R(4)=(X(1)*X(4)+X(2)*X(5)+X(3)*X(6))/R(1)
      R(5)=(X(3)*(X(1)*X(4)+X(2)*X(5))-(X(1)**2+X(2)**2)*X(6))/
     1 (R(1)*TEMP)
      R(6)=(X(1)*X(5)-X(2)*X(4))/TEMP
      RETURN
C          VERTICAL INCIDENCE
    2 R(1)=RO(1)+RO(4)*S
      R(2)=RO(2)
      R(3)=RO(3)
      R(4)=RO(4)
      R(5)=0.
      R(6)=0.
      RETURN
         END
 *
```

```
TT:=PRINTR.FOR
      SUBROUTINE PRINTR(NWHY1,NWHY2,CARD)
C           PRINTS OUTPUT AND PUNCHES RAYSETS WHEN REQUESTED
      DIMENSION G(3,3),G1(3,3),TYPE(3),HEADR1(20),HEADR2(20),UNITS(20),
     1          HEAD1(20),HEAD2(20),UNIT(20),RPRINT(20),NPR(20)
      COMMON /CONST/ PI,PIT2,PID2,DEGS,RAD,DUM(3)
      COMMON /FLG/ NTYP,NEWWR,NEWWP,PENET,LINES,IHOP,HPUNCH
      COMMON /RIN/ MODRIN(7),COLL,FIELD,SPACE,N2,N2I,PNP(10),POLAR(2),
     1          LPOLAR(2)
      COMMON R(20),T /WW/ ID(10),WO,W(400)
      EQUIVALENCE (THETA,R(2)),(PHI,R(3))
      EQUIVALENCE (EARTHR,W(2)),(XMTRH,W(3)),(TLAT,W(4)),(TLON,W(5)),
     1 (F,W(6)),(AZ1,W(10)),(BETA,W(14)),(RCVRH,W(20)),(HOP,W(22)),
     2 (PLAT,W(24)),(PLON,W(25)),(RAYSET,W(72))
      LOGICAL SPACE,NEWWR,NEWWP,PENET
      REAL N2,N2I,LPOLAR,MODRIN,ID,NWHY1,NWHY2
      COMPLEX PNP
      DATA TYPE /1HX,1HN,1HO/,
     1HEADR1(7) /4HPHAS/,HEADR2(7) /4HPATH/,UNITS(7)/4H KM /,
     2HEADR1(8) /4HABSO/,HEADR2(8) /4HRPTN/,UNITS(8)/4H DB /,
     3HEADR1(9) /4H DOP/,HEADR2(9) /4HPLER/,UNITS(9)/4H CPS/,
     4HEADR1(10) /4HPATH/,HEADR2(10) /4HLENG/,UNITS(10)/4H KM /
      CALL RINDEX
      IF (.NOT.NEWWP) GO TO 10
C********* NEW W ARRAY -- REINITIALIZE
      NEWWP=.FALSE.
      SPL=SIN (PLON-TLON)
      CPL=SIN (PID2-(PLON-TLON))
      SP=SIN (PLAT)
      CP=SIN (PID2-PLAT)
      SL=SIN (TLAT)
      CL=SIN (PID2-TLAT)
C********* MATRIX TO ROTATE COORDINATES
      G(1,1)=CPL*SP*CL-CP*SL
      G(1,2)=SPL*SP
      G(1,3)=-SL*SP*CPL-CL*CP
      G(2,1)=-SPL*CL
      G(2,2)=CPL
      G(2,3)=SL*SPL
      G(3,1)=CL*CP*CPL+SP*SL
      G(3,2)=CP*SPL
      G(3,3)=-SL*CP*CPL+SP*CL
      DENM=G(1,1)*G(2,2)*G(3,3)+G(1,2)*G(3,1)*G(2,3)+G(2,1)*G(3,2)*G(1,3
     1)-G(2,2)*G(3,1)*G(1,3)-G(1,2)*G(2,1)*G(3,3)-G(1,1)*G(3,2)*G(2,3)
C********* THE MATRIX G1 IS THE INVERSE OF THE MATRIX G
      G1(1,1)=(G(2,2)*G(3,3)-G(3,2)*G(2,3))/DENM
      G1(1,2)=(G(3,2)*G(1,3)-G(1,2)*G(3,3))/DENM
      G1(1,3)=(G(1,2)*G(2,3)-G(2,2)*G(1,3))/DENM
      G1(2,1)=(G(3,1)*G(2,3)-G(2,1)*G(3,3))/DENM
      G1(2,2)=(G(1,1)*G(3,3)-G(3,1)*G(1,3))/DENM
      G1(2,3)=(G(2,1)*G(1,3)-G(1,1)*G(2,3))/DENM
      G1(3,1)=(G(2,1)*G(3,2)-G(3,1)*G(2,2))/DENM
      G1(3,2)=(G(3,1)*G(1,2)-G(1,1)*G(3,2))/DENM
      G1(3,3)=(G(1,1)*G(2,2)-G(2,1)*G(1,2))/DENM
      RO=EARTHR+XMTRH
C********* CARTESIAN COORDINATES OF TRANSMITTER
      XR=RO*G(1,1)
      YR=RO*G(2,1)
      ZR=RO*G(3,1)
      CTHR=G(3,1)
```

```
      STHR=SIN (ATAN(SQRT(1-CTHR**2)/CTHR))
      PHIR=ATAN2(YR,XR)
      ALPH=ATAN2(G(3,2),G(3,3))
C*********
      NR=6
      NP=0
      DO 7 NN=7,20
      IF (W(NN+50).EQ.0.) GO TO 7
C********* DEPENDENT VARIABLE NUMBER NN IS BEING INTEGRATED
C********* NR IS THE NUMBER OF DEPENDENT VARIABLES BEING INTEGRATED
      NR=NR+1
      IF (W(NN+50).NE.2.) GO TO 7
C********* DEPENDENT VARIABLE NUMBER NN IS BEING INTEGRATED AND PRINTED.
C********* NP IS THE NUMBER OF DEPENDENT VARIABLES BEING INTEGRATED AND
C********* PRINTED
      NP=NP+1
C********* SAVE THE INDEX OF THE DEPENDENT VARIABLE TO PRINT
      NPR(NP)=NR
      HEAD1(NP)=HEADR1(NN)
      HEAD2(NP)=HEADR2(NN)
      UNIT(NP)=UNITS(NN)
    7 CONTINUE
      NP1=MIN0(NP,3)
      PDEV=0.
      ABSORB=0.
      DOPP=0.
C********* PRINT COLUMN HEADINGS AT THE BEGINNING OF EACH RAY
   10 IF (IHOP.NE.0) GO TO 12
      WRITE(7, 1100) (HEAD1(NN),HEAD2(NN),NN=1,NP1)
 1100 FORMAT (44X,7HAZIMUTH/41X,15HREAL  DEVIATION,4X,9HELEVATION/
     1 19X,16HHEIGHT      RANGE,1X,2(5X,12HXMTR    LOCAL),5X,
     2 26HPOLARIZATION      GROUP PATH,6(2X,A4))
      WRITE(7, 1150) (UNIT(NN),NN=1,NP1)
 1150 FORMAT (13X,2(8X,2HKM),2X,2(6X,3HDEG,5X,3HDEG),6X,12HREAL     IMAG,
     1 7X,2HKM,4X,6(6X,A4,2X))
   12 V=0.
      IF (N2.NE.0.) V=(R(4)**2+R(5)**2+R(6)**2)/N2-1.
      H=R(1)-EARTHR
      STH=SIN (THETA)
      CTH=SIN (PID2-THETA)
C********* CARTESIAN COORDINATES OF RAY POINT, ORIGIN AT TRANSMITTER
      XP=R(1)*STH*SIN (PID2-PHI)-XR
      YP=R(1)*STH*SIN (PHI)-YR
      ZP=R(1)*CTH-ZR
C********* CARTESIAN COORDINATES OF RAY POINT, ORIGIN AT TRANSMITTER AND
C********* ROTATED
      EPS=XP*G1(1,1)+YP*G1(1,2)+ZP*G1(1,3)
      ETA=XP*G1(2,1)+YP*G1(2,2)+ZP*G1(2,3)
      ZETA=XP*G1(3,1)+YP*G1(3,2)+ZP*G1(3,3)
      RCE2=ETA**2+ZETA**2
      RCE=SQRT (RCE2)
C********* GROUND RANGE
      RANGE=EARTHR*ATAN2(RCE,EARTHR+EPS)
C********* ANGLE OF WAVE NORMAL WITH LOCAL HORIZONTAL
      ELL=ATAN2(R(4),SQRT (R(5)**2+R(6)**2))*DEGS
C********* STRAIGHT LINE DISTANCE FROM TRANSMITTER TO RAY POINT
      SR=SQRT (RCE2+EPS**2)
      IF (NP.LT.1) GO TO 16
      DO 15 I=1,NP
      NN=NPR(I)
   15 RPRINT(I)=R(NN)
   16 IF (SR.GE.1.E-3) GO TO 20
C********* TOO CLOSE TO TRANSMITTER TO CALCULATE DIRECTION FROM
C********* TRANSMITTER
      WRITE(7,1500)V,NWHY1,NWHY2,H,RANGE,ELL,POLAR,T,
     1 (RPRINT(NN),NN=1,NP1)
```

```
 1500 FORMAT (1X,1PE7.0,1X,2A4,0PF10.4,F11.4,26X,F8.3,F9.3,F8.3,4F12.4)
      GO TO 40
C********* ELEVATION ANGLE OF RAY POINT FROM TRANSMITTER
   20 EL=ATAN2(EPS,RCE)*DEGS
      IF (RCE.GE.1.E-3) GO TO 30
C********* NEARLY DIRECTLY ABOVE OR BELOW TRANSMITTER. CAN NOT CALCULATE
C********* AZIMUTH DIRECTION FROM TRANSMITTER ACCURATELY
      WRITE(7,2500)V,NWHY1,NWHY2,H,RANGE,EL,ELL,POLAR,T,
     1 (RPRINT(NN),NN=1,NP1)
 2500 FORMAT (1X,1PE7.0,1X,2A4,0PF10.4,F11.4,17X,F9.3,F8.3,F9.3,F8.3,
     1 4F12.4)
      GO TO 40
C********* AZIMUTH ANGLE OF RAY POINT FROM TRANSMITTER
   30 ANGA=ATAN2(ETA,ZETA)
      AZDEV=ANGA*DEGS
      IF (R(5).NE.0..OR.R(6).NE.0.) GO TO 34
C********* WAVE NORMAL IS VERTICAL, SO AZIMUTH DIRECTION CANNOT BE
C********* CALCULATED
      WRITE(7,3000)V,NWHY1,NWHY2,H,RANGE,AZDEV,EL,ELL,POLAR,T,
     1 (RPRINT(NN),NN=1,NP1)
 3000 FORMAT (1X,1PE7.0,1X,2A4,0PF10.4,F11.4,F9.3,8X,F9.3,F8.3,F9.3,
     1 F8.3,4F12.4)
      GO TO 40
   34 ANA=ANGA-ALPH
      SANA=SIN (ANA)
      SPHI=SANA*STHR/STH
      CPHI=-SIN (PID2-ANA)*SIN (PID2-(PHI-PHIR))+SANA*SIN (PHI-PHIR)
     1 *CTHR
      AZA=180.-AMOD (540.-(ATAN2(SPHI,CPHI)-ATAN2(R(6),R(5)))*DEGS,360.)
      WRITE(7,3500)V,NWHY1,NWHY2,H,RANGE,AZDEV,AZA,EL,ELL,POLAR,T,
     1 (RPRINT(NN),NN=1,NP1)
 3500 FORMAT (1X,1PE7.0,1X,2A4,0PF10.4,F11.4,2(F9.3,F8.3),F9.3,F8.3,
     1 4F12.4)
C*********
   40 LINES=LINES+1
      IF (NP.LE.3) GO TO 45
C********* ADDITIONAL LINE TO PRINT REMAINING DEPENDENT INTEGRATION
C********* VARIABLES
      WRITE(7, 4000) (RPRINT(NN),NN=4,NP)
 4000 FORMAT (99X,3F12.4)
      LINES=LINES+1
   45 IF (CARD.EQ.0.) RETURN
      WRITE(7,4700)
 4700 FORMAT(1H0,10X,8HNO PUNCH)
      RETURN
      END
*
```

```
TT:=RKAM.FOR
      SUBROUTINE RKAM
C         NUMERICAL INTEGRATION OF DIFFERENTIAL EQUATIONS
      COMMON /RK/ NN,SPACE,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART
      COMMON Y(20),T,STEP,DYDT(20)
      DIMENSION DELY(4,20),BET(4),XV(5),FV(4,20),YU(5,20)
      DOUBLE PRECISION YU
      IF (RSTART.EQ.0.) GO TO 1000
      LL=1
      MM=1
      IF (MODE.EQ.1) MM=4
      ALPHA=T
      EPM=0.0
      BET(1)=0.5
      BET(2)=0.5
      BET(3)=1.0
      BET(4)=0.0
      STEP=SPACE
      R=19.0/270.0
      XV(MM)=T
      IF (E1MIN.LE.0.) E1MIN=E1MAX/55.
      IF (FACT.LE.0.) FACT=0.5
      CALL HAMLTN
      DO 320 I=1,NN
      FV(MM,I)=DYDT(I)
  320 YU(MM,I)=Y(I)
      RSTART=0.
      GO TO 1001
 1000 IF (MODE.NE.1) GO TO 2000
C          RUNGE-KUTTA
 1001 DO 1034 K=1,4
      DO 1350 I=1,NN
      DELY(K,I)=STEP*FV(MM,I)
      Z=YU(MM,I)
 1350 Y(I)=Z+BET(K)*DELY(K,I)
      T=BET(K)*STEP+XV(MM)
      CALL HAMLTN
      DO 1034 I=1,NN
 1034 FV(MM,I)=DYDT(I)
      DO 1039 I=1,NN
      DEL=(DELY(1,I)+2.0*DELY(2,I)+2.0*DELY(3,I)+DELY(4,I))/6.0
 1039 YU(MM+1,I)=YU(MM,I)+DEL
      MM=MM+1
      XV(MM)=XV(MM-1)+STEP
      DO 1400 I=1,NN
 1400 Y(I)=YU(MM,I)
      T=XV(MM)
      CALL HAMLTN
      IF (MODE.EQ.1) GO TO 42
      DO 150 I=1,NN
  150 FV(MM,I)=DYDT(I)
      IF (MM.LE.3) GO TO 1001
C          ADAMS-MOULTON
 2000 DO 2048 I=1,NN
      DEL=STEP*(55.*FV(4,I)-59.*FV(3,I)+37.*FV(2,I)-9.*FV(1,I))/24.
      Y(I)=YU(4,I)+DEL
 2048 DELY(1,I)=Y(I)
      T=XV(4)+STEP
      CALL HAMLTN
      XV(5)=T
```

```
      DO 2051 I=1,NN
      DEL=STEP$(9.$DYDT(I)+19.$FV(4,I)-5.$FV(3,I)+FV(2,I))/24.
      YU(5,I)=YU(4,I)+DEL
 2051 Y(I)=YU(5,I)
      CALL HAMLTN
      IF (MODE.LE.2) GO TO 42
C             ERROR ANALYSIS
      SSE=0.0
      DO 3033 I=1,NN
      EPSIL=R$ABS(Y(I)-DELY(1,I))
      IF (MODE.EQ.3.AND.Y(I).NE.0.) EPSIL=EPSIL/ABS(Y(I))
      IF (SSE.LT.EPSIL) SSE=EPSIL
 3033 CONTINUE
      IF (E1MAX.GT.SSE) GO TO 3035
      IF (ABS(STEP).LE.E2MIN) GO TO 42
      LL=1
      MM=1
      STEP=STEP$FACT
      GO TO 1001
 3035 IF (LL.LE.1.OR.SSE.GE.E1MIN.OR.E2MAX.LE.ABS(STEP)) GO TO 42
      LL=2
      MM=3
      XV(2)=XV(3)
      XV(3)=XV(5)
      DO 5363 I=1,NN
      FV(2,I)=FV(3,I)
      FV(3,I)=DYDT(I)
      YU(2,I)=YU(3,I)
 5363 YU(3,I)=YU(5,I)
      STEP=2.0$STEP
      GO TO 1001
C             EXIT ROUTINE
   42 LL=2
      MM=4
      DO 12 K=1,3
      XV(K)=XV(K+1)
      DO 12 I=1,NN
      FV(K,I)=FV(K+1,I)
   12 YU(K,I)=YU(K+1,I)
      XV(4)=XV(5)
      DO 52 I=1,NN
      FV(4,I)=DYDT(I)
   52 YU(4,I)=YU(5,I)
      IF (MODE.LE.2) RETURN
      E=ABS(XV(4)-ALPHA)
      IF (E.LE.EPM) GO TO 2000
      EPM=E
      RETURN
         END
```

```
TT:=HAMLTN.FOR
      SUBROUTINE HAMLTN
C********* CALCULATES HAMILTONS EQUATIONS FOR RAY TRACING
      COMMON /CONST/ PI,PIT2,PID2,DEGS,RAD,K,C,LOGTEN
      COMMON /RIN/ MODRIN(7),COLL,FIELD,SPACE,KAY2,KAY2I,
     1              H,HI,PHPT,PHPTI,PHPR,PHPRI,PHPTH,PHPTHI,PHPPH,PHPPHI
     2, PHPOM,PHPOMI,PHPKR,PHPKRI,PHPKTH,PHPKTI, PHPKPH,PHPKPI
     3 ,KPHPK,KPHPKI,POLAR,POLARI,LPOLAR,LPOLRI
      COMMON R(20),T,STP,DRDT(20) /WW/ ID(10),W0,W(400)
      EQUIVALENCE (TH,R(2)),(PH,R(3)),(KR,R(4)),(KTH,R(5)),(KPH,R(6)),
     1 (DTHDT,DRDT(2)),(DPHDT,DRDT(3)),(DKRDT,DRDT(4)),(DKTHDT,DRDT(5)),
     2 (DKPHDT,DRDT(6)),(F,W(6))
      REAL KR,KTH,KPH,KPHPK,KPHPKI,LPOLAR,LPOLRI,LOGTEN,K,KAY2,KAY2I
     1 ,MODRIN,ID
      OM=PIT2*1.E6*F
      STH=SIN(TH)
      CTH=SIN(PID2-TH)
      RSTH=R(1)*STH
      RCTH=R(1)*CTH
      CALL RINDEX
      DRDT(1)=-PHPKR/(PHPOM*C)
      DTHDT=-PHPKTH/(PHPOM*R(1)*C)
      DPHDT=-PHPKPH/(PHPOM*RSTH*C)
      DKRDT=PHPR/(PHPOM*C)+KTH*DTHDT+KPH*STH*DPHDT
      DKTHDT=(PHPTH/(PHPOM*C)-KTH*DRDT(1)+KPH*RCTH*DPHDT)/R(1)
      DKPHDT=(PHPPH/(PHPOM*C)-KPH*STH*DRDT(1)-KPH*RCTH*DTHDT)/RSTH
      NR=6
C********* PHASE PATH
      IF (W(57).EQ.0.) GO TO 10
      NR=NR+1
      DRDT(NR)=-KPHPK/PHPOM/OM
C********* ABSORPTION
   10 IF (W(58).EQ.0.) GO TO 15
      NR=NR+1
      DRDT(NR)= 10./LOGTEN*KPHPK*KAY2I/(KR*KR+KTH*KTH+KPH*KPH)/PHPOM/C
C********* DOPPLER SHIFT
   15 IF (W(59).EQ.0.) GO TO 20
      NR=NR+1
      DRDT(NR)=-PHPT/PHPOM/C/PIT2
C********* GEOMETRICAL PATH LENGTH
   20 IF (W(60).EQ.0.) GO TO 25
      NR=NR+1
      DRDT(NR)=-SQRT(PHPKR**2+PHPKTH**2+PHPKPH**2)/PHPOM    /C
C********* OTHER CALCULATIONS
   25 CONTINUE
      RETURN
      END
 *
```

```
TT:=AHWFWC.FOR
C      SUBROUTINE AHWFWC
       SUBROUTINE RINDEX
C          CALCULATES THE REFRACTIVE INDEX AND ITS GRADIENT USING THE
C          APPLETON-HARTREE FORMULA WITH FIELD, WITH COLLISIONS
       COMMON /CONST/ PI,PIT2,PID2,DEGS,RADIAN,K,C,LOGTEN
       COMMON /RIN/ MODRIN(7),COLL,FIELD,SPACE,KAY2,H,PHPT,PHPR,PHPTH,
     1             PHPPH,PHPOM,PHPKR,PHPKTH,PHPKPH,KPHPK,POLAR,LPOLAR
       COMMON /XX/ MODX(4),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
       COMMON /YY/ MODY(2),Y,PYPR,PYPTH,PYPPH,YR,PYRPR,PYRPT,PYRPP,YTH
     1      ,PYTPR,PYTPT,PYTPP,YPH,PYPPR,PYPPT,PYPPP
       COMMON /ZZ/ MODZ(2),Z,PZPR,PZPTH,PZPPH
       COMMON R,TH,PH,KR,KTH,KPH   /WW/ ID(10),WO,W(400)
       COMMON /RK/ N,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART
       EQUIVALENCE (RAY,W(1)),(F,W(6))
       LOGICAL SPACE
       REAL KR,KTH,KPH,K2,MODRIN,MODX,MODY,MODZ,ID,K,LOGTEN
       COMPLEX N2,PNPR,PNPTH,PNPPH,PNPVR,PNPVTH,PNPVPH,NNP,PNPT,
     1     POLAR,LPOLAR,I,U,RAD,D,PNPPS,PNPX,PNPY,PNPZ,UX,UX2,D2,
     2     KAY2,H,PHPT,PHPR,PHPTH,PHPPH,PHPOM,PHPKR,PHPKTH,PHPKPH,
     3      KPHPK
       DATA I/(0.,1.)/,ABSLIM/1.E-5/
       OM=PIT2*1.E6*F
       C2=C*C
       K2=KR*KR+KTH*KTH+KPH*KPH
       OM2=OM*OM
       VR =C/OM*KR
       VTH=C/OM*KTH
       VPH=C/OM*KPH
       CALL MAGY
       CALL ELECTX
       V2=VR**2+VTH**2+VPH**2
       VDOTY=VR*YR+VTH*YTH+VPH*YPH
       YLV=VDOTY/V2
       YL2=VDOTY**2/V2
       YT2=Y**2-YL2
       YT4=YT2*YT2
       CALL COLFRZ
       U=CMPLX(1.,-Z)
       UX=U-X
       UX2=UX*UX
       RAD=RAY*CSQRT(YT4+4.*YL2*UX2)
       D=2.*U*UX-YT2+RAD
       D2=D*D
       N2=1.-2.*X*UX/D
       PNPPS=2.*X*UX*(-1.+(YT2-2.*UX2)/RAD)/D/D
       PPSPR =YL2/Y*PYPR -(VR*PYRPR+VTH*PYTPR+VPH*PYPPR)*YLV
       PPSPTH=YL2/Y*PYPTH-(VR*PYRPT+VTH*PYTPT+VPH*PYPPT)*YLV
       PPSPPH=YL2/Y*PYPPH-(VR*PYRPP+VTH*PYTPP+VPH*PYPPP)*YLV
       PNPX=-(2.*U*UX2-YT2*(U-2.*X)+(YT4*(U-2.*X)+4.*YL2*UX*UX2)/RAD)/D/D
       PNPY=2.*X*UX*(-YT2+(YT4+2.*YL2*UX2)/RAD)
       PNPY=1./Y*PNPY/D/D
       PNPZ=I*X*(-2.*UX2-YT2+YT4/RAD)/D/D
       PNPR =PNPX*PXPR +PNPY*PYPR +PNPZ*PZPR +PNPPS*PPSPR
       PNPTH=PNPX*PXPTH+PNPY*PYPTH+PNPZ*PZPTH+PNPPS*PPSPTH
       PNPPH=PNPX*PXPPH+PNPY*PYPPH+PNPZ*PZPPH+PNPPS*PPSPPH
       PNPVR =PNPPS*(VR *YL2/V2-YLV*YR )
       PNPVTH=PNPPS*(VTH*YL2/V2-YLV*YTH)
       PNPVPH=PNPPS*(VPH*YL2/V2-YLV*YPH)
       NNP=N2-(2.*X*PNPX+Y*PNPY+Z*PNPZ)
```

```
      PNPT=PNPX*PXPT
      SPACE=ABS(REAL(N2)-1.).LT.0.5E-7.AND.ABS(AIMAG(N2)).LT.ABSLIM
      POLAR=-I*SQRT(V2)*(-YT2+RAD)/(2.*VDOTY*UX)
      GAM=REAL((-YT2+RAD)/(2.*UX))
      LPOLAR=1./UX/(U+GAM)
      LPOLAR=I*X*SQRT(YT2)*LPOLAR
      KAY2=OM2/C2*N2
      IF(RSTART.EQ.0.) GO TO 1
      SCALE=SQRT(REAL(KAY2)/K2)
      KR =SCALE*KR
      KTH=SCALE*KTH
      KPH=SCALE*KPH
    1 CONTINUE
C********* CALCULATES A HAMILTONIAN H
      H=.5*(C2*K2/OM2-N2)
C********* AND ITS PARTIAL DERIVATIVES WITH RESPECT TO
C********* TIME, R, THETA, PHI, OMEGA, KR, KTHETA, AND KPHI.
      PHPT =-PNPT
      PHPR =-PNPR
      PHPTH=-PNPTH
      PHPPH=-PNPPH
      PHPOM=-NNP/OM
      PHPKR =C2/OM2*KR -C/OM*PNPVR
      PHPKTH=C2/OM2*KTH-C/OM*PNPVTH
      PHPKPH=C2/OM2*KPH-C/OM*PNPVPH
      KPHPK=N2
      RETURN
         END
      BLOCK DATA
      COMMON/RIN/MODRIN(7),COLL,FIELD
      COMMON/XX/MODX(4),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
      COMMON/YY/MODY(2),Y,PYPR,PYPTH,PYPPH,YR,PYRPR,PYRPT,PYRPP,YTH,
     1 PYTPR,PYTPT,PYTPP,YPH,PYPPR,PYPPT,PYPPP
      COMMON/ZZ/MODZ(2),Z,PZPR,PZPTH,PZPPH
      REAL MODRIN,MODX,MODY,MODZ
      DATA MODRIN/4HAPPL,4HETON,4H-HAR,4HTREE,4H FOR,4HMULA,4H    /,
     1COLL/1./,
     2     FIELD/1./,
     3     X/0./,PXPR/0./,PXPTH/0./,PXPPH/0./,PXPT/0./,
     4     Y/0./,PYPR/0./,PYPTH/0./,PYPPH/0./,YR/0./,PYRPR/0./,
     5     PYRPT/0./,PYRPP/0./,YTH/0./,PYTPR/0./,PYTPT/0./,
     6     PYTPP/0./,YPH/0./,PYPPR/0./,PYPPT/0./,PYPPP/0./,
     7     Z/0./,PZPR/0./,PZPTH/0./,PZPPH/0./
      END
*
```

```
TT:=BOWFWC.FOR
C      SUBROUTINE BOWFWC
       SUBROUTINE RINDEX
C######### CALCULATES A HAMILTONIAN H
C######### (= BOOKER QUARTIC FOR VERTICAL INCIDENCE, S=0, C=1)
C######### AND ITS PARTIAL DERIVATIVES WITH RESPECT TO
C######### TIME, R, THETA, PHI, OMEGA, KR, KTHETA, AND KPHI.
C######### WITH FIELD, WITH COLLISIONS
      COMMON /CONST/ PI,PIT2,PID2,DEGS,RADIAN,K,C,LOGTEN
      COMMON /RIN/ MODRIN(7),COLL,FIELD,SPACE,KAY2,H,PHPT,PHPR,PHPTH,
     1       PHPPH,PHPOM,PHPKR,PHPKTH,PHPKPH,KPHPK,POLAR,LPOLAR,
     2       SGN
      COMMON /XX/ MODX(4),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
      COMMON /YY/ MODY(2),Y,PYPR,PYPTH,PYPPH,YR,PYRPR,PYRPT,PYRPP,YTH
     1   ,PYTPR,PYTPT,PYTPP,YPH,PYPPR,PYPPT,PYPPP
      COMMON /ZZ/ MODZ(2),Z,PZPR,PZPTH,PZPPH
      COMMON R,TH,PH,KR,KTH,KPH   /WW/ ID(10),WO,W(400)
      COMMON /RK/ N,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART
      COMMON /FLG/ NTYP,NEWWR,NEWWP,PENET,LINES,IHOP,HPUNCH
      EQUIVALENCE (RAY,W(1)),(F,W(6))
      LOGICAL SPACE
      REAL KR,KTH,KPH,K2,KDOTY,K4,KDOTY2,MODRIN,MODX,MODY,MODZ,ID,K
     1 ,LOGTEN
      COMPLEX KAY2,H,PHPT,PHPR,PHPTH,PHPPH,PHPOM,PHPKR,PHPKTH,PHPKPH,
     1       POLAR,LPOLAR,I,U,RAD,D,PNPPS,PNPX,PNPY,PNPZ,UX,UX2,D2,
     2       KPHPK,U2,A,B,ALPHA,BETA,GAMMA,PHPX,PHPY2,PHPK2,PHPU,PHPZ,
     3       N2,PNPR,PNPTH,PNPPH,PNPVR,PNPVTH,PNPVPH,NNP,PNPT,TEMP
      DATA     I/(0.,1.)/,ABSLIM/1.E-5/
      OM=PIT2*1.E6*F
      C2=C*C
      K2=KR*KR+KTH*KTH+KPH*KPH
      OM2=OM*OM
      CALL MAGY
      CALL ELECTX
      IF(X.LT..1) GO TO 2
      K4=K2*K2
      OM4=OM2*OM2
      C4=C2*C2
      Y2=Y*Y
      KDOTY=KR*YR+KTH*YTH+KPH*YPH
      KDOTY2=KDOTY*KDOTY
      CALL COLFRZ
      U=CMPLX(1.,-Z)
      U2=U*U
      UX=U-X
      UX2=UX*UX
      A=UX*U2-U*Y2
      B=-2.*U*UX2+Y2*(2.*U-X)
      ALPHA=A*C4*K4+X*KDOTY2*C4*K2
      BETA=B*C2*OM2*K2-X*KDOTY2*C2*OM2
      GAMMA=(UX2-Y2)*UX*OM4
      H=ALPHA+BETA+GAMMA
      PHPX=-U2*C4*K4+KDOTY2*C4*K2+(4.*U*UX-Y2)*C2*OM2*K2-KDOTY2*C2*OM2+
     1 (-3.*UX2+Y2)*OM4
      PHPY2=-U*C4*K4+(2.*U-X)*C2*OM2*K2-UX*OM4
      PHPKY2    =X*C2*(C2*K2-OM2)
      PHPU=(2.*U*UX+U2-Y2)*C4*K4+2.*(Y2-UX2-2.*U*UX)*C2*K2*OM2+(3.*UX2
     1 -Y2)*OM4
      PHPZ=-I*PHPU
      PHPK2=2.*A*C4*K2+X*KDOTY2*C4+B*C2*OM2
```

```
      PHPT=PHPX*PXPT
      PNPR =PHPX*PXPR +PHPY2*2.*Y*PYPR +PHPKY2  *2.*KDOTY*
     1 (KR*PYRPR+KTH*PYTPR+KPH*PYPPR) +PHPZ*PZPR
      PHPTH=PHPX*PXPTH+PHPY2*2.*Y*PYPTH+PHPKY2  *2.*KDOTY*
     1 (KR*PYRPT+KTH*PYTPT+KPH*PYPPT) +PHPZ*PZPTH
      PHPPH=PHPX*PXPPH+PHPY2*2.*Y*PYPPH+PHPKY2  *2.*KDOTY*
     1 (KR*PYRPP+KTH*PYTPP+KPH*PYPPP) +PHPZ*PZPPH
      PHPOM=(2.*BETA+4.*GAMMA)/OM
     1 -2.*PHPX*X/OM-2.*PHPY2*Y2/OM-2.*PHPKY2  *KDOTY2/OM -PHPZ*Z/OM
      PHPKR= 2.*PHPK2*KR +2.*KDOTY*PHPKY2  *YR
      PHPKTH=2.*PHPK2*KTH+2.*KDOTY*PHPKY2  *YTH
      PHPKPH=2.*PHPK2*KPH+2.*KDOTY*PHPKY2  *YPH
      TEMP=2.*CSQRT(ALPHA)*CSQRT(GAMMA)
      KAY2=K2*(-BETA+SGN*RAY*CSQRT(BETA-TEMP)*CSQRT(BETA+TEMP))/2.
      KAY2=CEXP(CLOG(KAY2)-CLOG(ALPHA))
      IF(RSTART.EQ.0.) GO TO 1
      SCALE=SQRT((-REAL(BETA)+SGN*RAY*SQRT(REAL(BETA)**2
     1 -4.*REAL(ALPHA)*REAL(GAMMA)))/(2.*REAL(ALPHA)))
      KR =SCALE*KR
      KTH=SCALE*KTH
      KPH=SCALE*KPH
    1 CONTINUE
C******** THE FOLLOWING 3 CARDS USED FOR RAY TRACING IN COMPLEX SPACE
C     IF(CABS((-BETA-SGN*RAY*CSQRT(BETA**2-4.*ALPHA*GAMMA))/ALPHA-2.).
C    1LT.CABS((-BETA+SGN*RAY*CSQRT(BETA**2-4.*ALPHA*GAMMA))/ALPHA-2.)
C    2 .AND.RSTART.EQ.0.) SGN=-SGN
      KPHPK=4.*ALPHA+2.*BETA
      SPACE=CABS(C2*KAY2/OM2-1.).LT.ABSLIM
      POLAR =SQRT(K2)*(U+X*OM2/(C2*KAY2-OM2))/KDOTY*I
      LPOLAR = SQRT(Y2-KDOTY2/K2)/UX*(1.-C2*KAY2/OM2)*I
      RETURN
C         CALCULATES THE REFRACTIVE INDEX AND ITS GRADIENT USING THE
C         APPLETON-HARTREE FORMULA WITH FIELD, WITH COLLISIONS
    2 CONTINUE
      VR =C/OM*KR
      VTH=C/OM*KTH
      VPH=C/OM*KPH
      V2=VR**2+VTH**2+VPH**2
      VDOTY=VR*YR+VTH*YTH+VPH*YPH
      YLV=VDOTY/V2
      YL2=VDOTY**2/V2
      YT2=Y**2-YL2
      YT4=EXP(2.*ALOG(YT2))
      CALL COLFRZ
      U=CMPLX(1.,-Z)
      UX=U-X
      UX2=UX*UX
      RAD=SGN*RAY*CSQRT(YT4+4.*YL2*UX2)
      D=2.*U*UX-YT2+RAD
      D2=D*D
      N2=1.-2.*X*UX/D
      PNPPS=2.*X*UX*(-1.+(YT2-2.*UX2)/RAD)/D/D
      PPSPR= YL2/Y*PYPR -(VR*PYRPR+VTH*PYTPR+VPH*PYPPR)*YLV
      PPSPTH=YL2/Y*PYPTH-(VR*PYRPT+VTH*PYTPT+VPH*PYPPT)*YLV
      PPSPPH=YL2/Y*PYPPH-(VR*PYRPP+VTH*PYTPP+VPH*PYPPP)*YLV
      PNPX=-(2.*U*UX2-YT2*(U-2.*X)+(YT4*(U-2.*X)+4.*YL2*UX*UX2)/RAD)/D/D
      PNPY=2.*X*UX*(-YT2+(YT4+2.*YL2*UX2)/RAD)
      PNPY=1./Y*PNPY/D/D
      PNPZ=I*X*(-2.*UX2-YT2+YT4/RAD)/D/D
      NNP=N2-(2.*X*PNPX+Y*PNPY+Z*PNPZ)
      PNPR =PNPX*PXPR +PNPY*PYPR +PNPZ*PZPR +PNPPS*PPSPR
      PNPTH=PNPX*PXPTH+PNPY*PYPTH+PNPZ*PZPTH+PNPPS*PPSPTH
      PNPPH=PNPX*PXPPH+PNPY*PYPPH+PNPZ*PZPPH+PNPPS*PPSPPH
      PNPVR =PNPPS*(VR *YL2-VDOTY*YR )/V2
      PNPVTH=PNPPS*(VTH*YL2-VDOTY*YTH)/V2
      PNPVPH=PNPPS*(VPH*YL2-VDOTY*YPH)/V2
```

```
      PNPT=PNPX*PXPT
      SPACE=ABS(REAL(N2)-1.).LT.0.5E-7.AND.ABS(AIMAG(N2)).LT.ABSLIM
      POLAR=-I*SQRT(V2)*(-YT2+RAD)/(2.*VDOTY*UX)
      GAM=REAL((-YT2+RAD)/(2.*UX))
      LPOLAR=1./UX/(U+GAM)
      LPOLAR=I*X*SQRT(YT2)*LPOLAR
      KAY2=OM2/C2*N2
      IF(RSTART.EQ.0.) GO TO 3
      SCALE=SQRT(REAL(KAY2)/K2)
      KR =SCALE*KR
      KTH=SCALE*KTH
      KPH=SCALE*KPH
    3 CONTINUE
      H=.5*(C2*K2/OM2-N2)
      PHPT =-PNPT
      PHPR =-PNPR
      PHPTH=-PNPTH
      PHPPH=-PNPPH
      PHPOM=-NNP/OM
      PHPKR =C2/OM2*KR -C/OM*PNPVR
      PHPKTH=C2/OM2*KTH-C/OM*PNPVTH
      PHPKPH=C2/OM2*KPH-C/OM*PNPVPH
      KPHPK=N2
      RETURN
         END
      BLOCK DATA
      COMMON/RIN/MODRIN(7),COLL,FIELD,DUM(27),SGN
      COMMON/XX/MODX(2),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
      COMMON/YY/MODY(2),Y,PYPR,PYPTH,PYPPH,YR,PYRPR,PYRPT,PYRPP,YTH
     1      ,PYTPR,PYTPT,PYTPP,YPH,PYPPR,PYPPT,PYPPP
      COMMON/ZZ/MODZ(2),Z,PZPR,PZPTH,PZPPH
      REAL MODRIN,MODX,MODY,MODZ
      DATA MODRIN/4HBOOK,4HER Q,4HUART,4HIC,  ,4HS=0 ,4HC=1 ,4H    /,
     1     COLL/1./,
     2     FIELD/1./,SGN/1./,
     3     X/0./,PXPR/0./,PXPTH/0./,PXPPH/0./,PXPT/0./,
     4     Y/0./,PYPR/0./,PYPTH/0./,PYPPH/0./,YR/0./,PYRPR/0./,
     5     PYRPT/0./,PYRPP/0./,YTH/0./,PYTPR/0./,PYTPT/0./,
     6     PYTPP/0./,YPH/0./,PYPPR/0./,PYPPT/0./,PYPPP/0./
     7    ,Z/0./,PZPR/0./,PZPTH/0./,PZPPH/0./
      END
```

```
TT:=CHAPX.FOR
C       SUBROUTINE CHAPX
        SUBROUTINE ELECTX
C               CHAPMAN LAYER WITH TILTS, RIPPLES, AND GRADIENTS
C               W(109) = 0.5 FOR AN ALPHA-CHAPMAN LAYER
C                      = 1.0 FOR A BETA-CHAPMAN LAYER
        COMMON /CONST/ PI,PIT2,PID2,DUM(5)
        COMMON /XX/ MODX(4),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
        COMMON/R(6) /WW/ ID(10),W0,W(400)
        EQUIVALENCE (THETA,R(2))
        EQUIVALENCE (EARTHR,W(2)),(F,W(6)),(FC,W(101)),(HM,W(102)),
      1 (SH,W(103)),(ALPHA,W(104)),(A,W(105)),(B,W(106)),(C,W(107)),
      2 (E,W(108)),(PERT,W(150))
        REAL MODX,ID
        THETA2=THETA-PID2
        HMAX=HM+EARTHR*E*THETA2
        H=R(1)-EARTHR
        Z=(H-HMAX)/SH
        D=0.
        IF (B.NE.0.) D=PIT2/B
        TEMP=1.+A*SIN(D*THETA2)+C*THETA2
        EXZ=1.-EXP(-Z)
        X=(FC/F)**2*TEMP*EXP(ALPHA*(EXZ-Z))
        PXPR=-ALPHA*X*EXZ/SH
        PXPTH=X*(D*A*SIN(PID2-D*THETA2)+C)/TEMP-PXPR*EARTHR*E
        IF (PERT.NE.0.) CALL ELECT1
        RETURN
            END
        BLOCK DATA
        COMMON/XX/MODX(4)
        REAL MODX
        DATA MODX(1)/3HCHA/,MODX(2)/3HPX /
            END
*
```

```
TT:=TABLEX.FOR
C     SUBROUTINE TABLEX
      SUBROUTINE ELECTX
C        CALCULATES ELECTRON DENSITY AND GRADIENT FROM PROFILES HAVING
C        THE SAME FORM AS THOSE USED BY CROFTS RAY TRACING PROGRAM
C MAKES AN EXPONENTIAL EXTRAPOLATION DOWN USING THE BOTTOM TWO POINTS
C        NEEDS SUBROUTINE GAUSEL
      DIMENSION HPC(50),FN2C(50),ALPHA(50),BETA(50),GAMMA(50),
     1 DELTA(50),SLOPE(50),MAT(4,5)
      COMMON /CONST/ PI,PIT2,PID2,DEGS,RAD,K,DUM(2)
      COMMON /XX/ MODX(4),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
      COMMON R(6) /WW/ ID(10),WO,W(400)
      EQUIVALENCE (EARTHR,W(2)),(F,W(6)),(READFN,W(100)),(PERT,W(150))
      REAL MAT,K,MODX,ID
      DATA HPC,FN2C,ALPHA,BETA,GAMMA,DELTA,SLOPE,MAT,NOC/370*0.,0/
      DATA A,F2,NH/0.,0.,0/
      IF (READFN.EQ.0.) GO TO 10
      READFN=0.
      READ(10,1000) NOC,((HPC(I),FN2C(I)),I=1,NOC)
 1000 FORMAT (I4/(F8.3,E12.4))
      WRITE(7, 1200) (HPC(I),FN2C(I),I=1,NOC)
 1200 FORMAT(1H1,14X,6HHEIGHT,4X,16HELECTRON DENSITY/(1X,F20.10,E20.10))
      A=0.
      IF(FN2C(1).NE.0.) A=ALOG(FN2C(2)/FN2C(1))/(HPC(2)-HPC(1))
      FN2C(1)=K*FN2C(1)
      FN2C(2)=K*FN2C(2)
      SLOPE(1)=A*FN2C(1)
      SLOPE(NOC)=0.
      NMAX=1
      DO 6 I=2,NOC
      IF (FN2C(I).GT.FN2C(NMAX)) NMAX=I
      IF (I.EQ.NOC) GO TO 4
      FN2C(I+1)=K*FN2C(I+1)
      DO 3 J=1,3
      M=I+J-2
      MAT(J,1)=1.
      MAT(J,2)=HPC(M)
      MAT(J,3)=HPC(M)**2
    3 MAT(J,4)=FN2C(M)
      CALL GAUSEL (MAT,4,3,4,NRANK)
      IF(NRANK.LT.3) GOTO 60
      SLOPE(I)=MAT(2,4)+2.*MAT(3,4)*HPC(I)
    4 DO 5 J=1,2
      M=I+J-2
      MAT(J,1)=1.
      MAT(J,2)=HPC(M)
      MAT(J,3)=HPC(M)**2
      MAT(J,4)=HPC(M)**3
      MAT(J,5)=FN2C(M)
      L=J+2
      MAT(L,1)=0.
      MAT(L,2)=1.
      MAT(L,3)=2.*HPC(M)
      MAT(L,4)=3.*HPC(M)**2
    5 MAT(L,5)=SLOPE(M)
      CALL GAUSEL (MAT,4,4,5,NRANK)
      IF (NRANK.LT.4) GO TO 60
      ALPHA(I)=MAT(1,5)
      BETA(I)=MAT(2,5)
      GAMMA(I)=MAT(3,5)
```

```
    6 DELTA(I)=MAT(4,5)
      HMAX=HPC(NMAX)
      NH=2
   10 H=R(1)-EARTHR
      F2=F*F
      PXPR=0.
      PXPTH=0.
      PXPPH=0.
      IF (H.GT.HPC(1)) GOTO 12
   11 NH=2
      X=0.
      IF(FN2C(1).EQ.0.) GO TO 50
      X=FN2C(1)*EXP(A*(H-HPC(1)))/F2
      PXPR=A*X
      GO TO 50
   12 IF (H.GE.HPC(NOC)) GO TO 18
      NSTEP=1
      IF (H.LT.HPC(NH-1)) NSTEP=-1
   15 IF (HPC(NH-1).LE.H.AND.H.LT.HPC(NH)) GO TO 16
      NH=NH+NSTEP
      GO TO 15
   16 X=(ALPHA(NH)+H*(BETA(NH)+H*(GAMMA(NH)+H*DELTA(NH))))/F2
      PXPR=(BETA(NH)+H*(2.*GAMMA(NH)+H*3.*DELTA(NH)))/F2
      GO TO 50
   18 X=FN2C(NOC)/F2
   50 IF (PERT.NE.0.) CALL ELECT1
      RETURN
   40 WRITE(7,6000) I
 6000 FORMAT(1H0,5H THE ,I4,40HTH POINT IN THE ELECTRON DENSITY PROFILE)
      WRITE(7,6500) HPC(I)
 6500 FORMAT(1H+,15H HAS THE HEIGHT,F8.2,26H KMW SAME AS ANOTHER POINT)
      CALL EXIT
         END
      BLOCK DATA
      COMMON/XX/MODX(4)
      REAL MODX
      DATA MODX(1)/3HTAB/,MODX(2)/3HLEX/
      END
```

APPENDIX 14

```
 TT:=GAUSEL.FOR
       SUBROUTINE GAUSEL (C,NRD,NRR,NCC,NSF)
C********* SAME AS SUBROUTINE GAUSSEL WRITTEN BY L. DAVID LEWIS ********
       DIMENSION C(NRD,NCC),L(128,2)
C           BITS = 2.**-18
       DATA BITS/3.8146972656E-6/
       NR=NRR
       NC=NCC
       IF(NC.LT.NR.OR.NR.GT.128.OR.NR.LT.0) CALL EXIT
C           INITIALIZE.
       NSF=0
       NRM=NR-1
       NRP=NR+1
       D=1.
       LSD=1
       DO 1 KR=1,NR
       L(KR,1)=KR
1      L(KR,2)=0
       IF(NR.EQ.1) GO TO 42
C           ELIMINATION PHASE.
       DO 41 KP=1,NRM
       KPP=KP+1
       PM=0.
       MPN=0
C           SEARCH COLUMN KP FROM DIAGONAL DOWN FOR MAX PIVOT.
       DO 2 KR=KP,NR
       LKR=L(KR,1)
       PT=ABS(C(LKR,KP))
       IF(PT.LE.PM) GO TO 2
       PM=PT
       MPN=KR
       LMP=LKR
2      CONTINUE
C           IF MAX PIVOT IS ZERO, MATRIX IS SINGULAR.
       IF(MPN.EQ.0) GO TO 9
       NSF=NSF+1
       IF(MPN.EQ.KP) GO TO 3
C           NEW ROW NUMBER KP HAS MAX PIVOT.
       LSD=-LSD
       L(KP,2)=L(KP,1)
       L(MPN,1)=L(KP,1)
       L(KP,1)=LMP
C           ROW OPERATIONS TO ZERO COLUMN KP BELOW DIAGONAL.
3      MKP=L(KP,1)
       P=C(MKP,KP)
       D=D*P
       DO 41 KR=KPP,NR
       MKR=L(KR,1)
       Q=C(MKR,KP)/P
       IF(Q.EQ.0.) GO TO 41
C           SUBTRACT Q * PIVOT ROW FROM ROW KR.
       DO 4 LC=KPP,NC
       R=Q*C(MKP,LC)
       C(MKR,LC)=C(MKR,LC)-R
4      IF(ABS(C(MKR,LC)).LT.ABS(R)*BITS) C(MKR,LC)=0.
41     CONTINUE
C           LOWER RIGHT HAND CORNER.
42     LNR=L(NR,1)
       P=C(LNR,NR)
       IF(P.EQ.0.) GO TO 9
```

```
      NSF=NSF+1
      D=D*P*LSD
      IF(NR.EQ.NC) GO TO 8
C         BACK SOLUTION PHASE.
      DO 61 MC=NRP,NC
      C(LNR,MC)=C(LNR,MC)/P
      IF(NR.EQ.X) GO TO 61
      DO 6 LL=1,NRM
      KR=NR-LL
      MR=L(KR,1)
      KRP=KR+1
      DO 5 MS=KRP,NR
      LMS=L(MS,1)
      R=C(MR,MS)*C(LMS,MC)
      C(MR,MC)=C(MR,MC)-R
5     IF(ABS(C(MR,MC)).LT.ABS(R)*BITS) C(MR,MC)=0.
6     C(MR,MC)=C(MR,MC)/C(MR,KR)
61    CONTINUE
C         SHUFFLE SOLUTION ROWS BACK TO NATURAL ORDER.
      DO 71 LL=1,NRM
      KR=NR-LL
      MKR=L(KR,2)
      IF(MKR.EQ.0) GO TO 71
      MKP=L(KR,1)
      DO 7 LC=NRP,NC
      Q=C(MKR,LC)
      C(MKR,LC)=C(MKP,LC)
7     C(MKP,LC)=Q
71    CONTINUE
C         NORMAL AND SINGULAR RETUPNS.  GOOD SOUUTION COULD HAVE D=0.
8     C(1,1)=D
      GO TO 91
9     C(1,1)=0.
   91 RETURN
      END
```

```
TT:=TABLE.FOR
C     SUBROUTINE TABLE
      SUBROUTINE ELECTX
C     CALCULATES ELECTRON DENSITY AND GRADIENT FROM TABLE OF VALUES.
C     NEEDS HEIGHT IN KM AND ELECTRON DENSITY IN EL/CM**3.
C     THE HEIGHTS SHOULD BE GIVEN IN ASCENDING ORDER.
C     EACH TWO SUCCESSIVE POINTS MUST HAVE TWO DIFFERENT VALUES OF
C     ELECTRON DENSITY.
      DIMENSION HTAB(50),NTAB(50),A(50),B(50)
      COMMON/XX/MODX(4),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
      COMMON R(6) /WW/ ID(10),W0,W(400)
      EQUIVALENCE (EARTHR,W(2)),(F,W(6)),(READTB,W(100)),(PERT,W(550))
      REAL NTAB,NTABO,N1,N2,K,MODX,ID
      DATA HTAB,HTABO,NTAB,NTABO,A,B,NOP,J/202*0.,2*0/
      DATA K /80.6523860SE-6/
      IF (READTB.EQ.0.) GOTO 10
C         READING AND PRINTING OF DATA
C             INITIALIZATION
      READTB=0.
      READ(10,1000)NOP,((HTAB(I),NTAB(I)),I=1,NOP)
 1000 FORMAT(I4/(F8.3,E12.4))
      WRITE(7,1200) (HTAB(I),NTAB(I),I=1,NOP)
 1200 FORMAT(1H1,14X,6HHEIGHT,4X,16HELECTRON DENSITY/(1X,F20.10,E20.10))
C               REARRANGING
      HTABO=HTAB(1)
      NTABO=NTAB(1)
      J=NOP-1
      DO 1 I=1,J
      HTAB(I)=HTAB(I+1)
    1 NTAB(I)=NTAB(I+1)
      HTAB(NOP)=0.
      NTAB(NOP)=0.
C  CALCULATING COEFFICIENTS FOR THE INTERPOLATION FORMULA
      A(1)=(HTAB(1)-HTABO)/ALOG(NTAB(1)/NTABO)
      B(1)=0.
      A(2)=A(1)
      B(2)=(HTAB(2)-HTAB(1)-A(2)*ALOG(NTAB(2)/NTAB(1)))/ALOG(NTAB(2)/NTA
     1B(1))**2
      DO 2 I=3,J
      A(I)=A(I-1)+2.*B(I-1)*ALOG(NTAB(I-1)/NTAB(I-2))
      B(I)=(HTAB(I)-HTAB(I-1)-A(I)*ALOG(NTAB(I)/NTAB(I-1)))/ALOG(NTAB(I)
     1/NTAB(I-1))**2
    2 CONTINUE
C            FINDING HMAX
      IMAX=1
      DO 20 I=2,J
      IF(NTAB(I).GT.NTAB(I-1)) IMAX=I
   20 CONTINUE
      HMAX=HTAB(IMAX)
C         SEARCHINGFOR HEIGHT INTERVAL
   10 H=R(1)-EARTHR
      F2=F*F
      PXPR=0.
      PXPTH=0.
      PXPPH=0.
      IF(H.LT.HTABO) GOTO 30
      IF(H.EQ.HTABO) GOTO 32
      IF(H.GT.HTAB(J)) GOTO 34
      IH=1
      DO 20 I=1,J
```

```
      IF(H.GE.HTAB(I)) IH=I+1
   20 CONTINUE
      IF(IH.EQ.1) GOTO 40
      IF(IH.GT.J) GOTO 36
      IF(H.EQ.HTAB(IH-1)) GOTO 38
C   BETWEEN TWO POINTS OF THE TABLE - INTERPOLATION IS REQUIRED
      DEL=SQRT(A(IH)**2-4.*B(IH)*(HTAB(IH-1)-H))
      P1=(-A(IH)+DEL)/(2.*B(IH))
      P2=(-A(IH)-DEL)/(2.*B(IH))
      N1=NTAB(IH-1)*EXP(P1)
      N2=NTAB(IH-1)*EXP(P2)
      IF(N1.GT.NTAB(IH-1).AND.N1.LT.NTAB(IH).OR.N1.LT.NTAB(IH-1)
     1.AND.N1.GT.NTAB(IH)) GOTO 23
      ELC=N2
      GOTO 100
   23 ELC=N1
      GOTO 100
C                BELOW IONOSPHERE
   30 ELC=0.
      X=0.
      IH=1
      PXPR=0.
      GOTO 50
C        FIRST POINT OF TABLE
   32 IH=1
      ELC=NTAB0
      GOTO 120
C               ABOVE IONOSPHERE
   34 ELC=0.
      IH=J
      X=0.
      PXPR=0.
      GOTO 50
C         LAST POINT OF TABLE
   36 IH=J
      X=0.
      PXPR=0.
      GOTO 50
C       EXACTLY ONE OF THE POINTS OF THE TABLE EXCLUDING
C       THE FIRST AND LAST ONES.
   38 IH=IH-1
      ELC=NTAB(IH)
      IF(IH.EQ.1) GOTO 120
      X=(K/F2)*ELC
      PXPR=(K/F2)*ELC/(A(IH)+2.*B(IH)*ALOG(ELC/NTAB(IH-1)))
      IF(NTAB(IH).GT.NTAB(IH-1).AND.PXPR.LT.0.) PXPR=-PXPR
      IF(NTAB(IH).LT.NTAB(IH-1).AND.PXPR.GT.0.) PXPR=-PXPR
      GOTO 50
C     SPECIAL CALCULATION FOR THE FIRST HEIGHT INTERVAL
   40 ELC=NTAB0*EXP((H-HTAB0)/A(1))
  120 X=K*ELC/F2
      PXPR=(K/F2)*ELC/A(1)
      GOTO 50
  100 X=K*ELC/F2
      PXPR=(K/F2)*ELC/(A(IH)+2.*B(IH)*ALOG(ELC/NTAB(IH-1)))
   50 CONTINUE
      IF(PERT.NE.0.) CALL ELECT1
      RETURN
      END
      BLOCK DATA
      COMMON/XX/MODX(4)
      REAL MODX
      DATA MODX(1)/3HTAB/,MODX(2)/3HLE /
      END
```

APPENDIX 16

```
TT:=ELECT1.FOR
      SUBROUTINE ELECT1
C        USE WHEN AN ELECTRON DENSITY PERTURBATION IS NOT WANTED
      COMMON /XX/MODX(4),X(6)
      COMMON /WW/ ID(10),WO,W(400)
      EQUIVALENCE (PERT,W(150))
      REAL MODX,ID
      PERT=0.
      RETURN
        END
      BLOCK DATA
      COMMON /XX/ MODX(4)
      REAL MODX
      DATA MODX(3)/3H NO/,MODX(4)/3HNE /
      END
*
```

```
TT:=WAVE.FOR
C     SUBROUTINE WAVE
      SUBROUTINE ELECT1
C        PERTURBATION TO AN ALPHA-CHAPMAN ELECTRON DENSITY MODEL
      COMMON /CONST/ PI,PIT2,PID2,DUM(5)
      COMMON /XX/ MODX(4),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
      COMMON R(6) /WW/ ID(10),W0,W(400)
      EQUIVALENCE (EARTHR,W(2)),(Z0,W(151)),(SH,W(152)),(DELTA,W(153)),
     1 (VSUBX,W(154)),(LAMBDX,W(155)),(LAMBDZ,W(156)),(TP,W(157))
      REAL LAMBDX,LAMBDZ,MODX,ID
      IF(X.EQ.0..AND.PXPR.EQ.0..AND.PXPTH.EQ.0..AND.PXPPH.EQ.0.) RETURN
      IF(DELTA.EQ.0..OR.SH.EQ.0.)  RETURN
      H=R(1)-EARTHR
      EXPQ=EXP(-((H-Z0)/SH)**2)
      TMP=PIT2*(TP+(PID2-R(2))*EARTHR/LAMBDX+H/LAMBDZ)
      SINW=SIN(TMP)
      COSW=SIN(PID2-TMP)
      CONS=1.0+DELTA*EXPQ*COSW
      IF (H.NE.0.) PXPR=PXPR*CONS-X*DELTA*EXPQ*(2.0/SH**2*(H-Z0)*COSW
     1 +PIT2/LAMBDZ*SINW)
      PXPTH=PXPTH*CONS+X*DELTA*PIT2*EARTHR/LAMBDX*SINW*EXPQ
      PXPPH=PXPPH*CONS
      PXPT=0.
      IF (VSUBX.NE.0.) PXPT=-PIT2*VSUBX/LAMBDX*X*DELTA*EXPQ*SINW
      X=X*CONS
      RETURN
         END
      BLOCK DATA
      COMMON /XX/ MODX(4)
      REAL MODX
      DATA MODX(3)/3H WA/,MODX(4)/3HVE /
      END
*
```

```
TT:=TROUGH.FOR
C       SUBROUTINE TROUGH
        SUBROUTINE ELECT1
C               A PERTURBATION TO AN ELECTRON DENSITY MODEL
        COMMON /CONST/ PI,PIT2,PID2,DUM(5)
        COMMON /XX/ MODX(4),X,PXPR,PXPTH,PXPPH,PXPT,HMAX
        COMMON R(6) /WW/ ID(10),WO,W(400)
        EQUIVALENCE (A,W(151)),(B,W(152)),(ALAT,W(153)),(FACTOR,W(154))
        REAL MODX,ID
        IF (X.EQ.0..AND.PXPR.EQ.0..AND.PXPTH.EQ.0..AND.PXPPH.EQ.0.) RETURN
        IF (A.EQ.0.) RETURN
        ANGLE=R(2)+ALAT-PID2
        WIDTH=B
        IF (ANGLE.GT.0.)    WIDTH=FACTOR*B
        ANGLE=ANGLE/WIDTH
        DELTA=A*EXP(-ANGLE**2)
        DEL1=DELTA+1.
        PXPR=PXPR*DEL1
        PXPTH=PXPTH*DEL1-2.*X*ANGLE*DELTA/WIDTH
        PXPPH=PXPPH*DEL1
        X=X*DEL1
        RETURN
          END
        BLOCK DATA
        COMMON/XX/MODX(4)
        REAL MODX
        DATA MODX(3)/3HTRO/,MODX(4)/3HUGH/
        END
*
```

```
TT:=DIPOLY.FOR
C     SUBROUTINE DIPOLY
      SUBROUTINE MAGY
      COMMON /CONST/ PI,PIT2,PID2,DUM(5)
      COMMON /YY/ MODY(2),Y,PYPR,PYPTH,PYPPH,YR,PYRPR,PYRPT,PYRPP,YTH
     1        ,PYTPR,PYTPT,PYTPP,YPH,PYPPR,PYPPT,PYPPP
      COMMON R(6) /WW/ ID(10),WO,W(400)
      EQUIVALENCE (EARTHR,W(2)),(F,W(6)),(FH,W(201))
      REAL MODY,ID
      SINTH=SIN(R(2))
      COSTH=SIN(PID2-R(2))
      TERM9=SQRT(1.+3.*COSTH**2)
      T1=FH*(EARTHR/R(1))**3/F
      Y=T1*TERM9
      YR= 2.*T1*COSTH
      YTH=T1*SINTH
      PYRPR=-3.*YR/R(1)
      PYRPT=-2.*YTH
      PYTPR=-3.*YTH/R(1)
      PYTPT=.5*YR
      PYPR=-3.*Y/R(1)
      PYPTH=-3.*Y*SINTH*COSTH/TERM9**2
      RETURN
         END
      BLOCK DATA
      COMMON/YY/MODY(2)
      REAL MODY
      DATA MODY/3HDIP,3HOLY/
      END
*
```

```
TT:=HARMNY.FOR
C      SUBROUTINE HARMNY
       SUBROUTINE MAGY
C    MODEL OF THE EARTH'S MAGNETIC FIELD BASED ON A HARMONIC ANALYSIS
       DIMENSION PHPTH(7,7),PGPTH(7,7),A1(7,7),B1(7,7)
       DIMENSION H(7,7),G(7,7),GG(7,7),HH(7,7),SINP(7),COSP(7)
       COMMON /YY/ MODY(2),Y,PYPR,PYPTH,PYPPH,YR,PYRPR,PYRPT,PYRPF,YTH
     1       ,PYTPR,PYTPT,PYTPP,YPH,PYPPR,PYPPT,PYPPP
       COMMON R(6) /WW/ ID(10),W0,W(400)
       COMMON /CONST/ PI,PIT2,PID2,DUM(5)
       EQUIVALENCE (THETA,R(2)),(PHI,R(3))
       EQUIVALENCE (EARTHR,W(2)),(F,W(6)),(READFH,W(200))
C    RATIO OF CHARGE TO MASS FOR ELECTRON
       DATA EOM/1.7589E+7/
       DATA SET/0./,H/1.,48*0./,G/49*0./,PHPTH/49*0./,PGPTH/49*0./
       DATA A1,B1,GG,HH/196*0./
       REAL MODY,ID
       IF(SET.NE.0.) GOTO 2
       DO 1 M=1,7
       DO 1 N=1,7
       B1(M,N)=(N+M-1)*(N-M+1)/(2*N-1.)
     1 A1(M,N)=B1(M,N)/(2*N+1)
       SET=1.
     2 IF(READFH.EQ.0.) GOTO 3
       READ(10, 2000)GG,HH
2000   FORMAT(1X,F9.4,6F10.4)
       WRITE(7, 2100)GG
2100   FORMAT(1H1,10X,1H0,14X,1H1,14X,1H2,14X,1H3,14X,1H4,14X,1H5,14X,1H6
     1 /9X,7(1HG,14X)/10X,7(1HN,14X)//(1X,7F15.6))
       WRITE(7, 2200)HH
2200   FORMAT(//  11X,1H0,14X,1H1,14X,1H2,14X,1H3,14X,1H4,14X,1H5,14X,1H6
     1 /9X,7(1HH,14X)/10X,7(1HN,14X)//(1X,7F15.6))
       READFH=0.
  3    COSTHE=COS(THETA)
       SINTHE=SIN(THETA)
       AOR=EARTHR/R(1)
       PAORPR=-AOR/R(1)
       CNST2=AOR
       PCNSPR=PAORPR
       FIN1=0.
       PFIN1R=0.
       PFIN1T=0.
       PFIN1P=0.
       FIN2=0.
       PFIN2R=0.
       PFIN2T=0.
       PFIN2P=0.
       FIN3=0.
       PFIN3R=0.
       PFIN3T=0.
       PFIN3P=0.
       DO 4 M=1,7
       SINP(M)=SIN((M-1)*PHI)
  4    COSP(M)=COS((M-1)*PHI)
       H(1,2)=COSTHE
       H(2,2)=SINTHE
       DO 5 M=1,5
       H(M+1,M+2)=COSTHE*H(M+1,M+1)
       H(M+2,M+2)=SINTHE*H(M+1,M+1)
       DO 5 N=M,5
```

```
5     H(M,N+2)=COSTHE*H(M,N+1)-A1(M,N)*H(M,N)
      DO 6 M=1,6
      G(M+1,M+1)=-M*COSTHE*H(M+1,M+1)
      PHPTH(M+1,M+1)=-G(M+1,M+1)/SINTHE
      PGPTH(M+1,M+1)=M*SINTHE*H(M+1,M+1)-M*COSTHE*PHPTH(M+1,M+1)
      DO 6 N=M,6
      G(M,N+1)=-N*COSTHE*H(M,N+1)+B1(M,N)*H(M,N)
      PHPTH(M,N+1)=-G(M,N+1)/SINTHE
6     PGPTH(M,N+1)=N*SINTHE*H(M,N+1)-N*COSTHE*PHPTH(M,N+1)+B1(M,N)*PHPTH
     1 (M,N)
      DO 8 N=1,7
      CR=0.
      PCRPTH=0.
      PCRPPH=0.
      CTH=0.
      PCTHPT=0.
      PCTHPP=0.
      CPH=0.
      PCPHPT=0.
      PCPHPP=0.
      DO 7 M=1,N
      TEMP1=GG(M,N)*COSP(M)+HH(M,N)*SINP(M)
      TEMP2=(M-1)*(HH(M,N)*COSP(M)-GG(M,N)*SINP(M))
      CR    =CR    +H(M,N)*TEMP1
      PCRPTH=PCRPTH+PHPTH(M,N)*TEMP1
      PCRPPH=PCRPPH+H(M,N)*TEMP2
      CTH    =CTH    +G(M,N)*TEMP1
      PCTHPT=PCTHPT+PGPTH(M,N)*TEMP1
      PCTHPP=PCTHPP+G(M,N)*TEMP2
      CPH    =CPH    +H(M,N)*TEMP2
      PCPHPT=PCPHPT+PHPTH(M,N)*TEMP2
7     PCPHPP=PCPHPP-H(M,N)*(M-1)**2*TEMP1
      CNST2=CNST2*AOR
      PCNSPR=CNST2*PAORPR+AOR*PCNSPR
      FIN1=FIN1+N*CNST2*CR
      PFIN1R=PFIN1R+N*PCNSPR*CR
      PFIN1T=PFIN1T+N*CNST2*PCRPTH
      PFIN1P=PFIN1P+N*CNST2*PCRPPH
      FIN2=FIN2+CNST2*CTH
      PFIN2R=PFIN2R+PCNSPR*CTH
      PFIN2T=PFIN2T+CNST2*PCTHPT
      PFIN2P=PFIN2P+CNST2*PCTHPP
      FIN3=FIN3+CNST2*CPH
      PFIN3R=PFIN3R+PCNSPR*CPH
      PFIN3T=PFIN3T+CNST2*PCPHPT
8     PFIN3P=PFIN3P+CNST2*PCPHPP
      HTHETA=-FIN2/SINTHE
      HPHI=FIN3/SINTHE
C********* CONVERT FROM MAG FIELD IN GAUSS TO GYROFREQ IN MHZ
      CONST=-EOM/PIT2*1.E-6/F
      YR=-CONST*FIN1
      YTH=CONST*HTHETA
      YPH=CONST*HPHI
      Y=SQRT(YR**2+YTH**2+YPH**2)
      PYRPR=-CONST*PFIN1R
      PYTPR=-CONST*PFIN2R/SINTHE
      PYPPR=CONST*PFIN3R/SINTHE
      PYPR=(YR*PYRPR+YTH*PYTPR+YPH*PYPPR)/Y
      PYRPT=-CONST*PFIN1T
      PYTPT=-CONST*(PFIN2T/SINTHE+HTHETA*COSTHE/SINTHE)
      PYPPT=CONST*(PFIN3T/SINTHE-HPHI*COSTHE/SINTHE)
      PYPTH=(YR*PYRPT+YTH*PYTPT+YPH*PYPPT)/Y
      PYRPP=-CONST*PFIN1P
      PYTPP=-CONST*PFIN2P/SINTHE
      PYPPP=CONST*PFIN3P/SINTHE
      PYPPH=(YR*PYRPP+YTH*PYTPP+YPH*PYPPP)/Y
```

```
RETURN
END
BLOCK DATA
COMMON/YY/MODY(2)
REAL MODY
DATA MODY/3HHAR,3HMNY/
END
```

APPENDIX 21

```
 TT:=EXPZ.FOR
C      SUBROUTINE EXPZ
       SUBROUTINE COLFRZ
C          EXPONENTIAL COLLISION FREQUENCY MODEL
       COMMON /CONST/ PI,PIT2,PID2,DUM(5)
       COMMON /ZZ/ MODZ(2),Z,PZPR,PZPTH,PZPPH
       COMMON R(6) /WW/ ID(10),WO,W(400)
       REAL NU,NUO,MODZ,ID
       EQUIVALENCE (EARTHR,W(2)),(F,W(6)),(NUO,W(251)),(HO,W(252)),
      1 (A,W(253))
       H=R(1)-EARTHR
       NU=NUO/EXP (A*(H-HO))
       Z=NU/(PIT2*F*1.E6)
       PZPR    =-A*Z
       RETURN
          END
       BLOCK DATA
       COMMON/ZZ/MODZ(2)
       REAL MODZ
       DATA MODZ/3H EX,3HPZ /
       END
*
```

```
TT:=EXPZ2.FOR
C     SUBROUTINE EXPZ2
      SUBROUTINE COLFRZ
C           COLLISION FREQUENCY PROFILE FROM TWO EXPONENTIALS
      COMMON /CONST/ PI,PIT2,PID2,DUM(5)
      COMMON /ZZ/ MODZ(2),Z,PZPR,PZPTH,PZPPH
      COMMON R(6) /WW/ ID(10),WO,W(400)
      EQUIVALENCE (EARTHR,W(2)),(F,W(6)),(NU1,W(251)),(H1,W(252)),
     1 (A1,W(253)),(NU2,W(254)),(H2,W(255)),(A2,W(256))
      REAL NU1,NU2,MODZ,ID
      H=R(1)-EARTHR
      EXP1= NU1* EXP(-A1*(H-H1))
      EXP2= NU2* EXP(-A2*(H-H2))
      Z=(EXP1+EXP2)/(PIT2*F*1.E6)
      PZPR=(-A1*EXP1-A2*EXP2)/(PIT2*F*1.E6)
      RETURN
         END
      BLOCK DATA
      COMMON/ZZ/MODZ(2)
      REAL MODZ
      DATA MODZ/3H EX,3HPZ2/
      END
*
```

```
TT:=TEST1.FOR
X01   TEST CASE
  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
 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
 24   78.5         1      ACCEPTED STANDARD LAT. OF NORTH MAGNETIC POLE, DEG
 25   291.         1      ACCEPTED STANDARD LONG. OF NORTH MAGNETIC POLE, DEG
 57   2.                  INTEGRATE AND PRINT PHASE PATH
 58   2.                  INTEGRATE AND PRINT ABSORPTION
 71   5.0                 NUMBER OF STEPS FOR EACH PRINTING
101   6.5                 CRITICAL FREQUENCY, MHZ
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.                LAMBDAX, HORIZONTAL WAVELENGTH, KM
156   100.                LAMBDAZ, VERTICAL WAVELENGTH, KM
201   0.8                 GYROFREQUENCY ON THE GROUND AT THE EQUATOR, MHZ
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
                          BLANK CARD
  $
```

```
  R PIP
 $TT:=TEST2.FOR
 X01  TEST CASE
   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
  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
  24  78.5        1         ACCEPTED STANDARD LAT. OF NORTH MAGNETIC POLE, DEG
  25  291.        1         ACCEPTED STANDARD LONG. OF NORTH MAGNETIC POLE, DEG
  41  3.                    INTEGRATION TYPE
  42  1.        E-4         MAX ERROR
  43 50.0                   DENOMINATOR OF ERATIO
  46  1.        E-8         MIN STEP
  47  0.50                  STEP FACTOR
  57  2.                    INTEGRATE AND PRINT PHASE PATH
  58  2.                    INTEGRATE AND PRINT ABSORPTION
  71  5.0                   NUMBER OF STEPS FOR EACH PRINTING
 100  1.                    READ TABLE OF ENECTRON DENSITY VALUES
 101  6.5                   CRITICAL FREQUENCY, MHZ
 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.                  LAMBDAX, HORIZONTAL WAVELENGTH, KM
 156  100.                  LAMBDAZ, VERTICAL WAVELENGTH, KM
 200  1.                    READ COEFFICIENTS FOR MAGNETIC FIELD
 201  0.8                   GYROFREQUENCY ON THE GROUND AT THE EQUATOR, MHZ
 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
                            BLANK CARD
   .000000
  +.300953 +.020298
  +.028106 -.05214   -.014435
  -.0308   +.06560   -.025252  -.006952
  -.041243 -.043956  -.016897  +.008021  -.002525
  +.014742 -.037078  -.018906  +.002819  +.003656  +.000036
  -.006713 -.012234  -.004364  +.02137   +.001593  -.000072  +.00068
   .000000
   .000000 -.057886
   .000000 +.035942  +.001129
   .000000 +.011084  -.004421  +.001180
   .000000 -.010299  +.008794  -.000086  +.002256
   .000000 -.003849  -.012615  +.007845  +.002207  -.000328
   .000000 +.003157  -.012670  -.009281  +.002286  -.000135  +.000243
 *
```

```
  TT:=TEST3.FOR
X01  TEST CASE
  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
 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
 24  78.5       1     ACCEPTED STANDARD LAT. OF NORTH MAGNETIC POLE, DEG
 25  291.       1     ACCEPTED STANDARD LONG. OF NORTH MAGNETIC POLE, DEG
 57  2.               INTEGRATE AND PRINT PHASE PATH
 58  2.               INTEGRATE AND PRINT ABSORPTION
 71  5.0              NUMBER OF STEPS FOR EACH PRINTING
100  1.               READ TABLE OF ELECTRON DENSITY VALUES
101  6.5              CRITICAL FREQUENCY, MHZ
102  300.0            HMAX, KM
103  62.              SCALE HEIGHT, KM
104  0.5              ALPHA CHAPMAN LAYER
150  1.               CALL PERTURBATION SUBROUTINE
151  250.             ZO, KM
152 100.              SH, SCALE HEIGHT, KM
153  0.1              DELTA
155  100.             LAMBDAX, HORIZONTAL WAVELENGTH, KM
156  100.             LAMBDAZ, VERTICAL WAVELENGTH, KM
201  0.8              GYROFREQUENCY ON THE GROUND AT THE EQUATOR, MHZ
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
                      BLANK CARD
   31
   87.580  1.
   90.535  2.
   93.642  4.
   96.926  8.
  100.400  16.
  104.091  32.
  108.028  64.
  112.245  128.
  116.787  256.
  121.709  512.
  127.085  1024.
  133.008  2048.
  147.069  8192.
  155.668  16384.
  165.819  32768.
  170.000  42084.
  180.000  71183.
  190.000  110007.
  200.000  157431.
  210.000  211034.
  220.000  267573.
  230.000  323564.
  240.000  375810.
```

250.000	421772.
260.000	459732.
270.000	488011.
280.000	508853.
285.000	515596.
290.000	520268.
295.000	522979.
300.000	523853.

*

```
R PIP
$
TT:=TEST5.FOR
X01  TEST CASE
  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
 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
 24  78.5          1         ACCEPTED STANDARD LAT. OF NORTH MAGNETIC POLE, DEG
 25  291.          1         ACCEPTED STANDARD LONG. OF NORTH MAGNETIC POLE, DEG
 41  3.                      INTEGRATION TYPE
 42  1.          E-4         MAX ERROR
 43  50.0                    DENOMINATOR OF ERATIO
 46  1.          E-8         MIN STEP
 47  0.50                    STEP FACTOR
 57  2.                      INTEGRATE AND PRINT PHASE PATH
 58  2.                      INTEGRATE AND PRINT ABSORPTION
 71  5.0                     NUMBER OF STEPS FOR EACH PRINTING
100  1.                      READ TABLE OF ELECTRON DENSITY VALUES
101  6.5                     CRITICAL FREQUENCY, MHZ
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.                    LAMBDAX, HORIZONTAL WAVELENGTH, KM
156  100.                    LAMBDAZ, VERTICAL WAVELENGTH, KM
200  1.                      READ COEFFICIENTS FOR MAGNETIC FIELD
201  0.8                     GYROFREQUENCY ON THE GROUND AT THE EQUATOR, MHZ
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
                             BLANK CARD
   .000000
  +.300953 +.020298
  +.028106 -.05214   -.014435
  -.0308   +.06560   -.025252  -.006952
  -.041243 -.043956  -.016897  +.008021  -.002525
  +.014742 -.037078  -.018906  +.002819  +.003656  +.000036
  -.006713 -.012234  -.004364  +.02137   +.001593  -.000072  +.00068
   .000000
   .000000 -.057886
   .000000 +.035942  +.001129
   .000000 +.011084  -.004421  +.001180
   .000000 -.010299  +.008794  -.000086  +.002256
   .000000 -.003849  -.012615  +.007845  +.002207  -.000328
   .000000 +.003157  -.012670  -.009281  +.002286  -.000135  +.000243
  31
  87.580  1.
  90.535  2.
  93.642  4.
```

96.926	8.
100.400	16.
104.091	32.
108.028	64.
112.245	128.
116.787	256.
121.709	512.
127.085	1024.
133.008	2048.
147.069	8192.
155.668	16384.
165.819	32768.
170.000	42084.
180.000	71183.
190.000	110007.
200.000	157431.
210.000	211034.
220.000	267573.
230.000	323564.
240.000	375810.
250.000	421772.
260.000	459732.
270.000	488811.
280.000	508853.
285.000	515594.
290.000	520268.
295.000	522979.
300.000	523853.

*

APPENDIX 27

```
X01  TEST CASE                                                                    4 678

CHAPX  WAVE    DIPOLY    EXPZ2               APPLETON-HARTREE FORMULA    EXTRAORDINARY    WITH COLLISIONS

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

   1 -1.00000000000E+00
   2  6.37000000000E+03
   4  6.98131680489E-01
   5 -1.83259570599E+00
   7  6.00000000000E+00
  11  7.85398185253E-01
  16  1.57079637051E+00
  17  2.61799395084E-01
  20  2.00000000000E+02
  22  3.00000000000E+00
  23  1.00000000000E+03
  24  1.37008345127E+00
  25  5.07890796661E+00
  41  3.00000000000E+00
  42  9.99999974738E-05
  43  5.00000000000E+01
  44  1.00000000000E+00
  45  1.00000000000E+02
  46  9.99999993923E-09
  47  5.00000000000E-01
  57  2.00000000000E+00
  58  2.00000000000E+00
  71  5.00000000000E+00
 101  6.50000000000E+00
 102  3.00000000000E+02
 103  6.20000000000E+01
 104  5.00000000000E-01
 150  1.00000000000E+00
 151  2.50000000000E+02
 152  1.00000000000E+02
 153  1.00000001490E-01
 155  1.00000000000E+02
 156  1.00000000000E+02
 201  8.00000011921E-01
 251  3.65000000000E+04
 252  1.00000000000E+02
 253  1.48000001907E-01
 254  3.00000000000E+01
 255  1.40000000000E+02
 256  1.83000005782E-02
```

X01 TEST CASE 4 678

CHAPX WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 0.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08	XMTR	0.0000	0.0007				0.000	0.000	-1.000	0.0000	0.0000	0.0000
-1.E-07	ENTR ION	73.9033	965.6646	45.000	-0.000	-0.000	8.686	0.095	-2.709	973.1300	973.1300	0.0000
-2.E-07		91.9331	1075.7850	45.000	-0.000	0.000	9.675	0.010	-3.547	1086.1300	1086.1299	0.0007
-1.E-07		105.8511	1153.3594	45.000	-0.000	-0.000	10.357	0.002	-4.690	1166.1300	1166.1268	0.0022
-2.E-07		120.6396	1230.5894	45.000	0.000	-0.005	10.908	0.000	-6.775	1246.1300	1246.0909	0.0045
2.E-06		135.8042	1307.4519	45.000	0.003	-0.033	10.787	0.000	-7.845	1326.1300	1325.8309	0.0066
-2.E-06		149.4229	1383.9340	44.999,	-0.020	-0.156	8.589	0.000	-4.021	1406.1300	1404.6534	0.0082
-5.E-06		155.2788	1429.6499	44.999	0.036	-0.330	5.618	0.000	-2.535	1454.1300	1451.1095	0.0091
-6.E-06		157.8027	1467.6357	44.999	0.032	-0.565	2.165	0.000	-1.921	1494.1300	1489.2479	0.0100
-1.E-07	MIN DIST	158.1475	1491.1564	44.998	-0.029	-0.753	0.000	0.000	-1.720	1518.9016	1512.7781	0.0105
-1.E-07	MIN DIST	158.1475	1491.1564	44.998	-0.029	-0.753	0.000	0.000	-1.720	1518.9016	1512.7781	0.0105
-5.E-07	WAVE REV	158.1182	1494.9558	44.998	-0.039	-0.786	-0.341	0.000	-1.695	1522.9016	1516.5803	0.0106
-2.E-06		151.2544	1583.3795	44.992	0.028	-1.756	-7.550	0.000	-1.385	1615.9016	1605.6678	0.0126
3.E-06		138.2036	1659.7026	44.993	0.024	-2.782	-10.588	0.000	-1.318	1695.9016	1684.0900	0.0143
5.E-06		108.1387	1813.6451	44.994	0.016	-4.796	-10.484	0.000	-1.341	1855.9016	1843.6638	0.0191
8.E-06		80.8872	1969.0037	44.996	0.015	-6.536	-9.113	0.008	-1.403	2015.9016	2003.6583	0.0217
8.E-06	EXIT ION	71.0610	2031.5000	44.996	0.014	-7.161	-8.551	0.034	-1.430	2079.9016	2067.6582	0.0219
-1.E-07	GRND REF	0.0000	2899.6401	45.000	0.010	-13.041	0.742	0.001	-1.000	2955.0845	2942.8411	0.0229
-6.E-08	ENTR ION	73.8477	3785.9297	45.003	0.008	-15.948	8.714	-0.068	2.218	3848.8345	3836.5911	0.0229
-2.E-07		94.6484	3911.5823	45.003	0.008	-16.259	9.842	-0.002	1.948	3977.8345	3965.5908	0.0238
-1.E-06	MAX LAT	105.8896	3973.6094	45.003	0.008	-16.406	10.385	-0.000	1.850	4041.8345	4029.5876	0.0252
-1.E-06	WAVE REV	105.8896	3973.6094	45.003	0.008	-16.406	10.385	-0.000	1.850	4041.8345	4029.5876	0.0252
-5.E-06		123.7598	4066.2302	45.004	0.009	-16.620	10.986	-0.000	1.750	4137.8345	4125.5269	0.0281
-5.E-06		147.0796	4188.8491	45.004	0.032	-16.923	9.041	-0.000	1.889	4265.8345	4252.3818	0.0313
-4.E-06		156.4619	4264.9683	45.006	0.047	-17.183	3.776	-0.000	3.082	4345.8345	4329.6294	0.0329
-6.E-08	MIN DIST	157.9038	4304.2812	45.007	0.074	-17.362	-0.000	-0.000	9.340	4387.2407	4369.0029	0.0339

X01 TEST CASE 4 678

CHAPX WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 15.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-1.E-07 XMTR	0.0000	0.0007				15.000	0.001	-1.000	0.0000	0.0000	0.0000
-6.E-08 ENTR ION	73.9321	253.9318	45.000	-0.000	15.000	17.284	0.614	-13.532	265.8701	265.8701	0.0000
1.E-07	91.0967	307.5912	45.000	-0.000	15.000	17.766	0.312	-86.387	322.8701	322.8701	0.0003
0.E-01	103.4126	345.0749	45.000	-0.000	15.000	18.098	-0.018	31.323	362.8701	362.8690	0.0010
1.E-06	126.0723	412.1809	45.000	0.000	14.991	18.524	-0.000	10.422	434.8701	434.8199	0.0030
3.E-05	150.8208	486.1591	45.000	0.010	14.851	17.031	-0.000	91.486	514.8701	513.9419	0.0047
-8.E-06	161.2964	522.8812	45.001	0.004	14.581	13.847	0.000	-4.812	554.8701	552.1654	0.0056
1.E-06	168.7964	559.5234	44.993	-0.082	14.054	8.984	0.000	-2.219	594.8701	589.0740	0.0066
-3.E-06	172.1084	595.9678	44.985	0.142	13.213	1.841	0.000	-1.558	634.8701	624.6326	0.0078
-6.E-08 MIN DIST	172.1396	604.1019	44.985	0.184	12.975	0.000	0.000	-1.481	643.8510	632.4653	0.0081
-6.E-08 MIN DIST	172.1396	604.1019	44.985	0.184	12.975	0.000	0.000	-1.481	643.8510	632.4653	0.0081
8.E-07 WAVE REV	172.0664	607.7208	44.986	0.196	12.864	-0.820	0.000	-1.452	647.8510	635.9481	0.0082
-3.E-05	153.8276	706.9570	44.974	-0.078	8.942	-15.755	0.000	-1.173	756.8510	735.2618	0.0114
-3.E-05	130.0049	780.9001	44.967	-0.036	5.835	-18.205	0.000	-1.154	836.8510	813.9053	0.0133
-3.E-05	105.1514	855.5070	44.963	-0.032	3.093	-17.862	0.000	-1.162	916.8510	893.8059	0.0160
-3.E-05	81.0537	930.6913	44.961	-0.030	0.752	-17.194	0.003	-1.174	996.8510	973.8041	0.0173
-3.E-05 EXIT ION	71.6670	960.9203	44.960	-0.029	-0.088	-16.923	0.012	-1.178	1028.8511	1005.8041	0.0174
-6.E-08 GRND REF	0.0000	1212.9148	44.954	-0.023	-5.455	14.656	-0.002	1.000	1292.1829	1269.1359	0.0177
0.E-01 ENTR ION	73.9004	1472.1527	44.950	-0.019	-3.776	16.988	-0.103	2.862	1563.1730	1540.1260	0.0177
-6.E-08	93.1899	1533.4208	44.949	-0.018	-3.460	17.538	-0.005	2.543	1628.1730	1605.1259	0.0181
-2.E-06	117.7251	1608.3182	44.948	-0.017	-3.107	18.151	-0.000	2.274	1708.1730	1685.1111	0.0201
-1.E-05	142.5928	1682.6185	44.948	-0.025	-2.804	17.739	-0.000	2.288	1788.1730	1764.7189	0.0222
-2.E-05	163.8271	1756.1754	44.949	0.010	-2.669	12.055	-0.000	7.856	1868.1730	1841.5321	0.0238
2.E-05	170.0366	1792.7699	44.947	-0.190	-2.751	6.651	0.000	-4.384	1908.1730	1877.9774	0.0249
-1.E-07 MIN DIST	171.9580	1828.6050	44.941	-0.066	-2.959	-0.000	0.000	-1.952	1947.3944	1912.8746	0.0261

X01 TEST CASE 4 678

CHAPX WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 30.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
0.E-01 XMTR	0.0000	0.0007				30.000	-0.000	1.000	0.0000	0.0000	0.0000
0.E-01 ENTR ION	73.8428	124.3390	45.000	-0.000	30.000	31.118	-0.034	1.616	145.2300	145.2300	0.0000
0.E-01	88.8779	148.8246	45.001	-0.001	30.000	31.338	-0.003	1.591	174.2300	174.2300	0.0001
-2.E-07	107.6729	179.0615	45.000	-0.000	30.000	31.604	-0.000	1.562	210.2300	210.2284	0.0008
-1.E-06	128.6909	212.4488	45.000	-0.001	29.993	31.772	-0.000	1.539	250.2300	250.1854	0.0020
5.E-06	149.5332	245.5833	45.003	0.009	29.933	31.058	-0.000	1.576	290.2300	289.7294	0.0029
-1.E-05	168.8418	278.3580	45.012	-0.072	29.650	27.526	-0.000	1.905	330.2300	327.3932	0.0038
2.E-05	184.2109	310.7926	45.016	0.038	28.894	19.801	-0.000	7.904	370.2300	361.4309	0.0052
2.E-06	191.3882	342.6454	45.027	0.440	27.277	5.738	0.000	-1.890	410.2300	390.3874	0.0073
-6.E-08 MIN DIST	191.5645	354.9407	45.023	0.219	26.398	-0.000	0.000	-1.530	425.7919	400.9610	0.0082
-6.E-08 MIN DIST	191.5645	354.9407	45.023	0.219	26.398	-0.000	0.000	-1.530	425.7919	400.9610	0.0082
3.E-06	172.2686	426.8875	44.865	-0.735	19.783	-23.513	0.000	-1.113	514.7919	468.9292	0.0125
2.E-05	135.6958	493.7141	44.765	-0.521	12.986	-29.961	0.000	-1.076	594.7919	544.6794	0.0146
2.E-05	95.7856	561.7269	44.702	-0.455	7.074	-29.718	0.000	-1.080	674.7919	624.5452	0.0172
2.E-05 EXIT ION	72.1250	602.9461	44.671	-0.424	4.067	-29.349	0.005	-1.083	722.7919	672.5450	0.0176
-6.E-08 GRND REF	0.0000	733.6045	44.595	-0.349	-3.299	28.173	-0.000	1.000	872.6821	822.4351	0.0179
-6.E-08 ENTR ION	73.7964	867.2018	44.541	-0.295	0.929	29.375	-0.028	1.520	1025.9821	975.7351	0.0179
-2.E-07	75.7593	870.6461	44.540	-0.294	1.021	29.406	-0.021	1.518	1029.9821	979.7351	0.0179
-3.E-05	137.9087	977.2224	44.508	-0.265	3.538	29.950	-0.000	1.463	1154.9821	1104.5828	0.0205
-1.E-05	164.5547	1024.1208	44.499	-0.229	4.389	26.666	-0.000	1.651	1210.9821	1158.5614	0.0217
-1.E-05	179.9297	1057.2023	44.492	-0.454	4.751	20.168	-0.000	2.738	1250.9821	1193.6320	0.0230
6.E-07	188.9844	1089.9198	44.486	0.158	4.771	8.455	0.000	-3.460	1290.9821	1224.6732	0.0248
1.E-07 MIN DIST	189.8228	1107.5205	44.486	0.453	4.581	0.000	0.000	-1.771	1312.8683	1240.1008	0.0260

X01 TEST CASE 4 678

CHAPX WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 45.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO DB	RPTN
-6.E-08 XMTR	0.0000	0.0007				45.000	-0.000	1.000	0.0000	0.0000		0.0000
0.E-01 ENTR ION	73.7090	72.4552	45.000	-0.000	45.000	45.652	-0.011	1.219	103.6500	103.6500		0.0000
-6.E-08	94.4785	92.4302	45.000	-0.000	45.000	45.831	-0.001	1.214	132.6500	132.6499		0.0002
-1.E-07	108.8389	106.1317	45.000	0.000	45.000	45.949	-0.000	1.211	152.6500	152.6485		0.0007
-3.E-07	123.2202	119.7706	45.000	-0.000	44.998	46.034	-0.000	1.208	172.6500	172.6342		0.0014
7.E-06	160.1025	154.8466	45.008	-0.028	44.901	44.711	-0.000	1.230	224.6500	223.5938		0.0026
6.E-05	185.4258	181.1429	45.034	0.010	44.439	39.009	-0.000	1.385	264.6500	258.2266		0.0040
0.E-01 RCVR	200.0000	200.2017	45.132	0.607	43.622	28.479	-0.000	2.293	295.1649	278.4394		0.0058
3.E-06	209.6841	233.2601	45.069	-1.590	40.436	4.780	0.000	-1.976	348.1649	304.3961		0.0095
0.E-01 APOGEE	209.6831	235.8634	45.040	-1.746	40.109	3.110	0.000	-1.831	352.1649	306.3130		0.0098
-2.E-06 WAVE REV	209.4355	241.0973	44.979	-1.982	39.430	-0.266	0.000	-1.623	360.1649	310.1891		0.0103
-8.E-07	205.9614	259.5199	44.756	-2.001	36.819	-12.893	0.000	-1.268	388.1649	324.3166		0.0122
-1.E-07 RCVR	200.0000	274.3787	44.611	-1.415	34.427	-23.455	0.000	-1.142	410.8530	336.8366		0.0137
9.E-06	172.6328	311.8737	44.453	-0.183	27.233	-41.318	0.000	-1.041	467.8530	377.6485		0.0169
5.E-06	117.8521	366.4801	44.432	-0.033	16.021	-45.154	0.000	-1.031	547.8530	454.5205		0.0193
6.E-06	89.5474	394.2845	44.430	-0.030	10.932	-44.927	0.000	-1.032	587.8530	494.5124		0.0204
7.E-06 EXIT ION	72.6206	411.0853	44.429	-0.029	8.110	-44.776	0.002	-1.033	611.8530	518.5124		0.0206
0.E-01 GRND REF	0.0000	484.7055	44.424	-0.025	-2.180	44.114	-0.000	1.000	715.5610	622.2204		0.0208
0.E-01 ENTR ION	73.6787	559.3801	44.421	-0.021	4.940	44.786	-0.011	1.205	820.7711	727.4304		0.0208
0.E-01	76.4971	562.1852	44.421	-0.021	5.170	44.811	-0.007	1.204	824.7711	731.4304		0.0208
-2.E-06	119.6260	604.6624	44.419	-0.020	8.362	45.165	-0.000	1.194	885.7711	792.4208		0.0220
1.E-05	147.8516	632.1733	44.419	-0.009	10.164	44.788	-0.000	1.199	925.7711	832.0873		0.0231
-3.E-05	174.4380	659.1933	44.422	-0.164	11.653	41.313	-0.000	1.264	965.7711	869.1633		0.0242
5.E-05	195.9644	685.2405	44.440	0.497	12.634	31.268	-0.000	1.691	1005.7711	899.3861		0.0261
0.E-01 RCVR	200.0000	691.5146	44.452	0.797	12.770	26.953	-0.000	2.159	1015.8576	905.3724		0.0268

X01 TEST CASE 4 678

CHAPX WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 60.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08	XMTR	0.0000	0.0007				60.000	-0.000	1.000	0.0000	0.0000	0.0000
-6.E-08	ENTR ION	73.5786	41.9165	45.000	-0.000	60.000	60.377	-0.005	1.103	84.8000	84.8000	0.0000
-6.E-08		86.6226	49.2313	45.000	0.000	60.000	60.443	-0.001	1.103	99.8000	99.8000	0.0001
-3.E-07		105.7681	59.9058	45.001	-0.001	60.000	60.537	-0.000	1.101	121.8000	121.7993	0.0005
-5.E-07		123.1816	69.5549	45.001	-0.001	59.999	60.599	-0.000	1.100	141.8000	141.7858	0.0012
1.E-05		161.0273	90.5114	45.013	0.018	59.944	59.791	-0.000	1.107	185.8000	184.8515	0.0023
-2.E-05		191.4844	108.5942	45.122	-0.136	59.584	54.129	-0.000	1.185	225.8000	217.2836	0.0041
0.E-01	RCVR	200.0000	114.4181	45.157	-0.851	59.325	50.578	-0.000	1.250	239.2548	225.6340	0.0050
1.E-04		224.6064	137.5934	45.234	0.796	57.441	24.698	-0.000	5.656	296.2548	248.7593	0.0090
-9.E-05	APOGEE	225.8384	146.6923	45.355	5.402	55.872	-5.298	0.000	-2.002	324.2548	253.2678	0.0114
-9.E-05	WAVE REV	225.8384	146.6923	45.355	5.402	55.872	-5.298	0.000	-2.002	324.2548	253.2678	0.0114
-1.E-04		221.4155	153.9709	45.523	9.624	54.028	-33.727	0.000	-1.188	348.2548	257.0922	0.0134
-3.E-05		204.2334	166.0794	46.210	16.099	49.687	-60.227	0.000	-1.030	388.2548	269.8035	0.0168
0.E-01	RCVR	200.0000	168.1634	46.383	16.876	48.744	-62.499	0.000	-1.025	395.1216	273.3152	0.0173
-1.E-05		153.9590	185.8712	48.075	16.994	38.460	-69.419	0.000	-1.013	452.1216	318.1385	0.0200
-3.E-05		116.7266	198.8440	49.206	15.804	29.290	-69.701	0.000	-1.013	492.1216	357.6174	0.0213
-2.E-05		79.2275	212.0596	50.215	14.796	19.415	-69.586	0.000	-1.013	532.1216	397.6118	0.0223
-2.E-05	EXIT ION	71.7310	214.7285	50.403	14.608	17.408	-69.561	0.001	-1.013	540.1216	405.6118	0.0223
-6.E-08	GRND REF	0.0000	240.7109	52.010	13.003	-1.083	69.320	-0.000	1.000	616.7315	482.2217	0.0224
0.E-01	ENTR ION	73.4365	267.4610	53.330	11.684	14.064	69.567	-0.003	1.051	695.1615	560.6517	0.0224
-4.E-06		111.8716	281.2508	53.910	11.104	20.251	69.690	-0.000	1.050	736.1615	601.6495	0.0232
-1.E-06		149.2188	294.5438	54.420	10.623	25.270	69.525	-0.000	1.050	776.1615	641.3242	0.0244
-3.E-05		184.0361	307.3666	54.887	9.368	29.163	66.871	-0.000	1.069	816.1615	676.5712	0.0259
-1.E-07	RCVR	200.0000	313.9101	55.115	8.555	30.682	63.564	-0.000	1.099	837.6989	691.0789	0.0271

X01 TEST CASE 4 678

CHAPX WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 75.000000 DEG

		HEIGHT	RANGE	AZIMUTH REAL XMTR	AZIMUTH DEVIATION LOCAL	ELEVATION XMTR	ELEVATION LOCAL	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH	PHAS PATH	ABSD RPTN
		KM	KM	DEG	DEG	DEG	DEG			KM	KM	DB
-6.E-08	XMTR	0.0000	0.0007				75.000	-0.000	1.000	0.0000	0.0000	0.0000
-6.E-08	ENTR ION	73.4502	19.4483	45.004	-0.004	75.000	75.175	-0.002	1.048	76.0100	76.0100	0.0000
-2.E-07		87.9521	23.2345	45.001	-0.001	75.000	75.209	-0.000	1.047	91.0100	91.0100	0.0001
-2.E-07		105.3569	27.7550	45.001	-0.001	75.000	75.249	-0.000	1.047	109.0100	109.0094	0.0005
-1.E-06		124.6909	32.7481	45.002	-0.001	75.000	75.279	-0.000	1.046	129.0100	128.9934	0.0012
2.E-07		143.9453	37.7001	45.007	-0.009	74.995	75.208	-0.000	1.047	149.0100	148.8246	0.0018
-6.E-06		177.1914	46.3821	45.057	-0.324	74.928	73.968	-0.000	1.056	185.0100	181.9999	0.0029
1.E-07	RCVR	200.0000	52.6870	45.303	1.333	74.783	71.357	-0.000	1.087	213.9179	202.1282	0.0046
4.E-05		224.9438	60.6692	46.678	1.369	74.379	52.074	-0.000	1.568	266.9179	217.2921	0.0091
2.E-04		230.7998	66.1620	46.711	-7.397	73.432	15.569	0.000	-9.826	306.9179	220.0211	0.0127
2.E-04	APOGEE	230.9185	67.5501	46.511	-8.854	73.111	8.237	0.000	-3.876	314.9179	220.4672	0.0134
6.E-05	WAVE REV	225.7690	79.1322	44.185	-13.731	70.012	-22.644	0.000	-1.247	362.9179	225.4475	0.0174
4.E-05		217.2280	89.9847	42.090	-14.313	66.749	-35.075	0.000	-1.085	394.9179	232.7583	0.0200
1.E-07	RCVR	200.0000	106.6322	39.488	-13.543	61.083	-46.475	0.000	-1.024	434.9711	249.2759	0.0232
2.E-05		161.6694	134.6167	36.458	-11.278	49.255	-55.293	0.000	-1.007	491.9711	291.7818	0.0263
-2.E-05		129.0156	155.6996	34.908	-9.754	38.661	-56.406	0.000	-1.006	531.9711	330.5991	0.0275
-2.E-06		95.7305	177.1835	33.715	-8.562	27.405	-56.281	0.000	-1.006	571.9711	370.5615	0.0289
-2.E-07	EXIT ION	69.1382	194.5781	32.945	-7.792	18.587	-56.124	0.001	-1.006	603.9711	402.5614	0.0292
0.E-01	GRND REF	0.0000	240.7632	31.443	-6.291	-1.083	55.705	-0.000	1.000	687.4501	486.0404	0.0293
0.E-01		0.0000	240.7632	31.443	-6.291	-1.083	55.705	-0.000	1.000	687.4501	486.0404	0.0293
-6.E-08	ENTR ION	73.5981	290.0073	30.371	-5.220	12.855	56.150	-0.007	1.135	776.3001	574.8904	0.0293
-6.E-06		121.0083	321.0473	29.865	-4.715	19.026	56.408	-0.000	1.130	833.3001	631.8800	0.0304
2.E-05		154.0586	342.5135	29.570	-4.420	22.416	55.867	-0.000	1.135	873.3001	671.3331	0.0315
5.E-05		184.5840	363.3682	29.321	-4.203	24.958	51.748	-0.000	1.198	913.3001	706.5306	0.0328
0.E-01	RCVR	200.0000	375.3563	29.205	-3.644	25.986	45.375	-0.000	1.374	937.9622	722.8931	0.0343

AD-A068 367 ARMY COMMUNICATIONS RESEARCH AND DEVELOPMENT COMMAND --ETC F/G 4/1
RUNNING AN IONOSPHERIC RAY TRACING PROGRAM ON THE PDP-11/40 MIN--ETC(U)
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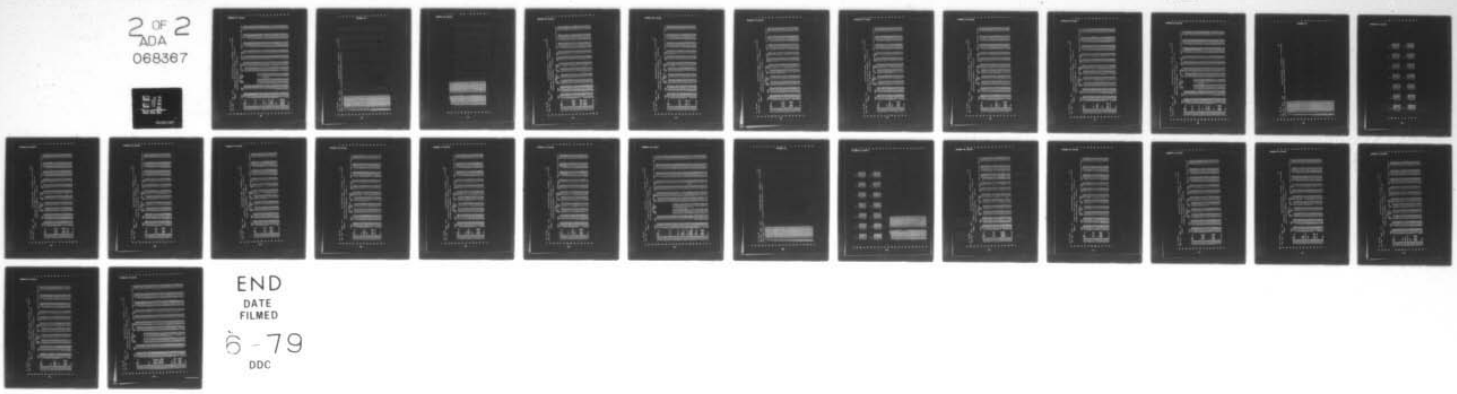

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X01 TEST CASE 4 678

CHAPX WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 90.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH DEVIATION REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08	XMTR	0.0000	0.0007				90.000	-0.000	1.000	0.0000	0.0000	0.0000
0.E-01	ENTR ION	73.3599	0.0006			89.999	90.000	-0.001	1.019	73.3600	73.3600	0.0000
0.E-01		77.3599	0.0006			90.000	90.000	-0.001	1.019	77.3600	77.3600	0.0000
0.E-01		81.8599	0.0006			90.000	90.000	-0.000	1.019	81.8600	81.8600	0.0000
0.E-01		86.8599	0.0006			90.000	90.000	-0.000	1.019	86.8600	86.8600	0.0001
-6.E-08		91.8599	0.0006			90.000	90.000	-0.000	1.018	91.8600	91.8600	0.0001
0.E-01		101.8599	0.0006			90.000	90.000	-0.000	1.018	101.8600	101.8597	0.0004
0.E-01		106.8594	0.0007			90.000	90.000	-0.000	1.018	106.8600	106.8592	0.0005
0.E-01		111.8589	0.0006			90.000	90.000	-0.000	1.018	111.8600	111.8579	0.0007
-6.E-08		116.8569	0.0005			90.000	90.000	-0.000	1.018	116.8600	116.8551	0.0009
0.E-01	WAVE REV	120.3550	0.0006			90.000	90.000	-0.000	1.018	120.3600	120.3515	0.0010
0.E-01		123.3525	0.0008			90.000	90.000	-0.000	1.018	123.3600	123.3467	0.0012
1.E-07		136.3184	0.0027	-178.810	9.076	89.999	89.998	-0.000	1.018	136.3600	136.2850	0.0016
-4.E-07		146.2319	0.0095	-173.647	3.914	89.996	89.990	-0.000	1.018	146.3600	146.1300	0.0019
7.E-07		156.0244	0.0258	-170.933	1.199	89.990	89.974	-0.000	1.019	156.3600	155.7572	0.0021
1.E-06		165.5923	0.0592	-170.335	0.601	89.979	89.962	-0.000	1.019	166.3600	164.9880	0.0024
2.E-06		173.9082	0.1062	-170.033	0.299	89.964	89.994	-0.000	1.020	175.3600	172.7839	0.0028
-6.E-07	WAVE REV	174.8105	0.1133	-170.038	-179.696	89.962	89.997	-0.000	1.020	176.3600	173.6137	0.0028
-9.E-07		182.7124	0.1754	-169.906	-179.828	89.943	89.845	-0.000	1.022	185.3600	180.7126	0.0033
0.E-01	RCVR	200.0000	0.3027	-169.834	-179.899	89.911	88.779	-0.000	1.030	207.1659	194.9666	0.0047
-6.E-06		218.5596	0.3932	-169.827	-179.907	89.893	87.446	-0.000	1.047	236.1659	207.6858	0.0069
-2.E-05		227.9863	0.7708	-169.779	-179.955	89.799	89.319	-0.000	1.054	256.1660	212.5943	0.0084
2.E-05	WAVE REV	230.2100	0.9816	-169.762	0.028	89.747	89.207	-0.000	1.052	262.1660	213.5203	0.0089
-1.E-03		237.7422	2.9001	-169.747	0.013	89.275	41.803	-0.000	1.094	298.1660	215.6516	0.0118
-1.E-03	APOGEE	238.2310	3.6107	-169.742	0.009	89.099	-11.164	-0.000	4.507	310.1660	215.7525	0.0127
-1.E-03	WAVE REV	238.2310	3.6107	-169.742	0.009	89.099	-11.164	-0.000	4.507	310.1660	215.7525	0.0127
-1.E-04		234.2695	5.8592	-169.739	0.006	88.515	-56.140	0.000	-1.584	342.1660	216.9642	0.0152
5.E-05		217.8496	11.0414	-169.737	0.004	86.999	-68.476	0.000	-1.160	382.1660	225.6375	0.0183
-1.E-07	RCVR	200.0000	15.3986	-169.736	0.002	85.459	-75.212	0.000	-1.080	411.0555	238.1685	0.0205
2.E-05		151.1553	24.7842	-169.735	0.001	80.468	-79.010	0.000	-1.042	468.0555	282.8988	0.0232
-1.E-05		112.0679	32.1406	-169.735	0.001	73.719	-79.109	0.000	-1.042	508.0555	322.5381	0.0244
2.E-06		72.7939	39.6112	-169.735	0.001	61.131	-79.044	0.002	-1.043	548.0555	362.5357	0.0252
2.E-06	EXIT ION	72.7939	39.6112	-169.735	0.001	61.131	-79.044	0.002	-1.043	548.0555	362.5357	0.0252
-6.E-08	GRND REF	0.0000	53.7056	-169.734	0.001	-0.241	78.917	-0.000	1.000	622.2167	436.6968	0.0253
-6.E-08	ENTR ION	73.3530	67.9072	-169.734	0.001	46.738	79.045	-0.000	1.006	696.9467	511.4268	0.0253
-6.E-08	MAX LONG	77.2803	68.6584	-169.734	0.000	47.900	79.052	-0.000	1.006	700.9467	515.4268	0.0253
-1.E-05		121.4609	77.0443	-169.734	0.000	57.019	79.119	-0.000	1.006	745.9467	560.4161	0.0264
3.E-05		160.2305	84.4043	-169.734	0.000	61.545	78.828	-0.000	1.006	785.9467	599.5110	0.0277
-2.E-06		194.6108	91.5000	-169.734	0.000	64.071	77.606	-0.000	1.006	825.9467	631.1945	0.0296
-2.E-07	RCVR	200.0000	92.7247	-169.734	0.000	64.367	77.232	-0.000	1.006	833.2783	635.5667	0.0301

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X01  TEST CASE                                                            4 678

TABLE  WAVE    DIPOLY   EXPZ2          APPLETON-HARTREE FORMULA    EXTRAORDINARY    WITH COLLISIONS

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

  1 -1.00000000000E+00
  2  6.37000000000E+03
  4  6.98131680489E-01
  5 -1.83259570599E+00
  7  6.00000000000E+00
 11  7.85398185253E-01
 16  1.57079637051E+00
 17  2.61799395084E-01
 20  2.00000000000E+02
 22  3.00000000000E+00
 23  1.00000000000E+03
 24  1.37008345127E+00
 25  5.07890796461E+00
 41  3.00000000000E+00
 42  9.99999974738E-05
 43  5.00000000000E+01
 44  1.00000000000E+00
 45  1.00000000000E+02
 46  9.99999993923E-09
 47  5.00000000000E-01
 57  2.00000000000E+00
 58  2.00000000000E+00
 71  5.00000000000E+00
100  1.00000000000E+00
101  6.50000000000E+00
102  3.00000000000E+02
103  6.20000000000E+01
104  5.00000000000E-01
150  1.00000000000E+00
151  2.50000000000E+02
152  1.00000000000E+02
153  1.00000001490E-01
155  1.00000000000E+02
156  1.00000000000E+02
201  8.00000011921E-01
251  3.65000000000E+04
252  1.00000000000E+02
253  1.48000001907E-01
254  3.00000000000E+01
255  1.40000000000E+02
256  1.83000005782E-02
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HEIGHT	ELECTRON DENSITY
87.5800018311	0.1000000000E+01
90.5350036621	0.2000000000E+01
93.6419982910	0.4000000000E+01
96.9260025024	0.8000000000E+01
100.4000015259	0.1600000000E+02
104.0910034180	0.3200000000E+02
108.0279998779	0.6400000000E+02
112.2450027466	0.1280000000E+03
116.7870025635	0.2560000000E+03
121.7089996338	0.5120000000E+03
127.0849990845	0.1024000000E+04
133.0079956055	0.2048000000E+04
147.0690002441	0.8192000000E+04
155.6679992676	0.1638400000E+05
165.8190002441	0.3276800000E+05
170.0000000000	0.4208400000E+05
180.0000000000	0.7118300000E+05
190.0000000000	0.1100070000E+06
200.0000000000	0.1574310000E+06
210.0000000000	0.2110340000E+06
220.0000000000	0.2675730000E+06
230.0000000000	0.3235640000E+06
240.0000000000	0.3758100000E+06
250.0000000000	0.4217720000E+06
260.0000000000	0.4597320000E+06
270.0000000000	0.4888110000E+06
280.0000000000	0.5088530000E+06
285.0000000000	0.5155960000E+06
290.0000000000	0.5202680000E+06
295.0000000000	0.5229790000E+06
300.0000000000	0.5238530000E+06

X01 TEST CASE 4 678

TABLE WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 0.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08	XMTR	0.0000	0.0007				0.000	0.000	-1.000	0.0000	0.0000	0.0000
-1.E-07	ENTR ION	87.5811	1050.3073	45.000	-0.000	-0.000	9.447	0.017	-3.298	1059.9298	1059.9298	0.0000
-1.E-07		97.1802	1105.6898	45.000	-0.000	-0.000	9.942	0.005	-3.907	1116.9298	1116.9293	0.0007
-1.E-07		104.2036	1144.4550	45.000	-0.000	-0.000	10.282	0.002	-4.519	1156.9298	1156.9275	0.0016
-2.E-07		111.4536	1183.1340	45.000	0.000	-0.001	10.601	0.001	-5.366	1196.9298	1196.9211	0.0027
-2.E-07		118.9043	1221.7251	45.000	0.000	-0.004	10.863	0.000	-6.491	1236.9298	1236.8999	0.0038
1.E-06		138.5352	1321.6274	45.000	0.006	-0.045	10.575	0.000	-7.282	1340.9298	1340.5104	0.0065
4.E-06		151.4922	1398.0459	44.999	-0.015	-0.200	7.847	0.000	-3.466	1420.9298	1419.0636	0.0081
-6.E-06		155.8789	1436.1116	44.999	0.045	-0.364	5.074	0.000	-2.397	1460.9298	1457.6222	0.0089
-5.E-06		157.9990	1474.0894	44.998	0.017	-0.613	1.581	0.000	-1.858	1500.9298	1495.7070	0.0097
-1.E-07	MIN DIST	158.1631	1491.4479	44.998	-0.030	-0.755	0.000	0.000	-1.720	1519.2100	1513.0717	0.0101
-1.E-07	MIN DIST	158.1631	1491.4479	44.998	-0.030	-0.755	0.000	0.000	-1.720	1519.2100	1513.0717	0.0101
-5.E-07	WAVE REV	158.1338	1495.2477	44.997	-0.039	-0.788	-0.339	0.000	-1.695	1523.2100	1516.8740	0.0102
-2.E-07		151.2866	1583.6697	44.993	0.029	-1.757	-7.537	0.000	-1.386	1616.2100	1605.9565	0.0122
-8.E-06		126.1631	1721.3795	44.993	0.016	-3.616	-11.003	0.000	-1.316	1760.2100	1748.0323	0.0156
-9.E-06		111.1060	1798.4691	44.994	0.016	-4.607	-10.608	0.000	-1.336	1840.2100	1827.9491	0.0182
-1.E-05		96.8203	1875.9144	44.995	0.016	-5.525	-9.951	0.001	-1.364	1920.2100	1907.9406	0.0203
-1.E-05	EXIT ION	87.3770	1930.3253	44.995	0.015	-6.127	-9.464	0.003	-1.386	1976.2100	1963.9401	0.0210
0.E-01	GRND REF	0.0000	2901.1787	45.001	0.010	-13.048	0.732	0.001	-1.000	2956.6543	2944.3843	0.0210
0.E-01		0.0000	2901.1787	45.001	0.010	-13.048	0.732	0.001	-1.000	2956.6543	2944.3843	0.0210
0.E-01	ENTR ION	87.5001	3873.2339	45.003	0.008	-16.173	9.475	-0.007	2.023	3938.3342	3926.0642	0.0210
-6.E-08	MAX LAT	104.2495	3967.3733	45.004	0.008	-16.398	10.309	-0.001	1.862	4035.3342	4023.0618	0.0227
-6.E-08	WAVE REV	104.2495	3967.3733	45.004	0.008	-16.398	10.309	-0.001	1.862	4035.3342	4023.0618	0.0227
-3.E-07		107.1309	3982.8538	45.004	0.008	-16.434	10.440	-0.000	1.840	4051.3342	4039.0601	0.0231
-1.E-07		122.0215	4060.0435	45.004	0.009	-16.612	10.958	-0.000	1.755	4131.3345	4119.0146	0.0256
-1.E-06		137.1812	4136.8530	45.004	0.018	-16.792	10.646	-0.000	1.751	4211.3345	4198.6860	0.0278
-7.E-06		150.4624	4213.2441	45.005	0.038	-17.001	7.896	-0.000	2.024	4291.3345	4277.2739	0.0295
-4.E-06		157.2954	4281.6885	45.006	0.058	-17.257	2.473	-0.000	3.894	4363.3345	4346.3989	0.0310
0.E-01	MIN DIST	157.9126	4307.0679	45.007	0.081	-17.376	-0.000	-0.000	9.258	4390.0674	4371.7949	0.0316

X01 TEST CASE 4 678

TABLE WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 15.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RFTN DB
-1.E-07	XMTR	0.0000	0.0007				15.000	0.001	-1.000	0.0000	0.0000	0.0000
-1.E-07	ENTR ION	87.5815	296.7405	45.000	-0.000	15.000	17.669	0.251	-41.297	311.3200	311.3200	0.0000
-6.E-08		96.4424	323.9609	45.000	0.000	15.000	17.913	-0.218	132.778	340.3200	340.3198	0.0004
-1.E-07		102.6211	342.6896	45.000	-0.000	15.000	18.077	-0.023	34.235	360.3200	360.3191	0.0008
1.E-07		113.8750	376.3098	45.000	-0.000	14.999	18.351	-0.002	15.089	396.3200	396.3125	0.0017
-3.E-07		126.5327	413.5271	45.000	0.000	14.990	18.525	-0.000	10.349	436.3200	436.2665	0.0029
0.E-01		139.1587	450.5916	45.000	-0.004	14.955	18.260	-0.000	10.860	476.3200	476.0539	0.0038
-7.E-06		161.6304	524.2101	45.001	-0.000	14.567	13.707	0.000	-4.619	556.3201	553.5262	0.0054
6.E-06		169.0010	560.8498	44.992	-0.080	14.029	8.761	0.000	-2.179	596.3201	590.3882	0.0064
8.E-07		172.1484	597.2819	44.985	0.150	13.177	1.603	0.000	-1.547	636.3201	625.9011	0.0076
-6.E-08	MIN DIST	172.1602	604.4181	44.985	0.185	12.968	-0.000	0.000	-1.481	644.2006	632.7719	0.0079
-6.E-08	MIN DIST	172.1602	604.4181	44.985	0.185	12.968	-0.000	0.000	-1.481	644.2006	632.7719	0.0079
2.E-06		166.5884	656.0370	44.984	0.017	11.109	-10.018	0.000	-1.243	701.2006	683.1152	0.0098
6.E-06		149.5122	722.0040	44.971	-0.068	8.308	-16.670	0.000	-1.165	773.2006	751.0206	0.0115
-1.E-05		125.1450	796.0886	44.965	-0.035	5.257	-18.224	0.000	-1.154	853.2006	830.1203	0.0136
-2.E-05		100.3989	870.8126	44.962	-0.032	2.599	-17.734	0.000	-1.164	933.2006	910.0689	0.0162
-2.E-05	EXIT ION	87.1309	912.1552	44.961	-0.031	1.308	-17.365	0.001	-1.171	977.2006	954.0682	0.0169
-1.E-07	GRND REF	0.0000	1213.7144	44.953	-0.023	-5.458	14.653	-0.002	1.000	1293.0428	1269.9105	0.0169
-1.E-07		0.0000	1213.7144	44.953	-0.023	-5.458	14.653	-0.002	1.000	1293.0428	1269.9105	0.0169
0.E-01	ENTR ION	87.5811	1516.6926	44.949	-0.019	-3.554	17.378	-0.012	2.625	1610.3929	1587.2606	0.0169
1.E-07		104.8320	1570.2106	44.948	-0.018	-3.292	17.852	-0.001	2.397	1667.3929	1644.2592	0.0179
-4.E-06		127.1875	1637.3960	44.947	-0.016	-2.990	18.244	-0.000	2.221	1739.3929	1716.1993	0.0200
-2.E-05		151.5107	1711.4447	44.947	-0.008	-2.727	16.570	-0.000	2.581	1819.3929	1795.2294	0.0217
-2.E-05		163.4761	1755.4836	44.948	0.012	-2.675	12.270	-0.000	7.055	1867.3929	1840.7936	0.0228
-9.E-06		169.8521	1792.0808	44.946	-0.186	-2.751	6.915	0.000	-4.706	1907.3929	1877.2913	0.0239
0.E-01	MIN DIST	171.9780	1829.7573	44.941	-0.054	-2.967	-0.000	0.000	-1.953	1948.6312	1913.9958	0.0251

X01 TEST CASE 4 678

TABLE WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 30.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
0.E-01 XMTR	0.0000	0.0007				30.000	-0.000	1.000	0.0000	0.0000	0.0000
1.E-07 ENTR ION	87.5835	146.7273	45.000	-0.000	30.000	31.320	-0.004	1.593	171.7400	171.7400	0.0000
-1.E-07	95.3936	159.3521	45.000	-0.000	30.000	31.433	-0.001	1.581	186.7400	186.7399	0.0002
-1.E-07	100.6138	167.7520	45.000	-0.000	30.000	31.507	-0.001	1.572	196.7400	196.7397	0.0004
-1.E-07	105.8452	176.1383	45.000	-0.000	30.000	31.579	-0.000	1.564	206.7400	206.7389	0.0006
-3.E-06	128.9595	212.8732	45.000	-0.001	29.993	31.772	-0.000	1.539	250.7400	250.6938	0.0019
9.E-06	149.7935	246.0038	45.003	0.009	29.931	31.035	-0.000	1.577	290.7400	290.2260	0.0028
-7.E-05	169.0688	278.7744	45.012	-0.074	29.644	27.453	-0.000	1.914	330.7400	327.8545	0.0037
7.E-05	184.3682	311.2025	45.017	0.047	28.880	19.634	-0.000	8.632	370.7400	361.8336	0.0051
8.E-05	191.1675	339.8859	45.027	0.458	27.458	7.112	0.000	-2.036	406.7400	388.0026	0.0070
0.E-01 MIN DIST	191.5786	355.1327	45.023	0.214	26.386	0.000	0.000	-1.530	426.0354	401.1255	0.0081
0.E-01 MIN DIST	191.5786	355.1327	45.023	0.214	26.386	0.000	0.000	-1.530	426.0354	401.1255	0.0081
-1.E-06 WAVE REV	191.4214	358.2994	45.020	0.131	26.142	-1.384	0.000	-1.476	430.0354	403.8564	0.0083
2.E-04	172.3486	427.0821	44.864	-0.732	19.782	-23.513	0.000	-1.113	515.0354	469.0688	0.0124
-4.E-05	153.3560	463.6315	44.801	-0.577	16.007	-28.711	0.000	-1.082	559.0354	509.5375	0.0137
-4.E-05	109.7905	537.9932	44.723	-0.470	9.012	-29.937	0.000	-1.078	647.0354	596.6586	0.0163
-4.E-05	85.9648	579.0274	44.689	-0.437	5.779	-29.580	0.001	-1.082	695.0354	644.6559	0.0174
-4.E-05 EXIT ION	85.9648	579.0274	44.689	-0.437	5.779	-29.580	0.001	-1.082	695.0354	644.6559	0.0174
-1.E-07 GRND REF	0.0000	733.8023	44.597	-0.345	-3.300	28.187	-0.000	1.000	872.9915	822.6120	0.0174
-1.E-07 ENTR ION	87.5815	891.3872	44.536	-0.284	1.555	29.605	-0.004	1.502	1054.2214	1003.8420	0.0174
-5.E-07	109.7282	929.8484	44.524	-0.273	2.492	29.940	-0.000	1.475	1099.2214	1048.8395	0.0183
-4.E-06	129.9424	963.8081	44.514	-0.264	3.253	30.081	-0.000	1.460	1139.2214	1088.7850	0.0195
1.E-05	149.7520	997.5195	44.506	-0.246	3.937	29.305	-0.000	1.491	1179.2214	1128.2988	0.0204
4.E-05	168.0034	1030.8517	44.501	-0.260	4.482	25.636	-0.000	1.736	1219.2214	1165.9510	0.0213
-5.E-05	183.5596	1067.1686	44.493	-0.381	4.802	17.329	-0.000	4.688	1263.2214	1203.5182	0.0229
-3.E-05	189.6543	1096.4634	44.489	0.313	4.717	5.417	0.000	-2.442	1299.2214	1230.4596	0.0247
0.E-01 MIN DIST	189.8408	1107.6459	44.489	0.458	4.580	0.000	0.000	-1.772	1313.1617	1240.2111	0.0254

X01 TEST CASE 4 678

TABLE WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 45.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08 XMTR	0.0000	0.0007				45.000	-0.000	1.000	0.0000	0.0000	0.0000
0.E-01 ENTR ION	87.5820	85.8178	45.001	-0.001	45.000	45.772	-0.001	1.216	123.0300	123.0300	0.0000
0.E-01	96.1860	94.0638	45.000	-0.000	45.000	45.846	-0.000	1.214	135.0300	135.0299	0.0002
-3.E-07	109.1118	106.3911	45.000	-0.000	45.000	45.952	-0.000	1.211	153.0300	153.0284	0.0006
-1.E-07	116.3013	113.2182	45.000	-0.001	44.999	46.002	-0.000	1.209	163.0300	163.0246	0.0009
5.E-05	149.2368	144.3884	45.004	0.003	44.962	45.586	-0.000	1.214	209.0300	208.6441	0.0022
-2.E-05	173.6016	168.3572	45.016	-0.129	44.732	42.582	-0.000	1.276	245.0300	242.0868	0.0031
3.E-05	199.1782	198.8999	45.124	0.601	43.699	29.422	-0.000	2.132	293.0300	277.2298	0.0055
0.E-01 RCVR	200.0000	200.1938	45.132	0.608	43.623	28.479	-0.000	2.293	295.1517	278.4353	0.0057
6.E-06	209.6841	233.2520	45.069	-1.589	40.438	4.810	0.000	-1.979	348.1517	304.3883	0.0094
1.E-06 APOGEE	209.6846	235.8549	45.040	-1.745	40.110	3.140	0.000	-1.833	352.1517	306.3052	0.0097
-1.E-06 WAVE REV	209.4399	241.0886	44.979	-1.981	39.432	-0.235	0.000	-1.625	360.1517	310.1812	0.0102
3.E-06	205.9814	259.5114	44.756	-1.999	36.822	-12.821	0.000	-1.269	388.1517	324.3047	0.0121
1.E-07 RCVR	200.0000	274.4505	44.611	-1.407	34.420	-23.463	0.000	-1.142	410.9649	336.8848	0.0136
-1.E-06	172.6172	311.9397	44.454	-0.174	27.226	-41.339	0.000	-1.041	467.9649	377.7036	0.0168
-1.E-04	146.0566	339.0077	44.437	-0.033	21.542	-44.846	0.000	-1.031	507.9649	414.8819	0.0179
-9.E-05	117.8267	366.5367	44.434	-0.025	16.014	-45.162	0.000	-1.031	547.9650	454.5807	0.0192
-8.E-05 EXIT ION	83.8735	399.9262	44.432	-0.023	9.967	-44.885	0.000	-1.032	595.9650	502.5724	0.0204
-1.E-07 GRND REF	0.0000	484.7059	44.428	-0.019	-2.180	44.122	-0.000	1.000	715.6183	622.2257	0.0204
-6.E-08 ENTR ION	87.5845	573.1597	44.425	-0.016	6.046	44.918	-0.001	1.202	840.5283	747.1357	0.0204
-3.E-06	110.9263	596.1272	44.425	-0.015	7.764	45.117	-0.000	1.196	873.5283	780.1334	0.0211
8.E-05	166.6392	650.9270	44.427	-0.071	11.242	42.875	-0.000	1.232	953.5283	858.2767	0.0233
1.E-04	197.5518	687.5246	44.450	0.625	12.692	29.789	-0.000	1.816	1009.5283	901.6531	0.0258
-2.E-07 RCVR	200.0000	691.4381	44.458	0.801	12.772	26.986	-0.000	2.154	1015.8427	905.3247	0.0263

X01 TEST CASE 4 678

TABLE WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 60.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSORPTION DB
-6.E-08	XMTR	0.0000	0.0007				60.000	-0.000	1.000	0.0000	0.0000	0.0000
-6.E-08	ENTR ION	87.5879	49.7713	45.001	-0.001	60.000	60.448	-0.001	1.102	100.9100	100.9100	0.0000
-6.E-08		98.8999	56.0853	45.000	-0.000	60.000	60.504	-0.000	1.101	113.9100	113.9098	0.0002
6.E-07		114.5708	64.7904	45.001	-0.001	60.000	60.575	-0.000	1.100	131.9100	131.9063	0.0008
6.E-07		131.9751	74.4099	45.001	-0.003	59.997	60.591	-0.000	1.099	151.9100	151.8629	0.0015
1.E-05		149.2607	83.9562	45.004	-0.011	59.979	60.341	-0.000	1.101	171.9100	171.5860	0.0019
3.E-05		166.0811	93.3624	45.021	0.055	59.919	59.385	-0.000	1.112	191.9100	190.4690	0.0024
4.E-05		181.7192	102.4766	45.072	0.159	59.770	56.972	-0.000	1.142	211.9100	207.3167	0.0033
-5.E-06		195.4644	111.2458	45.142	-0.424	59.477	52.606	-0.000	1.211	231.9100	221.2220	0.0044
0.E-01	RCVR	200.0000	114.4181	45.158	-0.852	59.325	50.580	-0.000	1.250	239.2544	225.6374	0.0049
2.E-05		215.2446	126.7887	45.157	-1.752	58.508	40.932	-0.000	1.586	268.2544	240.0419	0.0069
-7.E-05		222.6655	134.7017	45.198	-0.256	57.780	30.528	-0.000	2.854	288.2544	246.8394	0.0083
-9.E-05		226.1465	141.6423	45.288	2.658	56.847	13.534	0.000	-8.072	308.2544	250.9596	0.0099
-1.E-04	APOGEE	224.8589	149.1341	45.396	6.807	55.311	-15.229	0.000	-1.549	332.2544	254.4060	0.0120
-1.E-04	WAVE REV	224.8589	149.1341	45.396	6.807	55.311	-15.229	0.000	-1.549	332.2544	254.4060	0.0120
-5.E-04		219.0190	156.3787	45.614	11.026	53.306	-41.191	0.000	-1.118	356.2544	258.7795	0.0141
-1.E-07	RCVR	200.0000	168.1793	46.386	16.895	48.741	-62.506	0.000	-1.025	395.2125	273.3222	0.0173
-2.E-04		161.2012	183.3306	47.838	17.303	40.141	-69.164	0.000	-1.014	444.2125	310.6089	0.0198
-2.E-04		124.2236	196.2340	48.994	16.039	31.200	-69.716	0.000	-1.013	484.2125	349.6414	0.0209
-2.E-04		86.7271	209.4008	50.027	15.006	21.417	-69.614	0.000	-1.013	524.2125	389.6242	0.0221
-2.E-04	EXIT ION	86.7271	209.4008	50.027	15.006	21.417	-69.614	0.000	-1.013	524.2125	389.6242	0.0221
-6.E-08	GRND REF	0.0000	240.7042	52.016	13.018	-1.083	69.324	-0.000	1.000	616.8214	482.2331	0.0221
-6.E-08	ENTR ION	87.5811	272.5383	53.560	11.476	16.473	69.617	-0.000	1.051	710.3414	575.7531	0.0221
-6.E-07		111.0205	280.9300	53.907	11.129	20.128	69.691	-0.000	1.050	735.3414	600.7512	0.0227
-3.E-06		129.7637	287.6049	54.169	10.869	22.770	69.715	-0.000	1.049	755.3414	620.7192	0.0235
2.E-04		176.7695	304.5549	54.797	9.901	28.416	67.848	-0.000	1.062	807.3414	669.5438	0.0250
-1.E-07	RCVR	200.0000	313.8824	55.125	8.562	30.685	63.582	-0.000	1.099	837.7720	691.0796	0.0267

X01 TEST CASE 4 678

TABLE WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 75.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08	XMTR	0.0000	0.0007				75.000	-0.000	1.000	0.0000	0.0000	0.0000
-6.E-08	ENTR ION	87.5845	23.1386	45.001	-0.001	75.000	75.208	-0.000	1.048	90.6300	90.6300	0.0000
0.E-01		95.3198	25.1509	45.003	-0.003	75.000	75.226	-0.000	1.047	98.6300	98.6299	0.0001
-6.E-08		106.9233	28.1606	45.002	-0.002	75.000	75.252	-0.000	1.047	110.6300	110.6291	0.0004
0.E-01		116.5923	30.6598	45.001	-0.001	75.000	75.271	-0.000	1.047	120.6300	120.6252	0.0008
-7.E-07		139.7456	36.6209	45.005	-0.004	74.997	75.242	-0.000	1.047	144.6300	144.5137	0.0016
-2.E-05		158.7368	41.5179	45.021	-0.096	74.981	74.916	-0.000	1.049	164.6300	163.8661	0.0021
-5.E-05		176.8608	46.2934	45.056	-0.323	74.929	73.994	-0.000	1.056	184.6300	181.6867	0.0028
-1.E-04		193.2637	50.7885	45.175	0.391	74.834	72.409	-0.000	1.073	204.6300	196.5994	0.0038
0.E-01	RCVR	200.0000	52.6868	45.303	1.337	74.783	71.357	-0.000	1.087	213.9164	202.1290	0.0045
1.E-05		216.4512	57.5462	46.037	3.891	74.611	64.774	-0.000	1.197	242.9164	213.2395	0.0069
-1.E-04		230.3560	64.9027	46.842	-5.753	73.703	23.307	-0.000	15.355	298.9164	219.6018	0.0119
-1.E-04	APOGEE	230.5190	69.9072	46.091	-10.668	72.527	-1.656	0.000	-2.180	326.9164	221.2639	0.0143
-1.E-04	WAVE REV	230.5190	69.9072	46.091	-10.668	72.527	-1.656	0.000	-2.180	326.9164	221.2639	0.0143
-7.E-06		228.4902	74.6298	45.126	-12.762	71.273	-14.733	0.000	-1.449	346.9164	223.1781	0.0160
-2.E-04		219.7080	87.0560	42.626	-14.294	67.655	-32.405	0.000	-1.109	386.9164	230.5411	0.0193
1.E-04		204.0117	103.0470	39.992	-13.778	62.370	-44.566	0.000	-1.031	426.9164	245.1937	0.0225
-1.E-07	RCVR	200.0000	106.5454	39.503	-13.544	61.103	-46.519	0.000	-1.024	434.7635	249.2271	0.0231
1.E-05		170.8721	128.3344	37.027	-11.789	52.146	-54.296	0.000	-1.008	479.7635	281.0316	0.0258
-1.E-05		155.2808	138.6650	36.127	-10.949	47.265	-55.799	0.000	-1.006	499.7635	299.2176	0.0264
2.E-05		112.3257	166.2593	34.289	-9.123	33.061	-56.411	0.000	-1.006	551.7635	350.5217	0.0282
3.E-05	EXIT ION	85.6929	183.5246	33.424	-8.258	24.055	-56.261	0.000	-1.006	583.7635	382.5187	0.0290
-6.E-08	GRND REF	0.0000	240.4792	31.459	-6.294	-1.081	55.744	-0.000	1.000	687.1234	485.8785	0.0290
-6.E-08		0.0000	240.4792	31.459	-6.294	-1.081	55.744	-0.000	1.000	687.1234	485.8785	0.0290
-6.E-08	ENTR ION	87.5811	298.8470	30.225	-5.062	14.881	56.272	-0.001	1.133	792.7534	591.5085	0.0290
-2.E-07		111.7188	314.6137	29.971	-4.807	17.974	56.409	-0.000	1.130	821.7534	620.5063	0.0296
-2.E-05		154.7583	342.5395	29.579	-4.416	22.509	55.866	-0.000	1.135	873.7534	671.9139	0.0311
-7.E-05		182.3945	361.3225	29.353	-4.248	24.827	52.304	-0.000	1.188	909.7534	703.8334	0.0323
-5.E-05		195.5547	371.2286	29.252	-3.844	25.745	47.965	-0.000	1.290	929.7534	718.0795	0.0334
0.E-01	RCVR	200.0000	374.8719	29.220	-3.649	26.019	45.448	-0.000	1.372	937.5034	722.6270	0.0339

X01 TEST CASE 4 678

TABLE WAVE DIPOLY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 90.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSORPTN DB
-6.E-08 XMTR	0.0000	0.0007				90.000	-0.000	1.000	0.0000	0.0000	0.0000
0.E-01 ENTR ION	87.5801	0.0007			90.000	90.000	-0.000	1.019	87.5800	87.5800	0.0000
0.E-01	95.5801	0.0006			90.000	90.000	-0.000	1.018	95.5800	95.5799	0.0001
1.E-07	100.5801	0.0007			90.000	90.000	-0.000	1.018	100.5800	100.5798	0.0003
1.E-07	105.5796	0.0006			90.000	90.000	-0.000	1.018	105.5800	105.5794	0.0004
1.E-07	110.5791	0.0006			90.000	90.000	-0.000	1.018	110.5800	110.5783	0.0006
1.E-07	115.5776	0.0006			90.000	90.000	-0.000	1.018	115.5800	115.5760	0.0008
-1.E-07 WAVE REV	119.5757	0.0008			90.000	90.000	-0.000	1.018	119.5800	119.5725	0.0009
-6.E-08	121.5742	0.0007			90.000	90.000	-0.000	1.018	121.5800	121.5698	0.0010
2.E-07	131.5571	0.0020	170.681	19.585	89.999	89.999	-0.000	1.018	131.5800	131.5387	0.0014
8.E-07	141.5039	0.0054	-176.444	6.710	89.998	89.995	-0.000	1.018	141.5800	141.4425	0.0017
4.E-07	151.3647	0.0161	171.939	2.206	89.994	89.983	-0.000	1.018	151.5800	151.1926	0.0019
1.E-05	168.6050	0.0741	-170.144	0.410	89.974	89.966	-0.000	1.020	169.5800	167.8420	0.0025
2.E-05 WAVE REV	176.7993	0.1278	-169.980	-179.753	89.957	89.972	-0.000	1.021	178.5800	175.4297	0.0028
5.E-05	180.3179	0.1550	-169.932	-179.802	89.949	89.908	-0.000	1.022	182.5800	178.5959	0.0030
-2.E-05	196.5952	0.2844	-169.819	-179.915	89.915	89.078	-0.000	1.028	202.5800	192.3185	0.0043
-1.E-07 RCVR	200.0000	0.3024	-169.835	-179.899	89.911	88.779	-0.000	1.030	207.1634	194.9684	0.0046
6.E-05	218.5605	0.3933	-169.800	-179.934	89.893	87.447	-0.000	1.047	236.1634	207.6882	0.0068
2.E-04	227.9863	0.7708	-169.779	-179.955	89.799	89.320	-0.000	1.054	256.1634	212.5949	0.0083
1.E-04 WAVE REV	229.5005	0.9064	-169.770	0.036	89.766	89.762	-0.000	1.053	260.1634	213.2375	0.0087
4.E-04	234.2886	1.6336	-169.756	0.022	89.586	82.605	-0.000	1.032	276.1634	214.9053	0.0099
-9.E-04 APOGEE	238.2314	3.7327	-169.742	0.008	89.069	-18.018	-0.000	9.917	312.1634	215.7727	0.0128
-9.E-04 WAVE REV	238.2314	3.7327	-169.742	0.008	89.069	-18.018	-0.000	9.917	312.1634	215.7727	0.0128
-8.E-05	237.0483	4.7442	-169.740	0.006	88.811	-47.013	0.000	-2.275	328.1634	216.0816	0.0141
2.E-05	224.8623	8.9657	-169.737	0.003	87.636	-64.723	0.000	-1.235	368.1634	221.4572	0.0171
3.E-05	207.2993	13.7770	-169.736	0.002	86.074	-72.960	0.000	-1.103	400.1634	232.7659	0.0196
0.E-01 RCVR	200.0000	15.4092	-169.736	0.002	85.456	-75.207	0.000	-1.080	411.1068	238.1794	0.0204
9.E-05	177.1299	19.9072	-169.736	0.002	83.410	-78.304	0.000	-1.050	440.1068	257.6543	0.0222
-3.E-04	135.6030	27.7236	-169.735	0.001	78.201	-79.105	0.000	-1.041	484.1068	298.6186	0.0235
-3.E-04	96.3662	35.1374	-169.735	0.001	69.670	-79.079	0.000	-1.042	524.1068	338.5500	0.0249
-3.E-04 EXIT ION	80.6592	38.1300	-169.734	0.001	64.387	-79.053	0.001	-1.043	540.1068	354.5499	0.0250
-6.E-08 GRND REF	0.0000	53.7351	-169.734	0.001	-0.241	78.912	-0.000	1.000	622.2806	436.7237	0.0250
0.E-01 ENTR ION	87.5874	70.6628	-169.734	0.000	50.594	79.064	-0.000	1.006	711.5106	525.9537	0.0250
0.E-01	104.2793	73.8357	-169.734	0.000	54.146	79.093	-0.000	1.006	728.5106	542.9531	0.0254
-1.E-04	155.0181	83.4422	-169.734	0.000	61.042	78.923	-0.000	1.006	780.5106	594.3758	0.0271
5.E-04	190.3584	90.6097	-169.734	0.000	63.807	77.821	-0.000	1.006	820.5106	627.6298	0.0289
-1.E-07 RCVR	200.0000	92.7719	-169.734	0.000	64.355	77.234	-0.000	1.006	833.3375	635.5943	0.0297

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X01   TEST CASE                                                                                  4 678

CHAPX  WAVE    HARMNY    EXPZ2                  APPLETON-HARTREE FORMULA     EXTRAORDINARY     WITH COLLISIONS

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

   1 -1.00000000000E+00
   2  6.37000000000E+03
   4  6.98131680489E-01
   5 -1.83259570599E+00
   7  6.00000000000E+00
  11  7.85398185253E-01
  16  1.57079637051E+00
  17  2.61799395084E-01
  20  2.00000000000E+02
  22  3.00000000000E+00
  23  1.00000000000E+03
  24  1.37008345127E+00
  25  5.07890796661E+00
  41  3.00000000000E+00
  42  9.99999974738E-05
  43  5.00000000000E+01
  44  1.00000000000E+00
  45  1.00000000000E+02
  46  9.99999993923E-09
  47  5.00000000000E-01
  57  2.00000000000E+00
  58  2.00000000000E+00
  71  5.00000000000E+00
 100  1.00000000000E+00
 101  6.50000000000E+00
 102  3.00000000000E+02
 103  6.20000000000E+01
 104  5.00000000000E-01
 150  1.00000000000E+00
 151  2.50000000000E+02
 152  1.00000000000E+02
 153  1.00000001490E-01
 155  1.00000000000E+02
 156  1.00000000000E+02
 200  1.00000000000E+00
 201  8.00000011921E-01
 251  3.65000000000E+04
 252  1.00000000000E+02
 253  1.48000001907E-01
 254  3.00000000000E+01
 255  1.40000000000E+02
 256  1.83000005782E-02
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G_N^0	G_N^1	G_N^2	G_N^3	G_N^4	G_N^5	G_N^6
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.300953	0.020298	0.000000	0.000000	0.000000	0.000000	0.000000
0.028106	-0.052140	-0.014435	0.000000	0.000000	0.000000	0.000000
-0.030800	0.065600	-0.025252	-0.006952	0.000000	0.000000	0.000000
-0.041243	-0.043956	-0.016897	0.008021	-0.002525	0.000000	0.000000
0.014742	-0.037078	-0.018906	0.002819	0.003656	0.000036	0.000000
-0.006713	-0.012234	-0.004364	0.021370	0.001593	-0.000072	0.000680

H_N^0	H_N^1	H_N^2	H_N^3	H_N^4	H_N^5	H_N^6
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	-0.057886	0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.035942	0.001129	0.000000	0.000000	0.000000	0.000000
0.000000	0.011084	-0.004421	0.001180	0.000000	0.000000	0.000000
0.000000	-0.010299	0.008794	-0.000086	0.002256	0.000000	0.000000
0.000000	-0.003849	-0.012615	0.007845	0.002207	-0.000328	0.000000
0.000000	0.003157	-0.012670	-0.009281	0.002286	-0.000135	0.000243

X01 TEST CASE 4 678

CHAPX WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 0.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSD RPTN DB
-6.E-08	XMTR	0.0000	0.0007				0.000	0.000	-1.000	0.0000	0.0000	0.0000
0.E-01	ENTR ION	73.9106	965.7131	45.000	-0.000	0.000	8.686	-0.295	6.695	973.1801	973.1801	0.0000
0.E-01		91.9414	1075.8334	45.000	-0.000	-0.000	9.676	-0.012	4.233	1086.1801	1086.1799	0.0007
-6.E-08		105.8604	1153.4076	45.000	-0.000	-0.000	10.358	-0.001	3.427	1166.1801	1166.1768	0.0022
-2.E-07		120.6519	1230.6360	45.000	0.000	-0.005	10.907	-0.000	2.978	1246.1801	1246.1405	0.0046
3.E-06		135.8340	1307.4932	45.000	0.003	-0.032	10.778	-0.000	2.933	1326.1801	1325.8768	0.0067
-2.E-06		149.5278	1383.9529	45.001	-0.021	-0.152	8.552	-0.000	4.513	1406.1801	1404.6843	0.0083
-6.E-06		155.4751	1429.6472	45.001	0.034	-0.323	5.558	-0.000	41.522	1454.1801	1451.1248	0.0092
-6.E-06		158.0640	1467.6219	45.002	0.029	-0.555	2.097	0.000	-4.824	1494.1801	1489.2532	0.0101
-6.E-08	MIN DIST	158.4263	1490.4373	45.001	-0.031	-0.737	0.000	0.000	-3.063	1518.2091	1512.0771	0.0106
-6.E-08	MIN DIST	158.4263	1490.4373	45.001	-0.031	-0.737	0.000	0.000	-3.063	1518.2091	1512.0771	0.0106
-6.E-08	WAVE REV	158.4023	1494.2372	45.001	-0.041	-0.770	-0.340	0.000	-2.909	1522.2091	1515.8795	0.0107
-2.E-06		151.6001	1582.6748	44.996	0.025	-1.738	-7.539	0.000	-1.673	1615.2091	1604.9752	0.0126
3.E-06		138.5571	1658.9999	44.996	0.022	-2.765	-10.593	0.000	-1.509	1695.2091	1683.3949	0.0142
6.E-06		108.4478	1812.9257	44.997	0.014	-4.782	-10.505	0.000	-1.533	1855.2091	1842.9648	0.0188
8.E-06		81.1348	1968.2671	44.998	0.013	-6.525	-9.135	0.012	-1.635	2015.2091	2002.9592	0.0214
8.E-06	EXIT ION	71.2837	2030.7573	44.998	0.012	-7.151	-8.573	0.055	-1.681	2079.2092	2066.9592	0.0216
0.E-01	GRND REF	0.0000	2889.9067	45.002	0.009	-12.997	0.846	0.003	-1.000	2945.4358	2933.1858	0.0226
-6.E-08	ENTR ION	73.8647	3765.8335	45.004	0.007	-15.852	8.724	-0.062	2.107	3828.8259	3816.5759	0.0226
-2.E-07		94.6885	3891.4819	45.004	0.007	-16.161	9.852	-0.002	1.912	3957.8259	3945.5757	0.0235
-2.E-06	MAX LAT	111.7847	3984.4368	45.004	0.007	-16.378	10.646	-0.000	1.804	4053.8259	4041.5662	0.0257
-2.E-06	WAVE REV	111.7847	3984.4368	45.004	0.007	-16.378	10.646	-0.000	1.804	4053.8259	4041.5662	0.0257
-5.E-06		123.8276	4046.1230	45.005	0.008	-16.519	10.996	-0.000	1.759	4117.8262	4105.5117	0.0277
-4.E-06		147.1646	4168.7427	45.005	0.026	-16.821	9.053	-0.000	1.948	4245.8262	4232.3711	0.0308
-5.E-06		156.5610	4244.8696	45.007	0.019	-17.082	3.815	-0.000	3.568	4325.8262	4309.6289	0.0325
-6.E-08	MIN DIST	158.0122	4284.7354	45.007	0.026	-17.263	-0.000	-0.000	29.637	4367.8105	4349.5532	0.0334

X01 TEST CASE 4 678

CHAPX WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 15.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-1.E-07	XMTR	0.0000	0.0007				15.000	-0.001	1.000	0.0000	0.0000	0.0000
-1.E-07	ENTR ION	73.8550	253.6863	45.000	-0.000	15.000	17.282	-0.065	2.161	265.6100	265.6100	0.0000
-1.E-07		88.8848	300.7720	45.000	-0.000	15.000	17.705	-0.006	2.059	315.6100	315.6100	0.0003
-2.E-07		101.1611	338.2827	45.000	-0.000	15.000	18.039	-0.001	1.986	355.6100	355.6093	0.0009
-2.E-07		113.6514	375.6482	45.000	-0.000	14.999	18.346	-0.000	1.924	395.6100	395.6024	0.0020
-3.E-06		146.3271	472.0818	45.002	-0.004	14.907	17.651	-0.000	1.972	499.6100	499.0084	0.0047
-7.E-06		159.6714	516.1499	45.007	0.014	14.659	14.444	-0.000	2.655	547.6100	545.2542	0.0057
-3.E-06		167.9639	552.7157	45.009	-0.100	14.200	9.808	-0.000	9.022	587.6100	582.3228	0.0066
-6.E-06		172.2466	589.1602	45.004	0.081	13.430	3.061	0.000	-3.334	627.6100	618.0687	0.0078
0.E-01	MIN DIST	172.4937	602.8149	45.003	0.166	13.043	-0.000	0.000	-2.314	642.6814	631.2313	0.0083
0.E-01	MIN DIST	172.4937	602.8149	45.003	0.166	13.043	-0.000	0.000	-2.314	642.6814	631.2313	0.0083
-2.E-05		154.1577	705.6652	44.985	-0.086	8.995	-15.755	0.000	-1.296	755.6814	734.0172	0.0116
-2.E-05		130.3188	779.6007	44.976	-0.043	5.878	-18.215	0.000	-1.256	835.6814	812.6564	0.0134
-2.E-05		105.4463	854.1979	44.972	-0.038	3.128	-17.877	0.000	-1.267	915.6814	892.5556	0.0160
-2.E-05		81.3281	929.3721	44.969	-0.035	0.781	-17.210	0.005	-1.285	995.6814	972.5537	0.0173
-2.E-05	EXIT ION	71.9326	959.5980	44.968	-0.034	-0.061	-16.938	0.020	-1.292	1027.6814	1004.5537	0.0174
-6.E-08	GRND REF	0.0000	1212.3082	44.961	-0.027	-5.452	14.665	-0.000	1.000	1291.7826	1268.6549	0.0177
-1.E-07	ENTR ION	73.8315	1471.1733	44.956	-0.023	-3.773	16.994	-0.039	1.703	1562.3927	1539.2650	0.0177
-2.E-07		93.1279	1532.4406	44.955	-0.022	-3.456	17.544	-0.002	1.649	1627.3927	1604.2649	0.0182
-2.E-06		117.6704	1607.3358	44.954	-0.021	-3.102	18.156	-0.000	1.594	1707.3927	1684.2499	0.0202
-1.E-05		142.5425	1681.6295	44.953	-0.028	-2.799	17.728	-0.000	1.608	1787.3927	1763.8494	0.0223
-2.E-05		163.8066	1755.1489	44.956	0.011	-2.662	11.961	-0.000	2.282	1867.3927	1840.6150	0.0240
1.E-05		170.1733	1791.7006	44.956	-0.195	-2.738	6.502	-0.000	6.806	1907.3927	1877.0248	0.0251
-6.E-08	MIN DIST	172.2515	1826.8894	44.952	-0.089	-2.938	-0.000	0.000	-3.758	1945.9199	1911.3030	0.0263

X01 TEST CASE 4 678

CHAPX WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 30.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RFTN DB
0.E-01	XMTR	0.0000	0.0007				30.000	-0.000	1.000	0.0000	0.0000	0.0000
0.E-01	ENTR ION	73.7036	124.1109	45.000	-0.000	30.000	31.116	-0.018	1.336	144.9600	144.9600	0.0000
-6.E-08		88.7378	148.5977	45.000	-0.000	30.000	31.336	-0.002	1.328	173.9600	173.9600	0.0002
-1.E-07		107.5317	178.8356	45.000	-0.000	30.000	31.602	-0.000	1.318	209.9600	209.9584	0.0009
-1.E-06		128.5474	212.2236	45.000	-0.001	29.993	31.767	-0.000	1.310	249.9600	249.9135	0.0022
5.E-06		149.3760	245.3494	45.004	0.008	29.932	31.026	-0.000	1.327	289.9600	289.4367	0.0031
-2.E-05		168.6240	278.0718	45.019	-0.077	29.645	27.378	-0.000	1.443	329.9600	326.9971	0.0041
2.E-05		183.9756	310.3623	45.039	0.008	28.899	17.466	-0.000	2.037	369.9600	360.8415	0.0056
2.E-06		191.7139	341.8967	45.086	0.401	27.374	5.208	0.000	-5.283	409.9600	389.5866	0.0077
-6.E-08	MIN DIST	191.9409	352.8775	45.082	0.218	26.592	-0.000	0.000	-2.455	423.9418	399.0241	0.0086
-6.E-08	MIN DIST	191.9409	352.8775	45.082	0.218	26.592	-0.000	0.000	-2.455	423.9418	399.0241	0.0086
8.E-06		172.5039	424.6678	44.899	-0.781	19.923	-23.462	0.000	-1.196	512.9418	466.8556	0.0129
2.E-05		135.9917	491.5294	44.786	-0.574	13.092	-29.863	0.000	-1.132	592.9418	542.6068	0.0149
2.E-05		96.1929	559.5993	44.716	-0.501	7.159	-29.627	0.000	-1.137	672.9418	622.4698	0.0175
2.E-05	EXIT ION	72.5986	600.8530	44.681	-0.466	4.143	-29.257	0.008	-1.142	720.9418	670.4695	0.0179
-6.E-08	GRND REF	0.0000	732.8964	44.597	-0.383	-3.296	28.070	-0.000	1.000	872.2856	821.8133	0.0182
-6.E-08	ENTR ION	73.6919	866.8691	44.538	-0.324	0.925	29.275	-0.017	1.318	1025.8656	975.3933	0.0182
-1.E-07		75.6489	870.3173	44.537	-0.322	1.017	29.306	-0.013	1.317	1029.8656	979.3933	0.0182
-3.E-05		137.6084	977.0004	44.502	-0.290	3.523	29.849	-0.000	1.295	1154.8656	1104.2391	0.0210
-1.E-05		164.1543	1023.9247	44.492	-0.252	4.370	26.537	-0.000	1.383	1210.8656	1158.1895	0.0222
-1.E-05		179.4639	1056.9756	44.488	-0.481	4.730	19.962	-0.000	1.709	1250.8656	1193.1960	0.0236
-2.E-05		188.9146	1089.5793	44.489	0.112	4.772	8.230	-0.000	9.694	1290.8656	1224.2179	0.0254
-6.E-08	MIN DIST	190.0400	1106.7311	44.491	0.408	4.602	0.000	0.000	-3.159	1312.2441	1239.2915	0.0266

X01 TEST CASE 4 678

CHAPX WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 45.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08 XMTR	0.0000	0.0007				45.000	-0.000	1.000	0.0000	0.0000	0.0000
-6.E-08 ENTR ION	73.5659	72.3167	45.001	-0.001	45.000	45.650	-0.008	1.155	103.4500	103.4500	0.0000
-1.E-07	94.3354	92.2919	45.001	-0.001	45.000	45.830	-0.000	1.152	132.4500	132.4499	0.0002
-2.E-07	108.6948	105.9944	45.001	-0.001	45.000	45.948	-0.000	1.150	152.4500	152.4484	0.0008
-4.E-07	123.0757	119.6341	45.001	-0.001	44.998	46.032	-0.000	1.148	172.4500	172.4335	0.0015
7.E-06	159.9204	154.6940	45.013	-0.032	44.897	44.658	-0.000	1.163	224.4500	223.3412	0.0028
5.E-05	185.0654	180.9060	45.055	-0.018	44.423	38.768	-0.000	1.259	264.4500	257.7383	0.0043
0.E-01 RCVR	200.0000	200.7048	45.195	0.589	43.548	27.217	-0.000	1.699	296.4846	278.4769	0.0063
-2.E-05	209.6963	230.4285	45.246	-1.543	40.798	4.527	0.000	-4.705	345.4846	301.7887	0.0099
-1.E-05 APOGEE	209.7080	235.5190	45.190	-1.888	40.156	1.181	0.000	-2.988	353.4846	305.5308	0.0105
-1.E-05 WAVE REV	209.5703	238.0880	45.157	-2.025	39.818	-0.491	0.000	-2.571	357.4846	307.4321	0.0107
-1.E-05	206.8804	253.6986	44.938	-2.305	37.600	-10.849	0.000	-1.580	381.4846	319.3411	0.0124
-2.E-07 RCVR	200.0000	271.5798	44.711	-1.809	34.718	-22.997	0.000	-1.257	408.8005	334.3406	0.0142
2.E-05	172.9297	309.3345	44.461	-0.671	27.483	-40.448	0.000	-1.083	465.8005	375.2560	0.0173
2.E-05	118.9229	364.5892	44.359	-0.452	16.265	-44.414	0.000	-1.063	545.8005	452.0338	0.0197
2.E-05	90.9849	392.7442	44.326	-0.420	11.184	-44.188	0.000	-1.065	585.8005	492.0241	0.0209
2.E-05 EXIT ION	68.7207	415.4443	44.304	-0.397	7.471	-43.984	0.007	-1.066	617.8005	524.0241	0.0211
0.E-01 GRND REF	0.0000	487.0630	44.245	-0.339	-2.190	43.340	-0.000	1.000	717.3357	623.5593	0.0212
0.E-01	0.0000	487.0630	44.245	-0.339	-2.190	43.340	-0.000	1.000	717.3357	623.5593	0.0212
-6.E-08 ENTR ION	73.5669	563.6432	44.199	-0.293	4.854	44.029	-0.008	1.153	823.8457	730.0693	0.0212
-1.E-06	113.3105	603.9081	44.180	-0.273	7.812	44.380	-0.000	1.148	880.8457	787.0656	0.0222
2.E-06	141.2402	631.8502	44.168	-0.257	9.615	44.269	-0.000	1.148	920.8457	826.8901	0.0235
-2.E-05	168.0576	659.3550	44.161	-0.339	11.143	41.749	-0.000	1.178	960.8457	864.8905	0.0245
5.E-05	190.6523	685.9675	44.171	0.088	12.215	33.419	-0.000	1.345	1000.8457	897.0114	0.0263
-1.E-07 RCVR	200.0000	700.5823	44.200	0.496	12.533	23.870	-0.000	1.799	1024.0286	911.1450	0.0278

X01 TEST CASE 4 678

CHAPX WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 60.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08 XMTR	0.0000	0.0007				60.000	-0.000	1.000	0.0000	0.0000	0.0000
-1.E-07 ENTR ION	73.4399	41.8380	45.001	-0.001	60.000	60.376	-0.004	1.076	84.6400	84.6400	0.0000
-1.E-07	86.4834	49.1531	45.001	-0.001	60.000	60.442	-0.001	1.075	99.6400	99.6400	0.0001
-3.E-07	109.1118	61.7627	45.001	-0.001	60.000	60.552	-0.000	1.074	125.6400	125.6385	0.0007
-7.E-07	126.5225	71.4006	45.001	-0.002	59.998	60.599	-0.000	1.073	145.6400	145.6157	0.0015
5.E-05	167.4219	94.1503	45.034	0.061	59.904	59.184	-0.000	1.084	193.6400	191.9317	0.0028
-8.E-05	196.1284	111.9018	45.210	-0.560	59.411	51.796	-0.000	1.162	233.6400	221.7681	0.0050
-1.E-07 RCVR	200.0000	114.6787	45.236	-0.964	59.267	49.912	-0.000	1.188	240.1231	225.5139	0.0054
-1.E-04	223.7744	137.5780	45.446	0.368	57.350	22.788	-0.000	2.941	297.1231	247.7617	0.0097
-3.E-04 APOGEE	225.2622	146.2453	45.599	4.918	55.888	-7.774	0.000	-2.830	325.1231	252.1019	0.0121
-3.E-04 WAVE REV	225.2622	146.2453	45.599	4.918	55.888	-7.774	0.000	-2.830	325.1231	252.1019	0.0121
-3.E-04	222.6929	150.8430	45.660	7.828	54.746	-27.204	0.000	-1.508	341.1231	254.4481	0.0135
-6.E-05	207.2915	162.4975	46.135	14.753	50.725	-57.676	0.000	-1.074	381.1231	265.4940	0.0170
-1.E-07 RCVR	200.0000	166.1539	46.406	16.236	49.093	-62.140	0.000	-1.052	393.4093	271.4076	0.0179
1.E-05	154.1455	183.9223	48.020	16.209	38.798	-69.120	0.000	-1.025	450.4093	316.0038	0.0207
-1.E-05	116.9927	197.1074	49.123	15.047	29.573	-69.419	0.000	-1.025	490.4093	355.4594	0.0220
-9.E-07	79.5625	210.5448	50.104	14.066	19.635	-69.303	0.001	-1.026	530.4093	395.4535	0.0230
-7.E-07 EXIT ION	72.0796	213.2572	50.286	13.884	17.616	-69.278	0.002	-1.026	538.4093	403.4535	0.0231
-6.E-08 GRND REF	0.0000	239.8400	51.851	12.320	-1.079	69.032	-0.000	1.000	615.5367	480.5809	0.0232
0.E-01 ENTR ION	73.3169	267.0201	53.122	11.050	14.067	69.282	-0.002	1.035	693.9868	559.0309	0.0232
-4.E-06	111.6807	281.0238	53.680	10.493	20.235	69.406	-0.000	1.034	734.9868	600.0286	0.0240
-2.E-06	148.9502	294.5223	54.168	10.032	25.231	69.235	-0.000	1.034	774.9868	639.6938	0.0253
-4.E-05	183.5752	307.5565	54.620	8.803	29.085	66.496	-0.000	1.047	814.9868	674.8177	0.0268
0.E-01 RCVR	200.0000	314.5237	54.857	8.109	30.629	62.868	-0.000	1.070	837.5367	689.7441	0.0283

X01 TEST CASE 4 678

CHAPX WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 75.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08	XMTR	0.0000	0.0007				75.000	-0.000	1.000	0.0000	0.0000	0.0000
0.E-01	ENTR ION	73.3247	19.4164	45.002	-0.002	75.000	75.175	-0.002	1.035	75.8800	75.8800	0.0000
-6.E-08		87.8267	23.2019	45.003	-0.003	75.000	75.209	-0.000	1.035	90.8800	90.8800	0.0001
-6.E-08		105.2314	27.7224	45.002	-0.002	75.000	75.249	-0.000	1.034	108.8800	108.8793	0.0005
-9.E-07		124.5649	32.7157	45.002	-0.001	75.000	75.279	-0.000	1.034	128.8800	128.8628	0.0013
1.E-07		143.8130	37.6690	45.011	-0.012	74.994	75.204	-0.000	1.034	148.8800	148.6867	0.0020
-1.E-05		176.9609	46.3598	45.095	-0.368	74.916	73.924	-0.000	1.041	184.8800	181.7415	0.0031
0.E-01	RCVR	200.0000	52.8521	45.448	1.289	74.738	71.117	-0.000	1.064	214.5226	201.9766	0.0049
-3.E-04		223.8706	60.9923	47.153	1.563	74.231	50.281	-0.000	1.415	267.5226	216.2815	0.0097
-6.E-04		229.0825	66.2477	47.395	-6.923	73.298	8.829	0.000	-19.129	307.5226	218.6523	0.0134
-5.E-04	APOGEE	229.0576	67.4936	47.220	-8.374	72.999	0.670	0.000	-4.540	315.5226	219.0335	0.0142
-5.E-04	WAVE REV	228.7017	68.8556	46.970	-9.635	72.651	-6.620	0.000	-2.720	323.5226	219.4813	0.0149
-1.E-04		211.7461	87.8273	42.735	-13.745	66.741	-43.359	0.000	-1.092	395.5226	231.9508	0.0213
0.E-01	RCVR	200.0000	97.0462	41.113	-13.288	63.327	-50.253	0.000	-1.045	420.1245	242.3043	0.0233
5.E-05		160.0024	122.0556	38.066	-10.956	51.767	-59.284	0.000	-1.016	477.1245	284.2277	0.0266
-6.E-06		125.8652	141.0209	36.569	-9.456	40.835	-60.218	0.000	-1.015	517.1245	323.1943	0.0278
5.E-06		91.1782	160.3480	35.420	-8.307	28.726	-60.085	0.000	-1.015	557.1245	363.1703	0.0292
-1.E-06	EXIT ION	70.3872	172.0706	34.850	-7.738	21.362	-59.979	0.001	-1.016	581.1245	387.1703	0.0294
-6.E-08	GRND REF	0.0000	212.5186	33.371	-6.259	-0.956	59.612	-0.000	1.000	662.5688	468.6147	0.0295
0.E-01	ENTR ION	73.4663	254.8148	32.328	-5.217	14.847	59.994	-0.005	1.088	747.5688	553.6147	0.0295
-6.E-08		76.9307	256.7833	32.288	-5.177	15.426	60.012	-0.003	1.088	751.5688	557.6147	0.0295
-9.E-06		129.8145	286.5503	31.749	-4.639	22.862	60.217	-0.000	1.085	812.5688	618.5769	0.0311
4.E-05		163.8608	305.6837	31.464	-4.315	26.510	59.126	-0.000	1.095	852.5688	657.3225	0.0321
-1.E-04		193.4111	323.8179	31.256	-4.405	29.009	52.624	-0.000	1.169	892.5688	688.6534	0.0341
0.E-01	RCVR	200.0000	328.4969	31.209	-4.594	29.457	49.806	-0.000	1.212	903.2119	695.1920	0.0348

X01 TEST CASE 4 678

CHAPX WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 90.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08	XMTR	0.0000	0.0007				90.000	-0.000	1.000	0.0000	0.0000	0.0000
0.E-01	ENTR ION	73.2603	0.0007			89.999	90.000	-0.001	1.015	73.2600	73.2600	0.0000
0.E-01		77.2603	0.0006			90.000	90.000	-0.000	1.015	77.2600	77.2600	0.0000
0.E-01		81.7603	0.0007			89.999	90.000	-0.000	1.015	81.7600	81.7600	0.0000
0.E-01		86.7603	0.0007			90.000	90.000	-0.000	1.015	86.7600	86.7600	0.0001
0.E-01		91.7603	0.0008			89.999	90.000	-0.000	1.015	91.7600	91.7600	0.0002
-6.E-08		96.7603	0.0006			90.000	90.000	-0.000	1.015	96.7600	96.7599	0.0003
-6.E-08		101.7603	0.0007			90.000	90.000	-0.000	1.015	101.7600	101.7597	0.0004
0.E-01		106.7598	0.0005			90.000	90.000	-0.000	1.015	106.7600	106.7591	0.0006
-6.E-08		111.7588	0.0007			90.000	90.000	-0.000	1.015	111.7600	111.7578	0.0008
-6.E-08		116.7573	0.0006			90.000	90.000	-0.000	1.015	116.7600	116.7549	0.0010
-6.E-08	WAVE REV	119.7559	0.0007			90.000	90.000	-0.000	1.015	119.7600	119.7519	0.0011
-1.E-07		121.7539	0.0009			90.000	90.000	-0.000	1.015	121.7600	121.7490	0.0012
-6.E-08		126.7476	0.0009			90.000	90.000	-0.000	1.015	126.7600	126.7373	0.0014
-2.E-07		139.6943	0.0040	159.916	29.499	89.998	89.996	-0.000	1.015	139.7600	139.6427	0.0018
-5.E-07		149.5688	0.0135	166.319	23.277	89.995	89.985	-0.000	1.015	149.7600	149.4202	0.0021
-2.E-06		159.2817	0.0337	167.903	21.605	89.988	89.967	-0.000	1.015	159.7600	158.9133	0.0024
-5.E-06		168.7148	0.0732	167.811	20.859	89.974	89.966	-0.000	1.016	169.7600	167.9209	0.0027
-8.E-06	WAVE REV	175.0811	0.1135	167.168	-144.373	89.962	89.993	-0.000	1.017	176.7600	173.8235	0.0030
-6.E-06		178.6133	0.1399	166.410	-154.219	89.954	89.940	-0.000	1.017	180.7600	177.0199	0.0032
-3.E-05		194.9316	0.2767	156.788	-146.111	89.916	89.171	-0.000	1.022	200.7600	190.8668	0.0045
0.E-01	RCVR	200.0000	0.3160	150.929	-140.303	89.907	88.717	-0.000	1.024	207.6450	194.8032	0.0050
-1.E-05	MAX LAT	202.8125	0.3377	146.935	-136.322	89.902	88.433	-0.000	1.026	211.6450	196.9024	0.0053
-5.E-05	MAX LAT	215.9390	0.4890	127.630	-116.926	89.866	87.305	-0.000	1.036	232.6450	205.7608	0.0069
-8.E-05		218.1099	0.5343	126.228	-115.463	89.855	87.280	-0.000	1.038	236.6450	207.0486	0.0073
-2.E-04		227.2183	0.8880	133.833	-120.784	89.768	89.013	-0.000	1.044	256.6450	211.6910	0.0089
-4.E-04	WAVE REV	229.3530	1.0511	138.733	43.765	89.728	89.556	-0.000	1.042	262.6450	212.5547	0.0094
-5.E-03		236.0918	2.3467	159.627	30.170	89.409	53.553	-0.000	1.059	294.6450	214.4196	0.0121
-6.E-03	APOGEE	236.7139	3.0866	166.177	23.729	89.225	-18.358	-0.000	306.875	310.6450	214.5404	0.0134
-6.E-03	WAVE REV	236.7139	3.0866	166.177	23.729	89.225	-18.358	-0.000	306.875	310.6450	214.5404	0.0134
-3.E-03	MAX LONG	236.3379	3.4735	169.211	20.724	89.127	-38.549	0.000	-2.815	318.6450	214.6266	0.0140
-1.E-03		234.0825	4.3977	175.267	14.701	88.884	-54.778	0.000	-1.552	334.6450	215.2137	0.0154
-5.E-05		219.5601	8.6814	-174.174	4.128	87.658	-68.334	0.000	-1.145	374.6450	222.2271	0.0186
0.E-01	RCVR	200.0000	13.2663	-171.371	1.217	86.086	-75.996	0.000	-1.065	407.5788	235.5816	0.0212
1.E-04	MAX LONG	159.1558	20.5735	-170.417	0.208	82.451	-79.728	0.000	-1.035	456.5788	272.0791	0.0239
7.E-05		151.5010	21.9006	-170.390	0.180	81.579	-79.834	0.000	-1.034	464.5788	279.6770	0.0241
2.E-05		112.3296	28.7041	-170.335	0.124	75.415	-79.932	0.000	-1.033	504.5788	319.2846	0.0254
4.E-05		72.9502	35.6158	-170.311	0.100	63.688	-79.872	0.002	-1.034	544.5788	359.2819	0.0262
4.E-05	EXIT ION	72.9502	35.6158	-170.311	0.100	63.688	-79.872	0.002	-1.034	544.5788	359.2819	0.0262
0.E-01	GRND REF	0.0000	48.6492	-170.284	0.073	-0.219	79.755	-0.000	1.000	618.6970	433.4001	0.0263
0.E-01	ENTR ION	73.2568	61.7363	-170.268	0.057	49.438	79.873	-0.000	1.005	693.1270	507.8301	0.0263
-1.E-05		121.4927	70.1917	-170.261	0.051	59.431	79.941	-0.000	1.005	742.1270	556.8188	0.0275
2.E-05		160.3398	76.9920	-170.267	0.052	63.723	79.688	-0.000	1.005	782.1270	595.8742	0.0288
-2.E-05		194.6924	83.4900	-170.352	0.086	66.097	78.370	-0.000	1.006	822.1270	627.3975	0.0308
0.E-01	RCVR	200.0000	84.6153	-170.383	0.107	66.365	77.762	-0.000	1.006	829.4084	631.6696	0.0313

X01 TEST CASE 4 678

TABLE WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

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

1	-1.00000000000E+00
2	6.37000000000E+03
4	6.98131680489E-01
5	-1.83259570599E+00
7	6.00000000000E+00
11	7.85398185253E-01
16	1.57079637051E+00
17	2.61799395084E-01
20	2.00000000000E+02
22	3.00000000000E+00
23	1.00000000000E+03
24	1.37008345127E+00
25	5.07890796661E+00
41	3.00000000000E+00
42	9.99999974738E-05
43	5.00000000000E+01
44	1.00000000000E+00
45	1.00000000000E+02
46	9.99999993923E-09
47	5.00000000000E-01
57	2.00000000000E+00
58	2.00000000000E+00
71	5.00000000000E+00
100	1.00000000000E+00
101	6.50000000000E+00
102	3.00000000000E+02
103	6.20000000000E+01
104	5.00000000000E-01
150	1.00000000000E+00
151	2.50000000000E+02
152	1.00000000000E+02
153	1.00000001490E-01
155	1.00000000000E+02
156	1.00000000000E+02
200	1.00000000000E+00
201	8.00000011921E-01
251	3.65000000000E+04
252	1.00000000000E+02
253	1.48000001907E-01
254	3.00000000000E+01
255	1.40000000000E+02
256	1.83000005782E-02

G^{0}_{N}	G^{1}_{N}	G^{2}_{N}	G^{3}_{N}	G^{4}_{N}	G^{5}_{N}	G^{6}_{N}
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.300953	0.020298	0.000000	0.000000	0.000000	0.000000	0.000000
0.028106	-0.052140	-0.014435	0.000000	0.000000	0.000000	0.000000
-0.030800	0.065600	-0.025252	-0.006952	0.000000	0.000000	0.000000
-0.041243	-0.043956	-0.016897	0.008021	-0.002525	0.000000	0.000000
0.014742	-0.037078	-0.018906	0.002819	0.003656	0.000036	0.000000
-0.006713	-0.012234	-0.004364	0.021370	0.001593	-0.000072	0.000680

H^{0}_{N}	H^{1}_{N}	H^{2}_{N}	H^{3}_{N}	H^{4}_{N}	H^{5}_{N}	H^{6}_{N}
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	-0.057886	0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.035942	0.001129	0.000000	0.000000	0.000000	0.000000
0.000000	0.011084	-0.004421	0.001180	0.000000	0.000000	0.000000
0.000000	-0.010299	0.008794	-0.000086	0.002256	0.000000	0.000000
0.000000	-0.003849	-0.012615	0.007845	0.002207	-0.000328	0.000000
0.000000	0.003157	-0.012670	-0.009281	0.002286	-0.000135	0.000243

HEIGHT	ELECTRON DENSITY
87.5800018311	0.1000000000E+01
90.5350036621	0.2000000000E+01
93.6419982910	0.4000000000E+01
96.9260025024	0.8000000000E+01
100.4000015259	0.1600000000E+02
104.0910034180	0.3200000000E+02
108.0279998779	0.6400000000E+02
112.2450027466	0.1280000000E+03
116.7870025635	0.2560000000E+03
121.7089996338	0.5120000000E+03
127.0849990845	0.1024000000E+04
133.0079956055	0.2048000000E+04
147.0690002441	0.8192000000E+04
155.6679992676	0.1638400000E+05
165.8190002441	0.3276800000E+05
170.0000000000	0.4208400000E+05
180.0000000000	0.7118300000E+05
190.0000000000	0.1100070000E+06
200.0000000000	0.1574310000E+06
210.0000000000	0.2110340000E+06
220.0000000000	0.2675730000E+06
230.0000000000	0.3235640000E+06
240.0000000000	0.3758100000E+06
250.0000000000	0.4217720000E+06
260.0000000000	0.4597320000E+06
270.0000000000	0.4888110000E+06
280.0000000000	0.5088530000E+06
285.0000000000	0.5155960000E+06
290.0000000000	0.5202680000E+06
295.0000000000	0.5229790000E+06
300.0000000000	0.5238530000E+06

X01 TEST CASE 4 678

TABLE WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 0.000000 DEG

		HEIGHT	RANGE	AZIMUTH REAL XMTR	AZIMUTH DEVIATION LOCAL	ELEVATION XMTR	ELEVATION LOCAL	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH	PHAS PATH	ABSO RPTN
		KM	KM	DEG	DEG	DEG	DEG			KM	KM	DB
-6.E-08	XMTR	0.0000	0.0007				0.000	0.000	-1.000	0.0000	0.0000	0.0000
-1.E-07	ENTR ION	87.5811	1050.3073	45.000	-0.000	-0.000	9.447	-0.026	4.613	1059.9298	1059.9298	0.0000
-1.E-07		97.1802	1105.6898	45.000	-0.000	-0.000	9.942	-0.005	3.870	1116.9298	1116.9293	0.0007
-2.E-07		104.2036	1144.4550	45.000	-0.000	-0.000	10.282	-0.002	3.499	1156.9298	1156.9275	0.0016
-2.E-07		111.4546	1183.1340	45.000	-0.000	-0.001	10.600	-0.000	3.216	1196.9298	1196.9209	0.0027
-1.E-07		118.9067	1221.7246	45.000	-0.000	-0.003	10.863	-0.000	3.012	1236.9298	1236.8998	0.0039
5.E-07		137.0869	1313.9590	45.000'	-0.000	-0.037	10.688	-0.000	2.967	1332.9298	1332.5739	0.0065
4.E-06		150.5122	1390.3806	45.001	-0.001	-0.170	8.173	-0.000	5.042	1412.9298	1411.2518	0.0080
8.E-06		157.6978	1458.8627	45.001	-0.000	-0.493	3.077	0.000	-6.865	1484.9298	1480.4982	0.0095
-1.E-07	MIN DIST	158.5283	1491.6157	45.000	0.001	-0.743	-0.000	0.000	-3.072	1519.4230	1513.2809	0.0102
-1.E-07	MIN DIST	158.5283	1491.6157	45.000	0.001	-0.743	-0.000	0.000	-3.072	1519.4230	1513.2809	0.0102
-7.E-07		149.1392	1599.0233	44.997	0.005	-1.952	-8.509	0.000	-1.611	1632.4230	1621.6469	0.0125
1.E-07		135.3989	1675.4742	44.996	0.005	-2.990	-10.760	0.000	-1.503	1712.4230	1700.4534	0.0142
-1.E-06		120.2363	1752.3391	44.996	0.005	-4.017	-10.888	0.000	-1.507	1792.4230	1780.1899	0.0165
-2.E-06		105.4761	1829.5791	44.996	0.005	-4.978	-10.333	0.000	-1.544	1872.4230	1860.1545	0.0189
-1.E-06		91.5918	1907.1635	44.996	0.005	-5.868	-9.650	0.002	-1.593	1952.4230	1940.1516	0.0205
-3.E-06	EXIT ION	86.3042	1938.2893	44.996	0.005	-6.204	-9.371	0.005	-1.615	1984.4230	1972.1515	0.0208
0.E-01	PERIGEE	0.1475	2980.1079	44.998	0.003	-13.400	0.000	0.002	-1.000	3035.6553	3023.3838	0.0208
0.E-01	ENTR ION	87.5806	4029.5254	44.999	0.003	-16.927	9.439	-0.007	1.942	4094.6953	4082.4238	0.0208
0.E-01	MAX LAT	88.2378	4033.4175	44.999	0.003	-16.937	9.474	-0.006	1.937	4098.6953	4086.4238	0.0209
0.E-01		88.2378	4033.4175	44.999	0.003	-16.937	9.474	-0.006	1.937	4098.6953	4086.4238	0.0209
-4.E-07		109.9688	4154.6265	44.999	0.002	-17.235	10.531	-0.000	1.792	4223.6953	4211.4170	0.0233
-3.E-06		124.9438	4231.7539	44.999	0.002	-17.419	10.972	-0.000	1.737	4303.6953	4291.3486	0.0258
-5.E-07		139.9688	4308.4966	44.999	0.002	-17.607	10.395	-0.000	1.776	4383.6953	4370.9092	0.0278
5.E-06		152.5894	4384.8252	45.000	0.002	-17.829	7.186	-0.000	2.192	4463.6953	4449.2310	0.0294
-1.E-07	MIN DIST	158.5938	4469.5342	45.001	0.002	-18.177	0.000	-0.000	17.066	4552.8574	4534.4487	0.0312

X01 TEST CASE 4 678

TABLE WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 15.000000 DEG

	HEIGHT	RANGE	AZIMUTH REAL XMTR	AZIMUTH DEVIATION LOCAL	ELEVATION XMTR	ELEVATION LOCAL	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH	PHAS PATH	ABSO RFTN
	KM	KM	DEG	DEG	DEG	DEG	REAL	IMAG	KM	KM	DB
-1.E-07 XMTR	0.0000	0.0007				15.000	-0.001	1.000	0.0000	0.0000	0.0000
-6.E-08 ENTR ION	87.5815	296.7405	45.000	-0.000	15.000	17.669	-0.008	2.067	311.3200	311.3200	0.0000
-6.E-08	96.4424	323.9609	45.000	0.000	15.000	17.913	-0.002	2.012	340.3200	340.3198	0.0004
0.E-01	102.6211	342.6896	45.000	-0.000	15.000	18.077	-0.001	1.978	360.3200	360.3191	0.0008
2.E-07	113.8750	376.3096	45.000	-0.000	14.999	18.350	-0.000	1.923	396.3200	396.3121	0.0018
-5.E-07	126.5342	413.5254	45.000	-0.000	14.990	18.521	-0.000	1.885	436.3200	436.2647	0.0030
-8.E-06	155.7207	502.1535	45.004	-0.004	14.766	15.844	-0.000	2.278	532.3201	530.7375	0.0051
-1.E-05	171.1055	575.1997	45.009	-0.007	13.761	5.681	0.000	-6.400	612.3201	604.4474	0.0072
-1.E-07 MIN DIST	172.3730	604.0103	45.003	-0.000	12.998	-0.000	0.000	-2.295	644.0053	632.3608	0.0082
-1.E-07 MIN DIST	172.3730	604.0103	45.003	-0.000	12.998	-0.000	0.000	-2.295	644.0053	632.3608	0.0082
7.E-06	160.5195	684.9719	44.983	0.021	9.938	-13.878	0.000	-1.339	733.0053	712.4534	0.0108
-1.E-05	130.1660	780.7390	44.980	0.024	5.849	-18.481	0.000	-1.252	837.0053	813.8275	0.0133
-1.E-05	104.9575	855.2339	44.982	0.022	3.083	-18.126	0.000	-1.264	917.0053	893.7314	0.0158
-2.E-05	86.5376	911.4896	44.983	0.021	1.279	-17.628	0.002	-1.277	977.0053	953.7298	0.0169
-2.E-05 EXIT ION	86.5376	911.4896	44.983	0.021	1.279	-17.628	0.002	-1.277	977.0053	953.7298	0.0169
0.E-01 GRND REF	0.0000	1205.2469	44.988	0.016	-5.420	14.986	-0.000	1.000	1285.1270	1261.8514	0.0169
0.E-01 ENTR ION	87.5801	1502.2366	44.992	0.013	-3.458	17.657	-0.005	1.648	1596.6870	1573.4115	0.0169
0.E-01	102.6099	1548.1884	44.992	0.012	-3.220	18.065	-0.000	1.611	1645.6870	1622.4105	0.0177
-3.E-07	115.1157	1585.5396	44.992	0.012	-3.036	18.364	-0.000	1.585	1685.6870	1662.4016	0.0189
-6.E-06	142.8457	1667.1704	44.993	0.011	-2.682	17.954	-0.000	1.597	1773.6870	1749.9856	0.0212
-7.E-06	164.3691	1740.5906	44.996	0.010	-2.535	12.219	-0.000	2.236	1853.6870	1826.7090	0.0229
-3.E-05	171.5142	1784.3074	44.998	0.009	-2.642	4.894	-0.000	23.917	1901.6870	1870.0388	0.0243
0.E-01 MIN DIST	172.5308	1809.0179	44.998	0.010	-2.796	-0.000	0.000	-3.766	1928.8682	1893.9661	0.0252

X01 TEST CASE 4 678

TABLE WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 30.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO	RPTN DB
0.E-01 XMTR	0.0000	0.0007				30.000	-0.000	1.000	0.0000	0.0000		0.0000
-6.E-08 ENTR ION	87.5835	146.7273	45.000	-0.000	30.000	31.320	-0.002	1.329	171.7400	171.7400		0.0000
0.E-01	95.3936	159.3521	45.000	-0.000	30.000	31.433	-0.001	1.325	186.7400	186.7399		0.0002
-6.E-08	100.6138	167.7520	45.000	-0.000	30.000	31.507	-0.000	1.322	196.7400	196.7396		0.0004
-1.E-07	105.8452	176.1383	45.000	-0.000	30.000	31.579	-0.000	1.319	206.7400	206.7389		0.0007
-2.E-06	128.9580	212.8718	45.001	-0.000	29.993	31.765	-0.000	1.310	250.7400	250.6908		0.0021
4.E-06	149.7690	245.9928	45.004	-0.004	29.928	30.988	-0.000	1.327	290.7400	290.1926		0.0030
-4.E-05	169.0054	278.7112	45.018	-0.017	29.641	27.309	-0.000	1.447	330.7400	327.7409		0.0040
2.E-05	189.1401	326.8346	45.066	-0.058	28.218	12.935	-0.000	4.681	390.7400	376.2657		0.0065
-2.E-07 MIN DIST	192.3877	356.2355	45.048	-0.037	26.406	0.000	0.000	-2.418	427.7266	402.1775		0.0085
-2.E-07 MIN DIST	192.3877	356.2355	45.048	-0.037	26.406	0.000	0.000	-2.418	427.7266	402.1775		0.0085
-2.E-06 WAVE REV	192.2451	359.4076	45.042	-0.031	26.164	-1.460	0.000	-2.171	431.7266	404.9266		0.0088
3.E-06	182.6421	401.4090	44.978	0.036	22.347	-19.042	0.000	-1.274	484.7266	443.1398		0.0116
-3.E-05	163.8813	440.0236	44.952	0.063	18.203	-28.538	0.000	-1.149	532.7266	483.8935		0.0135
-1.E-05	144.1172	472.8406	44.950	0.066	14.638	-31.343	0.000	-1.125	572.7266	522.0721		0.0145
-2.E-05	123.1963	506.0381	44.954	0.063	11.274	-31.749	0.000	-1.123	612.7266	561.7645		0.0156
-2.E-05	102.2114	539.4844	44.958	0.059	8.212	-31.523	0.000	-1.126	652.7266	601.7413		0.0170
-2.E-05	85.5371	566.4002	44.960	0.056	5.979	-31.284	0.001	-1.129	684.7266	633.7407		0.0176
-2.E-05 EXIT ION	85.5371	566.4002	44.960	0.056	5.979	-31.284	0.001	-1.129	684.7266	633.7407		0.0176
-6.E-08 GRND REF	0.0000	709.8438	44.972	0.045	-3.192	29.994	-0.000	1.000	852.5601	801.5742		0.0176
-6.E-08 ENTR ION	87.5825	856.6058	44.979	0.037	1.937	31.314	-0.002	1.278	1024.3301	973.3442		0.0176
-5.E-07	111.0815	894.3920	44.981	0.036	2.985	31.641	-0.000	1.268	1069.3301	1018.3411		0.0186
4.E-07	132.1011	927.7420	44.982	0.034	3.835	31.736	-0.000	1.263	1109.3301	1058.2689		0.0199
6.E-06	152.7886	960.8137	44.985	0.032	4.592	30.662	-0.000	1.284	1149.3301	1097.5994		0.0208
2.E-05	171.5591	993.4481	44.991	0.028	5.183	26.331	-0.000	1.402	1189.3301	1134.6274		0.0218
6.E-05	184.6064	1022.3501	45.001	0.021	5.473	18.231	-0.000	1.895	1225.3301	1164.3044		0.0233
0.E-01 MIN DIST	192.5371	1065.7448	45.008	0.020	5.275	-0.000	0.000	-3.134	1279.9381	1203.4141		0.0262

X01 TEST CASE 4 678

TABLE WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 45.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH DEVIATION REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08	XMTR	0.0000	0.0007				45.000	-0.000	1.000	0.0000	0.0000	0.0000
0.E-01	ENTR ION	87.5820	85.8178	45.001	-0.001	45.000	45.772	-0.001	1.153	123.0300	123.0300	0.0000
-6.E-08		96.1860	94.0638	45.000	-0.000	45.000	45.846	-0.000	1.151	135.0300	135.0299	0.0002
-3.E-07		109.1118	106.3911	45.000	-0.000	45.000	45.951	-0.000	1.150	153.0300	153.0283	0.0007
-6.E-08		116.3013	113.2178	45.000	-0.000	45.000	46.001	-0.000	1.149	163.0300	163.0242	0.0010
4.E-05		149.2231	144.3832	45.005	-0.005	44.960	45.573	-0.000	1.152	209.0300	208.6272	0.0024
-3.E-05		173.4741	168.2785	45.033	-0.030	44.725	42.348	-0.000	1.196	245.0300	241.8765	0.0034
-1.E-05		185.2813	181.2043	45.069	-0.063	44.407	38.314	-0.000	1.269	265.0300	257.9648	0.0043
0.E-01	RCVR	200.0000	200.8328	45.158	-0.143	43.529	28.108	-0.000	1.632	296.3369	278.6627	0.0062
-2.E-05	APOGEE	210.4526	232.9604	45.212	-0.181	40.577	1.415	0.000	-3.404	349.3369	304.0358	0.0100
-2.E-05		210.4526	232.9604	45.212	-0.181	40.577	1.415	0.000	-3.404	349.3369	304.0358	0.0100
-2.E-05	WAVE REV	210.3091	235.3736	45.199	-0.167	40.254	-0.851	0.000	-2.759	353.3369	305.7413	0.0103
4.E-06		201.7046	262.0095	45.029	0.012	35.974	-24.026	0.000	-1.272	397.3369	326.2335	0.0135
0.E-01	RCVR	200.0000	265.0641	45.013	0.029	35.412	-26.251	0.000	-1.235	402.3213	328.9417	0.0139
2.E-06		176.1870	295.9979	44.923	0.127	29.082	-41.330	0.000	-1.083	451.3213	362.5567	0.0168
3.E-05		163.4551	309.1258	44.914	0.138	26.173	-44.134	0.000	-1.067	471.3213	379.9892	0.0176
2.E-05		132.6543	338.6722	44.918	0.134	19.661	-46.006	0.000	-1.059	515.3213	422.4881	0.0188
4.E-05		103.9072	365.9277	44.928	0.124	14.081	-45.909	0.000	-1.060	555.3213	462.4218	0.0202
3.E-05	EXIT ION	86.6909	382.4025	44.934	0.119	10.966	-45.763	0.000	-1.061	579.3213	486.4212	0.0207
-6.E-08	GRND REF	0.0000	467.3691	44.955	0.097	-2.102	44.999	-0.000	1.000	701.1113	608.2113	0.0207
-6.E-08		0.0000	467.3691	44.955	0.097	-2.102	44.999	-0.000	1.000	701.1113	608.2113	0.0207
0.E-01	ENTR ION	87.5869	553.1960	44.970	0.082	6.443	45.771	-0.001	1.139	824.1514	731.2513	0.0207
-1.E-05		128.5288	592.1647	44.976	0.077	9.456	46.032	-0.000	1.134	881.1514	788.2147	0.0224
2.E-05		156.8989	619.1293	44.981	0.072	11.259	45.008	-0.000	1.144	921.1514	827.4124	0.0234
3.E-06		180.1392	642.7969	44.995	0.062	12.544	40.326	-0.000	1.208	957.1514	859.1767	0.0246
-7.E-05		199.7979	668.0021	45.030	0.037	13.390	28.129	-0.000	1.551	997.1514	886.6130	0.0269
-1.E-07	RCVR	200.0000	668.3244	45.031	0.036	13.397	27.901	-0.000	1.562	997.6771	886.9158	0.0270

X01 TEST CASE 4 678

TABLE WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 60.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH DEVIATION REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08	XMTR	0.0000	0.0007				60.000	-0.000	1.000	0.0000	0.0000	0.0000
-1.E-07	ENTR ION	87.5879	49.7713	45.001	-0.001	60.000	60.448	-0.000	1.075	100.9100	100.9100	0.0000
-1.E-07		98.8999	56.0853	45.000	-0.000	60.000	60.504	-0.000	1.075	113.9100	113.9098	0.0002
5.E-07		114.5708	64.7904	45.001	-0.001	60.000	60.575	-0.000	1.074	131.9100	131.9062	0.0008
6.E-07		131.9731	74.4099	45.002	-0.002	59.996	60.589	-0.000	1.073	151.9100	151.8601	0.0016
1.E-05		149.2422	83.9513	45.008	-0.007	59.978	60.313	-0.000	1.075	171.9100	171.5578	0.0021
2.E-05		166.0015	93.3505	45.029	-0.027	59.911	59.280	-0.000	1.083	191.9100	190.3592	0.0026
1.E-04		181.5801	102.4937	45.081	-0.074	59.747	56.903	-0.000	1.104	211.9100	207.1898	0.0035
4.E-05		195.2598	111.2586	45.175	-0.160	59.448	52.700	-0.000	1.151	231.9100	221.0794	0.0047
1.E-07	RCVR	200.0000	114.5749	45.224	-0.205	59.290	50.437	-0.000	1.183	239.7581	225.6394	0.0052
-1.E-05		214.1450	126.1713	45.449	-0.409	58.506	38.682	-0.000	1.471	268.7581	238.4264	0.0075
-1.E-05	APOGEE	224.5693	144.7031	45.645	-0.562	56.095	2.524	0.000	-5.390	320.7581	250.4614	0.0118
-1.E-05		224.5693	144.7031	45.645	-0.562	56.095	2.524	0.000	-5.390	320.7581	250.4614	0.0118
-6.E-05	WAVE REV	224.2051	147.4894	45.596	-0.508	55.537	-4.077	0.000	-2.949	328.7581	251.8588	0.0125
2.E-04		217.1685	160.6468	45.273	-0.163	52.320	-31.030	0.000	-1.276	364.7581	259.7497	0.0155
-1.E-07	RCVR	200.0000	176.7267	44.998	0.134	47.295	-49.741	0.000	-1.070	404.6407	275.4511	0.0188
-8.E-05		165.8545	198.6337	44.893	0.253	38.601	-59.241	0.000	-1.029	453.6407	310.9708	0.0216
7.E-07		149.1475	208.0478	44.895	0.253	34.383	-60.310	0.000	-1.026	473.6407	329.7204	0.0222
8.E-07		107.5220	231.0704	44.917	0.231	23.728	-60.555	0.000	-1.026	521.6407	377.3533	0.0239
7.E-07	EXIT ION	86.6333	242.7083	44.928	0.220	18.427	-60.453	0.000	-1.026	545.6407	401.3521	0.0244
0.E-01	GRND REF	0.0000	291.9239	44.965	0.183	-1.313	60.010	-0.000	1.000	645.4429	501.1543	0.0244
-6.E-08	ENTR ION	87.5801	341.6692	44.992	0.156	12.743	60.458	-0.000	1.070	746.3329	602.0443	0.0244
0.E-01		91.0605	343.6143	44.993	0.155	13.193	60.475	-0.000	1.070	750.3329	606.0443	0.0245
-1.E-06		116.3071	357.6477	44.999	0.149	16.249	60.591	-0.000	1.069	779.3329	635.0392	0.0253
9.E-05		157.7183	380.5608	45.012	0.138	20.545	59.938	-0.000	1.073	827.3329	682.2616	0.0268
3.E-04		188.6724	398.8100	45.047	0.112	23.193	55.050	-0.000	1.115	867.3329	715.6417	0.0285
-1.E-07	RCVR	200.0000	406.4807	45.079	0.088	24.011	50.406	-0.000	1.172	885.2444	726.7593	0.0297

X01 TEST CASE 4 678

TABLE WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 75.000000 DEG

		HEIGHT KM	RANGE KM	AZIMUTH REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO	RFTN DB
-6.E-08	XMTR	0.0000	0.0007				75.000	-0.000	1.000	0.0000	0.0000		0.0000
-6.E-08	ENTR ION	87.5845	23.1386	45.001	-0.001	75.000	75.208	-0.000	1.035	90.6300	90.6300		0.0000
-6.E-08		95.3198	25.1509	45.003	-0.003	75.000	75.226	-0.000	1.034	98.6300	98.6299		0.0001
0.E-01		106.9233	28.1606	45.002	-0.002	75.000	75.252	-0.000	1.034	110.6300	110.6291		0.0005
-6.E-08		116.5918	30.6600	45.001	-0.001	75.000	75.271	-0.000	1.034	120.6300	120.6250		0.0009
-1.E-06		139.7422	36.6219	45.006	-0.006	74.996	75.241	-0.000	1.034	144.6300	144.5098		0.0017
-1.E-05		158.7114	41.5178	45.034	-0.032	74.979	74.925	-0.000	1.036	164.6300	163.8336		0.0023
-7.E-05		176.6992	46.2693	45.120	-0.111	74.924	73.965	-0.000	1.041	184.6300	181.4497		0.0030
-3.E-04		192.7866	50.7629	45.304	-0.280	74.807	71.971	-0.000	1.055	204.6300	195.9391		0.0042
0.E-01	RCVR	200.0000	52.9153	45.442	-0.405	74.720	70.443	-0.000	1.067	214.7959	201.8365		0.0049
-8.E-05		216.5708	58.4650	45.979	-0.896	74.385	63.431	-0.000	1.143	243.7959	213.3899		0.0073
-2.E-04		224.5356	61.7346	46.409	-1.288	74.091	54.920	-0.000	1.293	263.7959	217.6732		0.0090
-1.E-03	APOGEE	232.3779	69.1407	46.855	-1.622	72.834	-5.844	0.000	-3.437	319.7959	221.5291		0.0139
-1.E-03	WAVE REV	232.3779	69.1407	46.855	-1.622	72.834	-5.844	0.000	-3.437	319.7959	221.5291		0.0139
-1.E-03		232.3779	69.1407	46.855	-1.622	72.834	-5.844	0.000	-3.437	319.7959	221.5291		0.0139
-4.E-04		226.9697	74.4468	46.194	-0.895	71.204	-47.386	0.000	-1.166	355.7959	223.8621		0.0170
0.E-01	RCVR	200.0000	86.1285	45.149	0.243	65.988	-70.284	0.000	-1.021	415.3344	240.8551		0.0222
-8.E-05		177.9990	92.7786	44.977	0.439	61.725	-73.830	0.000	-1.014	444.3344	260.0175		0.0241
-6.E-05		160.1963	97.5833	44.952	0.471	57.894	-74.880	0.000	-1.012	464.3344	277.3699		0.0249
-8.E-05		141.2959	102.4883	44.962	0.463	53.283	-75.240	0.000	-1.012	484.3344	296.5867		0.0254
-4.E-05		91.0874	115.4520	45.012	0.414	37.554	-75.229	0.000	-1.012	536.3344	348.4389		0.0272
-4.E-05	EXIT ION	83.3521	117.4654	45.018	0.407	34.654	-75.211	0.000	-1.012	544.3344	356.4388		0.0273
0.E-01	GRND REF	0.0000	139.4810	45.082	0.343	-0.627	75.013	-0.000	1.000	630.5819	442.6864		0.0273
-6.E-08	ENTR ION	87.5801	162.5976	45.131	0.294	27.412	75.221	-0.000	1.033	721.2019	533.3064		0.0273
-5.E-06		123.3550	171.8558	45.147	0.278	34.634	75.290	-0.000	1.032	758.2019	570.2919		0.0285
-5.E-05		161.4912	181.6859	45.171	0.257	40.455	74.844	-0.000	1.034	798.2019	609.2954		0.0296
-4.E-04		194.9829	190.8487	45.266	0.186	44.318	71.579	-0.000	1.055	838.2019	640.4460		0.0317
0.E-01	RCVR	200.0000	192.3588	45.297	0.163	44.802	70.458	-0.000	1.064	845.3792	644.4982		0.0322

X01 TEST CASE 4 678

TABLE WAVE HARMNY EXPZ2 APPLETON-HARTREE FORMULA EXTRAORDINARY WITH COLLISIONS

FREQUECY = 6.000000 MHZ, AZIMUTH ANGLE OF TRANSMISSION = 45.000000 DEG

ELEVATION ANGLE OF TRANSMISSION = 90.000000 DEG

	HEIGHT KM	RANGE KM	AZIMUTH DEVIATION REAL XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION XMTR DEG	ELEVATION LOCAL DEG	POLARIZATION REAL	POLARIZATION IMAG	GROUP PATH KM	PHAS PATH KM	ABSO RPTN DB
-6.E-08 XMTR	0.0000	0.0007				90.000	-0.000	1.000	0.0000	0.0000	0.0000
0.E-01 ENTR ION	87.5801	0.0007			90.000	90.000	-0.000	1.015	87.5800	87.5800	0.0000
0.E-01	95.5801	0.0006			90.000	90.000	-0.000	1.015	95.5800	95.5799	0.0001
0.E-01	100.5801	0.0007			90.000	90.000	-0.000	1.015	100.5800	100.5798	0.0003
0.E-01	105.5796	0.0006			90.000	90.000	-0.000	1.015	105.5800	105.5793	0.0004
-1.E-07	110.5791	0.0006			90.000	90.000	-0.000	1.015	110.5800	110.5782	0.0006
-1.E-06	123.5718	0.0009			90.000	90.000	-0.000	1.015	123.5800	123.5653	0.0012
1.E-06	133.5483	0.0020	151.184	-3.430	89.999	90.000	-0.000	1.015	133.5800	133.5234	0.0015
7.E-06	153.3071	0.0173	162.919	-14.977	89.993	90.000	-0.000	1.015	153.5800	153.0954	0.0021
7.E-06	172.2671	0.0789	164.316	-16.249	89.973	89.998	-0.000	1.016	173.5800	171.2746	0.0028
-1.E-05	189.4556	0.2481	164.424	-16.335	89.923	89.994	-0.000	1.019	193.5800	186.5027	0.0039
0.E-01 RCVR	200.0000	0.4598	164.477	-16.446	89.864	89.988	-0.000	1.022	207.6327	194.8385	0.0049
-3.E-05	217.1333	1.1561	164.558	-16.875	89.685	89.961	-0.000	1.033	236.6327	205.9162	0.0073
2.E-04	225.3574	1.7795	164.592	-17.330	89.532	89.920	-0.000	1.043	256.6327	209.7452	0.0091
-6.E-02	234.8284	2.9880	164.555	-18.899	89.244	85.135	-0.000	1.039	312.6327	212.1990	0.0140
-9.E-01 MAX LONG	234.8384	2.9902	164.559	-18.948	89.244	41.125	-0.000	1.158	314.3827	212.1990	0.0142
-9.E-01 MAX LAT	234.8384	2.9902	164.559	-18.950	89.244	26.131	-0.000	1.414	314.4452	212.1990	0.0143
-8.E-01 MAX LAT	234.8389	2.9903	164.557	-18.948	89.244	16.669	-0.000	1.715	314.4764	212.1990	0.0143
-8.E-01 MAX LONG	234.8389	2.9903	164.557	-18.948	89.244	16.669	-0.000	1.715	314.4764	212.1990	0.0143
-8.E-01	234.8389	2.9903	164.557	-18.948	89.244	16.669	-0.000	1.715	314.4764	212.1990	0.0143
-8.E-01 APOGEE	234.8384	2.9902	164.559	-18.957	89.244	-50.799	0.000	-1.924	314.7264	212.1990	0.0144
-8.E-01 MAX LAT	234.8384	2.9902	164.559	-18.957	89.244	-50.799	0.000	-1.924	314.7264	212.1990	0.0144
-8.E-01 MAX LONG	234.8384	2.9902	164.559	-18.957	89.244	-50.799	0.000	-1.924	314.7264	212.1990	0.0144
-8.E-01 WAVE REV	234.8384	2.9902	164.559	-18.957	89.244	-50.799	0.000	-1.924	314.7264	212.1990	0.0144
-8.E-01	234.8384	2.9902	164.559	-18.957	89.244	-54.776	0.000	-1.733	314.7577	212.1990	0.0145
-3.E-01	234.8379	2.9902	164.556	-18.962	89.244	-74.065	0.000	-1.232	315.1014	212.1990	0.0145
-3.E-01	234.8364	2.9902	164.558	-18.972	89.244	-79.487	0.000	-1.160	315.4139	212.1990	0.0146
-1.E-01	234.8330	2.9895	164.561	-18.989	89.244	-83.487	0.000	-1.118	315.9764	212.1990	0.0146
-2.E-03	234.4233	2.9268	164.512	-19.179	89.258	-89.170	0.000	-1.070	326.9764	212.2215	0.0156
6.E-05	220.5391	1.4581	163.569	-18.443	89.608	-89.796	0.000	-1.037	384.9764	216.7536	0.0207
8.E-06	205.6523	0.7485	161.453	-16.095	89.785	-89.839	0.000	-1.025	412.9764	225.5225	0.0231
-1.E-07 RCVR	200.0000	0.5954	160.158	-14.737	89.824	-89.847	0.000	-1.022	421.4388	229.5597	0.0238
2.E-04	176.8140	0.3023	152.443	-6.875	89.899	-89.867	0.000	-1.017	450.4388	248.9398	0.0257
-1.E-04 MAX LAT	150.4238	0.2660	146.660	-1.050	89.896	-89.875	0.000	-1.015	478.4388	274.1378	0.0266
-1.E-04 MAX LONG	150.4238	0.2660	146.660	-1.050	89.896	-89.875	0.000	-1.015	478.4388	274.1378	0.0266
-2.E-04	134.5938	0.2900	145.874	-0.259	89.874	-89.876	0.000	-1.015	494.4388	289.8347	0.0271
-2.E-04	94.6333	0.3729	145.693	-0.077	89.771	-89.875	0.000	-1.015	534.4388	329.7695	0.0285
-2.E-04 EXIT ION	86.6343	0.3902	145.717	-0.102	89.738	-89.875	0.000	-1.015	542.4388	337.7694	0.0286
-6.E-08 GRND REF	0.0000	0.5788	145.644	-0.029	0.050	89.874	-0.000	1.000	629.0731	424.4037	0.0286
0.E-01 ENTR ION	87.5806	0.7699	145.627	-0.009	89.489	89.875	-0.000	1.015	716.6531	511.9837	0.0286
-2.E-05	128.5640	0.8583	145.654	-0.036	89.610	89.876	-0.000	1.015	757.6531	552.9539	0.0300
4.E-04	167.6528	0.9934	146.648	-1.007	89.652	89.869	-0.000	1.016	797.6531	591.3484	0.0312
6.E-04	194.8877	1.3323	150.404	-4.657	89.596	89.836	-0.000	1.020	829.6531	615.3121	0.0330
0.E-01 RCVR	200.0000	1.4592	151.486	-5.704	89.569	89.823	-0.000	1.022	836.6977	619.2343	0.0335