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MICROPREDIC

An HF Prediction Program for 8086/8088-based Computers

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L.E. Petrie and G.W. Goudie
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MICROPREDIC

ADDENDUM

3.1 LOADING THE PROGRAM

c) If the prompt "Terminate batch job (Y/N)?" appears
   - Press Ctrl + Break.
   - The above prompt will again appear
   - Press N and continue on to section 3.2.

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TABLE OF CONTENTS

ABSTRACT 1

1.0 INTRODUCTION 1

2.0 PROGRAM DESCRIPTION 3
2.1 GENERATION OF THE DATA BASE 3
2.2 STRUCTURE OF MICROPREDIC 3

3.0 OPERATIONS 5
3.1 LOADING THE PROGRAM 5
3.2 USER'S INPUT DATA 5
3.3 OUTPUT DATA 7
3.4 MODIFICATION TO PRINTER SETUP ROUTINE 9

4.0 REFERENCES 10

ANNEX

A1.0 GENERATION OF THE DATA BASE 12
A1.1 IONOSPHERIC DATA FILE 12
A1.2 DATA BASE FILES 12

A2.0 COMPUTATION OF PATH GEOMETRY 13
A2.1 INPUT PARAMETERS 14
A2.2 CONVERSION OF LATITUDE AND LONGITUDE FROM DEGREES TO RADIANS 14
A2.3 COMPUTATION OF GREAT CIRCLE DISTANCE 14
A2.4 COMPUTATION OF BEARING FROM TRANSMITTER TO RECEIVER 14
A2.5 COMPUTATION OF BEARING FROM RECEIVER TO TRANSMITTER 15
A2.6 COMPUTATION OF DISTANCE OF THE IONOSPHERIC REFLECTION POINTS FROM TRANSMITTER LOCATION 15
A2.7 COORDINATES OF IONOSPHERIC REFLECTION POINT 16
A2.8 GEOMAGNETIC PARAMETERS 17

A3.0 SELECTION AND COMPUTATION OF NUMERICAL COEFFICIENTS 18
A3.1 INPUT PARAMETERS 18
A3.2 COMPUTATION OF COEFFICIENTS AT A SPECIFIED SUNSPOT NUMBER R12 18
A3.3 COMPUTATION OF COEFFICIENTS FOR A SPECIFIED UNIVERSAL TIME (GMT) 19

A4.0 COMPUTATION OF IONOSPHERIC PARAMETERS 19

- A4.1 INPUT PARAMETERS 19
- A4.2 EVALUATION FOR A SPECIFIED GEOGRAPHIC LOCATION 20
- A4.3 COMPUTATION OF F2-LAYER PARAMETERS 20
- A4.4 COMPUTATION OF E-LAYER CRITICAL FREQUENCY 21

A5.0 COMPUTATION OF OWF AND LUF 21

- A5.1 COMPUTATION OF DISTANCE FACTORS FOR OWF 21
- A5.2 COMPUTATION OF OPTIMUM WORKING FREQUENCY 22
- A5.3 COMPUTATION OF LOWEST USABLE FREQUENCY 23

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ABSTRACT

HF propagation prediction techniques previously available only from programs running on large mainframe computer systems have been developed for the IBM PC and compatible 8086/8088-based microcomputers. The program MICROPREDIC makes use of the ionospheric database and methods recommended by the CCIR for prediction of E- and F2-layer MUF and E-layer screening frequency. The user provides location, sunspot number and season as requested by the program. The resulting table of OWF and LUF is displayed on the computer monitor and may be printed if desired.

1.0 INTRODUCTION

During the past twenty years, a number of computer programs have been developed for predicting the long-term performance of high frequency skywave circuits. Notable among these are ITSA1 [1], HFMUFES in several versions [2][3], IONCAP [4], CANPRED [5], MUFFY (a computer adaptation of [6]), FTZ [7], HFMLOSS [8] and SKYWAVE [9]. The earliest programs predicted only ionospheric reflection; the later ones permitted the inclusion of system parameters. Over the years, major improvements were incorporated into these programs, which operate on a mainframe computer. As recently as 1980, CCIR Study Group 6 established Interim Working Party 6/12 to adapt available computer prediction methods in order to make them more suitable for use in planning the HF broadcast spectrum. The results of its work were adopted by the CCIR in Report 894 [10], and, with some modification, by the First Session of the WARC for the planning of the HF bands allocated to the broadcasting service [11]. The IWP 6/12 program LIL252 implements the method of [10], and many of the techniques incorporated in this program have been used in the program MICROPREDIC documented in this report.

The program MICROPREDIC was developed by Petrie Telecommunications Limited, under DOC contract, for an IBM Personal Computer. MICROPREDIC is designed to operate on a computer with 8086/8088 microprocessors such as the IBM, Hyperion and Compaq personal computers. The program computes both the maximum usable frequency (MUF) and the E-layer screening frequency for any terrestrial HF path. The optimum working frequency (OWF) and lowest usable frequency (LUF), based on these, are displayed on the computer monitor and may be printed if desired. System parameters are not considered.

MICROPREDIC incorporates the following features:

- worldwide data base of ionospheric characteristics (for four seasons) as described in CCIR Report 340 [6];
- prediction of E- and F2-layer MUFs as described in CCIR Report 894 [10], sections 4.1.3 and 4.1.6;
- E-layer screening frequency as described in CCIR Report 894, section 4.1.4, which provides a first-order estimate of the lowest operating frequency (LUF) during the daytime hours.

MICROPREDIC was written in a high-level language to permit portability and easier modification. The C language was chosen because its speed and efficiency approach those of an assembly language, and its structured format produces readable programs. The Digital Research compiler was used, but several others are available (e.g. Lattice and Computer Innovations).

The accuracy of MICROPREDIC using double precision (32 bits) is comparable to that of similar programs running on a mainframe computer. The program requires about 63 kilobytes of storage and takes about four minutes to compute a prediction for the twenty-four hours of the day, for a given path, sunspot number and month. At present the coefficients for the F2-layer for four seasons (months) are easily stored on one 5.25-inch floppy disk (46 kilobytes for each season). The program will be modified to include performance assessment based on power and antenna gain, coefficients for twelve months and an optional graphic output. Future versions may also make use of the 8087 coprocessor chip present in many 8086/8088-based systems in order to increase the speed of floating-point computations.

Section 2 of this report describes the generation of the data base and the structure of MICROPREDIC. Section 3 gives operating instructions, including descriptions of the user's input and the program output. The Annex gives a detailed description of the procedures used.

2.0 PROGRAM DESCRIPTION

2.1 GENERATION OF THE DATA BASE

The LIL252 [5] and other programs use numerical maps of ionospheric characteristics as described in CCIR Report 340 [2]. Each map represents the worldwide geographic and diurnal variation of these characteristics as a function of latitude, longitude and time. The map coefficients are used in a Fourier time series to obtain the corresponding ionospheric characteristic.

The MICROPREDIC program requires the cofficients for foF2 and M(3000)F2 for four seasons. A separate program was used to select a subset of the maps, which was then transferred to Data Base Files on disk. The procedure is described in the Annex, Section A.1, and the relationship of this program to MICROPREDIC is shown on the left side of Figure 1.

2.2 STRUCTURE OF MICROPREDIC

The MICROPREDIC program is divided into four main sections as shown schematically on the right side of Figure 1. The function of each section is given below with more detail in the Annex (Sections A.2 through A.5). This detail will permit those who wish to adapt or modify the program for their own needs to do so. For consistency, the variable names used in the Annex are in most instances the same as those in the MICROPREDIC program and generally the same as those in relevant parts of program LIL252. Note that the numerical values of indices given in the Annex are greater by one than those in MICROPREDIC, which uses an index base of zero.

The primary functions of the four sections of MICROPREDIC are:

a) Computation of Path Geometry

Based on the geographic coordinates of the path terminals, supplied by the user, this section computes the path parameters required, i.e. the great circle distance and bearings, the location of the ionospheric reflection points, the geomagnetic latitude, the magnetic dip and the electron gyrofrequency.

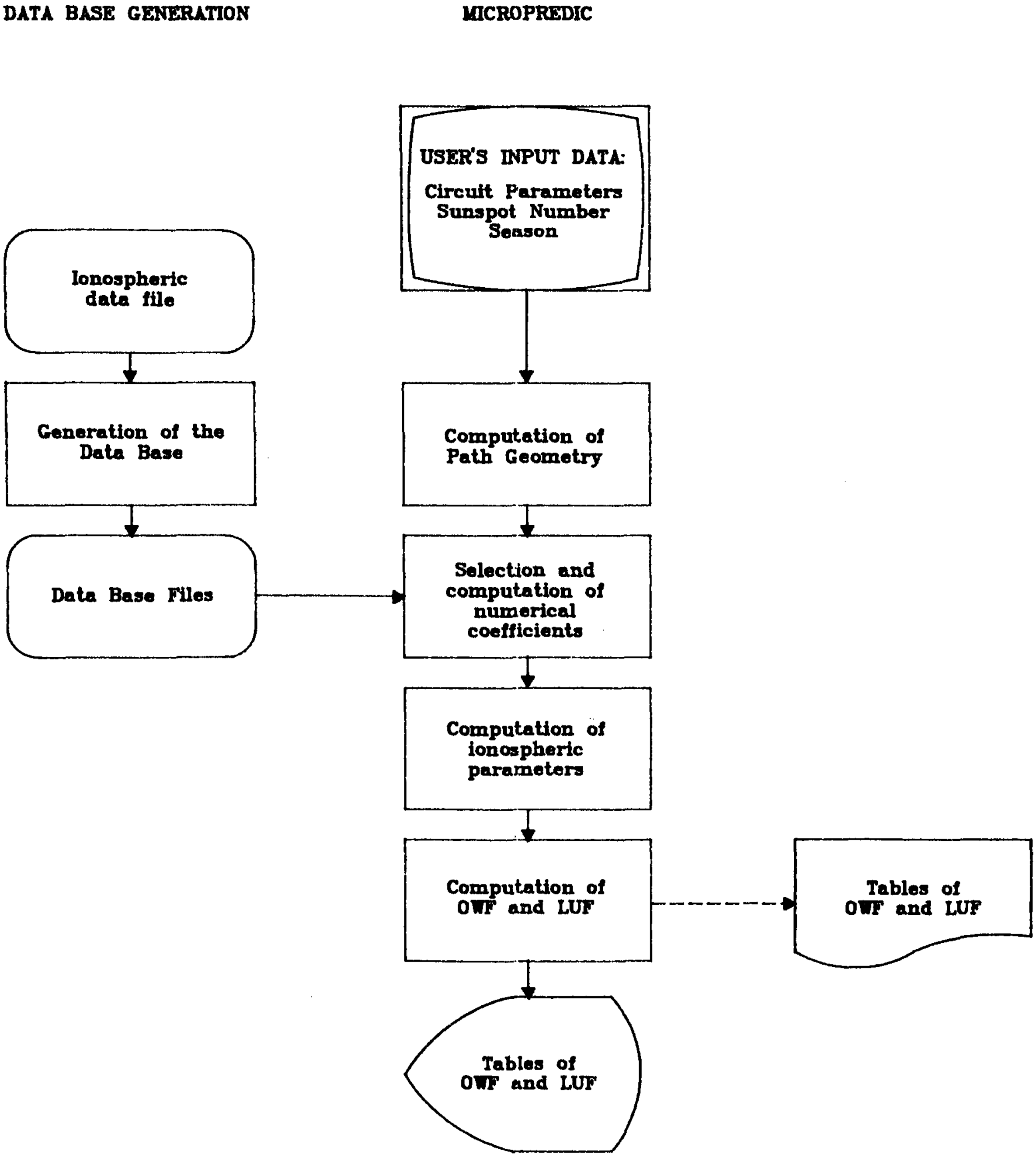


Figure 1 HF PREDICTION SYSTEM

b) Selection and Computation of Numerical Coefficients

This section reads the Data Base file for the specified season and computes the coefficients for the specified sunspot number and times.

c) Computation of Ionospheric Parameters

This section computes for each hour of GMT the median values of foF2, M(3000)F2 and foE at each ionospheric reflection point.

d) Computation of OWF and LUF

This section computes the optimum working frequency (OWF) for the path from the maximum usable frequencies (MUFs) for the various modes of propagation. In addition, the lowest usable frequency (LUF) due to E-layer screening of the F-layer is computed.

3.0 OPERATIONS

3.1 LOADING THE PROGRAM

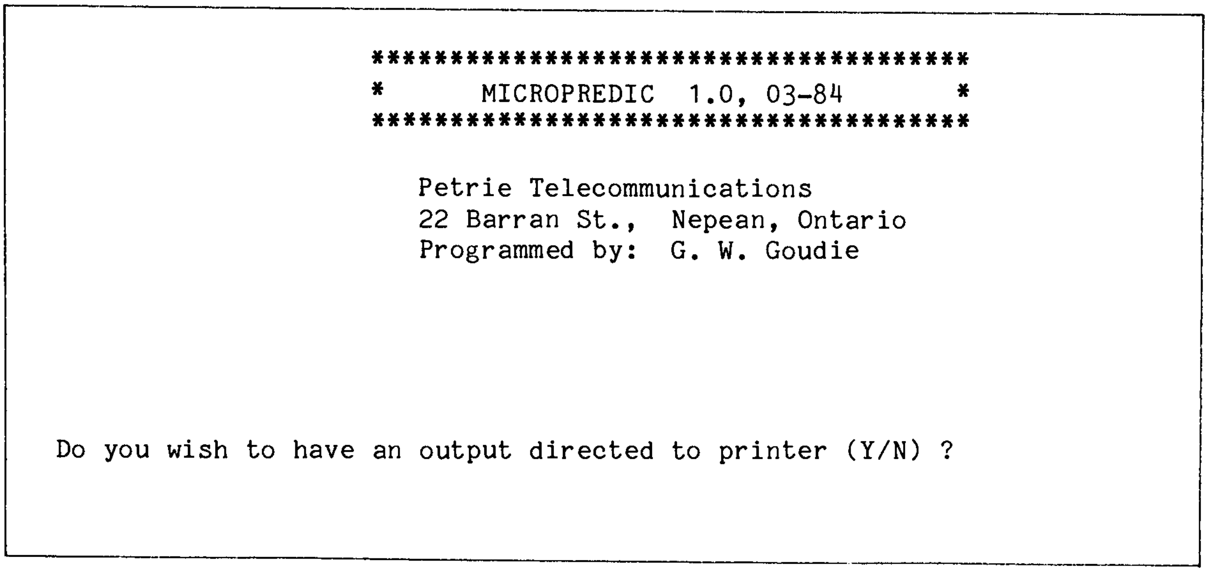
The program MICROPREDIC 1.0 03-84 is designed to operate on an IBM Personal Computer or compatible 8086/8088-based system with at least 128K of memory. The program disk contains an AUTOEXEC.BAT file that automatically runs the BASIC printer setup program (see Section 3.4) and then the prediction program. Instructions for initiating operations on the IBM PC are as follows:

a) If Power is "off"
- Insert program disk in drive A
- Turn on machine
- Wait one minute for identification instructions
- Enter information as requested on the screen

b) If Power is "on"
- Insert program disk in drive A
- Press and hold keys "Ctrl + Alt + Del"
- Enter information as requested on the screen

3.2 USER'S INPUT DATA

When the program has been loaded, a sign-on message is displayed (see Figure 2(a)) and the user is asked:



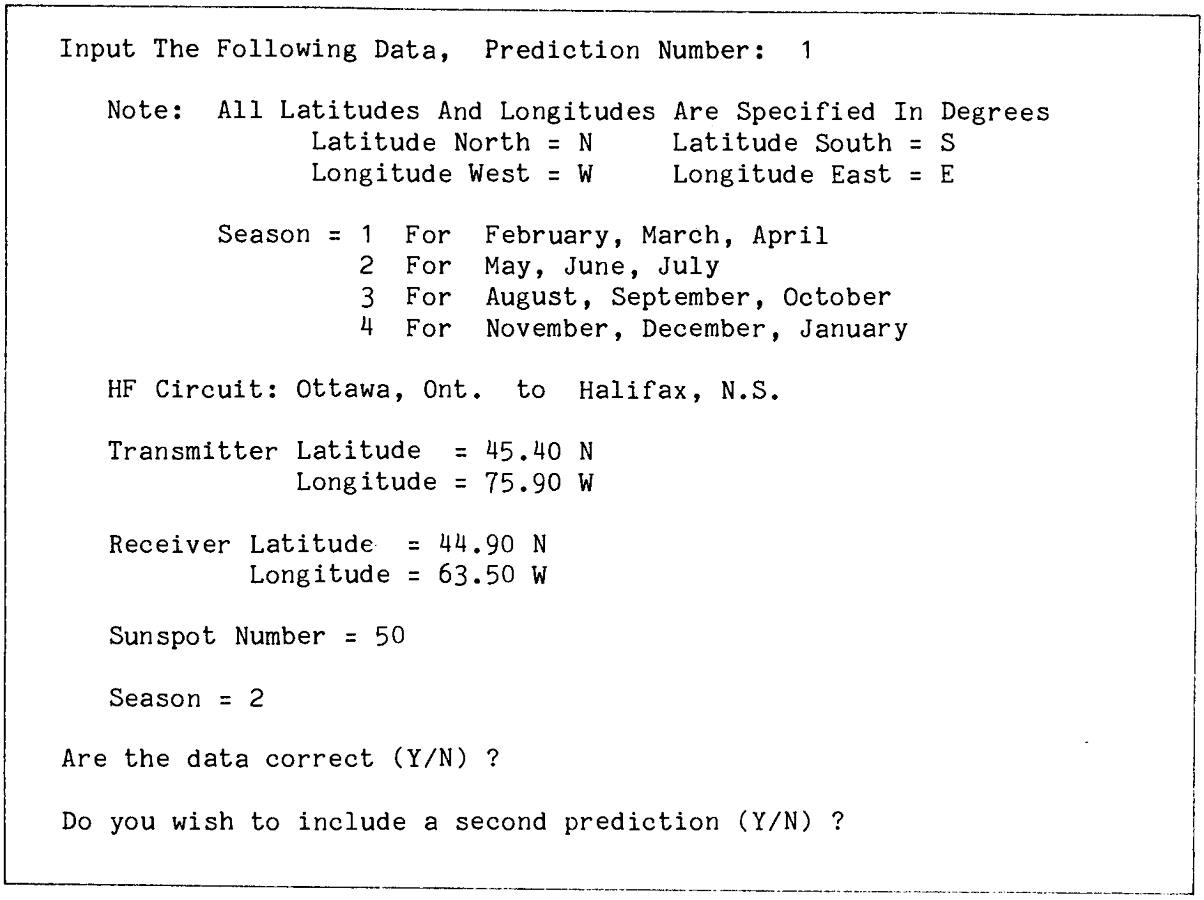
```
                        *************************************
                        *       MICROPREDIC  1.0, 03-84     *
                        *************************************

                           Petrie Telecommunications
                           22 Barran St.,  Nepean, Ontario
                           Programmed by:  G. W. Goudie




Do you wish to have an output directed to printer (Y/N) ?
```

Figure 2(a) OUTPUT CONTROL



```
Input The Following Data,  Prediction Number:  1

   Note:  All Latitudes And Longitudes Are Specified In Degrees
                Latitude North = N     Latitude South = S
                Longitude West = W     Longitude East = E

          Season = 1  For  February, March, April
                   2  For  May, June, July
                   3  For  August, September, October
                   4  For  November, December, January

   HF Circuit: Ottawa, Ont.  to  Halifax, N.S.

   Transmitter Latitude  = 45.40 N
               Longitude = 75.90 W

   Receiver Latitude  = 44.90 N
            Longitude = 63.50 W

   Sunspot Number = 50

   Season = 2

Are the data correct (Y/N) ?

Do you wish to include a second prediction (Y/N) ?
```

Figure 2(b) DATA INPUT

"Do you wish to have an output directed to the printer (Y/N)?"

If the operator types a "Y" the prediction computations are directed to the printer as well as being displayed on the terminal. If an "N" is entered the computations are displayed on the terminal only.

The second display on the terminal (Figure 2(b)) provides the following information to the user on submitting input data: the transmitter and receiver locations, sunspot number and a numerical code for the season. The names associated with the terminals of the HF circuit (up to a maximum of 59 characters in length) can be entered after the heading "HF Circuit". Then the computer program requests the user to supply information, initially indicated by zeros, after each of the headings. If the latitude entered is greater than 90° or not followed by "N" for north or "S" for south, or if the longitude is greater than 360° or not followed by "E" for east or "W" for west, the data must be re-entered before proceeding to the next heading. The carriage return key must be pressed to proceed to the next heading.

After all the data are entered the program asks if the data are correct with the following statement:

"Are the data correct (Y/N)?"

If an "N" is indicated, previously entered data are displayed for each heading. The carriage return key must be pressed to proceed to the next heading. Corrections, as required, can be made to each of the headings. After all headings are checked, the program again asks if the data are correct and, if necessary, the above process can be repeated. If the operator types a "Y" the program asks:

"Do you wish to include a second, third .....tenth prediction (Y/N)?"

If a "Y" is entered, data for an additional prediction are requested by the program. When an "N" is entered the prediction computations are performed for the data entered. The computation time is approximately four minutes for each prediction when a standard IBM PC (4.77 MHz clock) or equivalent is used. By comparison, real-time operation of the LIL252 program on a mainframe computer takes 2.2 seconds.

3.3 OUTPUT DATA

The output data displayed on the video screen consist of the user's input, and tables of OWF and LUF for the twenty-four hours of GMT. An example of the output data is shown in Figure 3.

```
************************* MICROPREDIC  1.0,  03-84 *************************

 HF Circuit: Ottawa, Ont.  to  Halifax, N.S.

    Transmitter Latitude  =  45.40 N      Receiver Latitude  =  44.90 N
                Longitude =  75.90 W               Longitude =  63.50 W

         Distance = 972.9   km               Bearings:  88.9 ,  277.7

                            Sunspot Number (R12) = 50

                            Season = May, June, July


 GMT  OWF   LUF      GMT  OWF   LUF      GMT  OWF   LUF      GMT  OWF   LUF

  1   7.1   2.7        7   4.3   -        13  12.6   6.3      19  13.3   6.4
  2   6.6   2.2        8   4.9   2.5      14  13.1   6.4      20  12.7   6.2
  3   6.0    -         9   6.5   3.3      15  13.5   6.5      21  12.0   5.9
  4   5.4    -        10   8.8   4.5      16  13.7   6.6      22  11.0   5.5
  5   5.0    -        11  10.6   5.5      17  13.7   6.6      23   9.4   4.8
  6   4.6    -        12  11.7   6.0      18  13.6   6.5      24   7.4   3.6
```

Figure 3 **DATA OUTPUT**

After the prediction data are displayed, the program asks if another prediction is desired with the following statement:

"Do you wish to run another prediction (Y/N)?"

If the operator types a "Y" the user's input information is displayed on the screen and data for another HF prediction can be entered as described in section 3.1. If an "N" is entered the program terminates and control is passed back to the operating system.

3.4 MODIFICATION TO PRINTER SETUP ROUTINE

The BASIC printer setup routine SETLP.BAS is designed for operation with an Epson printer and may be applicable to other printers. If desired, the parameters may be changed, by following the steps below.

a) Insert program disk in drive A
   Press and hold keys "Ctrl + Alt + Del"
   - Drive A starts, SETLP.BAS runs and the prediction program begins
   - Computer responds with "Do you wish to have an output directed to printer (Y/N) ?"

b) Press and hold keys "Ctrl + Scroll Lock"
   - Computer responds with "Terminate batch job (Y/N)?"
     Type "Y" and press "Enter"
   - Computer responds with "A>"

c) Type "BASIC" and press "Enter"
   - Drive A starts, loads the BASIC interpreter, and the computer responds with "OK"

d) Press "F3"
   - Computer responds with "LOAD"
     Type "SETLP" and press "Enter"
   - Drive A starts and loads program SETLP.BAS

e) Press "F1"
   - Computer responds with "LIST"
     Type "1-250" and press "Enter"
   - Lines 1 to 250 will be displayed on the screen (these lines contain the various parameters used by the printer setup routine, with explanations)

f) Move the cursor to the desired line using the four direction keys, change the parameter value to what is required and press "Enter"

Note that the default parameters are as follows:

[line 80]	PL	PL =	2	(page length 11.0")
[line 110]	SOP	SOP =	5	(skip 5 lines)
[line 140]	LM	LM =	1	(left margin 1)
[line 140]	RM	RM =	136	(right margin 136)
[line 170]	MD	MD =	1	(normal print)
[line 200]	CH	CH =	1	(pica)
[line 230]	LS	LS =	1	(line spacing 1/6")

Once all of the changes have been made, move the cursor to the bottom of the screen

g) Press "F4"
- Computer responds with "SAVE"
  Type "SETLP" and press "Enter"
- Drive A starts and the modified version of the printer setup routine is saved

Note: The modified printer setup routine will replace the old printer setup routine. If both setup routines are to be kept, rename the old setup routine, i.e., NAME "SETLP.BAS" AS "SETLP2.BAS" and store the new setup routine as "SETLP.BAS". The current printer setup routine always has the name "SETLP.BAS".

4.0 REFERENCES

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10. Propagation prediction method for high frequency broadcasting, (Report 894 (I)), Conclusions of the Interim Meeting of Study group 6 (Propagation in Ionized Media), CCIR Doc. 6/183, p. 126, ITU, Geneva, 1983.

11. Report to the Second Session of the Conference (See Resolution PLEN./1), World Administrative Radio Conference for the planning of the HF bands allocated to the broadcasting service - First Session, Geneva, 1984, ITU, Geneva, 1984.

ANNEX

A1.0 GENERATION OF THE DATA BASE

A1.1 IONOSPHERIC DATA FILE

The LIL252 [5] and other programs use numerical maps of ionospheric characteristics as described in CCIR Report 340 [2]. Each map represents the world-wide geographic and diurnal variation of these characteristics as a function of latitude, longitude and time. The map coefficients are stored on a data file on the CRC computer which is divided into 12 blocks corresponding to 12 months of the year. Each block contains three logical records with the following data in the first two records.

Record	Variable	Description
#1	IKIM	Summation limits.
	XF2COF	Coefficients for foF2 for low and high solar activity.
#2	XFM3CF	Coefficients for F2-layer (M3000) factor for low and high solar activity.
	XERCOF	Coefficients for foE for low and high solar activity.

These stored coefficients are used in a Fourier time series to obtain the corresponding ionospheric characteristic. The foF2 is the ordinary ray critical frequency at vertical incidence on the F2-layer, and M(3000)F2 is a factor which multiplies foF2 to give the basic MUF for a distance of 3000 km.

A1.2 DATA BASE FILES

For use by MICROPREDIC, four blocks of data were extracted from the ionospheric data file, corresponding to the four seasons of the year. Each season is represented by data for the month indicated in Table 1.

A FORTRAN language program was written for the CRC computer to select for each season the appropriate data block and create a file containing arrays of values of XF2COF and XFM3CF. Note that the values of IKIM are the same in each case and so are stored in MICROPREDIC, and that XERCOF is not used. The procedure is as follows:

- Skip the appropriate number of logical records on the ionospheric data file (i.e. 6 for March, 15 for June, 24 for September and 33 for December)
- Read IKIM, XF2COF
- Read XFM3CF, XERCOF
- Write XF2COF,XFM3CF

Each new file contained 2858 records, 1976 for XF2COF (array 13x76x2), and 882 for XFM3CF (array 9x49x2). These files were transferred one by one by telephone from the CRC computer to the IBM PC and each was stored as a single Data Base File on the disk. This process was repeated until the four files listed in Table 1 were created.

TABLE 1

Season	Representative Month	File Name
February, March, April	March	SEASN1.DAT
May, June, July	June	SEASN2.DAT
August, September, October	September	SEASN3.DAT
November, December, January	December	SEASN4.DAT

A2.0 COMPUTATION OF PATH GEOMETRY

This section of the MICROPREDIC program computes the path parameters necessary for the selection of ionospheric data and the computation of distance factors. Parameters computed are:

GCDKM = Great circle distance between transmitter and receiver (km)
BTRD = Bearing from transmitter to receiver (degrees)
BRTD = Bearing from receiver to transmitter (degrees)
RD = Great circle distance of ionospheric reflection point from transmitter location (radians)
CLAT = Latitude of ionospheric reflection point (radians)
CLONG = Longitude of ionospheric reflection point (radians)
GLAT = Geomagnetic latitude (radians)
GMDIP = Magnetic dip angle (radians)
GYZ = Gyrofrequency at ionospheric reflection point (MHz)

Note: In the following sections, D2R = .01745329251, R2D = 57.295779513, PI = 3.14159265359 and SQRT( ) denotes the square root of the quantity inside the brackets. Also, "Test QCOS" means that QCOS is limited to the range -1 to +1, i.e.

```
If |QCOS|>1.0
then QCOS  = -1.0 for QCOS<0
     QCOS  = +1.0 for QCOS>0
```

A2.1 INPUT PARAMETERS

Parameters supplied by the user (section 3.1).

TLATD = Transmitter geographic latitude (degrees)
RLATD = Receiver geographic latitude (degrees)
        Latitude North = "+"
        Latitude South = "-"
TLONGD= Transmitter geographic longitude (degrees)
RLONGD= Receiver geographic longitude (degrees)
        Longitude West = "+"
        Longitude East = "-"

A2.2 CONVERSION OF LATITUDE AND LONGITUDE FROM DEGREES TO RADIANS

TLAT = TLATD x D2R
RLAT = RLATD x D2R
TLONG = TLONGD x D2R
RLONG = RLONGD x D2R

A2.3 COMPUTATION OF GREAT CIRCLE DISTANCE

```
a)  DLONG = TLONG - RLONG
b)  If |DLONG|>PI
    then DLONG = DLONG + (2 x PI) for DLONG<0
         DLONG = DLONG - (2 x PI) for DLONG>0
c)  QCOS = Sin(TLAT)Sin(RLAT) + Cos(TLAT)Cos(RLAT)Cos(DLONG)
d)  Test QCOS
e)  Great circle distance (radians) = GCD

         $GCD = Cos^{-1}(QCOS)$
f)  If $GCD<10^{-6}$ then $GCD = 10^{-6}$
g)  Great circle distance (km) = GCDKM
         GCDKM = GCD x 6370
```

A2.4 COMPUTATION OF BEARING FROM TRANSMITTER TO RECEIVER

A2.4.1 For transmitter located near geographic pole

```
If $Cos(TLAT) \leq 10^{-7}$
then BTR = 0.0 for $TLAT \leq 0$
     BTR = PI  for TLAT>0
```

A2.4.2 For transmitter not near geographic pole

a) QCOS = [Sin(RLAT) - Sin(TLAT)Cos(GCD)] / [Cos(TLAT)Sin(GCD)]
b) Test QCOS
c) Bearing from transmitter to receiver (radians) = BTR

BTR = $\cos^{-1}$(QCOS)
d) If DLONG<0.0
BTR = (2 x PI) - BTR
e) Bearing from transmitter to receiver (degrees) = BTRD
BTRD = BTR x R2D

A2.5 COMPUTATION OF BEARING FROM RECEIVER TO TRANSMITTER

A2.5.1 For receiver located near geographic pole

If Cos(RLAT)$\leq 10^{-7}$
then BRT = 0.0 for RLAT$\leq$0
BRT = PI for RLAT$\geq$0

A2.5.2 For receiver not near geographic pole

a) QCOS = [Sin(TLAT) - Sin(RLAT)Cos(GCD)] / [Cos(RLAT)Sin(GCD)]
b) Test QCOS
c) Bearing from receiver to transmitter (radians) = BRT

BRT = $\cos^{-1}$(QCOS)
d) If DLONG>0.0
BRT = (2 x PI) - BRT
e) Bearing from receiver to transmitter (degrees) = BRTD
BRTD = BRT x R2D

A2.6 COMPUTATION OF DISTANCE OF THE IONOSPHERIC REFLECTION POINTS FROM TRANSMITTER LOCATION (RADIANS)

The path is assumed to be symmetrical, with the reflection point nearest a path terminal at 1000 km for the E-layer if the path is longer than 2000 km, and at 2000 km for the F-layer if the path is longer than 4000 km. See Section A2.3 for GCD and GCDKM.

A2.6.1 For distances equal to and less than 2000 km

RD(1) = Distance of all layer reflection points

If GCDKM$\leq$2000
then RD(1) = GCD/2

A2.6.2 For distances between 2000 and 4000 km

RD(1) = Distance of E-layer reflection point
RD(2) = Distance of F-layer reflection point
RD(3) = Distance of E-layer reflection point

```
        If $2000<GCDKM\leq4000$
        then  RD(1) = 1000/6370
              RD(2) = GCD/2
              RD(3) = GCD - RD(1)
```

A2.6.3 For distances greater than 4000km

RD(1) = Distance of E-layer reflection point
RD(2) = Distance of F-layer reflection point
RD(3) = Distance of E- or F-layer reflection point
RD(4) = Distance of F-layer reflection point
RD(5) = Distance of E-layer reflection point

```
        If GCDKM>4000
        then  RD(1) = 1000/6370
              RD(2) = 2 x (RD(1))
              RD(3) = GCD/2
              RD(4) = GCD - RD(2)
              RD(5) = GCD - RD(1)
```

A2.7 COORDINATES OF IONOSPHERIC REFLECTION POINT

A2.7.1 Initialize or select parameters

DRF = RD(1), RD(2), RD(3), RD(4), RD(5) as required
CTLAT = Cos(TLAT)

A2.7.2 For transmitter located near geographic pole

```
If $CTLAT\leq10^{-7}$
then RFLT  = TLAT - DRF for TLAT>0
     RFLT  = TLAT + DRF for TLAT<0
If $|RFLT|\leq PI/2$
then RFLT  = - PI/2 for RFLT<0
     RFLT  =   PI/2 for $RFLT\geq0$
     RFLG  = RLONG
```

A2.7.3 For transmitter not near geographic pole

QCOS = Cos(DRF)Sin(TLAT) + Sin(DRF)Cos(TLAT)Cos(BTR)
Test QCOS
RFLT = PI/2 - Cos^{-1}(QCOS)

A2.7.4 For reflection point latitude near geographic pole

```
If   $\mathrm{Cos(RFLT)} \leq 10^{-7}$
then $\mathrm{RFLG = TLONG}$
```

A2.7.5 For reflection point latitude not near geographic pole

```
a)  $\mathrm{QCOS = [Cos(DRF) - Sin(RFLT)Sin(TLAT)] / [Cos(RFLT)Cos(TLAT)]}$
b)  Test QCOS
c)  $\mathrm{RFLG = Cos^{-1}(QCOS)}$
d)  If $\mathrm{DRF \geq PI}$
    then $\mathrm{RFLG = (2 \times PI) - RFLG}$
e)  $\mathrm{RFLG = TLONG + RFLG}$ for $\mathrm{DLONG<0}$
    $\mathrm{RFLG = TLONG - RFLG}$ for $\mathrm{DLONG>0}$
f)  If $\mathrm{|RFLG| > PI}$
    then $\mathrm{RFLG = RFLG + (2 \times PI)}$ for $\mathrm{RFLG<0}$
         $\mathrm{RFLG = RFLG - (2 \times PI)}$ for $\mathrm{RFLG>0}$
```

A2.7.6 Reflection point latitude and longitude (radians)

```
$\mathrm{CLAT = RFLT}$
$\mathrm{CLONG = RFLG}$
```

A2.8 GEOMAGNETIC PARAMETERS

A2.8.1 Geomagnetic latitude (radians)

```
a)  $\mathrm{QCOS = Sin(GLT)Sin(RFLT) + Cos(GLT)Cos(RFLT)Cos(RFLG - GLG)}$
          where GLT = Latitude of geomagnetic pole = $78.5^{\circ}$
                GLG = Longitude of geomagnetic pole = $69.0^{\circ}$
b)  Test QCOS
c)  Geomagnetic latitude (radians) = GLAT

    $\mathrm{GLAT = PI/2 - Cos^{-1}(QCOS)}$
```

A2.8.2 Magnetic dip angle and gyrofrequency

```
a)  $\mathrm{Dip = Tan^{-1}[2.0 \times Tan(GLAT)]}$

    $\mathrm{Dnom = SQRT\{(Dip)^{2} + Cos(CLAT)\}}$

b)  $\mathrm{z = (6370/(6370 + 300))^{3}}$

    $\mathrm{y = (Sin(GLAT))^{2}}$
c)  Magnetic dip angle (radians) = GMDIP

    $\mathrm{GMDIP = Sin^{-1}(Dip/Dnom)}$
```

d) Gyrofrequency (MHz) = GYZ

GYZ = 2.8 x .347448 x z x [SQRT(1.0 + 3.0y)]

A3.0 SELECTION AND COMPUTATION OF NUMERICAL COEFFICIENTS

The numerical coefficients representing median values of foF2 and M(3000)F2 are stored on a Data Base File for each season for R12 values of 0 and 100. This section of the program reads the file for the specified season and computes the coefficients for the specified sunspot number and times. R12 is the 12-month running average of the monthly sunspot number.

A3.1 INPUT PARAMETERS

The XF2COF and XFM3CF arrays are obtained from the Data Base File for the appropriate season (section A1.2). IKIM is stored as data.

IKIM(3,10) = Summation limits in Fourier series
XF2COF(13,76,2) = Coefficients for foF2
XFM3CF(9,49,2) = Coefficients for M(3000)F2
SSN = Sunspot number R12 [sec. A3.0]
CLONG = Longitude of ionospheric reflection point [sec. A2.7.6]
CLAT = Latitude of ionospheric reflection point [sec. A2.7.6]
GMDIP = Magnetic dip angle at reflection point [sec. A2.8.2]

A3.2 COMPUTATION OF COEFFICIENTS AT A SPECIFIED SUNSPOT NUMBER R12

A3.2.1 Coefficients representing median values of foF2

F2COF(k,j) = [XF2COF(k,j,1) x (100 - SSN) + XF2COF(k,j,2) x SSN] /100

where k = 1 to 13

j = 1 to 76

and XF2COF(k,j,1) = Coefficient for foF2 at sunspot 0

XF2COF(k,j,2) = Coefficient for foF2 at sunspot 100

COFION(1 to 988) = F2COF

A3.2.2 Coefficients representing median values of M(3000)F2

FM3COF(k,j) = [XFM3CF(k,j,1) x (100 - SSN) + XFM3CF(k,j,2) x SSN] /100

where k = 1 to 9

j = 1 to 49

```
and XFM3CF(k,j.1)   = Coefficient for M(3000)F2 at sunspot 0
    XFM3CF(k,j,2)   = Coefficient for M(3000)F2 at sunspot 100
COFION(989 to 1429) = FM3COF
```

A3.3 COMPUTATION OF COEFFICIENTS FOR A SPECIFIED UNIVERSAL TIME (GMT)

```
a)  TIME  = (15. x GMT - 180) x D2R
b)  C(1)  = Cos(TIME)
    S(1)  = Sin(TIME)
c)  C(JB) = C(1) x C(JB - 1) - S(1) x S(JB - 1)
    S(JB) = C(1) x S(JB - 1) + S(1) x C(JB - 1)
            where JB = 2 to 8
d)  Limits for Fourier expansion are given by
        J = IKIM(IZ,10)
        I = IKIM(IZ,9) + 1
            where IZ  = 1 to 2
e)  Calculation of subscripts
    ISUBB = IA(IZ) + (JB - 1) x IB(IZ)
    ISUBA = IC(IZ) + JB - 1
            where IZ = 1 to 2
                  JB = 1 to I
            and where subscript limits
                  IA = 1,989,1430
                  IB = 13,9,9
                  IC = 1,77,126
    ISUBC = ISUBB + 2 x KA - 1
            where KA = 1 to J
f)  Addition of Fourier expansion
    ZAB(ISUBA)= COFION(ISUBB)                          [sec. A3.2]
    AB(ISUBA) = ZAB(ISUBA) + S(KA) x COFION(ISUBC)
                + C(KA) x COFION(ISUBC + 1)
            where KA = 1 to J
```

A4.0 COMPUTATION OF IONOSPHERIC PARAMETERS

This section computes for each hour of GMT the median values of foF2, M(3000)F2 and foE at each ionospheric reflection point.

A4.1 INPUT PARAMETERS

CLONG = Longitude of ionospheric reflection point [sec. A2.7.6]
CLAT = Latitude of ionospheric reflection point [sec. A2.7.6]
GMDIP = Magnetic dip angle at reflection point [sec. A2.8.2]
IC = Subscript limits for ISUBA [sec. A3.3]
AB = Computed coefficients [sec. A3.3]
MONS = Season [User-supplied]

A4.2 EVALUATION FOR A SPECIFIED GEOGRAPHIC LOCATION

In this section, the variable IZ takes the values 1 and 2.

```
a)  Limits for Fourier expansion are given by
         I = IKIM(IZ,9) + 1
         K = IKIM(IZ,1)
b)  If CLONG < 0  CLG = |CLONG|
       CLONG ≥ 0  CLG = (2 x PI) - CLONG
c)  GOB = Cos(CLAT)
    SX  = Sin(GMDIP)
d)  Calculate geographic coordinate function G
    G(1) = 1.
    G(2) = SX
    If K ≥ 2 then G(KA + 1) = SX x G(KA)
                  where KA = 2 to K
e)  KDIF     = IKIM(IZ,2) - K
    If KDIF = 0  (Go to step i)
    If KDIF ≠ 0  JG = 1; CX = GOB; T = CLG
f)  KK       = IKIM(IZ,JG) + 4
    G(KK - 2) = CX x Cos(T)
    G(KK - 1) = CX x Sin(T)
g)  LO       = IKIM(IZ,JG + 1)
    If KDIF ≠ 2 and LO ≥ KK
             then G(KA)     = SX x G(KA - 2)
                  G(KA + 1) = SX x G(KA - 1)
               where KA = KK, KK + 2,.... to LO
    If JG < 8     KDIF = IKIM(IZ,JG + 2) - LO
    If JG ≥ 8     KDIF = 0
h)  If KDIF ≠ 0  CX = CX x GOB
                 JG = JG + 1
                  T = JG x CLG
               (Repeat from step f)
i)  If KDIF = 0  ISUBA     = IC(IZ)
                 GAMMA(IZ) = G(1)  x AB(ISUBA)
    If  I ≥ 2    ISUBA     = IC(IZ) + JB - 1
                 GAMMA(IZ) = GAMMA(IZ) + AB(ISUBA) x G(JB)
                 where  JB = 2 to I
j)  GAMMA(IX) = GAMMA(IZ)
                where  IX = IZ + 3
```

A4.3 COMPUTATION OF F2-LAYER PARAMETERS

Median value of F2-layer critical frequency
XF2 = GAMMA(4)

Median value of M(3000)F2
XM3 = GAMMA(5)

A4.4 COMPUTATION OF E-LAYER CRITICAL FREQUENCY

A4.4.1 Computation of Solar Zenith Angle (CYCEN)

a) $\text{Cenlg} = \text{CLONG}$

b) $\text{Cenlat} = \text{CLAT}$

c) $\text{Cendog} = |\text{Cenlat} - \text{D2R} \times (\text{Sun}(1,\text{MONS}))|$

d) $\text{Cencat} = |\text{Cenlat} - \text{D2R} \times (\text{Sun}(2,\text{MONS}))|$

e) $\text{ssp} = \text{D2R} \times \text{Sun}(2,\text{MONS})$ for $\text{Cendog} \leq \text{Cencat}$

$= \text{D2R} \times \text{Sun}(1,\text{MONS})$ for $\text{Cendog} > \text{Cencat}$

where $\text{Sun}(1,1) = -7.88$ $\quad \text{Sun}(2,1) = 4.21$

$\text{Sun}(1,2) = 21.93$ $\quad \text{Sun}(2,2) = 23.45$

$\text{Sun}(1,3) = 8.55$ $\quad \text{Sun}(2,3) = -2.86$

$\text{Sun}(1,4) = 21.66$ $\quad \text{Sun}(2,4) = 23.45$

f) $\text{ssl} = \text{D2R} \times (15.0 \times \text{GMT} - 180)$ [hour angle]

g) $z = \text{ssl} - \text{Cenlg}$

h) $\text{CYCEN} = \text{Sin}(\text{Cenlat})\text{Sin}(\text{ssp}) + \text{Cos}(\text{Cenlat})\text{Cos}(\text{ssp})\text{Cos}(z)$

i) $\text{CYCEN} = \text{R2D} \times [\text{Cos}^{-1}(\text{CYCEN})]$ (degrees)

A4.4.2 Computation of median value of foE

a) If $\text{CYCEN} \leq 80$

$\text{CHIP} = \text{CYCEN}$

b) If $\text{CYCEN} > 116$

$\text{CHIP} = 89.907$

c) If $80 < \text{CYCEN} \leq 116$

$\text{CHIP} = 90 - \text{Exp}(.13 \times (116 - \text{CYCEN})) / 10.8$

CHIP = Minimum of CHIP or 89.907

d) $\text{CHIP} = \text{D2R} \times \text{CHIP}$ (radians)

e) Median value of foE = XFE

$\text{XFE} = .9[((180 + 1.44 \times \text{SSN}) \text{Cos}(\text{CHIP}))^{.25}]$

A5.0 COMPUTATION OF OWF AND LUF

This section computes the optimum working frequency (OWF) for the path from the maximum usable frequencies (MUFs) for the various modes of propagation. In addition, the lowest usable frequency (LUF) due to E-layer screening of the F-layer is computed.

A5.1 COMPUTATION OF DISTANCE FACTORS FOR OWF

The distance factors take account of the variation of MUF with path length. The E-layer factor is the secant of the ionospheric angle of incidence.

A5.1.1 Distance factor for E and F1-layer (EFDIST)

a) $d = GCDKM$
b) If $d > 3400$
    $d = 3400$
c) $EFDIST = 1 + 2.32 \times 10^{-3}d + 5.95 \times 10^{-7}d^2$
    $-4.95 \times 10^{-10}d^3 + 7.22 \times 10^{-14}d^4$

A5.1.2 Distance factor for F2-layer (FLFC)

a) $d = GCDKM$
b) If $d \geq 4000$
    $FLFC = 1$
c) If $d < 800$
    $FLFC = 1.64 \times 10^{-7}d^2$
d) If $800 \leq d < 4000$
    $FLFC = 1.26 \times 10^{-14}d^4 - 1.3 \times 10^{-10}d^3$
    $+ 4.1 \times 10^{-7}d^2 - 1.2 \times 10^{-4}d$

A5.1.3 Distance factor for E-layer (SECE)

a) HPE = 110 [reflection height]
b) PHL = Sin^{-1}[6370/(6370 + HPE)] [limiting value of PHE]
c) NHOPS = .5 x GCDKM/((PI/2 - PHL) x 6370)
d) PSI = GCDKM/(2 x 6370)
e) XHOPS = NHOPS + 1
f) PSI = PSI/XHOPS [half-angle of hop]
g) CPSI = Cos(PSI)
h) SPSI = Sin(PSI)
i) TANP = SPSI/(1 - CPSI + HPE/6370)

j) PHE = TAN^{-1}(TANP) [ionospheric angle of incidence]
k) DEL = PI/2 - PHE - PSI [elevation angle]
l) SPHE = 6370 x Cos(DEL)/(6370 + HPE) [sine of PHE]

m) SECE = $1/\mathrm{SQRT}(1 - \mathrm{SPHE}^2)$

A5.2 COMPUTATION OF OPTIMUM WORKING FREQUENCY

A5.2.1 E-layer MUF (EMUF)

XFE = Median value of foE [sec. A4.5.2]
SECE = E-layer distance factor [sec. A5.1.3]
EMUF = XFE x SECE

A5.2.2 F1-layer MUF (EF1MUF)

XFE = median value of foE
EFDIST = E and F1-layer distance factor [sec. A5.1.1]

EF1MUF = XFE x EFDIST

A5.2.3 F2-layer MUF (F2MUF)

a) If GCDKM≤4000
F2-layer MUF at 4000 km = F4
F4 = XF2 x XM3 x 1.1
F2-layer MUF at zero distance = FZ
FZ = XF2 + .5 x GYZ
F2MUF = FZ + (F4 - FZ) x FLFC
where XF2 = Median value of F2-layer critical frequency [sec. A4.2]
XM3 = Median value of M(3000)F2 [sec. A4.2]
GYZ = Gyrofrequency [sec. A2.8.2]
FLFC = Distance factor for F2-layer [sec. A5.1.2]
b) If GCDKM>4000
F2MUF = minimum value of F2MUF computed in paragraph a) for the various F-layer hops

A5.2.4 Optimum working frequency (ALLMUF)

ALLMUF = maximum of EMUF, EF1MUF, or 0.85 x F2MUF

A5.3 COMPUTATION OF LOWEST USABLE FREQUENCY

A5.3.1 Distance factor for E-layer screening of F-layer (SECP)

HPF2 = (1490/XM3(KC)) - 176 [F2-layer reflection height]

where XM3(KC) = value of M(3000)F2 [sec. A4.2]
at the F2-layer reflection point nearest the minimum value of the E-layer penetration frequency. SECP is computed using the procedure of sec. A5.1.3, where HPF2 replaces HPE in steps b) and i) (but not in step l)), and SECP replaces SECE in step m).

A5.3.2 LUF due to E-layer screening of F-layer

LUF = 1.05 x XFE(KL) x SECP
where XFE(KL) = minimum value of E-layer penetration frequency (sec. A4.5.2) at the E-layer ionospheric reflection points