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QUIET TIME LOWEST OBSERVABLE FREQUENCY (QLOF) CALCULATION PROGRAM--ETC(U)

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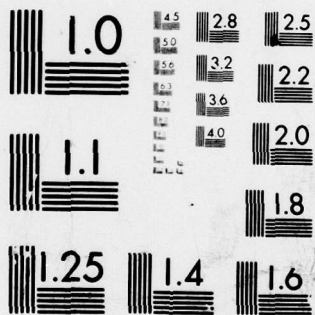
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**QUIET TIME LOWEST OBSERVABLE
FREQUENCY (QLOF),
CALCULATION PROGRAM**

PE Argo and DB Sailors

1 April 1979

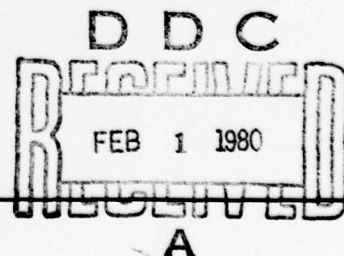
Interim Report: January 1978 — January 1979

Prepared for
Naval Environmental Prediction Research Facility
Monterey, California

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ADMINISTRATIVE INFORMATION

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Released by
J. H. Richter, Head
EM Propagation Division

Under authority of
J. D. Hightower, Head
Environmental Sciences Department

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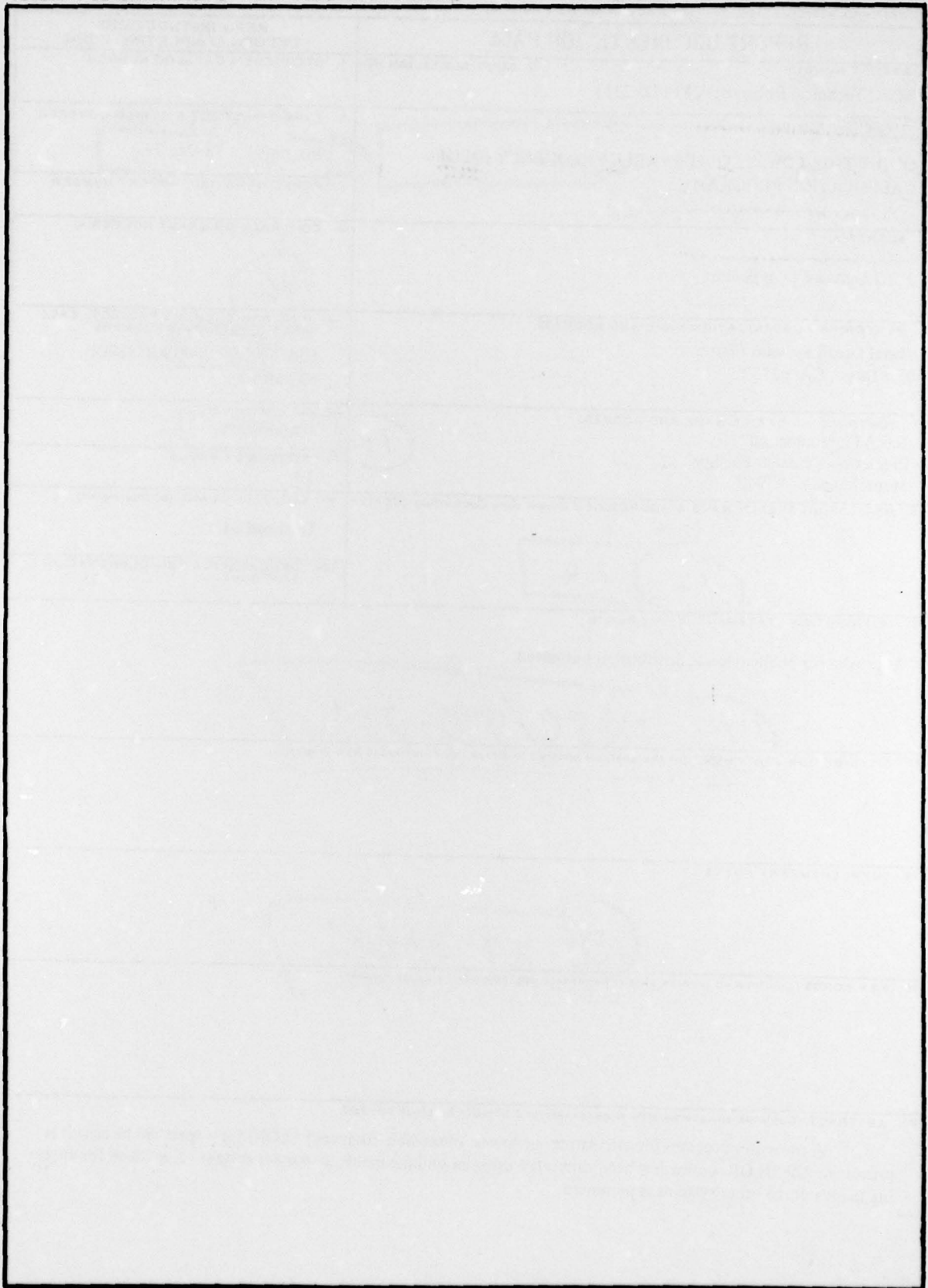
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INTRODUCTION

The lowest observable frequency (LOF) for a specified hf circuit is important when one is specifying the propagation window for that circuit. This lowest frequency is an absorption controlled effect. The major cause of absorption at low and midlatitudes is the solar created ionospheric D-region. During quiet solar conditions this D-region responds directly to the amount of ionizing solar radiation reaching it. As shown in Bleiweiss (1970, 1972) and Argo and Hill (1977), this solar control is directly related to the solar zenith angle. Other relevant parameters are latitude, sunspot number, and season (calculated from Julian day), which are all described in Argo and Hill (1977).

The computer program listing presented in the appendix contains the necessary subroutines for calculating the quiet time LOF (QLOF), and a sample control routine for driving the set of subroutines. The present setup will handle up to ten (10) paths and can easily be changed up or down.

The routine "SR" also provides MOF, FOT for paths < 2000 km. Notice that by calling "QLOF", after calling "SR", the LOF is defined for pathlengths > 1000 km by the "QLOF" routine.

These routines have been checked under many conditions and the outputs compare well with the oblique incident sounder data available at NOSC.

CALCULATING THE SIGNAL LOSS MARGIN (SLM)

Because the QLOF routine was calibrated using an oblique sounder system, it is necessary to modify the calculations to provide LOFs for other systems. The signal loss margin (SLM) is the difference (in dB) between the minimum usable signal at the receiver, and the signal level expected at the same terminal under conditions of no ionospheric absorption. For the NOSC sounder systems, this SLM was found to be 37 dB. The following paragraphs describe how to estimate the SLM for propagation circuits.

The signal loss margin SLM is given by:

$$SLM = S - N - R_1, \quad (1)$$

where S is the signal strength in the absence of ionospheric absorption, $N = F_{am} - 204$, F_{am} is the median value of radio noise power density F_a given in CCIR reports 322-1 and 258-2, and R_1 is the required signal to noise density ratio for the grade of service. Therefore, the SLM is given by

$$SLM = P_t + G_t + G_r - L_b - N - R_1 \quad (2)$$

where

P_t : source level, decibels above 1 watt

G_t : transmitting antenna gain (dB)

G_r : receiving antenna gain (dB)

L_b : basic transmission loss exclusive of ionospheric absorption.

We are assuming the losses in the transmitting and receiving antenna circuits are negligible. Otherwise, they would be added here. Note, also, that only L_b and N are system independent. Let

$$SLM = S' - S'' ; \quad (3)$$

where,

$$S' = P_t + G_t - G_r - R_l \quad (4)$$

and

$$S'' = L_b + N . \quad (5)$$

In at least one application it has been found that: (1) G_t is omnidirectional antenna with a gain of 4.76 dB/isotropic, and (2) G_r is a high gain antenna with a gain of 13.6 dB/isotropic. Thus,

$$S' = 18.36 + P_t - R_l . \quad (6)$$

Notice that the units of signal power in P_t and R_l must be the same (i.e., PEP or mean), and

$$S'' = L_{bf} + N = L_{bf} + F_{am} - 204, \quad (7)$$

assuming ground losses are negligible.

Here, L_{bf} is the basic free space loss, and is given by

$$L_{bf} = 32.45 + 20 \log_{10} d + 20 \log_{10} f , \quad (8)$$

where d is the propagation path length and f is the frequency in MHz. CCIR Report 258-2 gives the rural man-made noise as,

$$F_{am} = 67.2 - 27.7 \log_{10} f \quad (9)$$

and so in regions where rural man-made noise applies, S'' becomes,

$$S'' = -104.35 + 20 \log_{10} d - 7.7 \log_{10} f . \quad (10)$$

Note the S'' includes frequency, which is nominally unknown. One solution is to average the value of $\log_{10} f$ for 2.5 MHz and 30 MHz, giving $7.7 \log_{10} f = 7.22$. Another, more accurate solution, would be to modify QLOF and use the calculated sounder LOF at this point. Using the average value 7.22 in equation 10

$$S'' = -111.57 + 20 \log_{10} d . \quad (11)$$

Now, the sounder was calibrated using a 3800 km path and so for use here, d should be replaced by 3800 km.

Combining equations (6) and (11) we obtain,

$$SLM = 18.36 + P_t - 111.57 - 20 \log_{10} (3800) \quad (12)$$

$$= 58.36 + P_t - R_1$$

$$P_t = 10. \times \log_{10} (\text{power in watts})$$

and suggested values for R_1 are included in table 1 (from CCIR recommendation 339-3).

Table 1. Required signal-to-noise ratios.

50 baud telegraph	40 dB
Telephony, double side band	51 dB
Telephony, single side band	48 dB
Composite 16 channel, 75 baud each	60 dB

Remember that equation (12) has assumed specific receiving and transmitting antenna gains, and so in general

$$SLM = 40 + P_t - R_1 + G_t + G_r \quad (13)$$

REFERENCES

Argo, P. E. and J. R. Hill (1977), Lowest Observable Frequency (LOF) Model: SOLRAD Application, NELC/TN 3304, 27 Jan 1977.

Bleiweiss, M. P. (1970), Solar Influences on HF Absorption and the Resulting Hawaii to California Lowest Observed Frequency, NWC/TP 4911, May 1970.

Bleiweiss, M. P. (1977), A Prediction Scheme for the Lowest Observed Frequency (LOF) of the Guam-Northwest Cape HF Propagation Path and Eight Other Pacific Paths, NELC/TR 1851, 6 Dec 1972.

APPENDIX: QLOF CALCULATION PROGRAM

C	MAIN CLOF SAMPLE CONTROL ROUTINE FOR DRIVING CLOF	CLOF 1
C	BY PAUL ARCO AND JAY HILL, AUGUST 1, 1975	CLOF 2
	REAL K	CLOF 4
	DIMENSION TRP(4,10),CPNT(7,10),LOF(10),SSP(2)	CLOF 5
	DIMENSION FOT(10),MUF(10),DEL(10),SLM(10)	CLOF 6
	INTEGER TIME(4),YEAR	CLOF 7
C	S13=SUNSPOT NUMBER,YEAR=1922,JD=JULIAN DAY	
	WRITE(6,2)S13,YEAR,JD	CLOF 14
	TIME(1)=YEAR	CLOF 15
	TIME(2)=JD	CLOF 16
C	INPUT PATH ENDPOINTS	
	DO 10 I=1,N	CLOF 17
	READ(5,3)IAT1, LONG1, LAT2, LONG2	CLOF 18
	WRITE(6,3)IAT1, LONG1, LAT2, LONG2	CLOF 19
	TRP(I,1)=IAT1	CLOF 20
	TRP(I,2)=LONG1	CLOF 21
	TRP(I,3)=LAT2	CLOF 22
	TRP(I,4)=LONG2	CLOF 23
	SLM(I) = .77	CLOF 24
10	CONTINUE	CLOF 25
	CALL PATH(TOP,CPNT,N)	CLOF 26
	DO 100 THOUR=1,24	CLOF 27
	TIME(3)=THOUR	CLOF 28
	TIME(4)=0	CLOF 29
	CALL SUBSOL(TIME,SSP)	CLOF 30
	WRITE(6,70) THOUR	CLOF 31
70	FORMAT(//,I4)	CLOF 32
	CALL SPIN,CPNT,S13,TIME,SSP,SLM,LOF,FOT,MUF,DEL)	CLOF 33
	CALL CLOF(CPNT,N,SSP,TIME,S13,SLM,LOF)	CLOF 34
	DO 60 I=1,N	CLOF 35
60	DEL(I) = DEL(I)+57.29577951	CLOF 36
	WRITE (6,12)(LOF(I),FOT(I),MUF(I),DEL(I),I=1,N)	CLOF 37
12	FORMAT(/4X,4F8.2)	CLOF 38
100	CONTINUE	CLOF 39
	STOP	CLOF 40
	END	CLOF 41-
	SUBROUTINE CLOF(CPNT,N,SSP,TIME,S13,LOF)	
C	QUIET TIME LCF FORECAST	
C	THIS ROUTINE CALCULATES LOF FOR UP TO 10 PATHS	
C	INPUTS:	
C	CPNT(7,10) PATH CONTROL POINTS GIVEN FROM SUBROUTINE PATH	
C	(1) IF =1 PATH LT 3500KM, IF =2 THEN PATH GT 3500KM	
C	(2),(3) LAT, LONG OF MTPATH (RADIAN)	
C	(4-7) LAT, LONG OF POINTS 1000KM IN FROM EACH END (RADIAN)	
C	N NUMBER OF PATHS BEING CALCULATED	
C	SSP(2) LAT, LONG OF SUBSOLAR POINT (USE SUBROUTINE SUBSOL, (RADIAN)	
C	TIME(4) FOUR ELEMENT INTEGER ARRAY	
C	(1) YEAR	
C	(2) JULIAN DAY	
C	(3) HOUR	
C	(4) MINUTE	
C	S13 17 MONTH RUNNING AVERAGE OF SUNSPOT NUMBER	
C	RETURNS:	
C	LOF(10) CALCULATED LOF IN TEN ELEMENT ARRAY USING N ELEMENTS	
	REAL LOF(10),SSP(2),CPNT(7,10)	
	REAL LOF1,LOF2,K1,K2,M	
	INTEGER TIME(4)	
C	MEDUM(K1) AND LONG(K2) PATH CONSTANTS USED IN CONVERTING	
C	ABSORPTION INTO LOF	
	K1=0.58	
	K2=0.70	
	DO 2000 I=1,N	
C	INITIALIZE LCFS TO MINIMUM(2)	

```

      LOF(1)=2.
      LOF1=2.
      LOF2=2.
C   CHECK FOR SHORT OR LONG PATH
      IF(1/CP(1,1)) .EQ. 2) GO TO 500
C   SHORT PATH ,USE MIDPATH FOR ABSORPTION CALC
      CALL ABSORP(S13,TIME,CPNT(2,1),CPNT(3,1),SSP,ARS,CHI,M,CHINON)
      IF(ARS .LT. 1.E-10 .OR. CHI .GT. 1.80)GO TO 1000
      LOF(1)= K1*SQRT(ARS)*(CH(921.,CHI)/CH(921.,CHINON))**(-M)
      GO TO 1000
500   CONTINUE
C   LONG PATH ,CALCULATE ABSORPTION AT EACH CONTROL POINT,
C   THE ABSORPTION USED IN LOF CALCULATION WILL BE AN AVERAGE
C   WITH CENTER WEIGHTED DOUBLE. CHECKS AT EACH POINT FOR
C   NIGHT TIME (ZENITH ANGLE GT 1.4) OR VERY LOW ABSORPTION
C   ASSUME NO LOF LESS THAN 2 MHZ
      CALL ABSORP(S13,TIME,CPNT(2,1),CPNT(3,1),SSP,ARS,CHI,M,CHINON)
      AR1=0.
      IF(ARS .LT. 1.E-10 .OR. CHI .GT. 1.80)GO TO 800
      AR1=ARS*(CH(921.,CHI)/CH(921.,CHINON))**(-2.*M)
800   CONTINUE
      CALL ABSORP(S13,TIME,CPNT(4,1),CPNT(5,1),SSP,ARS,CHI,M,CHINON)
      AR2=0.
      IF(ARS .LT. 1.E-10 .OR. CHI .GT. 1.80)GO TO 900
      AR2=ARS*(CH(921.,CHI)/CH(921.,CHINON))**(-2.*M)
900   CONTINUE
      CALL ABSORP(S13,TIME,CPNT(6,1),CPNT(7,1),SSP,ARS,CHI,M,CHINON)
      AR3=0.
      IF(ARS .LT. 1.E-10 .OR. CHI .GT. 1.80)GO TO 950
      AR3=ARS*(CH(921.,CHI)/CH(921.,CHINON))**(-2.*M)
950   CONTINUE
      LOF(1)=K2*SQRT((AR1+2. + AR2 + AR3)/4.)
      LOF(1)=SQRT((37./SLM(1))*LOF(1)**2)
1000  CONTINUE
      IF(LOF(1) .LT. 2.)LOF(1)=2.
2000  CONTINUE
      RETURN
      END
      SUBROUTINE SP(N,CP,S13,TIME,SSP,SLM,LOF,FOT,MUF,DEL)
C   SHORT RANGE HF FORECAST USING E AND F2 LAYERS (F<2000KM)
C   FOT IS CHOSEN TO MINIMIZE MULTIPATH INTERFERENCE BY USING
C   E LAYER REFLECTIONS JUST ABOVE THE TWO HOP MUF OR AT THE
C   LOF WHEN LOF IS BELOW FOT. WHEN SPORADIC E IS PRESENT, LOF
C   IS RECOMMENDED FOR FOT. CALCULATION SKIPPED IF D>2000KM.
C
C   N = NUMBER OF PATHS          CP = PATH PARAMETERS
C   S13 = SMOOTHER SUNSPOT NUM.  TIME = TIME ARRAY
C   SLM = SIGNAL LOSS MARGIN      LOF = LOWEST OBSERVED FREQUENCY
C   FOT = FREQ OPTIMUM TRANS      MUF = MAXIMUM USABLE FREQUENCY
C   DEL = LAUNCH ANGLE AT FOT     SSP = SUBSOLAR POINT
C
C   BY JAY R. HILL, JULY 29, 1975
C
      INTEGER TIME(2)
      REAL MUF(10),LOF(10),FOT(10),DEL(10),SLM(10)
      DIMENSION CP(7,10),SSP(2),FMUF(2),FMUF(2)
      DATA P,YE,FE/6371.,30.,110./,PAD,FH/57.23578,1.5/
      DATA F1,F2,F1,F2/1.8,1.7,2.7,1.5/,HF/175./
      DO 1000 I=1,N
      IF(CP(1,1) .GT. 0.3139) GO TO 1000
      CALL ABSORP(S13,TIME,CP(2,1),CP(3,1),SSP,AL,CHI)
      PI = CP(1,1)/2.
      S1 = S1(PI)
      C1 = COS(PI)
      IF(CHI .LE. 1.4) GO TO 10
      LOF(1) = 2.

```

```

SR  1
SR  2
SR  3
SR  4
SR  5
SR  6
SR  7
SR  8
SR  9
SR 10
SR 11
SR 12
SR 13
SR 14
SR 15
SR 16
SR 17
SR 18
SR 19
SR 20
SR 21
SR 22
SR 23
SR 24
SR 25
SR 26
SR 27
SR 28

```

FOT(1) = 2.	SR	29
MUF(1) = 2.	SR	30
DEL(1) = ATAN((C1-0.985)/S1)	SR	31
GO TO 1000	SR	32
10 CC = COS (CHI)	SR	33
CC = CC/ABS(CC)***.4	SR	34
FE = E1+E2*CC	SR	35
FF = F1+F2*CC	SR	36
YE = (HF-FE)/SQRT(1.-(FE/FF)**2)	SR	37
EF = 1.-(FE/FF)**2	SR	38
LOF(1)=SQRT(A1/SLM(1)/SQRT(1.-.9784/(1.+((C1-.985)/S1)**2)))	SR	39
L1 = 10	SR	40
L2 = 10*FF	SR	41
IF(L2 .LT. L1) GO TO 1000	SR	42
DO 40 J = 1,2	SR	43
S2 = SIN(P1/J)	SR	44
C2 = COS(P1/J)	SR	45
EMUF(J) = 1.	SR	46
FMLF(J) = 1.	SR	47
TO 40 L=L1,L2	SR	48
F = 1./10.	SR	49
X = F/FE	SR	50
HV = HF+.5*YE*(X+ALOG((1.+X)/ABS(1.-X))-.2.)	SR	51
IF(X .GE. 1.0) GO TO 20	SR	52
H9 = HF-YE*SQRT(1.-X**2)	SR	53
GO TO 30	SR	54
20 Y = F/FF	SR	55
H9 = HF-YE*SQRT(1.-X**2)	SR	56
Y = SQRT(EF/(1.-X**2))	SR	57
HV = HV+YE*X*ALOG(Y+SQRT(Y**2+1.))	SR	58
30 D = ATAN((C2-1./((1.+HV/R))/S2)	SR	59
FM = F/SQRT(1.-(COS(D)/(1.+HV/R))**2)	SR	60
IF(FM .GT. EMUF(J) .AND. F .LT. FE) FMUF(J) = FM	SR	61
IF(FM .GT. FMUF(J) .AND. F .GE. FE) FMUF(J) = FM	SR	62
40 CONTINUE	SR	63
DEL(1) = ATAN((C1-0.985)/S2)	SR	64
FOT1 = FMUF(1)*(1.-.2/FE)	SR	65
FOT2 = FMUF(2)*(1.+2/FE)	SR	66
IF(FMUF(2) .LT. FMUF(1)) FOT2 = FMUF(2)*(1.+2/FF)	SR	67
IF(FOT2 .LT. FOT1) GO TO 50	SR	68
IF(FMUF(1) .GT. FMUF(1)) GO TO 50	SR	69
FOT1 = FMUF(1)*(1.-.2/FF)	SR	70
50 FOT(1) = FOT2	SR	71
IF(FOT2 .LT. LOF(1)) FOT(1) = FOT1	SR	72
MUF(1) = FMUF(1)	SR	73
IF(FMUF(1) .LT. FMUF(1)) MUF(1) = FMUF(1)	SR	74
IF(FOT(1) .GT. MUF(1) .AND. LOF(1) .LT. FE) FOT(1)=LOF(1)	SR	75
IF(FOT(1) .GT. MUF(1)) FOT(1) = MUF(1) - .2	SR	76
IF(LOF(1) .LT. 2.0) LOF(1) = 2.0	SR	77
IF(FOT(1) .LT. 2.0) FOT(1) = 2.0	SR	78
IF(MUF(1) .LT. 2.0) MUF(1) = 2.0	SR	79
IF(FOT(1) .GT. FMUF(1)) DEL(1) = ATAN((C1-.9785)/S1)	SR	80
1000 CONTINUE	SR	81
RETURN	SR	82
END	SR	83-
SUBROUTINE ARCORP(S13,TIME,LAT,LANG,SRP,ARSP,CHI,M,CHINON)		
C CALCULATES *ABSORPTION* AT A SPECIFIED POINT(LAT,LANG) ACCORDING TO		
C MODIFIED VERSION OF THE FORM GIVEN IN:		
C *NORMAL IONOSPHERIC ABSORPTION MEASUREMENTS*		
C FSSA PROFESSIONAL PAPER#4 BY SCHULTZ AND CALLET.		
C SEE PUBLICATION BY ARGO FOR MODIFICATIONS INCLUDED HERE.		
C MODEL INCLUDES LATITUDE, SOLAR CYCLE, SEASONALEFFECTS		
C AS WELL AS SOLAR CONTROLLED DIURNAL VARIATIONS		
C INPUTS:		
C S13 13 MONTH AVERAGE SUNSPOT NUMBER		
C TIME(4) YEAP, DAY, HR, MIN UT		

```

C      LAT, LONG CONTROL POINT IN RADIANS
C      SSP(2) SUBSOLAR POINT LAT, LONG IN RADIANS
C      RETURN
C      ARSP=ARSP(1) IN DEGREES
C      CHI ZENITH ANGLE (RADIANS)
C      M POWER OF COS(CHI) IN DIURNAL VARIATION
C      CHINON NOON ZENITH ANGLE
      DIMENSION SSP(2)
      INTEGER TIME(4)
      REAL LAT, LONG, M, N, LAT
      RAT=57.29577
      W=1.
      CHI=ARCCOS(SIN(LAT)*SIN(SSP(1)) + COS(LAT)*COS(SSP(1)))
      M=COS(SSP(2)-LONG)
C      CALCULATE NOONTIME ZENITH ANGLE
      CHINON=SSP(1)-LAT
C
C      WINTER ANOMALY FACTOR FOR DEC, JAN
      IF(LAT .LT. 0.5236) GO TO 100
      IF(TIME(2) .GT. 31 .AND. TIME(2) .LT. 335) GO TO 100
      W=1. + 0.027*(30.-ABS(60. -LAT+RAT))
100    CONTINUE
      N=2.+(COS(LAT))**2.40
      N=N/2.
      CSYN=(COS(CHINON))**N
C
C      CALCULATION OF ABSORPTION
C
      ARSP=2AR.*W*CSYN
      IF(ARSP .LT. 1.E-11) ARSP=1.E-11
C
C      CALCULATION OF M -- Z ANGLE DEP WITH LATITUDE
      LAT=LAT+RAT
      IF(LAT.GT.18.) GO TO 201
      M=0.5*(.58+(RAT*LAT/18.)*0.08)
      GO TO 300
201    CONTINUE
      IF(LAT.GT.24.) GO TO 202
      M=0.5*(0.66+.22*(RAT*LAT-18.)/6.)
      GO TO 300
202    CONTINUE
      IF(LAT.GT.28.) GO TO 203
      M=0.5*0.88
      GO TO 300
203    CONTINUE
      M=0.44
300    CONTINUE
      RETURN
      END
      SUBROUTINE PATH(TRP, CPNT, N)
C      DETERMINES CONTROL POINTS FOR RF ABSORPTION GIVEN ENDPOINTS
C      FOR LESS THAN OR EQUAL TO TEN(10) PATHS
C      INPUTS:
C      TRP(4,10) ARE LAT, LONG OF TRANSMITTER AND RECEIVER IN DEGREES
C      N NUMBER OF PATHS CONSIDERED (LE 10)
C      OUTPUTS:
C      CPNT(7,10) PATHLENGTH AND CONTROL POINT COORDINATES(RADIANS)
C      (1) PATHLENGTH IN RADIANS
C      (2),(3) LAT, LONG OF MIDPOINT(RADIANS)
C      (4-7) IF CPNT(1)=2 THEN ARE LAT, LONG OF POINTS 1000KM
C      CENTERWARD OF ENDPOINTS: IF CPNT(1)=1 THEN DUMMY
C
      DIMENSION TRP(4,10), CPNT(7,10)
      RAT=57.29577
      DO 10 I=1,N
      DO 10 J=1,4
      TRP(J,I)=TRP(J,I)/RAT

```

```

PATH 1
PATH 2
PATH 3
PATH 4
PATH 5
PATH 6
PATH 7
PATH 8
PATH 9
PATH 10
PATH 11
PATH 12
PATH 13
PATH 14
PATH 15
PATH 16
PATH 17

```

10	CONTINUE	PATH 18
	DO 2000 I=1,N	PATH 19
C	PATHLENGTH = TR	PATH 20
	TR=ARCOS(SIN(TRP(3,I))*SIN(TRP(1,I))+COS(TRP(3,I))*COS(TRP(1,I))	PATH 21
	* COS(TRP(2,I)-TRP(4,I))	PATH 22
	PTR=ARCSIN(COS(TRP(3,I))*SIN(TRP(4,I)-TRP(2,I))/SIN(TRP(1,I)))	PATH 23
	IF(TRP(3,I) .LT. TRP(1,I))PTR=3.141593-PTR	PATH 24
	CPNT(1,I)=TR	PATH 25
C	MIDPATH	PATH 26
	TQ=0.5*TR	PATH 27
C	LATITUDE	PATH 28
	CPNT(2,I)=ARCSIN(SIN(TRP(1,I))*COS(TQ)+COS(TRP(1,I))*SIN(TQ)	PATH 29
	* COS(PTR))	PATH 30
	TPG=ARCSIN(SIN(TQ)*SIN(PTR)/COS(CPNT(2,I)))	PATH 31
C	LONGITUDE	PATH 32
	CPNT(3,I)=TRP(2,I)+TPQ	PATH 33
C	CONTROL POINTS 1000KM CENTERWARD OF TRANS, RECEIVER	PATH 34
	TQ=0.14791	PATH 35
	CPNT(4,I)=ARCSIN(SIN(TRP(1,I))*COS(TQ)+COS(TRP(1,I))*SIN(TQ)	PATH 36
	* COS(PTR))	PATH 37
	TPG=ARCSIN(SIN(TQ)*SIN(PTR)/COS(CPNT(4,I)))	PATH 38
	CPNT(5,I)=TRP(2,I)+TPQ	PATH 39
	TQ=TP-0.14791	PATH 40
	CPNT(6,I)=ARCSIN(SIN(TRP(1,I))*COS(TQ)+COS(TRP(1,I))*SIN(TQ)	PATH 41
	* COS(PTR))	PATH 42
	TPG=ARCSIN(SIN(TQ)*SIN(PTR)/COS(CPNT(6,I)))	PATH 43
	CPNT(7,I)=TRP(2,I)+TPQ	PATH 44
2000	CONTINUE	PATH 45
	RETURN	PATH 46
	END	PATH 47-
	FUNCTION CH(Y,Y)	CH 1
C	CHAPMAN'S GRAZING INCIDENCE INTEGRAL	CH 2
C	PROGRAMMED BY JAY R. HILL, AUGUST 16, 1973	CH 3
C	ACCURACY <= 0.1% WHEN X(1-SIN(Y))<10 OR COS(Y)>0	CH 4
C	TIMING: IBM 360/65 = 3.5 MSEC AVERAGE	CH 5
	P(Z,U) = EXP(2.*X*SIN(Z+U/2.)*COS(Y+U/2.)/U+7)/U/L	CH 6
	F(Z) = P(Z,SIN(Z+Y))	CH 7
	CY = COS(Y)	CH 8
	CY1 = CY-0.01745329	CH 9
	IF(150.*Y .GT. X*CY1+4) GO TO 10	CH 10
	CH = 1./CY	CH 11
	RETURN	CH 12
10	G = (ARCSIN(X*SIN(Y)/(X+ALOG(X)+20.0))-Y)/20.0	CH 13
	IF(CY1 .LT. 0.0) GO TO 30	CH 14
	IF(X*CY1 .LT. 40.*Y) GO TO 20	CH 15
	CH=-X*SIN(Y)*G*(.1464466*F(17.414214)+.2535534*F(1.5857864))	CH 16
	RETURN	CH 17
20	CH=-X*SIN(Y)*G*(.5392947E-3*F(10.395071)+.03888791*F(4.536620)	CH 18
	* + .3574187*F(1.745761)+.6031541*F(1.3225477))	CH 19
	RETURN	CH 20
30	CH=-X*SIN(Y)*G*(.14249314E-6*F(16.27926)+.2825923E-4*F(11.84375)	CH 21
	* + .7530084E-3*F(8.330153)+.009501517*F(5.552496)	CH 22
	* + .06208746*F(3.401434)+.2180683*F(1.808343)	CH 23
	* + .4011106*F(1.7294545)+.3084411*F(1.1377935))	CH 24
	RETURN	CH 25
	END	CH 26-
	SUBROUTINE CURSOL(TIME,SSP)	
C	COMPUTE SPPSCALAR POINT	SURL 5
C	TIME IN HOURS AND DECIMAL FRACTIONS THEREOF	SURL 6
C	LAT & LONG IN DEGREES, EAST & SOUTH NEGATIVE	SURL 7
	DIMENSION TIME(4),SSP(2)	
	INTEGER YEAR, DAY	SURL 8
	INTEGER HOUR	
	INTEGER TIME	
	REAL LAT, LONG	SURL 9
	RAT=57.29577	

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YEAR=TIME(1)
DAY=TIME(2)
HOUR=TIME(3)
DAYHR = FLOAT(DAY) + FLOAT(HOUR)/24. + FLOAT(TIME(4))/144.
CALL ALMNAC (YEAR, DAYHR, DEC, EQNT)
LAT = DEC
GHA = FLOAT(HOUR) - (12.0 - EQNT/60.0)
LONG = 15.0+GHA
SSP(2)=LONG/RAD
SSP(1)=LAT/RAD
RETURN
END
SUBROUTINE ALMNAC ( YEAR, DAY, DEC, EQNT )
C COMPUTE THE SOLAR DECLINATION AND EQUATION OF TIME
C INPUTS: YEAR = INTEGER 1900 - 2000 A.D.
C DAY = JULIAN DAY NUMBER PLUS DECIMAL FRACTION
C OUTPUTS: DEC = DECLINATION OF SUN (DEGREES)
C EQNT = EQUATION OF TIME (MINUTES)
C G.H.A. OF THE SUN MAY BE COMPUTED IN DEGREES FROM:
C GHA = 15.0*(HOURS-(12.0+EQNT/60.0))
C PROGRAMMED BY JAY R. HILL, 1969
INTEGER YEAR
DATA A0/ 0.3798/.A1/-23.0009/
DATA A2,A3,A4,A5,A6/-0.3802, -0.1550, -0.0076, -0.0025, -0.0004/ALMC 11
DATA P1,P2,P3,P4,P5/ 3.5354, 0.0302, 0.0728, 0.0032, 0.0020/ALMC 12
DATA C1,C2,C3,C4,C5 /0.5965, -2.9502, -0.0653, -0.1248, -0.0103/ALMC 13
DATA D1,D2,D3,D4,D5/-7.3435, -9.4847, -0.3083, -0.1747, -0.0159/ALMC 14
DATA ONE, TWO / 1.0,2.0/ ALMC 15
K = MOD (YEAR, 4)
DATE = 365.*FLOAT(K) + 0.0078*FLOAT(YEAR-1968)
IF (K .NE. 0) DATE = DATE + 1.0
DATE = DATE + DAY
X = DATE/365.2500 *6.2831853
SX = SIN( X )
CX = COS( X )
TWCCX = TWO*CX
C2X = TWCCX*CX - ONE
S2X = TWCCX*SX
C3X = TWCCX*C2X - CX
S3X = TWCCX*S2X - SX
C4X = TWCCX*C3X - C2X
S4X = TWCCX*S3X - S2X
C5X = TWCCX*C4X - C3X
S5X = TWCCX*S4X - S3X
C6X = TWCCX*C5X - C4X
DEC = A0 + A1*CX + A2*C2X + A3*C3X + A4*C4X + A5*C5X + A6*C6X
EQNT = P1*CX + P2*C2X + P3*C3X + P4*C4X + P5*C5X
+ C1*SX + D2*S2X + D3*S3X + D4*S4X + D5*S5X
RETURN
END

```

EOF..