obtained with reasonable ease. The scientist may find more success in adapting his analysis to a computer rather than adapting a computer to a strictly analytical model.

The general flexibility of the theory of calculations used in this paper will be valuable as a model for other antenna studies. Conceptual simplicity as well as ease in obtaining numerical results are judged to be the major attributes of this method.

APPENDIX A

PROGRAM LISTING

```
$IBFTC FIELDN
C  FIELDN ANALYZES THE NEAR FIELD PROPAGATION OF CIRCULAR AND
C  RECTANGULAR APERTURES
C  SET IPLOT EQUAL TO 1 IF YOUR FACILITY HAS A SC-4020 PLOTTER
 55   CONTINUE
      READ(5,101) WL,RN,SD,FD,A,B,NT,NA,NB,IPLOT
 101  FORMAT(2(2X F6.4),4(2X F4.1),4(2X I1))
      IF(SD . LT . 0.0001)  SD = 0.001
      IF(FD . GT . 89.8)  FD = 89.8
      IF(B . GT . 0.) GO TO 50
C  IF B HAS A NON ZERO VALUE, A RECTANGULAR APERTURE IS ASSUMED
      CALL CIRCUL(WL,RN,SD,FD,A,NT,IPLOT)
      GO TO 55
 50   CONTINUE
      CALL RECTAN(WL,RN,SD,FD,A,B,NA,NB,IPLOT)
      GO TO 55
      END


$IBFTC CIRCUL
      SUBROUTINE CIRCUL(WL,RN,SD,FD,A,NT,IPLOT)
      DIMENSION AZ(1000),E(1000),ERELDB(1000),NOUT(1000),
     N  AZI(4),SPI(4),       BOX(3) ,SYSCAN(3),SXSCAN(3),IYFS(3),IXFS(3)
C     DIMENSION SIZE TO COVER ALL CASES
      PI = 3.1415927
      C = 299.793
      EL = 0.0001
      WRITE(6,200)
 200  FORMAT(1H1,//,10X 42HNEAR FIELD ANALYSIS OF A CIRCULAR APERTURE)
      WRITE(6,201) A
 201  FORMAT(1H ,//,15X 14HREFLECTOR SIZE,5X F5.1,1X 4HFEET)
C     A IS THE DIAMETER OF THE ANTENNA
C     WL IS THE FREE SPACE WAVELENGTH OF THE RADIATION
C     RN IS RANGE NORMALIZED WITH RESPECT TO FAR FIELD DISTANCE
C     NT IS THE POWER OF THE TAPER FUNCTION
C     WL, A, B, ARE ALL IN FEET
      WN = 2.0*PI/WL
C     WN IS IN INVERSE FEET
      AWLR = A / WL
      FNT = NT
      IF(RN.EQ.RNLAST . AND . AWLR.EQ.AWLAST)  GO TO 56
C  THIS TEST ALLOWS CIRCUL TO USE PREVIOUSLY CALCULATED VALUES WHERE
C  APPROPRIATE
      DFF = 2.0 * (A **2) / WL
C  DFF IS THE DISTANCE FROM THE ANTENNA TO THE FAR FIELD
      F = C*3.280833/WL
C     F IS IN MC/SEC
      FDR = FD * PI / 180.
      WRITE(6,202) F
 202  FORMAT(1H ,15X 9HFREQUENCY,8X F7.1,1X 4HMC/S)
      WRITE(6,203) WL
 203  FORMAT(1H ,15X 10HWAVELENGTH,9X F5.2,1X 4HFEET)
      WRITE(6,204) DFF
 204  FORMAT(1H ,15X 18HFAR FIELD DISTANCE,1X F6.0,4HFEET)
      IF(NT . EQ . 0)  GO TO 205
      WRITE(6,206) NT
 206  FORMAT(1H ,15X 26HILLUMINATION  (1-RHO**2)**,I1)
      GO TO 207
 205  CONTINUE
      WRITE(6,208)
 208  FORMAT(1H ,15X 21HILLUMINATION  UNIFORM)
 207  CONTINUE
      CALL MIDDLE(RN,FDR,DFF,A,AWLR,NT,N)
C  N**2 IS THE NUMBER OF ELEMENTARY ANTENNAS IN THE SQUARE CIRCUMSCRIBED
C  BY THE ANTENNA APERTURE
C     THIS PROGRAM EVALUATES THE CORRECT N WHICH DEPENDS ON RN
      AN = N
      AIN = 0.70711 * A
C  AIN IS THE LENGTH OF THE SIDES OF THE INSCRIBED SQUARE
      AEXTRA = (A - AIN) * 0.5
C  AEXTRA IS THE WIDTH OF THE OUTER AREA
      C1 = 0.5 / (PI * WN)
      SYSCAN(1) = 0.0
      SYSCAN(2) = 0.0
      SYSCAN(3) = 0.5 * AIN
      SXSCAN(1) = 0.0
      SXSCAN(2) = SYSCAN(3)
      SXSCAN(3) = 0.0
C  SXSCAN(L),SYSCAN(L),IYFS(L),IXFS(L),SET THE SCAN LIMITS FOR COVERING
C  THE ELEMENTARY ANTENNAS WITHIN THE INSCRIBED SQUARE AND NEAR THE
C  CIRCULAR EDGES
      IF(FD . LT . 0.001)  GO TO 60
C  IF TRUE, A SUBPROGRAM IS CALLED TO PRODUCE AN ON-AXIS VARIATION
      CALL PSPACE(AWLR,RN,AZI,SPI)
C  PSPACE CALCULATESTHE PARAMETERS USED FOR ANTENNA PATTERN POINT SPACING
      CALL FIELDP(AZI,SPI,SD,FD,AZ,NP)
C  FIELDP USES PARAMETERS CALCULATED IN PSPACE TO GENERATE AZ(I)
C     NP IS THE NUMBER OF POINTS IN EACH PATTERN
 56   CONTINUE
      BOX(1) = AIN / AN
C  BOX(L) IS THE SIDE LENGTH OF THE ELEMENTARY SQUARE ANTENNAS
C  COVERING THE INNER AND OUTER APERTURE AREA
      CALL OUTSID(AZ,AWLR,FNT,AN,NP,NOUT,SD,FD,ILL)
C  N2**2 IS PROPORTIONAL TO THE NUMBER OF ELEMENTARY ANTENNAS IN THE
C  OUTER APERTURE AREA
C  OUTSID DETERMINES THE RESOLUTION REQUIRED FOR EACH FIELD POINT
      IYFS(1) = N / 2
      BOX(1) = AIN / AN
      R = RN*DFF
      WRITE(6,209)
 209  FORMAT(1H ,////,10X 26HNEAR FIELD ANTENNA PATTERN)
      WRITE(6,210) RN
 210  FORMAT(1H ,/,15X 16HNORMALIZED RANGE,1X F6.4)
      WRITE(6,211) R
 211  FORMAT(1H ,15X 5HRANGE,1X F7.1,1X 4HFEET)
      WRITE(6,212)
 212  FORMAT(1H ,//,
     N 13X 42HOFF-AXIS ANGLE     RELATIVE POWER DENSITY,/)
      DO 35 K = 1,NP
      N2 = NOUT(K)
      AN2 = N2
      BOX(2) = AIN / AN2
      BOX(3) = BOX(2)
      IYFS(2) = N2 / 2
      IYFS(3) = AEXTRA / BOX(2) + 0.5
      AZR = PI*AZ(K)/180.0
      ELR = PI*EL/180.0
      X = R*SIN(AZR)
      Y = R*SIN(ELR)
      ZS = R**2 - X**2 - Y**2
      Z = SQRT(ZS)
C  (X,Y,Z) AND (R,AZ,EL) ARE THE FIELD COORDINATES
      CALL SCANCL(IYFS,C1,A,X,Y,Z,NT,SYSCAN,SXSCAN,BOX,ERSUM,ECSUM,WN)
C  SCANCL SCANS A CIRCULAR APERATURE
      ES = ERSUM**2+ECSUM**2
      E(K) = SQRT(ES)
  35  CONTINUE
      DO 37 NA = 1,NP
      EREL = E(NA) / E(1)
      ERELDB(NA) = 20.0*ALOG10(EREL)
      WRITE(6,190) AZ(NA),ERELDB(NA)
 190  FORMAT(1H ,18X F5.2,16X F6.1)
 37   CONTINUE
      IF(IPLOT.EQ.1)CALL PLOTTR(NP,AZ,ERELDB,RN,A,B,FNT,FNA,FNB,SD,FD)
C  PLOTTR IS A GRAPHICAL OUTPUT USING THE SC - 4020
      GO TO 55
 60   CONTINUE
      CALL AXISCL(RN,A,NT,WN,N,C1,ILL,IPLOT,AIN,AEXTRA,OFF,SYSCAN,
     N SXSCAN)
C  AXISCL YIELDS ON-AXIS POWER DENSITY VS NORMALIZED RANGE RN
 55   CONTINUE
      RNLAST = RN
      AWLAST = AWLR
      RETURN
      END


$IBFTC RECTAN
      SUBROUTINE RECTAN(WL,RN,SD,FD,A,B,NA,NB,IPLOT)
      DIMENSION AZ(1000),E(1000),ERELDB(1000),AZI(4),SPI(4)
C     DIMENSION SIZE TO COVER ALL CASES
      FNA = NA
      FNB = NB
      WRITE(6,200)
 200  FORMAT(1H1,//,
     N 10X 45HNEAR FIELD ANALYSIS OF A RECTANGULAR APERTURE)
      WRITE(6,201) A,B
 201  FORMAT(1H ,//,15X 14HREFLECTOR SIZE,2X F4.0,1X 2HBY,1X F4.0,
     N 1X 4HFEET)
C     WL IS THE FREE SPACE WAVELENGTH OF THE RADIATION
C     RN IS RANGE NORMALIZED WITH RESPECT TO FAR FIELD DISTANCE
      EL = 0.0001
      PI = 3.1415927
      WN = 2.0*PI/WL
C     WN IS IN INVERSE FEET
C     WL, A, B, ARE ALL IN FEET
      C = 299.793
      F = C*3.280833/WL
C     F IS IN MC/SEC
      AWLR = A / WL
      BWLR = B / WL
      IF(RN.EQ.RNLAST.AND .(AWLR.EQ.AWLAST.AND.BWLR.EQ.BWLAST)) GO TO 56
      DFF = 2. * (A **2 + B **2) / WL
      WRITE(6,202) F
 202  FORMAT(1H ,15X 9HFREQUENCY,8X F7.1,1X 4HMC/S)
      WRITE(6,203) WL
 203  FORMAT(1H ,15X 10HWAVELENGTH,9X F5.2,1X 4HFEET)
      WRITE(6,204) DFF
 204  FORMAT(1H ,15X 18HFAR FIELD DISTANCE,1X F6.0,4HFEET)
      IF(NA . EQ . 0 . AND . NB . EQ . 0)  GO TO 205
      WRITE(8,206) NA,NB
 206  FORMAT(1H ,15X 25HILLUMINATION ((1-RX**2)**,I1,13H)((1-RY**2)**,
     N I1,1H))
      GO TO 207
 205  CONTINUE
      WRITE(6,208)
 208  FORMAT(1H ,15X 21HILLUMINATION  UNIFORM)
 207  CONTINUE
      FDR = FD * PI / 180.
      CALL MIDDLE(RN,FDR,DFF,A,AWLR,NT,N)
C     THIS PROGRAM EVALUATES THE CORRECT N WHICH DEPENDS ON RN
C     N IS THE RESOLUTION OF THE ANALYSIS
      AN = N
      XBOX = A / AN
      YBOX = B / AN
      BYH = YBOX * .5
      BXH = XBOX * .5
      C1 = 0.5 / (PI * WN)
      C2 = WN * BXH
      C3 = WN * BYH
      JA = N/2
      IF(FD . LT . 0.001)  GO TO 60
C  IF TRUE, A SUBPROGRAM IS CALLED TO PRODUCE AN ON-AXIS VARIATION
      CALL PSPACE(AWLR,RN,AZI,SPI)
C  PSPACE CALCULATESTHE PARAMETERS USED FOR ANTENNA PATTERN POINT SPACING
 56   CONTINUE
      CALL FIELDP(AZI,SPI,SD,FD,AZ,NP)
C  FIELDP USES PARAMETERS CALCULATED IN PSPACE TO GENERATE AZ(I)
C     NP IS THE NUMBER OF POINTS IN EACH PATTERN
      R = RN*DFF
      WRITE(6,209)
 209  FORMAT(1H ,////,10X 26HNEAR FIELD ANTENNA PATTERN)
      WRITE(6,210) RN
 210  FORMAT(1H ,/,15X 16HNORMALIZED RANGE,1X F6.4)
      WRITE(6,211) R
 211  FORMAT(1H ,15X 5HRANGE,1X F7.1,1X 4HFEET)
      WRITE(6,212)
 212  FORMAT(1H ,//,
     N 13X 42HOFF-AXIS ANGLE     RELATIVE POWER DENSITY,/)
      DO 35 K = 1,NP
      AZR = PI*AZ(K)/180.0
      ELR = PI*EL/180.0
      X = R*SIN(AZR)
      Y = R*SIN(ELR)
      ZS = R**2 - X**2 - Y**2
      Z = SQRT(ZS)
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      CALL SCANRT(JA,BYH,BXH,X,Y,Z,C1,C2,C3,ERSUM,ECSUM,NA,NB,WN,A,B)
C  SCANRT SCANS A RECTANGULAR APERTURE
      ES = ERSUM**2+ECSUM**2
      E(K) = SQRT(ES)
   35 CONTINUE
      DO 37 NA = 1,NP
      EREL = E(NA) / E(1)
      ERELDB(NA) = 20.0*ALOG10(EREL)
      WRITE(6,190) AZ(NA),ERELDB(NA)
  190 FORMAT(1H ,18X F5.2,16X F6.1)
   37 CONTINUE
      IF(IPLOT.EQ.1)CALL PLOTTR(NP,AZ,ERELDB,RN,A,B,FNT,FNA,FNB,SD,FD)
      GO TO 55
   60 CONTINUE
      CALL AXISRT(RN,DFF,JA,BYH,BXH,IPLOT,C1,C2,C3,NA,NB,WN,A,B)
C  AXISRT YIELDS RECTANGULAR ON-AXIS FIELD STRENGTH
   55 CONTINUE
      RNLAST = RN
      AWLAST = AWLR
      BWLAST = BWLR
      RETURN
      END


$IBFTC MIDDLE
      SUBROUTINE MIDDLE(RN,FDR,DFF,A,AWLR,NT,N)
C     THIS PROGRAM EVALUATES THE CORRECT N WHICH DEPENDS ON RN
      IF(RN . EQ . 0.)  GO TO 21
      AH = .5 * A
      R = RN * DFF
      IF(R . LT . AH)  GO TO 20
      RPS = R **2 + AH **2 - A * R * SIN(FDR)
      RNP = SQRT(RPS) / DFF
      NTRY = 1. / SQRT(RNP)
      GO TO 25
   20 CONTINUE
      NTRY = 1. / SQRT(RN * COS(FDR))
      GO TO 25
   21 CONTINUE
      NTRY = 20
   25 CONTINUE
      NTAP = 100. * (1. - EXP(-.023 * AWLR))
      IF(NTAP . GT . NTRY . AND . NT . GT . 0 )  GO TO 10
      ILL = 0
      GO TO 11
   10 CONTINUE
      ILL = 1
      NTRY = NTAP
C  EXTRA N BECAUSE THE N REQUIRED FOR DISTANCE IS NOT SUFFICIENT FOR TAPER
      IF(FDR.LT.0.0349.AND.NTRY.GT.20) NTRY = 20
   11 CONTINUE
      NTRYH = NTRY / 2
      N = 2 * (NTRY - NTRYH + 1)
C     EXTRA 2 ALLOWS FOR GREATER CONVERGENCE OFF AXIS
C     N MUST BE EVEN
      RETURN
      END


$IBFTC PSPACE
      SUBROUTINE PSPACE(AWLR,RN,AZI,SPI)
C  PSPACE CALCULATESTHE PARAMETERS USED FOR ANTENNA PATTERN POINT SPACING
      DIMENSION AAWLR(5),BRN(5),AZI2(5,5),AZI3(5,5),SPI1(5,5),SPI2(5,5),
     N SPI3(5,5),SPI4(5,5),AZI(4),SPI(4)
      DATA(AAWLR(JM),JM = 1,5)/ 0.5,10.0,40.0,100.0,800.0/,
     N (BRN(JM),JM = 1,5)/ 0.001,0.02,0.08,0.14,3.0 /
      DATA(AZI2(1,L1),L1 = 1,5)/70.,50.,40.,20.,10./
      DATA(AZI2(2,L2),L2 = 1,5)/50.,40.,30.,15.,6./
      DATA(AZI2(3,L3),L3 = 1,5)/20.,15.,10.,8.,4./
      DATA(AZI2(4,L4),L4 = 1,5)/7.,6.,5.,4.,3./
      DATA(AZI2(5,L5),L5 = 1,5)/6.,5.,4.,3.,1.5/
      DATA(AZI3(1,L1),L1 = 1,5)/80.,65.,60.,50.,45./
      DATA(AZI3(2,L2),L2 = 1,5)/75.,62.,55.,49.,42./
      DATA(AZI3(3,L3),L3 = 1,5)/55.,50.,45.,43.,41./
      DATA(AZI3(4,L4),L4 = 1,5)/45.,43.,42.,41.,40./
      DATA(AZI3(5,L5),L5 = 1,5)/35.,33.,32.,31.,30./
      DATA(SPI1(1,K1),K1 = 1,5)/3.,3.,2.5,2.,1.5/
      DATA(SPI1(2,K2),K2 = 1,5)/2.7,2.5,2.1,1.2,.5/
      DATA(SPI1(3,K3),K3 = 1,5)/2.2,1.8,1.6,.6,.3/
      DATA(SPI1(4,K4),K4 = 1,5)/1.4,.8,.6,.4,.2/
      DATA(SPI1(5,K5),K5 = 1,5)/1.2,.7,.4,.2,.15/
      DATA(SPI2(1,K1),K1 = 1,5)/.9,.7,.4,.22,.16/
      DATA(SPI2(2,K2),K2 = 1,5)/.6,.3,.2,.16,.1/
      DATA(SPI2(3,K3),K3 = 1,5)/.5,.29,.12,.1,.08/
      DATA(SPI2(4,K4),K4 = 1,5)/.4,.26,.09,.08,.07/
      DATA(SPI2(5,K5),K5 = 1,5)/.3,.2,.08,.07,.06/
      DATA(SPI3(1,K1),K1 = 1,5)/4.,3.,2.,1.8,1.6/
      DATA(SPI3(2,K2),K2 = 1,5)/3.,2.,1.2,.7,.6/
      DATA(SPI3(3,K3),K3 = 1,5)/2.2,1.4,.8,.6,.5/
      DATA(SPI3(4,K4),K4 = 1,5)/1.9,1.,.7,.45,.2/
      DATA(SPI3(5,K5),K5 = 1,5)/1.4,.8,.5,.3,.1/
      DATA(SPI4(1,K1),K1 = 1,5)/5.,4.,3.,2.6,2./
      DATA(SPI4(2,K2),K2 = 1,5)/4.,3.,2.,1.,.8/
      DATA(SPI4(3,K3),K3 = 1,5)/3.2,1.8,1.2,.8,.6/
      DATA(SPI4(4,K4),K4 = 1,5)/2.6,1.6,1.,.5,.3/
      DATA(SPI4(5,K5),K5 = 1,5)/2.,1.2,.8,.4,.2/
      DO 90  JI = 1,5
      IF(AAWLR(JI) - AWLR)  90,91,92
   90 CONTINUE
   91 CONTINUE
      ALPHA = 0.0
      JJ = JI
      GO TO 93
   92 CONTINUE
      JJ = JI - 1
      ALPHA = (AWLR - AAWLR(JJ)) / (AAWLR(JI) - AAWLR(JJ))
   93 CONTINUE
C     NOTE, VALUE OF AWLR FALLS BETWEEN AAWLR(JJ) AND AAWLR(JI)
      DO 94  JK = 1,5
      IF(BRN(JK) - RN)  94,95,96
   94 CONTINUE
   95 CONTINUE
      BETA = 0.0
      JL = JK
      GO TO 97
   96 CONTINUE
      JL = JK - 1
      BETA = (RN - BRN(JL)) / (BRN(JK) - BRN(JL))
   97 CONTINUE
C     NOTE, VALUE OF RN FALLS BETWEEN BRN(JL) AND BRN(JK)
      SCALE = SQRT(ALPHA **2 + BETA **2) / 1.4142
      AZI(1) = 0.0
      AZI(2) = SCALE *(-AZI2(JL,JJ) + AZI2(JK,JI)) + AZI2(JL,JJ)
      AZI(3) = SCALE *(-AZI3(JL,JJ) + AZI3(JK,JI)) + AZI3(JL,JJ)
      AZI(4) = 90.0
      SPI(1) = SCALE *(-SPI1(JL,JJ) + SPI1(JK,JI)) + SPI1(JL,JJ)
      SPI(2) = SCALE *(-SPI2(JL,JJ) + SPI2(JK,JI)) + SPI2(JL,JJ)
      SPI(3) = SCALE *(-SPI3(JL,JJ) + SPI3(JK,JI)) + SPI3(JL,JJ)
      SPI(4) = SCALE *(-SPI4(JL,JJ) + SPI4(JK,JI)) + SPI4(JL,JJ)
      RETURN
      END


$IBFTC FIELDP
      SUBROUTINE FIELDP(AZI,SPI,SD,FD,AZ,NP)
C  FIELDP USES PARAMETERS CALCULATED IN PSPACE TO GENERATE AZ(I)
      DIMENSION AZI(4),SPI(4),DEGST(4),DEGBG(4),AZ(1000)
      DO 3  KA = 1,3
      KC = KA + 1
      IF(SD - AZI(KC)) 4,4,3
    3 CONTINUE
    4 CONTINUE
      KS = KA
      DO 5  KB = 1,3
      KD = KB + 1
      IF(FD - AZI(KD)) 6,6,5
    5 CONTINUE
    6 CONTINUE
      KE = KB
      AZ(1) = 0.00001
      AZ(2) = SD
      I = 3
      DO 80  JX = KS,KE
      JY = JX + 1
      SLOPE = (SPI(JY) - SPI(JX)) / (AZI(JY) - AZI(JX))
      SLP1 = 1.0 + SLOPE
      YINT = SPI(JX) - SLOPE * AZI(JX)
      DEL = YINT / SLOPE
      DEGBG(JX) = AZI(JX)
      IF(JX . EQ . KS)  DEGBG(JX) = SD
      DEGST(JX) = AZI(JY)
      IF(JX . EQ . KE)  DEGST(JX) = FD
      ANUM = (DEGST(JX) + DEL) / (DEGBG(JX) + DEL)
      IND     = ALOG(ABS(ANUM)) / ALOG(ABS(SLP1))
      DO 83  NY = 1,IND
      II = I - 1
      AZ(I) = SLP1 * AZ(II) + YINT
      I = I + 1
   83 CONTINUE
   80 CONTINUE
      NP = I - 1
      RETURN
      END


$IBFTC OUTSID
      SUBROUTINE OUTSID(AZ,AWLR,FNT,AN,NP,NOUT,SD,FD,ILL)
C  OUTSID DETERMINES THE RESOLUTION REQUIRED FOR EACH FIELD POINT
C  OUTSID DETERMINES THE ACCURACY OF REPRESENTING THE APERTURE EDGES
      DIMENSION AZ(1000),NOUT(1000),H(8),ANG(8)
      DATA(ANG(I),I = 1,8)/0.,5.,20.,40.,55.,65.,75.,89.9/
      IF(ILL . EQ . 1)  GO TO 40
      H(1) = 1.10 * AN
      H(2) = 1.15 * AN
      H(3) = 1.20 * AN
      H(4) = 1.25 * AN
      H(5) = 1.30 * AN
      H(6) = 1.32 * AN
      H(7) = 1.35 * AN
      H(8) = 1.40 * AN
      GO TO 41
   40 CONTINUE
C  H(I) VALUES ARE BASED UPON EMPIRICALLY DERIVED RESOLUTION VALUES
      AL = ALOG10(FNT + .1)
      H(1) = AN + .1 * AWLR + 2. - 4. * AL
      H(2) = H(1) + 3. - 6. * AL
      H(3) = H(2) + .167 * AWLR - 2. * AL
      H(4) = H(3) + 10. - 4. * AL
      H(5) = H(4) + .1 * AWLR + 2. - 8. * AL
      H(6) = H(5) + 15. + 4. * AL
      H(7) = H(6) + 3. - 3. * AL
      H(8) = H(7) + 4.
   41 CONTINUE
      DO 3  I = 1,7
      J = I + 1
      IF(SD . LT . ANG(J))  GO TO 5
    3 CONTINUE
    5 CONTINUE
      JS = I
      DO 4  IA = 1,7
      JA = IA + 1
      IF(FD . LT . ANG(JA))  GO TO 6
    4 CONTINUE
    6 CONTINUE
      JF = IA
      KS = 1
      K = 1
      DO 12  I = JS,JF
      M = I + 1
      SLOPE = (H(M) - H(I)) / (ANG(M) - ANG(I))
      B = H(I) - SLOPE * ANG(I)
      DO 13  J = KS,NP
      IF(AZ(K) . GE . ANG(M)) GO TO 11
      NH = SLOPE * AZ(K)  + B
      NHH = NH / 2
      NOUT(K) = 2 * (NH - NHH)
C  NOUT MUST BE EVEN
      K = K + 1
   13 CONTINUE
   11 CONTINUE
      KS = K
   12 CONTINUE
      RETURN
      END


$IBFTC SCANCL
      SUBROUTINE SCANCL(IYFS,C1,A,X,Y,Z,NT,SYSCAN,SXSCAN,BOX,ERSUM,
     N ECSUM,WN)
      DIMENSION IXFS(3),BOX(3),SYSCAN(3),SXSCAN(3),IYFS(3)
C  SCANCL SCANS A CIRCULAR APERATURE
C     DUE TO SYMMETRY, ONLY THE FIRST TWO QUADRANTS NEED BE CALCULATED
      AHS = (.5 * A) **2
      ERSUM = 0.
      ECSUM = 0.
C  ERSUM AND ECSUM COLLECT THE REAL AND IMAGINARY FIELD CONTRIBUTIONS
C  FROM THE ELEMENTARY ANTENNAS
      DO 34  LX = 1,3
      C2 = 0.5 * WN * BOX(LX)
      IYF = IYFS(LX)
      DO 15  M = 1,IYF
```

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C      SCAN ANTENNA IN THE Y DIRECTION
       W = M
       YSCAN = SYSCAN(LX) + (2.0 * W - 1.0) * BOX(LX) * 0.5
       Y1 = Y - YSCAN
       Y2 = Y1
       SLS = AHS - YSCAN **2
       SL = SQRT(SLS)
C      SL IS SCAN LIMIT FOR CIRCULAR APERTURES
       J = (SL - SXSCAN(LX)) / BOX(2) + 0.5
       IXFS(1) = IYF
       IXFS(2) = J
       IXFS(2) = J
       IXFS(3) = J
       IXF = IXFS(LX)
       DO 45  L = 1,IXF
C      SCAN ANTENNA IN THE X DIRECTION
       H = L
       XSCAN = SXSCAN(LX) + (2.0 * H - 1.0) * BOX(LX) * 0.5
       X1 = X - XSCAN
       X2 = X + XSCAN
       R1S = X1**2+Y1**2+Z**2
       R2S = X2**2+Y2**2+Z**2
       R1 = SQRT(R1S)
       R2 = SQRT(R2S)
       EZR1 = (Z + R1) * C1
       EZR2 = (Z + R2) * C1
       ARX1 = C2 * X1 / R1
       ARX2 = C2 * X2 / R2
       ARY1 = C2 * Y1 / R1
       ARY2 = C2 * Y2 / R2
       EX1 = (SIN(ARX1))/X1
       EX2 = (SIN(ARX2))/X2
       EY1 = (SIN(ARY1))/Y1
       EY2 = (SIN(ARY2))/Y2
       EA1 = EZR1*EX1*EY1
       EA2 = EZR2*EX2*EY2
       EA1R = EA1*SIN(WN*R1)
       EA2R = EA2*SIN(WN*R2)
       EA1C = EA1*COS(WN*R1)
       EA2C = EA2*COS(WN*R2)
       EA1RN = EA1R * SQRT(1.0 - (Y1/R1)**2)
       EA2RN = EA2R * SQRT(1.0 - (Y2/R2)**2)
       EA1CN = EA1C * SQRT(1.0 - (Y1/R1)**2)
       EA2CN = EA2C * SQRT(1.0 - (Y2/R2)**2)
C      EA1RN = EA4RN,EA2RN = EA3RN,EA1CN = EA4CN, AND EA2CN = EA3CN
       FILL = (1.0 - 4.0*(XSCAN **2 + YSCAN **2) / A **2) **NT
C  FILL IS THE ANTENNA ILLUMINATION FUNCTION
       ER = 2.0 * (EA1RN + EA2RN) * FILL
       EC = 2.0 * (EA1CN + EA2CN) * FILL
       ERSUM = ERSUM+ER
       ECSUM = ECSUM+EC
 45    CONTINUE
 15    CONTINUE
 34    CONTINUE
       RETURN
       END


$IBFTC SCANRT
       SUBROUTINE SCANRT(JA,BYH,BXH,X,Y,Z,C1,C2,C3,ERSUM,ECSUM,NA,NB,WN,
      N A,B)
C  SCANRT SCANS A RECTANGULAR APERTURE
       ERSUM = 0.0
       ECSUM = 0.0
C      DUE TO SYMMETRY, ONLY THE FIRST TWO QUADRANTS NEED BE CALCULATED
       DO 15    M=1,JA
C      SCAN ANTENNA IN THE Y DIRECTION
       W = M
       YSCAN = (2. * W - 1.) * BYH
       EILLY = (1. - 4. * (YSCAN/B)**2) **NB
       Y1 = Y - YSCAN
       Y2 = Y1
       DO 45    L=1,JA
C      SCAN ANTENNA IN THE X DIRECTION
       H = L
       XSCAN = (2. * H - 1.) * BXH
       EILLX = (1. - 4. * (XSCAN/A)**2) **NA
       X1 = X - XSCAN
       X2 = X + XSCAN
       R1S = X1**2+Y1**2+Z**2
       R2S = X2**2+Y2**2+Z**2
       R1 = SQRT(R1S)
       R2 = SQRT(R2S)
       EZR1 = (Z + R1) * C1
       EZR2 = (Z + R2) * C1
       ARX1 = C2 * X1 / R1
       ARX2 = C2 * X2 / R2
       ARY1 = C3 * Y1 / R1
       ARY2 = C3 * Y2 / R2
       EX1 = (SIN(ARX1))/X1
       EX2 = (SIN(ARX2))/X2
       EY1 = (SIN(ARY1))/Y1
       EY2 = (SIN(ARY2))/Y2
       EA1 = EZR1*EX1*EY1
       EA2 = EZR2*EX2*EY2
       EA1R = EA1*SIN(WN*R1)
       EA2R = EA2*SIN(WN*R2)
       EA1C = EA1*COS(WN*R1)
       EA2C = EA2*COS(WN*R2)
       EA1RN = EA1R * SQRT(1.0 - (Y1/R1)**2)
       EA2RN = EA2R * SQRT(1.0 - (Y2/R2)**2)
       EA1CN = EA1C * SQRT(1.0 - (Y1/R1)**2)
       EA2CN = EA2C * SQRT(1.0 - (Y2/R2)**2)
C      EA1RN = EA4RN,EA2RN = EA3RN,EA1CN = EA4CN, AND EA2CN = EA3CN
       EILL = EILLY * EILLX
C  EILL IS THE ANTENNA ILLUMINATION FUNCTION
       ER = 2.0 * (EA1RN + EA2RN) * EILL
       EC = 2.0 * (EA1CN + EA2CN) * EILL
       ERSUM = ERSUM+ER
       ECSUM = ECSUM+EC
 45    CONTINUE
 15    CONTINUE
       RETURN
       END
```

```
$IBFTC AXISCL
       SUBROUTINE AXISCL(RN,A,NT,WN,N,C1,ILL,IPLOT,AIN,AEXTRA,DFF,
      N SYSCAN,SXSCAN)
       DIMENSION RA(100),PD(100),PREL(100),SYSCAN(3),SXSCAN(3),IYFS(3),
      N BOX(3)
C  AXISCL YIELDS ON-AXIS POWER DENSITY VS NORMALIZED RANGE RN
       WRITE(6,213)
 213   FORMAT(1H ,////,10X 31HON-AXIS POWER DENSITY VARIATION)
       WRITE(6,214)
 214   FORMAT(1H ,//,
      N 13X 43HNORMALIZED RANGE   NORMALIZED POWER DENSITY,/)
       AN = N
       FNT = NT
       IF(ILL . GT . 0)  GO TO 5
       NTRY = AN + 5. + .1 * AWLR - 10. * ALOG10(FNT + .1)
       GO TO 6
 5     CONTINUE
       NTRY = AN * 1.2
 6     CONTINUE
       NTRYH = NTRY / 2
       N2 = 2 * (NTRY - NTRYH + 1)
       AN2 = N2
       BOX(1) = AIN / AN
       BOX(2) = AIN / AN2
       BOX(3) = BOX(2)
       IYFS(1) = N / 2
       IYFS(2) = N2 / 2
       IYFS(3) = AEXTRA / BOX(2) + 0.5
       WRITE(6,200)
 200   FORMAT(1H ,///,6X 17HRELATIVE RANGE RN,
      N 4X 24HNORMALIZED POWER DENSITY,//)
       NEND = 2
       RA(1) = RN
       RA(2) = 1.0
       IF(RN . EQ . 0.)  CALL ARRAYR(RA,NEND)
C  ARRAYR GENERATES RN VALUES FOR ON-AXIS PLOTS
       X = 0.00001
       Y = X
       DO 45 K = 1,NEND
       R = RA(K) * DFF
       Z = R
       CALL SCANCL(IYFS,C1,A,X,Y,Z,NT,SYSCAN,SXSCAN,BOX,ERSUM,ECSUM,WN)
C  SCANCL SCANS A CIRCULAR APERATURE
       PD(K) = ERSUM **2 + ECSUM **2
 45    CONTINUE
       DO 37  NA = 1,NEND
       PREL(NA) = PD(NA) / PD(NEND)
       WRITE(6,215) RA(NA),PREL(NA)
 215   FORMAT(1H ,18X F5.3,17X F6.2)
 37    CONTINUE
       IF(IPLOT . EQ . 1) CALL PLOTAX(RA,PREL,FNT,FNA,FNB,NEND,B)
C  PLOTAX IS A SC-4020 PLOTTING ROUTINE
       RETURN
       END


$IBFTC AXISRT
       SUBROUTINE AXISRT(RN,DFF,JA,BYH,BXH,IPLOT,C1,C2,C3,NA,NB,WN,A,B)
C  AXISRT YIELDS RECTANGULAR ON-AXIS FIELD STRENGTH
       DIMENSION RA(100),PD(100),PREL(100)
       X = 0.00001
       Y = X
       WRITE(6,213)
 213   FORMAT(1H ,////,10X 31HON-AXIS POWER DENSITY VARIATION)
 214   FORMAT(1H ,//,
      N 13X 43HNORMALIZED RANGE   NORMALIZED POWER DENSITY,/)
       NEND = 2
       RA(1) = RN
       RA(2) = 1.0
       IF(RN . EQ . 0.)  CALL ARRAYR(RA,NEND)
C  ARRAYR GENERATES RN VALUES FOR ON-AXIS PLOTS
       DO 45 K = 1,NEND
       R = RA(K) * DFF
       Z = R
       CALL SCANRT(JA,BYH,BXH,X,Y,Z,C1,C2,C3,ERSUM,ECSUM,NA,NB,WN,A,B)
       PD(K) = ERSUM **2 + ECSUM **2
 45    CONTINUE
       DO 37  NA = 1,NEND
       PREL(NA) = PD(NA) / PD(NEND)
       WRITE(6,215) RA(NA),PREL(NA)
 215   FORMAT(1H ,18X F5.3,17X F6.2)
 37    CONTINUE
       FNA = NA
       FNB = NB
       IF(IPLOT . EQ . 1) CALL PLOTAX(RA,PREL,FNT,FNA,FNB,NEND,B)
C  PLOTAX IS A SC-4020 PLOTTING ROUTINE
       RETURN
       END


$IBFTC ARRAYR
       SUBROUTINE ARRAYR(RA,NEND)
C  ARRAYR GENERATES RN VALUES FOR ON-AXIS PLOTS
       DIMENSION RA(100)
       RA(1) = .01
       DO 1  I = 1,85
       L = I + 1
       RA(L) = RA(I) + .05 * (EXP(RA(I)) - 1.)
 1     CONTINUE
       NEND = L + 1
       RA(NEND) = 1.0
       RETURN
       END


$IBFTC PLOTTR
       SUBROUTINE PLOTTR(NP,AZ,ERELDB,RN,A,B,FNT,FNA,FNB,SD,FD)
C  PLOTTR IS A GRAPHICAL OUTPUT USING THE SC - 4020
       DIMENSION AZ(1000),ERELDB(1000),IAZ(1000),IEDB(1000)
       NPLO = NP - 1
       NOP = NP / 100 + 1
C      NOP = NUMBER OF PLOTS
       XNOP = NOP
       DEGRPP = (FD - SD)/XNOP + 1.0
C      DEGRPP = ANGULAR RANGE PER PLOT
       START = SD
       FINISH = START + DEGRPP
       CALL GRIDIV(1,START,FINISH,-80.0,0.0,1.0,2.0,10,10,- 5,- 5,4,4)
```

```
      CALL RITE2V(350,800,1000,90,2,26,1,26HNEAR FIELD ANTENNA PATTERN,
     N NLAST)
      CALL RITE2V (400, 1000,1000, 90, 2,13, 1,13HAZIMUTH ANGLE,NLAST)
      CALL RITE2V (20 , 350,1000, 180, 2,27, 1,
     N 27HRELATIVE POWER DENSITY (DB),NLAST)
      CALL PRINTV(5,5HRN = ,900,960)
      CALL LABLV( RN,930,960,6,2,2)
      IF(B . GT . 0.) GO TO 70
      CALL RITE2V(400,700,1000,90,2,17,1,17HCIRCULAR APERTURE,NLAST)
      CALL PRINTV(5,5HDIA= ,900,900)
      CALL LABLV(A ,930,900,3,2,3)
      CALL PRINTV(20,20HILLUMINATION COEF. =,750,920)
      CALL LABLV(FNT,930,920,1,2,1)
      GO TO 75
70    CONTINUE
      CALL RITE2V(400,700,1000,90,2,20,1,20HRECTANGULAR APERTURE,NLAST)
      CALL PRINTV(17,17HDIMENSIONS      BY,800,900)
      CALL LABLV(A ,885,900,3,2,3)
      CALL LABLV(B, 940,900,3,2,3)
      CALL PRINTV(31,31HHORIZONTAL ILLUMINATION COEF. =,670,920)
      CALL LABLV(FNA,930,920,1,2,1)
      CALL PRINTV(29,29HVERTICAL ILLUMINATION COEF. =,695,940)
      CALL LABLV(FNB,930,940,1,2,1)
75    CONTINUE
      DO 601  MZ = 1,NP
      IAZ(MZ) = NXV(AZ(MZ))
      IEDB(MZ) = NYV(ERELDB(MZ))
601   CONTINUE
      I = 2
600   CONTINUE
400   CONTINUE
      IF(AZ(I) - FINISH)   300,301,301
300   CONTINUE
      IF(I - NPLO)  302,303,303
302   CONTINUE
      CALL POINTV(AZ(I),ERELDB(I),15)
      CALL LINEV(IAZ(I),IEDB(I),IAZ(I + 1),IEDB(I + 1))
      I = I + 1
      GO TO 400
301   CONTINUE
      START = FINISH
      FINISH = START + DEGRPP
      CALL GRID1V(1,START,FINISH,-80.0,0.0,1.0,2.0,10,10,- 5,- 5,4,4)
      CALL RITE2V(350,800,1000,90,2,26,1,26HNEAR FIELD ANTENNA PATTERN,
     N NLAST)
      CALL RITE2V (400, 1000,1000, 90, 2,13, 1,13HAZIMUTH ANGLE,NLAST)
      CALL RITE2V (20 , 350,1000, 180, 2,27, 1,
     N 27HRELATIVE POWER DENSITY (DB),NLAST)
      CALL PRINTV(5,5HRN = ,900,960)
      CALL LABLV( RN,930,960,6,2,2)
      IF(B . GT . 0.) GO TO 50
      CALL RITE2V(400,700,1000,90,2,17,1,17HCIRCULAR APERTURE,NLAST)
      CALL PRINTV(5,5HDIA= ,900,900)
      CALL LABLV(A ,930,900,3,2,3)
      CALL PRINTV(20,20HILLUMINATION COEF. =,750,920)
      CALL LABLV(FNT,930,920,1,2,1)
      GO TO 55
50    CONTINUE
      CALL RITE2V(400,700,1000,90,2,20,1,20HRECTANGULAR APERTURE,NLAST)
      CALL PRINTV(17,17HDIMENSIONS      BY,800,900)
      CALL LABLV(A ,885,900,3,2,3)
      CALL LABLV(B, 940,900,3,2,3)
      CALL PRINTV(31,31HHORIZONTAL ILLUMINATION COEF. =,670,920)
      CALL LABLV(FNA,930,920,1,2,1)
      CALL PRINTV(29,29HVERTICAL ILLUMINATION COEF. =,695,940)
      CALL LABLV(FNB,930,940,1,2,1)
55    CONTINUE
      DO 602  NZ = 1,NP
      IAZ(NZ) = NXV(AZ(NZ))
      IEDB(NZ) = NYV(ERELDB(NZ))
602   CONTINUE
      GO TO 600
303   CONTINUE
      RETURN
      END


$IBFTC PLOTAX
      SUBROUTINE PLOTAX(RA,PREL,FNT,FNA,FNB,NEND,B)
C  PLOTAX IS A SC-4020 PLOTTING ROUTINE
      DIMENSION RA(100),PREL(100),IRN(100),IPD(100)
      CALL SMXYV(1,1)
      CALL GRID1V(1,0.01,1.0,1.0,500.0,1.0,1.0,1,1,1,1,4,5)
      CALL RITE2V(350,10,1000,90,2,22,1,22HNORMALIZED DISTANCE RN,NLAST)
      CALL RITE2V(20,350,1000,180,2,13,1,13HPOWER DENSITY,NLAST)
      CALL RITE2V(300,900,900,90,2,37,1,
     N 37HAXIAL POWER DENSITY IN THE NEAR FIELD,NLAST)
      IF(B . GT . 0.) GO TO 50
      CALL RITE2V(350,850,1000,90,2,17,1,17HCIRCULAR APERTURE,NLAST)
      CALL PRINTV(18,18HILLUMINATION COEF.,500,750)
      CALL LABLV(FNT,680,750,1,2,1)
      GO TO 55
50    CONTINUE
      CALL RITE2V(350,850,1000,90,2,20,1,20HRECTANGULAR APERTURE,NLAST)
      CALL PRINTV(29,29HHORIZONTAL ILLUMINATION COEF.,500,750)
      CALL LABLV(FNA,790,750,1,2,1)
      CALL PRINTV(27,27HVERTICAL ILLUMINATION COEF.,500,710)
      CALL LABLV(FNB,770,710,1,2,1)
55    CONTINUE
      DO 54  LE = 1,NEND
      IRN(LE) = NXV(RA(LE))
      IPD(LE) = NYV(PREL(LE))
54    CONTINUE
      NPL = NEND - 1
      DO 7  LK = 1,NPL
      CALL LINEV(IRN(LK),IPD(LK),IRN(LK + 1),IPD(LK + 1))
      CALL LINEV(IRN(LK),IPD(LK),IRN(LK + 1),IPD(LK + 1))
7     CONTINUE
      CALL SMXYV(0,0)
      RETURN
      END
```

If the computer facility at which FIELDN is to be run does not have a SC-4020 plotter, dummy plotting routines must be used so that FIELDN may be loaded into the computer. The following dummy subroutines should be used:

```
$IBFTC PLOTR
       SUBROUTINE PLOTTR (NP,AZ,ERELDB,RN,A,B,FNT,
      N FNA,FNB,SD,FD)
       RETURN
       END

$IBFTC PLOTAX
       SUBROUTINE PLOTAX (RA,PREL,FNT,FNA,FNB,
      N NEND,B)
       RETURN
       END
```

APPENDIX B

DATA INPUT AND PROGRAM CONTROL

COLUMN(S) AND FORMAT	VARIABLE	UNITS	EFFECT
3 - 8* - . - - - - -	WL wavelength	Feet	Sets a value for the wavelength (also frequency)
11 - 16 - . - - - - -	RN normalized range	Unitless	Sets a value for range $RN = R/(2D^2/\lambda)$
19 - 22 - - . -	SD start degree	Degrees	Set the angle at which the antenna pattern begins. If a full pattern is desired, set = 00.0.
25 - 28 - - . -	FD finish degree	Degrees	Sets the angle at which the antenna pattern ends. Has a range from 00.0 to 90.0. For a pattern, FD should be greater then SD. If the On-Axis variation is desired, set FD = 00.0.
31 - 34 - - . -	A diameter/width	Feet	Sets a value for the diameter of a circular aperture or the width of a rectangular aperture.
37 - 40 - - . -	B height	Feet	Sets a value for the height of a rectangular aperture. If a circular aperture, Set B = 00.0
43 -	NT Ill. coef.	Unitless	Sets a value for the illumination function coefficient for circular apertures. For uniform illumination, set NT = 0.
46 -	NA Horiz. Ill. Coef.	Unitless	Sets a value for the horizontal illumination function coefficient for rectangular apertures.
49 -	NB Vert. Ill. Coef.	Unitless	Set a value for the vertical illumination function coefficient for rectangular apertures. For uniform illumination, set NA = NB = 0.
52 -	IPLOT Plot call	Unitless	Calls a SC-4020 Plotter which plots the results; SET IPLOT = 1. IF facility has no SC-4020, SET IPLOT ≠ 1.

*NOTE: There are two spaces between each entry.