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EVALUATION OF TIME DOMAIN EM COUPLING TECHNIQUES

IIT Research Institute

Dr. Allen Taflove

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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19 TR-80-251-VOL-2

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This research program investigated a new tool for the analysis of electromangetic coupling and shielding problems: the finite-difference, time-domain (FD-TD) solution of Maxwell's equations. The objective of the program was to evaluate the suitability of the FD-TD method to determine the amount of electromagnetic coupling through an aperture into an enclosed conducting container and the interaction and coupling of the penetrating fields with internal electronics. Two specific container

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models were used for the evaluation. The first, a conducting cylinder with one open end; the other, the guidance section of a missile. Each of these two configurations was modeled to calculate the electromagnetic field ocupled into the structure.

The following specific questions were addressed during this program:

1. Can the FD-TD method accurately model electromagnetic coupling into a conducting structure for arbitrary angles of incidence and arbitrary wave polarization?

2. Can the FD-TD method accurately model a complex structure with both irregular-shaped apertures and dielectric or permeable materials within the interior?

3. Can the FD-TD method predict the voltage, current, or power that the coupled field may indice on wires or cable bundles inside of a metal structure?

4. What are the size limits of an object that can be modeled using the FD-TD method?

5. What is the capability of the FD-TD method to interface with other analysis techniques, such as "Method of Moments?

Overall, this program showed that the FD-TD method can be successfully applied to electromagnetic coupling problems involving conducting structures with hole and sleeve-type apertures illuminated by a plane wave having an arbitrary polarization and angle of incidence. Further, the FD-TD method can be applied to complex cavity-like structures having internal metal and dielectric materials, as well as connecting wires. Accuracy of the FD-TD results was very good relative to the uncertainties of available experimental and numerical-theory approaches. Convergence of the leectromagnetic fields to the sinusoidal steady state occurred within about 3 cycles of the incident wave when a slight value of isotropic loss was assigned to the interior of the structures modeled. This resulted in program central processor times of less than 5 minutes for FD-TD lattices containing as many as 1.5 million unknowns time-stepped to n_{max} = 800 using the Control Data STAR-100 and Cyber 203 computers.

This program also established the feasibility of a hybrid MOM/FD-TD analysis technique based upon the use of Schelkunoff's equivalent electric current theorem at apertures of a cavity. This hybrid technique was shown to give consistent results for apertures strongly coupled to internal wires or other metal and dielectric structures.

This program has shown that the pure FD-TD and hybrid MOM/FD-TD methods have great promise for applications involving complex conducting and dielectric structures illuminated by plane waves at arbitrary angles of incidence and polarization. Further, great promise is shown for those structures that are simultaneously electrically large compared to a wavelength and penetrated by locally complex cavity-backed apertures having dimensions comparable to a wavelength. Such structures requiring resolution of both large and small details at the same time have not been well treated by any one previous analytical or numerical approach.

PREFACE

IIT Research Institute (IITRI) is pleased to submit this Final Report on "Evaluation of Time Domain Electromagnetic Coupling Techniques" to Rome Air Development Center (RADC/RBCT). The report covers work performed by IITRI under Air Force Contract No. F30602-79-C-0039, designated as IITRI Project No. E6461. The report is in two volumes. Volume 1 covers details of the technical work, including relevant theory and numerical results. Volume 2 provides listings of the Fortran computer programs used to obtain the results of Volume 1.

The principal investigator on this program was Dr. Allen Taflove, with support provided by Dr. Korada Umashankar of IITRI on Task 5; Mr. Neil Robertson of IITRI on data reduction and contour map plotting; and Prof. Donald Wilton and Dr. Allen Glisson of the University of Mississippi on computation of frequency-domain data for checking of results and for Task 5. The project duration was 7 December 1978 to 29 February 1980.

Respectfully submitted,
IIT RESEARCH INSTITUTE

Allen Taflove

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Research Engineer

TABLE OF CONTENTS

VOLUME 2 - LISTINGS OF FORTRAN COMPUTER PROGRAMS

1.0 INTRODUCTION

This volume documents the FD-TD computer programs written during the present research effort. Included are listings of the programs for the following problems:

A. Penetration of a 19.0 cm diameter, 68.5 cm long, open-ended aluminum cylinder by a 300 MHz plane wave at broadside incidence and TE polarization (Section 3.1 of Volume 1);

B. Same as Problem A, but for TM polarization (Section 3.2 of Volume 1);

C. Penetration of a 12.8 cm diameter, 28 cm long, missile guidance section by a 300 MHz plane wave at axial incidence, for the case of the interior dielectric components modeled (Section 4.1 of Volume 1);

D. Same as Problem C, but for the case of the interior dielectric and metal components and wires modeled (Section 4.2 of Volume 1);

E. Hybrid method of moments/FD-TD analysis of penetration of a 19.0 cm diameter, 68.5 cm long, open-ended aluminum cylinder by a 300 MHz plane wave at axial incidence (Section 7.4.1 of Volume 1);

F. Same as Problem E, but for TM polarization of the incident wave at 45° incidence relative to the cylinder axis (Section 7.4.2 of Volume 1);

G. Hybrid method of moments/FD-TD analysis of loaded missile guidance section of Problem D (Section 7.4.3 of Volume 1).

The computer program listings for Problems A and B were run without requiring any data cards, since the descriptions of the cylinder geometries employed are contained within the programs. Program listings for Problems C, D, E, F, and G required data-cards decks of sizes 720 cards, 720 cards, 72 cards, 72 cards, and 528 cards, respectively, to specify the interaction geometry. The data-card format for these programs is summarized in Section 3.1 of this volume. Further, program listings for Problems E, F, and G required data-card decks of sizes 144 cards, 288 cards, and 225 cards, respectively, to specify the aperture excitation for the hybrid method of moments/FD-TD approach. The data-card format for this specification is summarized in Section 3.2 of this volume.

All FD-TD computer programs were written using STAR Fortran Version 2.1 for processing by the Control Data STAR-100 or Cyber 203 computer systems under the 1.2 operating system. This Fortran version contains certain extensions to ANSI standard Fortran [1] that permit usage of the vector processing capabilities of these computers. The reader is referred to the STAR Fortran Manual for detailed discussion of these features [2].

2.0 FD-TD PROGRAM LISTINGS

In each of the programs of this section, FREQ = 3.0 E + 8 denotes the operating frequency, f = 300 MHz; DX denotes the lattice cell size, δ (in meters); MPR denotes the total number of media within the model; DATA EPS and DATA SIG give the assumed relative dielectric constant and conductivity (mhos/m) of each medium; and NMAX gives the number of the last time step of the algorithm.

2.1 Problem A -- Task 1, Case 1 (Section 3.1 of Volume 1)

The following 11 pages list the computer program for the 159 x 64 x 24 cell -- 800 time step run of Problem A. The problem solved is penetration of a 19.0 cm diameter, 68.5 cm long, open-ended aluminum cylinder by a 300 MHz plane wave at broadside incidence and TE polarization.

```
      PROGRAM FDTD(INPUT,OUTPUT,TAPE60=INPUT,TAPE8=TAPE8)
C
C     RUN TASK1-- STEADY 300 MHZ PLANE WAVE IRRADIATION OF A
C                 19.0 CM DIAMETER, 68.5 CM LONG, OPEN-ENDED
C                 ALUMINUM CYLINDER
C     CASE I- TE POLARIZATION OF THE INCIDENT WAVE
C             BROADSIDE INCIDENCE
C             INCIDENT WAVE COMPONENTS EZ AND HX
C     159 X 64 X 24 CELL CUBIC SPACE LATTICE IS USED
C     UNIT CELL DIAMETER = DX = 0.5 CM = WAVELENGTH/200
C     EVEN SYMMETRY ABOUT LATTICE PLANE Z = 24*DX IS ASSUMED
C     SOFT TEM WAVE SOURCE CONDITION IS USED AT PLANE Y = 3.0*DX
C     SOFT LATTICE TRUNCATIONS ARE USED
C     PROGRAM IS OPTIMIZED FOR THE CDC STAR-100
C
      REAL MUR,MUZ
      DIMENSION A(2422500),          A1(3840),A2(3840),AAL(3840),
     1          AAR(3840),          DD(160),AL(24),AR(24),CA(9),
     2          CB(9),EPS(3),SIG(3),           KEXB(19),KEXC(19)
      COMMON A
      DESCRIPTOR D1,D2,D3,D4,NFD,BV,BW,BX,BY,A1X,A2X,A1Y,A2Y,A1Z,
     1           A2Z
      BIT BV,BBB(3840),BW,BBW(3840),BX,BBX(3840),BY,BBY(159)
      ASSIGN A1X,A1(162;3678)
      ASSIGN A2X,A2(162;3678)
      ASSIGN A1Y,A1(161;3679)
      ASSIGN A2Y,A2(161;3679)
      ASSIGN A1Z,A1(1;3839)
      ASSIGN A2Z,A2(1;3839)
      ASSIGN BW,BBW(1;3840)
      ASSIGN BX,BBX(1;3840)
      ASSIGN BY,BBY(1;159)
      ASSIGN D4,DD(1;159)
      T1 = SECOND(CP)
      PRINT 150, T1
  150 FORMAT(F20.5)
C
C           .....I. PROBLEM PARAMETERS.....
      FREQ = 3.0E+8
      DX = 0.005
      MPR = 3
      DATA EPS/1.0,      1.0,      1.0/
      DATA SIG/0.0,    3.7E+7,    0.01/
      NMAX = 800
C
C           .....CYLINDER GEOMETRY DESCRIPTION.....
      DATA KEXB/19,17,15,13,12,11,10,9,9,8,8,7,7,7,6,6,6,6,6/
      DATA KEXC/25,19,17,15,13,12,11,10,9,9,8,8,7,7,7,6,6,6,6/
C
C           .....II. BASIC AND DERIVED CONSTANTS.....
      PI = 3.14159265
      MUZ = 4.0 * PI * 1.0E-7
      EPSZ = 8.854E-12
```

```
      DT = DX / 6.0E+8
      NHALF = 0.5 / FREQ / DT
      R = DT / 2.0 / EPSZ
      RA = DT**2 / DX**2 / MUZ / EPSZ
      RB = DT / DX / MUZ
      RC = 1.0E+4 / RB
      RD = 2.0 * PI * FREQ * DT
      IPUN = 0
C
      A1(1;3840) = 0.
      A2(1;3840) = 0.
      CA(1;9) = 0.
      CB(1;9) = 0.
      BW = Q8VMKO(1,160;BW)
      BX = Q8VMKZ(159,160;BX)
      DO 2 I=1,MPR
      EAF = R * SIG(I) / EPS(I)
      CA(I) = (1.0-EAF) / (1.0+EAF)
    2 CB(I) = RA / EPS(I) / (1.0+EAF)
C
C             .....III. LOAD VECTOR A.....
C             .....ZERO INITIAL FIELDS.....
      DO 3 I=1,65
      IDEL = (I-1) * 36900
    3 A(IDEL+1;36900) = 0.
      A(2398501;24000) = 0.
C
C             .....TYPE OF MEDIUM.....
C             .....ANISOTROPIC LOSSY AIR.....
      DO 4 I=2,64
      IDEL = (I-1) * 36900
      A(IDEL+1;3840) = 3.
      A(IDEL+8161;3840) = 3.
    4 A(IDEL+16321;3840) = 1.
C
C             .....BROADSIDE CIRCULAR CYLINDER.....
      DO 14 I=15,33
      IDEL = (I-1) * 36900
      KB = KEXB(I-14)
      KC = KEXC(I-14)
      DO 7 K=KB,KC
    7 A(IDEL+12+(K-1)*160;137) = 2.
C
      A(IDEL+8171+(KB-1)*160;138) = 2.
      DO 10 K=KB,24
   10 A(IDEL+8308+(K-1)*160) = 2.
C
      KC = KEXC(I-14) - 1
      DO 12 K=KB,KC
   12 A(IDEL+16331+(K-1)*160;138) = 2.
      KD = KC + 1
      DO 13 K=KD,24
      A(IDEL+16331+(K-1)*160;137) = 3.
```

```
   13 A(IDEL+16468+(K-1)*160) = 2.
C
      IA = 67 - I
      IDELA = (IA-1) * 36900
      A(IDELA+1;3840) = A(IDEL+1;3840)
      A(IDELA+16321;3840) = A(IDEL+16321;3840)
      IB = 66 - I
      IDELB = (IB-1) * 36900
   14 A(IDELB+8161;3840) = A(IDEL+8161;3840)
C
      T2 = SECOND(CP)
      PRINT 150,T2
C
C           .....IV. TIME-STEPPING LOOP.....
      DO 200 N=1,NMAX
      TERM = SIN(FLOAT(N)*RD) * RB
      MCALL = 3 + IFIX(FLOAT(N)/6.0)
      IF(MCALL.GT.21)MCALL=21
C
C           .....TRANSVERSE PLANE NO. 1.....
C           .....EX, EZ TRUNCATIONS.....
      A(4001;4000) = A(1;4000)
      A(1;4000) = A(40901;4000)
      A(20321;4000) = A(16321;4000)
      A(16321;4000) = A(57221;4000)
C
C           .....EY ITERATION.....
      ASSIGN D1,.DYN.3679
      ASSIGN D2,.DYN.3679
      ASSIGN D3,.DYN.3679
      A(12161) = 0.5 * (A(16161)+A(16162))
      A(12162;157) = 0.333 * (A(16161;157)+A(16162;157)
     1                                     +A(16163;157))
      A(12319) = 0.5 * (A(16318)+A(16319))
      A(16161;159) = A(12321;159)
      D1 = CA(3) * A(12321;3679)
      D2 = A(24641;3679) - A(24481;3679) + A(33011;3679)
     1                                   - A(33012;3679)
      D3 = CB(3) * D2
      A(12321;3679) = D1 + D3
      FREE
C
C           .....TRANSVERSE PLANES 2-64.....
      DO 82 JY=1,MCALL
      JDEL = (JY-1) * 110700
C
C           .....EX ITERATION.....
      ASSIGN D1,.DYN.3678
      ASSIGN D2,.DYN.3678
      ASSIGN D3,.DYN.3678
      ASSIGN NFD,.DYN.3678
      ASSIGN BV,BBB(1;3678)
C
```

```
      DO 30 MA=1,3
      M = JDEL + 36900*(MA-1)
C
C           .....SOFT LATTICE TRUNCATION.....
      A(40902+M) = 0.5 * (A(44902+M)+A(44903+M))
      A(40903+M;156) = 0.333 * (A(44902+M;156)+A(44903+M;156)
     1                                        +A(44904+M;156))
      A(41059+M) = 0.5 * (A(45058+M)+A(45059+M))
      A(44902+M;158) = A(41062+M;158)
C
C           .....MAIN EX LOOPS.....
      NFD = A(37062+M;3678)
      DO 22 JJ=1,MPR
      BV = NFD.EQ.JJ
      A1X = Q8VCTRL(CA(JJ),BV;A1X)
   22 A2X = Q8VCTRL(CB(JJ),BV;A2X)
      D1 = A1X * A(41062+M;3678)
      D2 = A(69912+M;3678) - A(33012+M;3678) + A(65542+M;3678)
     1                                       - A(65702+M;3678)
      D3 = A2X * D2
   30 A(41062+M;3678) = D1 + D3
      FREE
C
C           .....EY ITERATION.....
      ASSIGN D1,.DYN.3679
      ASSIGN D2,.DYN.3679
      ASSIGN D3,.DYN.3679
      ASSIGN NFD,.DYN.3679
      ASSIGN BV,BBB(1;3679)
C
      DO 40 MA=1,3
      M = JDEL + 36900*(MA-1)
C
C           .....SOFT LATTICE TRUNCATION.....
      A(49061+M) = 0.5 * (A(53061+M)+A(53062+M))
      A(49062+M;157) = 0.333 * (A(53061+M;157)+A(53062+M;157)
     1                                        +A(53063+M;157))
      A(49219+M) = 0.5 * (A(53218+M)+A(53219+M))
      A(53061+M;159) = A(49221+M;159)
C
C           .....MAIN EY LOOPS.....
      NFD = A(45221+M;3679)
      DO 32 JJ=1,MPR
      BV = NFD.EQ.JJ
      A1Y = Q8VCTRL(CA(JJ),BV;A1Y)
   32 A2Y = Q8VCTRL(CB(JJ),BV;A2Y)
      D1 = A1Y * A(49221+M;3679)
      D2 = A(61541+M;3679) - A(61381+M;3679) + A(69911+M;3679)
     1                                       - A(69912+M;3679)
      D3 = A2Y * D2
   40 A(49221+M;3679) = D1 + D3
      FREE
C
```

```
C            .....EZ ITERATION.....
      ASSIGN D1,.DYN.3839
      ASSIGN D2,.DYN.3839
      ASSIGN D3,.DYN.3839
      ASSIGN NFD,.DYN.3839
      ASSIGN BV,BBB(1;3839)
C
      DO 50 MA=1,3
      M = JDEL + 36900*(MA-1)
C
C            .....MAIN EZ LOOPS.....
      NFD = A(53221+M;3839)
      DO 42 JJ=1,MPR
      BV = NFD.EQ.JJ
      A1Z = Q8VCTRL(CA(JJ),BV;A1Z)
   42 A2Z = Q8VCTRL(CB(JJ),BV;A2Z)
      D1 = A1Z * A(57221+M;3839)
      D2 = A(65542+M;3839) - A(65541+M;3839) + A(24481+M;3839)
     1                                       - A(61381+M;3839)
      D3 = A2Z * D2
      A(57221+M;3839) = D1 + D3
C
C            .....EZ SOFT TEM WAVE SOURCE CONDITION.....
      IF(JY.GE.2.OR.MA.LE.2)GO TO 47
      A(131021;3839) = TERM + A(131021;3839)
C
C            .....EZ HOR. PLANE ENVELOPE COMPUTATION.....
   47 D4 = VABS(A(60901+M;159);D4)
      BY = D4.GT.A(61221+M;159)
   50 A(61221+M;159) = Q8VCTRL(D4,BY;A(61221+M;159))
C
C            .....HX ITERATION.....
      DO 60 MA=1,3
      M = JDEL + 36900*(MA-1)
C
C            .....MAIN HX LOOPS.....
      D1 = A(24481+M;3839)
      D2 = A(12321+M;3839) - A(12161+M;3839) + A(20321+M;3839)
     1                                       - A(57221+M;3839)
      A(24481+M;3839) = D1 + D2
C
C            .....HX HOR. PLANE ENVELOPE COMPUTATION.....
      D4 = VABS(A(28161+M;159);D4)
      BY = D4.GT.A(28481+M;159)
   60 A(28481+M;159) = Q8VCTRL(D4,BY;A(28481+M;159))
      FREE
C
C            .....HY ITERATION.....
      ASSIGN D1,.DYN.3838
      ASSIGN D2,.DYN.3838
C
      DO 70 MA=1,3
      M = JDEL + 36900*(MA-1)
```

```
C
C          .....SOFT LATTICE TRUNCATIONS.....
C          .....LEFT TRUNCATION.....
      AL(1) = 0.5 * (A(69541+M)+A(69542+M))
      AL(2;22) = 0.333 * (A(69541+M;22)+A(69542+M;22)
     1                          +A(69543+M;22))
      AL(24) = 0.333 * (A(69563+M)+2.0*A(69564+M))
      AAL(1;3840) = Q8VXPND(AL(1;24),BW;AAL(1;3840))
      A(69541+M;24) = Q8VCMPRS(A(65542+M;3840),BW;A(69541+M;24))
C
C          .....RIGHT TRUNCATION.....
      AR(1) = 0.5 * (A(69566+M)+A(69567+M))
      AR(2;22) = 0.333 * (A(69566+M;22)+A(69567+M;22)
     1                          +A(69568+M;22))
      AR(24) = 0.333 * (A(69588+M)+2.0*A(69589+M))
      AAR(1;3840) = Q8VXPND(AR(1;24),BX;AAR(1;3840))
      A(69566+M;24) = Q8VCMPRS(A(65540+M;3840),BX;A(69566+M;24))
C
C          .....MAIN HY LOOPS.....
      D1 = A(65542+M;3838)
      D2 = A(57222+M;3838) - A(57221+M;3838) + A(40902+M;3838)
     1                                       - A(41062+M;3838)
      A(65542+M;3838) = D1 + D2
C
      A(65541+M;3840) = Q8VCTRL(AAL(1;3840),BW;A(65541+M;3840))
      A(65541+M;3840) = Q8VCTRL(AAR(1;3840),BX;A(65541+M;3840))
C
C          .....HY HOR. PLANE ENVELOPE COMPUTATION.....
      D4 = VABS(A(69221+M;159);D4)
      BY = D4.GT.A(69591+M;159)
   70 A(69591+M;159) = Q8VCTRL(D4,BY;A(69591+M;159))
      FREE
C
C          .....HZ ITERATION.....
      ASSIGN D1,.DYN.3678
      ASSIGN D2,.DYN.3678
C
      DO 80 MA=1,3
      M = JDEL + 36900*(MA-1)
C
C          .....SOFT LATTICE TRUNCATIONS.....
C          .....LEFT TRUNCATION.....
      AL(2) = 0.5 * (A(36852+M)+A(36853+M))
      AL(3;21) = 0.333 * (A(36852+M;21)+A(36853+M;21)
     1                          +A(36854+M;21))
      AL(24) = 0.5 * (A(36873+M)+A(36874+M))
      AAL(1;3840) = Q8VXPND(AL(1;24),BW;AAL(1;3840))
      A(36851+M;24) = Q8VCMPRS(A(32852+M;3840),BW;A(36851+M;24))
C
C          .....RIGHT TRUNCATION.....
      AR(2) = 0.5 * (A(36877+M)+A(36878+M))
      AR(3;21) = 0.333 * (A(36877+M;21)+A(36878+M;21)
     1                          +A(36879+M;21))
```

```
      AR(24) = 0.5 * (A(36898+M)+A(36899+M))
      AAR(1;3840) = Q8VXPND(AR(1;24),BX;AAR(1;3840))
      A(36876+M;24) = Q8VCMPRS(A(32850+M;3840),BX;A(36876+M;24))
C
C          .....MAIN HZ LOOPS.....
      D1 = A(33012+M;3678)
      D2 = A(41062+M;3678) - A(4162+M;3678) + A(12321+M;3678)
     1                                     - A(12322+M;3678)
      A(33012+M;3678) = D1 + D2
C
      A(32851+M;3840) = Q8VCTRL(AAL(1;3840),BW;A(32851+M;3840))
   80 A(32851+M;3840) = Q8VCTRL(AAR(1;3840),BX;A(32851+M;3840))
      FREE
   82 CONTINUE
      IF(MCALL.LE.20)GO TO 94
C
C          .....TRANSVERSE PLANE NO. 65.....
      M = 63 * 36900
C
C          .....EX, EZ TRUNCATIONS.....
      A(40901+M;4000) = A(36901+M;4000)
      A(36901+M;4000) = A(45061+M;4000)
      A(45061+M;4000) = A(4001+M;4000)
C
      A(57221+M;4000) = A(53221+M;4000)
      A(53221+M;4000) = A(61381+M;4000)
      A(61381+M;4000) = A(20321+M;4000)
C
C          .....HX ITERATION.....
      ASSIGN D1,.DYN.3839
      ASSIGN D2,.DYN.3839
      D1 = A(24481+M;3839)
      D2 = A(12321+M;3839) - A(12161+M;3839) + A(20321+M;3839)
     1                                       - A(57221+M;3839)
      A(24481+M;3839) = D1 + D2
      D4 = VABS(A(28161+M;159);D4)
      BY = D4.GT.A(28481+M;159)
      A(28481+M;159) = Q8VCTRL(D4,BY;A(28481+M;159))
      FREE
C
C          .....HZ ITERATION.....
      ASSIGN D1,.DYN.3678
      ASSIGN D2,.DYN.3678
      AL(2) = 0.5 * (A(36852+M)+A(36853+M))
      AL(3;21) = 0.333 * (A(36852+M;21)+A(36853+M;21)
     1                               +A(36854+M;21))
      AL(24) = 0.5 * (A(36873+M)+A(36874+M))
      AAL(1;3840) = Q8VXPND(AL(1;24),BW;AAL(1;3840))
      A(36851+M;24) = Q8VCMPRS(A(32852+M;3840),BW;A(36851+M;24))
      AR(2) = 0.5 * (A(36877+M)+A(36878+M))
      AR(3;21) = 0.333 * (A(36877+M;21)+A(36878+M;21)
     1                               +A(36879+M;21))
```

```
      AR(24) = 0.5 * (A(36898+M)+A(36899+M))
      AAR(1;3840) = Q8VXPND(AR(1;24),BX;AAR(1;3840))
      A(36876+M;24) = Q8VCMPRS(A(32850+M;3840),BX;A(36876+M;24))
      D1 = A(33012+M;3678)
      D2 = A(41062+M;3678) - A(4162+M;3678) + A(12321+M;3678)
     1                                      - A(12322+M;3678)
      A(33012+M;3678) = D1 + D2
      A(32851+M;3840) = Q8VCTRL(AAL(1;3840),BW;A(32851+M;3840))
      A(32851+M;3840) = Q8VCTRL(AAR(1;3840),BX;A(32851+M;3840))
      FREE
C
C           .....VERT. PLANE ENVELOPE COMPUTATION.....
   94 ASSIGN D1,.DYN.3840
      ASSIGN D2,.DYN.3840
      ASSIGN BV,BBB(1;3840)
      M = 32 * 36900
      MZ = 65 * 36900
C
C           .....EX ENVELOPE.....
      D1 = 0.5 * (A(4001+M;3840)+A(40901+M;3840))
      D2 = VABS(D1;D2)
      BV = D2.GT.A(MZ+1;3840)
      A(MZ+1;3840) = Q8VCTRL(D2,BV;A(MZ+1;3840))
C
C           .....EY ENVELOPE.....
      D2 = VABS(A(12161+M;3840);D2)
      BV = D2.GT.A(MZ+4001;3840)
      A(MZ+4001;3840) = Q8VCTRL(D2,BV;A(MZ+4001;3840))
C
C           .....EZ ENVELOPE.....
      D1 = 0.5 * (A(20321+M;3840)+A(57221+M;3840))
      D2 = VABS(D1;D2)
      BV = D2.GT.A(MZ+8001;3840)
      A(MZ+8001;3840) = Q8VCTRL(D2,BV;A(MZ+8001;3840))
C
C           .....HX ENVELOPE.....
      D2 = VABS(A(24481+M;3840);D2)
      BV = D2.GT.A(MZ+12001;3840)
      A(MZ+12001;3840) = Q8VCTRL(D2,BV;A(MZ+12001;3840))
C
C           .....HY ENVELOPE.....
      D1 = 0.5 * (A(28641+M;3840)+A(65541+M;3840))
      D2 = VABS(D1;D2)
      BV = D2.GT.A(MZ+16001;3840)
      A(MZ+16001;3840) = Q8VCTRL(D2,BV;A(MZ+16001;3840))
C
C           .....HZ ENVELOPE.....
      D2 = VABS(A(32851+M;3840);D2)
      BV = D2.GT.A(MZ+20001;3840)
      A(MZ+20001;3840) = Q8VCTRL(D2,BV;A(MZ+20001;3840))
      FREE
      T3 = SECOND(CP)
      PRINT 150, T3
```

```
C
C            .....FIELD ENVELOPE PRINTOUT ROUTINE.....
      DO 100 L=NHALF,NMAX,NHALF
      IF(N.EQ.L)GO TO 101
  100 CONTINUE
      IF(N.EQ.NMAX)GO TO 101
      GO TO 199
C
C            .....AT HORIZONTAL SYMMETRY PLANE.....
  101 IF(N.EQ.NMAX)IPUN=1
      PRINT 102, N
  102 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
     1           //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENVH(24321,RC,IPUN)
C
      PRINT 103, N
  103 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
     1           //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENVH(28481,3.77E+6,IPUN)
C
      PRINT 104, N
  104 FORMAT(1H1,52X,27HHY ENVELOPE FOR TIME STEP =,I5,
     1           //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENVH(32691,3.77E+6,IPUN)
C
C            .....AT VERTICAL SYMMETRY PLANE.....
      PRINT 105, N
  105 FORMAT(1H1,52X,27HEX ENVELOPE FOR TIME STEP =,I5,
     1           //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(1,RC,IPUN)
C
      PRINT 106, N
  106 FORMAT(1H1,52X,27HEY ENVELOPE FOR TIME STEP =,I5,
     1           //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(4001,RC,IPUN)
C
      PRINT 107, N
  107 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
     1           //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(8001,RC,IPUN)
C
      PRINT 108, N
  108 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
     1           //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(12001,3.77E+6,IPUN)
C
      PRINT 109, N
  109 FORMAT(1H1,52X,27HHY ENVELOPE FOR TIME STEP =,I5,
     1           //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(16001,3.77E+6,IPUN)
C
      PRINT 110, N
```

```
  110 FORMAT(1H1,52X,27HHZ ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(20001,3.77E+6,IPUN)
C
  199 CONTINUE
  200 CONTINUE
      T4 = SECOND(CP)
      PRINT 150, T4
      STOP
      END

      SUBROUTINE ENVH(LOCA,SCALE,IPUNCH)
      DIMENSION A(2422500),IP(10240),NN(160)
      COMMON A
C
      DO 9 I=1,160
    9 NN(I) = I
C
      DO 1 LY=2,64
      LOC = LOCA + (LY-1)*36900
      LOCI = 1 + (LY-1)*160
      IP(LOCI;160) = SCALE * A(LOC;160)
    1 A(LOC;160) = 0.
C
      IF(IPUNCH.EQ.0)GO TO 4
      DO 2 LY=15,52
      LOCI = 1 + (LY-1)*160
      LOCII = LOCI + 158
    2 WRITE(8,3)  (IP(LL),LL=LOCI,LOCII)
    3 FORMAT(16I5)
C
    4 DO 7 LX=1,6
      LXA = 5 + (LX-1)*25
      LXB = LXA + 24
      DO 5 LY=2,64
      LYY = 66 - LY
      LOCI = LXA + (LYY-1)*160
      LOCII = LOCI + 24
    5 PRINT 6, LYY, (IP(LL),LL=LOCI,LOCII)
    6 FORMAT(1X,I2,2X,25I5)
    7 PRINT 8, (NN(LL),LL=LXA,LXB)
    8 FORMAT(//,4X,25I5,////)
C
      RETURN
      END

      SUBROUTINE ENVV(LOCZ,SCALE,IPUNCH)
      DIMENSION A(2422500),NN(160),IPR(25),IPP(160)
      COMMON A
C
      DO 8 I=1,160
    8 NN(I) = I
```

```
      LMN = LOCZ + 65*36900
C
      IF(IPUNCH.EQ.0)GO TO 3
      DO 1 LZ=1,24
      LOC = LMN + (LZ-1)*160
      IPP(1;159) = SCALE * A(LOC;159)
    1 WRITE(8,2) (IPP(LL),LL=1,159)
    2 FORMAT(16I5)
C
    3 DO 6 LX=1,6
      LXA = 5 + (LX-1)*25
      LXB = LXA + 24
      DO 4 LZ=1,24
      LZZ = 25 - LZ
      LOC = LMN + (LZZ-1)*160 + LXA-1
      IPR(1;25) = SCALE * A(LOC;25)
    4 PRINT 5, LZZ, (IPR(LL),LL=1,25)
    5 FORMAT(1X,I2,2X,25I5)
    6 PRINT 7, (NN(LL),LL=LXA,LXB)
    7 FORMAT(//,4X,25I5,////)
C
      A(LMN;3840) = 0.
      RETURN
      END
```

2.2 Problem B -- Task 1, Case 2 (Section 3.2 of Volume 1)

The following 11 pages list the computer program for the 159 x 64 x 24 cell -- 800 time step run of Problem B. The problem solved is penetration of a 19.0 cm diameter, 68.5 cm long, open-ended aluminum cylinder by a 300 MHz plane wave at broadside incidence and TM polarization.

```
      PROGRAM FDTD(INPUT,OUTPUT,TAPE60=INPUT,TAPE8=TAPE8)
C
C     RUN TASK1-- STEADY 300 MHZ PLANE WAVE IRRADIATION OF A
C                 19.0 CM DIAMETER, 68.5 CM LONG, OPEN-ENDED
C                 ALUMINUM CYLINDER
C     CASE II- TM POLARIZATION OF THE INCIDENT WAVE
C              BROADSIDE INCIDENCE
C              INCIDENT WAVE COMPONENTS HZ AND EX
C     159 X 64 X 24 CELL CUBIC SPACE LATTICE IS USED
C     UNIT CELL DIAMETER = DX = 0.5 CM = WAVELENGTH/200
C     EVEN SYMMETRY ABOUT LATTICE PLANE Z = 24.5*DX IS ASSUMED
C     SOFT TEM WAVE SOURCE CONDITION IS USED AT PLANE Y = 3.5*DX
C     SOFT LATTICE TRUNCATIONS ARE USED
C     PROGRAM IS OPTIMIZED FOR THE CDC STAR-100
C
      REAL MUR,MUZ
      DIMENSION A(2422500),CEXB(245760),CEYB(245760),CEZB(245760),
     1          DD(160),MO(24),AL(24),AR(24),CA(9),
     2          CB(9),EPS(3),SIG(3),          KEXB(19),KEXC(19)
      COMMON    A,CEXB,CEYB,CEZB
      DESCRIPTOR D1,D2,D3,D4,NFD,BV,BY,A1,A2
      BIT BV,BBB(3840),BY,BBY(159)
      ASSIGN BV,BBB(1;3840)
      ASSIGN BY,BBY(1;159)
      ASSIGN D4,DD(1;159)
      T1 = SECOND(CP)
      PRINT 150, T1
  150 FORMAT(F20.5)
C
C         .....I. PROBLEM PARAMETERS.....
      FREQ = 3.0E+8
      DX = 0.005
      MPP = 3
      DATA EPS/1.0,     1.0,     1.0/
      DATA SIG/0.0,   3.7E+7,   0.01/
      NMAX = 800
C
C         .....CYLINDER GEOMETRY DESCRIPTION.....
      DATA KEXB/19,16,14,13,12,11,10,9,8,8,7,7,7,6,6,6,6,6,6/
      DATA KEXC/24,19,16,14,13,12,11,10,9,8,8,7,7,7,6,6,6,6,6/
C
C         .....II. BASIC AND DERIVED CONSTANTS.....
      PI = 3.14159265
      MUZ = 4.0 * PI * 1.0E-7
      EPSZ = 8.854E-12
      DT = DX / 6.0E+8
      NHALF = 0.5 / FREQ / DT
      R = DT / 2.0 / EPSZ
      RA = DT**2 / DX**2 / MUZ / EPSZ
      RB = DT / DX / MUZ
      RC = 1.0E+4 / RB / 377.0
      RD = 2.0 * PI * FREQ * DT
      IPUN = 0
```

```
C
      CA(1:9) = 0.
      CB(1:9) = 0.
      DO 1 KK=1,24
    1 MQ(KK) = 160 * (KK-1)
      DO 2 I=1,MPR
      EAF = P * SIG(I) / EPS(I)
      CA(I) = (1.0-EAF) / (1.0+EAF)
    2 CB(I) = RA / EPS(I) / (1.0+EAF)
C
C           .....III. LOAD VECTOR A.....
C           .....ZERO INITIAL FIELDS.....
      DO 3 I=1,65
      IDEL = (I-1) * 36900
    3 A(IDEL+1:36900) = 0.
      A(2398501:24000) = 0.
C
C           .....TYPE OF MEDIUM.....
C           .....ANISOTROPIC LOSSY AIR.....
      DO 4 I=1,64
      IDEL = (I-1) * 36900
      A(IDEL+1:3840) = 1.
      A(IDEL+8161:3840) = 3.
    4 A(IDEL+16321:3840) = 3.
C
C           .....BROADSIDE CIRCULAR CYLINDER.....
      DO 14 I=15,33
      IDEL = (I-1) * 36900
      IDEM = I*36900
      KB = KEXB(I-14)
      KC = KEXC(I-14)
      DO 7 K=KB,KC
    7 A(IDEL+11+(K-1)*160:137) = 2.
      KD = KC + 1
      DO 8 K=KD,24
    8 A(IDEL+11+(K-1)*160:137) = 3.
C
      A(IDEM+8171+(KB-1)*160:138) = 2.
      DO 10 K=KB,24
   10 A(IDEM+8308+(K-1)*160) = 2.
C
      KB = KEXB(I-14) + 1
      IF(KB.GT.KC)GO TO 9
      DO 12 K=KB,KC
   12 A(IDEL+16331+(K-1)*160:138) = 2.
    9 DO 13 K=KB,24
   13 A(IDEL+16468+(K-1)*160) = 2.
C
      IA = 67 - I
      IDELA = (IA-1) * 36900
      A(IDELA+1:3840) = A(IDEL+1:3840)
      A(IDELA+16321:3840) = A(IDEL+16321:3840)
   14 A(IDELA+8161:3840) = A(IDEM+8161:3840)
```

```
C
C         .....MEDIA COEFFICIENTS.....
      ASSIGN A1,.DYN.3840
      ASSIGN A2,.DYN.3840
      ASSIGN NFD,.DYN.3840
      A1 = 0.
      A2 = 0.
      DO 23 I=1,64
      IDEL = (I-1) * 36900
      IDEM = (I-1) * 3840
C
      NFD = A(IDEL+1;3840)
      DO 20 JJ=1,MPR
      BV = NFD.EQ.JJ
      A1 = Q8VCTRL(CA(JJ),BV;A1)
   20 A2 = Q8VCTRL(CB(JJ),BV;A2)
      A(IDEL+1;3840) = A1
      CEXB(IDEM+1;3840) = A2
C
      NFD = A(IDEL+8161;3840)
      DO 21 JJ=1,MPR
      BV = NFD.EQ.JJ
      A1 = Q8VCTRL(CA(JJ),BV;A1)
   21 A2 = Q8VCTRL(CB(JJ),BV;A2)
      A(IDEL+8161;3840) = A1
      CEYB(IDEM+1;3840) = A2
C
      NFD = A(IDEL+16321;3840)
      DO 22 JJ=1,MPR
      BV = NFD.EQ.JJ
      A1 = Q8VCTRL(CA(JJ),BV;A1)
   22 A2 = Q8VCTRL(CB(JJ),BV;A2)
      A(IDEL+16321;3840) = A1
   23 CEZB(IDEM+1;3840) = A2
      FREE
      A(8161;3840) = 0.
C
      T2 = SECOND(CP)
      PRINT 150,T2
C
C         .....IV. TIME-STEPPING LOOP.....
      DO 200 N=1,NMAX
      TERM = SIN(FLOAT(N)*RD)
      MCALL = 3 + IFIX(FLOAT(N)/6.0)
      IF(MCALL.GT.21)MCALL=21
C
C         .....TRANSVERSE PLANE NO. 1.....
C         .....HX, HZ TRUNCATIONS.....
      A(4001;4000) = A(8161;4000)
      A(8161;4000) = A(4090l;4000)
      A(20321;4000) = A(28641;4000)
      A(28641;4000) = A(57221;4000)
C
```

```
C          .....HY ITERATION.....
      ASSIGN D1,.DYN.3679
      ASSIGN D2,.DYN.3679
      A(12161) = 0.5 * (A(16161)+A(16162))
      A(12162;157) = 0.333 * (A(16161;157)+A(16162;157)
     1                                 +A(16163;157))
      A(12319) = 0.5 * (A(16318)+A(16319))
      A(16161;159) = A(12321;159)
      D1 =           A(12321;3679)
      D2 = A(24641;3679) - A(24481;3679) + A(33011;3679)
     1                               - A(33012;3679)
      A(12321;3679) = D1 - D2
      FREE
C
C          .....TRANSVERSE PLANES 2-64.....
      DO 82 JY=1,MCALL
      JDEL = (JY-1) * 110700
      JDEM = (JY-1) * 11520
C
C          .....HX ITERATION.....
      ASSIGN D1,.DYN.3678
      ASSIGN D2,.DYN.3678
C
      DO 30 MA=1,3
      M = JDEL + 36900*(MA-1)
C
C          .....SOFT LATTICE TRUNCATION.....
      A(40902+M) = 0.5 * (A(44902+M)+A(44903+M))
      A(40903+M;156) = 0.333 * (A(44902+M;156)+A(44903+M;156)
     1                                 +A(44904+M;156))
      A(41059+M) = 0.5 * (A(45058+M)+A(45059+M))
      A(44902+M;158) = A(41062+M;158)
C
C          .....MAIN HX LOOPS.....
      D1 =        A(41062+M;3678)
      D2 = A(69912+M;3678) - A(33012+M;3678) + A(65542+M;3678)
     1                                 - A(65702+M;3678)
   30 A(41062+M;3678) = D1 - D2
      FREE
C
C          .....HY ITERATION.....
      ASSIGN D1,.DYN.3679
      ASSIGN D2,.DYN.3679
C
      DO 40 MA=1,3
      M = JDEL + 36900*(MA-1)
C
C          .....SOFT LATTICE TRUNCATION.....
      A(49061+M) = 0.5 * (A(53061+M)+A(53062+M))
      A(49062+M;157) = 0.333 * (A(53061+M;157)+A(53062+M;157)
     1                                 +A(53063+M;157))
      A(49219+M) = 0.5 * (A(53218+M)+A(53219+M))
      A(53061+M;159) = A(49221+M;159)
```

```
C
C          .....MAIN HY LOOPS.....
      D1 =        A(49221+M$3679)
      D2 = A(61541+M$3679) - A(61381+M$3679) + A(69911+M$3679)
     1                                       - A(69912+M$3679)
   40 A(49221+M$3679) = D1 - D2
      FREE
C
C          .....HZ ITERATION.....
      ASSIGN D1..DYN.3839
      ASSIGN D2..DYN.3839
C
      DO 50 MA=1,3
      M = JDEL + 36900*(MA-1)
C
C          .....MAIN HZ LOOPS.....
      D1 =        A(57221+M$3839)
      D2 = A(65542+M$3839) - A(65541+M$3839) + A(24481+M$3839)
     1                                       - A(61381+M$3839)
      A(57221+M$3839) = D1 - D2
C
C          .....HZ SOFT TEM WAVE SOURCE CONDITION.....
      IF(JY.GE.2.OR.MA.LE.2)GO TO 47
      A(131021$3839) = TERM + A(131021$3839)
C
C          .....HZ HOR. PLANE ENVELOPE COMPUTATION.....
   47 D4 = VABS(A(60901+M$159)$D4)
      BY = D4.GT.A(61221+M$159)
   50 A(61221+M$159) = Q8VCTRL(D4,BY$A(61221+M$159))
C
C          .....EX ITERATION.....
      ASSIGN D3..DYN.3839
C
      DO 60 MA=1,3
      M = JDEL + 36900*(MA-1)
      MM = JDEM + 3840*(MA-1)
C
C          .....MAIN EX LOOPS.....
      D1 = A(24481+M$3839) * A(1+M$3839)
      D2 = A(12321+M$3839) - A(12161+M$3839) + A(20321+M$3839)
     1                                       - A(57221+M$3839)
      D3 = CEXB(1+MM$3839) * D2
      A(24481+M$3839) = D1 - D3
C
C          .....EX HOR. PLANE ENVELOPE COMPUTATION.....
      D4 = VABS(A(28161+M$159)$D4)
      BY = D4.GT.A(28481+M$159)
   60 A(28481+M$159) = Q8VCTRL(D4,BY$A(28481+M$159))
      FREE
C
C          .....EY ITERATION.....
      ASSIGN D1..DYN.3838
      ASSIGN D2..DYN.3838
```

```
      ASSIGN D3..DYN.3838
C
      DO 70 MA=1,3
      M = JDEL + 36900*(MA-1)
      MM = JDEM + 3840*(MA-1)
C
C           .....SOFT LATTICE TRUNCATIONS.....
C           .....LEFT TRUNCATION.....
      AL(1) = 0.5 * (A(69541+M)+A(69542+M))
      AL(2;22) = 0.333 * (A(69541+M;22)+A(69542+M;22)
     1                             +A(69543+M;22))
      AL(24) = 0.333 * (A(69563+M)+2.0*A(69564+M))
C
C           .....RIGHT TRUNCATION.....
      AR(1) = 0.5 * (A(69566+M)+A(69567+M))
      AR(2;22) = 0.333 * (A(69566+M;22)+A(69567+M;22)
     1                             +A(69568+M;22))
      AR(24) = 0.333 * (A(69588+M)+2.0*A(69589+M))
C
      DO 61 KK=1,24
      MLE = M + KK
      MRI = M + MQ(KK)
      A(69540+MLE) = A(65542+MRI)
   61 A(69565+MLE) = A(65699+MRI)
C
C           .....MAIN EY LOOPS.....
      D1 = A(65542+M;3838) * A(45062+M;3838)
      D2 = A(57222+M;3838) - A(57221+M;3838) + A(40902+M;3838)
     1                                        - A(41062+M;3838)
      D3 = CEYB(3842+MM;3838) * D2
      A(65542+M;3838) = D1 - D3
C
      DO 69 KK=1,24
      MLE = M + MQ(KK)
      A(65541+MLE) = AL(KK)
   69 A(65700+MLE) = AR(KK)
C
C           .....EY HOR. PLANE ENVELOPE COMPUTATION.....
      D4 = VABS(A(69221+M;159);D4)
      BY = D4.GT.A(69591+M;159)
   70 A(69591+M;159) = Q8VCTRL(D4,BY;A(69591+M;159))
      FREE
C
C           .....EZ ITERATION.....
      ASSIGN D1..DYN.3678
      ASSIGN D2..DYN.3678
      ASSIGN D3..DYN.3678
C
      DO 80 MA=1,3
      M = JDEL + 36900*(MA-1)
      MM = JDEM + 3840*(MA-1)
C
C           .....SOFT LATTICE TRUNCATIONS.....
```

```
C          .....LEFT TRUNCATION.....
      AL(2) = 0.5 * (A(36852+M)+A(36853+M))
      AL(3;21) = 0.333 * (A(36852+M;21)+A(36853+M;21)
     1                                  +A(36854+M;21))
      AL(24) = 0.5 * (A(36873+M)+A(36874+M))
C
C          .....RIGHT TRUNCATION.....
      AR(2) = 0.5 * (A(36877+M)+A(36878+M))
      AR(3;21) = 0.333 * (A(36877+M;21)+A(36878+M;21)
     1                                  +A(36879+M;21))
      AR(24) = 0.5 * (A(36898+M)+A(36899+M))
C
      DO 71 KK=1,24
      MLE = M + KK
      MRI = M + MQ(KK)
      A(36850+MLE) = A(32852+MRI)
   71 A(36875+MLE) = A(33009+MRI)
C
C          .....MAIN EZ LOOPS.....
      D1 = A(33012+M;3678) * A(16482+M;3678)
      D2 = A(41062+M;3678) - A(4162+M;3678) + A(12321+M;3678)
     1                                      - A(12322+M;3678)
      D3 = CEZB(162+MM;3678) * D2
      A(33012+M;3678) = D1 - D3
C
      DO 80 KK=1,24
      MLE = M + MQ(KK)
      A(32851+MLE) = AL(KK)
   80 A(33010+MLE) = AR(KK)
      FREE
   82 CONTINUE
      IF(MCALL.LE.20)GO TO 94
C
C     .....TRANSVERSE PLANE NO. 65.....
      M = 63 * 36900
C
C          .....HX, HZ TRUNCATIONS.....
      A(40901+M;4000) = A(36901+M;4000)
      A(36901+M;4000) = A(45061+M;4000)
      A(45061+M;4000) = A(4001+M;4000)
C
      A(57221+M;4000) = A(53221+M;4000)
      A(53221+M;4000) = A(61381+M;4000)
      A(61381+M;4000) = A(20321+M;4000)
C
C          .....EX ITERATION.....
      ASSIGN D1,.DYN.3839
      ASSIGN D2,.DYN.3839
      ASSIGN D3,.DYN.3839
      D1 = A(24481+M;3839) * CA(1)
      D2 = A(12321+M;3839) - A(12161+M;3839) + A(20321+M;3839)
     1                                       - A(57221+M;3839)
      D3 = CB(1) * D2
```

```
      A(24481+M$3839) = D1 - D3
      D4 = VABS(A(28161+M$159)$D4)
      BY = D4.GT.A(28481+M$159)
      A(28481+M$159) = Q8VCTRL(D4,BY$A(28481+M$159))
      FREE
C
C          .....EZ ITERATION.....
      ASSIGN D1,.DYN.3678
      ASSIGN D2,.DYN.3678
      ASSIGN D3,.DYN.3678
      AL(2) = 0.5 * (A(36852+M)+A(36853+M))
      AL(3$21) = 0.333 * (A(36852+M$21)+A(36853+M$21)
     1                               +A(36854+M$21))
      AL(24) = 0.5 * (A(36873+M)+A(36874+M))
      AR(2) = 0.5 * (A(36877+M)+A(36878+M))
      AR(3$21) = 0.333 * (A(36877+M$21)+A(36878+M$21)
     1                               +A(36879+M$21))
      AR(24) = 0.5 * (A(36898+M)+A(36899+M))
      DO 91 KK=1,24
      MLE = M + KK
      MRI = M + MQ(KK)
      A(36850+MLE) = A(32852+MRI)
   91 A(36875+MLE) = A(33009+MRI)
      D1 = A(33012+M$3678) * CA(3)
      D2 = A(41062+M$3678) - A(4162+M$3678) + A(12321+M$3678)
     1                                       - A(12322+M$3678)
      D3 = CB(3) * D2
      A(33012+M$3678) = D1 - D3
      DO 92 KK=1,24
      MLE = M + MQ(KK)
      A(32851+MLE) = AL(KK)
   92 A(33010+MLE) = AR(KK)
      FREE
C
C          .....VERT. PLANE ENVELOPE COMPUTATION.....
   94 ASSIGN D1,.DYN.3840
      ASSIGN D2,.DYN.3840
      M = 32 * 36900
      MZ = 65 * 36900
C
C          .....HX ENVELOPE.....
      D2 = VABS(A(40901+M$3840)$D2)
      BV = D2.GT.A(MZ+1$3840)
      A(MZ+1$3840) = Q8VCTRL(D2,BV$A(MZ+1$3840))
C
C          .....HY ENVELOPE.....
      D1 = 0.5 * (A(12161+M$3840)+A(49061+M$3840))
      D2 = VABS(D1$D2)
      BV = D2.GT.A(MZ+4001$3840)
      A(MZ+4001$3840) = Q8VCTRL(D2,BV$A(MZ+4001$3840))
C
C          .....HZ ENVELOPE.....
      D2 = VABS(A(57221+M$3840)$D2)
```

```
      BV = D2.GT.A(MZ+8001;3840)
      A(MZ+8001;3840) = Q8VCTRL(D2,BV;A(MZ+8001;3840))
C
C             .....EX ENVELOPE.....
      D1 = 0.5 * (A(24481+M;3840)+A(61381+M;3840))
      D2 = VABS(D1;D2)
      BV = D2.GT.A(MZ+12001;3840)
      A(MZ+12001;3840) = Q8VCTRL(D2,BV;A(MZ+12001;3840))
C
C             .....EY ENVELOPE.....
      D2 = VABS(A(65541+M;3840);D2)
      BV = D2.GT.A(MZ+16001;3840)
      A(MZ+16001;3840) = Q8VCTRL(D2,BV;A(MZ+16001;3840))
C
C             .....EZ ENVELOPE.....
      D1 = 0.5 * (A(32851+M;3840)+A(69751+M;3840))
      D2 = VABS(D1;D2)
      BV = D2.GT.A(MZ+20001;3840)
      A(MZ+20001;3840) = Q8VCTRL(D2,BV;A(MZ+20001;3840))
      FREE
      T3 = SECOND(CP)
      PRINT 150, T3
C
C             .....FIELD ENVELOPE PRINTOUT ROUTINE.....
      DO 100 L=NHALF,NMAX,NHALF
      IF(N.EQ.L)GO TO 101
  100 CONTINUE
      IF(N.EQ.NMAX)GO TO 101
      GO TO 199
C
C             .....AT HORIZONTAL SYMMETRY PLANE.....
  101 IF(N.EQ.NMAX)IPUN=1
      PRINT 102, N
  102 FORMAT(1H1,52X,27HHZ ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENVH(24321,10000.0,IPUN)
C
      PRINT 103, N
  103 FORMAT(1H1,52X,27HEX ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENVH(28481,RC,IPUN)
C
      PRINT 104, N
  104 FORMAT(1H1,52X,27HEY ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENVH(32691,RC,IPUN)
C
C             .....AT VERTICAL SYMMETRY PLANE.....
      PRINT 105, N
  105 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(1,10000.0,IPUN)
C
```

```
      PRINT 106, N
  106 FORMAT(1H1,52X,27HHY ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(4001,10000.0,IPUN)
C
      PRINT 107, N
  107 FORMAT(1H1,52X,27HHZ ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(8001,10000.0,IPUN)
C
      PRINT 108, N
  108 FORMAT(1H1,52X,27HEX ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(12001,RC,IPUN)
C
      PRINT 109, N
  109 FORMAT(1H1,52X,27HEY ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(16001,RC,IPUN)
C
      PRINT 110, N
  110 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE Y = 32.5*DX,//,2X,1HK,/)
      CALL ENVV(20001,RC,IPUN)
C
  199 CONTINUE
  200 CONTINUE
      T4 = SECOND(CP)
      PRINT 150, T4
      STOP
      END

      SUBROUTINE ENVH(LOCA,SCALE,IPUNCH)
      DIMENSION A(2422500),IP(10240),NN(160)
      COMMON A
      DO 9 I=1,160
    9 NN(I) = I
C
      DO 1 LY=2,64
      LOC = LOCA + (LY-1)*36900
      LOCI = 1 + (LY-1)*160
      IP(LOCI$160) = SCALE * A(LOC$160)
    1 A(LOC$160) = 0.
C
      IF(IPUNCH.EQ.0)GO TO 4
      DO 2 LY=15,52
      LOCI = 1 + (LY-1)*160
      LOCII = LOCI + 158
    2 WRITE(8,3)  (IP(LL),LL=LOCI,LOCII)
    3 FORMAT(16I5)
C
    4 DO 7 LX=1,6
      LXA = 5 + (LX-1)*25
```

```
      LXB = LXA + 24
      DO 5 LY=2,64
      LYY = 66 - LY
      LOCI = LXA + (LYY-1)*160
      LOCII = LOCI + 24
    5 PRINT 6, LYY, (IP(LL),LL=LOCI,LOCII)
    6 FORMAT(1X,I2,2X,25I5)
    7 PRINT 8, (NN(LL),LL=LXA,LXB)
    8 FORMAT(//,4X,25I5,////)
C
      RETURN
      END

      SUBROUTINE ENVV(LOCZ,SCALE,IPUNCH)
      DIMENSION A(2422500),NN(160),IPR(25),IPP(160)
      COMMON A
C
      DO 8 I=1,160
    8 NN(I) = I
      LMN = LOCZ + 65*36900
C
      IF(IPUNCH.EQ.0)GO TO 3
      DO 1 LZ=1,24
      LOC = LMN + (LZ-1)*160
      IPP(1;159) = SCALE * A(LOC;159)
    1 WRITE(8,2) (IPP(LL),LL=1,159)
    2 FORMAT(16I5)
C
    3 DO 6 LX=1,6
      LXA = 5 + (LX-1)*25
      LXB = LXA + 24
      DO 4 LZ=1,24
      LZZ = 25 - LZ
      LOC = LMN + (LZZ-1)*160 + LXA-1
      IPR(1;25) = SCALE * A(LOC;25)
    4 PRINT 5, LZZ, (IPR(LL),LL=1,25)
    5 FORMAT(1X,I2,2X,25I5)
    6 PRINT 7, (NN(LL),LL=LXA,LXB)
    7 FORMAT(//,4X,25I5,////)
C
      A(LMN;3840) = 0.
      RETURN
      END
```

2.3 Problem C -- Task 2, Case 1 (Section 4.1 of Volume 1)

The following 10 pages list the computer program for the 24 x 100 x 24 cell -- 1800 time step run of Problem C. The problem solved is penetration of a 12.8 cm diameter, 28 cm long, missile guidance section by a 300 MHz plane wave at axial incidence, for the case of the interior dielectric components modeled.

```
      PROGRAM FDTD (INPUT,OUTPUT,TAPE60=INPUT,TAPE8=TAPE8)
C
C     RUN TASK2-- STEADY 300 MHZ PLANE WAVE IRRADIATION OF A
C                 12.8 CM DIAMETER MISSILE GUIDANCE SECTION
C     CASE I- INTERIOR DIELECTRIC COMPONENTS MODELED
C             AXIAL INCIDENCE
C             INCIDENT WAVE COMPONENTS EZ AND HX
C     24 X 100 X 24 CELL CUBIC SPACE LATTICE IS USED
C     UNIT CELL DIAMETER = DX = 0.33 CM = WAVELENGTH/300
C     EVEN SYMMETRY ABOUT LATTICE PLANES X = 24.5*DX AND
C          Z = 24.0*DX IS ASSUMED
C     SOFT TEM WAVE SOURCE CONDITION IS USED AT PLANE Y = 3.0*DX
C     SOFT LATTICE TRUNCATIONS ARE USED
C     PROGRAM IS OPTIMIZED FOR THE CDC STAR-100
C
      REAL MUR, MUZ
      DIMENSION A(599536),CEXB(60000),CEYB(60000),CEZB(60000),
     1          Z(5936),AAA(600),AA(25),DD(24),DE(24),CA(9),
     2          CB(9),EPS(6),SIG(6)
      COMMON A,CEXB,CEYB,CEZB
      DESCRIPTOR D1,D2,D3,D4,D5,NED,A1,A2,BV,BW,BX,BY
      BIT BV,BBB(600),BW,BBW(600),BX,BBX(600),BY,BBY(24)
      ASSIGN BV,BBB(1;600)
      ASSIGN BW,BBW(1;600)
      ASSIGN BX,BBX(1;600)
      ASSIGN BY,BBY(1;24)
      ASSIGN D4,DD(1;24)
      ASSIGN D5,DE(1;24)
      T1 = SECOND(CP)
      PRINT 150, T1
  150 FORMAT (F20.5)
C
C           .....I. PROBLEM PARAMETERS.....
      FREQ = 3.0E+8
      DX = 0.01/3.0
      MPR = 6
      DATA EPS/ 1.0,    1.0,    1.0,    5.5,    4.5,    5.3 /
      DATA SIG/ 0.0,   3.7E+7,  0.025,  0.0024, 0.0008, 0.0 /
      NMAX = 1800
      NMAX = 1800
C
C           .....II. BASIC AND DERIVED CONSTANTS.....
      PI = 3.14159265
      MUZ = 4.0 * PI * 1.0E-7
      EPSZ = 8.854E-12
      DT = DX / 6.0E+8
      NHALF = 0.5 / FREQ / DT
      R = DT / 2.0 / EPSZ
      RA = DT**2 / DX**2 / MUZ / EPSZ
      RB = DT / DX / MUZ
      RC = 1.0E+4 / RB
      RD = 2.0 * PI * FREQ * DT
      IRUN = 0
```

```
C
      CA(1;9) = 0.
      CB(1;9) = 0.
      BW = Q8VMKO(1,25;BW)
      BX = Q8VMKZ(24,25;BX)
      DO 2 I=1,MPP
      FAF = B * SIG(I) / EPS(I)
      CA(I) = (1.0-FAF) / (1.0+FAF)
    2 CB(I) = RA / EPS(I) / (1.0+FAF)
C
C          .....III. LOAD VECTOR A.....
C          .....ZERO INITIAL FIELDS.....
      Z(1;5936) = 0.
      A(1;5936) = 0.
      A(593601;5936) = 0.
C
C          .....TYPE OF MEDIUM.....
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
    4 FORMAT (75F1.0)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      DO 5 J=2,6
      JDEL = (J-1) * 5936
    5 A(JDEL+1;5936) = Z(1;5936)
C
      DO 55 J=7,14
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      JDEL = (J-1) * 5936
   55 A(JDEL+1;5936) = Z(1;5936)
C
      DO 6 JA=15,71,7
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      JDEL = (JA-1) * 5936
      A(JDEL+1;5936) = Z(1;5936)
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      DO 6 JB=1,6
      JDEL = (JA+JB-1) * 5936
    6 A(JDEL+1;5936) = Z(1;5936)
      DO 7 J=93,100
      JDEL = (J-1) * 5936
    7 A(JDEL+1;5936) = Z(1;5936)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      DO 8 J=75,77
      JDEL = (J-1) * 5936
    8 A(JDEL+1;5936) = Z(1;5936)
```

```
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      J = 78
      JDEL = (J-1) * 5936
      A(JDEL+1;5936) = Z(1;5936)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      J = 79
      JDEL = (J-1) * 5936
      A(JDEL+1;5936) = Z(1;5936)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      DO 9 J=80,84
      JDEL = (J-1) * 5936
    9 A(JDEL+1;5936) = Z(1;5936)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      J = 85
      JDEL = (J-1) * 5936
      A(JDEL+1;5936) = Z(1;5936)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      DO 10 J=86,87
      JDEL = (J-1) * 5936
   10 A(JDEL+1;5936) = Z(1;5936)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      DO 11 J=88,91
      JDEL = (J-1) * 5936
   11 A(JDEL+1;5936) = Z(1;5936)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      J = 92
      JDEL = (J-1) * 5936
      A(JDEL+1;5936) = Z(1;5936)
C
C           .....MEDIA COEFFICIENTS.....
      ASSIGN A1,,DYN,600
      ASSIGN A2,,DYN,600
      ASSIGN NED,,DYN,600
      A1 = 0.
      A2 = 0.
      DO 23 J=2,100
      JDEL = (J-1) * 5936
      JDEM = (J-1) * 600
```

```
C
      NFD = A(JDEL+1;600)
      DO 20 JJ=1,MPH
      BV = NFD.EQ.JJ
      A1 = QRVCTRL(CA(JJ),BV;A1)
   20 A2 = QRVCTRL(CB(JJ),BV;A2)
      A(JDEL+1;600) = A1
      CEXB(JDEM+1;600) = A2
C
      NFD = A(JDEL+1301;600)
      DO 21 JJ=1,MPH
      BV = NFD.EQ.JJ
      A1 = QRVCTRL(CA(JJ),BV;A1)
   21 A2 = QRVCTRL(CB(JJ),BV;A2)
      A(JDEL+1301;600) = A1
      CEYB(JDEM+1;600) = A2
C
      NFD = A(JDEL+2601;600)
      DO 22 JJ=1,MPH
      BV = NFD.EQ.JJ
      A1 = QRVCTRL(CA(JJ),BV;A1)
   22 A2 = QRVCTRL(CB(JJ),BV;A2)
      A(JDEL+2601;600) = A1
   23 CEZB(JDEM+1;600) = A2
      FREE
C
      T2 = SECOND(CP)
      PRINT 150, T2
C
C            .....IV. TIME-STEPPING LOOP.....
      DO 200 N=1,NMAX
      TERM = SIN(FLOAT(N)*PD) * RH
      MCALL = 3 + IFIX(FLOAT(N)/6.0)
      IF(MCALL.GT.33)MCALL=33
C
C     .....TRANSVERSE PLANE NO. 1.....
C            .....EX, EZ TRUNCATIONS.....
      A(626;625) = A(1;625)
      A(1;625) = A(6562;625)
      A(3226;625) = A(2601;625)
      A(2601;625) = A(9162;625)
C
C            .....EY ITERATION.....
      ASSIGN D1,.DYN.574
      ASSIGN D2,.DYN.574
      ASSIGN D3,.DYN.574
      A(1926) = 0.5 * (A(2551)+A(2552))
      A(1927;22) = 0.333 * (A(2551;22)+A(2552;22)+A(2553;22))
      A(1949) = 0.333 * (A(2573) + 2.0*A(2574))
      A(2551;24) = A(1951;24)
      D1 = CA(3) * A(1951;574)
      D2 = A(3926;574) - A(3901;574) + A(5276;574) - A(5277;574)
      D3 = CB(3) * D2
```

```
      A(1951:574) = D1 + D3
      FREE
C
C           .....TRANSVERSE PLANES 2 - 100.....
      DO 82 JY=1,MCALL
      JDEL = (JY-1) * 17808
      JDEM = (JY-1) * 1800
C
C           .....EX ITERATION.....
      ASSIGN D1,.DYN.573
      ASSIGN D2,.DYN.573
      ASSIGN D3,.DYN.573
C
      DO 30 MA=1,3
      M = JDEL + 5936*(MA-1)
      MM = JDEM + 600*(MA-1)
C
C           .....SOFT LATTICE TRUNCATION.....
      A(6563+M) = 0.5 * (A(7188+M)+A(7189+M))
      A(6564+M:21) = 0.333 * (A(7188+M:21)+A(7189+M:21)
     1                                 +A(7190+M:21))
      A(6585+M) = 0.5 * (A(7209+M)+A(7210+M))
      A(7188+M:23) = A(6588+M:23)
C
C           .....MAIN EX LOOPS.....
      D1 = A(5963+M:573) * A(6588+M:573)
      D2 = A(11213+M:573)-A(5277+M:573)+A(10513+M:573)
     1                               -A(10538+M:573)
      D3 = CEXP(627+MM:573) * D2
   30 A(6588+M:573) = D1 + D3
      FREE
C
C           .....EY ITERATION.....
      ASSIGN D1,.DYN.574
      ASSIGN D2,.DYN.574
      ASSIGN D3,.DYN.574
C
      DO 40 MA=1,3
      M = JDEL + 5936*(MA-1)
      MM = JDEM + 600*(MA-1)
C
C           .....SOFT LATTICE TRUNCATION.....
      A(7862+M) = 0.5 * (A(8487+M)+A(8488+M))
      A(7863+M:22) = 0.333 * (A(8487+M:22)+A(8488+M:22)
     1                                 +A(8489+M:22))
      A(7885+M) = 0.333 * (A(8509+M) + 2.0*A(8510+M))
      A(8487+M:24) = A(7887+M:24)
C
C           .....MAIN EY LOOPS.....
      D1 = A(7262+M:574) * A(7887+M:574)
      D2 = A(9862+M:574)-A(9837+M:574)+A(11212+M:574)
     1                              -A(11213+M:574)
      D3 = CEYB(626+MM:574) * D2
```

```
      A(7887+M;574) = D1 + D3
C
C           .....EY ENVELOPE COMPUTATION.....
      D4 = Q8VCMPRS(A(7861+M;600),BX;D4)
      D5 = VABS(D4;D5)
      BY = D5.GT.A(8512+M;24)
   40 A(8512+M;24) = Q8VCTRL(D5,BY;A(8512+M;24))
      FREE
C
C           .....EZ ITERATION.....
      ASSIGN D1,.DYN.599
      ASSIGN D2,.DYN.599
      ASSIGN D3,.DYN.599
C
      DO 50 MA=1,3
      M = JDEL + 5936*(MA-1)
      MM = JDEM + 600*(MA-1)
C
C           .....MAIN EZ LOOPS.....
      D1 = A(8537+M;599) * A(9162+M;599)
      D2 = A(10513+M;599)-A(10512+M;599)+A(3901+M;599)
     1                                    -A(9837+M;599)
      D3 = CEZE(601+MM;599) * D2
      A(9162+M;599) = D1 + D3
C
C           .....EZ SOFT TEM WAVE SOURCE CONDITION.....
      IF(JY.GE.2.OR.MA.LE.2)GO TO 47
      A(21034;599) = TERM + A(21034;599)
C
C           .....EZ ENVELOPE COMPUTATION.....
   47 D4 = VABS(A(9737+M;24);D4)
      BY = D4.GT.A(9787+M;24)
      A(9787+M;24) = Q8VCTRL(D4,BY;A(9787+M;24))
      D4 = Q8VCMPRS(A(9161+M;600),BX;D4)
      D5 = VABS(D4;D5)
      BY = D5.GT.A(9812+M;24)
   50 A(9812+M;24) = Q8VCTRL(D5,BY;A(9812+M;24))
C
C           .....HX ITERATION.....
      DO 60 MA=1,3
      M = JDEL + 5936*(MA-1)
C
C           .....MAIN HX LOOPS.....
      D1 = A(3901+M;599)
      D2 = A(1951+M;599)-A(1926+M;599)+A(3226+M;599)
     1                                -A(9162+M;599)
      A(3901+M;599) = D1 + D2
C
C           .....HX ENVELOPE COMPUTATION.....
      D4 = VABS(A(4476+M;24);D4)
      BY = D4.GT.A(4526+M;24)
      A(4526+M;24) = Q8VCTRL(D4,BY;A(4526+M;24))
      D4 = Q8VCMPRS(A(3900+M;600),BX;D4)
```

```
      D5 = VABS(D4;D5)
      BY = D5.GT.A(4551+M;24)
   60 A(4551+M;24) = Q8VCTRL(D5,BY;A(4551+M;24))
      FREE
C
C           .....HY ITERATION.....
      ASSIGN D1,.DYN.598
      ASSIGN D2,.DYN.598
C
      DO 70 MA=1,3
      M = JDEL + 5936*(MA-1)
C
C           .....SOFT LATTICE TRUNCATION.....
      AA(1) = 0.5 * (A(11137+M)+A(11138+M))
      AA(2;22) = 0.333 * (A(11137+M;22)+A(11138+M;22)
     1                                 +A(11139+M;22))
      AA(24) = 0.333 * (A(11159+M) + 2.0*A(11160+M))
      AAA(1;600) = Q8VXPND(AA(1;24),BW;AAA(1;600))
      A(11137+M;24) = Q8VCMPRS(A(10513+M;600),BW;A(11137+M;24))
C
C           .....MAIN HY LOOPS.....
      D1 = A(10513+M;598)
      D2 = A(9163+M;598)-A(9162+M;598)+A(6563+M;598)
     1                               -A(6588+M;598)
      A(10513+M;598) = D1 + D2
C
      A(10512+M;600) = Q8VCTRL(AAA(1;600),BW;A(10512+M;600))
      A(10512+M;600) = Q8VCTRL(0.0,BX;A(10512+M;600))
C
C           .....HY ENVELOPE COMPUTATION.....
      D4 = VABS(A(11087+M;24);D4)
      BY = D4.GT.A(11162+M;24)
   70 A(11162+M;24) = Q8VCTRL(D4,BY;A(11162+M;24))
      FREE
C
C           .....HZ ITERATION.....
      ASSIGN D1,.DYN.573
      ASSIGN D2,.DYN.573
C
      DO 80 MA=1,3
      M = JDEL + 5936*(MA-1)
C
C           .....SOFT LATTICE TRUNCATION.....
      AA(2) = 0.5 * (A(5877+M)+A(5878+M))
      AA(3;21) = 0.333 * (A(5877+M;21)+A(5878+M;21)
     1                               +A(5879+M;21))
      AA(24) = 0.5 * (A(5898+M) + A(5899+M))
      AAA(1;600) = Q8VXPND(AA(1;24),BW;AAA(1;600))
      A(5876+M;24) = Q8VCMPRS(A(5252+M;600),BW;A(5876+M;24))
C
C           .....MAIN HZ LOOPS.....
      D1 = A(5277+M;573)
```

```
      D2 = A(6588+M$573)-A(652+M$573)+A(1951+M$573)
     1                                -A(1952+M$573)
      A(5277+M$573) = D1 + D2
C
      A(5251+M$600) = Q8VCTRL(AAA(1$600),BW$A(5251+M$600))
   80 A(5251+M$600) = Q8VCTRL(0.0,HX$A(5251+M$600))
      FREE
   82 CONTINUE
      IF(MCALL.LE.32)GO TO 94
C
C           .....TRANSVERSE PLANE NO. 101.....
      M = 99 * 5636
C
C           .....EX, EZ TRUNCATIONS.....
      A(6562+M$625) = A(5937+M$625)
      A(5937+M$625) = A(7237+M$625)
      A(7237+M$625) = A(626+M$625)
      A(9162+M$625) = A(8537+M$625)
      A(8537+M$625) = A(9837+M$625)
      A(9837+M$625) = A(3226+M$625)
C
C           .....HX ITERATION.....
      ASSIGN D1,.DYN.599
      ASSIGN D2,.DYN.599
      D1 = A(3901+M$599)
      D2 = A(1951+M$599)-A(1926+M$599)+A(3226+M$599)
     1                                  -A(9162+M$599)
      A(3901+M$599) = D1 + D2
      D4 = VABS(A(4476+M$24)$D4)
      BY = D4.GT.A(4526+M$24)
      A(4526+M$24) = Q8VCTRL(D4,HY$A(4526+M$24))
      D4 = Q8VCMPRS(A(3900+M$600),HX$D4)
      D5 = VABS(D4$D5)
      BY = D5.GT.A(4551+M$24)
      A(4551+M$24) = Q8VCTRL(D5,HY$A(4551+M$24))
      FREE
C
C           .....HZ ITERATION.....
      ASSIGN D1,.DYN.573
      ASSIGN D2,.DYN.573
      AA(2) = 0.5 * (A(5877+M)+A(5878+M))
      AA(3$21) = 0.333 * (A(5877+M$21)+A(5878+M$21)
     1                                  +A(5879+M$21))
      AA(24) = 0.5 * (A(5898+M) + A(5899+M))
      AAA(1$600) = Q8VXPND(AA(1$24),HW$AAA(1$600))
      A(5876+M$24) = Q8VCMPRS(A(5252+M$600),BW$A(5876+M$24))
      D1 = A(5277+M$573)
      D2 = A(6588+M$573)-A(652+M$573)+A(1951+M$573)
     1                                -A(1952+M$573)
      A(5277+M$573) = D1 + D2
      A(5251+M$600) = Q8VCTRL(AAA(1$600),BW$A(5251+M$600))
      A(5251+M$600) = Q8VCTRL(0.0,HX$A(5251+M$600))
      FREE
```

```
 94 T3 = SECOND(CP)
    PRINT 150, T3
C
C          .....FIELD ENVELOPE PRINTOUT ROUTINE.....
    DO 100 L=NHALF,NMAX,NHALF
    IF(N.EQ.L)GO TO 101
100 CONTINUE
    IF(N.EQ.NMAX)GO TO 101
    GO TO 199
C
C          .....AT HORIZONTAL SYMMETRY PLANE.....
101 IF(N.EQ.NMAX)IPUN=1
    PRINT 102, N
102 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
   1         //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
    CALL ENV(3851,HC,IPUN)
C
    PRINT 104, N
104 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
   1         //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
    CALL ENV(4526,3.77E+6,IPUN)
C
    PRINT 105, N
105 FORMAT(1H1,52X,27HHY ENVELOPE FOR TIME STEP =,I5,
   1         //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
    CALL ENV(5226,3.77E+6,IPUN)
C
C          .....AT VERTICAL SYMMETRY PLANE.....
    PRINT 106, N
106 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
   1         //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
    CALL ENV(3676,HC,IPUN)
C
    PRINT 108, N
108 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
   1         //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
    CALL ENV(4551,3.77E+6,IPUN)
C
    PRINT 109, N
109 FORMAT(1H1,52X,27HEY ENVELOPE FOR TIME STEP =,I5,
   1         //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
    CALL ENV(2576,HC,IPUN)
C
199 CONTINUE
200 CONTINUE
201 T4 = SECOND(CP)
    PRINT 150, T4
    STOP
    END

    SUBROUTINE ENV(LOCA,SCALE,IPUNCH)
    DIMENSION A(599536),IP(2500),NN(25)
    COMMON A
```

```
C
      DO 8 I=1,25
    8 NN(I) = I
C
      DO 1 LY=2,100
      LOC = LOCA + (LY-1)*5936
      LOCI = 1 + (LY-1)*25
      IP(LOCI;25) = SCALE * A(LOC;25)
    1 A(LOC;25) = 0.
C
      IF(IPUNCH.EQ.0)GO TO 4
      DO 2 LY=2,100
      LOCI = 5 + (LY-1)*25
      LOCII = LOCI + 19
    2 WRITE(8,3) (IP(LL),LL=LOCI,LOCII)
    3 FORMAT(10I6)
C
    4 DO 5 LY=2,100
      LYY = 102 - LY
      LOCI = 5 + (LYY-1)*25
      LOCII = LOCI + 19
    5 PRINT 6, LYY, (IP(LL),LL=LOCI,LOCII)
    6 FORMAT(1X,I3,5X,20I6)
      PRINT 7, (NN(LL),LL=5,24)
    7 FORMAT(//,8X,20I6)
C
      RETURN
      END
```

2.4 Problem D -- Task 2, Case 2 (Section 4.2 of Volume 1)

The following 12 pages list the computer program for the 24 x 100 x 48 cell -- 1800 time step run of Problem D. The problem solved is penetration of a 12.8 cm diameter, 28 cm long, missile guidance section by a 300 MHz plane wave at axial incidence, for the case of the interior dielectric components, metal components, and wires modeled.

```
      PROGRAM FDTD(INPUT,OUTPUT,TAPE60=INPUT,TAPE8=TAPE8)
C
C     RUN TASK2-- STEADY 300 MHZ PLANE WAVE IRRADIATION OF A
C                 12.8 CM DIAMETER MISSILE GUIDANCE SECTION
C     CASE II- INTERIOR METAL AND DIELECTRIC COMPONENTS MODELED
C              INCIDENT WAVE COMPONENTS ARE EZ AND HX
C     24 X 100 X 48 CELL CUBIC SPACE LATTICE IS USED
C     UNIT CELL DIAMETER = DX = 0.33 CM = WAVELENGTH/300
C     EVEN SYMMETRY ABOUT LATTICE PLANE X = 24.5*DX IS ASSUMED
C     SOFT TEM WAVE SOURCE CONDITION IS USED AT PLANE Y = 3.0*DX
C     SOFT LATTICE TRUNCATIONS ARE USED
C     PROGRAM IS OPTIMIZED FOR THE CDC STAR-100
C
      REAL MUR, MUZ
      DIMENSION A(1565500),Z(15500),AAA(1200),BUF(600),AA(48),
     1          DD(24),DE(48),DF(48),CA(9),CB(9),EPS(9),SIG(9)
      COMMON A
      DESCRIPTOR D1,D2,D3,D4,D5,D6,NFD,A1,A2,BU,BV,BW,BX,BY,BZ
      BIT BU,BBU(600),BV,BBV(1200),BW,BBW(1200),BX,BBX(1200),
     1    BY,BBY(24),BZ,BBZ(48)
      ASSIGN BU,BBU(1;600)
      ASSIGN BV,BBV(1;1200)
      ASSIGN BW,BBW(1;1200)
      ASSIGN BX,BBX(1;1200)
      ASSIGN BY,BBY(1;24)
      ASSIGN BZ,BBZ(1;48)
      ASSIGN D4,DD(1;24)
      ASSIGN D5,DE(1;48)
      ASSIGN D6,DF(1;48)
      T1 = SECOND(CP)
      PRINT 150, T1
  150 FORMAT(F20.5)
C
C          .....I. PROBLEM PARAMETERS.....
      FREQ = 3.0E+8
      DX = 0.01/3.0
      MPR = 9
      DATA EPS /1.0, 1.0, 1.0, 5.5, 4.5, 5.3, 1.0, 1.0, 8.0/
      DATA SIG /0.0, 3.7E+7, 0.025, 0.0024, 0.0008, 0.0, 6.6E+6,
     1          3.7E+7, 0.01/
      NMAX = 1800
C
C          .....II. BASIC AND DERIVED CONSTANTS.....
      PI = 3.14159265
      MUZ = 4.0 * PI * 1.0E-7
      EPSZ = 8.854E-12
      DT = DX / 6.0E+8
      NHALF = 0.5 / FREQ / DT
      R = DT / 2.0 / EPSZ
      RA = DT**2 / DX**2 / MUZ / EPSZ
      RB = DT / DX / MUZ
      RC = 1.0E+4 / RB
```

```
      RD = 2.0 * PI * FREQ * DT
      IPUN = 0
C
      CA(1$9) = 0.
      CB(1$9) = 0.
      BW = Q8VMKO(1,25$BW)
      BX = Q8VMKZ(24,25$BX)
      DO 2 I=1,MPR
      EAF = R * SIG(I) / EPS(I)
      CA(I) = (1.0 - EAF) / (1.0 + EAF)
    2 CB(I) = RA / EPS(I) / (1.0 + EAF)
C
C           .....III. LOAD VECTOR A.....
C           .....ZERO INITIAL FIELDS.....
      Z(1$15500) = 0.
      A(1$15500) = 0.
      A(1550001$15500) = 0.
C
C           .....TYPE OF MEDIUM.....
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
    4 FORMAT(75F1.0)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      DO 5 J=2,6
      JDEL = (J-1) * 15500
    5 A(JDEL+1$15500) = Z(1$15500)
C
      DO 55 J=7,14
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      JDEL = (J-1) * 15500
   55 A(JDEL+1$15500) = Z(1$15500)
C
      DO 6 JA=15,71,7
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      JDEL = (JA-1) * 15500
      A(JDEL+1$15500) = Z(1$15500)
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      DO 6 JB=1,6
      JDEL = (JA+JB-1) * 15500
    6 A(JDEL+1$15500) = Z(1$15500)
      DO 7 J=93,100
      JDEL = (J-1) * 15500
    7 A(JDEL+1$15500) = Z(1$15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
```

```
      DO 8 J=75,77
      JDEL = (J-1) * 15500
    8 A(JDEL+1$15500) = Z(1$15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      J = 78
      JDEL = (J-1) * 15500
      A(JDEL+1$15500) = Z(1$15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      J = 79
      JDEL = (J-1) * 15500
      A(JDEL+1$15500) = Z(1$15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      DO 9 J=80,84
      JDEL = (J-1) * 15500
    9 A(JDEL+1$15500) = Z(1$15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      J = 85
      JDEL = (J-1) * 15500
      A(JDEL+1$15500) = Z(1$15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      DO 10 J=86,87
      JDEL = (J-1) * 15500
   10 A(JDEL+1$15500) = Z(1$15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      DO 11 J=88,91
      JDEL = (J-1) * 15500
   11 A(JDEL+1$15500) = Z(1$15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      J = 92
      JDEL = (J-1) * 15500
      A(JDEL+1$15500) = Z(1$15500)
C
C            .....PARTIAL SYMMETRY ABOUT Z = 24.0*DX.....
      DO 12 J=2,100
      JDEL = (J-1) * 15500
      KMAX = 49
      DO 12 JA=1,3
```

```
      JB = JDEL + (JA-1)*2500 + 1
      BUF(1;600) = A(JB;600)
      BU = BUF(1;600).GT.6.5
      BUF(1;600) = Q8VCTRL(3.0,BU;BUF(1;600))
      IF(JA.EQ.3)KMAX=48
      A(JB+600;25) = BUF(576;25)
      DO 12 K=1,24
      KA = (K-1) * 25
      KB = (KMAX-K) * 25
   12 A(JB+KB;25) = BUF(KA+1;25)
C
C           .....NON-SYMMETRIC GROUND WIRE.....
      DO 13 J=43,57
      JDEL = (J-1) * 15500
      A(JDEL+3199) = 7.0
      A(JDEL+3224) = 7.0
   13 A(JDEL+5699) = 7.0
C
      DO 14 K=18,28
      KDEL = (K-1)*25 + 24
      A(JDEL+2500+KDEL) = 7.0
      A(JDEL+5000+KDEL) = 7.0
   14 A(JDEL+20500+KDEL) = 7.0
C
C           .....MEDIA COEFFICIENTS.....
      ASSIGN A1,.DYN.1200
      ASSIGN A2,.DYN.1200
      ASSIGN NFD,.DYN.1200
      A1 = 0.
      A2 = 0.
      DO 21 J=2,100
      JDEL = (J-1) * 15500
      DO 21 JA=1,3
      JB = (JA-1)*2500 + 1
      JC = JB + 1250
      NFD = A(JDEL+JB;1200)
      DO 20 JJ=1,MPR
      BV = NFD.EQ.JJ
      A1 = Q8VCTRL(CA(JJ),BV;A1)
   20 A2 = Q8VCTRL(CB(JJ),BV;A2)
      A(JDEL+JB;1200) = A1
   21 A(JDEL+JC;1200) = A2
      FREE
C
      T2 = SECOND(CP)
      PRINT 150, T2
C
C           .....IV. TIME-STEPPING LOOP.....
      DO 200 N=1,NMAX
      TERM = SIN(FLOAT(N)*RD) * RB
      MCALL = 3 + IFIX(FLOAT(N)/6.0)
      IF(MCALL.GT.33)MCALL=33
```

```
C
C         .....TRANSVERSE PLANE NO. 1.....
C         .....EX, EZ TRUNCATIONS.....
      A(7501$1250) = A(1$1250)
      A(1$1250) = A(23001$1250)
      A(10201$1250) = A(1251$1250)
      A(1251$1250) = A(25701$1250)
C
C         .....EY ITERATION.....
      ASSIGN D1,.DYN.1174
      ASSIGN D2,.DYN.1174
      ASSIGN D3,.DYN.1174
C
      A(8826) = 0.5 * (A(10076)+A(10077))
      A(8827$22) = 0.333 * (A(10076$22)+A(10077$22)+A(10078$22))
      A(8849) = 0.333 * (A(10098)+2.0*A(10099))
      A(10076$24) = A(8851$24)
C
      A(10026) = 0.5 * (A(10101)+A(10102))
      A(10027$22) = 0.333 * (A(10101$22)+A(10102$22)+A(10103$22))
      A(10049) = 0.333 * (A(10123)+2.0*A(10124))
      A(10101$24) = A(10001$24)
C
      D1 = CA(3) * A(8851$1174)
      D2 = A(11551$1174)-A(11526$1174)+A(14201$1174)-A(14202$1174)
      D3 = CB(3) * D2
      A(8851$1174) = D1 + D3
      FREE
C
C         .....TRANSVERSE PLANES 2 - 100.....
      DO 82 JY=1,MCALL
      JDEL = (JY-1) * 46500
C
C         .....EX ITERATION.....
      ASSIGN D1,.DYN.1173
      ASSIGN D2,.DYN.1173
      ASSIGN D3,.DYN.1173
C
      DO 30 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C         .....SOFT LATTICE TRUNCATIONS.....
      A(23002+M) = 0.5 * (A(24252+M)+A(24253+M))
      A(23003+M$21) = 0.333 * (A(24252+M$21)+A(24253+M$21)
     1                                   +A(24254+M$21))
      A(23024+M) = 0.5 * (A(24273+M)+A(24274+M))
      A(24252+M$23) = A(23027+M$23)
C
      A(24202+M) = 0.5 * (A(24277+M)+A(24278+M))
      A(24203+M$21) = 0.333 * (A(24277+M$21)+A(24278+M$21)
     1                                   +A(24279+M$21))
      A(24224+M) = 0.5 * (A(24298+M)+A(24299))
```

```
      A(24277+M$23) = A(24177+M$23)
C
C             .....MAIN EX LOOPS.....
      D1 = A(15527+M$1173) * A(23027+M$1173)
      D2 = A(29702+M$1173)-A(14202+M$1173)+A(28352+M$1173)
     1                                   -A(28377+M$1173)
      D3 = A(16777+M$1173) * D2
      A(23027+M$1173) = D1 + D3
C
C             .....EX ENVELOPE COMPUTATION.....
      D4 = VABS(A(23601+M$24)$D4)
      BY = D4.GT.A(24301+M$24)
   30 A(24301+M$24) = Q8VCTRL(D4,BY$A(24301+M$24))
      FREE
C
C             .....EY ITERATION.....
      ASSIGN D1,.DYN.1174
      ASSIGN D2,.DYN.1174
      ASSIGN D3,.DYN.1174
C
      DO 40 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C             .....SOFT LATTICE TRUNCATIONS.....
      A(24326+M) = 0.5 * (A(25576+M)+A(25577+M))
      A(24327+M$22) = 0.333 * (A(25576+M$22)+A(25577+M$22)
     1                                    +A(25578+M$22))
      A(24349+M) = 0.333 * (A(25598+M)+2.0*A(25599+M))
      A(25576+M$24) = A(24351+M$24)
C
      A(25526+M) = 0.5 * (A(25601+M)+A(25602+M))
      A(25527+M$22) = 0.333 * (A(25601+M$22)+A(25602+M$22)
     1                                    +A(25603+M$22))
      A(25549+M) = 0.333 * (A(25623+M)+2.0*A(25624+M))
      A(25601+M$24) = A(25501+M$24)
C
C             .....MAIN EY LOOPS.....
      D1 = A(18026+M$1174) * A(24351+M$1174)
      D2 = A(27051+M$1174)-A(27026+M$1174)+A(29701+M$1174)
     1                                   -A(29702+M$1174)
      D3 = A(19276+M$1174) * D2
      A(24351+M$1174) = D1 + D3
C
C             .....EY ENVELOPE COMPUTATION.....
      D4 = VABS(A(24926+M$24)$D4)
      BY = D4.GT.A(25626+M$24)
      A(25626+M$24) = Q8VCTRL(D4,BY$A(25626+M$24))
C
      D5 = Q8VCMPRS(A(24325+M$1200),BX$D5)
      D6 = VABS(D5$D6)
      BZ = D6.GT.A(25651+M$48)
   40 A(25651+M$48) = Q8VCTRL(D6,BZ$A(25651+M$48))
      FREE
```

```
C
C          .....EZ ITERATION.....
      ASSIGN D1,.DYN.1199
      ASSIGN D2,.DYN.1199
      ASSIGN D3,.DYN.1199
C
      DO 50 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C          .....MAIN EZ LOOPS.....
      D1 = A(20501+M$1199) * A(25701+M$1199)
      D2 = A(28352+M$1199)-A(28351+M$1199)+A(11526+M$1199)
     1                                    -A(27026+M$1199)
      D3 = A(21751+M$1199) * D2
      A(25701+M$1199) = D1 + D3
C
C          .....EZ SOFT TEM WAVE SOURCE CONDITION.....
      IF(JY.GE.2.OR.MA.LE.2)GO TO 47
      A(56701$1199) = TERM + A(56701$1199)
C
C          .....EZ ENVELOPE COMPUTATION.....
   47 A(26926+M$24) = 0.5 * (A(26276+M$24)+A(26301+M$24))
      D4 = VABS(A(26926+M$24)$D4)
      BY = D4.GT.A(26951+M$24)
      A(26951+M$24) = Q8VCTRL(D4,BY$A(26951+M$24))
C
      D5 = Q8VCMPRS(A(25700+M$1200),BX$D5)
      D6 = VABS(D5$D6)
      BZ = D6.GT.A(26976+M$48)
   50 A(26976+M$48) = Q8VCTRL(D6,BZ$A(26976+M$48))
C
C          .....HX ITERATION.....
      DO 60 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C          .....MAIN HX LOOPS.....
      D1 = A(11526+M$1199)
      D2 = A(8851+M$1199)-A(8826+M$1199)+A(10201+M$1199)
     1                                 -A(25701+M$1199)
      A(11526+M$1199) = D1 + D2
C
C          .....HX ENVELOPE COMPUTATION.....
      A(12751+M$24) = 0.5 * (A(12101+M$24)+A(12126+M$24))
      D4 = VABS(A(12751+M$24)$D4)
      BY = D4.GT.A(12776+M$24)
      A(12776+M$24) = Q8VCTRL(D4,BY$A(12776+M$24))
C
      D5 = Q8VCMPRS(A(11525+M$1200),HX$D5)
      D6 = VABS(D5$D6)
      BZ = D6.GT.A(12801+M$48)
   60 A(12801+M$48) = Q8VCTRL(D6,BZ$A(12801+M$48))
      FREE
```

```
C
C          .....HY ITERATION.....
      ASSIGN D1,.DYN.1198
      ASSIGN D2,.DYN.1198
C
      DO 70 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C          .....SOFT LATTICE TRUNCATION.....
      AA(1) = 0.5 * (A(29601+M)+A(29602+M))
      AA(2;46) = 0.333 * (A(29601+M;46)+A(29602+M;46)
     1                                  +A(29603+M;46))
      AA(48) = 0.5 * (A(29647+M)+A(29648+M))
      AAA(1;1200) = Q8VXPND(AA(1;48),BW;AAA(1;1200))
      A(29601+M;48) = Q8VCMPRS(A(28352+M;1200),BW;A(29601+M;48))
C
C          .....MAIN HY LOOPS.....
      D1 = A(28352+M;1198)
      D2 = A(25702+M;1198)-A(25701+M;1198)+A(23002+M;1198)
     1                                       -A(23027+M;1198)
      A(28352+M;1198) = D1 + D2
C
      A(28351+M;1200) = Q8VCTRL(AAA(1;1200),BW;A(28351+M;1200))
      A(28351+M;1200) = Q8VCTRL(0.0,BX;A(28351+M;1200))
C
C          .....HY ENVELOPE COMPUTATION.....
      A(29576+M;24) = 0.5 * (A(28926+M;24)+A(28951+M;24))
      D4 = VABS(A(29576+M;24);D4)
      BY = D4.GT.A(29651+M;24)
   70 A(29651+M;24) = Q8VCTRL(D4,BY;A(29651+M;24))
      FREE
C
C          .....HZ ITERATION.....
      ASSIGN D1,.DYN.1173
      ASSIGN D2,.DYN.1173
C
      DO 80 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C          .....SOFT LATTICE TRUNCATION.....
      AA(2) = 0.5 * (A(15427+M)+A(15428+M))
      AA(3;45) = 0.333 * (A(15427+M;45)+A(15428+M;45)
     1                                  +A(15429+M;45))
      AA(48) = 0.5 * (A(15472+M)+A(15473+M))
      AAA(1;1200) = Q8VXPND(AA(1;48),BW;AAA(1;1200))
      A(15426+M;48) = Q8VCMPRS(A(14177+M;1200),BW;A(15426+M;48))
C
C          .....MAIN HZ LOOPS.....
      D1 = A(14202+M;1173)
      D2 = A(23027+M;1173)-A(7527+M;1173)+A(8851+M;1173)
     1                                     -A(8852+M;1173)
      A(14202+M;1173) = D1 + D2
```

```
C
      A(14176+M$1200) = Q8VCTRL(AAA(1$1200),BW$A(14176+M$1200))
      A(14176+M$1200) = Q8VCTRL(0.0,EX$A(14176+M$1200))
C
C           .....HZ ENVELOPE COMPUTATION.....
      D4 = VABS(A(14776+M$24)$D4)
      BY = D4.GT.A(15476+M$24)
   80 A(15476+M$24) = Q8VCTRL(D4,BY$A(15476+M$24))
      FREE
   82 CONTINUE
      IF(MCALL.LE.32)GO TO 94
C
C           .....TRANSVERSE PLANE NO. 101.....
      M = 99 * 15500
C
C           .....EX, EZ TRUNCATIONS.....
      A(23001+M$1250) = A(15501+M$1250)
      A(15501+M$1250) = A(16751+M$1250)
      A(16751+M$1250) = A(7501+M$1250)
C
      A(25701+M$1250) = A(18001+M$1250)
      A(18001+M$1250) = A(19251+M$1250)
      A(19251+M$1250) = A(10201+M$1250)
C
C           .....HX ITERATION.....
      ASSIGN D1,.DYN.1199
      ASSIGN D2,.DYN.1199
      D1 = A(11526+M$1199)
      D2 = A(8851+M$1199)-A(8826+M$1199)+A(10201+M$1199)
     1                                  -A(25701+M$1199)
      A(11526+M$1199) = D1 + D2
C
      A(12751+M$24) = 0.5 * (A(12101+M$24)+A(12126+M$24))
      D4 = VABS(A(12751+M$24)$D4)
      BY = D4.GT.A(12776+M$24)
      A(12776+M$24) = Q8VCTRL(D4,BY$A(12776+M$24))
C
      D5 = Q8VCMPRS(A(11525+M$1200),BX$D5)
      D6 = VABS(D5$D6)
      BZ = D6.GT.A(12801+M$48)
      A(12801+M$48) = Q8VCTRL(D6,BZ$A(12801+M$48))
      FREE
C
C           .....HZ ITERATION.....
      ASSIGN D1,.DYN.1173
      ASSIGN D2,.DYN.1173
      AA(2) = 0.5 * (A(15427+M)+A(15428+M))
      AA(3$45) = 0.333 * (A(15427+M$45)+A(15428+M$45)
     1                                 +A(15429+M$45))
      AA(48) = 0.5 * (A(15472+M)+A(15473+M))
      AAA(1$1200) = Q8VXPND(AA(1$48),BW$AAA(1$1200))
      A(15426+M$48) = Q8VCMPRS(A(14177+M$1200),BW$A(15426+M$48))
C
```

```
      D1 = A(14202+M$1173)
      D2 = A(23027+M$1173)-A(7527+M$1173)+A(8851+M$1173)
     1                                         -A(8852+M$1173)
      A(14202+M$1173) = D1 + D2
      A(14176+M$1200) = Q8VCTRL(AAA(1$1200),BW$A(14176+M$1200))
      A(14176+M$1200) = Q8VCTRL(0.0,BX$A(14176+M$1200))
C
      D4 = VABS(A(14776+M$24)$D4)
      BY = D4.GT.A(15476+M$24)
      A(15476+M$24) = Q8VCTRL(D4,BY$A(15476+M$24))
      FREE
   94 T3 = SECOND(CP)
      PRINT 150, T3
C
C          .....FIELD ENVELOPE PRINTOUT ROUTINE.....
      DO 100 L=NHALF,NMAX,NHALF
      IF(N.EQ.L)GO TO 101
  100 CONTINUE
      IF(N.EQ.NMAX)GO TO 101
      GO TO 199
C
C          .....AT HORIZONTAL OBSERVATION PLANE.....
  101 IF(N.EQ.NMAX)IPUN=1
      PRINT 102, N
  102 FORMAT(1H1,52X,27HEX ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(8801,20,RC,IPUN)
C
      PRINT 103, N
  103 FORMAT(1H1,52X,27HEY ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(10126,20,RC,IPUN)
C
      PRINT 104, N
  104 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(11451,20,RC,IPUN)
C
      PRINT 105, N
  105 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(12776,20,3.77E+6,IPUN)
C
      PRINT 106, N
  106 FORMAT(1H1,52X,27HHY ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(14151,20,3.77E+6,IPUN)
C
      PRINT 107, N
  107 FORMAT(1H1,52X,27HHZ ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(15476,20,3.77E+6,IPUN)
```

```
C
C          .....AT VERTICAL SYMMETRY PLANE.....
      PRINT 108, N
  108 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(11476,40,RC,IPUN)
C
      PRINT 109, N
  109 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(12801,40,3.77E+6,IPUN)
      CUR1 = A(49*15500+10178) * RC * 73.33
      CUR2 = A(78*15500+10161) * RC * 73.33
      PRINT 150, CUR1
      PRINT 150, CUR2
C
      PRINT 110, N
  110 FORMAT(1H1,52X,27HEY ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(10151,40,RC,IPUN)
C
  199 CONTINUE
  200 CONTINUE
  201 T4 = SECOND(CP)
      PRINT 150, T4
      STOP
      END

      SUBROUTINE ENV(LOCA,NUM,SCALE,IPUNCH)
      DIMENSION A(1565500),IP(4000),NN(50)
      COMMON A
C
      DO 1 I=1,50
    1 NN(I) = I
C
      DO 2 LY=2,100
      LOC = LOCA + (LY-1)*15500 + 4
      LOCI = 1 + (LY-1)*40
      IP(LOCI$NUM) = SCALE * A(LOC$NUM)
    2 A(LOC$NUM) = 0.
C
      IF(IPUNCH.EQ.0)GO TO 5
      DO 3 LY=2,100
      LOCI = 1 + (LY-1)*40
      LOCII = LOCI - 1 + NUM
    3 WRITE(8,4) (IP(LL),LL=LOCI,LOCII)
    4 FORMAT(10I6)
C
    5 LXM = NUM/20
      DO 8 LX=1,LXM
      LXA = 1 + (LX-1)*20
      LA = LXA + 4
      LZ = LA + 19
```

```
      DO 6 LY=2,100
      LYY = 102 - LY
      LOCI = LXA + (LYY-1)*40
      LOCII = LOCI + 19
    6 PRINT 7, LYY, (IP(LL),LL=LOCI,LOCII)
    7 FORMAT(1X,I3,5X,20I6)
    8 PRINT 9, (NN(LL),LL=LA,LZ)
    9 FORMAT(//,8X,20I6,//////)
C
      RETURN
      END
```

2.5 Problem E -- Task 5, Case 1
(Section 7.4.1 of Volume 1)

The following 10 pages list the computer program for the 24 x 163 x 24 cell -- 800 time step run of Problem E. The problem solved is a hybrid method of moments/FD-TD analysis of penetration of a 19.0 cm diameter, 68.5 cm long, open-ended aluminum cylinder by a 300 MHz plane wave at axial incidence.

```
      PROGRAM FDTD (INPUT,OUTPUT,TAPE60=INPUT,TAPE8=TAPE8)
C
C     RUN TASK5-- INTERFACING THE FD-TD METHOD WITH THE METHOD OF
C                 MOMENTS
C     CASE I- STEADY 300 MHZ TEM IRRADIATION OF A 19.0 CM
C             DIAMETER, 68.5 CM LONG, OPEN-ENDED ALUMINUM
C             CYLINDER
C     AXIAL-INCIDENCE PLANE WAVE WITH COMPONENTS EZ AND HX
C          MODELED USING SCHELKUNOFF EQUIVALENCE THEOREM WITH
C          PROF. DON WILTON'S M-O-M APERTURE CURRENT DATA
C     24 X 163 X 24 CELL CUBIC SPACE LATTICE IS USED
C     UNIT CELL DIAMETER = DX = 0.5 CM = WAVELENGTH/200
C     EVEN SYMMETRY ABOUT LATTICE PLANES X = 24.5*DX AND
C          Z = 24.0*DX IS ASSUMED
C     SOFT LATTICE TRUNCATIONS ARE USED
C     PROGRAM IS OPTIMIZED FOR THE CDC STAR-100
C
      REAL MUR, MUZ, JXMAG, JXPHA, JXSRC, JZMAG, JZPHA, JZSRC
      DIMENSION A(973504),CEXB(97800),CEYB(97800),CEZB(97800),
     1          Z(5936),AAA(600),JXMAG(600),JXPHA(600),JXSRC(600),
     2          JZMAG(600),JZPHA(600),JZSRC(600),AA(25),DD(24),
     3          DE(24),CA(9),CB(9),EPS(3),SIG(3)
      COMMON A,CEXB,CEYB,CEZB
      DESCRIPTOR D1,D2,D3,D4,D5,NFD,A1,A2,BV,BW,BX,BY,BQ
      BIT BV,BBB(600),BW,BBW(600),BX,BBX(600),BY,BBY(24),
     1    BQ,BBQ(600)
      ASSIGN BQ,BBQ(1;600)
      ASSIGN BV,BBB(1;600)
      ASSIGN BW,BBW(1;600)
      ASSIGN BX,BBX(1;600)
      ASSIGN BY,BBY(1;24)
      ASSIGN D4,DD(1;24)
      ASSIGN D5,DE(1;24)
      T1 = SECOND(CP)
      PRINT 150, T1
  150 FORMAT (F20.5)
C
C          .....I. PROBLEM PARAMETERS.....
      FREQ = 3.0E+8
      DX = 0.005
      MPR = 3
      DATA EPS/ 1.0,    1.0,    1.0 /
      DATA SIG/ 0.0,  3.7E+7,  0.01 /
      NMAX = 800
C
C          .....II. BASIC AND DERIVED CONSTANTS.....
      PI = 3.14159265
      MUZ = 4.0 * PI * 1.0E-7
      EPSZ = 8.854E-12
      DT = DX / 6.0E+8
      NHALF = 0.5 / FREQ / DT
      R = DT / 2.0 / EPSZ
```

```
      RA = DT**2 / DX**2 / MUZ / EPSZ
      RB = DT / DX / MUZ
      RC = 1.0 / RB
      RD = 2.0 * PI * FREQ * DT
      IPUN = 0
C
      CA(1;9) = 0.
      CB(1;9) = 0.
      BW = QBVMKO(1,25;BW)
      BX = QBVMKZ(24,25;BX)
      DO 2 I=1,MPR
      EAF = R * SIG(I) / EPS(I)
      CA(I) = (1.0-EAF) / (1.0+EAF)
    2 CB(I) = RA / EPS(I) / (1.0+EAF)
C
C           .....III. LOAD VECTOR A.....
C           .....ZERO INITIAL FIELDS.....
      Z(1;5936) = 0.
      A(1;5936) = 0.
      A(967569;5936) = 0.
C
C           .....TYPE OF MEDIUM.....
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
    4 FORMAT (75F1.0)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      DO 5 J=2,13
      JDEL = (J-1) * 5936
    5 A(JDEL+1;5936) = Z(1;5936)
      DO 6 J=152,163
      JDEL = (J-1) * 5936
    6 A(JDEL+1;5936) = Z(1;5936)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      DO 7 J=14,150
      JDEL = (J-1) * 5936
    7 A(JDEL+1;5936) = Z(1;5936)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2601,3200)
      READ(60,4,END=201,ERR=201) (Z(I),I=1301,1900)
      J = 151
      JDEL = (J-1) * 5936
      A(JDEL+1;5936) = Z(1;5936)
C
C           .....APERTURE EXCITATION.....
      READ(60,10,END=201,ERR=201) (JXMAG(I),I=1,600)
      READ(60,11,END=201,ERR=201) (JXPHA(I),I=1,600)
      READ(60,10,END=201,ERR=201) (JZMAG(I),I=1,600)
      READ(60,11,END=201,ERR=201) (JZPHA(I),I=1,600)
   10 FORMAT (12F6.2,/,13F6.2)
```

```
   11 FORMAT (25F3.0)
C
C           .....MEDIA COEFFICIENTS.....
      ASSIGN A1,.DYN.600
      ASSIGN A2,.DYN.600
      ASSIGN NED,.DYN.600
      A1 = 0.
      A2 = 0.
      DO 23 J=2,163
      JDEL = (J-1) * 5936
      JDEM = (J-1) * 600
C
      NED = A(JDEL+1;600)
      DO 20 JJ=1,MPR
      BV = NED.EQ.JJ
      A1 = Q8VCTRL(CA(JJ),BV;A1)
   20 A2 = Q8VCTRL(CB(JJ),BV;A2)
      A(JDEL+1;600) = A1
      CEXB(JDEM+1;600) = A2
C
      NED = A(JDEL+1301;600)
      DO 21 JJ=1,MPR
      BV = NED.EQ.JJ
      A1 = Q8VCTRL(CA(JJ),BV;A1)
   21 A2 = Q8VCTRL(CB(JJ),BV;A2)
      A(JDEL+1301;600) = A1
      CEYB(JDEM+1;600) = A2
C
      NED = A(JDEL+2601;600)
      DO 22 JJ=1,MPR
      BV = NED.EQ.JJ
      A1 = Q8VCTRL(CA(JJ),BV;A1)
   22 A2 = Q8VCTRL(CB(JJ),BV;A2)
      A(JDEL+2601;600) = A1
   23 CEZB(JDEM+1;600) = A2
      FREE
C
      T2 = SECOND(CP)
      PRINT 150, T2
C
C           .....IV. TIME-STEPPING LOOP.....
      DO 200 N=1,NMAX
C
C           .....COMPUTE APERTURE SOURCE CURRENTS.....
      ASSIGN D1,.DYN.600
      ASSIGN D2,.DYN.600
      ASSIGN D3,.DYN.600
C
      D1 = FLOAT(N) - JXPHA(1;600)
      BQ = D1.LT.0.0
      D1 = Q8VCTRL(0.0,BQ;D1)
      D2 = D1 * RD
```

```
      D3 = VSIN(D2$D3)
      JXSRC(1$600) = -1.0 * JXMAG(1$600) * CB(1) * D3
C
      D1 = FLOAT(N) - JZPHA(1$600)
      BQ = D1.LT.0.0
      D1 = QBVCTRL(0.0,BQ$D1)
      D2 = D1 * RD
      D3 = VSIN(D2$D3)
      JZSRC(1$600) = JZMAG(1$600) * CB(1) * D3
      FREE
C
      MCALL = 7 + IFIX(FLOAT(N)/6.0)
      IF(MCALL.GT.54)MCALL=54
C
C          .....TRANSVERSE PLANE NO. 1.....
C          .....EX, EZ TRUNCATIONS.....
      A(626$625) = A(1$625)
      A(1$625) = A(6562$625)
      A(3226$625) = A(2601$625)
      A(2601$625) = A(9162$625)
C
C          .....EY ITERATION.....
      ASSIGN D1,.DYN.574
      ASSIGN D2,.DYN.574
      ASSIGN D3,.DYN.574
      A(1926) = 0.5 * (A(2551)+A(2552))
      A(1927$22) = 0.333 * (A(2551$22)+A(2552$22)+A(2553$22))
      A(1949) = 0.333 * (A(2573) + 2.0*A(2574))
      A(2551$24) = A(1951$24)
      D1 = CA(3) * A(1951$574)
      D2 = A(3926$574) - A(3901$574) + A(5276$574) - A(5277$574)
      D3 = CB(3) * D2
      A(1951$574) = D1 + D3
      FREE
C
C          .....TRANSVERSE PLANES 2 - 163.....
      DO 82 JY=1,MCALL
      JDEL = (JY-1) * 17808
      JDEM = (JY-1) * 1800
C
C          .....EX ITERATION.....
      ASSIGN D1,.DYN.573
      ASSIGN D2,.DYN.573
      ASSIGN D3,.DYN.573
C
      DO 30 MA=1,3
      M = JDEL + 5936*(MA-1)
      MM = JDEM + 600*(MA-1)
C
C          .....SOFT LATTICE TRUNCATION.....
      A(6563+M) = 0.5 * (A(7188+M)+A(7189+M))
      A(6564+M$21) = 0.333 * (A(7188+M$21)+A(7189+M$21)
     1                                   +A(7190+M$21))
```

```
      A(6585+M) = 0.5 * (A(7209+M)+A(7210+M))
      A(7188+M$23) = A(6588+M$23)
C
C          .....MAIN EX LOOPS.....
      D1 = A(5963+M$573) * A(6588+M$573)
      D2 = A(11213+M$573)-A(5277+M$573)+A(10513+M$573)
     1                                -A(10538+M$573)
      D3 = CEXB(627+MM$573) * D2
      A(6588+M$573) = D1 + D3
C
C          .....JX APERTURE SOURCE CONDITION.....
      IF(M.EQ.12*5936) A(6562+M$600)=JXSRC(1$600)+A(6562+M$600)
   30 CONTINUE
      FREE
C
C          .....EY ITERATION.....
      ASSIGN D1,.DYN.574
      ASSIGN D2,.DYN.574
      ASSIGN D3,.DYN.574
C
      DO 40 MA=1,3
      M = JDEL + 5936*(MA-1)
      MM = JDEM + 600*(MA-1)
C
C          .....SOFT LATTICE TRUNCATION.....
      A(7862+M) = 0.5 * (A(8487+M)+A(8488+M))
      A(7863+M$22) = 0.333 * (A(8487+M$22)+A(8488+M$22)
     1                                +A(8489+M$22))
      A(7885+M) = 0.333 * (A(8509+M) + 2.0*A(8510+M))
      A(8487+M$24) = A(7887+M$24)
C
C          .....MAIN EY LOOPS.....
      D1 = A(7262+M$574) * A(7887+M$574)
      D2 = A(9862+M$574)-A(9837+M$574)+A(11212+M$574)
     1                                -A(11213+M$574)
      D3 = CEYB(626+MM$574) * D2
      A(7887+M$574) = D1 + D3
C
C          .....EY ENVELOPE COMPUTATION.....
      D4 = Q8VCMPRS(A(7861+M$600),BX$D4)
      D5 = VABS(D4$D5)
      BY = D5.GT.A(8512+M$24)
   40 A(8512+M$24) = Q8VCTRL(D5,BY$A(8512+M$24))
      FREE
C
C          .....EZ ITERATION.....
      ASSIGN D1,.DYN.599
      ASSIGN D2,.DYN.599
      ASSIGN D3,.DYN.599
C
      DO 50 MA=1,3
      M = JDEL + 5936*(MA-1)
      MM = JDEM + 600*(MA-1)
```

```
C
C           .....MAIN FZ LOOPS.....
      D1 = A(8537+M$599) * A(9162+M$599)
      D2 = A(10513+''$599)-A(10512+M$599)+A(3901+M$599)
     1                                      -A(9837+M$599)
      D3 = CEZB(601+MM$599) * D2
      A(9162+M$599) = D1 + D3
C
C           .....JZ APERTURE SOURCE CONDITION.....
      IF(M.EQ.12*5936) A(9162+M$600) = JZSRC(1$600)+A(9162+M$600)
C
C           .....EZ ENVELOPE COMPUTATION.....
      D4 = VABS(A(9737+M$24)$D4)
      BY = D4.GT.A(9787+M$24)
      A(9787+M$24) = Q8VCTRL(D4,BY$A(9787+M$24))
      D4 = Q8VCMPRS(A(9161+M$600),BX$D4)
      D5 = VABS(D4$D5)
      BY = D5.GT.A(9812+M$24)
   50 A(9812+M$24) = Q8VCTRL(D5,BY$A(9812+M$24))
C
C           .....HX ITERATION.....
      DO 60 MA=1,3
      M = JDEL + 5936*(MA-1)
C
C           .....MAIN HX LOOPS.....
      D1 = A(3901+M$599)
      D2 = A(1951+M$599)-A(1926+M$599)+A(3226+M$599)
     1                                   -A(9162+M$599)
      A(3901+M$599) = D1 + D2
C
C           .....HX ENVELOPE COMPUTATION.....
      D4 = VABS(A(4476+M$24)$D4)
      BY = D4.GT.A(4526+M$24)
      A(4526+M$24) = Q8VCTRL(D4,BY$A(4526+M$24))
      D4 = Q8VCMPRS(A(3900+M$600),HX$D4)
      D5 = VABS(D4$D5)
      BY = D5.GT.A(4551+M$24)
   60 A(4551+M$24) = Q8VCTRL(D5,BY$A(4551+M$24))
      FREE
C
C           .....HY ITERATION.....
      ASSIGN D1,.DYN.598
      ASSIGN D2,.DYN.598
C
      DO 70 MA=1,3
      M = JDEL + 5936*(MA-1)
C
C           .....SOFT LATTICE TRUNCATION.....
      AA(1) = 0.5 * (A(11137+M)+A(11138+M))
      AA(2$22) = 0.333 * (A(11137+M$22)+A(11138+M$22)
     1                                 +A(11139+M$22))
      AA(24) = 0.333 * (A(11159+M) + 2.0*A(11160+M))
      AAA(1$600) = Q8VXPND(AA(1$24),BW$AAA(1$600))
```

```
      A(11137+M$24) = Q8VCMPRS(A(10513+M$600),BW$A(11137+M$24))
C
C           .....MAIN HY LOOPS.....
      D1 = A(10513+M$598)
      D2 = A(9163+M$598)-A(9162+M$598)+A(6563+M$598)
     1                                  -A(6588+M$598)
      A(10513+M$598) = D1 + D2
C
      A(10512+M$600) = Q8VCTRL(AAA(1$600),BW$A(10512+M$600))
      A(10512+M$600) = Q8VCTRL(0.0,BX$A(10512+M$600))
C
C           .....HY ENVELOPE COMPUTATION.....
      D4 = VABS(A(11087+M$24)$D4)
      BY = D4.GT.A(11162+M$24)
   70 A(11162+M$24) = Q8VCTRL(D4,BY$A(11162+M$24))
      FREE
C
C           .....HZ ITERATION.....
      ASSIGN D1,.DYN.573
      ASSIGN D2,.DYN.573
C
      DO 80 MA=1,3
      M = JDEL + 5936*(MA-1)
C
C           .....SOFT LATTICE TRUNCATION.....
      AA(2) = 0.5 * (A(5877+M)+A(5878+M))
      AA(3$21) = 0.333 * (A(5877+M$21)+A(5878+M$21)
     1                                  +A(5879+M$21))
      AA(24) = 0.5 * (A(5898+M) + A(5899+M))
      AAA(1$600) = Q8VXPND(AA(1$24),BW$AAA(1$600))
      A(5876+M$24) = Q8VCMPRS(A(5252+M$600),BW$A(5876+M$24))
C
C           .....MAIN HZ LOOPS.....
      D1 = A(5277+M$573)
      D2 = A(6588+M$573)-A(652+M$573)+A(1951+M$573)
     1                                  -A(1952+M$573)
      A(5277+M$573) = D1 + D2
C
      A(5251+M$600) = Q8VCTRL(AAA(1$600),BW$A(5251+M$600))
   80 A(5251+M$600) = Q8VCTRL(0.0,BX$A(5251+M$600))
      FREE
   82 CONTINUE
      IF(MCALL.LE.53)GO TO 94
C
C           .....TRANSVERSE PLANE NO. 164.....
      M = 162 * 5936
C
C           .....EX, EZ TRUNCATIONS.....
      A(6562+M$625) = A(5937+M$625)
      A(5937+M$625) = A(7237+M$625)
      A(7237+M$625) = A(626+M$625)
      A(9162+M$625) = A(8537+M$625)
```

```
      A(8537+M$625) = A(9837+M$625)
      A(9837+M$625) = A(3226+M$625)
C
C            .....HX ITERATION.....
      ASSIGN D1,,DYN,599
      ASSIGN D2,,DYN,599
      D1 = A(3901+M$599)
      D2 = A(1951+M$599)-A(1926+M$599)+A(3226+M$599)
     1                                 -A(9162+M$599)
      A(3901+M$599) = D1 + D2
      D4 = VABS(A(4476+M$24)$D4)
      BY = D4.GT.A(4526+M$24)
      A(4526+M$24) = Q8VCTRL(D4,BY$A(4526+M$24))
      D4 = Q8VCMPRS(A(3900+M$600),BX$D4)
      D5 = VABS(D4$D5)
      BY = D5.GT.A(4551+M$24)
      A(4551+M$24) = Q8VCTRL(D5,BY$A(4551+M$24))
      FREE
C
C            .....HZ ITERATION.....
      ASSIGN D1,,DYN,573
      ASSIGN D2,,DYN,573
      AA(2) = 0.5 * (A(5877+M)+A(5878+M))
      AA(3$21) = 0.333 * (A(5877+M$21)+A(5878+M$21)
     1                                 +A(5879+M$21))
      AA(24) = 0.5 * (A(5898+M) + A(5899+M))
      AAA(1$600) = Q8VXPND(AA(1$24),BW$AAA(1$600))
      A(5876+M$24) = Q8VCMPRS(A(5252+M$600),BW$A(5876+M$24))
      D1 = A(5277+M$573)
      D2 = A(6588+M$573)-A(652+M$573)+A(1951+M$573)
     1                                -A(1952+M$573)
      A(5277+M$573) = D1 + D2
      A(5251+M$600) = Q8VCTRL(AAA(1$600),BW$A(5251+M$600))
      A(5251+M$600) = Q8VCTRL(0.0,BX$A(5251+M$600))
      FREE
   94 T3 = SECOND(CP)
      PRINT 150, T3
C
C            .....FIELD ENVELOPE PRINTOUT ROUTINE.....
      DO 100 L=NHALF,NMAX,NHALF
      IF(N.EQ.L)GO TO 101
  100 CONTINUE
      IF(N.EQ.NMAX)GO TO 101
      GO TO 199
C
C            .....AT HORIZONTAL SYMMETRY PLANE.....
  101 IF(N.EQ.NMAX)IPUN=1
      PRINT 102, N
  102 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(3851,RC,IPUN)
C
```

```
      PRINT 104, N
  104 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL FNV(4526,376.7,IPUN)
C
      PRINT 105, N
  105 FOPMAT(1H1,52X,27HHY FNVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(5226,376.7,IPUN)
C
C            .....AT VERTICAL SYMMETRY PLANE.....
      PRINT 106, N
  106 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(3876,RC,IPUN)
C
      PRINT 108, N
  108 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(4551,376.7,IPUN)
C
      PRINT 109, N
  109 FORMAT(1H1,52X,27HEY ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(2576,RC,IPUN)
C
  199 CONTINUE
  200 CONTINUE
  201 T4 = SECOND(CP)
      PRINT 150, T4
      STOP
      END
      SUBROUTINE ENV(LOCA,SCALE,IPUNCH)
      DIMENSION A(973504),IP(4100),NN(25)
      COMMON A
C
      DO 8 I=1,25
    8 NN(I) = I
C
      DO 1 LY=2,163
      LOC = LOCA + (LY-1)*5936
      LOCI = 1 + (LY-1)*25
      IP(LOCI$25) = SCALE * A(LOC$25)
    1 A(LOC$25) = 0.
C
      IF(IPUNCH.EQ.0)GO TO 4
      DO 2 LY=2,163
      LOCI = 5 + (LY-1)*25
      LOCII = LOCI + 19
    2 WRITE(8,3) (IP(LL),LL=LOCI,LOCII)
    3 FORMAT(10I6)
C
```

```
    4 DO 5 LY=2,163
      LYY = 165 - LY
      LOCI = 5 + (LYY-1)*25
      LOCII = LOCI + 19
    5 PRINT 6, LYY, (IP(LL),LL=LOCI,LOCII)
    6 FORMAT(1X,I3,5X,20I6)
      PRINT 7, (NN(LL),LL=5,24)
    7 FORMAT(//,8X,20I6)
C
      RETURN
      END
```

2.6 Problem F -- Task 5, Case 2
(Section 7.4.2 of Volume 1)

The following 11 pages list the computer program for the 24 x 163 x 48 cell -- 800 time step run of Problem F. The problem solved is a hybrid method of moments/FD-TD analysis of penetration of a 19.0 cm diameter, 68.5 cm long, open-ended aluminum cylinder by a 300 MHz plane wave at 45° incidence relative to the cylinder axis and TM polarized.

```
      PROGRAM FDTD(INPUT,OUTPUT,TAPE60=INPUT,TAPE6=TAPE3)
C
C     RDP TASK5-- INTERFACING THE FD-TD METHOD WITH THE METHOD
C                 OF MOMENTS
C     CASE II-- STEADY 300 MHZ TM-POLARIZED PLANE-WAVE IRRADIATION
C               OF A 19.0 CM DIAMETER, 68.5 CM LONG, OPEN-ENDED
C               CONDUCTING CYLINDER
C     OBLIQUE-INCIDENCE PLANE WAVE WITH COMPONENTS EZ AND HX
C           MODELED
C           USING SCHELKUNOFF EQUIVALENCE THEOREM FOR WILTON/
C           GLISSON M-O-M APERTURE CURRENT DATA
C     24 X 163 X 48 CELL CUBIC SPACE LATTICE IS USED
C     UNIT CELL DIAMETER = DX = 0.50 CM = WAVELENGTH/200
C     EVEN SYMMETRY ABOUT LATTICE PLANE X = 24.5*DX IS ASSUMED
C     SOFT LATTICE TRUNCATIONS ARE USED
C     PROGRAM IS OPTIMIZED FOR THE CDC STAR-100
C
      REAL MUR,MUZ,JXMAG,JXPHA,JXSRC,JZMAG,JZPHA,JZSRC
      DIMENSION A(2542000),Z(15500),AAA(1200),BUF(600),AA(48),
     1          DD(24),DE(48),DF(48),CA(9),CB(9),EPS(3),SIG(3)
      DIMENSION JXMAG(1200),JXPHA(1200),JXSRC(1200),
     1          JZMAG(1200),JZPHA(1200),JZSRC(1200)
      COMMON A
      DESCRIPTOR D1,D2,D3,D4,D5,D6,DFD,A1,A2,BU,BV,BW,BX,BY,BZ
      DESCRIPTOR BQ
      BIT BU,BBU(600),BV,BBV(1200),BW,BBW(1200),BX,BBX(1200),
     1    BY,BBY(24),BZ,BBZ(48)
      BIT BQ, BBQ(1200)
      ASSIGN BU,BBU(1;600)
      ASSIGN BV,BBV(1;1200)
      ASSIGN BW,BBW(1;1200)
      ASSIGN BX,BBX(1;1200)
      ASSIGN BY,BBY(1;24)
      ASSIGN BZ,BBZ(1;48)
      ASSIGN BQ,BBQ(1;1200)
      ASSIGN D4,DD(1;24)
      ASSIGN D5,DE(1;48)
      ASSIGN D6,DF(1;48)
      T1 = SECOND(CP)
      PRINT 150, T1
  150 FORMAT(F20.5)
C
C           .....I. PROBLEM PARAMETERS.....
      FREQ = 3.0E+8
      DX = 0.005
      MPR = 3
      DATA EPS /1.0, 1.0, 1.0/
      DATA SIG /0.0, 3.7E+7, 0.01/
      NMAX = 800
C
C           .....II. BASIC AND DERIVED CONSTANTS.....
      PI = 3.14159265
      MUZ = 4.0 * PI * 1.0E-7
```

```
      EPSZ = 8.854E-12
      DT = DX / 6.0E+8
      NHALF = 0.5 / FREQ / DT
      R = DT / 2.0 / EPSZ
      RA = DT**2 / DX**2 / MUZ / EPSZ
      RB = DT / DX / MUZ
      RC = 1.0/RB
      RF = 2.0 * PI * FREQ * DT
      IRUN = 0
C
      CA(1;9) = 0.
      CB(1;9) = 0.
      BY = Q8VMFO(1,25;BW)
      BX = Q8VMKZ(24,25;BX)
      DO 2 I=1,MPR
      EAF = R * SIG(I) / EPS(I)
      CA(I) = (1.0 - EAF) / (1.0 + EAF)
    2 CB(I) = RA / EPS(I) / (1.0 + EAF)
C
C           .....III. LOAD VECTOR A.....
C           .....ZERO INITIAL FIELDS.....
      Z(1;15500) = 0.
      A(1;15500) = 0.
      A(2526501;15500) = 0.
C
C           .....TYPE OF MEDIUM.....
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
    4 FORMAT(75F1.0)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      DO 5 J=2,13
      JDEL = (J-1) * 15500
    5 A(JDEL+1;15500) = Z(1;15500)
      DO 6 J=152,163
      JDEL = (J-1) * 15500
    6 A(JDEL+1;15500) = Z(1;15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      DO 7 J=14,150
      JDEL = (J-1) * 15500
    7 A(JDEL+1;15500) = Z(1;15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      J = 151
      JDEL = (J-1) * 15500
      A(JDEL+1;15500) = Z(1;15500)
C
C           .....APERTURE EXCITATION.....
      READ(60,15,END=201,ERR=201) (JXMAG(I),I=1,1200)
```

```
      READ(60,16,END=201,ERR=201) (UXPHA(I),I=1,1200)
      READ(60,15,END=201,ERR=201) (UZMAG(I),I=1,1200)
      READ(60,16,END=201,ERR=201) (UZPHA(I),I=1,1200)
   15 FORMAT(12F6.2,/,13F6.2)
   16 FORMAT(25F3.0)
C
C           .....SYMMETRY ABOUT Z = 24.0*DX.....
      DO 12 J=2,163
      JDEL = (J-1) * 15500
      KMAX = 49
      DO 12 JA=1,3
      JB = JDEL + (JA-1)*2500 + 1
      BUF(1;600) = A(JB;600)
      IF(JA.EQ.3)KMAX=48
      A(JB+600;25) = BUF(576;25)
      DO 12 K=1,24
      KA = (K-1) * 25
      KB = (KMAX-K) * 25
   12 A(JB+KB;25) = BUF(KA+1;25)
C
C
C           .....MEDIA COEFFICIENTS.....
      ASSIGN A1,.DYN.1200
      ASSIGN A2,.DYN.1200
      ASSIGN MED,.DYN.1200
      A1 = 0.
      A2 = 0.
      DO 21 J=2,163
      JDEL = (J-1) * 15500
      DO 21 JA=1,3
      JB = (JA-1)*2500 + 1
      JC = JB + 1250
      MED = A(JDEL+JB;1200)
      DO 20 JJ=1,MPR
      BV = MED.EQ.JJ
      A1 = Q8VCTRL(C4(JJ),BV;A1)
   20 A2 = Q8VCTRL(C5(JJ),BV;A2)
      A(JDEL+JB;1200) = A1
   21 A(JDEL+JC;1200) = A2
      FREE
C
      T2 = SECOND(CP)
      PRINT 150, T2
C
C           .....IV. TIME-STEPPING LOOP.....
      DO 200 N=1,NMAX
      ASSIGN D1,.DYN.1200
      ASSIGN D2,.DYN.1200
      ASSIGN D3,.DYN.1200
C
      D1 = FLOAT(N) - UXPHA(1;1200)
      B0 = D1.LT.0.0
      D1 = Q8VCTRL(0.0,B0;D1)
```

```
      D2 = D1 * RD
      D3 = VSIN(D2;D3)
      JXSRC(1;1200) = JXMAG(1;1200) * CR(1) * D3
C
      D1 = FLOAT(N) - JZPHA(1;1200)
      RD = D1.LT.0.0
      D1 = GRVCTRL(0.0,RD;D1)
      D2 = D1 * RD
      D3 = VSIN(D2;D3)
      JZSRC(1;1200) = JZMAG(1;1200) * CB(1) * D3
      FREE
C
      MCALL = 7 + IFIX(FLOAT(N)/6.0)
      IF(MCALL.GT.54) MCALL=54
C
C           .....TRANSVERSE PLANE NO. 1.....
C           .....EX, EZ TRUNCATIONS.....
      A(7501;1250) = A(1;1250)
      A(1;1250) = A(23001;1250)
      A(10201;1250) = A(1251;1250)
      A(1251;1250) = A(25701;1250)
C
C           .....EY ITERATION.....
      ASSIGN D1,.DYN.1174
      ASSIGN D2,.DYN.1174
      ASSIGN D3,.DYN.1174
C
      A(8826) = 0.5 * (A(10076)+A(10077))
      A(8827;22) = 0.333 * (A(10076;22)+A(10077;22)+A(10078;22))
      A(8849) = 0.333 * (A(10098)+2.0*A(10099))
      A(10076;24) = A(8851;24)
C
      A(10026) = 0.5 * (A(10101)+A(10102))
      A(10027;22) = 0.333 * (A(10101;22)+A(10102;22)+A(10103;22))
      A(10049) = 0.333 * (A(10123)+2.0*A(10124))
      A(10101;24) = A(10001;24)
C
      D1 = CA(3) * A(8851;1174)
      D2 = A(11551;1174)-A(11526;1174)+A(14201;1174)-A(14202;1174)
      D3 = CB(3) * D2
      A(8851;1174) = D1 + D3
      FREE
C
C           .....TRANSVERSE PLANES 2 - 163.....
      DO 82 JY=1,MCALL
      JREL = (JY-1) * 46500
C
C           .....EX ITERATION.....
      ASSIGN D1,.DYN.1173
      ASSIGN D2,.DYN.1173
      ASSIGN D3,.DYN.1173
C
      DO 30 MA=1,3
```

```
      M = JDEL + 15500*(MA-1)
C
C          .....SOFT LATTICE TRUNCATIONS.....
      A(23002+M) = 0.5 * (A(24252+M)+A(24253+M))
      A(23003+M;21) = 0.333 * (A(24252+M;21)+A(24253+M;21)
     1                                +A(24254+M;21))
      A(23024+M) = 0.5 * (A(24273+M)+A(24274+M))
      A(24252+M;23) = A(23027+M;23)
C
      A(24202+M) = 0.5 * (A(24277+M)+A(24278+M))
      A(24203+M;21) = 0.333 * (A(24277+M;21)+A(24278+M;21)
     1                                +A(24279+M;21))
      A(24224+M) = 0.5 * (A(24298+M)+A(24299))
      A(24277+M;23) = A(24177+M;23)
C
C          .....MAIN EX LOOPS.....
      D1 = A(15527+M;1173) * A(23027+M;1173)
      D2 = A(24702+M;1173)-A(14202+M;1173)+A(26352+M;1173)
     1                                -A(26377+M;1173)
      D3 = A(16777+M;1173) * D2
      A(23027+M;1173) = D1 + D3
C
C          .....JX APERTURE SOURCE CONDITION.....
      IF(M.EQ.12*15500) A(23001+M;1200) = JXSRC(1;1200) +
     1                                A(23001+M;1200)
C
C          .....EX ENVELOPE COMPUTATION.....
      D4 = VABS(A(23601+M;24);D4)
      BY = D4.GT.A(24301+M;24)
   30 A(24301+M;24) = Q8VCTRL(D4,BY;A(24301+M;24))
      FREE
C
C          .....EY ITERATION.....
      ASSIGN D1,.DYN.1174
      ASSIGN D2,.DYN.1174
      ASSIGN D3,.DYN.1174
C
      DO 40 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C          .....SOFT LATTICE TRUNCATIONS.....
      A(24326+M) = 0.5 * (A(25576+M)+A(25577+M))
      A(24327+M;22) = 0.333 * (A(25576+M;22)+A(25577+M;22)
     1                                +A(25578+M;22))
      A(24349+M) = 0.333 * (A(25598+M)+2.0*A(25599+M))
      A(25576+M;24) = A(24351+M;24)
C
      A(25526+M) = 0.5 * (A(25601+M)+A(25602+M))
      A(25527+M;22) = 0.333 * (A(25601+M;22)+A(25602+M;22)
     1                                +A(25603+M;22))
      A(25549+M) = 0.333 * (A(25623+M)+2.0*A(25624+M))
      A(25601+M;24) = A(25501+M;24)
C
```

```
C          .....MAIN EY LOOPS.....
      D1 = A(16026+M;1174) * A(24351+M;1174)
      D2 = A(27051+M;1174)-A(27026+M;1174)+A(29701+M;1174)
     1                                     -A(29702+M;1174)
      D3 = A(19276+M;1174) * D2
      A(24351+M;1174) = D1 + D3
C
C          .....EY ENVELOPE COMPUTATION.....
      D4 = VABS(A(24926+M;24);D4)
      BY = D4.GT.A(25626+M;24)
      A(25626+M;24) = QBVCTRL(D4,BY;A(25626+M;24))
C
      D5 = QBVCMPRS(A(24325+M;1200),BX;D5)
      D6 = VABS(D5;D6)
      BZ = D6.GT.A(25651+M;48)
   40 A(25651+M;48) = QBVCTRL(D6,BZ;A(25651+M;48))
      FREE
C
C          .....EZ ITERATION.....
      ASSIGN D1,.DYN.1199
      ASSIGN D2,.DYN.1199
      ASSIGN D3,.DYN.1199
C
      DO 50 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C          .....MAIN EZ LOOPS.....
      D1 = A(20501+M;1199) * A(25701+M;1199)
      D2 = A(28352+M;1199)-A(28351+M;1199)+A(11526+M;1199)
     1                                     -A(27026+M;1199)
      D3 = A(21751+M;1199) * D2
      A(25701+M;1199) = D1 + D3
C
C          .....JZ APERTURE SOURCE CONDITION.....
      IF(M.EQ.12*15500) A(25701+M;1200) = JZSRC(1;1200) +
     1                                    A(25701+M;1200)
C
C          .....EZ ENVELOPE COMPUTATION.....
      A(26926+M;24) = 0.5 * (A(26276+M;24)+A(26301+M;24))
      D4 = VABS(A(26926+M;24);D4)
      BY = D4.GT.A(26951+M;24)
      A(26951+M;24) = QBVCTRL(D4,BY;A(26951+M;24))
C
      D5 = QBVCMPRS(A(25700+M;1200),BX;D5)
      D6 = VABS(D5;D6)
      BZ = D6.GT.A(26976+M;48)
   50 A(26976+M;48) = QBVCTRL(D6,BZ;A(26976+M;48))
C
C          .....HX ITERATION.....
      DO 60 MA=1,3
      M = JDEL + 15500*(MA-1)
C
```

```
C          .....MAIN HX LOOPS.....
      D1 = A(11526+M;1199)
      D2 = A(8851+M;1199)-A(8826+M;1199)+A(10201+M;1199)
     1                                    -A(25701+M;1199)
      A(11526+M;1199) = D1 + D2
C
C          .....HX ENVELOPE COMPUTATION.....
      A(12751+M;24) = 0.5 * (A(12101+M;24)+A(12126+M;24))
      D4 = VABS(A(12751+M;24);D4)
      BY = D4.GT.A(12776+M;24)
      A(12776+M;24) = QBVCTRL(D4,BY;A(12776+M;24))
C
      D5 = QBVCMPRS(A(11525+M;1200),BX;D5)
      D6 = VABS(D5;D6)
      BZ = D6.GT.A(12801+M;48)
   60 A(12801+M;48) = QBVCTRL(D6,BZ;A(12801+M;48))
      FREE
C
C          .....HY ITERATION.....
      ASSIGN D1,.DYN.1198
      ASSIGN D2,.DYN.1198
C
      DO 70 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C          .....SOFT LATTICE TRUNCATION.....
      AA(1) = 0.5 * (A(29601+M)+A(29602+M))
      AA(2;46) = 0.333 * (A(29601+M;46)+A(29602+M;46)
     1                               +A(29603+M;46))
      AA(48) = 0.5 * (A(29647+M)+A(29648+M))
      AAA(1;1200) = QBVXPND(AA(1;48),BW;AAA(1;1200))
      A(29601+M;48) = QBVCMPRS(A(28352+M;1200),BW;A(29601+M;48))
C
C          .....MAIN HY LOOPS.....
      D1 = A(28352+M;1198)
      D2 = A(25702+M;1198)-A(25701+M;1198)+A(23002+M;1198)
     1                                    -A(23027+M;1198)
      A(28352+M;1198) = D1 + D2
C
      A(28351+M;1200) = QBVCTRL(AAA(1;1200),BW;A(28351+M;1200))
      A(28351+M;1200) = QBVCTRL(0.0,BX;A(28351+M;1200))
C
C          .....HY ENVELOPE COMPUTATION.....
      A(29576+M;24) = 0.5 * (A(28926+M;24)+A(28951+M;24))
      D4 = VABS(A(29576+M;24);D4)
      BY = D4.GT.A(29651+M;24)
   70 A(29651+M;24) = QBVCTRL(D4,BY;A(29651+M;24))
      FREE
C
C          .....HZ ITERATION.....
      ASSIGN D1,.DYN.1173
      ASSIGN D2,.DYN.1173
C
```

```
      DO 80 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C           .....SOFT LATTICE TRUNCATION.....
      AA(2) = 0.5 * (A(15427+M)+A(15428+M))
      AA(3;45) = 0.333 * (A(15427+M;45)+A(15428+M;45)
     1                                  +A(15429+M;45))
      AA(48) = 0.5 * (A(15472+M)+A(15473+M))
      AAA(1;1200) = Q8VXPND(AA(1;48),BW;AAA(1;1200))
      A(15426+M;48) = Q8VCMPRS(A(14177+M;1200),BW;A(15426+M;48))
C
C           .....MAIN HZ LOOPS.....
      D1 = A(14202+M;1173)
      D2 = A(23027+M;1173)-A(7527+M;1173)+A(8851+M;1173)
     1                                    -A(8852+M;1173)
      A(14202+M;1173) = D1 + D2
C
      A(14176+M;1200) = Q8VCTRL(AAA(1;1200),BW;A(14176+M;1200))
      A(14176+M;1200) = Q8VCTRL(0.0,FX;A(14176+M;1200))
C
C           .....HZ ENVELOPE COMPUTATION.....
      D4 = VABS(A(14776+M;24);D4)
      BY = D4.GT.A(15476+M;24)
   80 A(15476+M;24) = Q8VCTRL(D4,BY;A(15476+M;24))
      FREE
   82 CONTINUE
      IF(MCALL.LE.53)GO TO 94
C
C           .....TRANSVERSE PLANE NO. 164.....
      M = 162 * 15500
C
C           .....EX, EZ TRUNCATIONS.....
      A(23001+M;1250) = A(15501+M;1250)
      A(15501+M;1250) = A(16751+M;1250)
      A(16751+M;1250) = A(7501+M;1250)
C
      A(25701+M;1250) = A(18001+M;1250)
      A(18001+M;1250) = A(19251+M;1250)
      A(19251+M;1250) = A(10201+M;1250)
C
C           .....HX ITERATION.....
      ASSIGN D1,.DYN.1199
      ASSIGN D2,.DYN.1199
      D1 = A(11526+M;1199)
      D2 = A(8851+M;1199)-A(8826+M;1199)+A(10201+M;1199)
     1                                    -A(25701+M;1199)
      A(11526+M;1199) = D1 + D2
C
      A(12751+M;24) = 0.5 * (A(12101+M;24)+A(12126+M;24))
      D4 = VABS(A(12751+M;24);D4)
      BY = D4.GT.A(12776+M;24)
      A(12776+M;24) = Q8VCTRL(D4,BY;A(12776+M;24))
C
```

```
      D5 = Q8VCMPRS(A(11525+M;1200),BX;D5)
      D6 = VABS(D5;D6)
      BZ = D6.GT.A(12801+M;48)
      A(12801+M;48) = Q8VCTRL(D6,BZ;A(12801+M;48))
      FREE
C
C           .....HZ ITERATION.....
      ASSIGN D1,.DYN.1173
      ASSIGN D2,.DYN.1173
      AA(2) = 0.5 * (A(15427+M)+A(15428+M))
      AA(3;45) = 0.333 * (A(15427+M;45)+A(15428+M;45)
     1                                +A(15429+M;45))
      AA(48) = 0.5 * (A(15472+M)+A(15473+M))
      AAA(1;1200) = Q8VXPND(AA(1;48),BW;AAA(1;1200))
      A(15426+M;48) = Q8VCMPRS(A(14177+M;1200),BW;A(15426+M;48))
C
      D1 = A(14202+M;1173)
      D2 = A(23027+M;1173)-A(7527+M;1173)+A(8851+M;1173)
     1                                    -A(8852+M;1173)
      A(14202+M;1173) = D1 + D2
      A(14176+M;1200) = Q8VCTRL(AAA(1;1200),BW;A(14176+M;1200))
      A(14176+M;1200) = Q8VCTRL(0.0,BX;A(14176+M;1200))
C
      D4 = VABS(A(14776+M;24);D4)
      BY = D4.GT.A(15476+M;24)
      A(15476+M;24) = Q8VCTRL(D4,BY;A(15476+M;24))
      FREE
   94 T3 = SECOND(CP)
      PRINT 150, T3
C
C           .....FIELD ENVELOPE PRINTOUT ROUTINE.....
      DO 100 L=NHALF,NMAX,NHALF
      IF(N.EQ.L)GO TO 101
  100 CONTINUE
      IF(N.EQ.NMAX)GO TO 101
      GO TO 199
C
C           .....AT HORIZONTAL OBSERVATION PLANE.....
  101 IF(N.EQ.NMAX)IPUN=1
      IPUN = 0
      PRINT 102, N
  102 FORMAT(1H1,52X,27HEX ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(8801,20,RC,IPUN)
C
      PRINT 103, N
  103 FORMAT(1H1,52X,27HEY ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(10126,20,RC,IPUN)
C
      PRINT 104, N
  104 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
```

```
      CALL ENV(11451,20,RC,IPUN)
C
      PRINT 105, N
  105 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(12776,20,376.7,IPUN)
C
      PRINT 106, N
  106 FORMAT(1H1,52X,27HHY ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(14151,20,376.7,IPUN)
C
      PRINT 107, N
  107 FORMAT(1H1,52X,27HHZ ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(15476,20,376.7,IPUN)
C
C             .....AT VERTICAL SYMMETRY PLANE.....
      PRINT 108, N
  108 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(11476,40,RC,IPUN)
C
      PRINT 109, N
  109 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(12801,40,376.7,IPUN)
C
      PRINT 110, N
  110 FORMAT(1H1,52X,27HEY ENVELOPE FOR TIME STEP =,I5,
     1         //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(10151,40,RC,IPUN)
C
  199 CONTINUE
  200 CONTINUE
  201 T4 = SECOND(CP)
      PRINT 150, T4
      STOP
      END

      SUBROUTINE ENV(LOCA,NUM,SCALE,IPUNCH)
      DIMENSION A(2542000),IP(8000),NN(50)
      COMMON A
C
      DO 1 I=1,50
    1 NN(I) = I
      IP(1;8000) = 0
C
      DO 2 LY=2,163
      LOC = LOCA + (LY-1)*15500 + 4
      LOCI = 1 + (LY-1)*40
      IP(LOCI;NUM) = SCALE * A(LOC;NUM)
    2 A(LOC;NUM) = 0.
```

```
C
      IF(IPUNCH.EQ.0)GO TO 5
      DO 3 LY=2,163
      LOCI = 1 + (LY-1)*40
      LOCII = LOCI - 1 + NUM
    3 WRITE(8,4) (IP(LL),LL=LOCI,LOCII)
    4 FORMAT(10I6)
C
    5 LXM = NUM/20
      DO 8 LX=1,LXM
      LXA = 1 + (LX-1)*20
      LA = LXA + 4
      LZ = LA + 19
      DO 6 LY=2,163
      LYY = 165 - LY
      LOCI = LXA + (LYY-1)*40
      LOCII = LOCI + 19
    6 PRINT 7, LYY, (IP(LL),LL=LOCI,LOCII)
    7 FORMAT(1X,I3,5X,20I6)
    8 PRINT 9, (NN(LL),LL=LA,LZ)
    9 FORMAT(//,8X,20I6,//////)
C
      RETURN
      END
```

2.7 Problem G -- Task 5, Case 3 (Section 7.4.3 of Volume 1)

The following 13 pages list the computer program for the 24 x 100 x 48 cell -- 1800 time step run of Problem G. The problem solved is a hybrid method of moments/FD-TD analysis of penetration of a 12.8 cm diameter, 28 cm long, missile guidance section by a 300 MHz plane wave at axial incidence, for the case of the interior dielectric components, metal components, and wires modeled.

```
      PROGRAM FDTD(INPUT,OUTPUT,TAPE60=INPUT,TAPE6=TAPEM)
C
C     RUN TASK5-- INTERFACING THE FD-TD METHOD WITH THE METHOD
C                 OF MOMENTS
C     CASE III- STEADY 300 MHZ PLANE WAVE IRRADIATION OF A
C               12.8 CM DIAMETER MISSILE GUIDANCE SECTION
C     INTERIOR METAL AND DIELECTRIC COMPONENTS MODELED
C     AXIAL-INCIDENCE PLANE WAVE WITH COMPONENTS EZ AND HX MODELED
C          USING SCHELKUNOFF EQUIVALENCE THEOREM FOR WILTON/
C          GLISSON M-O-M APERTURE CURRENT DATA
C     24 X 100 X 48 CELL CUBIC SPACE LATTICE IS USED
C     UNIT CELL DIAMETER = DX = 0.33 CM = WAVELENGTH/300
C     EVEN SYMMETRY ABOUT LATTICE PLANE X = 24.5*DX IS ASSUMED
C     SOFT LATTICE TRUNCATIONS ARE USED
C     PROGRAM IS OPTIMIZED FOR THE CDC STAR-100
C
      REAL MUR,MUZ,JXMAG,JXPHA,JXSRC,JYMAG,JYPHA,JYSRC,JZMAG,
     1     JZPHA,JZSRC
      DIMENSION A(1565500),Z(15500),AAA(1200),BUF(600),AA(48),
     1          DD(24),DE(48),DF(48),CA(9),CB(9),EPS(9),SIG(9)
      DIMENSION JXMAG(1200),JXPHA(1200),JXSRC(1200),
     1          JYMAG(1200),JYPHA(1200),JYSRC(1200),
     2          JZMAG(1200),JZPHA(1200),JZSRC(1200)
      COMMON A
      DESCRIPTOR D1,D2,D3,D4,D5,D6,NFD,A1,A2,BU,BV,BW,BX,BY,BZ
      DESCRIPTOR BQ
      BIT BU,BBU(600),BV,BBV(1200),BW,BBW(1200),BX,BBX(1200),
     1    BY,BBY(24),BZ,BBZ(48)
      BIT BQ, BBQ(1200)
      ASSIGN BU,BBU(1;600)
      ASSIGN BV,BBV(1;1200)
      ASSIGN BW,BBW(1;1200)
      ASSIGN BX,BBX(1;1200)
      ASSIGN BY,BBY(1;24)
      ASSIGN BZ,BBZ(1;48)
      ASSIGN BQ,BBQ(1;1200)
      ASSIGN D4,DD(1;24)
      ASSIGN D5,DE(1;48)
      ASSIGN D6,DF(1;48)
      T1 = SECOND(CP)
      PRINT 150, T1
  150 FORMAT(F20.5)
C
C          .....I. PROBLEM PARAMETERS.....
      FREQ = 3.0E+8
      DX = 0.01/3.0
      MPR = 9
      DATA EPS /1.0, 1.0, 1.0, 5.5, 4.5, 5.3, 1.0, 1.0, 8.0/
      DATA SIG /0.0, 3.7E+7, 0.025, 0.0024, 0.0008, 0.0, 6.6E+6,
     1          3.7E+7, 0.01/
      NMAX = 1800
C
```

```
C          .....II. BASIC AND DERIVED CONSTANTS.....
      PI = 3.14159265
      MUZ = 4.0 * PI * 1.0E-7
      EPSZ = 8.854E-12
      DT = DX / 6.0E+8
      NHALF = 0.5 / FREQ / DT
      R = DT / 2.0 / EPSZ
      RA = DT**2 / DX**2 / MUZ / EPSZ
      RB = DT / DX / MUZ
      RC = 1.0/RB
      RD = 2.0 * PI * FREQ * DT
      IPUN = 0
C
      CA(1;9) = 0.
      CB(1;9) = 0.
      BW = Q8VMKO(1,25;BW)
      BX = Q8VMKZ(24,25;BX)
      DO 2 I=1,MPR
      EAF = R * SIG(I) / EPS(I)
      CA(I) = (1.0 - EAF) / (1.0 + EAF)
    2 CB(I) = RA / EPS(I) / (1.0 + EAF)
C
C          .....III. LOAD VECTOR A.....
C          .....ZERO INITIAL FIELDS.....
      Z(1;15500) = 0.
      A(1;15500) = 0.
      A(1550001;15500) = 0.
C
C          .....TYPE OF MEDIUM.....
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
    4 FORMAT(75F1.0)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      DO 5 J=2,14
      JDEL = (J-1) * 15500
    5 A(JDEL+1;15500) = Z(1;15500)
C
      DO 6 JA=15,71,7
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      JDEL = (JA-1) * 15500
      A(JDEL+1;15500) = Z(1;15500)
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      DO 6 JB=1,6
      JDEL = (JA+JB-1) * 15500
    6 A(JDEL+1;15500) = Z(1;15500)
      DO 7 J=93,100
      JDEL = (J-1) * 15500
    7 A(JDEL+1;15500) = Z(1;15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
```

```
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      DO 8 J=75,77
      JDEL = (J-1) * 15500
    8 A(JDEL+1;15500) = Z(1;15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      J = 78
      JDEL = (J-1) * 15500
      A(JDEL+1;15500) = Z(1;15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      J = 79
      JDEL = (J-1) * 15500
      A(JDEL+1;15500) = Z(1;15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      DO 9 J=80,84
      JDEL = (J-1) * 15500
    9 A(JDEL+1;15500) = Z(1;15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      J = 85
      JDEL = (J-1) * 15500
      A(JDEL+1;15500) = Z(1;15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      DO 10 J=86,87
      JDEL = (J-1) * 15500
   10 A(JDEL+1;15500) = Z(1;15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      READ(60,4,END=201,ERR=201) (Z(I),I=2501,3100)
      DO 11 J=88,91
      JDEL = (J-1) * 15500
   11 A(JDEL+1;15500) = Z(1;15500)
C
      READ(60,4,END=201,ERR=201) (Z(I),I=1,600)
      READ(60,4,END=201,ERR=201) (Z(I),I=5001,5600)
      J = 92
      JDEL = (J-1) * 15500
      A(JDEL+1;15500) = Z(1;15500)
C
C           .....APERTURE EXCITATION.....
      READ(60,15,END=201,ERR=201)(JXMAG(I),I=1,625)
      READ(60,16,END=201,ERR=201)(JXPHA(I),I=1,625)
      READ(60,15,END=201,ERR=201)(JYMAG(I),I=1,625)
```

```
      READ(60,16,END=201,ERR=201)(JYPHA(I),I=1,625)
      READ(60,15,END=201,ERR=201)(JZMAG(I),I=1,625)
      READ(60,16,END=201,ERR=201)(JZPHA(I),I=1,625)
   15 FORMAT(12F6.2,/,13F6.2)
   16 FORMAT(25F3.0)
C
C           .....PARTIAL SYMMETRY ABOUT Z = 24.0*DX.....
      DO 12 J=2,100
      JDEL = (J-1) * 15500
      KMAX = 49
      DO 12 JA=1,3
      JB = JDEL + (JA-1)*2500 + 1
      BUF(1;600) = A(JB;600)
      BU = BUF(1;600).GT.6.5
      BUF(1;600) = Q8VCTRL(3.0,BU;BUF(1;600))
      IF(JA.EQ.3)KMAX=48
      A(JB+600;25) = BUF(576;25)
      DO 12 K=1,24
      KA = (K-1) * 25
      KB = (KMAX-K) * 25
   12 A(JB+KB;25) = BUF(KA+1;25)
C
C           .....NON-SYMMETRIC GROUND WIRE.....
      DO 13 J=43,57
      JDEL = (J-1) * 15500
      A(JDEL+3199) = 7.0
      A(JDEL+3224) = 7.0
   13 A(JDEL+5699) = 7.0
C
      DO 14 K=18,28
      KDEL = (K-1)*25 + 24
      A(JDEL+2500+KDEL) = 7.0
      A(JDEL+5000+KDEL) = 7.0
   14 A(JDEL+20500+KDEL) = 7.0
C
C           .....APERTURE EXCITATION.....
      DO 17 K=2,24
      KA = (K-1)*25 + 1
      KB = (49-K)*25 + 1
      JXMAG(KB;25) = -JXMAG(KA;25)
      JXPHA(KB;25) = JXPHA(KA;25)
      JYMAG(KB;25) = -JYMAG(KA;25)
      JYPHA(KB;25) = JYPHA(KA;25)
      KA = KA - 25
      JZMAG(KB;25) = JZMAG(KA;25)
   17 JZPHA(KB;25) = JZPHA(KA;25)
C
C           .....MEDIA COEFFICIENTS.....
      ASSIGN A1,.DYN.1200
      ASSIGN A2,.DYN.1200
      ASSIGN NFD,.DYN.1200
      A1 = 0.
      A2 = 0.
```

```
      DO 21 J=2,100
      JDEL = (J-1) * 15500
      DO 21 JA=1,3
      JB = (JA-1)*2500 + 1
      JC = JB + 1250
      NFD = A(JDEL+JB;1200)
      DO 20 JJ=1,MPR
      BV = NFD.EQ.JJ
      A1 = QBVCTRL(CA(JJ),BV;A1)
   20 A2 = QBVCTRL(CB(JJ),BV;A2)
      A(JDEL+JB;1200) = A1
   21 A(JDEL+JC;1200) = A2
      FREE
C
      T2 = SECOND(CP)
      PRINT 150, T2
C
C           .....IV. TIME-STEPPING LOOP.....
      DO 200 N=1,NMAX
      ASSIGN D1,.DYN.1200
      ASSIGN D2,.DYN.1200
      ASSIGN D3,.DYN.1200
C
      D1 = FLOAT(N) - JXPHA(1;1200)
      BQ = D1.LT.0.0
      D1 = QBVCTRL(0.0,BQ;D1)
      D2 = D1 * RD
      D3 = VSIN(D2;D3)
      JXSRC(1;1200) = JXMAG(1;1200) * CB(1) * D3
C
      D1 = FLOAT(N) - JYPHA(1;1200)
      BQ = D1.LT.0.0
      D1 = QBVCTRL(0.0,BQ;D1)
      D2 = D1 * RD
      D3 = VSIN(D2;D3)
      JYSRC(1;1200) = JYMAG(1;1200) * CB(1) * D3
C
      D1 = FLOAT(N) - JZPHA(1;1200)
      BQ = D1.LT.0.0
      D1 = QBVCTRL(0.0,BQ;D1)
      D2 = D1 * RD
      D3 = VSIN(D2;D3)
      JZSRC(1;1200) = JZMAG(1;1200) * CB(1) * D3
      FREE
C
      MCALL = 33
C
C           .....TRANSVERSE PLANE NO. 1.....
C           .....EX, EZ TRUNCATIONS.....
      A(7501;1250) = A(1;1250)
      A(1;1250) = A(23001;1250)
      A(10201;1250) = A(1251;1250)
      A(1251;1250) = A(25701;1250)
```

```
C
C          .....EY ITERATION.....
      ASSIGN D1,.DYN.1174
      ASSIGN D2,.DYN.1174
      ASSIGN D3,.DYN.1174
C
      A(8826) = 0.5 * (A(10076)+A(10077))
      A(8827;22) = 0.333 * (A(10076;22)+A(10077;22)+A(10078;22))
      A(8849) = 0.333 * (A(10098)+2.0*A(10099))
      A(10076;24) = A(8851;24)
C
      A(10026) = 0.5 * (A(10101)+A(10102))
      A(10027;22) = 0.333 * (A(10101;22)+A(10102;22)+A(10103;22))
      A(10049) = 0.333 * (A(10123)+2.0*A(10124))
      A(10101;24) = A(10001;24)
C
      D1 = CA(3) * A(8851;1174)
      D2 = A(11551;1174)-A(11526;1174)+A(14201;1174)-A(14202;1174)
      D3 = CB(3) * D2
      A(8851;1174) = D1 + D3
      FREE
C
C          .....TRANSVERSE PLANES 2 - 100.....
      DO 82 JY=1,MCALL
      JDEL = (JY-1) * 46500
C
C          .....EX ITERATION.....
      ASSIGN D1,.DYN.1173
      ASSIGN D2,.DYN.1173
      ASSIGN D3,.DYN.1173
C
      DO 30 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C          .....SOFT LATTICE TRUNCATIONS.....
      A(23002+M) = 0.5 * (A(24252+M)+A(24253+M))
      A(23003+M;21) = 0.333 * (A(24252+M;21)+A(24253+M;21)
     1                                    +A(24254+M;21))
      A(23024+M) = 0.5 * (A(24273+M)+A(24274+M))
      A(24252+M;23) = A(23027+M;23)
C
      A(24202+M) = 0.5 * (A(24277+M)+A(24278+M))
      A(24203+M;21) = 0.333 * (A(24277+M;21)+A(24278+M;21)
     1                                    +A(24279+M;21))
      A(24224+M) = 0.5 * (A(24298+M)+A(24299))
      A(24277+M;23) = A(24177+M;23)
C
C          .....MAIN EX LOOPS.....
      D1 = A(15527+M;1173) * A(23027+M;1173)
      D2 = A(29702+M;1173)-A(14202+M;1173)+A(28352+M;1173)
     1                                 -A(28377+M;1173)
      D3 = A(16777+M;1173) * D2
      A(23027+M;1173) = D1 + D3
```

```
C
C           .....JX APERTURE SOURCE CONDITION.....
      IF(M.EQ.12*15500) A(23001+M$1200) = JXSRC(1$1200) +
     1                                    A(23001+M$1200)
C
C           .....EX ENVELOPE COMPUTATION.....
      D4 = VABS(A(23601+M$24)$D4)
      BY = D4.GT.A(24301+M$24)
   30 A(24301+M$24) = Q8VCTRL(D4,BY$A(24301+M$24))
      FREE
C
C           .....EY ITERATION.....
      ASSIGN D1,.DYN.1174
      ASSIGN D2,.DYN.1174
      ASSIGN D3,.DYN.1174
C
      DO 40 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C           .....SOFT LATTICE TRUNCATIONS.....
      A(24326+M) = 0.5 * (A(25576+M)+A(25577+M))
      A(24327+M$22) = 0.333 * (A(25576+M$22)+A(25577+M$22)
     1                                      +A(25578+M$22))
      A(24349+M) = 0.333 * (A(25598+M)+2.0*A(25599+M))
      A(25576+M$24) = A(24351+M$24)
C
      A(25526+M) = 0.5 * (A(25601+M)+A(25602+M))
      A(25527+M$22) = 0.333 * (A(25601+M$22)+A(25602+M$22)
     1                                      +A(25603+M$22))
      A(25549+M) = 0.333 * (A(25623+M)+2.0*A(25624+M))
      A(25601+M$24) = A(25501+M$24)
C
C           .....MAIN EY LOOPS.....
      D1 = A(18026+M$1174) * A(24351+M$1174)
      D2 = A(27051+M$1174)-A(27026+M$1174)+A(29701+M$1174)
     1                                    -A(29702+M$1174)
      D3 = A(19276+M$1174) * D2
      A(24351+M$1174) = D1 + D3
C
C           .....JY APERTURE SOURCE CONDITION.....
      IF(M.EQ.83*15500) A(24326+M$1200) = JYSRC(1$1200) +
     1                                    A(24326+M$1200)
C
C           .....EY ENVELOPE COMPUTATION.....
      D4 = VABS(A(24926+M$24)$D4)
      BY = D4.GT.A(25626+M$24)
      A(25626+M$24) = Q8VCTRL(D4,BY$A(25626+M$24))
C
      D5 = Q8VCMPRS(A(24325+M$1200),BX$D5)
      D6 = VABS(D5$D6)
      BZ = D6.GT.A(25651+M$48)
   40 A(25651+M$48) = Q8VCTRL(D6,BZ$A(25651+M$48))
      FREE
```

```
C
C         .....EZ ITERATION.....
      ASSIGN D1,,DYN.1199
      ASSIGN D2,,DYN.1199
      ASSIGN D3,,DYN.1199
C
      DO 50 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C         .....MAIN EZ LOOPS.....
      D1 = A(20501+M;1199) * A(25701+M;1199)
      D2 = A(28352+M;1199)-A(28351+M;1199)+A(11526+M;1199)
     1                                        -A(27026+M;1199)
      D3 = A(21751+M;1199) * D2
      A(25701+M;1199) = D1 + D3
C
C         .....JZ APERTURE SOURCE CONDITION.....
      IF(M.EQ.12*15500) A(25701+M;1200) = JZSRC(1;1200) +
     1                                        A(25701+M;1200)
C
C         .....EZ ENVELOPE COMPUTATION.....
      A(26926+M;24) = 0.5 * (A(26276+M;24)+A(26301+M;24))
      D4 = VABS(A(26926+M;24);D4)
      BY = D4.GT.A(26951+M;24)
      A(26951+M;24) = Q8VCTRL(D4,BY;A(26951+M;24))
C
      D5 = Q8VCMPRS(A(25700+M;1200),BX;D5)
      D6 = VABS(D5;D6)
      BZ = D6.GT.A(26976+M;48)
   50 A(26976+M;48) = Q8VCTRL(D6,BZ;A(26976+M;48))
C
C         .....HX ITERATION.....
      DO 60 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C         .....MAIN HX LOOPS.....
      D1 = A(11526+M;1199)
      D2 = A(8851+M;1199)-A(8826+M;1199)+A(10201+M;1199)
     1                                    -A(25701+M;1199)
      A(11526+M;1199) = D1 + D2
C
C         .....HX ENVELOPE COMPUTATION.....
      A(12751+M;24) = 0.5 * (A(12101+M;24)+A(12126+M;24))
      D4 = VABS(A(12751+M;24);D4)
      BY = D4.GT.A(12776+M;24)
      A(12776+M;24) = Q8VCTRL(D4,BY;A(12776+M;24))
C
      D5 = Q8VCMPRS(A(11525+M;1200),BX;D5)
      D6 = VABS(D5;D6)
      BZ = D6.GT.A(12801+M;48)
   60 A(12801+M;48) = Q8VCTRL(D6,BZ;A(12801+M;48))
      FREE
C
```

```
C         .....HY ITERATION.....
      ASSIGN D1,.DYN.1198
      ASSIGN D2,.DYN.1198
C
      DO 70 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C         .....SOFT LATTICE TRUNCATION.....
      AA(1) = 0.5 * (A(29601+M)+A(29602+M))
      AA(2;46) = 0.333 * (A(29601+M;46)+A(29602+M;46)
     1                            +A(29603+M;46))
      AA(48) = 0.5 * (A(29647+M)+A(29648+M))
      AAA(1;1200) = Q8VXPND(AA(1;48),BW;AAA(1;1200))
      A(29601+M;48) = Q8VCMPRS(A(28352+M;1200),BW;A(29601+M;48))
C
C         .....MAIN HY LOOPS.....
      D1 = A(28352+M;1198)
      D2 = A(25702+M;1198)-A(25701+M;1198)+A(23002+M;1198)
     1                                    -A(23027+M;1198)
      A(28352+M;1198) = D1 + D2
C
      A(28351+M;1200) = Q8VCTRL(AAA(1;1200),BW;A(28351+M;1200))
      A(28351+M;1200) = Q8VCTRL(0.0,BX;A(28351+M;1200))
C
C         .....HY ENVELOPE COMPUTATION.....
      A(29576+M;24) = 0.5 * (A(28926+M;24)+A(28951+M;24))
      D4 = VABS(A(29576+M;24);D4)
      BY = D4.GT.A(29651+M;24)
   70 A(29651+M;24) = Q8VCTRL(D4,BY;A(29651+M;24))
      FREE
C
C         .....HZ ITERATION.....
      ASSIGN D1,.DYN.1173
      ASSIGN D2,.DYN.1173
C
      DO 80 MA=1,3
      M = JDEL + 15500*(MA-1)
C
C         .....SOFT LATTICE TRUNCATION.....
      AA(2) = 0.5 * (A(15427+M)+A(15428+M))
      AA(3;45) = 0.333 * (A(15427+M;45)+A(15428+M;45)
     1                            +A(15429+M;45))
      AA(48) = 0.5 * (A(15472+M)+A(15473+M))
      AAA(1;1200) = Q8VXPND(AA(1;48),BW;AAA(1;1200))
      A(15426+M;48) = Q8VCMPRS(A(14177+M;1200),BW;A(15426+M;48))
C
C         .....MAIN HZ LOOPS.....
      D1 = A(14202+M;1173)
      D2 = A(23027+M;1173)-A(7527+M;1173)+A(8851+M;1173)
     1                                    -A(8852+M;1173)
      A(14202+M;1173) = D1 + D2
C
      A(14176+M;1200) = Q8VCTRL(AAA(1;1200),BW;A(14176+M;1200))
```

```
      A(14176+M;1200) = QBVCTRL(0.0,BX;A(14176+M;1200))
C
C             .....HZ ENVELOPE COMPUTATION.....
      D4 = VABS(A(14776+M;24);D4)
      BY = D4.GT.A(15476+M;24)
   80 A(15476+M;24) = QBVCTRL(D4,BY;A(15476+M;24))
      FREE
   82 CONTINUE
      IF(MCALL.LE.32)GO TO 94
C
C             .....TRANSVERSE PLANE NO. 101.....
      M = 99 * 15500
C
C             .....EX, EZ TRUNCATIONS.....
      A(23001+M;1250) = A(15501+M;1250)
      A(15501+M;1250) = A(16751+M;1250)
      A(16751+M;1250) = A(7501+M;1250)
C
      A(25701+M;1250) = A(18001+M;1250)
      A(18001+M;1250) = A(19251+M;1250)
      A(19251+M;1250) = A(10201+M;1250)
C
C             .....HX ITERATION.....
      ASSIGN D1,.DYN.1199
      ASSIGN D2,.DYN.1199
      D1 = A(11526+M;1199)
      D2 = A(8851+M;1199)-A(8826+M;1199)+A(10201+M;1199)
     1                                   -A(25701+M;1199)
      A(11526+M;1199) = D1 + D2
C
      A(12751+M;24) = 0.5 * (A(12101+M;24)+A(12126+M;24))
      D4 = VABS(A(12751+M;24);D4)
      BY = D4.GT.A(12776+M;24)
      A(12776+M;24) = QBVCTRL(D4,BY;A(12776+M;24))
C
      D5 = QBVCMPRS(A(11525+M;1200),EX;D5)
      D6 = VABS(D5;D6)
      BZ = D6.GT.A(12801+M;48)
      A(12801+M;48) = QBVCTRL(D6,BZ;A(12801+M;48))
      FREE
C
C             .....HZ ITERATION.....
      ASSIGN D1,.DYN.1173
      ASSIGN D2,.DYN.1173
      AA(2) = 0.5 * (A(15427+M)+A(15428+M))
      AA(3;45) = 0.333 * (A(15427+M;45)+A(15428+M;45)
     1                                  +A(15429+M;45))
      AA(48) = 0.5 * (A(15472+M)+A(15473+M))
      AAA(1;1200) = QBVXPND(AA(1;48),BW;AAA(1;1200))
      A(15426+M;48) = QBVCMPRS(A(14177+M;1200),BW;A(15426+M;48))
C
      D1 = A(14202+M;1173)
```

```
      D2 = A(23027+M$1173)-A(7527+M$1173)+A(8851+M$1173)
     1                                     -A(8852+M$1173)
      A(14202+M$1173) = D1 + D2
      A(14176+M$1200) = Q8VCTRL(AAA(1$1200),HW$A(14176+M$1200))
      A(14176+M$1200) = Q8VCTRL(0.0,HX$A(14176+M$1200))
C
      D4 = VABS(A(14776+M$24)$D4)
      BY = D4.GT.A(15476+M$24)
      A(15476+M$24) = Q8VCTRL(D4,BY$A(15476+M$24))
      FREE
   94 T3 = SECOND(CP)
      PRINT 150, T3
C
C           .....FIELD ENVELOPE PRINTOUT ROUTINE.....
      DO 100 L=NHALF,NMAX,NHALF
      IF(N.EQ.L)GO TO 101
  100 CONTINUE
      IF(N.EQ.NMAX)GO TO 101
      GO TO 199
C
C           .....AT HORIZONTAL OBSERVATION PLANE.....
  101 IF(N.EQ.NMAX)IPUN=1
      IPUN = 0
      PRINT 102, N
  102 FORMAT(1H1,52X,27HEX ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(8801,20,RC,IPUN)
C
      PRINT 103, N
  103 FORMAT(1H1,52X,27HEY ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(10126,20,RC,IPUN)
C
      PRINT 104, N
  104 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(11451,20,RC,IPUN)
C
      PRINT 105, N
  105 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(12776,20,376.7,IPUN)
C
      PRINT 106, N
  106 FORMAT(1H1,52X,27HHY ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(14151,20,376.7,IPUN)
C
      PRINT 107, N
  107 FORMAT(1H1,52X,27HHZ ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,15HPLANE Z = 24*DX,//,2X,1HJ,/)
      CALL ENV(15476,20,376.7,IPUN)
C
```

```
C          .....AT VERTICAL SYMMETRY PLANE.....
      PRINT 108, N
  108 FORMAT(1H1,52X,27HEZ ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(11476,40,RC,IPUN)
C
      PRINT 109, N
  109 FORMAT(1H1,52X,27HHX ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(12801,40,376.7,IPUN)
      CUR1 = A(49*15500+10178) * RC * 73.33
      CUR2 = A(78*15500+10161) * RC * 73.33
      PRINT 150, CUR1
      PRINT 150, CUR2
C
      PRINT 110, N
  110 FORMAT(1H1,52X,27HEY ENVELOPE FOR TIME STEP =,I5,
     1          //,62X,17HPLANE X = 24.5*DX,//,2X,1HJ,/)
      CALL ENV(10151,40,RC,IPUN)
C
  199 CONTINUE
  200 CONTINUE
  201 T4 = SECOND(CP)
      PRINT 150, T4
      STOP
      END

      SUBROUTINE ENV(LOCA,NUM,SCALE,IPUNCH)
      DIMENSION A(1565500),IP(4000),NN(50)
      COMMON A
C
      DO 1 I=1,50
    1 NN(I) = I
C
      DO 2 LY=2,100
      LOC = LOCA + (LY-1)*15500 + 4
      LOCI = 1 + (LY-1)*40
      IP(LOCI$NUM) = SCALE * A(LOC$NUM)
    2 A(LOC$NUM) = 0.
C
      IF(IPUNCH.EQ.0)GO TO 5
      DO 3 LY=2,100
      LOCI = 1 + (LY-1)*40
      LOCII = LOCI - 1 + NUM
    3 WRITE(8,4) (IP(LL),LL=LOCI,LOCII)
    4 FORMAT(10I6)
C
    5 LXM = NUM/20
      DO 8 LX=1,LXM
      LXA = 1 + (LX-1)*20
      LA = LXA + 4
      LZ = LA + 19
      DO 6 LY=2,100
```

```
      LYY = 102 - LY
      LOCI = LXA + (LYY-1)*40
      LOCII = LOCI + 19
    6 PRINT 7, LYY, (IP(LL),LL=LOCI,LOCII)
    7 FORMAT(1X,I3,5X,20I6)
    8 PRINT 9, (NN(LL),LL=LA,LZ)
    9 FORMAT(//,8X,20I6,//////)
C
      RETURN
      END
```

3.0 DATA CARD FORMAT

3.1 Type of Medium at Each Lattice Cell

For most realistic interaction geometries, data cards are needed to specify the type of medium at each location of an electric field component. Up to 9 distinct media can be efficiently specified within a lattice using the following format.

Using the Fortran statement 4 FORMAT (75F1.0) a medium-type integer 1, 2,..., 9 can be assigned to the 600 locations of an electric field component in one plane j = *constant with only* 8 *data cards.* The 600 locations are ordered as shown in Figure 1. Within the 75F1.0 format, we have:

Data Card	Assigns Type Integer to Consecutive Locations
1	1 - 75.
2	76 - 150
3	151 - 225
4	226 - 300
5	301 - 375
6	376 - 450
7	451 - 525
8	526 - 600

In all data cards, column 25, column 50, and columns 75 - 80 are left blank.

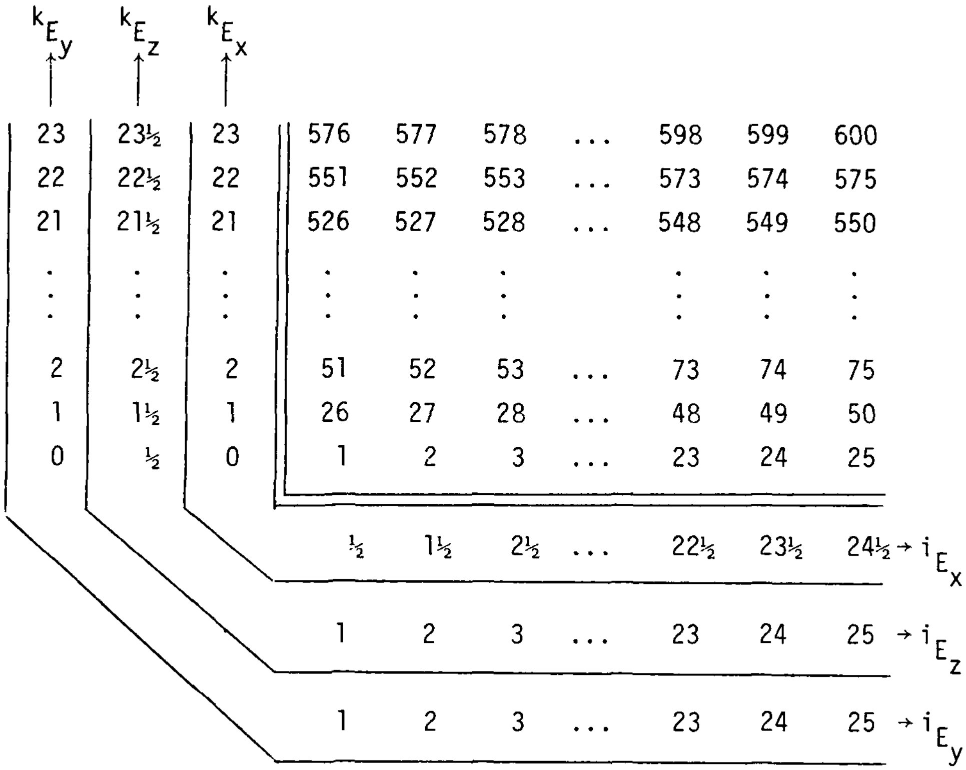

FIGURE 1 ORDERING OF THE ELECTRIC FIELD COMPONENT LOCATIONS IN THE LATTICE PLANE j = CONSTANT

3.2 Equivalent Electric Current Aperture Excitation

For the case of the hybrid method of moments/FD-TD analysis, data cards are needed to specify the Schelkunoff equivalent electric current excitation at each point in the aperture plane marked by the location of an electric field component. The electric current excitation is given in amperes/meter and is normalized (for purposes of achieving a wide-range print out) to an incident wave electric field of 10^4 volts/meter. In addition, the electric current excitation is characterized at each point by an integer number representing the number of time steps of delay of the current relative to the earliest appearance of current at any point within the aperture plane.

Using the Fortran statement 15 FORMAT (12F6.2,/,13F6.2), a current-excitation magnitude can be assigned to the 600 locations of an electric field component in one plane j = constant with only 48 data cards. The 600 locations are ordered as shown in Figure 1. With this format, we have:

Data Cards	Assigns Current Magnitude to Consecutive Locations
1 and 2	1 - 25
3 and 4	26 - 50
5 and 6	51 - 75
⋮	⋮
47 and 48	576 - 600

In all data cards, the quantity 0.0 is assigned to electric field component locations either at the boundary of the aperture or outside of the aperture. In all even-numbered data cards, the quantity 0.0 is assigned to the thirteenth entry (columns 73-78).

Using the Fortran statement 16 FORMAT (25F3.0), a current-excitation delay can be assigned to the 600 locations of an electric field component in one plane j = constant with only 24 data cards. The 600 locations are ordered as shown in Figure 1. With this format, we have:

AD-A092 032 IIT RESEARCH INST CHICAGO IL F/G 20/14
EVALUATION OF TIME DOMAIN EM COUPLING TECHNIQUES. VOLUME II.(U)
AUG 80 A TAFLOVE F30602-79-C-0039
UNCLASSIFIED RADC-TR-80-251-VOL-2 NL

2 OF 2
AD
A092032

END
DATE
FILMED
1 84
DTIC

Data Card	Assigns Current Delay to Consecutive Locations
1	1 - 25
2	26 - 50
3	51 - 75
⋮	⋮
24	576 - 600

In all data cards, the quantity 0 is assigned to electric field component locations either at the boundary of the aperture or outside of the aperture. Further, in all cards, the quantity 0 is assigned to the twenty-fifth entry (columns 73-75).

REFERENCES

[1] American National Standards Institute (ANSI) X3.9 - 1966.

[2] STAR Fortran Language Version 2 Reference Manual. Control Data Corporation, Sunnyvale, California, 1977.

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