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NAVAL POSTGRADUATE SCHOOL

Monterey, California

ADA 050,015

"ASAP"

ANTENNAS-SCATTERERS ANALYSIS PROGRAM: A USER-ORIENTED THIN WIRE ANTENNA COMPUTER CODE

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REVISED VERSION

Approved for public release; distribution unlimited

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THIN-WIRE STRUCTURES
FINITE GROUND

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

Previous thin-wire antenna programs have either been very specialized or all-encompassing. A beginning or occasional user does not need expertise in programming to gain insight into wire antenna structures, using this general purpose user-oriented code. The revisions contained herein correct deficiencies of handling the image problem in the original code and improve the accuracy of calculations of structures

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SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)* over finite ground.

SUMMARY

Previous thin-wire antenna programs have either been very specialized or all-encompassing. A beginning or occasional user does not need expertise in programming to gain insight into wire antenna structures, using this general purpose user-oriented code. The revisions contained herein correct deficiencies of handling the image problem in the original code and improve the accuracy of calculations of structures over finite ground.

TABLE OF CONTENTS

EXPLANATION OF REVISIONS TO ASAP

Since the issuance of the original ASAP report in December 1974, and distribution of the source program, feedback from many users and direct assistance from Dr. Robert Bevensee of Lawrence Livermore Labs, University of California enabled the preparation of this revised version. During the past 2 years, no additional discrepencies have arisen and it is now felt that the code can be safely called "revised".

The nature of the improvements was as follows:

1. To correct the manner in which structures were treated when elevated over a ground plane.
2. Improvements and corrections in calculating finite ground plane effects.
3. Text corrections in explanation of ground effects.
4. Instructional changes in the DESCRIPTION, FREQUENCY, and CHANGE cards.
5. Corrected sample problem outputs.

The user should note that some facilities will experience printing errors when NEAR FIELDS are called for. Statement 58 in the MAIN program should be suitably rewritten if that occurs.

I• INTRODUCTION

Although many thin-wire computer programs have been developed for the purpose of analyzing antennas and scatterers, few of these programs have been directed toward the student of electro-magnetic theory. The majority of the programs are directed to the engineer or advanced student for the purpose of analyzing designed structures or verifying experimental data.

The purpose of the study is to develop a computer program by modifying an existing computer code which can be utilized as an educational method to develop insight into radiating structures by the beginning student of electro-magnetic theory.

The modified Ohio State University Antennas-Scatterers Analysis Program (OSUMOD or ASAP) is directed toward the beginning student who does not yet have the expertise necessary to manipulate the input data for proper execution of the larger more comprehensive analysis program. Even though ASAP is small in core requirements and is fast in run time, it is capable of analyzing structures to assist the engineer with design problems.

Since the resulting program, ASAP, is primarily directed toward students, the program has been limited to structures which contain less than 50 monopoles (segments), no longer than one-fourth of a wavelength, and which have less than 51 nodes (intersections and endpoints). If a ground plane, either perfect or finite is present; the stated limits above are halved due to the generation of an image structure.

II. ORIGINAL PROGRAM

A. THEORY

Reference 1 presents the electro-magnetic theory for the analysis of antennas and scatterers in an isotropic, linear, and homogeneous ambient medium. The analysis is performed in the frequency domain with an excitation caused by either a generator or an incident wave.

In the analysis, a piecewise-sinusoidal expansion is used for the current distribution. The matrix equation $Z\ I = V$ is generated by enforcing reaction tests with a set of sinusoidal dipoles located in the interior region of the wire. Since the current distribution has the same form as the expansion mode, this formulation is known as the "sinusoidal reaction technique".

B. COMPUTER PROGRAM

Reference 2 presents the computer program corresponding to the theory presented in Ref. 1.

1. Input Format

In the program, the input data must specify the frequency, wire radius, wire conductivity, the parameters of the exterior medium, coordinates of the points to describe the shape and size of the wire configuration, a list of the wire segments, and the indicators for the various outputs. Table 1 is the input data necessary to analyze a half-wave dipole.

2. Output Format

In the original form, the only outputs which could be requested by the input data stream are the following:

a. Antenna Problems

(1) Current Distribution on the Structure.

(2) Input Impedance.

(3) Radiation Efficiency.

(4) Near-Zone Field.

(5) Far-Zone Field.

b. Backscattering Problems

(1) Absorption Cross Section.

(2) Scattering Cross Section.

(3) Extinction Cross Section.

(4) Complex Elements of the Polarization Scattering Matrix

c. Bistatic Scattering Problems

Echo Area.

Table 2 is an example of the output data available for data of table 1.

3. LIMITATION

Although the program can analyze a structure with up to 50 segments, 55 points and 60 dipoles modes; it can not analyze a structure in the presence of a finite ground plane.

```
0.002     2.56      -1.0      0.0005
0.001     1.00      1.0       -1.0      0.0
1         1         1         1         0         3         4         5
300.      0.        90.       0.        90.       45.       45.
1         2
2         3
3         4
4         5
0.        0.        -0.250
0.        0.        -0.125
0.        0.        0.
0.        0.        0.125
0.        0.        0.250
1.        1.        1.
```

AN EXAMPLE OF THE INPUT DATA FOR THE ORIGINAL PROGRAM

TABLE 1

```
98.18     0.0095    82.97     43.26
-.091     0.080     -0.091    0.080     0.224     -0.096
0.0       90.0      0.0       1.615
0.0       90.0      0.0       0.0       0.0       0.608
0.0       0.0069    0.0       0.377     0.0       0.370
45.0      45.0      0.0       0.0       0.0       0.239
```

AN EXAMPLE OF THE OUTPUT DATA FOR THE ORIGINAL PROGRAM

TABLE 2

III• MODIFIED COMPUTER PROGRAM

A. Input Format

As illustrated in table 1 the format for the input data cards is not self explanatory. This format can be determined by referring to the FORMAT statements of the program of Ref. 2. Since the modified program is directed toward the student, the input data format was changed to allow free format. Reference 2 was written in a form which permitted modifications to allow flexibility in specifying input data for the analysis program. Appendix B, titled "User's Manual", discusses the input data cards necessary for proper execution of an analysis problem. Appendix B is self-contained and may be used independently of the remainder of this document.

B. Output Format

In the original computer program, the absence of labels encumbered the output data and lessened the usefulness of the program. To improve the usefulness of the modified version, detailed labels were added to the output data. As with the input data, Ref. 2 was written in a form which enabled modification to allow more specific output data for the analyzed problem. With the addition of the polar plotting package, the far-zone electric field intensity polar radiation and reradiation patterns can be plotted. A sample problem can be found on page 120 in Appendix B, User's Manual.

C. Finite Ground

To enable the student or the engineer to have an improved analysis program, the finite ground effects were added to ASAP. The theory corresponding to the ground effects, which utilize Fresnel reflection coefficients, is discussed in Appendix A, titled "System Manual". Also discussed in Appendix A is the modified computer program and the corresponding theory. The electro-magnetic theory was developed in Refs. 1, 2, and 3; and it is restated with its corresponding computer code to assist in the understanding of the methods applied. Appendix A is self-contained and may be used independently of the remainder of this document.

IV• CONCLUSION

The addition of ground effect techniques to the original program did not alter the accuracy or the computational capabilities of the program. The ground effect techniques utilized the results of the original program and modified these results to account for the effects of the presence of the finite ground.

To verify the numerical results of ASAP, the input impedances of both a horizontal and a vertical dipole were compared to the solutions of the exact form of the Sommerfield's equation. As can be seen in table 3 the finite ground treatment of ASAP agrees favorably with Sommerfield's solutions. The ASAP finite ground results are also in excellent agreement with the previous computer solutions of Refs. 4 and 5.

V• RECOMMENDATIONS

Although the program is a general analysis tool for students, several future modifications will enhance the program as a design tool for engineers. These items include: varying the wire radius on the structure; incorporation of non-radiating elements such as transmission lines; varying the wire insulation radius, conductivity, and dielectric constant; and a geometry generation package such as dipole array or helix. One major change that would both improve the speed and reduce the core requirement is that of symmetry. No attempt was made to utilize the symmetry in the admittance matrix when the ground plane is present. If symmetry were applied, the structure size limit with the ground plane present would be approximately that of the structure without the ground plane.

VERTICAL DIPOLE
FREQUENCY 3MHZ
LENGTH .5 WAVELENGTH
RADIUS .005 METERS
DIELECTRIC CONSTANT (RELATIVE) 10

CONDUCTIVITY	HEIGHT/WAVELENGTH	ASAP	EXACT*
.1	.25	123.75+J 68.30	126.5+J 83.89
	.30	98.62+J 38.26	100.2+J 49.52
	.35	87.60+J 35.64	88.50+J 46.52
	.45	78.69+J 41.79	79.21+J 52.60
.001	.25	107.18+J 55.36	119.4+J 71.46
	.30	91.80+J 40.18	94.30+J 49.02
	.35	85.15+J 39.30	85.41+J 48.93
	.45	80.26+J 43.52	80.17+J 54.83
.00001	.25	103.20+J 57.99	115.1+J 73.89
	.30	91.83+J 41.99	94.09+J 50.69
	.35	85.90+J 40.14	86.01+J 49.83
	.45	86.78+J 43.23	80.72+J 54.63

HORIZONTAL DIPOLE
FREQUENCY 3 MHZ
LENGTH .5 WAVELENGTH
RADIUS .001 METERS
DIELECTRIC CONSTANT (RELATIVE) 10

CONDUCTIVITY	HEIGHT/WAVELENGTH	ASAP	EXACT*
.1	.5	84.20+J 23.69	87.74+J 41.77
	.3	132.45+J 46.09	136.0+J 67.91
	.1	39.46+J 84.99	40.54+J 88.71
.001	.5	88.09+J 31.80	91.41+J 50.65
	.3	117.69+J 42.39	120.3+J 62.69
	.1	71.92+J 71.07	78.77+J 69.91
.00001	.5	90.37+J 31.33	93.85+J 50.28
	.3	115.77+J 45.06	117.9+J 66.07
	.1	70.07+J 63.07	77.67+J 60.81

* COURTESY OF LAWRENCE LIVERMORE LABORATORY

TABLE 3

APPENDIX A
SYSTEM MANUAL

TABLE OF CONTENTS

SYSTEM MANUAL

INTRODUCTION: The Antennas-scatterers Analysis Program (ASAP) for thin wire structures in a homogenous conducting medium performs a frequency domain analysis of antennas and scatterers. The program is applicable in the presence of a ground either perfect or finite. This appendix will describe the computer program which accomplishes this. Although the program was written for the IBM 360 computer system it can be executed on another system with minor modifications.

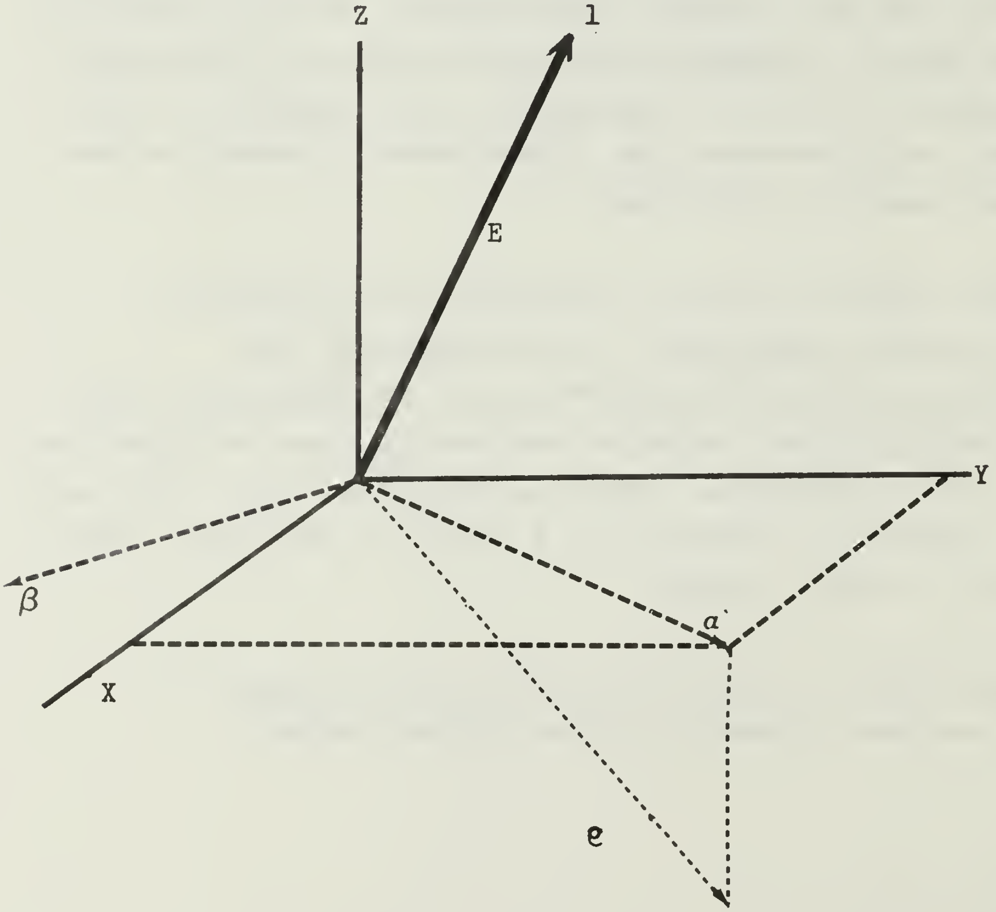
A piecewise-sinusoidal expansion is used for the current distribution. The matrix equation ZI = V is generated by enforcing reaction tests with a set of sinusoidal dipoles located in the interior region of the wire. Since the test dipoles have the same current distribution as the expansion modes, this may be regarded as an application of Galerkin's method. Rumsey's reaction concept was most helpful in this development, and therefore the formualtion is known as the "sinusoidal reaction technique".

The main routine and each subroutine is discussed separately in this appendix. The writeups for the subroutines are arranged alphabetically by subroutine name after the main program. Each of the discussions includes the purpose of the subroutine, brief description, and a listing. After the subroutine writeups is a table of the more common symbols used in this program.

The input data and program limits are discussed in detail in the next appendix titled "USERS MANUAL".

GROUND EFFECTS: In the modified antenna analysis computer program finite and infinite ground effects were added by using the reflection coefficient technique. The method in which this technique was used required the generation of an image structure. In this section the reflection technique will be discussed in detail.

In order to apply ground effects to the electric field, the field for the image structure was first calculated as if a ground were not present. Then, the field was decomposed into parallel and perpendicular components. (A parallel component is the component which is parallel to the plane of incidence. A perpendicular component is one which is perpendicular to this plane. The plane of incidence is the plane containing the normal to the reflecting surface and the incident ray.)



Consider an image monopole with the electric field in the l direction. The ray, ρ, is a vector which is perpendicular to l and passes thru the point of interest. To apply reflection technique, the plane of incident must be found. It is advantageous to define a new coordinate system (α, β, z) where α and β are parallel to the xy plane with α in the plane of incident and β perpendicular.

If the direction cosines (cosx, cosy, and cosz) are known, it can be shown that the components of the field in the $\alpha\beta$ (xy) plane have the following relationship:

$$\begin{bmatrix} E^{\parallel} \\ E^{\perp} \end{bmatrix} = \begin{bmatrix} \cos\phi & \sin\phi \\ \sin\phi & -\cos\phi \end{bmatrix} \begin{bmatrix} E_x \\ E_y \end{bmatrix}$$

where $\phi = \arctan(\text{cosy}/\text{cosx})$.

Now the reflection coefficients for the interface can be applied as:

$$E^{\parallel(R)} = R_{\parallel} E^{\parallel}$$

$$E^{\perp(R)} = R_{\perp} E^{\perp}$$

where $R_{\parallel}$ and $R_{\perp}$ will be defined later in this section.

Applying the matrix equation above yeilds:

$$\begin{bmatrix} E_x^{(R)} \\ \\ E_y^{(R)} \end{bmatrix} = \begin{bmatrix} \cos\phi & \sin\phi \\ \\ \sin\phi & -\cos\phi \end{bmatrix} \begin{bmatrix} E^{||(R)} \\ \\ E^{|(R)} \end{bmatrix}$$

(the square matrix is unique, in that, the inverse is equal to the original matrix). Since the image direction is opposite to the original monopole, that is,

$$(\bar{I} \times \bar{z})_{\text{original}} = -(\bar{I} \times \bar{z})_{\text{image}} ,$$

the z component of the field, which is in the plane of incident, is given by:

$$E_z^{(R)} = -R_{||} E_z .$$

From electro-magnetic theory the reflection coefficients for the fields in medium (1) at the interface with another medium (2) are defined as:

for perpendicular

$$R_H = \frac{\cos\theta - \sqrt{\varepsilon' - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon' - \sin^2\theta}}$$

and for parallel

$$R_V = \frac{\varepsilon' \cos\theta - \sqrt{\varepsilon' - \sin^2\theta}}{\varepsilon' \cos\theta + \sqrt{\varepsilon' - \sin^2\theta}}$$

where θ is the angle of incident as measured from the normal to the interface and

$$\varepsilon' = (\varepsilon_2 + \sigma_2/j\omega)/(\varepsilon_1 + \sigma_1/j\omega)$$

where the subscripts correspond to the mediums above.

To determine the relationship between $R_{||}$, $R_{\perp}$ and R_V, R_H a perfect ground ($\varepsilon_r = 0$, $\sigma = \infty$) was investigated.

$$\text{limit } R_H = -1$$

$$\text{limit } R_V = +1$$

But, for a perfect ground the contributions to the field from the image monopole would be equal to the field of the original monopole but opposite in sign due to the chosen reference direction,

$$E^{||(R)} = R_{||} E^{||} = - E^{||}$$

$$E^{\perp(R)} = R_{\perp} E^{\perp} = - E^{\perp}$$

therefore

$$R_{||} = - R_V$$

$$R_{\perp} = R_H$$

In summary, the contribution to the electric field of a monopole over a ground plane at a given point is given by:

$$E^{(R)} = E_x^{(R)} \cos x + E_y^{(R)} \cos y + E_z^{(R)} \cos z$$

where

$$E_x^{(R)} = R_{\perp} E \cos x + (R_{||} - R_{\perp}) E \cos x \cos^2 \phi$$

$$+ (R_{||} - R_{\perp}) E \cos y \sin \phi \cos \phi$$

$$E_y^{(R)} = R_{\parallel} E \cos y - (R_{\parallel} - R_{\perp}) E \cos y \cos^2 \phi$$

$$+ (R_{\parallel} - R_{\perp}) E \cos x \sin \phi \cos \phi$$

$$E_z^{(R)} = - R_{\parallel} E \cos z$$

where E is the field without the ground plane present and

$$R_{\parallel} = \frac{- \varepsilon' \cos \theta + \sqrt{\varepsilon' - \sin^2 \theta}}{\varepsilon' \cos \theta + \sqrt{\varepsilon' - \sin^2 \theta}}$$

$$R_{\perp} = \frac{\cos \theta - \sqrt{\varepsilon' - \sin^2 \theta}}{\cos \theta + \sqrt{\varepsilon' - \sin^2 \theta}}$$

$$\varepsilon' = \varepsilon_r - j(\sigma/\varepsilon_o \omega)$$

MAIN

PURPOSE: to control the input, output, and the flow of calculations.

METHOD: The main program controls the flow of the required calculations by calling only a few subroutines. These subroutines in turn call other subroutines which actually do the required calculations. The order of the calling sequence is diagramed after the listing for the main program.

The DIMENSION statements at the beginning of the main routine provides the required storage for a wire structure with up to 50 segments, 60 nodes and 60 dipoles without the presence of a ground plane. If a ground plane is present one-half of the reserved storage is required for the image, therefore a wire structure with up to 25 segments and 30 nodes can be analyzed.

NM denotes the actual number of monopoles (segments), INM is the corresponding dimension, and the dimension for CG, VG, and ZLD is twice INM. The second subscript for MD always has a dimension of 4 to correspond to the number of segments meeting at a given node.

N denotes the number of simultaneous linear equations and ICJ is the corresponding dimension. The dimension for C is (ICJ * ICJ + ICJ)/2.

In the statements above statement 4, the initial conditions and defaults are established. After calling subroutine READ to determine the input parameters, the IF statements output the parameters to be used for the calculations. In the DO LOOP ending at statement 7, the the input data of the structure geometry is stored in order to recall if the structure is to be moved for ground plane calculations.

After the image structure is generated and structure location is moved, subroutine SORT is called to determine the dipole modes. Prior to calling SGANT, the load and generator information is established.

Subroutine SGANT is then called to calculate the elements of the impedance matrix. If FEEDS or GENERATORS are specified by the input data stream, subroutine GANT1 is called to solve for the current distribution due to these forcing functions.

In the DO LOOP ending with statement 29, subroutine GNFLD is called to calculate the near-zone field for the current distribution of the subroutine GANT1.

The subroutine GFFLD is called for the far-zone field of the current distribution of the subroutine GANT1 in the DO LOOP ending at statement 35. The subroutine GFFLD is called again in DO LOOPs ending at statements 42 and 51, if bistatic and backscattering calculations are requested by the input data stream.

CALLS TO: GANT1

GFFLD

GNFLD

POLPRT

READ

SGANT

SORT

```
      OIMENSION X(60), Y(60), Z(60), XG(60), YG(60), ZG(60)
      DIMENSION I1(60), I2(60), I3(60), JA(60), J8(60), KFLAG(30)
      DIMENSION CPHI(500), CTHET(500)
      DIMENSION OATY1(360), OATY2(360), OATY3(360), OATY4(360)
      DIMENSION O(50), IA(50), I8(50), ISC(50), MD(50,4), ND(50)
      OIMENSION LZO(60), KGEN(60)
      COMMON IWL
      OIMENSION XNP(50), YNP(50), ZNP(50)
      COMPLEX C(1830)
      COMPLEX CDAT1(500),CDAT2(500),CDAT3(500),CDAT4(500)
      COMPLEX CJ(60),EP(60),EPP(60),ET(60),ETT(60)
      COMPLEX CGO(50),SGO(60),CG(100),VG(100),ZLD(100)
      COMPLEX VOLT(60),ZLLD(60)
      COMPLEX EPPS,EPTS,ETPS,ETTS,EX,EY,EZ
      COMPLEX EP2,EP3,EP4,ERR,ETA,GAM,Y11,Z11,ZS
      OATA PI,TP/3.14159,6.28318/
      OATA EQ,UO/8.854E-12,1.2566E-6/
    1 NGEN = -1
      IGRO = -1
      LOAO = -1
      8M = -1
      ICARO = 0
      AM = -1
      IFLAG = 0
      VOLT(1) = (1.,0.)
      HGT = 0.
      NM = 0
      NP = 0
      MSG = 0
      SIG2 = -1.
      TO2 = -1.
      SIG3 = -1
      ER3 = 1
      TO3 = 0.
      CMM = 50.
      ER2 = 1.
      FMC = 300.
      INM = 50
      ICJ = 60
      WRITE (6,74)
C
      DO 2 I=1,30
    2 KFLAG(I) = -1
C
C
      DO 3 J=1,INM
      ISC(J) = 0
      VG(J) = (.0,.0)


      ZLO(J) = (.0,.0)
      JJ = J+INM
      VG(JJ) = (.0,.0)
    3 ZLO(JJ) = (.0,.0)
C
    4 NFFP = 0
      N8IP = 0
      N8AP = 0
      AFFP = 1000.
      AFFT = 1000.
      A8IP = 1000.
      ABIT = 1000.
      A6AP = 1000.
      A8AT = 1000.
      STEP = 1.
      KNM = 0
      CALL REAO (IA,I8,I8ISC,ICARO,IGAIN,IGRD,INEAR,INT,ISCAT,IWR,IFLAG,
     1KFLAG,KGEN,LOAO,LZD,MSG,N8AP,N8IP,NFFP,NGEN,NM,NP,A8AP,ABAT,AFFP,A
     2FFT,A8IP,ABIT,AM,8M,CMM,ER2,ER3,ER4,FMC,HGT,PHAF,PHAI,PHIF,PHII,PH
     3SF,PHSI,THAF,THAI,THIF,THII,THSF,THSI,SIG2,SIG3,SIG4,TD2,TD3,VOLT,
     4X,XNP,Y,YNP,Z,ZLLD,ZNP,STEP)
      WRITE (6,56)
      IF (MSG.LT.1) GO TO 5
      IF (MSG.EQ.1) WRITE (6,70) KFLAG(30)
      IF (IFLAG.EQ.4) GO TO 1
    5 IF (IFLAG.EQ.5) STOP
      IF (AM.LT.O) WRITE (6,127)
      IF (AM.LT.O) GO TO 6
      IF ((NM.GT.O).AND.(NP.GT.O)) GO TO 7
      WRITE (6,116)
    6 IF (IFLAG.EQ.1) GO TO 1
      MSG = 2
      GO TO 4
    7 WRITE (6,114)
      WRITE (6,113)
      WRITE (6,112)
      IF (KFLAG(1).EQ.1) WRITE (6,83) FMC
      IF (KFLAG(2).EQ.1) WRITE (6,84) AM
      IF (KFLAG(3).EQ.1) WRITE (6,85) CMM
      IF (KFLAG(20).NE.1) WRITE (6,87)
      IF (KFLAG(4).EQ.1) WRITE (6,86)
      IF (KFLAG(4).EQ.1) WRITE (6,88) 8M
      IF (KFLAG(5).EQ.1) WRITE (6,89) SIG2
      IF (KFLAG(6).EQ.1) WRITE (6,90) ER2
      IF (KFLAG(7).EQ.1) WRITE (6,91) TD2
      IF (KFLAG(8).NE.1) WRITE (6,92)
      IF (KFLAG(9).EQ.1) WRITE (6,93) SIG3
      IF (KFLAG(10).EQ.1) WRITE (6,94) ER3
```

```
      IF (KFLAG(11).EQ.1) WRITE (6,95) TD3
      IF (KFLAG(26).NE.1) WRITE (6,122)
      IF ((IGRD.GT.1).AND.(KFLAG(25).EQ.1)) WRITE (6,123)
      IF ((IGRD.EQ.1).AND.(KFLAG(25).EQ.1)) WRITE (6,125)
      IF ((IGRD.GT.1).AND.(KFLAG(25).EQ.1)) WRITE (6,124) ER4,SIG4
      IF ((IGRD.GT.0).AND.(KFLAG(25).EQ.1)) WRITE (6,126) HGT
      IF (KFLAG(21).EQ.1) WRITE (6,121) INT
      WRITE (6,111)
      IF (KFLAG(12).EQ.1) WRITE (6,96) (I,IA(I),X(IA(I)),Y(IA(I)),Z(IA(I
     1)),IB(I),X(IB(I)),Y(IB(I)),Z(IB(I)),I=1,NM)
      WRITE (6,111)
      IF (KFLAG(24).GT.0) WRITE (6,119) (LZO(I),ZLLD(I),I=1,LOAD)
      IF (KFLAG(14).GT.0) WRITE (6,118) (LZO(I),ZLLD(I),I=1,LOAD)
      WRITE (6,111)
      IF (KFLAG(23).GT.0) WRITE (6,120) (KGEN(I),VOLT(I),I=1,NGEN)
      IF (KFLAG(13).GT.0) WRITE (6,97) (KGEN(I),VOLT(I),I=1,NGEN)
      WRITE (6,111)
      WRITE (6,114)
      WRITE (6,98)
      WRITE (6,112)
      IF (KFLAG(22).NE.1) WRITE (6,110)
      IF (KFLAG(15).EQ.1) WRITE (6,99)
      IF (KFLAG(16).EQ.1) WRITE (6,100) PHAI,PHAF,THAI,THAF,STEP
      IF (KFLAG(17).EQ.1) WRITE (6,101) PHII,PHIF,THII,THIF,STEP
      IF (KFLAG(18).EQ.1) WRITE (6,102) PHSI,PHSF,THSI,THSF,STEP
      IF (KFLAG(19).EQ.1) WRITE (6,103) (XNP(I),YNP(I),ZNP(I),I=1,INEAR)
      IF (AFFP.LT.500.) WRITE (6,105) AFFP
      IF (AFFT.LT.500.) WRITE (6,104) AFFT
      IF (ABAP.LT.500.) WRITE (6,109) ABAP
      IF (ABAT.LT.500.) WRITE (6,108) ABAT
      IF (ABIP.LT.500.) WRITE (6,107) ABIP
      IF (ABIT.LT.500.) WRITE (6,106) ABIT
      IF ((IBISC.GT.0).AND.(ISCAT.LT.0)) WRITE (6,73)
      IF (KFLAG(4).LT.1) GO TO 129
      DO 128 I=1,INM
  128 ISC(I)=1
  129 FHZ = FMC*1.E6
      OMEGA = TP*FHZ
      IF (SIG2.LT.0.) EP2=ER2*EO*CMPLX(1.,-TD2)
      IF (TD2.LT.0.) EP2 = CMPLX(ER2*EO,-SIG2/OMEGA)
      IF (SIG3.LT.0.) EP3=ER3*EO*CMPLX(1.,-TD3)
      IF (TD3.LT.0.) EP3 = CMPLX(ER3*EO,-SIG3/OMEGA)
      IF (IGRD.GT.1) EP4 = CMPLX(ER4*EO,-SIG4/OMEGA)
      IF (IGRD.GT.1) ERR = EP4/EP3
      IF (KFLAG(21).GT.0) WRITE (6,121) INT
      ETA = CSQRT(UO/EP3)
      GAM = OMEGA*CSQRT(-UO*EP3)
      IF (KFLAG(12).NE.1) GO TO 9



      NPG = NP
      NMG = NM
C
      DO 8 I=1,NPG
      XG(I) = X(I)
      YG(I) = Y(I)
    8 ZG(I) = Z(I)
C
C
    9 DO 10 I=1,NPG
      X(I) = XG(I)
      Y(I) = YG(I)
   10 Z(I) = ZG(I)
C
      NP = NPG
      NM = NMG
      IWL = 0
      IF (IGRD.LE.0) GO TO 15
C     SET UP IMAGE FOR GROUND PLANE
      ZMIN = Z(1)
      K = 0
C
      IF (Z(I).LT.ZMIN) ZMIN=Z(I)
      DO 11 I=1,NP
      Z(I) = Z(I)+HGT
      IF (Z(I).GT.1.E-60) GO TO 11
      IWL = IWL+1
   11 CONTINUE
C
      IF (ZMIN.GE.0.0)GOTO12
      WRITE (6,117)
      IF (IFLAG.EQ.1) GO TO 1
      IF (IFLAG.EQ.2) STOP
      MSG = 2
      GO TO 4
C
   12 DO 13 J=1,NM
      K = J+NM
      IA(K) = IA(J)
      IF (IA(J).GT.IWL) IA(K)=IA(J)+NP-IWL
   13 IB(K) = IB(J)+NP-IWL
C
      IWLP = IWL+1
C
      DO 14 I=IWLP,NP
      J = I+NP-IWL
      X(J) = X(I)
      Y(J) = Y(I)
```

```
   14 Z(J) = -Z(I)
C
      KNM = NM+1
      NM = 2*NM
      NP = 2*NP-IWL
   15 CALL SORT (IA,IB,I1,I2,I3,JA,JB,MD,ND,NM,NP,N,MAX,MIN,ICJ,INM)
      IF (MAX.LE.4) GO TO 16
      WRITE (6,71)
      IF (IFLAG.EQ.1) GO TO 1
      IF (IFLAG.EQ.2) STOP
      MSG = 2
      GO TO 4
   16 IF (MIN.GE.1) GO TO 17
      WRITE (6,72)
      IF (IFLAG.EQ.1) GO TO 1
      IF (IFLAG.EQ.2) STOP
      MSG = 2
      GO TO 4
   17 WRITE (6,56)
      IF (MAX.GT.4.OR.MIN.LT.1.OR.N.GT.ICJ) GO TO 54
      I12 = 1
      IF (LOAD.GT.0) GO TO 19
C
      DO 18 I=1,NM
   18 ZLO(I) = (0.,0.)
C
   19 IF (NGEN.GT.0) GO TO 21
C
      DO 20 I=1,NM
   20 VG(I) = (0.,0.)
C
   21 KN = NM
      IF (IGRD.GT.0) KN = NM/2
      J = 1
C     ANTENNA CALCULATIONS
      IF (LOAD.LE.0) GO TO 24
      IF (KFLAG(24).GT.0) GO TO 22
C
      OO 23 J=1,KN
C
   22 OO 23 I=1,LOAD
      K = LZD(I)
      IF ((IA(J).EQ.K).AND.(KFLAG(14).GT.0)) ZLD(J)=ZLLO(I)
      IF (KFLAG(24).GT.0) ZLO(K)=ZLLD(I)
      IF ((KFLAG(14).GT.0).ANO.(IGRD.GT.0)) ZLO(J+KN)=ZLO(J)
      IF ((KFLAG(24).GT.0).AND.(IGRO.GT.0)) ZLO(K+KN)=ZLO(K)
   23 CONTINUE
C

   24 IF (NGEN.LT.0) GO TO 27
      KN = NM
      IF (IGRO.GT.0) KN = NM/2
      IF (KFLAG(23).GT.0) GO TO 25
C
      OO 26 J=1,KN
C
   25 OO 26 I=1,NGEN
      K = KGEN(I)
      IF ((IA(J).EQ.K).AND.(KFLAG(13).GT.0)) VG(J)=VOLT(I)
      IF (KFLAG(23).GT.0) VG(K)=VOLT(I)
      IF ((KFLAG(13).GT.0).AND.(IGRO.GT.0))  VG(J+KN)=-VG(J)
      IF ((IGRO.GT.0).ANO.(KFLAG(23).GT.0)) VG(K+KN)=-VG(K)
   26 CONTINUE
C
   27 CALL SGANT (IA,IB,INM,INT,ISC,I1,I2,I3,JA,JB,MD,N,NO,NM,NP,AM,BM,C
     1,CGD,CMM,D,EP2,EP3,ETA,FHZ,GAM,SGD,X,Y,Z,ZLD,ZS,ERR,IGRD)
      IF (N.GT.0) GO TO 28
      IF (IFLAG.EQ.2) STOP
      MSG = 2
      IF (IFLAG.EQ.1) GO TO 1
      GO TO 4
   28 IF (NGEN.LE.0) GO TO 36
      WRITE (6,75)
      WRITE (6,76)
      WRITE (6,77)
      WRITE (6,82)
      CALL GANT1 (IA,IB,INM,IWR,I1,I2,I3,I12,JA,JB,MD,N,ND,NM,AM,C,CJ,CG
     1,CMM,D,EFF,GAM,GG,CGO,SGO,VG,Y11,Z11,ZLD,ZS,IGRD)
      WRITE (6,57) EFF,GG,Z11
C     NEAR FIELD
      IF (INEAR.LE.0) GO TO 30
      WRITE (6,75)
      WRITE (6,78)
      WRITE (6,77)
C
      DO 29 I=1,INEAR
      XP = XNP(I)
      YP = YNP(I)
      ZP = ZNP(I)
      CALL GNFLD (IA,IB,INM,I1,I2,I3,MD,N,NO,NM,AM,CGO,SGD,ETA,GAM,CJ,D,
     1X,Y,Z,XP,YP,ZP,EX,EY,EZ,IGRD,ERR)
      WRITE (6,58) XP,YP,ZP
      WRITE (6,59) EX,EY,EZ
   29 CONTINUE
C
C     FAR FIELO
   30 IF (IGAIN.LE.0) GO TO 36
```

```
C
      OO 31 I=1,360
      DATY1(I) = 0
      DATY2(I) = 0
      OATY3(I) = 0
   31 DATY4(I) = 0
C
      WRITE (6,75)
      WRITE (6,79)
      WRITE (6,77)
      WRITE (6,82)
      INC = 0
      NPL = -1
      IF (KFLAG(16).EQ.1) WRITE (6,69)
      IF (NFFP.EQ.1) GO TO 32
      NPHA = (PHAF-PHAI)/STEP+1
      NTHA = (THAF-THAI)/STEP+1
      GO TO 34
   32 IF (AFFT.GT.500.) GO TO 33
      NPL = 1
      NPHA = 360
      NTHA = 1
      PHAI = 0.
      THAI = AFFT
      STEP = 1.
      GO TO 34
   33 NPL = 2
      NPHA = 1
      NTHA = 360
      PHAI = AFFP
      THAI = 0.
      STEP = 1.
   34 PH = PHAI-STEP
      OO 35 K=1,NPHA
      PH = PH+STEP
      TH = THAI-STEP
      OO 35 I=1,NTHA
      PHSPH = 0.
      PHSTH = 0.
      TH = TH+STEP
      IF ((IGRD.GT.0).ANO.((TH.GT.90).ANO.(TH.LT.270))) GO TO 35
      CALL GFFLO ( IA,IB,INC,INM,IWR,I1,I2,I3,I12,MO,N,ND,NM,AM,ACSP,ACST
     1,C,CGO,CG,CJ,CMM,D,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ETTS,GG,
     2GPP,GTT,PH,SGD,SCSP,SCST,SP PM,SPTM,STPM,STTM,TH,X,Y,Z,ZLD,ZS,ETA,G
     3AM,ERR,IGRD)
      ETMAG = CA8S(ETTS)
      EPMAG = CABS(EPPS)
      IF(ETMAG.GT.1.E-32) PHSTH=57.295779*ATAN2(AIMAG(ETTS),REAL(ETTS))


      IF(EPMAG.GT.1.E-32) PHSPH=57.295779*ATAN2(AIMAG(EPPS),REAL(EPPS))
      IF (NPL.EQ.1) OATY1(K)=EPMAG
      IF (NPL.EQ.1) DATY2(K)=ETMAG
      IF (NPL.EQ.2) OATY1(I)=EPMAG
      IF (NPL.EQ.2) OATY2(I)=ETMAG
      IF (KFLAG(16).NE.1) GO TO 35
      WRITE (6,60) TH,PH,GTT,GPP,ETTS,ETMAG,PHSTH,EPPS,EPMAG,PHSPH
   35 CONTINUE
C
      WRITE (6,56)
      IF (NPL.LE.0) GO TO 36
      CALL POLPRT (1,DATY1)
      CALL POLPRT (2,DATY2)
C     BACK SCATTERING
   36 IF (ISCAT.LE.0) GO TO 54
      WRITE (6,75)
      WRITE (6,80)
      WRITE (6,77)
      WRITE (6,82)
      L = 0
      NPL = -1
      INC = 1
      IF (N8AP.EQ.1) GO TO 37
      NPHI = (PHIF-PHII)/STEP+1
      NTHI = (THIF-THII)/STEP+1
      IF (IWR.LE.0) WRITE (6,62)
      GO TO 39
   37 IF (A8AT.GT.500.) GO TO 38
      NPL = I
      NPHI = 360
      NTHI = 1
      PHII = 0.
      THII = ABAT
      STEP = 1.
      GO TO 39
   38 NPL = 2
      NPHI = 1
      NTHI = 360
      PHII = A8AP
      THII = 0.
      STEP = 1.
   39 PH = PHII-STEP
C
      DO 42 K=1,NPHI
      PH = PH+STEP
      TH = THII-STEP
C
      DO 42 I=1,NTHI
```

```
      TH = TH+STEP
      IF ((IGRD.GT.0).AND.((TH.GT.90).AND.(TH.LT.270))) GO TO 42
      L = L+1
      CALL GFFLD (IA,IB,INC,INM,IWR,I1,I2,I3,I12,MD,N,ND,NM,AM,ACSP,ACST
     1,C,CGD,CG,CJ,CMM,D,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ETTS,GG,
     2GPP,GTT,PH,SGD,SCSP,SCST,SPPM,SPTM,STPM,STTM,TH,X,Y,Z,ZLD,ZS,ETA,G
     3AM,ERR,IGRD)
      IF (IWR.GT.0) GO TO 40
      IF (NPL.LT.0) WRITE (6,63) PH,TH,SPPM,SPTM,STPM,STTM,ACSP,ACST,ECS
     1P,ECST,SCSP,SCST
   40 CPHI(L) = PH
      CTHET(L) = TH
      CDAT1(L) = EPPS
      CDAT2(L) = EPTS
      CDAT3(L) = ETPS
      CDAT4(L) = ETTS
      IF (NPL.NE.1) GO TO 41
      DATY1(K) = CABS(EPPS)
      DATY2(K) = CABS(EPTS)
      DATY3(K) = CABS(ETPS)
      DATY4(K) = CABS(ETTS)
      GO TO 42
   41 DATY1(I) = CABS(EPPS)
      DATY2(I) = CABS(EPTS)
      DATY3(I) = CABS(ETPS)
      DATY4(I) = CABS(ETTS)
   42 CONTINUE
C
      WRITE (6,82)
      IF (NPL.LE.0) GO TO 43
      CALL POLPRT (7,DATY1)
      CALL POLPRT (8,DATY2)
      CALL POLPRT (9,DATY3)
      CALL POLPRT (10,DATY4)
      IF (KFLAG(17).NE.1) GO TO 45
   43 WRITE (6,64)
C
      DO 44 I=1,L
   44 WRITE (6,65) CPHI(I),CTHET(I),CDAT1(I),CDAT2(I),CDAT3(I),CDAT4(I)
C
C     BISTATIC SCATTERING
   45 IF (IBISC.LE.0) GO TO 54
      WRITE (6,75)
      WRITE (5,81)
      WRITE (6,77)
      WRITE (6,82)
      WRITE (6,61) CPHI(L),CTHET(L)
      WRITE (6,82)


      L = 0
      INC = 2
      NPL = -1
      IF (NBIP.EQ.1) GO TO 46
      NPHS = (PHSF-PHSI)/STEP+1
      NTHS = (THSF-THSI)/STEP+1
      IF (IWR.LE.0) WRITE (6,67)
      GO TO 48
   46 IF (ABIT.GT.500.) GO TO 47
      NPL = 1
      NPHS = 360
      NTHS = 1
      PHSI = 0.
      THSI = ABIT
      STEP = 1.
      GO TO 48
   47 NPL = 2
      NPHS = 1
      NTHS = 360
      PHSI = ABIP
      THSI = 0.
      STEP = 1.
   48 PH = PHSI-STEP
C
      DO 51 K=1,NPHS
      PH = PH+STEP
      TH = THSI-STEP
      IF ((IGRD.GT.0).AND.((TH.GT.90).AND.(TH.LT.270))) GO TO 51
C
      DO 51 I=1,NTHS
      TH = TH+STEP
      L = L+1
      CALL GFFLD (IA,IB,INC,INM,IWR,I1,I2,I3,I12,MD,N,ND,NM,AM,ACSP,ACST
     1,C,CGD,CG,CJ,CMM,D,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ETTS,GG,
     2GPP,GTT,PH,SGD,SCSP,SCST,SPPM,SPTM,STPM,STTM,TH,X,Y,Z,ZLD,ZS,ETA,G
     3AM,ERR,IGRD)
      IF (IWR.GT.0) GO TO 49
      IF (NPL.LT.0) WRITE (6,63) PH,TH,SPPM,SPTM,STPM,STTM
   49 CPHI(L) = PH
      CTHET(L) = TH
      CDAT1(L) = EPPS
      CDAT2(L) = EPTS
      CDAT3(L) = ETPS
      CDAT4(L) = ETTS
      IF (NPL.NE.1) GO TO 50
      DATY1(K) = CABS(EPPS)
      DATY2(K) = CABS(EPTS)
      DATY3(K) = CABS(ETPS)
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      OATY4(K) = CABS(ETTS)
   50 IF (NPL.NE.2) GO TO 51
      DATY1(I) = CABS(EPPS)
      DATY2(I) = CABS1EPTS)
      DATY3(I) = CABS(ETPS)
      DATY4(I) = CABS(ETTS)
   51 CONTINUE
C
      WRITE (6,82)
      IF (NPL.LE.D) GO TO 52
      CALL POLPRT (3,DATY1)
      CALL POLPRT 14,DATY2)
      CALL POLPRT 15,DATY3)
      CALL POLPRT (6,DATY4)
      IF (KFLAG(18).NE.1) GO TO 54
   52 WRITE (6,66)
C
      DO 53 I=1,L
   53 WRITE (6,65) CPHI(I),CTHET1I),CDAT1(I),CDAT21I),CDAT31I),CDAT4(I)
C
   54 IF (IFLAG.EQ.1) GO TO 1
      IF (IFLAG.EQ.2) STOP
C
      KKFLAG=D
      KJFLAG=D
      KMFLAG=D
      KNFLAG=D
      IF (KFLAG(13).GT.0) KKFLAG=1
      IF (KFLAG(23).GT.0) KJFLAG=1
      IF 1KFLAG(14).GT.D) KMFLAG=1
      IF (KFLAG(24).GT.0) KNFLAG=1
      DO 55 I=1,3D
   55 KFLAG(I) = -1
C
      KFLAG(8) = 1
      KFLAG120) = 1
      KFLAG(26) = 1
      IF (KKFLAG.GT.0) KFLAG(13)=1
      IF (KJFLAG.GT.0) KFLAG(23)=1
      IF (KMFLAG.GT.0) KFLAG(14)=1
      IF (KNFLAG.GT.0) KFLAG(24)=1
      IF (IFLAG.EQ.3) WRITE (6,68)
      IF (IFLAG.EQ.6) WRITE (6,115)
      GO TO 4
C
   56 FORMAT (1H0)
   57 FORMAT (10X,'THE RADIATION EFFICIENCY IS ',F15.7//10X,'THE TIME-AV
     1ERAGE POWER INPUT IS ',F15.7//10X,'THE ANTENNA IMPEOANCE IS ',F15.

     27,' +J',F15.7//)
   58 FORMAT (10X,'THE NEAR-FIELD ELECTRIC FIELD INTENSITY AT THE OBSERV
     1ATION POINT ',E11.5,',',E11.5,',',E11.5,' (X,Y,Z RESPECTIVELY) IS:
     2'//)
   59 FORMAT 120X,'EX=',F15.7,' +J',F15.7/20X,'EY=',F15.7,' +J',F15.7/20
     1X,'EZ=',F15.7,' +J',F15.7////)
   60 FORMAT (3X,F5.1,2X,F5.1,3X,E10.4,2X,E10.4,2(3X,3(E10.4,2X),F6.1,1X
     1))
   61 FORMAT (T41,'FOR BISTATIC SCATTERING THE INCIOENT'/T41,'PLANE WAVE
     1 IS PHI=',F5.1,' THETA=',F5.1///)
   62 FORMAT (' INCIDENT',T27,'ECHO AREA SIGMA',T66,'A8SORPTION',T90,'EX
     1TINCTION',T114,'SCATTERING'/'  PLANE',T25,'(INCIDENT-SCATTEREO)',1
     24X,3(5X,'CROSS SECTION',6X)/'  WAVE ',52X,3(1DX,'FOR',11X)/'  PHI
     3 THETA',3X,'PHI-PHI',3X,'PHI-THETA',4X,'THETA-PHI',2X,'THETA-THETA
     4',3(5X,'PHI',7X,'THETA',4X))
   63 FORMAT (1X,2(F5.1,1X),10(E10.4,2X))
   64 FORMAT (T54,'8ACKSCATTERING'/' INCIDENT',T37,'ELECTRIC FIELO POLAR
     1IZATION SCATTERING MATRIX'/'  PLANE',T49,'(INCIDENT-SCATTEREO)'/3X
     2,'WAVE',T23,'PHI-PHI',T49,'PHI-THETA',T75,'THETA-PHI',T102,'THETA-
     3THETA'/'  PH(  THETA',3X,4(3X,'REAL',8X,'IMAG',8X))
   65 FORMAT (1X,2(F5.I,1X),2X,4(E11.5,2X,E11.5,3X))
   66 FORMAT (T54,'BISTATIC'/T37,'ELECTRIC FIELD POLARIZATION SCATTERING
     1 MATRIX'/' O8SERVATION',T50,'(INCIDENT-SCATTERED)'/'   POINT',14X,
     2 'PHI-PHI',T49,'PHI-THETA',T76,'THETA-PHI',T1D1,'THETA-THETA'/'  P
     3HI  THETA',4X,4(3X,'REAL',8X,'IMAG',8X))
   67 FORMAT (' O8ERSVATION',T27,'ECHO AREA SIGMA'/'   POINT',T25,'(INCI
     1DENT-SCATTERED)'/'  PHI  THETA',T14,'PHI-PHI',T24,'PHI-THETA',T37,
     2  'THETA-PHI',T48,'THETA-THETA')
   68 FORMAT (1H1,5X,'CONTINUE EXECUTION WITH THE FOLLOWING AOOITIONS AN
     1D/OR CHANGES'//)
   69 FORMAT (54X,'ELECTRIC FIELD INTENSITY'/5X,'OEGREES',11X,'POWER GAI
     1N',28X,'THETA',42X,'PHI'/3X,'THETA',3X,'PHI',7X,'THETA',8X,'PHI',1
     2X,2(8X,'REAL',8X,'IMAG',8X,'MAGN',5X,'PHASE'))
   7D FORMAT (10X,'*****ERROR IN OATA CARD NUMBER ',I2,'  EXECUTION STOP
     1PED*******')
   71 FORMAT (40X,'*      A WIRE SEGMENT MAYNOT BE SHARED BY MORE THAN FO
     1UR     *'/40X,'*      OIPOLE MODES---------CHECK OESCRIPTION OATA CA
     2RD     *'/40X,'*                     EXECUTION STOPPEO
     3       *')
   72 FORMAT (40X,'*      AN ISOLATEO WIRE MUST HAVE AT LEAST TWO SEGMENT
     1S      *'/4DX,'*      ANO THREE POINTS-----CHECK DESCRIPTION OATA CA
     2RD     *'/40X,'*                     EXECUTION STOPPEO
     3       *')
   73 FORMAT 130X,'A 8ACKSCATTERING CALL MUST BE INCLUOEO FOR A BISTATIC
     1 CALL'//50X,'REQUEST IGNORED'/////)
   74 FORMAT 1'1',T50,37('*')/T50,'*',T86,'*'/
     1 T50,'*       OHIO STATE UNIVERSITY          *'/
     2 T50,'*     ANTENNA ANALYSIS PROGRAM         *'/
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  3 T50,'*         MODIFIED FOR USE AT              *'/
  4 T50,'*      NAVAL POSTGRADUATE SCHOOL           *'/
  5 T50,'*           3 SEPTEMBER 1975               *'/
  6 T50,'*',T86,'*'/T50,37('*'))
 75 FORMAT ('1',T50,29('*')/T50,'*',T78,'*')
 76 FORMAT (T50,'*',11X,'ANTENNA',T78,'*')
 77 FORMAT (T50,'*',8X,'CALCULATIONS',T78,'*'/T50,'*',T78,'*'/T50,29('
   1*'))
 78 FORMAT (T50,'*',9X,'NEAR FIELD',T78,'*')
 79 FORMAT (T50,'*',9X,'FAR FIELD',T78,'*')
 80 FORMAT (T50,'*',7X,'BACKSCATTERING',T78,'*')
 81 FORMAT (T50,'*',4X,'BISTATIC SCATTERING',T78,'*')
 82 FORMAT (/////)
 83 FORMAT (T30,'FREQUENCY (MHZ)',T81,E11.5)
 84 FORMAT (T30,'WIRE RADIUS (METERS)',T81,E11.5)
 85 FORMAT (T30,'WIRE CONDUCTIVITY (MEGAMHOS/METER)',T81,E11.5)
 86 FORMAT (T30,'WIRE INSULATED (NO/YES)',T85,'YES')
 87 FORMAT (T30,'WIRE INSULATED (NO/YES)',T85,'NO')
 88 FORMAT (T30,'INSULATION RADIUS (METERS)',T81,E11.5)
 89 FORMAT (T30,'INSULATION CONDUCTIVITY (MHOS/METER)',T81,E11.5)
 90 FORMAT (T30,'INSULATION DIELECTRIC CONSTANT (RELATIVE)',T81,E11.5)
 91 FORMAT (T30,'INSULATION LOSS TANGENT',T81,E11.5)
 92 FORMAT (T30,'EXTERIOR MEDIUM',T81,'FREE SPACE')
 93 FORMAT (T30,'EXTERIOR MEDIUM CONDUCTIVITY (MHOS/METER)',T81,E11.5)
 94 FORMAT (T30,'EXTERIOR MEDIUM DIELECTRIC CONSTANT (RELATIVE)',T81,
   1 E11.5)
 95 FORMAT (T30,'EXTERIOR MEDIUM LOSS TANGENT',T81,E11.5)
 96 FORMAT (T50,'WIRE STRUCTURE'//T20,'SEG',4X,2('NODE',19X,'LOCATION'
   1,18X)/T21,'NO.',3X,2(' NO.',9X,'X',13X,'Y',13X,'Z',7X)/(T21,I2,5X,
   22(I2,5X,E11.5,4X,E11.5,4X,E11.5,1X)))
 97 FORMAT (T50,'ANTENNA FEEDS'/T40,'NODE',16X,'VOLTS'/T41,'NO.',12X,
   1 'REAL',7X,'IMAGINARY'/(T41,I2,6X,2(4X,E11.5)))
 98 FORMAT (T50,'*', 6X,'OUTPUT REQUESTED',T78,'*')
 99 FORMAT (T30,'STRUCTURE CURRENTS')
100 FORMAT (T30,'FAR FIELDS FOR PHI VARYING FROM',1X,F5.1,' TO ',F5.1,
   1 'AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
   2T50,'IN STEPS OF ',F5.1,' DEGREES.')
101 FORMAT (T30,'BACKSCATTERING FOR PHI VARYING FROM ',F5.1,' TO ',F5.
   11,' AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
   2T50,'IN STEPS OF ',F5.1,' DEGREES.')
102 FORMAT (T30,'BISTATIC SCATTERING FOR PHI VARYING FROM ',F5.1,' TO
   1',F5.1,' AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
   2T50,'IN STEPS OF ',F5.1,' DEGREES.')
103 FORMAT (T30,'NEAR FIELDS FOR FOLLOWING POINTS (X,Y,Z)'/50(T40,3(E1
   11.5,5X)))
104 FORMAT (T30,'PLOT FOR FAR FIELD THETA=',F5.1)
105 FORMAT (T30,'PLOT FOR FAR FIELD PHI=',F5.1)
106 FORMAT (T30,'PLOT FOR BISTATIC SCATTERING-FOR THETA=',F5.1)



107 FORMAT (T30,'PLOT FOR BISTATIC SCATTERING FOR PHI=',F5.1)
108 FORMAT (T30,'PLOT FOR BACKSCATTERING THETA=',F5.1)
109 FORMAT (T30,'PLOT FOR BACKSCATTERING PHI=',F5.1)
110 FORMAT (T30,'NO OUTPUT OR PLOTS REQUESTED')
111 FORMAT (///)
112 FORMAT (T50,'*',T78,'*'/T50,29('*'))
113 FORMAT (T50,'*', 8X,'INPUT DATA ',T78,'*')
114 FORMAT (T50,29('*')/T50,'*',T78,'*')
115 FORMAT (10X,'SINCE THIS DATA BLOCK DOES NOT HAVE A TERMINATION CAR
   1D A CHANGE CARD IS ASSUMED')
116 FORMAT (//10X,40('*')/10X,'THE DESCRIPTION AND THE GEOMETRY OF THE
   1 STRUCTURE'/10X,'MUST BE STATED IN THE FIRST DATA BLOCK.'/10X,'***
   2* EXECUTION STOPPED ***')
117 FORMAT (//10X,'NO PART OF THE WIRE STRUCTURE CAN LIE BELOW THE GRO
   1 UND PLANE.'/10X,'****EXECUTION STOPPED****')
118 FORMAT (T50,'STRUCTURE LOADS'/T40,'NODE',16X,'OHMS'/T41,'NO.',12X
   1 ,'REAL',7X,'IMAGINARY'/(T41,I2,6X,2(4X,E11.5)))
119 FORMAT (T50,'STRUCTURE LOADS'/T39,'SEGMENT',14X,'OHMS'/T41,'NO',12
   1X,'REAL',7X,'IMAGINARY'/(T41,I2,6X,2(4X,E11.5)))
120 FORMAT (T50,'ANTENNA FEEDS'/T39,'SEGMENT',14X,'VOLTS'/T41,'NO.',12
   1X,'REAL',7X,'IMAGINARY'/(T41,I2,6X,2(4X,E11.5)))
121 FORMAT (//T30,'THE NUMBER OF INTERVALS FOR CALCULATING THE ELEMENT
   1S'/T30,'IN THE IMPEDANCE MATRIX WITH SIMPSONS-RULE INTEGRATION IS'
   2,/T30,I3,'.  IF CLOSED FORM INTEGRATION IS REQUIRED SET INT=0'///)
122 FORMAT (T30,'GROUND PLANE (NO/YES)',T85,'NO')
123 FORMAT (T30,'GROUND PLANE (NO/YES)',T85,'YES')
124 FORMAT (T30,'GROUND DIELECTRIC CONSTANT (RELATIVE)',T81,E11.5/
   1 T30,'GROUND CONDUCTIVITY (MHOS/METER)',T81,E11.5)
125 FORMAT (T30,'GROUND PLANE',T83,'PERFECT')
126 FORMAT (T30,'ANTENNA HEIGHT (METERS)',T81,E11.5)
127 FORMAT (//10X,40('*')/10X,'THE WIRE RADIUS MUST BE STATED'/10X,40(
   1'*'))
    END
```

BLNK

PURPOSE: to compress data to the left by removal of the blank spaces on the input data cards.

METHOD: A(I) character is compared to the blank; and if it is true, the A(I+1) character is shifted to the A(I) position.

CALLED BY: READ

CALLS TO: NONE

```
      SUBROUTINE BLNK (A)
      DIMENSION A(80)
      DATA BLANK/' '/
      K = 0
C
      DO 1 I=1,80
      J = I-K
      A(J) = A(I)
    1 IF (A(I).EQ.BLANK) K=K+1
C
      IF (K.EQ.0) RETURN
      A(81-K) = BLANK
      RETURN
      END
```

CBES

PURPOSE: to calculate the quantity B01 where

$$B01 = J_0(z) \ / \ J_1(z).$$

METHOD: If the absolute value of the argument for the Bessel function is less than 12, B01 is calculated via the power series expansion for the Bessel function in the DO LOOP ending at statement 3. If greater than 12, the asymptotic expression is utilized at statement 4. If the magnitude of the complex part of the argument for the Bessel function is greater than 20, B01 is set to (0.,-1). If the complex part of the argument is negative, the sign of B01 is changed prior to returning to the calling program.

CALLED BY: SGANT

CALLS TO: NONE

```
      SUBROUTINE CBES (Z,B01)
      COMPLEX ARG,CC,CS,EX
      COMPLEX B01,Z,TERMJ,TERMN,MZ24,JN(2)
      DATA PI/3.14159/
      IF (CABS(Z).GE.12.0) GO TO 4
      FACTOR = 0.0
      TERMN = (0.,0.)
      MZ24 = -0.25*Z*Z
      TERMJ = (1.0,0.0)
C
      DO 3 NP=1,2
      N = NP-1
      JN(NP) = TERMJ
      M = 0
    1 M = M+1
      TERMJ = TERMJ*MZ24/FLOAT(M*(N+M))
      JN(NP) = JN(NP)+TERMJ
      IF (NP.NE.1) GO TO 2
      FACTOR = FACTOR+1.0/FLOAT(M)
      TERMN = TERMN+TERMJ*FACTOR
    2 ERROR = CABS(TERMJ)
      IF (ERROR.GT.1.0E-10) GO TO 1
    3 TERMJ = 0.5*Z
C
      B01 = JN(1)/JN(2)
      RETURN
    4 Y = AIMAG(Z)
      IF (ABS(Y).GT.20.) GO TO 5
      ARG = (.0,1.)*Z
      EX = CEXP(ARG)
      CC = EX+1./EX
      CS = (.0,-1.)*(EX-1./EX)
      B01 = (CS+CC)/(CS-CC)
      RETURN
    5 B01 = (.0,-1.)
      IF (Y.LT.0.) B01 = (.0,1.)
      RETURN
      END
```

DSHELL

PURPOSE: to calculate the mutual impedance term contributed by the dielectric insulation on the surface of a thin wire.

METHOD: The contribution to the impedance matrix is calculated utilizing the equation below

$$z_{mn} = - \frac{(\varepsilon_2 - \varepsilon)\ \ln(b/a)}{2\pi\ jw\varepsilon\varepsilon_2} \int_{m,n} F'_m(l)\ F'_n(l)\ dl\ ,$$

where z_{mn} is defined in subroutine SGANT, ε_2 is the dielectric constant of the insulation, b is the outer radius of the insulation, a is the inner radius, ε is dielectric constant of the external medium, and F is the sinusoidal expansion function.

CALLED BY: SGANT

CALLS TO: NONE

```
SUBROUTINE DSHELL (AM,BM,DK,CGDS,SGDS,EP2,EP,ETA,GAM,P11,P12)
COMPLEX CGDS,SGDS,EP2,EP,ETA,GAM,P11,P12,GD,CST
DATA PI/3.14159/
GD = GAM*DK
CST = (EP2-EP)*ETA*ALOG(BM/AM)/(4.*PI*EP2*SGDS*SGDS)
P11 = -CST*(GD+SGDS*CGDS)
P12 = CST*(GD*CGDS+SGDS)
RETURN
END
```

EQUAL

PURPOSE: to determine position (location) of the equal symbol on input data card.

METHOD: The character search begins in the column passed to the subroutine. On returning to the calling program, the argument passed is the column following the equal symbol.

CALLED BY: READ

CALLS TO: NONE

```
      SUBROUTINE EQUAL (N)
      INTEGER A, EQULS
      COMMON /A/ A(80)
      DATA EQULS/'='/
      K = N
C
      DO 1 I=K,80
      N = I+1
      IF (A(I).EQ.EQULS) GO TO 2
    1 CONTINUE
C
      N = 1
    2 RETURN
      END
```

EXPJ

PURPOSE: to calculate the exponential integral with complex limits.

METHOD: The exponential integral is defined as:

$$W12 = \int_{V1}^{V2} \frac{e^{-v}}{v} dv = E_1(V1) - E_1(V2) + j2n\pi ,$$

where the integration path is the straight line from V1 to V2 on the complex v plane and

$$E_1(z) = \int_{z}^{\infty} \frac{e^{-t}}{t} dt .$$

The integration path is a horizontal line in the w plane or an inclined straight line from V1 to V2 the v plane. The integer n is zero unless this path intersects the negative real v axis at a point between V1 and V2. When there is such an intersection,

a) $n = 1$ if $Im(V1) > Im(V2)$

b) $n = -1$ if $Im(V1) < Im(V2)$.

The term $j2n\pi$ is caluclated below statement 12.

CALLED BY: GGMM

CALLS TO: NONE

```
      SUBROUTINE EXPJ (V1,V2,W12)
      COMPLEX EC,E15,S,T,UC,VC,V1,V2,W12,Z
      DIMENSION V(21), W(21), D(16), E(16)
      DATA V/0.22284667E00,0.11889321E01,0.29927363E01,0.57751436E01,0.9
     18374674E01,0.15982874E02,0.93307812E-01,0.49269174E00,0.12155954E0
     21,0.22699495E01,0.36676227E01,0.54253366E01,0.75659162E01,0.101202
     328E02,0.13130282E02,0.16654408E02,0.20776479E02,0.25623894E02,0.31
     4407519E02,0.38530683E02,0.48026086E02/
      DATA W/0.45896460E00,0.41700083E00,0.11337338E00,0.10399197E-01,0.
     126101720E-03,0.89854791E-06,0.21823487E00,0.34221017E00,0.26302758
     2E00,0.12642582E00,0.40206865E-01,0.85638778E-02,0.12124361E-02,0.1
     31167440E-03,0.64599267E-05,0.22263169E-06,0.42274304E-08,0.3921897
     43E-10,0.14565152E-12,0.14830270E-15,0.16005949E-19/
      DATA D/0.22495842E02,0.74411568E02,-0.41431576E03,-0.78754339E02,0
     1.11254744E02,0.16021761E03,-0.23862195E03,-0.50094687E03,-0.684878
     254E02,0.12254778E02,-0.10161976E02,-0.47219591E01,0.79729681E01,-0
     3.21069574E02,0.22046490E01,0.89728244E01/
      DATA E/0.21103107E02,-0.37959787E03,-0.97489220E02,0.12900672E03,0
     1.17949226E02,-0.12910931E03,-0.55705574E03,0.13524801E02,0.1469672
     21E03,0.17949528E02,-0.32981014E00,0.31028836E02,0.81657657E01,0.22
     3236961E02,0.39124892E02,0.81636799E01/
      Z = V1
C
      DO 12 JIM=1,2
      X = REAL(Z)
      Y = AIMAG(Z)
      E15 = (.0,.0)
      AB = CABS(Z)
      IF (AB.EQ.0.) GO TO 11
      IF (X.GE.0..AND.AB.GT.10.) GO TO 10
      YA = ABS(Y)
      IF (X.LE.0..AND.YA.GT.10.) GO TO 10
      IF (YA-X.GE.17.5.OR.YA.GE.6.5.OR.X+YA.GE.5.5.OR.X.GE.3.) GO TO 2
      IF (X.LE.-9.) GO TO 6
      IF (YA-X.GE.2.5) GO TO 7
      IF (X+YA.GE.1.5) GO TO 3
      N = 6.+3.*AB
      E15 = 1./(N-1.)-Z/N**2
    1 N = N-1
      E15 = 1./(N-1.)-Z*E15/N
      IF (N.GE.3) GO TO 1
      E15 = Z*E15-CMPLX(.577216+ALOG(AB),ATAN2(Y,X))
      GO TO 11
    2 J1 = 1
      J2 = 6
      GO TO 4
    3 J1 = 7
      J2 = 21

    4 S = (.0,.0)
      YS = Y*Y
C
      DO 5 I=J1,J2
      X1 = V(I)+X
      CF = W(I)/(X1*X1+YS)
    5 S = S+CMPLX(X1*CF,-YA*CF)
C
      GO TO 9
    6 T3 = X*X-Y*Y
      T4 = 2.*X*YA
      T5 = X*T3-YA*T4
      T6 = X*T4+YA*T3
      UC = CMPLX(D(11)+D(12)*X+D(13)*T3+T5-E(12)*YA-E(13)*T4,E(11)+E(12)
     1*X+E(13)*T3+T6+D(12)*YA+D(13)*T4)
      VC = CMPLX(D(14)+D(15)*X+D(16)*T3+T5-E(15)*YA-E(16)*T4,E(14)+E(15)
     1*X+E(16)*T3+T6+D(15)*YA+D(16)*T4)
      GO TO 8
    7 T3 = X*X-Y*Y
      T4 = 2.*X*YA
      T5 = X*T3-YA*T4
      T6 = X*T4+YA*T3
      T7 = X*T5-YA*T6
      T8 = X*T6+YA*T5
      T9 = X*T7-YA*T8
      T10 = X*T8+YA*T7
      UC = CMPLX(D(1)+D(2)*X+D(3)*T3+D(4)*T5+D(5)*T7+T9-(E(2)*YA+E(3)*T4
     1+E(4)*T6+E(5)*T8),E(1)+E(2)*X+E(3)*T3+E(4)*T5+E(5)*T7+T10+(D(2)*YA
     2+D(3)*T4+D(4)*T6+D(5)*T8))
      VC = CMPLX(D(6)+D(7)*X+D(8)*T3+D(9)*T5+D(10)*T7+T9-(E(7)*YA+E(8)*T
     14+E(9)*T6+E(10)*T8),E(6)+E(7)*X+E(8)*T3+E(9)*T5+E(10)*T7+T10+(D(7)
     2*YA+D(8)*T4+D(9)*T6+D(10)*T8))
    8 EC = UC/VC
      S = EC/CMPLX(X,YA)
    9 EX = EXP(-X)
      T = EX*CMPLX(COS(YA),-SIN(YA))
      E15 = S*T
      IF (Y.LT.0.) E15 = CONJG(E15)
      GO TO 11
   10 E15 = .409319/(Z+.193044)+.421831/(Z+1.02666)+.147126/(Z+2.56788)+
     1.206335E-1/(Z+4.90035)+.107401E-2/(Z+8.18215)+.158654E-4/(Z+12.734
     222)+.317031E-7/(Z+19.3957)
      E15 = E15*CEXP(-Z)
   11 IF (JIM.EQ.1) W12 = E15
   12 Z = V2
C
      Z = V2/V1
      TH = ATAN2(AIMAG(Z),REAL(Z))-ATAN2(AIMAG(V2),REAL(V2))+ATAN2(AIMAG

     1(V1),REAL(V1))
      AB = ABS(TH)
      IF (AB.LT.1.) TH = .0
      IF (TH.GT.1.) TH = 6.2831853
      IF (TH.LT.-1.) TH = -6.2831853
      W12 = W12-E15+CMPLX(.0,TH)
      RETURN
      END
```

GANT1

PURPOSE: to consider the wire structure as a transmitting antenna and calculate the input impedance and current distribution.

METHOD: If a wire antenna is driven by a voltage generator v_i located at one of the current sampling points l_i and if displacement currents are neglected, Ampere's law yields

$$V_m = v_i F_m(l_i)$$

where F is the sinusoidal expansion function. Thus, the excitation voltages V_m will vanish everywhere except where v_i is not zero.

The DO LOOP ending with statement 2 uses the delta-gap model defined above to determine the excitation voltage CJ(I) for all the dipole modes. These are stored temporarily in CG(I). Then subroutine SQROT is called to obtain a solution of the simultaneous linear equations. SQROT stores the solution (the loop currents) in CJ(I).

In the DO LOOP ending at statement 6 , the complex power input and input impedance(s) are calculated. The time-average power input (PIN) is the real part of the complex power input.

Subroutine RITE is called to make the transformation from the loop currents to the branch currents. If IWR is a positive integer, RITE will write out the list of branch currents.

Finally, GANT1 calculates the radiation efficiency by calling subrouinte GDISS to obtain the time-average power dissipated in the lumped loads and the imperfectly conducting wire.

CALLED BY: MAIN

CALLS TO: GDISS

RITE

SQROT

```
      SUBROUTINE GANT1 (IA,IB,INM,IWR,I1,I2,I3,I12,JA,JB,MD,N,ND,NM,AM,C
     1,CJ,CG,CMM,D,EFF,GAM,GG,CGD,SGD,VG,Y11,Z11,ZLD,ZS,IGRD)
      COMPLEX YY , CGEN
      COMPLEX C(1),CJ(1),CGD(1),SGD(1),VG(1),ZLD(1),Y11,Z11,ZS,GAM,CG(1)
      OIMENSION D(1), IA(1), IB(1), JA(1), JB(1)
      DIMENSION I1(1), I2(1), I3(1), MD(INM,4), ND(1)
      CCMMON IWL
C
      DO 3 I=1,N
      CJ(I) = (.0,.0)
      K = JA(I)
C
C
      DO 2 KK=1,2
      KA = IA(K)
      KB = IB(K)
      JJ = K
      FI = 1.
      IF (KB.EQ.I2(I)) GO TO 1
      IF (KB.EQ.I1(I)) FI=-1.
      CJ(I) = CJ(I)+FI*VG(JJ)
      GO TO 2
    1 IF (KA.EQ.I3(I)) FI=-1.
      JJ = K+NM
      CJ(I) = CJ(I)+FI*VG(JJ)
    2 K = JB(I)
C
C
    3 CONTINUE
C
C
C
C
      DO 4 I=1,N
    4 CG(I) = CJ(I)
C
C
      CALL SQROT (C,CJ,0,I12,N)
      I12 = 2
      Y11 = (.0,.0)
      NNN = N
      IF (IGRD.GT.0) NNN = (N+IWL)/2
C
C
      DO 6 I=1,NNN
      NN = IA(JB(I))
      CGEN = CG(I)
      IF (I.LE.IWL) CGEN=CGEN/2.


      YY = CJ(I)*CONJG(CGEN)
      IF (CABS(YY).LT.1.E-20) GO TO 5
      Z11 = (1./YY)*(CABS(CGEN)**2)
      WRITE (6,8) NN,Z11
    5 Y11 = Y11+YY
    6 CONTINUE
C
C
      IF (IWR.GT.0) WRITE (6,7)
      CALL RITE (IA,IB,INM,IWR,I1,I2,I3,MD,ND,NM,CJ,CG,IGRD)
      GG = REAL(Y11)
      IF (IGRO.GT.0) GG=2.*REAL(Y11)
      PIN = GG
      CALL GOISS (AM,CG,CMM,D,DISS,GAM,NM,SGD,ZLD,ZS)
      PRAD = PIN-DISS
      EFF = 100.*PRAD/PIN
      RETURN
C
C
    7 FORMAT (50X,'ANTENNA BRANCH CURRENTS')
    8 FORMAT (10X,'THE INPUT IMPEDANCE AT NODE ',I3,' IS',F15.7,' + J',
     1F15.7//)
      END
```

GDISS

PURPOSE: to calculate the time-average power dissipated in the imperfectly conducting wire and in the lumped loads.

METHOD: The time-average power dissipated by the wire is calculated in the DO LOOP ending at statement 1 utilizing the equation below:

$$P_d = \frac{R_s}{2\pi a} \int_0^l I I^* dl$$

where R_s is the surface resistance of the wire and a is the radius of the wire.

The power dissipated by the lumped loads is calculated by the DO LOOP ending at statement 3. If the wire is perfectly conducting, CMM <0, the first calculation is by-passed.

CALLED BY: GANT1

CALLS TO: NONE

```
      SUBROUTINE GDISS (AM,CG,CMM,D,DISS,GAM,NM,SGD,ZLD,ZS)
      COMPLEX CG(I),SGD(1),ZLD(1),CJA,CJB,GAM,ZS
      DIMENSION D(I)
      DATA PI/3.14159/
      DISS = .0
      IF (CMM.LE.0.) GO TO 2
      ALPH = REAL(GAM)
      BETA = AIMAG(GAM)
      RH = REAL(ZS)/(4.*PI*AM)
C
      DO I K=1,NM
      DK = D(K)
      DEN = CABS(SGD(K))**2
      EAD = EXP(ALPH*DK)
      CAD = (EAD+1./EAD)/2.
      CBD = COS(BETA*DK)
      SAD = DK
      IF (ALPH.NE.0.) SAD=(EAD-1./EAD)/(2.*ALPH)
      SBD = DK
      IF (BETA.NE.0.) SBD=SIN(BETA*DK)/BETA
      FA = RH*(SAD*CAD-SBD*CBD)/DEN
      FB = 2.*RH*(CAD*SBD-SAD*CBD)/DEN
      CJA = CG(K)
      L = K+NM
      CJB = CG(L)
    1 DISS = DISS+FA*(CABS(CJA)**2+CABS(CJB)**2)+FB*(REAL(CJA)*REAL(CJB)
     1+AIMAG(CJA)*AIMAG(CJ3))
C
C
    2 DO 3 J=1,NM
      K = J+NM
    3 DISS = DISS+REAL(ZLD(J))*(CABS(CG(J))**2)+REAL(ZLD(K))*(CABS(CG(K)
     1)**2)
C
      RETURN
      END
```

GFF

PURPOSE: to calculate the far-zone field of a sinusoidal electric monopole.

METHOD: If an electric line source has length d and endpoints at (x_1, y_1, z_1) and (x_2, y_2, z_2), then the coordinates of any point on the source are

$$x = x_1 + l \cos x$$

$$y = y_1 + l \cos y$$

$$z = y_1 + l \cos z$$

where cosx, cosy, cosz are the direction cosines of the l axis, and l is the distance along the source measured from the endpoint (x_1, y_1, z_1). Let the current distribution on the monopole be

$$I(l) = \frac{I_1 \sinh \gamma(d - l) + I_2 \sinh \gamma l}{\sinh \gamma d}$$

where I_1 and I_2 are the endpoint currents. The far-zone field of this source is

$$E_\phi = (\cos x \cos\theta \cos\phi - \cos y \cos\theta \sin\phi - \cos z \sin\theta)\ E_1$$

$$E_\theta = (-\cos x \sin\phi + \cos y \cos\phi)\ E_1$$

where

$$E_1 = \frac{\eta e^{-\gamma r}}{4\pi r\ (1-g^2) \sinh \gamma d} \left[(e^{\gamma g d} - g \sinh \gamma d - \cosh \gamma d)\ I_1 e^{\gamma f(1)} + (e^{\gamma d} + g \sinh \gamma d - \cosh \gamma d)\ I_2\ e^{\gamma f(2)} \right]$$

$$f^{(1)} = x_1 \sin\theta \cos\phi + y_1 \sin\theta \sin\phi + z_1 \cos\theta$$

$$f^{(2)} = x_2 \sin\theta \cos\phi + y_2 \sin\theta \sin\phi + z_2 \cos\theta$$

$$g = \cos x \sin\theta \cos\phi + \cos y \sin\theta \sin\phi + \cos z \cos\theta$$

and (r,θ,ϕ) are the spherical coordinates of the observation point.

In this subroutine the range dependence has been suppressed. The far field vanishes in the endfire direction where GK = 0. If a ground plane is present (IGRD > 0) the E_1 equation above is decomposed into the x, y, and z components and the reflection coefficients are applied before E_θ and E_ϕ field components are returned to the calling program.

CALLED BY: GFFLD

CALLS TO: NONE

```
      SUBROUTINE GFF (XA,YA,ZA,XB,YB,ZB,D,CGD,SGD,CTH,STH,CPH,SPH,GAM,ET
     1A,ET1,ET2,EP1,EP2,IGRD,ERR)
      COMPLEX ERR,RV,RH,RR,EX,EY,EZ,EE
      COMPLEX ET1,ET2,EP1,EP2,GAM,ETA
      COMPLEX GD,CGD,SGD,EGD
      COMPLEX EGFA,EGFB,EGGD,ESA,ESB
      COMPLEX CST
      FP = 12.56637
      XAB = XB-XA
      YAB = YB-YA
      ZAB = ZB-ZA
      CA = XAB/D
      CB = YAB/D
      CG = ZAB/D
      G = (CA*CPH+CB*SPH)*STH+CG*CTH
      GK = 1.-G*G
      ET1 = (.0,.0)
      ET2 = (.0,.0)
      EP1 = (.0,.0)
      EP2 = (.0,.0)
      IF (GK.LT..001) GO TO 3
      FA = (XA*CPH+YA*SPH)*STH+ZA*CTH
      FB = (XB*CPH+YB*SPH)*STH+ZB*CTH
      EGFA = CEXP(GAM*FA)
      EGFB = CEXP(GAM*FB)
      EGGD = CEXP(GAM*G*D)
      CST = ETA/(GK*SGD*FP)
      ESA = CST*EGFA*(EGGD-G*SGD-CGD)
      ESB = CST*EGFB*(1./EGGD+G*SGD-CGD)
      IF (IGRD.LE.0) GO TO 2
      RV = (-1.,0)
      RH = (-1.,0)
      IF (IGRD.EQ.1) GO TO 1
      RR = CSQRT(ERR-STH*STH)
      RV = -(ERR*CTH-RR)/(ERR*CTH+RR)
      RH = (CTH-RR)/(CTH+RR)
    1 EX = CA*ESA
      EY = CB*ESA
      EZ = CG*ESA
      EE = (EX*SPH-EY*CPH)*(RH-RV)
      EX = EX*RV+EE*SPH
      EY = EY*RV-EE*CPH
      EZ = -EZ*RV
      ESA =-EX*CA-EY*CB+EZ*CG
      EX = CA*ESB
      EY = CB*ESB
      EZ = CG*ESB
      EE = (EX*SPH-EY*CPH)*(RH-RV)


      EX = EX*RV+EE*SPH
      EY = EY*RV-EE*CPH
      EZ = -EZ*RV
      ESB =-EX*CA-EY*CB+EZ*CG
    2 T = (CA*CPH+CB*SPH)*CTH-CG*STH
      P = -CA*SPH+CB*CPH
      ET1 = T*ESA
      ET2 = T*ESB
      EP1 = P*ESA
      EP2 = P*ESB
    3 CONTINUE
      RETURN
      END
```

GFFLD

PURPOSE: to calculate the far-field for the thin wire structure.

METHOD: The far-field for the structure is calculated from the loop currents. The loop currents are either the currents produced by the transmiiting antenna calculations of subroutine GANT1 or the currents produced by an incident plane wave.

If the incident field is generated by a distance source with spherical coordinates (r_0, θ_0, ϕ_0), the excitation voltages induced by a incident plane wave are

$$V_m = \int_m F_m E_i \; dl$$

where

$$E_i = E_0 \exp(\gamma \; \bar{r} \cdot \bar{r}_0)$$

where E_0 is a vector constant, $\bar{r}_0$ is a vector from the coordinate origin to the distance source, and $\bar{r}$ is the radial vector from the origin to the observation point.

The field E_M is generated by test dipole m when radiating in the homogeneous medium. Using the vector potential, the field at the distance point (r_0, θ_0, ϕ_0) is

$$E_m = - \frac{jwu \; e^{-\gamma r_o}}{4\pi r_o} \int_m F_m \; \exp(\gamma \; \bar{r} \cdot \bar{r}_o) \; dl$$

where the radial component is to be suppressed. From the above equations,

$$V_m = -\frac{4\pi r_o}{jwu} e^{\gamma r_o} e_o e_m .$$

If an antenna gain calculation is desired, INC is set to zero. PH and TH denote the spherical coordinate direction of the distance observation point. The phi-polarized (EPPS) and the theta-polarized (ETTS) components of the electric field intensity are returned to the calling program.

If INC = 1, a backscattering calculation is desired. In this case PH and TH denotes the incident angles for the incident plane wave. These are also the spherical coordinates of the distance source. The outputs returned to the calling program include absorption, extinction, and scattering cross section for each polarization; scattered electric field; and echo areas.

If INC = 2, a bistatic calculation is desired. In this case PH and TH denote the spherical coordinate of a distance observer. Since this calculation uses the induced loop currents (EP and ET), a backscattering call must preceed this calculation. The outputs returned to the calling program consist of the scattered electric field components and echo areas.

EPP(I) and ETT(I) denote the phi-polarized and theta-polarized far-zone fields of dipole mode I with unit terminal current. In a backscattering situation, the excitation voltages EP(I) and ET(I) are obtained by multiplying EPP and ETT by the constant CJI. Then calls are made to SQROT which stores the solution (the induced loop currents) in EP(I) and ET(I). RITE is called for the branch currents CG(J), and GDISS is called for the time-average power dissipated in the imperfectly conducting wire and the lumped loads. This power is denoted PDISS and TDISS for phi-polarized and theta-polarized incident waves, respectively.

In scattering problems, the incident plane wave has unit electric field intensity at the origin. GGG denotes the time-average power density of the incident wave at the origin. ACSP and ACST denote the absorption cross sections for the phi and theta polarizations.

PIN and TIN denote the time-average power input to the wire structure, delivered by the equivalent voltage generators VP and VT at the terminals. PIN and TIN apply for the phi and theta polarizations, respectivity. The time-average power input is regarded as the sum of the time-average power dissipated and the time-average power radiated or scattered by the wire. ECSP and ECST denote the extinction cross sections and SCSP and SCST denote the scattering cross sections.

The distance field is calculated in the DO LOOP ending with statement 7 for scattering situations, and in the DO LOOP ending with statement 9 for the antenna situation.

The radar cross sections (echo areas) SPPM, SPTM, STPM, and STTM, are defined as

$$\sigma = \lim_{r \to \infty} 4\pi r^2 e^{2\alpha r} S_s / S_i$$

where S_s and S_i denote the time-average power densities in the scattered and incident fields evaluated at the origin.

For an antenna, the following definition is employed for the power gains:

$$G_p(\theta,\phi) = \lim_{r\to\infty} 4\pi r^2 e^{2\alpha r} S(r,\theta,\phi) / P_i$$

where P_i, GG, denote the time-average power input and $S(r,\theta,\phi)$ is the time-average power density in the radiated field. GPP and GTT denote the power gains associated with the phi-polarized and the theta-polarized components of the field, respectively.

The use of the variables JFLAG and KFLAG are described in subroutine SGANT.

CALLED BY: MAIN

CALLS TO: GDISS

GFF

RITE

SQROT

```
      SUBROUTINE GFFLD (IA,IB,INC,INM,IWR,I1,I2,I3,I12,MD,N,ND,NM,AM,ACS
     1P,ACST,C,CGD,CG,CJ,CMM,D,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ET
     2TS,GG,GPP,GTT,PH,SGD,SCSP,SCST,SPPM,SPTM,STPM,STTM,TH,X,Y,Z,ZLD,ZS
     3,ETA,GAM,ERR,IGRD)
      CCMPLEX ERR
      COMPLEX CJI,ET1,ET2,EP1,EP2,EPPS,ETTS,EPTS,ETPS,ZS,VP,VT
      COMPLEX C(1),CJ(1),EP(1),ET(1),EPP(1),ETT(1),ZLD(1)
      COMPLEX ETA,GAM,CGD(1),SGD(1),CG(1)
      DIMENSION IA(1), IB(1), I1(1), I2(1), I3(1), ND(1), MD(INM,4)
      DIMENSION D(1), X(1), Y(1), Z(1)
      DATA PI,TP/3.14159,6.28318/
      CJI = -4.*PI/(ETA*GAM)
      GGG = REAL(1./ETA)
      THR = .0174533*TH
      CTH = COS(THR)
      STH = SIN(THR)
      PHR = .0174533*PH
      CPH = COS(PHR)
      SPH = SIN(PHR)
C
      DO 1 I=1,N
      ETT(I) = (.0,.0)
    1 EPP(I) = (.0,.0)
C
C
      DO 3 K=1,NM
      KA = IA(K)
      KB = IB(K)
      NGRD = IGRD
      IF (K.LE.NM/2) IGRD=-1
      CALL GFF (X(KA),Y(KA),Z(KA),X(KB),Y(KB),Z(KB),D(K),CGD(K),SGD(K),C
     1TH,STH,CPH,SPH,GAM,ETA,ET1,ET2,EP1,EP2,IGRD,ERR)
      IGRD = NGRD
      NDK = ND(K)
C
      DO 3 II=1,NDK
      I = MD(K,II)
      FI = 1.
      IF (KB.EQ.I2(I)) GO TO 2
      IF (KB.EQ.I1(I)) FI=-1.
      EPP(I) = EPP(I)+FI*EP1
      ETT(I) = ETT(I)+FI*ET1
      GO TO 3
    2 IF (KA.EQ.I3(I)) FI=-1.
      EPP(I) = EPP(I)+FI*EP2
      ETT(I) = ETT(I)+FI*ET2
    3 CONTINUE
C

      EPPS = (.0,.0)
      ETTS = (.0,.0)
      IF (INC.EQ.0) GO TO 8
      IF (INC.EQ.2) GO TO 6
C
      DO 4 I=1,N
      ET(I) = ETT(I)*CJI
    4 EP(I) = EPP(I)*CJI
C
      CALL SCROT (C,EP,0,I12,N)
      I12 = 2
      CALL SCROT (C,ET,0,I12,N)
      IF (IWR.GT.0) WRITE (6,10) PH,TH
      IF (IWR.GT.0) WRITE (6,11)
      CALL RITE (IA,IB,INM,IWR,I1,I2,I3,MD,ND,NM,EP,CG,IGRD)
      CALL GDISS (AM,CG,CMM,D,PDIS,GAM,NM,SGD,ZLD,ZS)
      IF (IWR.GT.0) WRITE (6,12)
      CALL RITE (IA,IB,INM,IWR,I1,I2,I3,MD,ND,NM,ET,CG,IGRD)
      CALL GDISS (AM,CG,CMM,D,TDIS,GAM,NM,SGD,ZLD,ZS)
      ACSP = PDIS/GGG
      ACST = TDIS/GGG
      PIN = .0
      TIN = .0
C
      DO 5 I=1,N
      VP = CJI*EPP(I)
      VT = CJI*ETT(I)
      PIN = PIN+REAL(VP*CONJG(EP(I)))
    5 TIN = TIN+REAL(VT*CONJG(ET(I)))
C
      ECSP = PIN/GGG
      ECST = TIN/GGG
      SCSP = ECSP-ACSP
      SCST = ECST-ACST
    6 EPTS = (.0,.0)
      ETPS = (.0,.0)
C
      DO 7 I=1,N
      EPPS = EPPS+EP(I)*EPP(I)
      EPTS = EPTS+EP(I)*ETT(I)
      ETTS = ETTS+ET(I)*ETT(I)
    7 ETPS = ETPS+ET(I)*EPP(I)
C
      SPPM = 2.*TP*(CABS(EPPS)**2)
      SPTM = 2.*TP*(CABS(EPTS)**2)
      STPM = 2.*TP*(CABS(ETPS)**2)
      STTM = 2.*TP*(CABS(ETTS)**2)
      RETURN

C
    8 DO 9 I=1,N
      ETTS = ETTS+CJ(I)*ETT(I)
    9 EPPS = EPPS+CJ(I)*EPP(I)
C
      APP = CABS(EPPS)
      ATT = CABS(ETTS)
      GPP = 4.*PI*APP*APP*GGG/GG
      GTT = 4.*PI*ATT*ATT*GGG/GG
      RETURN
C
   10 FORMAT (10X,'BRANCH CURRENTS ASSOCIATED WITH PLANE-WAVE SCATTERING
     1 FOR THE INCIDENT ANGLES, PHI=',F5.1,' AND THETA=',F5.1//)
   11 FORMAT (44X,'CURRENTS INDUCED BY THE PHI POLARIZED WAVE')
   12 FORMAT (44X,'CURRENTS INDUCED BY THE THETA POLARIZED WAVE')
      END
```

GGMM

PURPOSE: to calucate the mutual impedance between two filamentary monopoles with sinusoidal current distribution.

METHOD: As stated in subroutine SGANT, the mutual impedance of coupled dipoles may be expressed as sum of four monopole-monopole impedances. This subroutine calculates the mutual impedance with closed-form expressions in terms of exponential integrals.

For skew monopoles it can be shown that the monopole-monopole mutual impedance is given by:

$$z_{ij} = (-1)^{i+j} B \left[e^{t_n} \left(F_{j1} - e^{-z_m} G_{12} + e^{z_m} G_{22} \right) - e^{-t_n} \left(F_{j2} - e^{-z_m} G_{11} + e^{z_m} G_{21} \right) \right]$$

where m= 2/i, n = 2/j and

$$B = \frac{\eta}{16 \pi \sinh d_1 \sinh d_2} .$$

The functions F_{ik} are defined by:

$$F_{ik} = 2 \sinh d_1 \, e^{q z_i \cos \Psi} \, E(R_i + q z_i \cos \Psi - qt)$$

where $q = (-1)^k$, d_1 and d_2 are the lengths of the monopoles being considered. The functions G_{ik} are defined as follows:

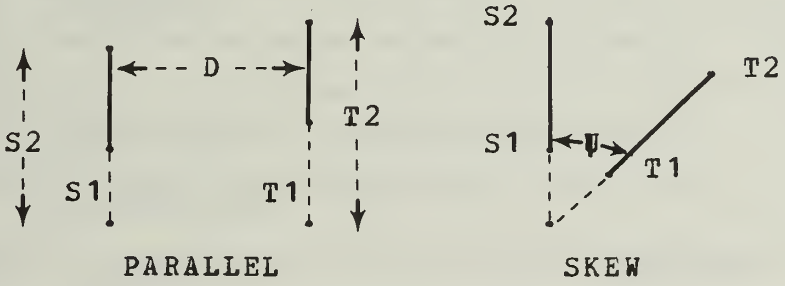
$$G_{ik} = E(R_2 + qz_2 + q't - jq'') + E(R_2 + qz_2 + q't + jq'')$$
$$- E(r_1 + qz_1 + q't - jq'') - E(R_1 + qz_1 + q't + jq'')$$

where $q = (-1)^i$, $q' = (-1)^k$, and $q'' = qb + q'c$ with $b = c \cos \Psi$ and $c = d/\sin \Psi$. The angle Ψ is the angle formed by the apparent intersection of the two monopoles. This will be discussed later in detail.

In the above equation for G^{ik}, t denotes the position of an observation point somewhere on monopole 2. R_1 and R_2 are the distances from the endpoints of monopole 1 to this observation point. Finally, the E functions are defined as follows:

$$E(a + jq'') = e^{j\gamma q''} \int_{a_1+jq''}^{a_2+jq''} \frac{e^{-\gamma w}}{w}\, dw$$

where a and q" are real quantities with dimensions of length, a is a function of t, $a_1 = a(t_1)$, $a_2 = a(t_2)$ and $\gamma = jw\sqrt{u\varepsilon}$. The integral above is evaluated by subroutine EXPJ.



To explain the input data for GGMM, refer to the above figure. If the monopoles are parallel, then the new coordinate system is defined such that the new z axis is parallel to the monopoles. The coordinate origin may be selected arbitrarily. S1 and S2 denote the z coordinates of the endpoints of the test monopole, T1 and T2 are the coordinates of the endpoints of the expansion monopole, and D is the perpendicular distance (displacement) between the monopoles. The mutual impedance of parallel monopoles is calculates in the last part of GGMM below statement 5.

For skew monopoles, let the test monopole s lie in the xy plane and the expansion monopole t in the plane z = D. (D is the perpendicular distance between the parallel planes.) If the monopoles are viewed along a line of sight parallel with the z axis, the extended axes of the two monopoles will appear to intersect at a point on the xy plane. Let s measure the distance along the axis of the test monopole with the origin at the apparent intersection. S1 and S2 denote the s coordinates of the endpoints of the test monopole. Similarily, let t measure the distance along the axis of the expansion monopole with the origin at the apparent intersection. T1 and T2 denote the t coordinates of the endpoints of the expansion monopole. Let $\bar{s}$ snd $\bar{t}$ be unit vectors parallel with the positive s and t axes, respectively. Then CPSI = $\bar{s} \cdot \bar{t} = \cos \psi$. The monopole lengths are d_s and d_t.

The output data from GGMM are the impedances P11, P12, P21, and P22. In defining these impedances, the reference direction is from S1 to S2 for the current on monopole s, and from T1 to T2 for the current on monopole t. In the impedance P_{ij}, the first subscript is 1 or 2 if the test dipole has terminals at S1 or S2 on monopole s. The second subscript is 1 or 2 if the expansion dipole has terminals at T1 or T2 on monopole t. The monopole lengths d_s and d_t are assumed positive in defining the input data CGDS, SGD1 and

SGD2.

For parallel monopoles, CPSI = 1 or -1. S1, S2, T1, and T2 are cartesian coordinates for parallel monopoles and spherical coordinates for skew monopoles. For skew monopoles, the radial coordinates S1, S2, T1, and T2 tend to infinity as the angle Ψ tends to zero or π. Therefore, if the monopoles are within 4.5° of being parallel, they are approximated by parallel dipoles.

CALLED BY: GGS

SGANT

CALLS TO: EXPJ

```
      SUBROUTINE GGMM (S1,S2,T1,T2,D,CGDS,SGD1,SGD2,CPSI,ETA,GAM,P11,P12
     1,P21,P22)
      DOUBLE PRECISION R1,R2,DPQ,S1S,TS1,TS2,ST1,ST2,CD,BD,CPSS,SK,TL1,T
     1L2,TD1,TD2,SD1,DPSI,DD,ZD
      COMPLEX CGDS,SGDS,SGDT,SGD1,SGD2,ETA,GAM,P11,P12,P21,P22
      COMPLEX CST,EB,EC,EK,EL,EKL,EGZI,ES1,ES2,ET1,ET2,EXPA,EXPB
      COMPLEX E(2,2),F(2,2)
      COMPLEX EGZ(2,2),GM(2),GP(2)
      DATA PI/3.14159/
      DSQ = D*D
      SGDS = SGD1
      IF (S2.LT.S1) SGDS = -SGD1
      SGDT = SGD2
      IF (T2.LT.T1) SGDT = -SGD2
      IF (ABS(CPSI).GT..997) GO TO 5
      ES1 = CEXP(GAM*S1)
      ES2 = CEXP(GAM*S2)
      ET1 = CEXP(GAM*T1)
      ET2 = CEXP(GAM*T2)
      DD = D
      DPSI = CPSI
      TD1 = T1
      TD2 = T2
      CPSS = DPSI*DPSI
      CD = DD/DSQRT(1.D0-CPSS)
      C = CD
      BD = CD*DPSI
      B = BD
      EB = CEXP(GAM*CMPLX(.0,B))
      EC = CEXP(GAM*CMPLX(.0,C))
C
      DO 1 K=1,2
C
      DO 1 L=1,2
    1 E(K,L) = (.0,.0)
C
      TS1 = TD1*TD1
      TS2 = TD2*TD2
      DPQ = DD*DD
      SI = S1
C
      DO 4 I=1,2
      FI = (-1)**I
      SD1 = SI
      S1S = SD1*SD1
      ST1 = 2.*SD1*TD1*DPSI
      ST2 = 2.*SD1*TD2*DPSI
      R1 = DSQRT(DPQ+S1S+TS1-ST1)
```

```
      R2 = DSQRT(DPQ+SIS+TS2-ST2)
      EK = EB
C
      DO 3 K=1,2
      FK = (-1)**K
      SK = FK*SDI
      EL = EC
C
      DO 2 L=1,2
      FL = (-1)**L
      EKL = EK*EL
      XX = FK*BD+FL*CD
      TL1 = FL*TD1
      TL2 = FL*TD2
      RR1 = R1+SK+TL1
      RR2 = R2+SK+TL2
      CALL EXPJ (GAM*CMPLX(RR1,-XX),GAM*CMPLX(RR2,-XX),EXPA)
      CALL EXPJ (GAM*CMPLX(RRI,XX),GAM*CMPLX(RR2,XX),EXPB)
      E(K,L) = E(K,L)+FI*(EXPA*EKL+EXPB/EKL)
    2 EL = 1./EC
C
    3 EK = 1./EB
C
      ZD = SDI*DPSI
      ZC = ZD
      EGZ1 = CEXP(GAM*ZC)
      RRI = R1+ZD-TD1
      RR2 = R2+ZD-TD2
      CALL EXPJ (GAM*RR1,GAM*RR2,EXPB)
      RR1 = R1-ZD+TDI
      RR2 = R2-ZD+TD2
      CALL EXPJ (GAM*RRI,GAM*RR2,EXPA)
      F(I,I) = 2.*SGDS*EXPA/EGZI
      F(I,2) = 2.*SGDS*EXPB*EGZI
    4 SI = S2
C
      CST = ETA/(16.*PI*SGDS*SGDT)
      P11 = CST*((F(I,1)+E(2,2)*ES2-E(1,2)/ES2)*ET2+(-F(1,2)-E(2,1)*ES2+
     1E(1,1)/ES2)/ET2)
      P12 = CST*((-F(1,1)-E(2,2)*ES2+E(1,2)/ES2)*ET1+(F(1,2)+E(2,1)*ES2-
     1E(1,1)/ES2)/ET1)
      P21 = CST*((-F(2,1)-E(2,2)*ES1+E(1,2)/ES1)*ET2+(F(2,2)+E(2,1)*ES1-
     1E(1,1)/ES1)/ET2)
      P22 = CST*((F(2,1)+E(2,2)*ES1-E(1,2)/ES1)*ET1+(-F(2,2)-E(2,1)*ES1+
     1E(1,1)/ES1)/ET1)
      RETURN
    5 IF (CPSI.LT.D.) GO TO 6
      TA = T1

      TB = T2
      GO TO 7
    6 TA = -T1
      TB = -T2
      SGDT = -SGDT
    7 S1 = S1
C
      DO 9 I=1,2
      TJ = TA
C
      DO 8 J=1,2
      Z1J = TJ-SI
      R = SQRT(DSQ+ZIJ*ZIJ)
      W = R+ZIJ
      IF (Z1J.LT.D.) W = DSQ/(R-ZIJ)
      V = R-ZIJ
      IF (ZIJ.GT.D.) V = DSQ/(R+ZIJ)
      IF (J.EQ.I) V1 = V
      IF (J.EQ.1) W1 = W
      EGZ(I,J) = CEXP(GAM*ZIJ)
    8 TJ = TB
C
      CALL EXPJ (GAM*VI,GAM*V,GP(I))
      CALL EXPJ (GAM*W1,GAM*W,GM(I))
    9 SI = S2
C
      CST = -ETA/(8.*PI*SGDS*SGDT)
      P1I = CST*(GM(2)*EGZ(2,2)+GP(2)/EGZ(2,2)-CGDS*(GM(1)*EGZ(1,2)+GP(1
     1)/EGZ(1,2)))
      P12 = CST*(-GM(2)*EGZ(2,1)-GP(2)/EGZ(2,1)+CGDS*(GM(1)*EGZ(1,1)+GP(
     11)/EGZ(1,1)))
      P21 = CST*(GM(1)*EGZ(1,2)+GP(1)/EGZ(1,2)-CGDS*(GM(2)*EGZ(2,2)+GP(2
     1)/EGZ(2,2)))
      P22 = CST*(-GM(1)*EGZ(1,1)-GP(1)/EGZ(1,1)+CGDS*(GM(2)*EGZ(2,1)+GP(
     12)/EGZ(2,1)))
      RETURN
      END
```

GGS

PURPOSE: to calculate the mutual impedances between two filamentary monopoles with sinusoidal current distributions.

METHOD: The monopole-monopole mutual impedance as defined by SGANT is calculated using the equations defined in subroutine GNF. The endpoints of the axial test monopole s are (XA,YA,ZA) and (XB,YB,ZB), and the endpoints of the expansion monopole t are (X1,Y1,Z1) and (X2,Y2,Z2). DS and DT denote the lengths of monopoles s and t, respectively, CAS, CBS and CGS are the direction cosines of monopole s, and CA, CB and CG are the direction cosines of monopole t.

The effects of ground for vertical co-linear monopoles are applied in a slightly different manner than mentioned previously. As with self impedance calculations, the test monopole and the expansion monopole are laterally displaced by the wire radius. This lateral displacement is used to determine the angle of incident. This technique is applied at statement 8.

If INT = 0, GGS calls GGMM for the closed form impedance calculations. Otherwise GGS calculates the mutual impedance via Simpson's-rule integration with the following number of sample points: IP = INT + 1. If the monopoles are parallel with small displacement, GGS calls GGMM to avoid the difficulties of numerical integration.

Since the point (X,Y,Z) of subroutine GNF lies on the expansion monopole t, T is the integration variable and is measured from (X1,Y1,Z1). C1 is the current at T for the mode with terminals at (X1,Y1,Z1), and C2 is the current at T for the mode with terminals at (X2,Y2,Z2). C denotes the Simpson's-rule weighting coefficient.

Below statement 7, GGS performs some analytic geometry in preparation for calling GGMM. The remainder of this section is concerned with this preparation.

Let $\bar{s}$ denote a unit vector in the direction from (XA,YA,ZA) toward (XB,YB,ZB). Also let $\bar{t}$ denote a unit vector from (X1,Y1,Z1) toward (X2,Y2,Z2). Then $\bar{s}\bullet\bar{t} = \cos\theta$ = CC where θ is the angle formed by the axes of the two monopoles. Let monopole s lie in one plane P_s and monopole t lie in another parallel plane P_t. CAD, CBD and CGD are the direction cosines of the unit vector $\bar{d} = \bar{t} \times \bar{s} / \sin\theta$ which is perpendicular to both planes. To obtain the distance DK between the two planes, a vector $\bar{R}_{11}$ is constructed from (XA,YA,ZA) to (X1,Y1,Z1) and take DK = $\bar{R}_{11}\bullet\bar{d}$.

A line is constructed from (X1,Y1,Z1) to the test monopole, such that the line is perpendicular to the test monopole. SZ denotes the s coordinate of the intersection of this line with the test monopole, and the cartesian coordinates of this intersection are XZ, YZ, and ZZ. The direction cosines of $\bar{s} \times \bar{d}$ are CAP, CBP, and CGP.

From the point (X1,Y1,Z1) in plane P_t, a line is constructed perpendicular to the point (XP1,YP1,ZP1) in the plane P_s. This line is parallel with $\bar{d}$ and has length DK. Let $\bar{R}$ represent a vector from (XZ,YZ,ZZ) to (XP1,YP1,ZP1). P1 denotes $\bar{R}$ $(\bar{s} \times \bar{d})$. S1 and T1 are defined in subroutine GGMM.

CALLED BY: SGANT

CALLS TO: GGMM

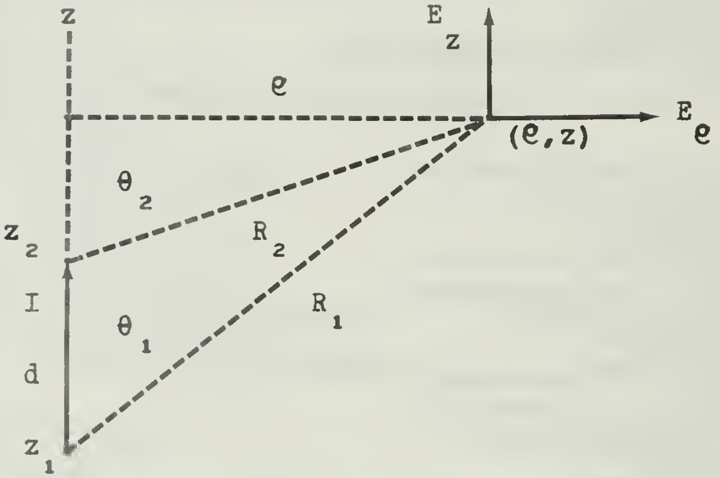
```
      SUBROUTINE GGS (XA,YA,ZA,XB,YB,ZB,X1,Y1,Z1,X2,Y2,Z2,AM,DS,CGDS,SGD
     1S,DT,SGDT,INT,ETA,GAM,P11,P12,P21,P22,ERR,IGRD)
      COMPLEX EX1,EY1,EX2,EY2,EZ1,EZ2
      COMPLEX P11,P12,P21,P22,EJA,EJB,EJ1,EJ2,ETA,GAM,C1,C2,CST
      COMPLEX EGD,CGDS,SGDS,SGDT,ER1,ER2,ET1,ET2
      CCMPLEX ERR
      COMPLEX EE,EXX,EYY
      CCMPLEX PP,PX,PY,PZ
      CCMPLEX RR1,RR2,RR3,RR4,RH1,RV1,RH2,RV2,RH3,RV3,RH4,RV4
      DATA FP/12.56637/
      CA = (X2-X1)/DT
      CB = (Y2-Y1)/DT
      CG = (Z2-Z1)/DT
      CAS = (XB-XA)/DS
      CBS = (YB-YA)/DS
      CGS = (ZB-ZA)/DS
      CC = CA*CAS+CB*CBS+CG*CGS
      IF ((CG.LE..003).AND.(CGS.LE..003).AND.(IGRD.GT.0)) GO TO 1
      IF (ABS(CC).GT..997) GO TO 6
    1 SZ = (X1-XA)*CAS+(Y1-YA)*CBS+(Z1-ZA)*CGS
      IF (INT.LE.0) GO TO 7
      INS = 2*(INT/2)
      IF (INS.LT.2) INS = 2
      IP = INS+1
      DELT = DT/INS
      T = .0
      DSZ = CC*DELT
      P11 = (.0,.0)
      P12 = (.0,.0)
      P21 = (.0,.0)
      P22 = (.0,.0)
      AMS = AM*AM
      SGN = -1.
C
C
      DO 5 IN=1,IP
      ZZ1 = SZ
      ZZ2 = SZ-DS
      XXZ = X1+T*CA-XA-SZ*CAS
      YYZ = Y1+T*CB-YA-SZ*CBS
      ZZZ = Z1+T*CG-ZA-SZ*CGS
      RS = XXZ**2+YYZ**2+ZZZ**2
      R1 = SQRT(RS+ZZ1**2)
      EJA = CEXP(-GAM*R1)
      EJ1 = EJA/R1
      R2 = SQRT(RS+ZZ2**2)
      EJB = CEXP(-GAM*R2)
      EJ2 = EJB/R2
```

```
      ER1 = EJA*SGDS+ZZ1*EJ1*CGDS-ZZ2*EJ2
      ER2 = -EJB*SGDS+ZZ2*EJ2*CGDS-ZZ1*EJ1
      FAC = .0
      IF (RS.GT.AMS) FAC = (CA*XXZ+CB*YYZ+CG*ZZZ)/RS
      ET1 = CC*(EJ2-EJ1*CGDS)+FAC*ER1
      ET2 = CC*(EJ1-EJ2*CGDS)+FAC*ER2
      IF (IGRD.LT.0) GO TO 4
      RV1 = (-1.,0)
      RH1 = (-1.,0)
      RV2 = (-1.,0)
      RH2 = (-1.,0)
      IF (IGRD.EQ.1) GO TO 2
      XG1 = X1+T*CA-XA
      YG1 = Y1+T*CB-YA
      ZG1 = Z1+T*CG-ZA
      XG2 = X1+T*CA-XB
      YG2 = Y1+T*CB-YB
      ZG2 = Z1+T*CG-ZB
      RG1 = SQRT(XG1*XG1+YG1*YG1)
      RG2 = SQRT(XG2*XG2+YG2*YG2)
      TT1 = ATAN(RG1/ZG1)
      TT2 = ATAN(RG2/ZG2)
      CTH1 = COS(TT1)
      SSTH1 = SIN(TT1)*SIN(TT1)
      CTH2 = COS(TT2)
      SSTH2 = SIN(TT2)*SIN(TT2)
      RR1 = CSQRT(ERR-SSTH1)
      RH1 = (CTH1-RR1)/(CTH1+RR1)
      RV1 = -(ERR*CTH1-RR1)/(ERR*CTH1+RR1)
      RR2 = CSQRT(ERR-SSTH2)
      RH2 = (CTH2-RR2)/(CTH2+RR2)
      RV2 = -(ERR*CTH2-RR2)/(ERR*CTH2+RR2)
    2 RG = SQRT((XB-XA)*(XB-XA)+(YB-YA)*(YB-YA))
      CPH = 0
      SPH = 0
      IF (RG.LT.1.E-32) GO TO 3
      CPH = (XB-XA)/RG
      SPH = (YB-YA)/RG
    3 EXX = ET1*CAS
      EYY = ET1*CBS
      EE = (EXX*SPH-EYY*CPH)*(RH1-RV1)
      EX1 = EXX*RV1+EE*SPH
      EY1 = EYY*RV1-EE*CPH
      EZ1 = -ET1*RV1*CGS
      ET1 =-EX1*CAS-EY1*CBS+EZ1*CGS
      EXX = ET2*CAS
      EYY = ET2*CBS
      EE = (EXX*SPH-EYY*CPH)*(RH2-RV2)

      EX2 = EXX*RV2+EE*SPH
      EY2 = EYY*RV2-EE*CPH
      EZ2 = -ET2*CGS*RV2
      ET2 =-EX2*CAS-EY2*CBS+EZ2*CGS
    4 C = 3.+SGN
      IF (IN.EQ.1.OR.IN.EQ.IP) C=1.
      EGD = CEXP(GAM*(DT-T))
      C1 = C*(EGD-1./EGD)/2.
      EGD = CEXP(GAM*T)
      C2 = C*(EGD-1./EGD)/2.
      P11 = P11+ET1*C1
      P12 = P12+ET1*C2
      P21 = P21+ET2*C1
      P22 = P22+ET2*C2
      T = T+DELT
      SZ = SZ+DSZ
    5 SGN = -SGN
C
C
      CST = -ETA*DELT/(3.*FP*SGDS*SGOT)
      P11 = CST*P11
      P12 = CST*P12
      P21 = CST*P21
      P22 = CST*P22
      RETURN
    6 SZ1 = (X1-XA)*CAS+(Y1-YA)*CBS+(Z1-ZA)*CGS
      DR1 = SQRT((X1-XA-SZ1*CAS)**2+(Y1-YA-SZ1*CBS)**2+(Z1-ZA-SZ1*CGS)**
     12)
      SZ2 = SZ1+DT*CC
      DR2 = SQRT((X2-XA-SZ2*CAS)**2+(Y2-YA-SZ2*CBS)**2+(Z2-ZA-SZ2*CGS)**
     12)
      DOD = (DR1+DR2)/2.
      IF (ODD.GT.20.*AM.AND.INT.GT.0) GO TO 1
      IF (DDD.LT.AM) DDD = AM
      CALL GGMM (.0,DS,SZ1,SZ2,ODD,CGDS,SGDS,SGDT,1.,ETA,GAM,P11,P12,P21
     1,P22)
      IF (IGRD.LE.1) RETURN
      IF (IGRD.GT.1) GO TO 8
C
    7 SS = SQRT(1.-CC*CC)
      CAD = (CGS*CB-CBS*CG)/SS
      CBD = (CAS*CG-CGS*CA)/SS
      CGD = (CBS*CA-CAS*CB)/SS
      DK = (X1-XA)*CAD+(Y1-YA)*CBD+(Z1-ZA)*CGD
      DK = ABS(DK)
      IF (OK.LT.AM) DK = AM
      XZ = XA+SZ*CAS
      YZ = YA+SZ*CBS
```

```
      ZZ = ZA+SZ*CGS
      XP1 = X1-DK*CAD
      YP1 = Y1-DK*CBD
      ZP1 = Z1-DK*CGD
      CAP = CBS*CGD-CGS*CBD
      CBP = CGS*CAD-CAS*CGD
      CGP = CAS*CBD-CBS*CAD
      P1 = CAP*(XP1-XZ)+CBP*(YP1-YZ)+CGP*(ZP1-ZZ)
      T1 = P1/SS
      S1 = T1*CC-SZ
      CALL GGMM (S1,S1+DS,T1,T1+DT,DK,CGDS,SGDS,SGDT,CC,ETA,GAM,P11,P12,
     1P21,P22)
      RETURN
C
    8 AMS = AM*AM
      RG = (X1-XA)*(X1-XA)+(Y1-YA)*(Y1-YA)
      IF (RG.LT.AMS) RG = AMS
      DG = SQRT((Z1-ZA)*(Z1-ZA)+RG)
      CPH = ABS(Z1-ZA)/DG
      SSPH = RG/(DG*DG)
      RR1 = CSQRT(ERR-SSPH)
      RV1 = -(ERR*CPH-RR1)/(ERR*CPH+RR1)
      P11 =-P11*RV1
      RG = (X1-XB)*(X1-XB)+(Y1-YB)*(Y1-YB)
      IF (RG.LT.AMS) RG = AMS
      DG = SQRT((Z1-ZB)*(Z1-ZB)+RG)
      CPH = ABS(Z1-ZB)/DG
      SSPH = RG/(DG*DG)
      RR1 = CSQRT(ERR-SSPH)
      RV1 = -(ERR*CPH-RR1)/(ERR*CPH+RR1)
      P12 =-P12*RV1
      RG = (X2-XA)*(X2-XA)+(Y2-YA)*(Y2-YA)
      IF (RG.LT.AMS) RG = AMS
      DG = SQRT((Z2-ZA)*(Z2-ZA)+RG)
      CPH = ABS(Z2-ZA)/DG
      SSPH = RG/(DG*DG)
      RR1 = CSQRT(ERR-SSPH)
      RV1 = -(ERR*CPH-RR1)/(ERR*CPH+RR1)
      P21 =-P21*RV1
      RG = (X2-XB)*(X2-XB)+(Y2-YB)*(Y2-YB)
      IF (RG.LT.AMS) RG = AMS
      DG = SQRT((Z2-ZB)*(Z2-ZB)+RG)
      CPH = ABS(Z2-ZB)/DG
      SSPH = RG/(DG*DG)
      RR1 = CSQRT(ERR-SSPH)
      RV1 = -(ERR*CPH-RR1)/(ERR*CPH+RR1)
      P22 =-P22*RV1
      RETURN


      END
```

GNF

PURPOSE: to calculate the near-zone electric field of a sinusoidal electric monopole.



METHOD: An electric line source is located on the z axis with endpoints at z_1 and z_2 as shown in the above figure. Let the electric monopole have the following current distribution:

$$I(l) = \frac{I_1 \sinh \gamma(d - l) + I_2 \sinh \gamma l}{\sinh \gamma d}$$

where I_1 and I_2 are the endpoint currents, γ is the complex propagation constant of the medium, $d = z_2 - z_1$ is the source length. The cylindrical components of the field are $E(\theta) = 0$ and

$$\begin{aligned} E(\rho) = \frac{\eta}{4\pi\rho \sinh \gamma d} \Big[& (I_1 e^{-\gamma R_1} - I_2 e^{-\gamma R_2}) \sinh \gamma d \\ & + (I_1 \cosh \gamma d - I_2)\, e^{-\gamma R_1} \cos \theta_1 \\ & + (I_2 \cosh \gamma d - I_1)\, e^{-\gamma R_2} \cos \theta_2 \Big] \end{aligned}$$

$$E(z) = \frac{\eta}{4\pi \sinh \gamma d} \left[(I_1 - I_2 \cosh \gamma d) \frac{e^{-\gamma R_2}}{R_2} + (I_2 - I_1 \cosh \gamma d) \frac{e^{-\gamma R_1}}{R_1} \right]$$

where is the intrinsic impedance of the medium and where (ρ,ϕ,z) denote the cylindrical coordinates in a coordinate system centered at the endpoint of z_1.

These expressions exclude the field contributions from the point changes at the endpoints of the line source, since these charges disappear when two monopoles are connected to form a dipole.

Let the coordinate s measure distance along the test monopole with the origin at (XA,YA,ZA). From any point X,Y,Z, a line is constructed perpendicular to the monopole. SZ denotes the s coordinate of the intersection of this line with the monopole. The length of the line is the radial coordinate ρ, and RS denote ρ^2. R1 and R2 are the distances from (XA,YA,ZA) and (XB,YB,ZB) to the point (X,Y,Z).

In the statements above statement 1, the above equations are solved; and after statement 1, the cartesian components (E_x,E_y,E_z) of the field are determined. If a ground plane is present (IGRD>0) the reflection coefficients are applied to the cartesian components before returning to the calling program.

CALLED BY: GNFLD

CALLS TO: NONE

```
      SUBROUTINE GNF (XA,YA,ZA,XB,YB,ZB,X,Y,Z,AM,DS,CGDS,SGDS,ETA,GAM,EX
     11,EY1,EZ1,EX2,EY2,EZ2,IGRD,ERR)
      COMPLEX ERR,RV1,RH1,RV2,RH2,RR1,RR2,EE
      COMPLEX EJA,EJB,EJ1,EJ2,ER1,ER2,ES1,ES2,SGDS,GAM,CST,CGDS,ETA
      COMPLEX EX1,EY1,EZ1,EX2,EY2,EZ2
      DATA PI/3.14159/
      CAS = (XB-XA)/DS
      CBS = (YB-YA)/DS
      CGS = (ZB-ZA)/DS
      SZ = (X-XA)*CAS+(Y-YA)*CBS+(Z-ZA)*CGS
      ZZ1 = SZ
      ZZ2 = SZ-DS
      XXZ = X-XA-SZ*CAS
      YYZ = Y-YA-SZ*CBS
      ZZZ = Z-ZA-SZ*CGS
      RS = XXZ**2+YYZ**2+ZZZ**2
      R1 = SQRT(RS+ZZ1**2)
      EJA = CEXP(-GAM*R1)
      EJ1 = EJA/R1
      R2 = SQRT(RS+ZZ2**2)
      EJB = CEXP(-GAM*R2)
      EJ2 = EJB/R2
      ES1 = EJ2-EJ1*CGDS
      ES2 = EJ1-EJ2*CGDS
      ER1 = (.0,.0)
      ER2 = (.0,.0)
      AMS = AM*AM
      IF (RS.LT.AMS) GO TO 1
      CTH1 = ZZ1/R1
      CTH2 = ZZ2/R2
      ER1 = (EJA*SGDS+EJA*CGDS*CTH1-EJB*CTH2)/RS
      ER2 = (-EJB*SGDS+EJB*CGDS*CTH2-EJA*CTH1)/RS
    1 CST = ETA/(4.*PI*SGDS)
      EX1 = CST*(ES1*CAS+ER1*XXZ)
      EY1 = CST*(ES1*CBS+ER1*YYZ)
      EZ1 = CST*(ES1*CGS+ER1*ZZZ)
      EX2 = CST*(ES2*CAS+ER2*XXZ)
      EY2 = CST*(ES2*CBS+ER2*YYZ)
      EZ2 = CST*(ES2*CGS+ER2*ZZZ)
      IF (IGRD.LE.0) RETURN
      RV1 = (-1.,0)
      RH1 = (-1.,0)
      RV2 = (-1.,0)
      RH2 = (-1.,0)
      IF (IGRD.EQ.1) GO TO 2
      R1 = SQRT((XA-X)*(XA-X)+(YA-Y)*(YA-Y))
      R2 = SQRT((XB-X)*(XB-X)+(YB-Y)*(YB-Y))
      TH1 = ATAN(R1/(ZA-Z))


      TH2 = ATAN(R2/(ZB-Z))
      RR1 = CSQRT(ERR-SIN(TH1)*SIN(TH1))
      RR2 = CSQRT(ERR-SIN(TH2)*SIN(TH2))
      RV1 = -(ERR*COS(TH1)-RR1)/(ERR*COS(TH1)+RR1)
      RH1 = (COS(TH1)-RR1)/(COS(TH1)+RR1)
      RV2 = -(ERR*COS(TH2)-RR2)/(ERR*COS(TH2)+RR2)
      RH2 = (COS(TH2)-RR2)/(COS(TH2)+RR2)
    2 RG = SQRT((XA-XB)*(XA-XB)+(YA-YB)*(YA-YB))
      CPH = 0
      SPH = 0
      IF (RG.LT.1.E-32) GO TO 3
      CPH = (XB-XA)/RG
      SPH = (YB-YA)/RG
    3 EE = (EX1*SPH-EY1*CPH)*(RH1-RV1)
      EX1 = -EX1*RV1+EE*SPH
      EY1 = -EY1*RV1-EE*CPH
      EZ1 = EZ1*(-RV1)
      EE = (EX2*SPH-EY2*CPH)*(RH2-RV2)
      EX2 = -EX2*RV2+EE*SPH
      EY2 = -EY2*RV2-EE*CPH
      EZ2 = EZ2*(-RV2)
      RETURN
      END
```

GNFLD

PURPOSE: to calculate the near-zone electric field intensity at a given point.

METHOD: This subroutine calls GNF for the near-zone field of each wire segment, and sums over all segments to obtain the near-zone field of the wire antenna. FI is used in a manner similiar to FI of subroutine SGANT. CJ(I) is the loop currents calculated by subroutine GANT1.

The use of the variables JFLAG and KFLAG are described in subroutine SGANT.

CALLED BY: MAIN

CALLS TO: GFF

```
      SUBROUTINE GNFLD (IA,IB,INM,I1,I2,I3,MD,N,ND,NM,AM,CGD,SGD,ETA,GAM
     1,CJ,D,X,Y,Z,XP,YP,ZP,EX,EY,EZ,IGRD,ERR)
      COMPLEX EX,EY,EZ,EX1,EY1,EZ1,EX2,EY2,EZ2,ETA,GAM
      COMPLEX ERR
      COMPLEX CJ(1),CGD(1),SGD(1)
      DIMENSION IA(1), IB(1), I1(1), I2(1), I3(1), D(1), X(1), Y(1), Z(1
     1)
      DIMENSION MD(INM,4), ND(1)
      DATA PI,TP/3.14159,6.28318/
      EX = (.0,.0)
      EY = (.0,.0)
      EZ = (.0,.0)
C
      DO 2 K=1,NM
      KA = IA(K)
      KB = IB(K)
      NGRD = IGRD
      IF (K.LE.NM/2) IGRD=-1
      CALL GNF (X(KA),Y(KA),Z(KA),X(KB),Y(KB),Z(KB),XP,YP,ZP,AM,D(K),CGD
     1(K),SGD(K),ETA,GAM,EX1,EY1,EZ1,EX2,EY2,EZ2,IGRD,ERR)
      IGRD = NGRD
      NDK = ND(K)
C
      DO 2 II=1,NDK
      I = MD(K,II)
      FI = 1.
      IF (KB.EQ.I2(I)) GO TO 1
      IF (KB.EQ.I1(I)) FI=-1.
      EX = EX+FI*EX1*CJ(I)
      EY = EY+FI*EY1*CJ(I)
      EZ = EZ+FI*EZ1*CJ(I)
      GO TO 2
    1 IF (KA.EQ.I3(I)) FI=-1.
      EX = EX+FI*EX2*CJ(I)
      EY = EY+FI*EY2*CJ(I)
      EZ = EZ+FI*EZ2*CJ(I)
    2 CONTINUE
C
      RETURN
      END
```

LEFT

PURPOSE: to determine position (location) of the left paren symbol on the input data card.

METHOD: The character search begins in the column passed to the subroutine. On returning to the calling program the argument passed is the column following the left paren symbol.

CALLED BY: READ

CALLS TO: NONE

```
      SUBROUTINE LEFT (N)
      COMMON /A/ A(80)
      DATA PLEFT/'('/
      K = N
C
      DO 1 I=K,80
      N = I+1
      IF (A(I).EQ.PLEFT) GO TO 2
    1 CONTINUE
C
      N = 1
    2 RETURN
      END
```

LINECK

PURPOSE: to insert grid characters on the polar plot.

METHOD: The peroid character (ISM(2)) is inserted in the proper position in the statements above statement 4. In the statements after statement 4, the grid numbers labels are inserted on the horizontal axis.

CALLED BY: POLPLOT

CALLS TO: NONE

```
      SUBROUTINE LINECK (X,Y)
C
C     THIS SUBROUTINE INSURES ALL GRID CHARACTORS LIE ON THE POLAR GRID
C
      COMMON ISYM,LINE
      INTEGER Y
      DIMENSION ISYM(14), LINE(130)
      IF (Y.EQ.0) GO TO 3
      K = 0
      IF (X.LT.10.0) GO TO 5
C
C     SET UP AREAS OF "PERIOD" POLAR GRID POINT CHARACTERS
C
      I = INT(X)
      I = IABS(I)
      Z = ABS(X)
      IF ((Z-I).GT.0.5) I=I+1
    1 IF (Z.LT.10.0.OR.Z.GT.111.0) GO TO 2
      LINE(I) = ISYM(2)
      LINE(60) = ISYM(3)
      LINE(62) = ISYM(3)
      K = K+1
      IF (K.EQ.2) GO TO 2
      I = 122-I
      GO TO 1
    2 LINE(61) = ISYM(2)
      IF (Y.NE.0) GO TO 5
C
    3 DO 4 K=11,111
      LINE(K) = ISYM(2)
    4 CONTINUE
C
C
C     FILL IN GRID NUMBER LABELS ON HORIZONTAL AXIS
C
      LINE(11) = ISYM(7)
      LINE(20) = ISYM(10)
      LINE(21) = ISYM(5)
      LINE(22) = ISYM(11)
      LINE(30) = ISYM(9)
      LINE(31) = ISYM(5)
      LINE(32) = ISYM(11)
      LINE(40) = ISYM(8)
      LINE(41) = ISYM(5)
      LINE(42) = ISYM(11)
      LINE(50) = ISYM(7)
      LINE(51) = ISYM(5)
      LINE(52) = ISYM(11)

      LINE(61) = ISYM(1)
      LINE(70) = ISYM(7)
      LINE(71) = ISYM(5)
      LINE(72) = ISYM(11)
      LINE(80) = ISYM(8)
      LINE(81) = ISYM(5)
      LINE(82) = ISYM(11)
      LINE(90) = ISYM(9)
      LINE(91) = ISYM(5)
      LINE(92) = ISYM(11)
      LINE(100) = ISYM(10)
      LINE(101) = ISYM(5)
      LINE(102) = ISYM(11)
      LINE(111) = ISYM(7)
    5 CONTINUE
      RETURN
      END
```

NUMB

PURPOSE: to place degree numbers on the polar plot.

METHOD: The current line which is being printed is passed to the subroutine in the calling argument. If this line contains degree numbers, these numbers are placed in the correct position by the IF statements.

CALLED BY: PTPLOT

CALLS TO: NONE

```
      SUBROUTINE NUMB (Y)
C
C     THIS SUBROUTINE PUTS DEGREE NUMBERS ON POLAR GRID
C
      COMMON ISYM,LINE
      INTEGER Y
      DIMENSION ISYM(14), LINE(130)
      IF (Y.NE.37) GO TO 1
      LINE(33) = ISYM(7)
      LINE(34) = ISYM(8)
      LINE(35) = ISYM(6)
      LINE(87) = ISYM(6)
      LINE(88) = ISYM(12)
      LINE(89) = ISYM(6)
    1 IF (Y.NE.21) GO TO 2
      LINE(12) = ISYM(7)
      LINE(13) = ISYM(11)
      LINE(14) = ISYM(6)
      LINE(108) = ISYM(6)
      LINE(109) = ISYM(9)
      LINE(110) = ISYM(6)
    2 IF (Y.NE.0) GO TO 3
      LINE(7) = ISYM(7)
      LINE(8) = ISYM(13)
      LINE(9) = ISYM(6)
      LINE(113) = ISYM(6)
      LINE(114) = ISYM(6)
      LINE(115) = ISYM(6)
    3 IF (Y.NE.-21) GO TO 4
      LINE(12) = ISYM(8)
      LINE(13) = ISYM(7)
      LINE(14) = ISYM(6)
      LINE(108) = ISYM(9)
      LINE(109) = ISYM(9)
      LINE(110) = ISYM(6)
    4 IF (Y.NE.-37) GO TO 5
      LINE(33) = ISYM(8)
      LINE(34) = ISYM(10)
      LINE(35) = ISYM(6)
      LINE(87) = ISYM(9)
      LINE(88) = ISYM(6)
      LINE(89) = ISYM(6)
    5 CONTINUE
      RETURN
      END
```

NUMBER

PURPOSE: to convert alpha-numeric numbers to floating or fixed point numbers.

METHOD: After initially determining the sign of the number, the DO LOOP ending at statement 6 scans each character beginning at N1. The DO LOOP ending at statement 3 terminates the outer DO LOOP if the character being compared is not an alpha-numeric number. The DO LOOP ending at statement 5 converts the alpha-numeric number to an actual number. Below statement 7, the multiplier correction is applied to the floating point number before returning to the calling program.

CALLED BY: READ

CALLS TO: NONE

```
      SUBROUTINE NUMBER (N1,N2,X,IX)
      COMMON /A/ A(80)
      DIMENSION B(10)
      DATA 8/'0','I','2','3','4','5','6','7','8','9'/
      DATA AMNUS,PLUS,POINT/'-','+','.'/
      DATA AK,AM,AU/'K','M','U'/
      N = N1
      NSIGN = 0
      II = -1
      IX = 0
      ISET = 0
      IF (A(N).EQ.PLUS) N=N+1
      IF (A(N).NE.AMNUS) GO TO 1
      NSIGN = 1
      N = N+1
C
    1 DO 6 I=N,80
      IF (A(I).NE.POINT) GO TO 2
      ISET = 1
      GO TO 6
    2 IF (ISET.EQ.1) 11 = 11+1
C
      DO 3 K=1,10
      IF (A(I).EQ.8(K)) GO TO 4
    3 CONTINUE
C
      GO TO 7
C
    4 DO 5 K=1,10
      KK = K-1
      IF (A(I).EQ.8(K)) NUM8=KK
    5 CONTINUE
C
      IX = NUM8+10*1X
      N2 = I+1
    6 CONTINUE
C
    7 IF (NSIGN.EQ.1) IX = -1X
      Y = IX
      IF (II.LT.0) II = 0
      X = Y/(10**II)
      IF (A(N2).EQ.POINT) N2=N2+1
      IF (A(N2).EQ.AK) X = X*1000.
      IF (A(N2).EQ.AM) X = X*0.001
      IF (A(N2).EQ.AU) X = X*0.000001
      IF((A(N2).EQ.AK).OR.(A(N2).EQ.AM).OR.(A(N2).EQ.AU)) N2=N2+1
      N1 = N2
      RETURN

      END
```

POLPRT

PURPOSE: to control the plotting of the polar plot.

METHOD: This subroutine is the main subroutine in the polar plot package and is responsible for calling the various subroutines of the package.

The scale factor, S, must be changed according to the printer characteristics. The scale factor in this subroutine is set for ten, 10, characters per inch for the abscissa and eight, 8, characters per inch for the ordinate axis. Therefore S = 10./8.

After initializing DATAX, DATAY, and X, the input data, Y, is scanned to determine the normalizing factor. If this normalizing factor is less than 1.E-32, an error statement is printed and the plotting is abortted.

In the DO LOOP ending with statement 8, each line of the polar plot is printed after a call is made to PTPLOT to establish the ploar grid information. The variable, DIM, is used to as a scaling factor for the polar plot. The value of 1.0 will cause all of input data to be plotted, however, if only the values less than one-half of the normalizing factor are of interest, then DIM can be set to .5. This will enlarge of the center of the polar plot.

CALLED BY: MAIN

CALLS TO: PTPLOT

SART

```
      SUBROUTINE POLPRT (NAME,Y)
      COMMON ISYM,LINE
      DIMENSION X(360), Y(360), DATAX(360), DATAY(360), LINE(130), ISYM(
     114)
      DIMENSION TITLA(2), TITL2(2)
      DATA TITLA/'PHI ','THET'/
      N = 360
      DIM = 1.0
      NST = 1
      KST = 1
C
C     S IS SCALE FACTOR OF PRINTER:
C     ABSCISSA CHAR. PER INCH / ORDINATE CHAR. PER INCH
C
      S = 10.0/8.0
C
C     ZERO DATAX AND DATAY
C
C
      DO 1 IA=1,N
      D = IA-1
      DATA X(IA) = 0.0
      DATA Y(IA) = 0.0
    1 X(IA) = D*3.1415927/180.0
C
C
C     FACTOR IS THE NORMALIZING DIVISOR
C
      FACTOR = Y(1)
C
      DO 2 IA=2,N
    2 IF (FACTOR.LT.Y(IA)) FACTOR=Y(IA)
C
C
      IF (NAME.EQ.1) TITL1=TITLA(1)
      IF (NAME.EQ.2) TITL1=TITLA(2)
      IF ((NAME.EQ.3).OR.(NAME.EQ.4).OR.(NAME.EQ.7).OR.(NAME.EQ.8)) TITL
     12(1)=TITLA(1)
      IF ((NAME.EQ.5).OR.(NAME.EQ.6).OR.(NAME.EQ.9).OR.(NAME.EQ.10)) TIT
     1L2(1)=TITLA(2)
      IF ((NAME.EQ.3).OR.(NAME.EQ.5).OR.(NAME.EQ.7).OR.(NAME.EQ.9)) TITL
     12(2)=TITLA(1)
      IF ((NAME.EQ.4).OR.(NAME.EQ.6).OR.(NAME.EQ.8).OR.(NAME.EQ.10)) TIT
     1L2(2)=TITLA(2)
      IF (FACTOR.GT.1.E-32) GO TO 3
      IF (NAME.LE.2) WRITE (6,9) TITL1
      IF (NAME.GE.3) WRITE (6,10) TITL2
      RETURN

C
C     NORMALIZE DATA TO ONE
C
C
    3 DO 4 IA=1,N
    4 Y(IA) = Y(IA)/FACTOR
C
C
      IF (NAME.LE.2) WRITE (6,11) TITL1,FACTOR
      IF ((NAME.GE.3).AND.(NAME.LE.6)) WRITE (6,13) TITL2,FACTOR
      IF (NAME.GE.7) WRITE (6,12) TITL2,FACTOR
C     FILL DATAX AND DATAY ARRAY FROM X AND Y ARRAY
C
C
      DO 5 IA=1,N
      DATA X(IA) = Y(IA)*COS(X(IA))
    5 DATA Y(IA)= Y(IA)*SIN(X(IA))
C
C
C     SORT DATA BY ORDINATE MAGNITUDE
C
      CALL SART (DATAX,DATAY,N)
C
C     DATAX AND DATAY ARE SORTED BY DESENDING MAGNITUDE ON THE DATAY VAL
C     SET UP FOR PLOTTING POLAR GRID WITH DATA
C
C
      DO 8 IYY=1,81
C
      CALL PTPLOT (IYY,S)
C
C     LINE IS RETURNED WITH POLAR GRID INFORMATION
C
C     SET UP 'Y' BIN SIZE UPPER AND LOWER LIMITS
C     ULL IS THE LOWER BIN LIMIT
C     UL IS THE UPPER BIN LIMIT
C
      BIN = DIM/80.0
      ULL = DIM-(2*IYY-1)*BIN
      UL = ULL+2*BIN
C
C
C     CYCLE THROUGH DATA TO FIND WHICH ONES FALL IN 'Y' BINS
C
C
      IF (NST.GT.N) GO TO 7
C
      DO 6 JJ=NST,N
```

```
      IF (DATAY(JJ).LT.ULL) GO TO 7
      KST = JJ
      AMAG = SQRT(DATAX(JJ)*DATAX(JJ)+DATAY(JJ)*DATAY(JJ))
C
C     CHECK THAT MAGNITUDE IS NOT OVER DIM
C
      IF (AMAG.GT.DIM) GO TO 6
C
C     OK IS THE FINAL LINE POSITION FOR THE '*'
C
      OK = DATAX(JJ)*S*40.0/DIM+61.0
      IF (OK.LT.10.0) GO TO 6
      K = INT(OK)
      K = IABS(K)
      OK = ABS(OK)
      IF ((OK-K).GT.0.5) K=K+1
      IF (OK.LT.10.0.OR.OK.GT.111.0) GO TO 6
      LINE(K) = ISYM(4)
    6 CONTINUE
C
    7 CONTINUE
      NST = KST+1
C
C     PRINT OUT ONE LINE OF PLOT
C
      WRITE (6,14) LINE
    8 CONTINUE
C
      RETURN
C
    9 FORMAT (10X,1A4,' COMPONENT OF THE ELECTRIC FIELD IS LESS'/10X,
     1 'THAN 1.E-64, THEREFORE THIS FIELD WAS NOT '/10X,'PLOTTED.   EXEC
     2UTION WILL CONTINUE AS NORMAL.'//)
   10 FORMAT (10X,'THE MAXIMUM VALUE OF THE BISTATIC PATTERN FOR '/
     1 10X,1A4,'-',1A4,' (INCIDENT-SCATTERED) IS LESS THAN '/
     2 10X, ' 1.E-30.)    POLAR PLOT NOT CALLED.'///)
   11 FORMAT ('1',1A4,' ELECTRIC FIELD ANTENNA PATTERN FOR SPECIFIED PLA
     1NE.',9X,'NORMALIZING FACTOR= ',E10.5)
   12 FORMAT ('1BISTATIC SCATTERING PATTERN FOR',1A4,'-',1A4,'(INCIDENT-
     1SCATTERED) POLARIZATION.',9X,'NORMALIZING FACTOR=',E10.5)
   13 FORMAT ('1BACKSCATTERING PATTERN FOR',1A4,'-',1A4,'(INCIDENT-SCATT
     1ERED) POLARIZATION.',9X,'NORMALIZING FACTOR=',E10.5)
   14 FORMAT (1X,130A1)
      END
```

PTPLOT

PURPOSE: to establish the grid information for the polar plot.

METHOD: In the DO LOOP ending at statement 1 the alpha-numeric characters are transferred to ISYN in order to pass via COMMON to other subroutines. In the statements following statement 2, the equations for the plotted concentric circles are established. Below statement 7 the grid marks on the 090-270 axis are inserted.

CALLED BY: POLPRT

CALLS TO: LINECK

NUMB

```
      SUBROUTINE PTPLOT (IYY,S)
C
C     THIS SUBROUTINE SETS UP POLAR GRID INFORMATION
C
      COMMON ISYM,LINE
      DIMENSION LINE(130), ISYM(14), ISYN(14)
      DATA ISYN/1H+,1H.,1H ,1H*,1H/,1H0,1H1,1H2,1H3,1H4,1H5,1H6,1H8,1H9/
      INTEGER Y,YY,W
C
C     SET UP ISYM FROM ISYN FOR COMMON
C
C
      DO 1 K=1,14
      ISYM(K) = ISYN(K)
    1 CONTINUE
C
C
C     CLEAR LINE AND SET TO BLANK
C
C
      DO 2 I=1,130
    2 LINE(I) = ISYM(3)
C
      Y = 41-IYY
      IF (Y.EQ.0) GO TO 7
C
C     SET UP EQUATIONS FOR CONCENTRIC CIRCLES
C
      YY = Y*Y
      Z = (YY*2.5/2)*S
      X = 61.0+SQRT(2500.0-Z)
      CALL LINECK (X,Y)
      IF (Y.GT.32.OR.Y.LT.-32) GO TO 3
      X = 61.0+SQRT(1600.0-Z)
      CALL LINECK (X,Y)
    3 IF (Y.GT.24.OR.Y.LT.-24) GO TO 4
      X = 61.0+SQRT(900.0-Z)
      CALL LINECK (X,Y)
    4 IF (Y.GT.16.OR.Y.LT.-16) GO TO 5
      X = 61.0+SQRT(400.0-Z)
      CALL LINECK (X,Y)
    5 IF (Y.GT.8.OR.Y.LT.-8) GO TO 6
      X = 61.0+SQRT(100-Z)
      CALL LINECK (X,Y)
C     SET UP EQUATIONS FOR MULTIPLES OF 30 DEGREES
    6 X = 61.0+1.732051*Y*S
      CALL LINECK (X,Y)
      X = 61.0+Y*S/1.732051
```

```
    7 CALL LINECK (X,Y)
C
C     PUT IN POLAR PLOT NUMBER LABELS
C
      CALL NUMB (Y)
      W = IABS(Y)
C
C     FILL IN POLAR PLOT AT 000, 090, 180, AND 270
C
      IF (W.NE.40) GO TO 8
      LINE(55) = ISYM(2)
      LINE(57) = ISYM(2)
      LINE(59) = ISYM(2)
      LINE(63) = ISYM(2)
      LINE(65) = ISYM(2)
      LINE(67) = ISYM(2)
    8 IF (W.NE.32) GO TO 9
      LINE(56) = ISYM(2)
      LINE(58) = ISYM(2)
      LINE(60) = ISYM(2)
      LINE(62) = ISYM(2)
      LINE(64) = ISYM(2)
      LINE(66) = ISYM(2)
    9 IF (W.NE.24) GO TO 10
      LINE(57) = ISYM(2)
      LINE(59) = ISYM(2)
      LINE(60) = ISYM(2)
      LINE(62) = ISYM(2)
      LINE(63) = ISYM(2)
      LINE(65) = ISYM(2)
   10 IF (W.NE.16) GO TO 11
      LINE(58) = ISYM(2)
      LINE(60) = ISYM(2)
      LINE(62) = ISYM(2)
      LINE(64) = ISYM(2)
   11 IF (W.NE.08) GO TO 12
      LINE(59) = ISYM(2)
      LINE(63) = ISYM(2)
   12 CONTINUE
      RETURN
      END
```

READ

PURPOSE: to interpret and translate the input data cards.

METHOD: The program utilizes free format for the data cards, that is, the program uses character recognition to determine which parameters are being read. In the IF statements containing A(1), A(2), A(3), and A(4), the first four characters on the data card are compared to the first four letters of the key words. This will determine the type of parameters that card contains. The other IF statements determine which parameters are being read.

Subroutine BLNK is called to remove the blank spaces on the parameter cards. Subroutines EQUAL and LEFT are called to determine the position of the equal character and the left paren, respectively. Subroutine NUMBER is called to convert the alpha-numeric characters to numbers, either fixed or floating point. This numerical value is assigned to the parameter just determined.

A detailed explanation of the data cards is found in appendix II titled "USERS MANUAL".

CALLED BY: BLNK

EQUAL

LEFT

NUMBER

```
      SUBROUTINE READ (IA,IB,IBISC,ICARD,IGAIN,IGRD,INEAR,INT,ISCAT,IWR,
     1IFLAG,KFLAG,KGEN,LOAD,LZD,MSG,NBAP,NBIP,NFFP,NGEN,NM,NP,ABAP,ABAT,
     2AFFP,AFFT,ABIP,ABIT,AM,BM,CMM,ER2,ER3,ER4,FMC,HGT,PHAF,PHAI,PHIF,P
     3HII,PHSF,PHSI,THAF,THAI,THIF,THII,THSF,THSI,SIG2,SIG3,SIG4,TD2,TD3
     4,VOLT,X,XNP,Y,YNP,Z,ZLLD,ZNP,STEP)
      COMMON /A/ A(80)
      COMPLEX VOLT(1),ZLLD(1)
      DIMENSION IA(1), IB(1), X(1), Y(1), Z(1), KGEN(1), KFLAG(1)
      DIMENSION XNP(1), YNP(1), ZNP(1), LZD(1)
      DATA AA,AB,AC,AD,AE,AF,AG,AH,AI,AK,AL,AMA,AN,AO,AP,AQ,AR,AS,AT,AU,
     1AW,AX/'A','B','C','D','E','F','G','H','I','K','L','M','N','O','P',
     2'Q','R','S','T','U','W','X'/
      DATA BLANK,COMMA,MINUS,PLEFT,POINT,RIGHT,SLANT/' ',',','-','(','.'
     1,')','/'/
      RAD = 57.295779
      INT = 4
      IBISC = -1
      IGAIN = -1
      INEAR = -1
      ISCAT = -1
      IWR = -1
      IF (IFLAG.EQ.6) GO TO 2
      IF (MSG.NE.0) GO TO 4
    1 READ (5,76,END=72) A
    2 IF ((A(1).NE.AC).OR.(A(2).NE.BLANK).OR.(A(3).NE.BLANK).OR.(A(4).NE
     1.BLANK)) GO TO 3
      WRITE (6,74) A
      GO TO 1
    3 WRITE (6,75)
      GO TO 5
    4 READ (5,76,END=72) A
    5 ICARD = ICARD+1
      WRITE (6,77) ICARD,A
      IF ((MSG.NE.0).AND.((A(1).EQ.AE).AND.(A(2).EQ.AN).AND.(A(3).EQ.AO)
     1)) GO TO 70
      IF ((MSG.NE.0).AND.((A(1).EQ.AS).AND.(A(2).EQ.AT).AND.(A(3).EQ.AO)
     1.AND.(A(4).EQ.AP))) GO TO 69
      IF ((A(1).EQ.AC).AND.(A(2).EQ.BLANK).AND.(A(3).EQ.BLANK).AND.(A(4)
     1.EQ.BLANK)) GO TO 73
      IF (MSG.GT.0) GO TO 4
      CALL BLNK (A)
      N = 4
C
C     INSULATION
C
      IF ((A(1).NE.AI).OR.(A(2).NE.AN).OR.(A(3).NE.AS).OR.(A(4).NE.AU))
     1GO TO 10
      KFLAG(20) = 1


      CALL LEFT (N)
C
    6 IF ((A(N).NE.AR).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AD).OR.(A(N+3).NE
     1.A))) GO TO 7
      KFLAG(4) = 1
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      BM = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 6
C
    7 IF ((A(N).NE.AD).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AE).OR.(A(N+3).NE
     1.AL)) GO TO 8
      KFLAG(6) = 1
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      ER2 = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 6
C
    8 IF ((A(N).NE.AC).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AN).OR.(A(N+3).NE
     1.AD)) GO TO 9
      KFLAG(5) = 1
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      SIG2 = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 6
C
    9 IF ((A(N).NE.AL).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AS).OR.(AIN+3).NE
     1.AS)) GO TO 71
      KFLAG(7) = 1
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      TD2 = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 6
C
C     WIRE
C
```

```
   10 IF ((A(1).NE.AW).OR.(A(2).NE.AI).OR.(A(3).NE.AR).OR.(A(4).NE.AE))
     1GO TO 13
      CALL LEFT (N)
C
   11 IF ((A(N).NE.AR).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AD).OR.(A(N+3).NE
     1.AI)) GO TO 12
      KFLAG(2) = 1
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      AM = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 11
C
   12 IF ((A(N).NE.AC).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AN).OR.(A(N+3).NE
     1.AO)) GO TO 71
      KFLAG(3) = 1
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      CMM = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 11
C
C     EXTERNAL MEDIUM
C
   13 IF ((A(1).NE.AE).OR.(A(2).NE.AX).OR.(A(3).NE.AT).OR.(A(4).NE.AE))
     1GO TO 17
      KFLAG(8) = 1
      CALL LEFT (N)
C
   14 IF ((A(N).NE.AC).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AN).OR.(A(N+3).NE
     1.AO)) GO TO 15
      KFLAG(9) = 1
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      SIG3 = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 14
C
   15 IF ((A(N).NE.AD).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AE).OR.(A(N+3).NE
     1.AL)) GO TO 16
      KFLAG(10) = 1
      CALL EQUAL (N)

      CALL NUMBER (N,N2,X1,IX)
      ER3 = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 14
C
   16 IF ((A(N).NE.AL).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AS).OR.(A(N+3).NE
     1.AS)) GO TO 71
      KFLAG(11) = 1
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      TO3 = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 14
C
C
C     LOAD
C
   17 IF ((A(1).NE.AL).OR.(A(2).NE.AO).OR.(A(3).NE.AA).OR.(A(4).NE.AD))
     1GO TO 18
      KFLAG(14) = 1
      GO TO 19
   18 IF ((A(1).NE.AI).OR.(A(2).NE.AMA).OR.(A(3).NE.AP).OR.(A(4).NE.AE))
     1 GO TO 22
      KFLAG(24) = 1
   19 I = 1
      CALL LEFT (N)
   20 CALL NUMBER (N,N2,X1,IX)
      IF (IX.LE.0) GO TO 21
      LZO(I) = IX
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      RMAG = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      RDEG = X1
      RREAL = RMAG*COS(RDEG/RAD)
      RIMAG = RMAG*SIN(RDEG/RAD)
      ZLLD(I) = CMPLX(RREAL,RIMAG)
      LOAD = I
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      I = I+1
      N = N2+1
      GO TO 20
```

```
   21 KFLAG(24) = -1
      LOAD = -1
      GO TO 4
C
C     FREQUENCY
C
   22 IF ((A(1).NE.AF).OR.(A(2).NE.AR).OR.(A(3).NE.AE).OR.(A(4).NE.AQ))
     1GO TO 23
      KFLAG(1) = 1
      CALL LEFT (N)
      CALL NUMBER (N,N2,X1,IX)
      FMC = X1
      GO TO 4
C
C     PLOT
C
   23 IF ((A(1).NE.AP).OR.(A(2).NE.AL).OR.(A(3).NE.AO).OR.(A(4).NE.AT))
     1GO TO 31
      KFLAG(22) = 1
      CALL LEFT (N)
C
   24 IF ((A(N).NE.AF).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AR).OR.(A(N+3).NE
     1.AF)) GO TO 25
      IGAIN = 1
      NFFP = 1
      GO TO 27
   25 IF ((A(N).NE.AB).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AS).OR.(A(N+3).NE
     1.AT)) GO TO 26
      IBISC = 1
      NBIP = 1
      GO TO 27
   26 IF ((A(N).NE.AB).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AC).OR.(A(N+3).NE
     1.AK)) GO TO 71
      ISCAT = 1
      NBAP = 1
C
C
C
   27 DO 28 (=N,80
      K = I+1
      IF (A(I).EQ.SLANT) GO TO 29
   28 CONTINUE
C
C
C
      GO TO 71
   29 N = K
      IF ((A(N).NE.AT).OR.(A(N+1).NE.AH).OR.(A(N+2).NE.AE).OR.(A(N+3).NE
     1.AT)) GO TO 30
      CALL EQUAL (N)
      CALL NUMBER (N,V2,X1,IX)
      IF (NFFP.EQ.1) AFFT=X1
      IF (NB(P.EQ.() ABIT=X1
      IF (NBAP.EQ.1) ABAT=X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      (F (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 24
   30 IF ((A(N).NE.AP).OR.(A(N+1).NE.AH).OR.(A(N+2).NE.AI)) GO TO 71
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      IF (NFFP.EQ.1) AFFP=X1
      IF (NB(P.EQ.1) ABIP=X1
      IF (NBAP.EQ.1) ABAP=X1
      IF (A(N2).EQ.R(GHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 24
C
C     OUTPUT
C
   31 IF ((A(1).NE.AO).OR.(A(2).NE.AU).OR.(A(3).NE.AT).OR.(A(4).NE.AP))
     1GO TO 44
      KFLAG(22) = 1
      CALL LEFT (N)
C
   32 IF ((A(N).NE.AB).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AS).OR.(A(N+3).NE
     1.AT)) GO TO 33
      KFLAG(18) = 1
      IB(SC = 1
      CALL ECUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      PHSI = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,(X)
      PHSF = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      THSI = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      THSF = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 32
```

```
C
   33 IF ((A(N).NE.AF).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AR).OR.(A(N+3).NE
     1.AF)) GO TO 34
      KFLAG(16) = 1
      IGAIN = 1
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      PHAI = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      PHAF = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      THAI = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      THAF = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 32
C
   34 IF ((A(N).NE.AN).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AA).OR.(A(N+3).NE
     1.AR)) GO TO 40
      KFLAG(19) = 1
      INEAR = 2
      CALL EQUAL (N)
      IF (A(N).EQ.PLEFT) GO TO 35
      INEAR = 1
      I = 1
      GO TO 36
C
C
C
   35 DO 37 L=1,50
      I = L
      N = N+1
   36 CALL NUMBER (N,N2,X1,IX)
      XNP(I) = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      YNP(I) = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      ZNP(I) = X1
      IF (INEAR.EQ.1) GO TO 39
      INEAR = L+1
      IF (A(N2).EQ.RIGHT) GO TO 38


      N = N2
   37 CONTINUE
C
C
C
      GO TO 71
   38 N2 = N2+1
      INEAR = INEAR-1
   39 IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 32
C
   40 IF ((A(N).NE.AB).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AC).OR.(A(N+3).NE
     1.AK)) GO TO 41
      KFLAG(17) = 1
      ISCAT = 1
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      PHII = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      PHIF = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      THII = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      THIF = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 32
C
   41 IF ((A(N).NE.AC).OR.(A(N+1).NE.AU).OR.(A(N+2).NE.AR).OR.(A(N+3).NE
     1.AR)) GO TO 43
      KFLAG(15) = 1
      IWR = 1
C
C
C
      DO 42 K=N,80
      IF (A(K).EQ.RIGHT) GO TO 4
      N = K+1
      IF (A(K).EQ.SLANT) GO TO 32
   42 CONTINUE
C
      GO TO 71
```

```
C
   43 IF ((A(N).NE.AS).OR.(A(N+1).NE.AT).OR.(A(N+2).NE.AE).OR.(A(N+3).NE
     1.AP)) GO TO 71
      CALL EQUAL (N)
      CALL NUMBER (N,N2,X1,IX)
      STEP = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      N = N2+1
      GO TO 32
C
C     FEED POINT
C
   44 IF ((A(1).NE.AF).OR.(A(2).NE.AE).OR.(A(3).NE.AE).OR.(A(4).NE.AD))
     1GO TO 45
      KFLAG(13) = 1
      GO TO 46
   45 IF ((A(1).NE.AG).OR.(A(2).NE.AE).OR.(A(3).NE.AN).OR.(A(4).NE.AE))
     1GO TO 49
      KFLAG(23) = 1
   46 NGEN = 0
      CALL LEFT (N)
   47 CALL NUMBER (N,N2,X1,IX)
      NGEN = NGEN+1
      KGEN(NGEN) = IX
      IF (A(N2).EQ.RIGHT) GO TO 4
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      VMAG = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      VDEG = X1
      VREAL = VMAG*COS(VDEG/RAD)
      VIMAG = VMAG*SIN(VDEG/RAD)
      VOLT(NGEN) = CMPLX(VREAL,VIMAG)
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      IF ((A(N2).EQ.SLANT).AND.(A(N2+1).EQ.BLANK)) GO TO 48
      N = N2+1
      GO TO 47
   48 READ (5,76) A
      ICARD = ICARD+1
      WRITE (6,77) ICARD,A
      N = 1
      CALL BLNK (A)
      GO TO 47
C
C
C     DESCRIPTION
C
   49 IF ((A(1).NE.AD).OR.(A(2).NE.AE).OR.(A(3).NE.AS).OR.(A(4).NE.AC))
     1GO TO 52
      KFLAG(12) = 1
      J = 0
      CALL LEFT (N)
   50 CALL NUMBER (N,N2,X1,IX)
      J = J+1
      NM = J
      IA(J) = IX
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      IB(J) = IX
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      IF ((A(N2).EQ.SLANT).AND.(A(N+1).EQ.BLANK)) GO TO 51
      N = N2+1
      GO TO 50
   51 READ (5,76) A
      ICARD = ICARD+1
      CALL BLNK (A)
      WRITE (6,77) ICARD,A
      N = 1
      GO TO 50
C
C     GEOMETRY
C
   52 IF ((A(1).NE.AG).OR.(A(2).NE.AE).OR.(A(3).NE.AO).OR.(A(4).NE.AMA))
     I GO TO 55
      KFLAG(12) = 1
      JJ = 0
      CALL LEFT (N)
   53 CALL NUMBER (N,N2,X1,IX)
      JJ = JJ+1
      NP = JJ
      X(JJ) = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      Y(JJ) = X1
      N = N2+1
      CALL NUMBER (N,N2,X1,IX)
      Z(JJ) = X1
      IF (A(N2).EQ.RIGHT) GO TO 4
      IF (A(N2).NE.SLANT) GO TO 71
      IF ((A(N2).EQ.SLANT).AND.(A(N+1).EQ.BLANK)) GO TO 54
      N = N2+1
      GO TO 53
```

```
54 READ (5,76) A
   ICARD = ICARD+1
   WRITE (6,77) ICARD,A
   CALL BLNK (A)
   N = 1
   GO TO 53
C
C     INTERVAL FOR CALCULATION
C
55 IF ((A(1).NE.AI).OR.(A(2).NE.AN).OR.(A(3).NE.AT).OR.(A(4).NE.AE))
  1GO TO 56
   KFLAG(21) = 1
   CALL LEFT (N)
   CALL NUMBER (N,N2,X1,IX)
   INT = IX
   IF (A(N2).EQ.RIGHT) GO TO 4
   GO TO 71
C
C     GROUND
C
56 IF ((A(1).NE.AG).OR.(A(2).NE.AR).OR.(A(3).NE.AO).OR.(A(4).NE.AU))
  1GO TO 66
   KFLAG(25) = 1
   KFLAG(26) = 1
   IGRD = 2
   CALL LEFT (N)
57 IF ((A(N).NE.AP).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AR).OR.(A(N+3).NE
  1.AF)) GO TO 58
   IGRD = 1
   GO TO 64
58 IF ((A(N).NE.AG).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AO).OR.(A(N+3).NE
  1.AD)) GO TO 59
   ER4 = 30.
   SIG4 = .02
   GO TO 64
59 IF ((A(N).NE.AP).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AO).OR.(A(N+3).NE
  1.AR)) GO TO 60
   ER4 = 4.
   SIG4 = .001
   GO TO 64
60 IF ((A(N).NE.AS).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AA)) GO TO 61
   ER4 = 80.
   SIG4 = 4.
   GO TO 64
61 IF ((A(N).NE.AH).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AI).OR.(A(N+3).NE
  1.AG)) GO TO 62
   CALL EQUAL (N)
   CALL NUMBER (N,N2,X1,IX)


   HGT = X1
   IF (A(N2).EQ.RIGHT) GO TO 4
   IF (A(N2).NE.SLANT) GO TO 71
   N = N2+1
   GO TO 57
62 IF ((A(N).NE.AC).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AN).OR.(A(N+3).NE
  1.AD)) GO TO 63
   CALL EQUAL (N)
   CALL NUMBER (N,N2,X1,IX)
   SIG4 = X1
   IF (A(N2).EQ.RIGHT) GO TO 4
   IF (A(N2).NE.SLANT) GO TO 71
   N = N2+1
   GO TO 57
63 IF ((A(N).NE.AD).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AE).OR.(A(N+3).NE
  1.AL)) GO TO 71
   CALL EQUAL (N)
   CALL NUMBER (N,N2,X1,IX)
   ER4 = X1
   IF (A(N2).EQ.RIGHT) GO TO 4
   IF (A(N2).NE.SLANT) GO TO 71
   N = N2+1
   GO TO 57
C
C
C
64 DO 65 K=N,80
   IF (A(K).EQ.RIGHT) GO TO 4
   N = K+1
   IF (A(K).EQ.SLANT) GO TO 57
65 CONTINUE
C
C
C
   GO TO 71
C
C
66 IF ((A(1).NE.AS).OR.(A(2).NE.AT).OR.(A(3).NE.AO).OR.(A(4).NE.AP))
  1GO TO 67
   IFLAG = 2
   RETURN
C
67 IF ((A(1).NE.AC).OR.(A(2).NE.AH).OR.(A(3).NE.AA).OR.(A(4).NE.AN))
  1GO TO 68
   IFLAG = 3
   RETURN
C
68 IF ((A(1).NE.AE).OR.(A(2).NE.AN).OR.(A(3).NE.AD)) GO TO 71


   IFLAG = 1
   RETURN
69 IFLAG = 5
   RETURN
70 IFLAG = 4
   RETURN
71 MSG = 1
   KFLAG(30) = ICARD
   GO TO 4
72 IF (IFLAG.NE.5) WRITE (6,78)
   IFLAG = 5
   RETURN
C
73 IFLAG = 6
   ICARD = ICARD-1
   RETURN
C
C
C
74 FORMAT (5X,80A1)
75 FORMAT (////5X,'DATA CARDS'//)
76 FORMAT (80A1)
77 FORMAT (6X,I2,2X,80A1)
78 FORMAT ('     $$$$$ END CARD/STOP CARD MISSING*****')
   END
```

RITE

PURPOSE: to generate a list of branch currents from the input loop currents.

METHOD: The generation of branch currents is accomplished in the DO LOOP ending at statement 2. The branch currents are stored in CJ(I) by the latter part of the DO LOOP ending at statement 3. If the branch currents are requested for output (IWR positive), the DO LOOP ending at statement 5 accomplishes this.

CALLED BY: GANT1

GFFLD

CALLS TO: NONE

```
      SUBROUTINE RITE (IA,IB,INM,IWR,I1,I2,I3,MD,ND,NM,CJ,CG,IGRD)
      COMPLEX CJ(1),CG(1),CJA,CJB
      DIMENSION IA(1), IB(1), I1(1), I2(1), I3(1), MD(INM,4), ND(1)
      AMAX = .0
C
C
      DO 3 K=1,NM
      KA = IA(K)
      KB = IB(K)
      CJA = (.0,.0)
      CJB = (.0,.0)
      NDK = ND(K)
C
C
      DO 2 II=1,NDK
      I = MD(K,II)
      FI = 1.
      IF (KB.EQ.I2(I)) GO TO 1
      IF (KB.EQ.I1(I)) FI=-1.
      CJA = CJA+FI*CJ(I)
      GO TO 2
    1 IF (KA.EQ.I3(I)) FI=-1.
      CJB = CJB+FI*CJ(I)
    2 CONTINUE
C
C
      CG(K) = CJA
      KK = K+NM
      CG(KK) = CJB
      ACJ = CABS(CJA)
      BCJ = CABS(CJB)
      IF (ACJ.GT.AMAX) AMAX=ACJ
      IF (BCJ.GT.AMAX) AMAX=BCJ
    3 CONTINUE
C
C
      IF (IWR.GT.0) GO TO 4
      RETURN
    4 IF (AMAX.LE.0.) AMAX=1.
      WRITE (6,8)
      NMG = NM
      IF (IGRD.GT.0) NMG = NM/2
C
      DO 5 K=1,NMG
      CJA = CG(K)
      KK = K+NM
      CJB = CG(KK)
      CCJA = CABS(CJA)
```

```
      CCJB = CABS(CJB)
      ACJ = CCJA/AMAX
      BCJ = CCJB/AMAX
      PA = .0
      PB = .0
      IF (ACJ.GT.0.) PA = 57.29578*ATAN2(AIMAG(CJA),REAL(CJA))
      IF (BCJ.GT.0.) PB = 57.29578*ATAN2(AIMAG(CJB),REAL(CJB))
    5 WRITE (6,7) K,IA(K),CJA,CCJA,ACJ,PA,IB(K),CJB,CCJB,BCJ,PB
C
C
      WRITE (6,6)
      RETURN
C
C
    6 FORMAT (1H0)
    7 FORMAT (2X,I2,2(2X,I2,2X,E11.5,1X,E11.5,1X,E11.5,1X,E11.5,1X,F6.1)
     1)
    8 FORMAT (/2(46X,'NORMALIZED',5X)/' SEG',2(' NODE',4X,'REAL',6X,'IMA
     1GINARY',3X,'MAGNITUDE',3X,'MAGNITUDE',3X,'PHASE'))
      END
```

SART

PURPOSE: to sort data for polar plot.

METHOD: This subroutine sorts the values of the points to be plotted by the polar plot package starting with the greatest positive value of y to the greatest negative value. In the DO LOOP ending at statement 1, the value of (x_i, y_i) is interchanged with the value of (x_j, y_j) if y_j is greater than y_i.

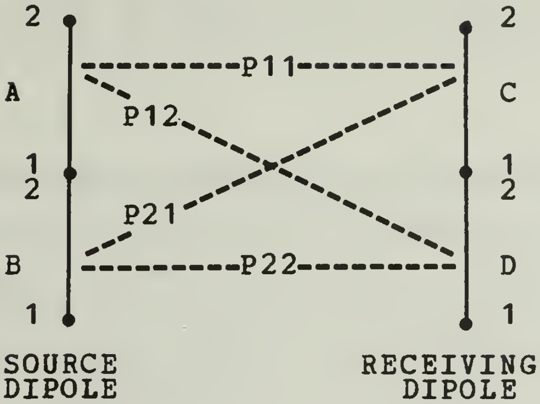
CALLED BY: POLPRT

CALLS TO: NONE

```
      SUBROUTINE SART (DATAX,DATAY,N)
      DIMENSION DATAX(500), DATAY(500)
C
C     THIS ROUTINE SORTS DATA IN DATAY BY MAGNITUDE
C
      NN = N-1
C
      DO 2 I=1,NN
      NM = I+1
C
      DO 1 J=NM,N
      IF (DATAY(I).GE.DATAY(J)) GO TO 1
      STOR = DATAY(I)
      DATA Y(I) = DATAY(J)
      DATA Y(J) = STOR
      STOR = DATAX(I)
      DATA X(I) = DATAX(J)
      DATA X(J) = STOR
    1 CONTINUE
C
    2 CONTINUE
C
      RETURN
      END
```

SGANT

PURPOSE: to calculate the mutual impedance between filamentary monopoles.



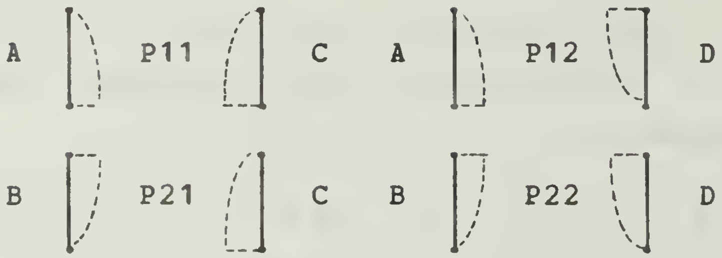
$$Z = P11 + P12 + P21 + P22$$

METHOD: In the induced emf formulation, the mutual impedance of coupled dipoles is

$$Z = - \int I_2(t)\ E_1(t)\ dt$$

where $I_2(t)$ denotes the current distribution (normalized to unit terminal current) on dipole 2, and $E_1(t)$ is the field of dipole 1 when it transmits with unit terminal current. Distance along the axis of dipole 2 is denoted by the coordinate t. E_1 may be expressed as the sum of the fields from each of the monopoles comprising dipole 1. Furthermore, the integral is the sum of the integrations over each of the monopoles comprising dipole 2. Thus, the dipole-dipole mutual impedance may be expressed as the sum of four monopole-monopole impedances.

It may be convenient to draw the above figure in terms of monopoles with the current distribution shown as dotted lines. (The monopole letters remain the same.)



The surface impedance is calculated just above statement 2. B01 denotes J_0 / J_1 where J_0 and J_1 are the Bessel functions of order zero and one with complex argument, ZARG. It is assumed that all the wire segments have the same radius, conductivity and surface impedance.

In the DO LOOP ending with statement 3, SGANT calculates the segment lengths D(J). DMIN and DMAX denote the lengths of the shortest and longest segments. If the wire radius or the segment lengths are clearly beyond the range of thin-wire theory, N is set to zero at statement 4 followed by RETURN to the main program to abort the calculation.

At statement 5, the program selects a segment K, and a few statements below this it selects another segment L. K is a segment of test diple I, and L is a segment of expansion mode J. The mutual impedance between segments K and L is obtained by calling subroutine GGS or GGMM. In statement 18, this impedance is lumped into C(MMM). The mutual impedance Z_{ij} between dipoles I and J is the sum of four segment-segment impedances.

The variables IFLAG and JFLAG are used if a ground plane is present for the calculation of the mutual impedance elements. If IFLAG is equal to JFLAG, the mutual impedance terms will not have the effects of a ground plane since both monopoles lie on the same side of the ground interface. If the monopoles are on the opposite sides of the interface (IFLAG not equal to JFLAG), the reflection coefficient correction must be applied to the mutual impedance elements. This same technique is applied in subroutines GNFLD and GFFLD.

In SGANT, segment K has endpoints KA and KB, and segment L has endpoints LA and LB. It is convenient to think of KA and KB as points 1 and 2 on segment K, and LA and LB as points 1 and 2 on L. The four segment-segment impedances can be defined as P(IS,JS). The first subscript IS refers to the terminal point on segment K, and the second subscript JS refers to the terminal point on L. Thus IS=1 or 2 if dipole I has its terminal point I2(I) at KA (point 1) or KB (point 2), respectively. Similarly, JS=1 or 2 if mode J has its terminal point I2(J) at LA or LB. The impedances P(IS,JS) are defined with the following reference directions for current flow: from point 1 toward point 2 on each segment. If dipole I has this same reference direction on segment K, FI=1; otherwise FI=-1. Similarly FJ=1 or -1 in accordance with the reference direction for mode J on segment L. In statement 18, P(IS,JS) is multiplied by FI and FJ before its contribution is added to Z_{ij}.

Subroutine GGMM calculates the impedances Q(KK,LL) which are like the P(IS,JS) but have different conventions for reference directions and subscript meaning. The transformation from the Q impedances to the P impedances is accomplished in the DO LOOP ending with statement 13.

If the wire has finite conductivity, the appropriate modification is applied to the impedance matrix just above statement 15. The terms arising from the dielectric shell on an insulated segment are obtained from subroutine DSHELL just above statement 16. Finally, the lumped loads, ZLD, are added to the diagonal elements of the impedance matrix in the DO LOOP ending at statement 23.

K is a segment of test dipole I, and L is a segment of expansion mode J. When the segment numbers K and L are equal, SGANT calls GGMM to obtain the mutual impedance between two filamentary electric monopoles. These monopoles are parallel and have the same length. Monopole K is positioned on the axis of the wire segment, and monopole L is on the surface of the same wire segment. Thus, the displacement is equal to the wire radius. The two monopoles are side-by-side with no stagger.

When segments K and L intersect, SGANT again calls GGMM for the mutual impedance between the two filamentary monopoles. Monopole K is situated on the axis of wire segment K, and monopole L is on the surface of wire segment L. The axes of segments K and L define a plane P,and monopole K lies in this plane. Monopole L is parallel with plane P and is displaced from it by a distance equal to the wire radius.

CALLED BY:	MAIN
CALLS TO:	CBES
	DSHELL
	GGMM
	GGS

```
      SUBROUTINE SGANT (IA,IB,INM,INT,ISC,I1,I2,I3,JA,JB,MD,N,ND,NM,NP,A
     1M,BM,C,CGD,CMM,D,EP2,EP3,ETA,FHZ,GAM,SGD,X,Y,Z,ZLD,ZS,ERR,IGRD)
      COMPLEX ERR
      COMPLEX ZG,ZH,ZS,EGD,GD,CGDS,SGDS,SGDT,BDI
      COMPLEX P11,P12,P21,P22,Q11,Q12,Q21,Q22,EP2,EP,ETA,GAM,EP3
      COMPLEX EPSILA,CWEA,BETA,ZARG
      COMPLEX P(2,2),Q(2,2),CGD(1),SGD(1),C(1),ZLD(1)
      DIMENSION X(1), Y(1), Z(1), D(1), IA(1), IB(1), MD(INM,4)
      DIMENSION I1(1), I2(1), I3(1), JA(1), JB(1), ND(1), ISC(1)
      DATA E0,TP,U0/8.854E-12,6.28318,1.2566E-6/
      EP = EP3
      ICC = (N*N+N)/2
C
      DO 1 I=1,ICC
    1 C(I) = (.0,.0)
C
      ZS = (.0,.0)
      IF (CMM.LE.0.) GO TO 2
      OMEGA = TP*FHZ
      EPSILA = CMPLX(E0,-CMM*1.E6/OMEGA)
      CWEA = (.0,1.)*OMEGA*EPSILA
      BETA = OMEGA*SQRT(U0)*CSQRT(EPSILA-EP)
      ZARG = BETA*AM
      CALL CBES (ZARG,BDI)
      ZS = BETA*BDI/CWEA
    2 ZH = ZS/(TP*AM*GAM)
      DMIN = 1.E30
      DMAX = .0
C
      DO 3 J=1,NM
      K = IA(J)
      L = IB(J)
      D(J) = SQRT((X(K)-X(L))**2+(Y(K)-Y(L))**2+(Z(K)-Z(L))**2)
      IF (D(J).LT.DMIN) DMIN=D(J)
      IF (D(J).GT.DMAX) DMAX=D(J)
      EGD = CEXP(GAM*D(J))
      CGD(J) = (EGD+1./EGD)/2.
    3 SGD(J) = (EGD-1./EGD)/2.
C
      IF (DMIN.LT.2.*AM) GO TO 4
      IF (CABS(GAM*AM).GT.0.06) GO TO 4
      IF (CABS(GAM*DMAX).GT.3.) GO TO 4
      IF (AM.GT.0.) GO TO 5
    4 CONTINUE
C     N=0
      WRITE (6,24) AM,DMAX,DMIN
      WRITE (6,25)
C

    5 DO 19 K=1,NM
      IFLAG = 0
      IF ((IGRD.GT.0).AND.(K.GT.NM/2)) IFLAG=1
      NDK = ND(K)
      KA = IA(K)
      KB = IB(K)
      DK = D(K)
      CGDS = CGD(K)
      SGDS = SGD(K)
C
      DO 19 L=1,NM
      JFLAG = 0
      IF ((IGRD.GT.0).AND.(L.GT.NM/2)) JFLAG=1
      NDL = ND(L)
      LA = IA(L)
      LB = IB(L)
      DL = D(L)
      SGDT = SGD(L)
      NIL = 0
C
      DO 19 II=1,NDK
      I = MD(K,II)
      MM = (I-1)*N-(I*I-I)/2
      FI = 1.
      IF (KB.EQ.I2(I)) GO TO 6
      IF (KB.EQ.I1(I)) FI=-1.
      IS = 1
      GO TO 7
    6 IF (KA.EQ.I3(I)) FI=-1.
      IS = 2
C
    7 DO 19 JJ=1,NDL
      J = MD(L,JJ)
      MMM = MM+J
      IF (I.GT.J) GO TO 19
      FJ = 1.
      IF (LB.EQ.I2(J)) GO TO 8
      IF (LB.EQ.I1(J)) FJ=-1.
      JS = 1
      GO TO 9
    8 IF (LA.EQ.I3(J)) FJ=-1.
      JS = 2
    9 IF (NIL.NE.0) GO TO 18
      NIL = 1
      IF (K.EQ.L) GO TO 14
      IND = (LA-KA)*(LB-KA)*(LA-KB)*(LB-KB)
      NGRD = IGRD
      IF (IFLAG.EQ.JFLAG) IGRD=-1
```

```
      IF (IND.EQ.0) GO TO 10
C     SEGMENTS K AND L SHARE NO POINTS
      CALL GGS (X(KA),Y(KA),Z(KA),X(KB),Y(KB),Z(KB),X(LA),Y(LA),Z(LA),X(
     1LB),Y(LB),Z(LB),AM,DK,CGDS,SGDS,DL,SGDT,INT,ETA,GAM,P(1,1),P(1,2),
     2P(2,1),P(2,2),ERR,IGRD)
      IGRD = NGRD
      GO TO 18
C     SEGMENTS K AND L SHARE ONE PO(NT (THEY (NTERSECT)
   10 KG = 0
      JM = KB
      JC = KA
      KF = 1
      IND = (KB-LA)*(KB-LB)
      IF (IND.NE.0) GO TO 11
      JC = KB
      KF = -1
      JM = KA
      KG = 3
   11 LG = 3
      JP = LA
      LF = -1
      IF (LB.EQ.JC) GO TO 12
      JP = LB
      LF = 1
      LG = 0
   12 SGN = KF*LF
      CPSI = ((X(JP)-X(JC))*(X(JM)-X(JC))+(Y(JP)-Y(JC))*(Y(JM)-Y(JC))+(Z
     1(JP)-Z(JC))*(Z(JM)-Z(JC)))/(DK*DL)
      CALL GGMM (.0,DK,.0,DL,AM,CGDS,SGDS,SGDT,CPS(,ETA,GAM,Q(1,1),Q(1,2
     1),Q(2,1),Q(2,2))
C
      DO 13 KK=1,2
      KP = IABS(KK-KG)
C
      DO 13 LL=1,2
      LP = IABS(LL-LG)
      P(KP,LP) = SGN*Q(KK,LL)
   13 CONTINUE
C
      IGRD=NGRD
      GO TO 18
C     K=L  (SELF REACT(ON OF SEGMENT K)
   14 Q11 = (.0,.0)
      Q12 = (.0,.0)
      IF (CMM.LE.0.) GO TO 15
      GD = GAM*DK
      ZG = ZH/(SGDS**2)
      Q11 = ZG*(SGDS*CGDS-GD)/2.


      Q12 = ZG*(GD*CGDS-SGDS)/2.
   15 ISCK = (SC(K)
      P11 = (.0,.0)
      P12 = (.0,.0)
      IF (ISCK.EQ.0) GO TO 16
      IF (BM.LE.AM) GO TO 16
      CALL DSHELL (AM,BM,DK,CGDS,SGDS,EP2,EP,ETA,GAM,P11,P12)
   16 Q11 = P11+Q11
      Q12 = P12+Q12
      CALL GGMM (.0,DK,.0,DK,AM,CGDS,SGDS,SGDS,1.,ETA,GAM,P11,P12,P21,P2
     12)
      Q11 = P11+Q11
      Q12 = P12+Q12
      P(1,1) = Q11
      P(1,2) = Q12
      P(2,1) = Q12
      P(2,2) = Q11
      IF (KA.NE.LA) GO TO 17
      GO TO 18
   17 P(1,1) = -Q12
      P(1,2) = -Q11
      P(2,1) = -Q11
      P(2,2) = -Q12
   18 C(MMM) = C(MM4)+FI*FJ*P((S,JS)
   19 CONTINUE
C
C
      DO 23 I=1,N
      MM = (I-1)*N-(I*I-I)/2
      IJ = MM+I
      JJA = JA(I)
      J1 = JJA
      I(2 = I2(I)
      II1 = (1(I)
      IF ((I2.EQ.IB(J1)) J1=J1+NM
      JJB = JB(I)
      J2 = JJB
      IF (II2.EQ.IB(J2)) J2=J2+NM
      C(IJ) = C(IJ)+ZLD(J1)+ZLD(J2)
      JJJ = JJA
C
      DO 22 K=1,2
      NDJ = ND(JJJ)
C
      DO 21 JJ=1,NDJ
      J = MD(JJJ,JJ)
      IF (J.EQ.I) GO TO 21
      IF (I2(J).NE.II2) GO TO 21
```

```
      IJ = MM+J
      FI = 1.
      IF (K.EQ.2) GO TO 20
      IF (I1(J).NE.I1I) FI=-1.
      C(IJ) = C(IJ)+FI*ZLD(J1)
      GO TO 21
   20 IF (I3(J).NE.I3(I)) FI=-1.
      C(IJ) = C(IJ)+FI*ZLD(J2)
   21 CONTINUE
C
   22 JJJ = JJB
C
   23 CONTINUE
C
      RETURN
C
   24 FORMAT (3X,'AM = ',E10.3,3X,'DMAX = ',E10.3,3X,'DMIN = ',E10.3)
   25 FORMAT (' WARNING **********************************************'/
     1,' THIS PROBLEM EXCEED LIMIT OF THIN WIRE CONDITION, THE RESULTS
     2 ARE NOT CORRECT')
      END
```

SORT

PURPOSE: to define the set of dipole modes.

METHOD: In the DO LOOP ending at statement 3, the set of dipoles is defined by filling the vectors I1(I) and I3(I) (the endpoints of dipole I); I2(I) (the terminal point of dipole I); and the vectors JA(I) and JB(I) (the monopoles comprising dipole I) with the node numbers and segment numbers, respectively. The DO LOOP ending at statement 8 determines MD(J,K) (the list of dipoles sharing segment J) and ND(K) (the number of dipoles sharing segment J).

CALLED BY: MAIN

CALLS TO: NONE

```
      SUBROUTINE SORT (IA,IB,I1,I2,I3,JA,JB,MD,ND,NM,NP,N,MAX,MIN,ICJ,IN
     1M)
      DIMENSION JSP(20)
      DIMENSION I1(1), I2(1), I3(1), JA(1), JB(1)
      DIMENSION IA(1), IB(1), ND(1), MD(INM,4)
      I = 0
C
      DO 3 K=1,NP
      NJK = 0
C
      DO 1 J=1,NM
      IND = (IA(J)-K)*(IB(J)-K)
      IF (IND.NE.0) GO TO 1
      NJK = NJK+1
      JSP(NJK) = J
    1 CONTINUE
C
      MOD = NJK-1
      IF (MOD.LE.0) GO TO 3
C
      DO 2 IMD=1,MOD
      I = I+1
      IF (I.GT.ICJ) GO TO 2
      IPD = IMD+1
      JAI = JSP(IMD)
      JA(I) = JAI
      JBI = JSP(IPD)
      JB(I) = JBI
      I1(I) = IA(JAI)
      IF (IA(JAI).EQ.K) I1(I)=IB(JAI)
      I2(I) = K
      I3(I) = IA(JBI)
      IF (IA(JBI).EQ.K) I3(I)=IB(JBI)
    2 CONTINUE
C
    3 CONTINUE
C
      N = I
C
      DO 4 J=1,NM
      ND(J) = 0
C
      DO 4 K=1,4
    4 MD(J,K) = 0
C
      III = N
      IF (N.GT.ICJ) III = ICJ
C
```

```
      DO 8 I=1,III
      J = JA(I)
C
      DO 7 L=1,2
      ND(J) = ND(J)+1
      K = 1
      M = 0
    5 MJK = MD(J,K)
      IF (MJK.NE.0) GO TO 6
      M = 1
      MD(J,K) = I
    6 K = K+1
      IF (K.GT.4) GO TO 7
      IF (M.EQ.0) GO TO 5
    7 J = JB(I)
C
    8 CONTINUE
C
      MIN = 100
      MAX = 0
C
      DO 9 J=1,NM
      NDJ = ND(J)
      IF (NDJ.GT.MAX) MAX=NDJ
    9 IF (NDJ.LT.MIN) MIN=NDJ
C
      RETURN
      END
```

SQROT

PURPOSE: to solve the set of simultaneous equations to determine the currents on the thin wire structure.

METHOD: This subroutine considers the matrix equation ZI = V which represents a system of simultaneous linear equations. NEQ denotes the number of simultaneous equations and the size of the matrix Z.

On entry to SQROT, S is the excitation column V. On exit, the solution I is stored in S. Z(I,J) denotes the symmetric square matrix. Also on entry, the upper-right triangular position of Z(I,J) is stored by rows in C(K) with

K = (I - 1) * NEQ - (I * I) / 2 + J .

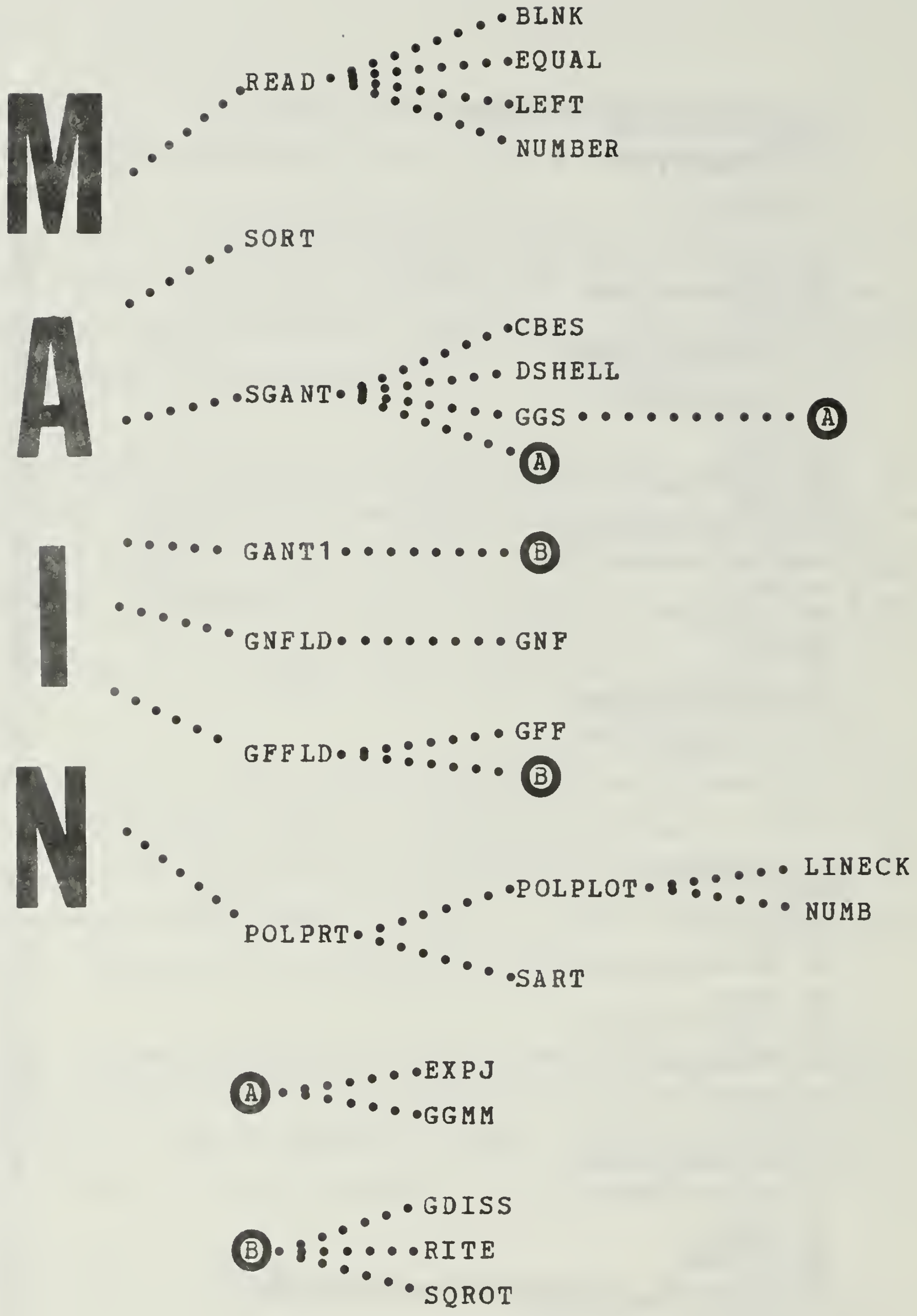
If I12 = 1, SQROT will transform the symmetric matrix into the auxiliary matrix (implicit inverse), store the result in C(K) and use the auxiliary matrix to solve the simultaneous equations. If I12 = 2, this indicates that C(K) already contains the auxiliary matrix.

The transfromation from the symmetric matrix to the auxiliary matrix is accomplished in the DO LOOP ending at statement 5. The solution of the simultaneous equations is accomplished in the remainder of the program.

CALLED BY: GFFLD

CALLS TO: NONE

```
      SUBROUTINE SQROT (C,S,IWR,I12,NEQ)
      COMPLEX C(1),S(1),SS
      N = NEQ
      IF (I12.EQ.2) GO TO 6
      C(1) = CSQRT(C(1))
C
      DO 1 K=2,N
    1 C(K) = C(K)/C(1)
C
C
      DO 5 I=2,N
      IMO = I-1
      IPO = I+1
      ID = (I-1)*N-(I*I-I)/2
      II = ID+I
C
      DO 2 L=1,IMO
      LI = (L-1)*N-(L*L-L)/2+I
    2 C(II) = C(II)-C(LI)*C(LI)
C
      C(II) = CSQRT(C(II))
      IF (IPO.GT.N) GO TO 5
C
      DO 4 J=IPO,N
      IJ = ID+J
C
      DO 3 M=1,IMO
      MO = (M-1)*N-(M*M-M)/2
      MI = MO+I
      MJ = MO+J
    3 C(IJ) = C(IJ)-C(MJ)*C(MI)
C
    4 C(IJ) = C(IJ)/C(II)
C
    5 CONTINUE
C
    6 S(1) = S(1)/C(1)
C
      DO 8 I=2,N
      IMO = I-1
C
      DO 7 L=1,IMO
      LI = (L-1)*N-(L*L-L)/2+I
    7 S(I) = S(I)-C(LI)*S(L)
C
      II = (I-1)*N-(I*I-I)/2+I
    8 S(I) = S(I)/C(II)
C

      NN = ((N+1)*N)/2
      S(N) = S(N)/C(NN)
      NMO = N-1
C
      DO 10 I=1,NMO
      K = N-I
      KPO = K+1
      KO = (K-1)*N-(K*K-K)/2
C
      DO 9 L=KPO,N
      KL = KO+L
    9 S(K) = S(K)-C(KL)*S(L)
C
      KK = KO+K
   10 S(K) = S(K)/C(KK)
C
      IF (IWR.LE.0) GO TO 13
      CNOR = .0
C
      DO 11 I=1,N
      SA = CABS(S(I))
   11 IF (SA.GT.CNOR) CNOR=SA
C
      IF (CNOR.LE.0.) CNOR=1.
C
      DO 12 I=1,N
      SS = S(I)
      SA = CABS(SS)
      SNOR = SA/CNOR
      PH = .0
      IF (SA.GT.0.) PH = 57.29578*ATAN2(AIMAG(SS),REAL(SS))
   12 WRITE (6,14) I,SNOR,SA,PH,SS
C
      WRITE (6,15)
   13 RETURN
C
   14 FORMAT (1X,I15,1F10.3,1F15.7,1F10.0,2F15.6)
   15 FORMAT (1H0)
      END
```



CALLING SEQUENCE OF THE SUBROUTINES

SYMBOL DICTIONARY

A	characters of the input data cards
ABAP	backscattering phi plane angle for plotting
ABAT	backscattering theta plane angle for plotting
ABIP	bistatic scattering phi plane angle for plotting
ABIT	bistatic scattering theta plane angle for plotting
ACSP	absorption cross section for phi polarization
ACST	absorption cross section for theta polarization
AFFP	far-zone phi plane angle for plotting
AFFT	far-zone theta plane angle for plotting
AM	radius of the thin wire of the structure
BM	outer radius of the dielectric shell of the insulation of the wire
C	elements of the open-circuit impedance matrix
CG	branch currents for the structure
CGD	cosh γd for a given segment
CJ	loop currents for the structure
CMM	conductivity of the wire
D	length of a given segment
ECSP	extinction cross section for phi polarization
ECST	extinction cross section for theta polarization
EFF	radiation efficiency
EP	loop currents induced by a phi polarized wave
EPP	phi-polarized far-zone feild of the dipole mode
EPPS	scattered electric field in the phi direction due to a phi polarized wave
EPTS	scattered electric field in the theta direction due to a phi polarized wave
EP2	complex permittivity of insulation
EP3	complex permittivity of ambient medium
EP4	complex permittivity of ground
ERR	EP4/EP3
ER2	relative dielectric constant of insulation

ER3	relative dielectric constant of the ambient medium
ER4	relative dielectric constant of the ground
ET	loop current induced by a theta polarized wave
ETA	intrinic impedance of ambient medium
ETPS	scattered electric field in the phi direction due to a theta polarized wave
ETT	theta polarized far-zone field of the dipole mode
ETTS	scattered electric field on the theta direction due to theta polarized wave
EX	near-zone electric field in x direction
EY	near-zone electric field in the y direction
EZ	near-zone electric field in z direction
E0	8.854E-12
FHZ	frequency in hertz
FMC	frequency in megahertz
GAM	intrinic progration constant of the ambient medium
GG	time-average power input
GPP	power gain associated with the phi polarized component
GTT	power gain associated with the theta polarized component
HGT	height of the structure above ground plane
IA	first node of a given segment
IB	second node of a given segment
IBISC	indicator for bistatic scatter calculations
ICARD	indicator for the data cards
ICJ	dimension corresponding to the number of simultaneous linear equations
IFLAG	indicator for program termination
IGAIN	indicator for antenna gain calculations
IGRD	indicator for presence of the ground plane
INC	indicator for the type of far-zone calculations
INEAR	indicator for near-zone calculations
INM	dimension corresponding to the number of monpoles
INT	number of integration steps

ISC	indicator for the insualtion
ISCAT	indicator for backscatter calculations
IWR	indicator for current distribution output
I1	endpoint node of a given dipole
I12	indicator for auxiliary matrix
I2	terminal node number of a given dipole
I3	endpoint node number of a given dipole
JA	first segment number of a given dipoile
JB	second segment number of a given dipole
KFLAG	print indicator
KGEN	list of generator/feed locations
LOAD	indicator for structure load
LZD	list of impedance/load locations
MAX	maximum of the number of segments connected to any one given node
MD	list of dipoles sharing a given segment
MIN	minimum of the number of segments that connected to any one given node
MSG	indicator for error printout
N	number of simultaneous linear equations
ND	total number of dipoles sharing a given segment
NGEN	indicator for antenna calculations
NM	number of segments
NPL	indicator for polar plot
OMEGA	angular frequency
PH	phi angle for far-zone calculations
SCSP	scattering cross section for phi polarization
SCST	scattering cross section for theta polarization
SGD	sinh γd of a given segment
SIG2	conductivity of insulation
SIG3	conductivity of the ambient medium
SIG4	conductivity of ground
SPPM	echo area phi incident-phi scattered wave
SPTM	echo area phi incident-theta scattered wave
STPM	echo area theta incident-phi scattered wave
STTM	echo area theta incident-theta scattered wave

TD2	loss tangent of the insulation
TD3	loss tangent of ambient medium
TH	theta angle for far-zone calculations
TP	2π (6.28318)
UO	1.2566E-6
VG	antenna complex driving voltages
VOLT	list of VG's
X	x-coordinate of each node
XNP	list of XP's
XP	x-coordinate for near-zone calculations
Y	y-coordinate of each node
YNP	list of YP's
YP	y-coordinate for near-zone calculations
Y11	complex power input
Z	z-coordinate of each node
ZLD	complex load at a given node
ZLLD	list of ZLD's
ZNP	list of ZP's
ZP	z-coordinate for near-zone calculations
ZS	surface impedance of the wire
Z11	antenna input impedance

APPENDIX B
USER'S MANUAL

TABLE OF CONTENTS

USER'S MANUAL

The Antennas-Scatterers Analysis Program (ASAP) for thin wire structures in a homogenous conducting medium performs a frequency domain analysis of antennas and scatters. The program is applicable in the presence of either a perfect or a finite ground. This appendix will describe and explain the data cards necessary to execute the compute program. Although the program was written for the IBM 360 computer system, it can be executed on another system with minor modifications.

The program utilizes piecewise sinusoidal expansion for the current distribution with Kirchhoff Current Law enforced everywhere on the structure. If the structure contains end points, the currents at these points are assumed to vanish.

I. Program Limits

The thin wire assumptions are questionable and the accuracy and convergence deteriorate if the radius of wire utilized for the structure exceeds 0.01 of a wavelength, if the longest segment is greater than one-fourth of a wavelength, if the length ratio of the longest and shortest segments exceeds 100, or if the total wire length is less than 30 times the wire diameter. If a wire is bent sharply to form a small acute angle (less than 30 degrees), the thin wire model is questionable. It is assumed that the wire conductivity greatly exceeds the conductivity of the ambient medium. For insulated wires, the dielectric layer is assumed to be electrically thin.

II. Minimum Data

The minimum data necessary to execute the program is:

a. description of structure

b. radius of wire used for the structure

The program will default to the other parameters necessary. The default parameters are:

a. wire for the structure is copper

b. frequency of operation is 300 mhz

c. homogneous medium is free space

A more detailed explanation of the defaults will be discussed when the data card for the parameter is described.

III. Outputs

In antenna problems, the output includes structure currents, impedance(s) of feed(s), gain, polar radiation plots, and near field calculations. In bistatic scattering problems, the output includes structure currents, complex elements of the polarization scattering matrix, polar reradiation pattern plots, and echo areas produced by a plane wave. For backscattering problems the output includes absorption, scattering and extinction cross sections in addition to the outputs of bistatic scattering. Most of the outputs are suppressed and must be requested. Since the program can produce a large volume of output, care should be exercised until the user is familiar with the outputs.

IV. Data Cards

The Analysis Program utilizes free format for the data cards, that is, the program utilizes character recognition to determine which parameters are being read. Data placement (location) on the input card is not critial. Blank characters, on all input cards but the COMMENT data card, are ignored and may be used at the discretion of the user. Since character recognition is used, only the first four characters of the key words must be present and correct.

The format for the COMMENT CARD utilizes standard FORTRAN format (i.e. 'C' in column 1 followed by at least four blanks). The COMMENT CARD is the only type of input card that position in the data block is critial. This (these) card(s) must be placed at the beginning of a data block. A data block is a series of related data cards. Several data blocks may be used to define an analysis problem. This will become clear when the termination cards (END, STOP, or CHANGE) are discussed. There is no limit to the number of comment cards that may be used. As a check for the user, all input data cards will appear on the output as they appear in the input deck.

The format of other data can be of one of two forms:

a. type of card (option 1/option 2/.........)

b. parameter (value) .

The type of format to use will be apparent as the individual data cards are discussed.

The numerical values for the parameters may be stated in any one of the following forms. The program will translate the number to the proper form for the specified parameter, either fixed or floating point. All of the following examples have the same value.

0.0001 or .0001 or 100.U or 100U or .1M or 0.1M or .0000001K

$U = 10^{-6}$ $M = 10^{-3}$ $K = 10^{3}$

1. WIRE This card is used to define the parameters associated with the wire utilized by the thin wire structure. Two options are available and are defined as:

RADIUS=value of the radius of the wire in meters

CONDUCTIVITY=value in megamhos per meters .

The wire data card must appear in the first data block to define wire radius. The default value of the conductivity is 50 megamhos/meter (copper).

```
WIRE(  RADIUS=.001/  CONDU=28.5)
```

2. INSULATION This card is utilized to define the parameters associated with the insulation of the wire used for the structure to be analyzed. If this card is omitted, the program assumes that the structure is uninsulated. Four options are available and are defined as:

RADIUS=value of outer radius in meters

CONDUCTIVITY=value in micromhos per meter

DIELECTRIC=value of relative dielectric constant

LOSS TANGENT=value .

The conductivity and either the relative dielectric constant or the loss tangent (but not all three) options may be stated.

```
INSULATION( RADIUS=.015/ COND=7./DIEL=5)
```

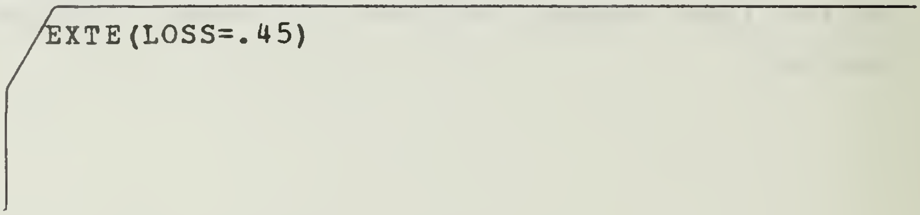
3. EXTERIOR MEDIUM This card is utilized to describe the homogeneous medium surrounding the structure. If the medium is free space, this card may be omitted. Three options are available and are defined as:

DIELECTRIC=value of relative dielectric constant

CONDUCTIVITY=value in micromhos per meter

LOSS TANGENT=value .

As with INSULATION card state either conductivity or loss tangent.



```
EXTE(LOSS=.45)
```

4. <u>DESCRIPTION</u> This card is utilized to describe the shape of the wire structure to the program. The user must divide the wire structure into segments of the appropriate length and number each node starting at one. A node is a point where a segment begins or ends. A maximium of four segments can meet at any given node. An isolated wire must contain at least two segments and three nodes. Thus the DESCRIPTION CARD must show at least 3 consecutive nodes for all portions of the wire structure. The structure is described by stating the node numbers that each segment connects. The description of a square loop might appear as:

```
DESCRIPTION(1-2/2-3/3-4/4-1) .
```

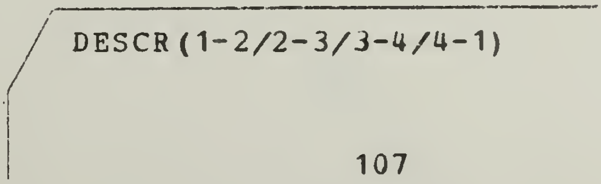
The description of a dipole and reflector might appear as:

```
DESCRIPTION(1-2/2-3/3-4/4-5/6-7/7-8/8-9/9-10).
```

If the description will not fit on one data card continue on the next card as if the previous card were longer. The dipole example might appear as:

```
DESCRIPTION(1-2/2-3/3-4/4-5/

6-7/7-8/8-9/9-10).
```

Note that the last character on the card to be continued is a slant (/). As many cards as necessary may be used. The maximum number of nodes permitted is fifty. If ground plane is present, the maximum number is twenty-five. If a ground plane is present and the structure touches the ground plane, the lowest node numbers MUST be used for the touching nodes. That is, if the structure touches the ground plane at two points, node numbers 1 and 2 MUST be assigned to these nodes.



```
DESCR(1-2/2-3/3-4/4-1)
```

5. <u>GEOMETRY</u> This card is used to state the physical location in rectangular coordinates of each node of the DESCRIPTION CARD . The rectangular grid is in units of meters. If node 1 is located at x1,y1,z1 and node 2 at x2,y2,z2 and node 3 at x3,y3,z3,etc., the GEOMETRY CARD might appear as:

```
GEOMETRY(x1,y1,z1/x2,y2,z2/x3,y3,z3/...........)
```

As with the DESCRIPTION CARD, continuation cards are permitted.

```
GEOM(.1,0,.1/-.1,0.1/-.1,0-.1/.1,0,-.1)
```

6. FEED For antenna analysis the feed point(s) and voltage(s) must be stated. In the foremention dipole and reflector example if the feeds were at node 2 with a voltage source of .5 at an angle of -90 degrees and at node 4 with a voltage source of .5 at an angle of +90 degrees the FEED CARD might appear as:

```
FEED(2,.5,-90/4,.5,+90)
```

The order of the information for each voltage source is node number, magnitude, and phase angle. This order is repeated until all sources are stated. If the source information will not fit on one card, use another card similiar to the initial one; that is, repeat the word "FEED". If only one voltage source is applied to the structure, only the node number must be stated. In the dipole example, if the drive is at node 3, the FEED CARD might appear as:

```
FEED(3)
```

A default source of one volt at zero degree phase is assumed. Voltage sources should only be stated for nodes with only two segments.

FEED(2,.5,-90/4,.5,+90)

7. LOAD This card is used to describe the loads to be placed at various locations on the structure. The format for this card is similiar to that of the FEED CARD, that is, the word "LOAD" is used in the place of "FEED". The order of the information on the card is the same. Since this card is frequency dependent, it must be changed if the frequency of operation is changed. No default parameters are available. The structure is assumed unloaded unless this card is used. Once the structure is loaded, it will remain loaded for the remainder of the data block series. To unload the structure the following card may be used:

```
LOAD(-1)
```

```
LOAD(1,120,-45/3,120,+45)
```

8. OUTPUT This card is used to request output data. Most of the output is in tabular form. More than one OUTPUT CARD is permitted per data block, but not for the same type of output. If only the antenna input impedance, antenna efficiency, or time-average power input is of interest, no OUTPUT CARD is necessary. These parameters are automatically printed if a FEED CARD or GENERATOR CARD is utilized. One or more of the following options may be used to request the various outputs available.

FAR FIELD=phi initial, phi final, theta initial, theta final

This option gives the components of the electric field intensity in the far field as phi and theta varies between limits specified in one degree divisions.

BACKSCATERING=phi initial, phi final, theta initial, theta final

This option gives the absorption, scattering, and extinction cross sections, and the complex elements of the polarization scattering matrix for an incident plane wave illuminating the structure from the spherical direction of phi, theta as both vary between limits specified in one degree divisions.

BISTATIC=phi inital, phi final, theta initial, theta final

This option gives echo area and the complex elements of the polarization scattering matrix for an incident plane wave illuminating the structure from the spherical direction phi, theta final of the backscattering output option, reradiated in the phi, theta direction as both vary between limits specified in one degree divisions. A bistatic output request must be accompanied with a backscattering request in the same data block.

STEP=value in degrees

This option will cause any of the above output options to be stepped at a different interval size. That is, if one of the above options is to be stepped at ten degrees intervals, use this option. This option overrides the one degree stepping.

CURRENT

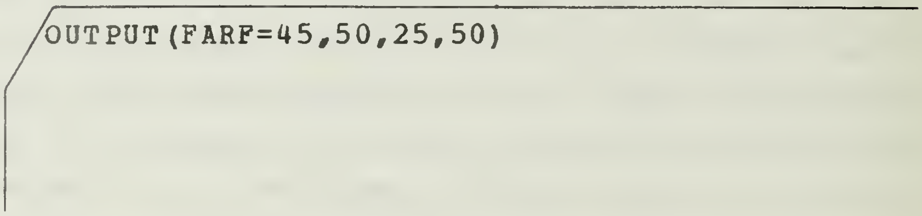
This option gives the currents on the structure which are produced by the feed/generator voltages and/or the incident plane wave of the backscattering request.

NEAR=x1,y1,z1

or

NEAR=(x1,y1,z1/x2,y2,z2/x3,y3,z3/etc.....)

This option gives the value of electric field components in the near field for the antenna at the point or points specified.



```
OUTPUT(FARF=45,50,25,50)
```

9. **PLOT** This card will produce normalized polar plots in the specifed plane for the stated option. The plane is specified by stating either "PHI=____" or "THETA=____". The PLOT CARD overrides the limits of the OUTPUT CARD for the same option. If only a normalized pattern is of interest, only a PLOT CARD is necessary. If a table of values and a normalized pattern is desired, both a PLOT CARD and OUTPUT CARD must be used. Only one PLOT CARD is permitted per data block. The following pattern plots are available:

FAR FIELD/plane

This option will plot the far field intensity for each component of the electric field.

BACKSCATTERING/plane

This option will plot the normalized magnitude of each of the elements of the polarization scattering matrix.

BISTATIC/plane

This option will plot the normalized magnitude of each of the elements of the polarization scattering matrix produced by the incident plane wave stated by final limits of the backscattering option of the output request.

```
PLOT (FARF/THET=90)
```

10. GROUND This card is used to describe the ground parameters if a ground plane is present. If no ground plane is present, the structure is assumed to be in free space or the homogeneous medium of the EXTERIOR MEDIUM data card. Seven options are available and are defined as:

PERFECT

This option will analyze the structure over a perfect ground plane.

GOOD

This option will analyze the structure over a good ground plane where the conductivity of the ground is .02 mhos/meter and the relative dielectric constant is 30.

POOR

This option will analyze the structure over a poor ground plane where the conductivity of the ground is .001 mhos/meter and the relative dielectric constant is 4.

SEA

This option will analyze the structure over salt water where the conductivty of the water is 4. mhos/meter and the relative dielectric constant is 80.

HEIGHT=value in meters

This option will analyze the structure with origin of the GEOMETRY card this height above the ground plane. The lowest point of the structure must not lie below the ground plane. It may lie on the ground plane.

CONDUCTIVITY= value in mhos/meter

This option is used to state the value of conductivity of the ground plane if the default values mentioned above are not utilized.

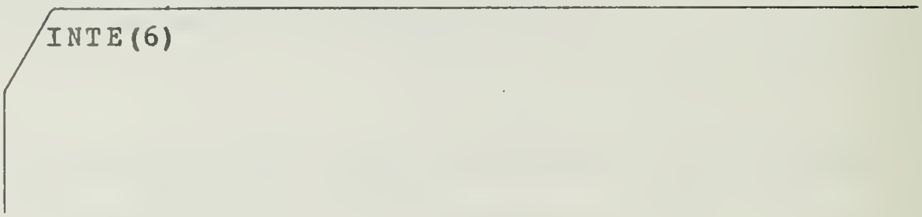
DIELECTRIC= value

This option is used to state the relative dielectric constant of the ground plane if the default values mentioned above are not utilized.

```
GROUND(HEIG=10/COND=.002/DIEL=10)
```

11. INTERVAL FOR CALCULATION This card is used to state the number of intervals to be used for calculating the elements of the impedance matrix with Simpson's-rule integration. A large value for the number improves the accuracy at the expense of greater execution time. For most problems a suitable combination of speed and accuracy is obtained with a value of four, the default value. If the rigiorous closed-form impedance expressions in terms of the exponential integrals is desired, set this value to zero.

```
INTERVAL=value
```



12. GENERATOR This card is similiar to the FEED CARD in use, except that the segment numbers are stated instead of the node numbers. This is useful if three or four segments meet at a node. The positive terminal of the generator is connected to the specified segment such that current is forced in the the positive direction. The positive direction of current flow is from the first stated node number of that segment toward the second stated as ordered on the DESCRIPTION CARD.

```
GENE(2,.5,-90/4,.5,+90)
```

13. IMPEDANCE This card is similiar to the LOAD CARD in use, except that the segment numbers are stated instead of the node numbers. As with the GENERATOR CARD, this is used if three or four segments are connected to a node. The impedance will be connected to the positive terminal of the specified segment. The format of this card is the same as the LOAD CARD.

```
IMPE(1,120,-45/3,120,+45)
```

14. FREQUENCY This card is used to specify the frequency in megahertz if it is to be other than the default value of 300 MHz.

```
FREQ(12.5)
```

15. CHANGE This card at the end of the data block signals the program that the following data cards are changes to the previously read data, for the next run. If a "CHANGE CARD" is used, the outputs must be requested again in the next data block. The "CHANGE CARD" cannot be used to change "DESCRIPTION CARD" or "GEOMETRY CARD" data when operating with a "GROUND CARD". Use an "END CARD" to make changes when a "GROUND CARD" is used.

16. END This card signals the program that this is the end of a data block series and to reinitialize data for the next problem. An "END CARD" cannot be used with a "CHANGE CARD".

17. STOP This card signals the program that all of the data cards have been read and to terminate itself when execution is completed. This card must be used as the last card in place of the "END CARD" of the last data block series. A "STOP CARD" cannot be used with an " END CARD" in the same data block.

```
C       AN EXAMPLE PROBLEM
C
C       V ANTENNA
C
WIRE(RADIUS=1M)
GEOM(0,-.18,+.18/0,-.09,+.09/0,0,0/0,0.09,.09/0,.18,.18)
DESC(1-2/2-3/3-4/4-5)
FEED(3)
OUTPUT(FARF=45,50,65,80/STEP=5)
CHANGE
OUTPUT(BIST=45,45,45,45/BACK=0,0,10,12)
OUTPUT(CURRENT)
CHANGE
C
C       CHANGE STRUCTURE SHAPE TO DIPOLE
C
GEOM(0,-.25,0/0,-.125,0/0,0,0/0,.125,0/0,.25,0)
PLOT(FARF/PHI=90)
GROUND(HEIGHT=.25/GOOD)
STOP
```

THE ABOVE DATA DECK WILL PRODUCE THE OUTPUT ON THE FOLLOWING PAGES.

```
                                   ************************************
                                   *                                  *
                                   *     OHIO STATE UNIVERSITY        *
                                   *   ANTENNA ANALYSIS PROGRAM       *
                                   *      MODIFIED FOR USE AT         *
                                   *   NAVAL POSTGRADUATE SCHOOL      *
                                   *       3 SEPTEMBER 1975           *
                                   *                                  *
                                   ************************************


DATA CARDS

  1  WIRE(RADI=1M)
  2  GEOM(0,-.18,+.18/0,-.09,+.09/0,0,0/0,.09,.09/0,.18,.18)
  3  DESC(1-2/2-3/3-4/4-5)
  4  FEED(3)
  5  OUTP(FARF=45,50,65,80/STEP=5)
  6  CHANGE

                                   ****************************
                                   *                          *
                                   *        INPUT DATA        *
                                   *                          *
                                   ****************************
                  WIRE RADIUS (METERS)                                    0.10000E-02
                  WIRE INSULATED (NO/YES)                                      NO
                  EXTERIOR MEDIUM                                         FREE SPACE
                  GROUND PLANE (NO/YES)                                        NO


                                   WIRE STRUCTURE

        SEG    NODE                LOCATION                     NODE                    LOCATION
        NO.    NO.          X         Y            Z            NO.          X             Y            Z
         1      1     0.0        -.18000E 00   0.18000E 00   2     0.0         -.90000E-01   0.90000E-01
         2      2     0.0        -.90000E-01   0.90000E-01   3     0.0         0.0           0.0
         3      3     0.0        0.0           0.0           4     0.0         0.90000E-01   0.90000E-01
         4      4     0.0        0.90000E-01   0.90000E-01   5     0.0         0.18000E 00   0.18000E 00


                                   ANTENNA FEEDS
                         NODE                VOLTS
                         NO.             REAL         IMAGINARY
                          3           0.10000E 01     0.0

                                   ****************************
                                   *                          *
                                   *     OUTPUT REQUESTED     *
                                   *                          *
                                   ****************************
                  FAR FIELDS FOR PHI VARYING FROM  45.0 TO  50.0AND THETA VARYING FROM  65.0 TO  80.0
                                   IN STEPS OF   5.0 DEGREES.
```

```
                                      *****************************
                                      *                           *
                                      *           ANTENNA         *
                                      *        CALCULATIONS       *
                                      *                           *
                                      *****************************

THE INPUT IMPEDANCE AT NODE   3 IS    46.2782898 + J     26.5534973

THE RADIATION EFFICIENCY IS      99.5343018
THE TIME-AVERAGE POWER INPUT IS      0.0162564
THE ANTENNA IMPEDANCE IS      46.2782898 +J    26.5534973
```

```
                                  ****************************
                                  *                          *
                                  *        FAR FIELD         *
                                  *       CALCULATIONS       *
                                  *                          *
                                  ****************************

                                                    ELECTRIC FIELD INTENSITY
  DEGREES          POWER GAIN                                THETA                                                         PHI
THETA   PHI       THETA          PHI            REAL          IMAG           MAGN       PHASE         REAL          IMAG           MAGN        PHASE
 65.0   45.0   0.2144E 00   0.6663E 00     -.2811E 00   -.1596E 00   0.3233E 00   -150.4     -.2148E 00   -.5278E 00   0.5699E 00   -112.1
 70.0   45.0   0.1816E 00   0.6635E 00     -.2802E 00   -.9983E-01   0.2975E 00   -160.4     -.2315E 00   -.5194E 00   0.5685E 00   -114.0
 75.0   45.0   0.1554E 00   0.6611E 00     -.2723E 00   -.3959E-01   0.2752E 00   -171.7     -.2484E 00   -.5104E 00   0.5676E 00   -116.0
 80.0   45.0   0.1365E 00   0.6591E 00     -.2571E 00   0.1987E-01   0.2579E 00    175.6     -.2654E 00   -.5008E 00   0.5668E 00   -117.9
 65.0   50.0   0.2482E 00   0.5408E 00     -.3028E 00   -.1710E 00   0.3478E 00   -150.6     -.1939E 00   -.4754E 00   0.5134E 00   -112.2
 70.0   50.0   0.2101E 00   0.5378E 00     -.3017E 00   -.1066E 00   0.3200E 00   -160.5     -.2088E 00   -.4674E 00   0.5119E 00   -114.1
 75.0   50.0   0.1799E 00   0.5352E 00     -.2931E 00   -.4191E-01   0.2961E 00   -171.9     -.2238E 00   -.4591E 00   0.5107E 00   -116.0
 80.0   50.0   0.1581E 00   0.5331E 00     -.2767E 00   0.2190E-01   0.2776E 00    175.5     -.2388E 00   -.4503E 00   0.5097E 00   -117.9
```

```
CONTINUE EXECUTION WITH THE FOLLOWING ADDITIONS AND/OR CHANGES



 DATA CARDS

   7  OUTP(BIST=45,45,45,45/BACK=0,0,10,12)
   8  OUTP(CURR)
   9  CHANGE
                                        *****************************
                                        *                           *
                                        *        INPUT DATA         *
                                        *                           *
                                        *****************************



                                   ANTENNA FEEDS
                             NODE            VOLTS
                              NO.          REAL        IMAGINARY
                               3      0.10000E 01       0.0

                                        *****************************
                                        *                           *
                                        *     OUTPUT REQUESTED      *
                                        *                           *
                                        *****************************
                    STRUCTURE CURRENTS
                    BACKSCATTERING FOR PHI VARYING FROM    0.0 TO    0.0 AND THETA VARYING FROM  10.0 TO  12.0
                                       IN STEPS OF    1.0 DEGREES.
                    BISTATIC SCATTERING FOR PHI VARYING FROM  45.0 TO  45.0 AND THETA VARYING FROM  45.0 TO  45.0
                                       IN STEPS OF    1.0 DEGREES.
```

```
                                   ****************************
                                   *                          *
                                   *          ANTENNA         *
                                   *       CALCULATIONS       *
                                   *                          *
                                   ****************************

       THE INPUT IMPEDANCE AT NODE   3 IS     46.2782898 + J     26.5534973

                                   ANTENNA BRANCH CURRENTS
                                        NORMALIZED                                                          NORMALIZED
SEG NODE   REAL       IMAGINARY   MAGNITUDE    MAGNITUDE   PHASE NODE    REAL      IMAGINARY    MAGNITUDE   MAGNITUDE   PHASE
 1   1  0.0          0.0         0.0         0.0            0.0   2  0.12023E-01 -.79175E-02 0.14396E-01 0.76810E 00 -33.4
 2   2  0.12023E-01 -.79175E-02 0.14396E-01 0.76810E 00   -33.4   3  0.16256E-01 -.93276E-02 0.18742E-01 0.10000E 01 -29.8
 3   3  0.16256E-01 -.93276E-02 0.18742E-01 0.10000E 01   -29.8   4  0.12023E-01 -.79175E-02 0.14396E-01 0.76810E 00 -33.4
 4   4  0.12023E-01 -.79175E-02 0.14396E-01 0.76810E 00   -33.4   5  0.0          0.0         0.0         0.0            0.0

       THE RADIATION EFFICIENCY IS      99.5343018

       THE TIME-AVERAGE POWER INPUT IS       0.0162564

       THE ANTENNA IMPEDANCE IS      46.2782898 +J     26.5534973
```

```
                              ******************************
                              *                            *
                              *       BACKSCATTERING       *
                              *        CALCULATIONS        *
                              *                            *
                              ******************************


        BRANCH CURRENTS ASSOCIATED WITH PLANE-WAVE SCATTERING FOR THE INCIDENT ANGLES, PHI=  0.0 AND THETA= 10.0

                                          CURRENTS INDUCED BY THE PHI POLARIZED WAVE

                                                 NORMALIZED                                                            NORMALIZED
SEG NODE     REAL        IMAGINARY    MAGNITUDE   MAGNITUDE     PHASE NODE     REAL        IMAGINARY    MAGNITUDE   MAGNITUDE     PHASE
  1   1  0.0          0.0          0.0          0.0             0.0   2  0.31772E-02 -.49074E-03 0.32149E-02 0.73326E 00   -8.8
  2   2  0.31772E-02 -.49074E-03 0.32149E-02 0.73326E 00      -8.8   3  0.43371E-02 -.64178E-03 0.43844E-02 0.10000E 01   -8.4
  3   3  0.43371E-02 -.64178E-03 0.43844E-02 0.10000E 01      -8.4   4  0.31772E-02 -.49073E-03 0.32149E-02 0.73326E 00   -8.8
  4   4  0.31772E-02 -.49073E-03 0.32149E-02 0.73326E 00      -8.8   5  0.0          0.0          0.0          0.0            0.0

                                          CURRENTS INDUCED BY THE THETA POLARIZED WAVE

                                                 NORMALIZED                                                            NORMALIZED
SEG NODE     REAL        IMAGINARY    MAGNITUDE   MAGNITUDE     PHASE NODE     REAL        IMAGINARY    MAGNITUDE   MAGNITUDE     PHASE
  1   1  0.0          0.0          0.0          0.0             0.0   2  -.16843E-04 0.28762E-04 0.33331E-04 0.99999E 00  120.4
  2   2  -.16843E-04 0.28762E-04 0.33331E-04 0.99999E 00     120.4   3  0.44948E-09 -.95513E-11 0.44958E-09 0.13488E-04   -1.2
  3   3  0.44948E-09 -.95513E-11 0.44958E-09 0.13488E-04      -1.2   4  0.16844E-04 -.28762E-04 0.33332E-04 0.10000E 01  -59.6
  4   4  0.16844E-04 -.28762E-04 0.33332E-04 0.10000E 01     -59.6   5  0.0          0.0          0.0          0.0            0.0

        BRANCH CURRENTS ASSOCIATED WITH PLANE-WAVE SCATTERING FOR THE INCIDENT ANGLES, PHI=  0.0 AND THETA= 11.0

                                          CURRENTS INDUCED BY THE PHI POLARIZED WAVE

                                                 NORMALIZED                                                            NORMALIZED
SEG NODE     REAL        IMAGINARY    MAGNITUDE   MAGNITUDE     PHASE NODE     REAL        IMAGINARY    MAGNITUDE   MAGNITUDE     PHASE
  1   1  0.0          0.0          0.0          0.0             0.0   2  0.31773E-02 -.49499E-03 0.32156E-02 0.73328E 00   -8.9
  2   2  0.31773E-02 -.49499E-03 0.32156E-02 0.73328E 00      -8.9   3  0.43372E-02 -.64765E-03 0.43853E-02 0.10000E 01   -8.5
  3   3  0.43372E-02 -.64765E-03 0.43853E-02 0.10000E 01      -8.5   4  0.31773E-02 -.49499E-03 0.32156E-02 0.73328E 00   -8.9
  4   4  0.31773E-02 -.49499E-03 0.32156E-02 0.73328E 00      -8.9   5  0.0          0.0          0.0          0.0            0.0

                                          CURRENTS INDUCED BY THE THETA POLARIZED WAVE

                                                 NORMALIZED                                                            NORMALIZED
SEG NODE     REAL        IMAGINARY    MAGNITUDE   MAGNITUDE     PHASE NODE     REAL        IMAGINARY    MAGNITUDE   MAGNITUDE     PHASE
  1   1  0.0          0.0          0.0          0.0             0.0   2  -.18454E-04 0.31643E-04 0.36631E-04 0.99998E 00  120.2
  2   2  -.18454E-04 0.31643E-04 0.36631E-04 0.99998E 00     120.2   3  0.53724E-09 -.15861E-09 0.56016E-09 0.15292E-04  -16.4
  3   3  0.53724E-09 -.15861E-09 0.56016E-09 0.15292E-04     -16.4   4  0.18455E-04 -.31644E-04 0.36632E-04 0.10000E 01  -59.7
  4   4  0.18455E-04 -.31644E-04 0.36632E-04 0.10000E 01     -59.7   5  0.0          0.0          0.0          0.0            0.0
```

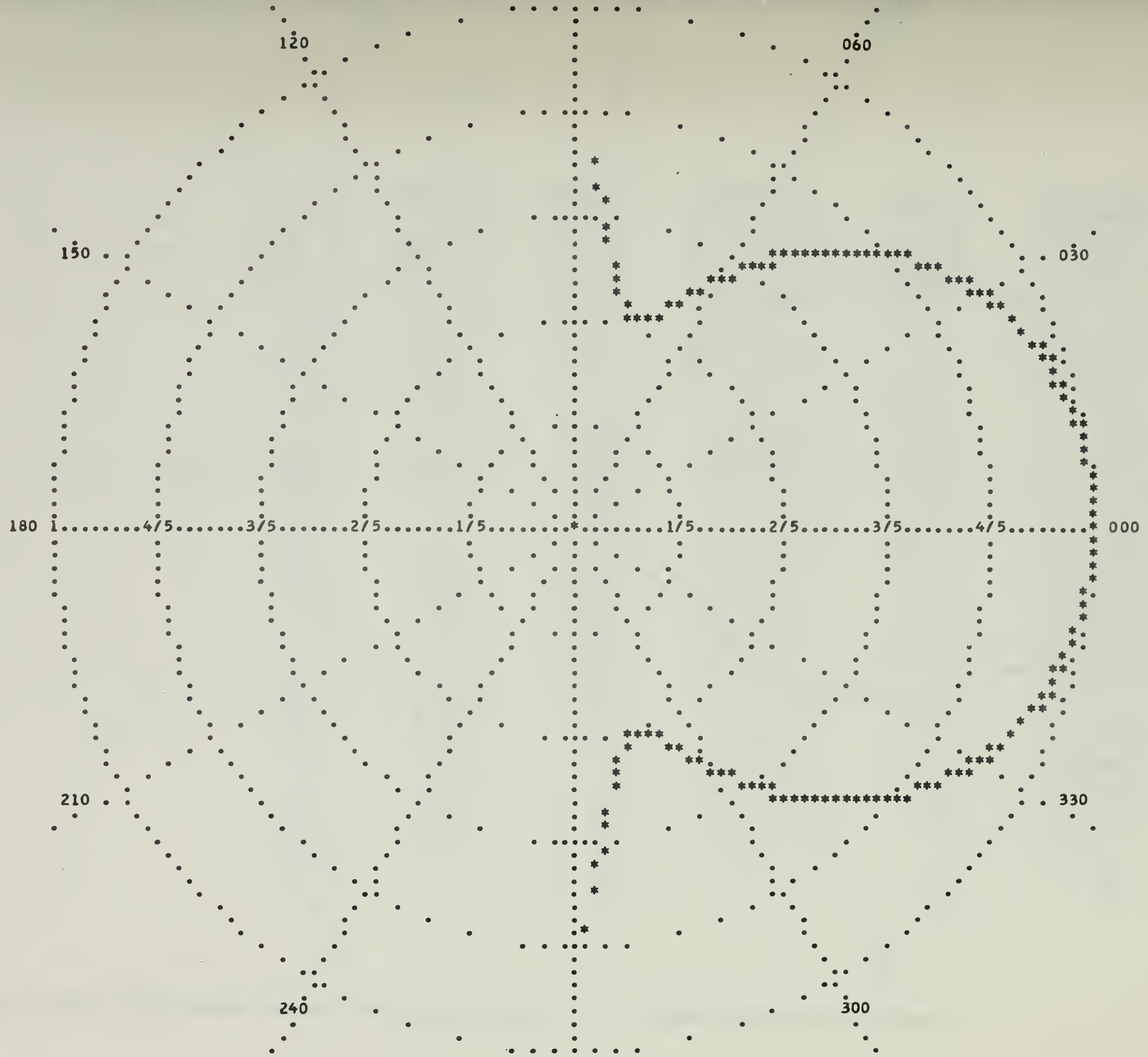
```
     BRANCH CURRENTS ASSOCIATED WITH PLANE-WAVE SCATTERING FOR THE INCIDENT ANGLES, PHI=  0.0 AND THETA= 12.0

                                              CURRENTS INDUCED BY THE PHI POLARIZED WAVE

                                                NORMALIZED                                                                NORMALIZED
SEG NODE      REAL        IMAGINARY   MAGNITUDE   MAGNITUDE      PHASE NODE     REAL        IMAGINARY   MAGNITUDE    MAGNITUDE      PHASE
  1   1  0.0          0.0          0.0          0.0               0.0   2  0.31775E-02 -.49965E-03 0.32165E-02 0.73330E 00    -8.9
  2   2  0.31775E-02 -.49965E-03 0.32165E-02 0.73330E 00        -8.9   3  0.43373E-02 -.65407E-03 0.43863E-02 0.10000E 01    -8.6
  3   3  0.43373E-02 -.65407E-03 0.43863E-02 0.10000E 01        -8.6   4  0.31775E-02 -.49964E-03 0.32165E-02 0.73330E 00    -8.9
  4   4  0.31775E-02 -.49964E-03 0.32165E-02 0.73330E 00        -8.9   5  0.0          0.0          0.0          0.0             0.0

                                              CURRENTS INDUCED BY THE THETA POLARIZED WAVE

                                                NORMALIZED                                                                NORMALIZED
SEG NODE      REAL        IMAGINARY   MAGNITUDE   MAGNITUDE      PHASE NODE     REAL        IMAGINARY   MAGNITUDE    MAGNITUDE      PHASE
  1   1  0.0          0.0          0.0          0.0               0.0   2  -.20044E-04 0.34526E-04 0.39922E-04 0.99998E 00   120.1
  2   2  -.20044E-04 0.34526E-04 0.39922E-04 0.99998E 00       120.1.  3  0.57514E-09 -.26965E-09 0.63522E-09 0.15911E-04   -25.1
  3   3  0.57514E-09 -.26965E-09 0.63522E-09 0.15911E-04       -25.1   4  0.20045E-04 -.34526E-04 0.39923E-04 0.10000E 01   -59.9
  4   4  0.20045E-04 -.34526E-04 0.39923E-04 0.10000E 01       -59.9   5  0.0          0.0          0.0          0.0             0.0



                                                         BACKSCATTERING
   INCIDENT                                 ELECTRIC FIELD POLARIZATION SCATTERING MATRIX
    PLANE                                                  (INCIDENT-SCATTERED)
     WAVE                   PHI-PHI                         PHI-THETA                    THETA-PHI                       THETA-THETA
   PHI   THETA        REAL          IMAG             REAL          IMAG            REAL          IMAG              REAL          IMAG
    0.0   10.0    0.47452E-01  -.18107E 00    0.18626E-08  -.14901E-07    0.69849E-08  -.19325E-07    0.93990E-04  0.17389E-03
    0.0   11.0    0.47001E-01  -.18128E 00    -.74506E-08  -.14901E-07    0.25611E-08  -.25611E-07    0.11430E-03  0.21566E-03
    0.0   12.0    0.46506E-01  -.18150E 00    -.74506E-08  -.33528E-07    -.13970E-08  -.29337E-07    0.13677E-03  0.25562E-03
```

```
                                                 ******************************
                                                 *                            *
                                                 *    BISTATIC SCATTERING     *
                                                 *        CALCULATIONS        *
                                                 *                            *
                                                 ******************************


                                        FOR BISTATIC SCATTERING THE INCIDENT
                                        PLANE WAVE IS PHI=  0.0 THETA= 12.0



                                                     BISTATIC
                                    ELECTRIC FIELD POLARIZATION SCATTERING MATRIX
0OBSERVATION                                     (INCIDENT-SCATTERED)
  POINT              PHI-PHI                    PHI-THETA                  THETA-PHI                THETA-THETA
 PHI  THETA       REAL        IMAG           REAL        IMAG           REAL        IMAG           REAL        IMAG
 45.0  45.0   0.17345E-01  -.12954E 00    -.14328E-01  -.98727E-01   0.23251E-03  -.15151E-03   0.74103E-03  0.65082E-03
```

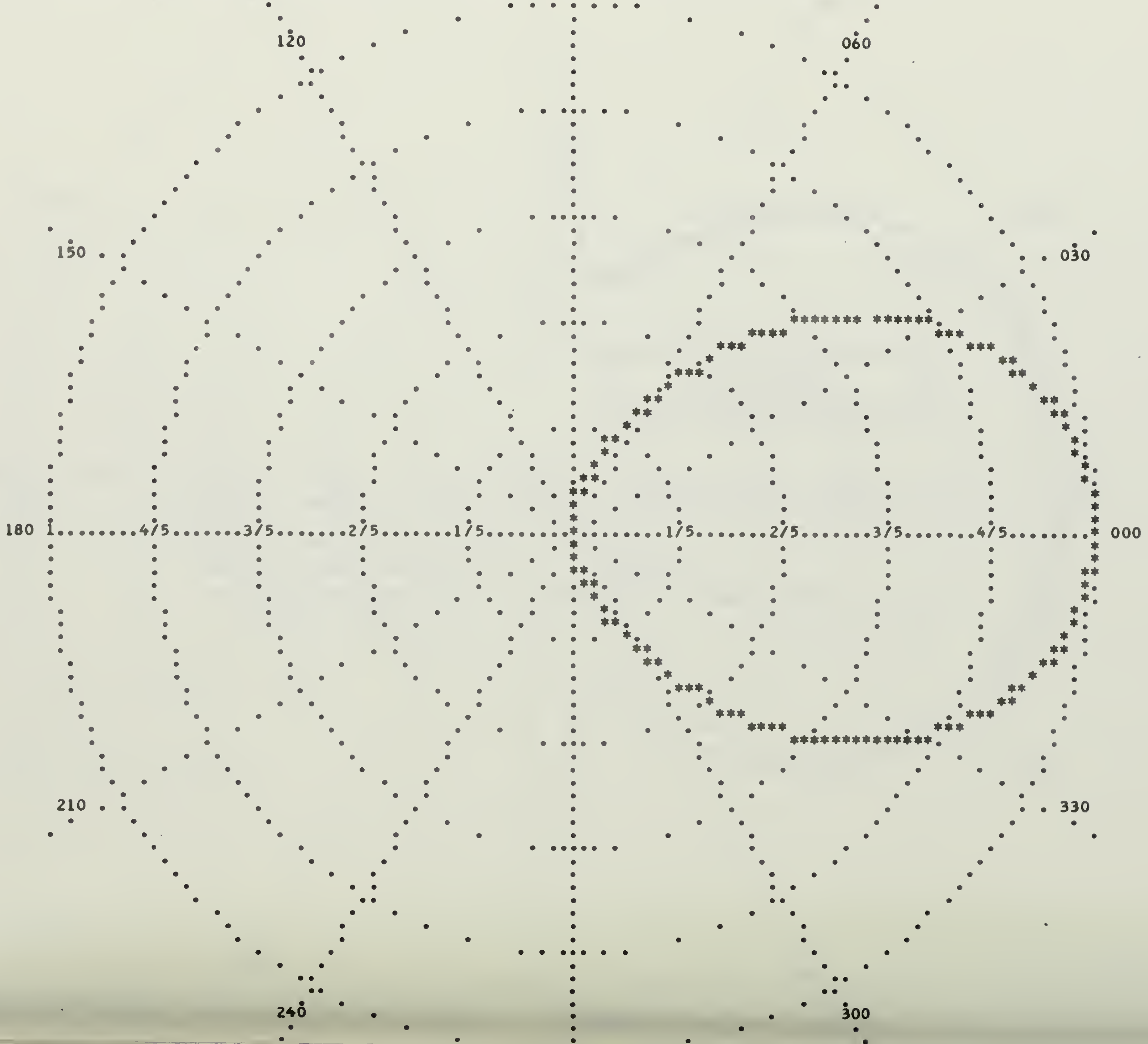
```
 CONTINUE EXECUTION WITH THE FOLLOWING ADDITIONS AND/OR CHANGES



DATA CARDS

 10  GEOM(0,-.25,0/0,-.125,0 /0,0,0/0,.125,0/0,.25,0)
 11  PLOT(FARF/PHI=090)
 12  GROUND(HEIG=.25/GOOD)
 13  STOP

                                            *****************************
                                            *                           *
                                            *         INPUT DATA        *
                                            *                           *
                                            *****************************
                        GROUND PLANE (NO/YES)                                 YES
                        GROUND DIELECTRIC CONSTANT (RELATIVE)             0.30000E 02
                        GROUND CONDUCTIVITY (MHOS/METER)                  0.20000E-01
                        ANTENNA HEIGHT (METERS)                           0.25000E 00


                                            WIRE STRUCTURE

              SEG    NODE                   LOCATION                 NODE                    LOCATION
              NO.    NO.          X            Y             Z        NO.          X            Y            Z
                1      1     0.0            -.25000E 00   0.0          2     0.0            -.12500E 00   0.0
                2      2     0.0            -.12500E 00   0.0          3     0.0            0.0           0.0
                3      3     0.0            0.0           0.0          4     0.0            0.12500E 00   0.0
                4      4     0.0            0.12500E 00   0.0          5     0.0            0.25000E 00   0.0



                                            ANTENNA FEEDS
                                  NODE                VOLTS
                                   NO.            REAL       IMAGINARY
                                    3          0.10000E 01    0.0

                                            *****************************
                                            *                           *
                                            *      OUTPUT REQUESTED     *
                                            *                           *
                                            *****************************
                        PLOT FOR FAR FIELD PHI= 90.0
```

```
                                      *****************************
                                      *                           *
                                      *           ANTENNA         *
                                      *        CALCULATIONS       *
                                      *                           *
                                      *****************************

THE INPUT IMPEDANCE AT NODE   3 IS     97.1284332 + J     68.7537079

THE RADIATION EFFICIENCY IS     99.7729645
THE TIME-AVERAGE POWER INPUT IS      0.0137177
THE ANTENNA IMPEDANCE IS     97.1284332 +J     68.7537079
```

PHI ELECTRIC FIELD ANTENNA PATTERN FOR SPECIFIED PLANE. NORMALIZING FACTOR= .28833E-06



THET ELECTRIC FIELD ANTENNA PATTERN FOR SPECIFIED PLANE.   NORMALIZING FACTOR= .91830E 00



LIST OF REFERENCES

1. Richmond, J.H., "Radiation and Scattering by Thin-Wire Structures in the Complex Frequency Domain," Report 2902-10, July, 1973, The Ohio State Unversity ElectroScience Labortory, Department of Electrical Engineering; prepared under Grant NGL 36-008-138 for National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia 23365.

2. (a) Richmond, J.H., "Computer Program for Thin-Wire Structures in a Homogeneous Conducting Medium," NASA Contractor Report CR-2399, June 1974, for sale by the National Technical Information Service, Springfield, Virginia, 22151, Price $3.75.

   (b) Richmond, J.H., "Computer Program for Thin-Wire Structures in a Homogeneous Conducting Medium," Report 2902-12, August 1973, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering prepared under Grant NGL 36-008-138 for National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia 23665.

3. Richmond, J.H. and Geary, N.H., "Mutal Impedance of Nonplanar-Skew Sinusoidal Dipoles," Report 2902-18, August 1974, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering.

4. Miller, E.K., Poggio,A.J., Burle, G.J., and Selden, E.S., "Analysis of Wire Antennas in the Presence of a Conducting Half Space: Part I. The Vertical Antenna in Free Space," Canadian Journal of Physics, 50, pp 879-888.

5. Miller, E.K., Poggio,A.J., Burle, G.J., and Selden, E.S., "Analysis of Wire Antennas in the Presence of a Conducting Half Space: Part II. The Horizontal Antenna in Free Space, Canadian Journal of Physics, 50 pp 2614-2627.

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