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'ASAP' ANTENNAS-SCATTERERS ANALYSIS PROGRAM: A USER-ORIENTED TH--ETC(U)

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"ASAP"

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

Richard W. Adler

August 1977

REVISED VERSION

Approved for public release; distribution  
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Prepared for: Naval Ocean Systems Center  
San Diego, CA 92152



NAVAL POSTGRADUATE SCHOOL  
Monterey, CA

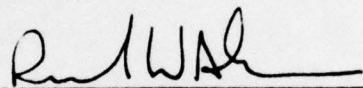
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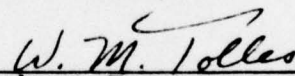


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### SUMMARY

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.

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## 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 Bevenssee of Lawrence Livermore Labs, University of California enabled the preparation of this revised version. During the past 2 years, no additional discrepancies 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	0.0	5
0.001	1.00	1.0	-1.0	0.0	
1.300.	1.0	90.	1.0	90.	4
1	0.		0.		45.
2	0.				
3	0.				
4	0.				
5	0.				
0.	-0.250				
0.	-0.125				
0.	0.				
0.	0.125				
0.	0.250				
1.	1.				

AN EXAMPLE OF THE INPUT DATA FOR THE ORIGINAL PROGRAM

TABLE 1

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

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	85.4+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	39.44+J 84.99	40.5+J 88.71
.001	.5	88.09+J 31.80	91.61+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 42.06	117.9+J 66.07
	.1	70.07+J 63.07	77.67+J 60.81

\* COURTESY OF LAWRENCE LIVERMORE LABORATORY

TABLE 3





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## 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.

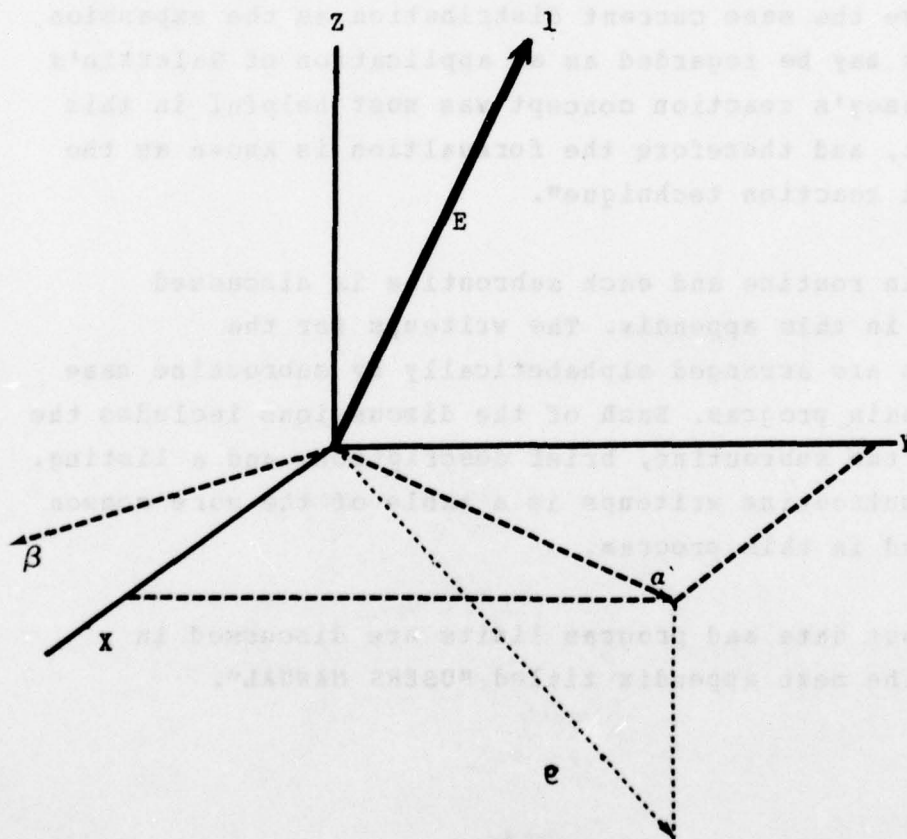
A piecewise-sinusoidal expansion is used for the current distribution. The matrix equation  $ZI = V$  is generated by enforcing reaction tests with a set of sinusoidal dipoles located in the interior region of the wire. Since the test dipoles have the same current distribution as the expansion modes, this may be regarded as an application of Galerkin's method. Rumsey's reaction concept was most helpful in this development, and therefore the formulation 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,  $e$ , 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  $(\alpha, \beta, z)$  where  $\alpha$  and  $\beta$  are parallel to the  $xy$  plane with  $\alpha$  in the plane of incident and  $\beta$  perpendicular.

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

$$\begin{bmatrix} E_{||} \\ E_{\perp} \end{bmatrix} = \begin{bmatrix} \cos \phi & \sin \phi \\ \sin \phi & -\cos \phi \end{bmatrix} \begin{bmatrix} E_x \\ E_y \end{bmatrix}$$

where  $\phi = \arctan(\cos y / \cos x)$ .

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

$$E_{||}(R) = R_{||} E_{||}$$

$$E_{\perp}(R) = R_{\perp} E_{\perp}$$

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

Applying the matrix equation above yields:



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

(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,

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

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

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

and for parallel

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

where  $\theta$  is the angle of incident as measured from the normal to the interface and

$$\epsilon' = (\epsilon_2 + \sigma_2/j\omega) / (\epsilon_1 + \sigma_1/j\omega)$$

where the subscripts correspond to the mediums above.



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

$$\lim_{H} R_{||} = -1$$

$$\lim_{V} R_{\perp} = +1$$

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

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

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

$$E_y^{(R)} = R_{||} E \cos \gamma - (R_{||} - R_{\perp}) E \cos \gamma \cos^2 \phi + (R_{||} - R_{\perp}) E \cos \alpha \sin \phi \cos \phi$$

$$E_z^{(R)} = -R_{||} E \cos \alpha$$

where E is the field without the ground plane present and

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

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

$$\epsilon' = \epsilon_r - j(\sigma/\epsilon_0 \omega)$$

## 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



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DIMENSION X(60), Y(60), Z(60), XG(60), YG(60), ZG(60) 0001
DIMENSION I1(60), I2(60), I3(60), JA(60), JB(60), KFLAG(30) 0002
DIMENSION CPHI(500), CTHT(500) 0003
DIMENSION DATY1(360), DATY2(360), DATY3(360), DATY4(360) 0004
DIMENSION D(50), IA(50), IB(50), ISC(50), MD(50.4), MD(50) 0005
DIMENSION LZD(60), KGEN(60) 0006
COMMON /WL 0007
DIMENSION XNP(50), YNP(50), ZNP(50) 0008
COMPLEX C(1830) 0009
COMPLEX CDAT1(500), CDAT2(500), CDAT3(500), CDAT4(500) 0010
COMPLEX CJ(60), EP(60), EPP(60), ET(60), ETT(60) 0011
COMPLEX CGD(50), SGD(60), CG(100), VG(100), ZLD(100) 0012
COMPLEX VOLT(60), ZLLD(60) 0013
COMPLEX EPP5(60), EPP6(60), ETT5, ETT6, EX, EY, EZ 0014
COMPLEX EP2, EP3, EP4, ERR, ETA, GAM, VII, ZII, ZS 0015
DATA PI, TP/3.14159, 6.28318/ 0016
DATA EQ,UO/8.854E-12,1.2566E-6/ 0017
1 NGEN = -1 0018
  JLOAD = -1 0019
  LOAD = -1 0020
  BM = -1 0021
  ICARD = 0 0022
  AM = -1 0023
  IFLAG = 0 0024
  VOLT(1) = (1.,0.) 0025
  HGT = 0. 0026
  NM = 0 0027
  NP = 0 0028
  MSG = 0 0029
  SIG2 = -1. 0030
  TD2 = -1. 0031
  SIG3 = -1 0032
  ER3 = 1 0033
  TD3 = 0. 0034
  CMM = 50. 0035
  ER2 = 100. 0036
  FMC = 300. 0037
  INM = 50 0038
  ICJ = 60 0039
  WRITE (6,74) 0040
C 0041
DO 2 I=1,30 0042
2 KFLAG(I) = -1 0043
C 0044
DO 3 J=1,INM 0045
  ISC(J) = 0 0046
  VG(J) = (.0.,0) 0047
C 0048
ZLD(J) = (.0.,0) 0049
JJ = J+INM 0050
VG(JJJ) = (.0.,0) 0051
3 ZLD(JJJ) = (.0.,0) 0052
C 0053
4 NFFP = 0 0054
  NBIP = 0 0055
  NBAP = 0 0056
  AAFP = 1000. 0057
  AFFT = 1000. 0058
  ABIP = 1000. 0059
  ABIT = 1000. 0060
  ABAP = 1000. 0061
  ABAT = 1000. 0062
  STEP = 1. 0063
  KNM = 0 0064
  CALL READ (IA,IB,IBISC,ICARD,IGA,IN,IGRD,INEAR,INT,ISCAT,INR,IFLAG, 0065
1 KFLAG,KGEN,LOAD,LZD,MSG,NBAP,NBIP,NFFP,NGEN,NM,NP,ABAP,ABAT,AAFP,A 0066
2 FFT,ABIP,ABIT,AM,BM,CMM,ER2,ER3,ER4,FMC,HGT,PHAF,PHAI,PHIE,PHII,PH 0067
3 SF,PHSI,THAF,THAI,THIF,THII,THSF,THSI,SIG2,SIG3,SIG4,TD2,TD3,VOLT, 0068
4 X,XNP,Y,YNP,Z,ZLLD,ZNP,STEP) 0069
  WRITE (6,56) 0070
  IF (MSG.EQ.1) GO TO 5 0071
  IF (MSG.EQ.1) WRITE (6,70) KFLAG(30) 0072
  IF (IFLAG.EQ.4) GO TO 1 0073
  IF (IFLAG.EQ.5) STOP 0074
  IF (AM.LT.0) WRITE (6,127) 0075
  IF (AM.LT.0) GO TO 6 0076
  IF ((NM.GT.0).AND.(NP.GT.0)) GO TO 7 0077
  WRITE (6,116) 0078
  IF (IFLAG.EQ.1) GO TO 1 0079
  MSG = 2 0080
  GO TO 4 0081
7 WRITE (6,114) 0082
  WRITE (6,113) 0083
  WRITE (6,112) 0084
  IF (KFLAG(1).EQ.1) WRITE (6,83) FNC 0085
  IF (KFLAG(2).EQ.1) WRITE (6,84) AM 0086
  IF (KFLAG(3).EQ.1) WRITE (6,85) CNM 0087
  IF (KFLAG(20).NE.1) WRITE (6,87) 0088
  IF (KFLAG(4).EQ.1) WRITE (6,88) BM 0089
  IF (KFLAG(5).EQ.1) WRITE (6,89) SIG2 0090
  IF (KFLAG(6).EQ.1) WRITE (6,90) ER2 0091
  IF (KFLAG(7).EQ.1) WRITE (6,91) TD2 0092
  IF (KFLAG(8).NE.1) WRITE (6,92) 0093
  IF (KFLAG(9).EQ.1) WRITE (6,93) SIG3 0094
  IF (KFLAG(10).EQ.1) WRITE (6,94) ER3 0095
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IF (KFLAG(11).EQ.1) WRITE (6,95) TD3 0097
IF (KFLAG(26).NE.1) WRITE (6,122) 0098
IF ((IGRD.GT.1).AND.(KFLAG(25).EQ.1)) WRITE (6,123) 0099
IF ((IGRD.EQ.1).AND.(KFLAG(25).EQ.1)) WRITE (6,124) 0100
IF ((IGRD.GT.1).AND.(KFLAG(25).EQ.1)) WRITE (6,124) ER4,SIG4 0101
IF ((IGRD.GT.0).AND.(KFLAG(25).EQ.1)) WRITE (6,126) HGT 0102
IF (KFLAG(21).EQ.1) WRITE (6,121) INT 0103
WRITE (6,111) 0104
IF (KFLAG(12).EQ.1) WRITE (6,96) ((,IA(I),X(IA(I)),Y(IA(I)),Z(IA(I) 0105
),,JB(I),X(JB(I)),Y(JB(I)),Z(JB(I))),I=1,NM) 0106
WRITE (6,111) 0107
IF (KFLAG(24).GT.0) WRITE (6,119) (LZD(I),ZLLD(I),I=1,LOAD) 0108
IF (KFLAG(14).GT.0) WRITE (6,118) (LZD(I),ZLLD(I),I=1,LOAD) 0109
WRITE (6,111) 0110
IF (KFLAG(23).GT.0) WRITE (6,120) (KGEN(I),VOLT(I),I=1,NGEN) 0111
IF (KFLAG(13).GT.0) WRITE (6,97) (KGEN(I),VOLT(I),I=1,NGEN) 0112
WRITE (6,111) 0113
WRITE (6,114) 0114
WRITE (6,98) 0115
WRITE (6,112) 0116
IF (KFLAG(22).NE.1) WRITE (6,110) 0117
IF (KFLAG(15).EQ.1) WRITE (6,99) 0118
IF (KFLAG(16).EQ.1) WRITE (6,100) PHA,PHAF,THA,THAF,STEP 0119
IF (KFLAG(17).EQ.1) WRITE (6,101) PHI,PHIF,THI,THIF,STEP 0120
IF (KFLAG(18).EQ.1) WRITE (6,102) PHS,PHSF,THS,THSF,STEP 0121
IF (KFLAG(19).EQ.1) WRITE (6,103) (XNP(I),YNP(I),ZNP(I),I=1,INEAR) 0122
IF (AFFP.LT.500.) WRITE (6,105) AFFP 0123
IF (AFFT.LT.500.) WRITE (6,104) AFFT 0124
IF (ABAP.LT.500.) WRITE (6,109) ABAP 0125
IF (ABAT.LT.500.) WRITE (6,108) ABAT 0126
IF (ABIP.LT.500.) WRITE (6,107) ABIP 0127
IF (ABIT.LT.500.) WRITE (6,106) ABIT 0128
IF ((IBISC.GT.0).AND.(ISCAT.LT.0)) WRITE (6,73) 0129
IF (KFLAG(4).LT.1) GO TO 129 0130
DO 128 I=1,NM 0131
128 ISC(I)=1 0132
129 FHZ = FMC*1.E6 0133
OMEGA = TP*FHZ 0134
IF (SIG2.LT.0.) EP2=ER2*EO*CMPLX(1.,-TD2) 0135
IF (TD2.LT.0.) EP2 = CMPLX(ER2*EO,-SIG2/OMEGA) 0136
IF (SIG3.LT.0.) EP3=ER3*EO*CMPLX(1.,-TD3) 0137
IF (TD3.LT.0.) EP3 = CMPLX(ER3*EO,-SIG3/OMEGA) 0138
IF (IGRD.GT.1) EP4 = CMPLX(ER4*EO,-SIG4/OMEGA) 0139
IF (IGRD.GT.1) ERR = EP4/EP3 0140
IF (KFLAG(21).GT.0) WRITE (6,121) INT 0141
ETA = CSQRT(UO*EP3) 0142
GAM = OMEGA*CSQRT(-UO*EP3) 0143
IF (KFLAG(12).NE.1) GO TO 9 0144

NPG = NP 0145
NMG = NM 0146
C DO 8 I=1,NPG 0147
XG(I) = X(I) 0148
YG(I) = Y(I) 0149
B ZG(I) = Z(I) 0150
C C 0151
C 9 DO 10 I=1,NPG 0152
X(I) = XG(I) 0153
Y(I) = YG(I) 0154
10 Z(I) = ZG(I) 0155
C NP = NPG 0156
NM = NMG 0157
IWL = 0 0158
IF (IGRD.LE.0) GO TO 15 0159
SET UP IMAGE FOR GROUND PLANE 0160
ZMIN = Z(1) 0161
K = 0 0162
C IF (Z(I).LT.ZMIN) ZMIN=Z(I) 0163
DO 11 I=1,NP 0164
Z(I) = Z(I)+HGT 0165
IF (Z(I).GT.1.E-60) GO TO 11 0166
IWL = IWL+1 0167
11 CONTINUE 0168
IF (ZMIN.GE.0.0)GOTO12 0169
WRITE (6,117) 0170
IF (IFLAG.EQ.1) GO TO 1 0171
IF (IFLAG.EQ.2) STOP 0172
MSG = 2 0173
GO TO 4 0174
C 12 DO 13 J=1,NM 0175
K = J+NM 0176
IA(K) = IA(J) 0177
IF (IA(J).GT.IWL) IA(K)=IA(J)+NP-IWL 0178
13 IB(K) = IB(J)+NP-IWL 0179
C IMLP = IWL+1 0180
C DO 14 I=1,IMLP,NP 0181
J = I+NP-IWL 0182
X(J) = X(I) 0183
Y(J) = Y(I) 0184
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C      DO 31 I=1,360
      DATY1(I) = 0
      DATY2(I) = 0
      DATY3(I) = 0
      DATY4(I) = 0
31
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 (NFRP.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
      DO 35 K=1,NPHA
      PH = PH+STEP
      TH = THAI-STEP
      DO 35 I=1,NTHA
      PHSPH = 0.
      PHSTH = 0.
      TH = TH+STEP
      IF ((IGRD.GT.0).AND.((TH.GT.90).AND.(TH.LT.270))) GO TO 35
      CALL GFFLD (IA,IB,INC,INM,IWR,1,12,13,12,MD,N,MD,NM,AM,ACSP,ACST
      I,C,CGD,CG,CJ,CMM,O,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ETTS,GG,
      ZGPP,GTT,PH,SGD,SCSP,SCST,SPPH,SPTM,STPH,STTM,TH,X,Y,Z,ZLD,ZS,ETA,G
      3AM,ERR,IGRD)
      ETMAG = CAB2(ETTS)
      EPAG = CAB3(EPTS)
      IF(ETMAG.GT.1.E-32) PHSTH=57.295779*ATAN2(AIMAG(ETTS),REAL(ETTS))
      IF(EPAG.GT.1.E-32) PHSPH=57.295779*ATAN2(AIMAG(EPTS),REAL(EPTS))
      IF (NPL.EQ.1) DATY1(K)=ETMAG
      IF (NPL.EQ.2) DATY2(K)=EPAG
      IF (NPL.EQ.2) DATY1(I)=ETMAG
      IF (NPL.EQ.2) DATY2(I)=EPAG
      IF (KFLAG(16).NE.1) GO TO 35
      WRITE (6,60) TH,PH,GTT,GPP,ETTS,ETMAG,PHSTH,EPPS,EPNAG,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 (NBAP.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 (ABAT.GT.500.) GO TO 38
      NPL = 1
      NPHI = 360
      NTHI = 1
      PHII = 0.
      THII = ABAT
      STEP = 1.
      GO TO 39
38 NPL = 2
      NPHI = 1
      NTHI = 360
      PHII = ABAP
      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

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TH = TH+STEP
IF ((IGRD.GT.0).AND.((TH.GT.90).AND.(TH.LT.270))) GO TO 42
L = L+1
CALL GFFLD (1A,1B,INC,INM,IWR,11,12,13,112,MD,N,ND,NM,AM,ACSP,ACST
1,C,CGO,CG,CJ,CMN,D,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ETTS,GG,
2,GPP,GTI,PH,SGD,SCSP,SCST,SPPH,SPTM,STPH,STTM,TH,X,Y,Z,ZLD,ZS,ETA,G
3AM,ERR,IGRD)
IF (IWR.GT.0) GO TO 40
IF (INPL.LT.0) WRITE (6,63) PH,TH,SPPH,SPTM,STPH,STTM,ACSP,ACST,ECS
40 CPHI(L) = PH
CTHET(L) = TH
CDAT1(L) = EPPS
CDAT2(L) = EPTS
CDAT3(L) = ETPS
CDAT4(L) = ETTS
IF (INPL.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(K) = CABS(EPPS)
DATY2(K) = CABS(EPTS)
DATY3(K) = CABS(ETPS)
DATY4(K) = CABS(ETTS)
42 CONTINUE
C
WRITE (6,82)
IF (INPL.E.0) GO TO 43
CALL POLPR (7,DATY1)
CALL POLPR (8,DATY2)
CALL POLPR (9,DATY3)
CALL POLPR (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
45 BISTATIC SCATTERING
IF (IBISC.LE.0) GO TO 54
WRITE (6,75)
WRITE (6,91)
WRITE (6,82)
WRITE (6,61) CPHI(L),CTHET(L)
WRITE (6,82)
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L = 0
INC = 2
NPL = 1
IF (NBTP.EQ.1) GO TO 46
NPHS = (PHSF-PHS1)/STEP+1
NTHS = (THSF-THS1)/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
PHS1 = 0.
THS1 = ABIT
STEP = 1.
GO TO 48
47 NPL = 2
NPHS = 1
NTHS = 360
PHS1 = ABIP
THS1 = 0.
STEP = 1.
48 PH = PHS1-STEP
C
DO 51 K=1,NPHS
PH = PH+STEP
TH = THS1-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 (1A,1B,INC,INM,IWR,11,12,13,112,MD,N,ND,NM,AM,ACSP,ACST
1,C,CGO,CG,CJ,CMN,D,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ETTS,GG,
2,GPP,GTI,PH,SGD,SCSP,SCST,SPPH,SPTM,STPH,STTM,TH,X,Y,Z,ZLD,ZS,ETA,G
3AM,ERR,IGRD)
IF (IWR.GT.0) GO TO 49
IF (INPL.LT.0) WRITE (6,63) PH,TH,SPPH,SPTM,STPH,STTM
49 CPHI(L) = PH
CTHET(L) = TH
CDAT1(L) = EPPS
CDAT2(L) = EPTS
CDAT3(L) = ETPS
CDAT4(L) = ETTS
IF (INPL.NE.1) GO TO 50
DATY1(K) = CABS(EPPS)
DATY2(K) = CABS(EPTS)
DATY3(K) = CABS(ETPS)
DATY4(K) = CABS(ETPS)
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50 DATY4(K) = CABS(ETTS)
   IF (NPL.LE.2) GO TO 51
   DATY1(I) = CABS(EPPS)
   DATY2(I) = CABS(EPTS)
   DATY3(I) = CABS(ETPS)
   DATY4(I) = CABS(ETTS)
51 CONTINUE
C
   WRITE (6,82)
   IF (NPL.LE.0) GO TO 52
   CALL POLPRT (3,DATY1)
   CALL POLPRT (4,DATY2)
   CALL POLPRT (5,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),CTHET(I),CDAT1(I),CDAT2(I),CDAT3(I),CDAT4(I)
C
54 IF (IFLAG.EQ.1) GO TO 1
   IF (IFLAG.EQ.2) STOP
C
   KKFLAG=0
   KJFLAG=0
   KMFLAG=0
   KNFLAG=0
   IF (KFLAG(13).GT.0) KKFLAG=1
   IF (KFLAG(23).GT.0) KJFLAG=1
   IF (KFLAG(14).GT.0) KMFLAG=1
   IF (KFLAG(24).GT.0) KNFLAG=1
   DO 55 I=1,30
55 KFLAG(I) = -1
C
   KFLAG(8) = 1
   KFLAG(20) = 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
   ERAGE POWER INPUT IS ',F15.7//10X,'THE ANTENNA IMPEDANCE IS ',F15.
27. ' * J',F15.7//)
58 FORMAT (10X,'THE NEAR-FIELD ELECTRIC FIELD INTENSITY AT THE OBSERV
   ATION POINT ',E11.5,' ',E11.5,' ',E11.5,' (X,Y,Z RESPECTIVELY) IS:
2//)
59 FORMAT (20X,'EX=',F15.7,' * J',F15.7/20X,'EY=',F15.7,' * J',F15.7/20
   X,'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 (T4,'FOR BISTATIC SCATTERING THE INCIDENT'/T41,'PLANE WAVE
   IS PHI=',F5.1,' THETA=',F5.1//)
62 FORMAT (1,' INCIDENT',T27,'ECHO AREA SIGMA',T66,'ABSORPTION',T90,'EX
   LTINGION',T114,'SCATTERING',T1,' PLANE',T25,'(INCIDENT-SCATTERED)',1
   24X,3(5X,'CROSS SECTION',6X) // WAVE ',524,3(10X,'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,'BACKSCATTERING',T1,' INCIDENT',T37,'ELECTRIC FIELD POLAR
   IZATION SCATTERING MATRIX',T1,' PLANE',T49,'(INCIDENT-SCATTERED)',23X
   2,' WAVE',T23,'PHI-PHI',T49,'PHI-THETA',T75,'THETA-PHI',T102,'THETA-
   3THETA',T1,' PHI-THETA',3X,4(3X,'REAL',8X,'IMAG',8X))
65 FORMAT (1X,2(F5.1,1X),2X,E11.5,2X,E11.5,3X)
66 FORMAT (T54,'BISTATIC',T37,'ELECTRIC FIELD POLARIZATION SCATTERING
   1 MATRIX',T1,' OBSERVATION',T50,'(INCIDENT-SCATTERED)',T1,' POINT',14X,
   2,' PHI-PHI',T49,'PHI-THETA',T76,'THETA-PHI',T101,'THETA-THETA',T1,'
   3PHI-THETA',4X,4(3X,'REAL',8X,'IMAG',8X))
67 FORMAT (1,' OBSERVATION',T27,'ECHO AREA SIGMA',T1,' POINT',T25,'(INCI
   IDENT-SCATTERED)',T1,' PHI-THETA',T14,'PHI-PHI',T24,'PHI-THETA',T37,
   2,' THETA-PHI',T48,'THETA-THETA')
68 FORMAT (1H1,5X,'CONTINUE EXECUTION WITH THE FOLLOWING ADDITIONS AN
   D/OR CHANGES//)
69 FORMAT (54X,'ELECTRIC FIELD INTENSITY',5X,'DEGREES',11X,'POWER GAI
   N',28X,'THETA',2X,'PHI',73X,'THETA',3X,'PHI',7X,'THETA',8X,'PHI',1
   2X,2(8X,'REAL',8X,'IMAG',8X,'MAGN',5X,'PHASE'))
70 FORMAT (10X,'*****ERROR IN DATA CARD NUMBER ',I2,' EXECUTION STOP
   1PED*****')
71 FORMAT (40X,' A WIRE SEGMENT MAYNOT BE SHARED BY MORE THAN FO
   1UR ',40X,' DIPOLE MODES-----CHECK DESCRIPTION DATA CA
   2RD ',40X,' EXECUTION STOPPED
   3)
72 FORMAT (40X,' AN ISOLATED WIRE MUST HAVE AT LEAST TWO SEGMENT
   1S ',40X,' AND THREE POINTS-----CHECK DESCRIPTION DATA CA
   2RD ',40X,' EXECUTION STOPPED
   3)
73 FORMAT (30X,'A BACKSCATTERING CALL MUST BE INCLUDED FOR A BISTATIC
   1 CALL',50X,'REQUEST IGNORED',7//)
74 FORMAT (1,' T50,3//',150,' ',186,' //
   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 (I1,'T50,29(**)/T50,**,T78,**)
76 FORMAT (T50,**,I1X,'ANTENNA',T78,**)
77 FORMAT (T50,**,8X,'CALCULATIONS',T78,**/T50,**,T78,**/T50,29(I
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,
E11.5)
95 FORMAT (T30,'EXTERIOR MEDIUM LOSS TANGENT',T81,E11.5)
96 FORMAT (T50,'WIRE STRUCTURE',T20,'SEG',I4X,2('NODE',I9X,'LOCATION',
I18X)/T21,'NO.',I3X,2('NO.',I9X,'X',I13X,'Y',I13X,'Z',I7X)/T21,I2,5X,
I12,I2,5X,E11.5,4X,E11.5,4X,E11.5,4X,E11.5)
97 FORMAT (T50,'ANTENNA FEEDS',T40,'NODE',I6X,'VOLTS',T41,'NO.',I2X,
I1,'REAL',I7X,'IMAGINARY',/T41,I2,6X,2(I4X,E11.5))
98 FORMAT (T50,**,6X,'OUTPUT REQUESTED',T78,**)
99 FORMAT (T30,'STRUCTURE CURRENTS')
100 FORMAT (T30,'FAR FIELDS FOR PHI VARYING FROM',I1X,F5.1,' TO ',F5.1,
I1,' AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
2150,' IN STEPS OF ',F5.1,' DEGREES.')
101 FORMAT (T30,'BACKSCATTERING FOR PHI VARYING FROM ',F5.1,' TO ',F5.
I1,' AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
2150,' IN STEPS OF ',F5.1,' DEGREES.')
102 FORMAT (T30,'BISTATIC SCATTERING FOR PHI VARYING FROM ',F5.1,' TO
I1,' AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
2150,' IN STEPS OF ',F5.1,' DEGREES.')
103 FORMAT (T30,'NEAR FIELDS FOR FOLLOWING POINTS (X,Y,Z)/90(T40,3(EI
I1,5,5X))
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 (I0X,'SINCE THIS DATA BLOCK DOES NOT HAVE A TERMINATION CAR
D A CHANGE CARD IS ASSUMED')
116 FORMAT (//I0X,40I(**)/I0X,'THE DESCRIPTION AND THE GEOMETRY OF THE
1 STRUCTURE',/I0X,'MUST BE STATED IN THE FIRST DATA BLOCK',/I0X,***
2* EXECUTION STOPPED ***)
117 FORMAT (//I0X,'NO PART OF THE WIRE STRUCTURE CAN LIE BELOW THE GRO
UND PLANE',/I0X,****EXECUTION STOPPED****)
118 FORMAT (T50,'STRUCTURE LOADS',T40,'NODE',I6X,'OHMS',/T41,'NO.',I2X
I1,'REAL',I7X,'IMAGINARY',/T41,I2,6X,2(I4X,E11.5))
119 FORMAT (T50,'STRUCTURE LOADS',/T40,'SEGMENT',I6X,'OHMS',/T41,'NO',I2
I1,'REAL',I7X,'IMAGINARY',/T41,I2,6X,2(I4X,E11.5))
120 FORMAT (T50,'ANTENNA FEEDS',/T39,'SEGMENT',I4X,'VOLTS',/T41,'NO.',I2
I1,'REAL',I7X,'IMAGINARY',/T41,I2,6X,2(I4X,E11.5))
121 FORMAT (//T30,'THE NUMBER OF INTERVALS FOR CALCULATING THE ELEMENT
15',/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/
I 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 (//I0X,40I(**)/I0X,'THE WIRE RADIUS MUST BE STATED',/I0X,40I
L**))
END

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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)
C     1 IF (A(I).EQ.BLANK) K=K+1
C     IF (K.EQ.0) RETURN
      A(81-K) = BLANK
      RETURN
      END
```

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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 (ABS(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*(M+1))
JN(NP) = JN(NP)+TERMJ
IF (NP.NE.1) GO TO 2
FACTOR = FACTOR+1.0/FLOAT(M)
TERMN = TERMN+TERMJ*FACTOR
2 ERROR = ABS(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 = (0.0,1.)*Z
EX = CEXP(ARG)
CC = EX+1./EX
CS = (0.0,1.)*(EX-1.)/EX
B01 = (CS*CC)/(CS-CC)
RETURN
5 B01 = (0.0,-1.)
IF (Y.LT.0.) B01 = (0.0,1.)
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

$$z_{mn} = - \frac{(\epsilon_2 - \epsilon) \ln(b/a)}{2\pi j\omega\epsilon\epsilon_2} \int_{m,n} F'_m(l) F'_n(l) dl ,$$

where  $z_{mn}$  is defined in subroutine SGANT,  $\epsilon_2$  is the dielectric constant of the insulation, b is the outer radius of the insulation, a is the inner radius,  $\epsilon$  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
```

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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 = I
2 RETURN
END
0001
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```

EXPJ

PURPOSE: to calculate the exponential integral with complex limits.

METHOD: The exponential integral is defined as:

$$W_{12} = \int_{V1}^{V2} \frac{e^{-v}}{v} dv = E_1(V1) - E_1(V2) + j2n\pi,$$

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  $\text{Im}(V1) > \text{Im}(V2)$

b)  $n = -1$  if  $\text{Im}(V1) < \text{Im}(V2)$ .

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

CALLED BY: GGMM

CALLS TO: NONE



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```
SUBROUTINE EXPJ (V1,V2,W1Z)
  COMPLEX FC,E15,S,T,UC,VC,V1,V2,W1Z,Z
  DIMENSION V(21),W(21),D(16),E(16)
  DATA V/0.,2284657E00,0.11889321E01,0.29927363E01,0.57751436E01,0.9
  18374674E01,0.15782874E02,0.93307812E-01,0.49269174E00,0.12155954E0
  21,0.22699495E01,0.36676227E01,0.54253366E01,0.75659162E01,0.101202
  328E02,0.13130292E02,0.16654408E02,0.20776479E02,0.25623894E02,0.31
  4407519E02,0.38530683E02,0.48026086E02/
  DATA W/0.45896460E00,0.41700083E00,0.11337338E00,0.10399197E-01,0.
  12610172E-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
  3.2106954E02,0.22046490E01,0.8972824E01/
  DATA E/0.21103107E02,0.31959787E03,-0.97489220E02,0.12900672E03,0
  1.17949226E02,-0.12910931E03,-0.55705574E03,0.13524801E02,0.1469612
  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
  XI = W(I)*X
  CF = W(I)*(X*XI+YS)
  5 S = S+CMPLX(XI)*CF,-YA*CF)
C
  GO TO 9
  6 T3 = X*X-Y*Y
  T4 = 2.*X*Y
  T5 = X*T3-Y*T4
  T6 = X*T4+Y*T3
  T7 = X*T5-Y*T6
  T8 = X*T6+Y*T5
  T9 = X*T7+Y*T6
  T10 = X*T8+Y*T7
  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*Y
  T5 = X*T3-Y*T4
  T6 = X*T4+Y*T3
  T7 = X*T5-Y*T6
  T8 = X*T6+Y*T5
  T9 = X*T7+Y*T6
  T10 = X*T8+Y*T7
  UC = CMPLX(D(11)*D(12)*X+D(13)*T3+D(14)*T5+D(15)*T7+T9-(E(2)*YA+E(3)*T4
  1+E(4)*T6+E(5)*T8),E(11)*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(16)*D(17)*X+D(18)*T3+D(19)*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
  EX = EXPL(X)
  9 EX = EXPL(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+.02666)+.147126/(Z+.256788)+
  1.206335E-1/(Z+.490035)+.107401E-2/(Z+.8.18215)+.158654E-4/(Z+.12.734
  22)+.317031E-7/(Z+.19.3957)
  E15 = E15*EXPL(-Z)
  11 IF (JIM.EQ.1) W1Z = 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
  W1Z = W1Z-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

$$V_m = v_i F(l_i)$$

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,IMR,I1,I2,I3,I12,JA,JB,MD,N,NO,NM,AM,C      0001
1,CJ,CG,CMN,D,EFF,GAM,GG,CGD,SGD,VG,Y11,Z11,ZLD,ZS,IGRD)          0002
COMPLEX YY,CGEN                                                    0003
COMPLEX C(1),CJ(1),CGD(1),SGD(1),VG(1),ZLD(1),Y11,Z11,ZS,GAM,CG(1)  0004
DIMENSION D(1),IA(1),IB(1),JA(1),JB(1)                          0005
DIMENSION I1(1),I2(1),I3(1),MD(INM,4),ND(1)                     0006
COMMON IWL                                                         0007
C                                                                    0008
DO 3 I=1,N                                                         0009
CJ(I) = (.0,.0)                                                   0010
K = JA(I)                                                         0011
C                                                                    0012
DO 2 KK=1,2                                                         0013
KA = IA(K)                                                         0014
KB = IB(K)                                                         0015
JJ = K                                                             0016
ZI = 1.0                                                           0017
IF (KB.EQ.I2(1)) GO TO 1                                          0018
IF (KB.EQ.I1(1)) FI=-1.0                                          0019
CJ(I) = CJ(I)+FI*VG(JJ)                                          0020
GO TO 2                                                            0021
1 IF (KA.EQ.I3(1)) FI=-1.0                                        0022
JJ = K+NM                                                          0023
CJ(I) = CJ(I)+FI*VG(JJ)                                          0024
2 K = JB(I)                                                         0025
C                                                                    0026
3 CONTINUE                                                         0027
C                                                                    0028
C                                                                    0029
C                                                                    0030
C                                                                    0031
C                                                                    0032
C                                                                    0033
DO 4 I=1,N                                                         0034
4 CG(I) = CJ(I)                                                    0035
C                                                                    0036
CALL SQROT (C,CJ,0,I12,N)                                          0037
I12 = 2                                                            0038
Y11 = (.0,.0)                                                      0039
NNN = N                                                            0040
IF (IGRD.GT.0) NNN = (N+IWL)/2                                     0041
C                                                                    0042
DO 6 I=1,NNN                                                       0043
NN = IA(JB(I))                                                     0044
CGEN = CG(I)                                                       0045
IF (I.LE.IWL) CGEN=CGEN/2.                                         0046
C                                                                    0047
YY = CJ(I)*CONJ(CGEN)                                              0048
IF (CABS(YY).L1.E-20) GO TO 5                                     0049
Z11 = (1./YY)*(CABS(CGEN)**2)                                       0050
WRITE (6,8) NN,Z11                                                0051
5 Y11 = Y11+YY                                                    0052
6 CONTINUE                                                         0053
C                                                                    0054
IF (IMR.GT.0) WRITE (6,7)                                          0055
CALL RITE (IA,IB,INM,IMR,I1,I2,I3,MD,NO,NM,CJ,CG,IGRD)          0056
GG = REAL(Y11)                                                     0057
IF (IGRD.GT.0) GG=2.*REAL(Y11)                                       0058
PIN = GG                                                            0059
CALL GDISS (AM,CG,CMN,D,DISS,GAM,NK,SGD,ZLD,ZS)                  0060
PRAD = PIN-DISS                                                    0061
EFF = 100.*PRAD/PIN                                                0062
RETURN                                                             0063
C                                                                    0064
7 FORMAT (50X,'ANTENNA BRANCH CURRENTS')                          0065
8 FORMAT (10X,'THE INPUT IMPEDANCE AT NODE ',I3,' IS',F15.7,' + J',  0066
IF15.7//)                                                         0067
END                                                                0068

```

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 GOISS (AM,CG,CMM,D,DISS,GAM,NM,SGD,ZLD,ZS)
COMPLEX CG(I),SGD(I),ZLD(I),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 1 K=1,NM
DK = DK(K)
DEN = CABS(SGD(K))**2
EAD = EXP(ALPH*DK)
CAD = (EAD+1./EAD)/2.
CBD = COS(BETA*DK)
SAU = 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)
+AIMAG(CJA)*AIMAG(CJB))
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)
)**2)
C
RETURN
END

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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  $\cos x$ ,  $\cos y$ ,  $\cos z$  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

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

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

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

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

and  $(r, \theta, \phi)$  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  $E_\theta$  and  $E_\phi$  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) 0001
IA=ET1,ET2,EP1,EP2,IGRD,ERR) 0002
COMPLEX ER, RV, RH, RR, EX, EY, EZ, EE 0003
COMPLEX ET1, ET2, EP1, EP2, GAM, ETA 0004
COMPLEX GD, CGD, SGD, EGD 0005
COMPLEX EGFA, EGFB, EGGD, ESA, ESB 0006
COMPLEX CST 0007
FP = 12.56637 0008
XB = XB-XA 0009
YB = YB-YA 0010
ZB = ZB-ZA 0011
CA = XAB/D 0012
CB = YAB/D 0013
CG = ZAB/D 0014
GK = (CA*CPH+CB*SPH)*STH+CG*CTH 0015
ET1 = 1.,0.,0) 0016
ET2 = (.0.,0) 0017
EP1 = (1.,0.,0) 0018
EP2 = (1.,0.,0) 0019
IF (GK,LT,.001) GO TO 3 0020
FA = (XACPH+YA*SPH)*STH+ZA*CTH 0021
FB = (XBCPH+YB*SPH)*STH+ZB*CTH 0022
EGFA = CEXP(GAM*FA) 0023
EGFB = CEXP(GAM*FB) 0024
EGGD = CEXP(GAM*GD) 0025
CST = ETA/(GK*SGD*FP) 0026
ESA = CST*EGFA*(EGGD-G*SGD-CGD) 0027
ESB = CST*EGFB*(1./EGGD+G*SGD-CGD) 0028
IF (IGRD,LE,0) GO TO 2 0029
RV = (-1.,0) 0030
RH = (-1.,0) 0031
IF (IGRD,EQ,1) GO TO 1 0032
RR = CSQRT(ERR-STH*STH) 0033
RV = (ERR*CTH-RR)/(ERR*CTH+RR) 0034
RH = (CTH-RR)/(CTH+RR) 0035
1 EX = CA*ESA 0036
EY = CB*ESA 0037
EZ = CG*ESA 0038
EXX = (EX*SPH-EY*CPH)*(RH-RV) 0039
EYY = (EY*RV+EX*SPH) 0040
EYZ = (EY*RV-EX*CPH) 0041
EZZ = (EZ*RV) 0042
EXXGA = (EXX*CA-EY*CB+EZ*CG) 0043
EYYGA = (EYX*CB) 0044
EZZGA = (EYZ*CB) 0045
EYX = (EX*RV+EY*SPH) 0046
EYV = (EY*RV-EX*CPH) 0047
EYXGA = (EX*SPH-EY*CPH)*(RH-RV) 0048
EYVGA = (EY*RV+EX*SPH) 0049
EYVGA = (EY*RV-EX*CPH) 0050
EYVGA = (EY*RV-EX*CPH) 0051
EZ = (EZ*RV) 0052
T = (EX*CA-EY*CB+EZ*CG) 0053
2 T = (CA*CPH+CB*SPH)*CTH-CG*STH 0054
P = (CA*SPH+CB*CPH) 0055
ET1 = T*ESA 0056
ET2 = T*ESB 0057
EP1 = P*ESA 0058
EP2 = P*ESB 0059
3 CONTINUE 0060
RETURN 0060
END 0061

```



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 transmitting 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  $(r_0, \theta_0, \phi_0)$ , the excitation voltages induced by a incident plane wave are

$$V_m = \int_m \vec{F}_m \cdot \vec{E}_i dl$$

where

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

where  $E_0$  is a vector constant,  $\vec{r}_0$  is a vector from the coordinate origin to the distance source, and  $\vec{r}$  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  $(r_0, \theta_0, \phi_0)$  is

$$E_m = - \frac{j\omega \mu e^{-\gamma r_0}}{4\pi r_0} \int_m \vec{F}_m \exp(\gamma \vec{r} \cdot \vec{r}_0) dl$$

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

$$V_m = - \frac{4\pi r_0}{j\omega a} e^{j\gamma r_0} e_0 e_m .$$

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 precede 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.  $G_{GG}$  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, respectively. 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

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

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:

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

where  $P_i$ ,  $G_p$ , denote the time-average power input and  $S(r, \theta, \phi)$  is the time-average power density in the radiated field.  $G_{pp}$  and  $G_{\theta\theta}$  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

GPF

RITE

SQROT



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```

SUBROUTINE GFFLD (IA,IB,INC,INM,IMR,11,12,13,112,MD,N,ND,NM,AM,ACS
1 P,ACST,C,CGO,CG,CJI,CMM,D,ECSP,ECST,EP,ET,EPP,ETT,EPPS,ETPS,ETP
2 S,GG,GPA,GTT,PH,SGD,SCSP,SCST,SPPH,SAPH,STPH,STTM,THM,TK,Y,Z,ZLD,ZS
3 ,ETA,GAM,ERR,IGRD)
C COMPLEX ERR
C COMPLEX CJI,ET1,ET2,EPI,EP2,EPPS,ETTS,ETPS,ETPS,ZS,VP,VT
C COMPLEX ETA,GAM,CGO(1),SGD(1),CMM(1),EPP(1),ZLD(1)
C DIMENSION IA(1),IB(1),I(1),C(1),EPP(1),ETT(1),ZLD(1)
C DIMENSION D(1),X(1),Y(1),Z(1),I2(1),I3(1),MD(1),MD(INM,4)
C DATA PI,TP/3.14159,0.20318)
CJI = -4.*PI/(ETA*GAM)
GGG = REAL(1/ETA)
THR = .0174533*TH
CTM = COS(THR)
STM = 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),CGO(K),SGD(K),C
1 TH,STM,CPH,SPH,GAM,ETA,ET1,ET2,EPI,EP2,IGRD,ERR)
IGRD = NGRD
NOK = MD(K)
C
DO 3 I1=1,NOK
I = MD(K,I1)
FI = 1.
IF (KB.EQ.12(I)) GO TO 2
IF (KB.EQ.11(I)) FI=-1.
EPP(I) = EPP(I)+F|*EP1
ETT(I) = ETT(I)+F|*ET1
GO TO 3
2 IF (KA.EQ.13(I)) FI=-1.
EPP(I) = EPP(I)+F|*EP2
ETT(I) = ETT(I)+F|*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
EP(I) = EPP(I)*CJI
C
CALL SCROT (C,EP,0,112,N)
I12 = 2
CALL SCROT (C,ET,0,112,N)
IF (IMR.GT.0) WRITE (6,10) PH,TH
IF (IMR.GT.0) WRITE (6,11)
CALL RTE (IA,IB,INM,IMR,11,12,13,MD,ND,NM,EP,CG,IGRD)
CALL GOISS (AM,CG,CMM,D,POIS,GAM,NM,SGD,ZLD,ZS)
IF (IMR.GT.0) WRITE (6,12)
CALL RTE (IA,IB,INM,IMR,11,12,13,MD,ND,NM,ET,CG,IGRD)
CALL GOISS (AM,CG,CMM,D,TOIS,GAM,NM,SGD,ZLD,ZS)
ACSP = POIS/GGG
ACST = TOIS/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)))
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)
ETPS = EPTS+ET(I)*ETT(I)
ETTS = ETTS+ET(I)*ETT(I)
7 ETPS = ETPS+ET(I)*EPP(I)
C
SPPH = 2.*TP*(CABS(EPPS)**2)
STPH = 4.*TP*(CABS(ETPS)**2)
STTM = 2.*TP*(CABS(ETTS)**2)
RETURN
C
DO 9 I=1,N
ETTS = ETTS+CJI(I)*ETT(I)
9 EPPS = EPPS+CJI(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
11 FOR THE INCIDENT ANGLES, PHI=' ,FS.1, ' AND THETA=' ,FS.1//)
11 FORMAT (44X,'CURRENTS INDUCED BY THE PHI POLARIZED WAVE')
12 FORMAT (44X,'CURRENTS INDUCED BY THE THETA POLARIZED WAVE')
END

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GGMM

PURPOSE: to calculate 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:

$$z_{ij} = (-1)^{i+j} B [ e^{tn} (F_{j1} - e^{-zm} G_{12} + e^{zm} G_{22}) - e^{-tn} (F_{j2} - e^{-zm} G_{11} + e^{zm} G_{21}) ]$$

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:

$$F_{ik} = 2 \sinh d_1 e^{iqz_i \cos \psi} E(R_i + qz_i \cos \psi - qt)$$

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:

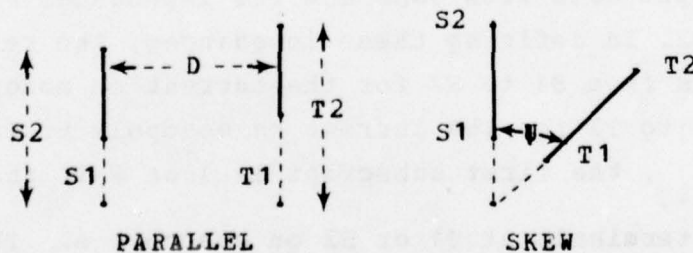
$$G_{ik} = E(R_2 + qz_2 + q't - jq'') + E(R_2 + qz_2 + q't + jq'') \\ - E(R_1 + qz_1 + q't - jq'') - E(R_1 + qz_1 + q't + jq'')$$

where  $q = (-1)^i$ ,  $q' = (-1)^k$ , and  $q'' = qb + q'c$  with  $b = c \cos \psi$  and  $c = d/\sin \psi$ . The angle  $\psi$  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:

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

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  $\gamma = jw \sqrt{\mu\epsilon}$ . 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 calculated 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. Similarly, 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  $\bar{s}$  and  $\bar{t}$  be unit vectors parallel with the positive s and t axes, respectively. Then  $\text{CPSI} = \bar{s} \cdot \bar{t} = \cos \psi$ . 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  $\psi$  tends to zero or  $\pi$ . Therefore, if the monopoles are within  $4.5^\circ$  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)
2
DOUBLE PRECISION R1,R2,DPQ,SIS,TS1,TS2,ST1,ST2,CD,HD,CPSS,SK,TL1,T
3
LL2,TD1,TD2,SD1,DPSI,CD,ZD
4
COMPLEX CGDS,SGDS,SGDT,SGD1,SGD2,ETA,GAM,P11,P12,P21,P22
5
COMPLEX CS1,EB,EC,EK,EL,EKL,EGZ1,ES1,ES2,ET1,ET2,EXPA,EXPB
6
COMPLEX EG2(2,2),GM(2),GP(2)
7
DATA PI/3.14159/
8
DSQ = D*D
9
SGDS = SGD1
10
IF (S2.LT.S1) SGDS = -SGD1
11
SGDT = SGD2
12
IF (T2.LT.T1) SGDT = -SGD2
13
IF (ABS(CPSI).GT..997) GO TO 5
14
IF (ABS(CPSI).GT..997) GO TO 5
15
ES1 = CEXP(GAM*S1)
16
ES2 = CEXP(GAM*S2)
17
ET1 = CEXP(GAM*T1)
18
ET2 = CEXP(GAM*T2)
19
DD = D
20
DPSI = CPSI
21
TD1 = T1
22
TD2 = T2
23
CPSS = DPSI*DPSI
24
CD = DD/DSQRT(1.00-CPSS)
25
C = CD
26
BD = CD*DPSI
27
B = BD
28
EB = CEXP(GAM*CMPLX(.0,B))
29
EC = CEXP(GAM*CMPLX(.0,C))
30
C
DO 1 K=1,2
31
C
DO 1 L=1,2
32
I E(K,L) = (.0,.0)
33
C
TS1 = TD1*TD1
34
TS2 = TD2*TD2
35
OPQ = DD*DD
36
S1 = S1
37
C
DO 4 I=1,2
38
FI = (-1)**I
39
SD1 = S1
40
SIS = SD1*SD1
41
ST1 = 2.*SD1*TD1*DPSI
42
ST2 = 2.*SD1*TD2*DPSI
43
R1 = DSQRT(DPQ*SIS+TS1-ST1)
44
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```

RZ = DSQRT(DPQ+SIS+TS2-ST2)
EK = EB
C
DO 3 K=1,2
FK = (-1)**K
SK = FK*SD1
EL = EC
C
DO 2 L=1,2
FL = (-1)**L
EKL = EK*EL
XX = FK*RD*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(RR1,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 = SD1*DPSI
ZC = ZD
EGZ1 = CEXP(GAM*ZC)
RR1 = R1+ZD-TD1
RR2 = R2+ZD-TD2
CALL EXPJ (GAM*RR1,GAM*RR2,EXPB)
RR1 = R1-ZD+TD1
RR2 = R2-ZD+TD2
CALL EXPJ (GAM*RR1,GAM*RR2,EXPA)
F(I,1) = Z.*SGDS*EXPA/EGZ1
F(I,2) = Z.*SGDS*EXPB/EGZ1
4 S1 = S2
C
CST = ETA/(16.*PI*SGDS*SGDT)
P11 = CST*((F(1,1)*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 TA = (CPSI.LT.0.) GO TO 6
TA = TI

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TB = T2
GO TO 6
6 TA = -T1
TB = -T2
SGDT = -SGDT
7 S1 = S1
C
DO 9 I=1,2
TJ = TA
C
DO 8 J=1,2
ZIJ = TJ-S1
R = SQRT(DSQ+ZIJ*ZIJ)
W = R+ZIJ
IF (ZIJ.GT.0.) W = DSQ/(R-ZIJ)
V = R-ZIJ
IF (ZIJ.GT.0.) V = DSQ/(R+ZIJ)
IF (J.EQ.1) V1 = V
IF (J.EQ.1) W1 = W
EGZ(I,J) = CEXP(GAM*ZIJ)
8 TJ = TB
C
CALL EXPJ (GAM*V1,GAM*V,GP(1))
CALL EXPJ (GAM*W1,GAM*W,GM(1))
9 S1 = S2
C
CST = -ETA/(8.*PI*SGDS*SGDT)
P11 = 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(
1)/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

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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 monopoles are  $(X_A, Y_A, Z_A)$  and  $(X_B, Y_B, Z_B)$ , and the endpoints of the expansion monopole  $t$  are  $(X_1, Y_1, Z_1)$  and  $(X_2, Y_2, Z_2)$ .  $D_S$  and  $D_T$  denote the lengths of monopoles  $s$  and  $t$ , respectively,  $C_{AS}$ ,  $C_{BS}$  and  $C_{GS}$  are the direction cosines of monopole  $s$ , and  $C_A$ ,  $C_B$  and  $C_G$  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  $(X_1, Y_1, Z_1)$ .  $C_1$  is the current at  $T$  for the mode with terminals at  $(X_1, Y_1, Z_1)$ , and  $C_2$  is the current at  $T$  for the mode with terminals at  $(X_2, Y_2, Z_2)$ .  $C$  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  $(X_A, Y_A, Z_A)$  toward  $(X_B, Y_B, Z_B)$ . Also let  $\bar{t}$  denote a unit vector from  $(X_1, Y_1, Z_1)$  toward  $(X_2, Y_2, Z_2)$ . Then  $\bar{s} \cdot \bar{t} = \cos \theta = CC$  where  $\theta$  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  $(X_A, Y_A, Z_A)$  to  $(X_1, Y_1, Z_1)$  and take  $DK = \bar{R}_{11} \cdot \bar{d}$ .

A line is constructed from  $(X_1, Y_1, Z_1)$  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  $(X_1, Y_1, Z_1)$  in plane  $P_t$ , a line is constructed perpendicular to the point  $(X_{P1}, Y_{P1}, Z_{P1})$  in the



plane P . This line is parallel with  $\vec{d}$  and has length DK.  
<sub>S</sub>

Let  $\vec{R}$  represent a vector from (XZ,YZ,ZZ) to (XP1,YP1,ZP1).

P1 denotes  $\vec{R} (\vec{S} \times \vec{d})$ . 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 0001
1  S,DT,SGDT,INT,ETA,GAM,P11,P12,P21,P22,ERR,IGRD) 0002
COMPLEX EX1,EY1,EX2,EY2,EZ1,EZ2 0003
COMPLEX P11,P12,P21,P22,EJA,EJB,EJ1,EJ2,ETA,GAM,C1,C2,CST 0004
COMPLEX EGD,CGDS,SGDS,SGDT,ER1,ER2,ET1,ET2 0005
COMPLEX ERR 0006
COMPLEX EE,EXX,EYY 0007
COMPLEX PP,PX,PY,PZ 0008
COMPLEX RR1,RR2,RR3,RR4,RM1,RV1,RM2,RV2,RM3,RV3,RM4,RV4 0009
DATA FP/12.56637/ 0010
CA = (X2-X1)/DT 0011
CB = (Y2-Y1)/DT 0012
CG = (Z2-Z1)/DT 0013
CAS = (XB-XA)/DS 0014
CBS = (YB-YA)/DS 0015
CGS = (ZB-ZA)/DS 0016
CC = CA*CAS+CB*CBS+CG*CGS 0017
IF ((CG.LE..003).AND.(CGS.LE..003)).AND.(IGRD.GT.0) GO TO 1 0018
IF (ABS(C1).GT..997) GO TO 6 0019
1  SZ = (X1-XA)*CAS+(Y1-YA)*CBS+(Z1-ZA)*CGS 0020
IF (INT.LE.0) GO TO 7 0021
INS = 2*(INT/2) 0022
IF (INS.LT.2) INS = 2 0023
DELTA = DT/INS 0024
E = .0 0025
DSZ = CC*DELTA 0027
P11 = (.0,.0) 0028
P12 = (.0,.0) 0029
P21 = (.0,.0) 0030
P22 = (.0,.0) 0031
AMS = AM*AM 0032
SGM = -1. 0033
DO 5 IN=1,IP 0034
YY1 = SY 0035
XXY = X1+T*CA-XA-SZ*CAS 0036
YYZ = Y1+T*CB-YA-SZ*CBS 0037
ZZZ = Z1+T*CG-ZA-SZ*CGS 0038
RS = XXZ**2+YYZ**2+ZZZ**2 0039
R1 = SQRT(RS+ZZ1**2) 0040
EJA = CEXP(-GAM*R1) 0041
EJ1 = EJA/R1 0042
R2 = SQRT(RS+ZZ2**2) 0043
EJB = CEXP(-GAM*R2) 0044
EJ2 = EJB/R2 0045
0046
0047
0048

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ER1 = EJA*SGDS+Z1*EJ1*CGDS-Z12*EJ2
ER2 = -EJB*SGDS+Z2*EJ2*CGDS-Z21*EJ1
FAC = 0
IF (RS.GT.AMS) FAC = (CA*XXZ+CB*YYZ+CG*ZZ)/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)
RV2 = (-1.,0)
RH1 = (-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
XX = TT1*CAS
YY = TT1*CBS
E = (XX*SPH-EYY*CPH)*(RH1-RV1)
XX = TT1*RV1+EE*SPH
YY = TT1*RV1-EE*CPH
TT1 = TT1+RV1*CGS
XX = TT2*CAS-EY1*CBS+EZ1*CGS
YY = TT2*CBS
RE = (XX*SPH-EYY*CPH)*(RH2-RV2)
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EX2 = EXX*RV2+E*SPH
EY2 = EYY*RV2-EE*CPH
EZ2 = EZ1+CGS*RV2
TNZ = EX2*CAS-EY2*CBS+EZ2*CGS
4
C = 3.+SGN
IF ((IN.COD.1.OR.IN.EQ.(PI) C=1.
CGD = C*EXP(GAM*(DT-T))
C1 = C*(EGD-1./EGD)/2.
CGD = C*EXP(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+DEL
Z = Z+SZ
5
SGN = -SGN
C
CST = -ETA*DEL/(3.*FP*SGDS*SGDT)
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)**2)
X12 = SZ1+DT*CC
DR2 = SQRT((X2-XA-SZ2*CAS)**2+(Y2-YA-SZ2*CBS)**2+(Z2-ZA-SZ2*CGS)**2)
Z1 = (DR1+DR2)/2.
DDD = (DDD.GT.20.*AM.AND.INT.GT.0) GO TO 1
IF (DDD.LT.AM) DDD = AM
CALL GGMM (.0,DS,SZ1,SZ2,DDD,CGDS,SGDS,SGDT,1.,ETA,GAM,P11,P12,P21
1
P22)
IF (IGRD.LT.1) RETURN
IF (IGRD.GT.1) GO TO 8
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 = (1-XA)*CAD+(Y1-YA)*CBD+(Z1-ZA)*CGD
DK = ABS(DK)
IF (DK.LT.AM) DK = AM
XZ = XA+SZ*CAS
YZ = YA+SZ*CBS
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ZZ = ZA+SZ*CGS
XP1 = X1-DK*CAO
YP1 = Y1-DK*CAD
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 GMM (S1,S1*DS,T1,T1*DT,DK,CGDS,SGDS,SGDT,CC,ETA,GAM,P11,P12,
I P21,P22)
RETURN
C
B 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

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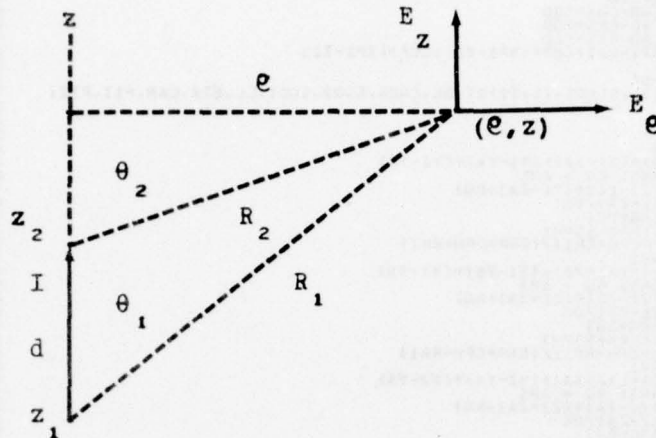
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GNF

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,  $\gamma$  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

$$E(e) = \frac{\eta}{4\pi e \sinh \gamma d} \left[ (I_1 e^{-\gamma R_1} - I_2 e^{-\gamma R_2}) \sinh \gamma d \right. \\ \left. + (I_1 \cosh \gamma d - I_2) e^{-\gamma R_1} \cos \theta_1 \right. \\ \left. + (I_2 \cosh \gamma d - I_1) e^{-\gamma R_2} \cos \theta_2 \right]$$



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

where  $\eta$  is the intrinsic impedance of the medium and where  $(\rho, \phi, z)$  denote the cylindrical coordinates in a coordinate system centered at the endpoint of  $z_1$ .

These expressions exclude the field contributions from the point charges 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  $(X_A, Y_A, Z_A)$ . From any point  $X, Y, Z$ , a line is constructed perpendicular to the monopole.  $S_2$  denotes the  $s$  coordinate of the intersection of this line with the monopole. The length of the line is the radial coordinate  $\rho$ , and  $RS$  denote  $\rho^2$ .  $R_1$  and  $R_2$  are the distances from  $(X_A, Y_A, Z_A)$  and  $(X_B, Y_B, Z_B)$  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
1  I,EY1,EZ1,EX2,EY2,EZ2,IGRD,ERR)
2  COMPLEX ERR,RV1,RH1,RV2,RH2,RR1,RR2,EE
3  COMPLEX EJA,EJB,EJ1,EJ2,ER1,ER2,ES1,ES2,SGDS,GAM,CST,CGDS,ETA
4  COMPLEX EX1,EY1,EZ1,EX2,EY2,EZ2
5  DATA PI/3.14159/
6  CAS = (XB-XA)/DS
7  CBS = (YB-YA)/DS
8  CGS = (ZB-ZA)/DS
9  SZ = (X-XA)*CAS+(Y-YA)*CBS+(Z-ZA)*CGS
10 ZZ1 = SZ
11 ZZ2 = SZ-DS
12 XXZ = X-XA-SZ*CAS
13 YYZ = Y-YA-SZ*CBS
14 ZZZ = Z-ZA-SZ*CGS
15 RS = XXZ**2+YYZ**2+ZZZ**2
16 R1 = SQRT(RS+ZZ1**2)
17 EJA = CEXP(-GAM*R1)
18 EJ1 = EJA/R1
19 R2 = SQRT(RS+ZZ2**2)
20 EJB = CEXP(-GAM*R2)
21 EJ2 = EJB/R2
22 ES1 = EJ2-EJ1*CGDS
23 ES2 = EJ1-EJ2*CGDS
24 ER1 = (.0,.0)
25 ER2 = (.0,.0)
26 AMS = AM*AM
27 IF (RS.LT.AMS) GO TO 1
28 CTH1 = ZZ1/R1
29 CTH2 = ZZ2/R2
30 ER1 = (EJA*SGDS+EJA*CGDS*CTH1-EJB*CTH2)/RS
31 ER2 = (-EJB*SGDS+EJB*CGDS*CTH2-EJA*CTH1)/RS
32 CST = ETA/(4.*PI*SGDS)
33 EX1 = CST*(ES1*CAS+ER1*XXZ)
34 EY1 = CST*(ES1*CBS+ER1*YYZ)
35 EZ1 = CST*(ES1*CGS+ER1*ZZZ)
36 EX2 = CST*(ES2*CAS+ER2*XXZ)
37 EY2 = CST*(ES2*CBS+ER2*YYZ)
38 EZ2 = CST*(ES2*CGS+ER2*ZZZ)
39 IF (IGRD.LE.0) RETURN
40 RV1 = (-1.,0)
41 RH1 = (-1.,0)
42 RV2 = (-1.,0)
43 RH2 = (-1.,0)
44 IF (IGRD.EQ.1) GO TO 2
45 R1 = SQRT((XA-X)*(XA-X)+(YA-Y)*(YA-Y))
46 R2 = SQRT((XB-X)*(XB-X)+(YB-Y)*(YB-Y))
47 TH1 = ATAN(R1/(ZA-Z))
48
49 TH2 = ATAN(R2/(ZB-Z))
50 RR1 = CSQRT(ER2*SIN(TH1)*SIN(TH1))
51 RR2 = CSQRT(ER2*SIN(TH2)*SIN(TH2))
52 RV1 = -(ERR*COS(TH1)-RR1)/(ERR*COS(TH1)+RR1)
53 RH1 = (COS(TH1)-RV1)/(COS(TH1)+RV1)
54 RV2 = -(ERR*COS(TH2)-RR2)/(ERR*COS(TH2)+RR2)
55 RH2 = (COS(TH2)-RV2)/(COS(TH2)+RV2)
56 2  RG = SQRT((XA-XB)*(XA-XB)+(YA-YB)*(YA-YB))
57 CPH = 0
58 SPH = 0
59 IF (RG.LT.1.E-32) GO TO 3
60 CPH = (XB-XA)/RG
61 SPH = (YB-YA)/RG
62 3  EX1 = (EX1*SPH-EY1*CPH)*(RH1-RV1)
63 EY1 = -(EX1*RV1+EY1*SPH)
64 EZ1 = (EZ1*(-RV1))
65 ER1 = (EX2*SPH-EY2*CPH)*(RH2-RV2)
66 EX2 = -(EX2*RV2+EY2*SPH)
67 EY2 = -(EY2*RV2-EY2*CPH)
68 EZ2 = (EZ2*(-RV2))
69 RETURN
70 END
71

```

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: GFP

```

SUBROUTINE GNFLD (IA,IB,INM,I1,I2,I3,MO,N,NO,NM,AM,CGD,SGD,ETA,GAM      0001
1,CJ,D,X,Y,Z,XP,YP,ZP,EX,EY,EZ,IGRD,ERR)                               0002
COMPLEX EX,EY,EZ,EX1,EY1,EZ1,EX2,EY2,EZ2,ETA,GAM                     0003
COMPLEX ERR                                                            0004
COMPLEX CJ(I),CGD(I),SGD(I)                                           0005
DIMENSION IA(I),IB(I),I1(I),I2(I),I3(I),D(I),X(I),Y(I),Z(I)         0006
1)                                                                    0007
DIMENSION MO(INM,4),NO(I)                                             0008
DATA PI,TP/3.14159,6.28318/                                           0009
EX = (.0,.0)                                                           0010
EY = (.0,.0)                                                           0011
EZ = (.0,.0)                                                           0012
C                                                                    0013
DO 2 K=1,NM                                                            0014
KA = IA(K)                                                             0015
KB = IB(K)                                                             0016
NGRD = IGRD                                                            0017
IF (K.EQ.NM/2) IGRD=-1                                               0018
CALL GNF (X(KA),Y(KA),Z(KA),X(KB),Y(KB),Z(KB),XP,YP,ZP,AM,D(K),CGD  0019
1(K),SGD(K),ETA,GAM,EX1,EY1,EZ1,EX2,EY2,EZ2,IGRD,ERR)              0020
IGRD = NGRD                                                            0021
NDK = NO(K)                                                            0022
C                                                                    0023
DO 2 II=1,NDK                                                         0024
FI = MO(K,II)                                                         0025
IF (KB.EQ.I2(II)) GO TO 1                                             0026
IF (KB.EQ.I1(II)) F=-1.                                              0027
EX = EX+FI*EX1*CGJ(II)                                               0028
EY = EY+FI*EY1*CGJ(II)                                               0029
EZ = EZ+FI*EZ1*CGJ(II)                                               0030
GO TO 2                                                                0031
1 EX = EX+FI*EX2*CGJ(II)                                               0032
EY = EY+FI*EY2*CGJ(II)                                               0033
EZ = EZ+FI*EZ2*CGJ(II)                                               0034
2 CONTINUE                                                            0035
C                                                                    0036
RETURN                                                                0037
END                                                                    0038
                                                                    0039
                                                                    0040

```

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 = I
2 RETURN
END
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LINECK

PURPOSE: to insert grid characters on the polar plot.

METHOD: The period 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
1 I = INT(X)
1 I = ABS(I)
2 Z = ABS(X)
IF (Z-1).GT.0.5) I=I+1
1 IF (Z.LT.10.0-0.9) Z.GT.111.0) GO TO 2
LINE(1) = ISYM(2)
LINE(6) = ISYM(3)
LINE(62) = ISYM(3)
K = K+1
IF (K.EQ.2) GO TO 2
I = I-1
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 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

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C
C
SUBROUTINE NUMB (Y)
THIS SUBROUTINE PUTS DEGREE NUMBERS ON POLAR GRID
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
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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(B0)
DIMENSION B(10)
DATA B/'0','1','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
C
2 IF (ISET.EQ.1) II = II+1
C
DO 3 K=1,10
IF (A(I).EQ.B(K)) GO TO 4
3 CONTINUE
C
GO TO 7
C
4 DO 5 K=1,10
KK = K-1
IF (A(I).EQ.B(K)) NUMB=KK
5 CONTINUE
C
IX = NUMB+10*IX
N2 = I+1
6 CONTINUE
C
7 IF (NSIGN.EQ.1) IX = -IX
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

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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  $DATA_X$ ,  $DATA_Y$ , 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 aborted.

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 polar 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 TITL1(2), TITL2(2)
DATA TITL1/'PHI ', 'THETA'
N = 360
DIM = 1.0
NST = 1
KST = 1
S IS SCALE FACTOR OF PRINTER:
ABSCISSA CHAR. PER INCH / ORDINATE CHAR. PER INCH
S = 10.0/8.0
ZERO DATAX AND DATAY
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
FACTOR IS THE NORMALIZING DIVISOR
FACTOR = Y(1)
DO 2 IA=2,N
2 IF (FACTOR.LT.Y(IA)) FACTOR=Y(IA)
IF (NAME.EQ.1) TITL1=TITL1(1)
IF (NAME.EQ.2) TITL1=TITL1(2)
IF ((NAME.EQ.3).OR.(NAME.EQ.4).OR.(NAME.EQ.7).OR.(NAME.EQ.8)) TITL
12(1)=TITL1(1)
IF ((NAME.EQ.5).OR.(NAME.EQ.6).OR.(NAME.EQ.9).OR.(NAME.EQ.10)) TIT
12(1)=TITL1(2)
IF ((NAME.EQ.3).OR.(NAME.EQ.5).OR.(NAME.EQ.7).OR.(NAME.EQ.9)) TITL
12(2)=TITL1(1)
IF ((NAME.EQ.4).OR.(NAME.EQ.6).OR.(NAME.EQ.8).OR.(NAME.EQ.10)) TIT
12(2)=TITL1(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
NORMALIZE DATA TO ONE
3 DO 4 IA=1,N
4 Y(IA) = Y(IA)/FACTOR
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
FILL DATAX AND DATAY ARRAY FROM X AND Y ARRAY
DO 5 IA=1,N
DATA X(IA) = Y(IA)*COS(X(IA))
5 DATA Y(IA) = Y(IA)*SIN(X(IA))
SORT DATA BY ORDINATE MAGNITUDE
CALL SART (DATAX,DATAY,N)
DATAX AND DATAY ARE SORTED BY DESCENDING MAGNITUDE ON THE DATAY VAL
SET UP FOR PLOTTING POLAR GRID WITH DATA
DO 8 IYY=1,81
CALL PTPLT (IYY,S)
LINE IS RETURNED WITH POLAR GRID INFORMATION
SET UP 'Y' BIN SIZE UPPER AND LOWER LIMITS
ULL IS THE LOWER BIN LIMIT
UL IS THE UPPER BIN LIMIT
BIN = DIM/80.0
ULL = DIM-(2*IYY-1)*BIN
UL = ULL+2*BIN
CYCLE THROUGH DATA TO FIND WHICH ONES FALL 'N 'Y' BINS
IF (NST.GT.N) GO TO 7
DO 6 JJ=NST,N

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	IF (DATAY(JJ).LT.ULL) GO TO 7	97
	KST = JJ	98
	AMAG = SQRT(DATAX(JJ)*DATAX(JJ)+DATAY(JJ)*DATAY(JJ))	99
C	CHECK THAT MAGNITUDE IS NOT OVER DIM	100
	IF (AMAG.GT.DIM) GO TO 6	101
	OK IS THE FINAL LINE POSITION FOR THE '**'	102
	OK = DATAX(JJ)*S*40.0/DIM*61.0	103
	IF (OK.LT.10.0) GO TO 6	104
	K = INT(OK)	105
	K = IABS(K)	106
	OK = ABS(OK)	107
	IF ((OK-K).GT.0.5) K=K+1	108
	IF (OK.LT.10.0.OR.OK.GT.111.0) GO TO 6	109
	LINE(K) = ISYM(4)	110
	6 CONTINUE	111
C	7 CONTINUE	112
	NST = KST+1	113
	PRINT OUT ONE LINE OF PLOT	114
	WRITE (6,14) LINE	115
C	8 CONTINUE	116
	RETURN	117
C	*9 FORMAT (10X,1A4,' COMPONENT OF THE ELECTRIC FIELD IS LESS'/10X,	118
	1 'THAN 1.E-64, THEREFORE THIS FIELD WAS NOT '/10X,'PLOTTED. EXEC	119
	2 UTION WILL CONTINUE AS NORMAL.'//)	120
	10 FORMAT (10X,' THE MAXIMUM VALUE OF THE BISTATIC PATTERN FOR '/	121
	1 10X,1A4,'-',1A4,' (INCIDENT-SCATTERED) IS LESS THAN '/	122
	2 10X, ' 1.E-30.) POLAR PLOT NOT CALLED.'//)	123
	11 FORMAT ('',1A4,' ELECTRIC FIELD ANTENNA PATTERN FOR SPECIFIED PLA	124
	NE.',9X,'NORMALIZING FACTOR='',E10.5)	125
	12 FORMAT ('',BISTATIC SCATTERING PATTERN FOR',1A4,'-',1A4,'(INCIDENT-	126
	13 SCATTERED) POLARIZATION.',9X,'NORMALIZING FACTOR='',E10.5)	127
	13 FORMAT ('',BACKSCATTERING PATTERN FOR',1A4,'-',1A4,'(INCIDENT-SCATT	128
	14 ERED) POLARIZATION.',9X,'NORMALIZING FACTOR='',E10.5)	129
	14 FORMAT (1X,130A1)	130
	END	131
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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 PTPLDT (IYY,S)
THIS SUBROUTINE SETS UP POLAR GRID INFORMATION
COMMON ISYM,LINE
DIMENSION LINE(130), ISYM(14), ISYN(14)
DATA ISYN/1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*/
INTEGER Y,YY,W
SET UP ISYM FROM ISYN FOR COMMON
DO 1 K=1,14
  ISYM(K) = ISYN(K)
1 CONTINUE
CLEAR LINE AND SET TO BLANK
DO 2 I=1,130
  LINE(I) = ISYM(3)
2 Y = 41-IYY
  IF (Y.EQ.0) GO TO 7
SET UP EQUATIONS FOR CONCENTRIC CIRCLES
YY = Y+Y
Z = (YY**2.5/2)*5
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(100.0-Z)
CALL LINECK (X,Y)
6 SET UP EQUATIONS FOR MULTIPLES OF 30 DEGREES
X = 61.0+1.732051*Y*5
CALL LINECK (X,Y)
X = 61.0+Y*5/1.732051
7 CALL LINECK (X,Y)
PUT IN POLAR PLOT NUMBER LABELS
CALL NUMB (Y)
W = IABS(Y)
FILL IN POLAR PLOT AT 000, 090, 180, AND 270
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

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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

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SUBROUTINE READ (IA,IB,IBISC,ICARD,IGAIN,IGRD,INEAR,INT,ISCAT,IWR,
1 KFLAG,KFLAG,KGEN,LOAD,LZO,MSG,NBAP,NBIP,NFFP,NGEN,NM,NP,ABAP,ABAT,
2 AAFP,AFBI,ADIP,ABIT,AM,BM,CMM,ER2,ER3,ER4,FMC,HGT,PHAF,PHIF,P
3 HII,PHSF,PHSI,THAF,THAI,THIF,THII,THSF,THSI,SIG2,SIG3,SIG4,TD2,TD3
4 ,VOLT,X,XNP,Y,YNP,Z,ZLLO,ZNP,STEP)
COMMON /A/ AIBO)
COMPLEX VOLT(1),ZLLO(1)
DIMENSION IA(1), IB(1), X(1), Y(1), Z(1), KGEN(1), KFLAG(1)
DIMENSION XNP(1), YNP(1), ZNP(1), LZO(1)
DATA AA,AB,AC,AD,AE,AF,AG,AH,AI,AK,AL,AMA,AN,AO,AP,AQ,AR,AS,AT,AU,
1 AW,AX/ 'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'K', 'L', 'M', 'N', 'O', 'P',
2 'Q', 'R', 'S', 'T', 'U', 'V', '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 (KFLAG.EQ.6) GO TO 2
IF (MSG.NE.0) GO TO 4
1 READ (5,76,END=72) A
2 IF (IA(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
INSULATION
IF ((A(1).NE.AI).OR.(A(2).NE.AN).OR.(A(3).NE.AS).OR.(A(4).NE.AU))
1) GO TO 10
KFLAG(20) = 1
CALL LEFT (N)
6 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 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
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
8 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 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
9 IF ((A(N).NE.AL).OR.(A(N+1).NE.AD).OR.(A(N+2).NE.AS).OR.(A(N+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
WIRE

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	10 IF ((A(1).NE.AW).OR.(A(2).NE.AI).OR.(A(3).NE.AR).OR.(A(4).NE.AE))	97
	1 GO TO 13	98
	CALL LEFT (N)	99
C	11 IF ((A(N).NE.AR).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AD).OR.(A(N+3).NE	100
	1.A1)) GO TO 12	101
	KFLAG(2) = 1	102
	CALL EQUAL (N)	103
	CALL NUMBER (N,N2,X1,IX)	104
	AM = X1	105
	IF (A(N2).EQ.RIGHT) GO TO 4	106
	IF (A(N2).NE.SLANT) GO TO 71	107
	N = N2+1	108
	GO TO 11	109
C	12 IF ((A(N).NE.AC).OR.(A(N+1).NE.AD).OR.(A(N+2).NE.AN).OR.(A(N+3).NE	110
	1.AD)) GO TO 71	111
	KFLAG(3) = 1	112
	CALL EQUAL (N)	113
	CALL NUMBER (N,N2,X1,IX)	114
	CMH = X1	115
	IF (A(N2).EQ.RIGHT) GO TO 4	116
	IF (A(N2).NE.SLANT) GO TO 71	117
	N = N2+1	118
	GO TO 11	119
C	EXTERNAL MEDIUM	120
C		121
C		122
C	13 IF ((A(1).NE.AE).OR.(A(2).NE.AX).OR.(A(3).NE.AT).OR.(A(4).NE.AE))	123
	1 GO TO 17	124
	KFLAG(8) = 1	125
	CALL LEFT (N)	126
C	14 IF ((A(N).NE.AC).OR.(A(N+1).NE.AD).OR.(A(N+2).NE.AN).OR.(A(N+3).NE	127
	1.AD)) GO TO 15	128
	KFLAG(9) = 1	129
	CALL EQUAL (N)	130
	CALL NUMBER (N,N2,X1,IX)	131
	SIG3 = X1	132
	IF (A(N2).EQ.RIGHT) GO TO 4	133
	IF (A(N2).NE.SLANT) GO TO 71	134
	N = N2+1	135
	GO TO 14	136
C	15 IF ((A(N).NE.AD).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AE).OR.(A(N+3).NE	137
	1.AL)) GO TO 16	138
	KFLAG(10) = 1	139
	CALL EQUAL (N)	140
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	CALL NUMBER (N,N2,X1,IX)	145
	ER3 = X1	146
	IF (A(N2).EQ.RIGHT) GO TO 4	147
	IF (A(N2).NE.SLANT) GO TO 71	148
	N = N2+1	149
	GO TO 14	150
C	16 IF ((A(N).NE.AL).OR.(A(N+1).NE.AD).OR.(A(N+2).NE.AS).OR.(A(N+3).NE	151
	1.AS)) GO TO 71	152
	KFLAG(11) = 1	153
	CALL EQUAL (N)	154
	CALL NUMBER (N,N2,X1,IX)	155
	TD3 = X1	156
	IF (A(N2).EQ.RIGHT) GO TO 4	157
	IF (A(N2).NE.SLANT) GO TO 71	158
	N = N2+1	159
	GO TO 14	160
C		161
C		162
C	LOAD	163
C		164
C		165
C	17 IF ((A(1).NE.AL).OR.(A(2).NE.AD).OR.(A(3).NE.AA).OR.(A(4).NE.AD))	166
	1 GO TO 18	167
	KFLAG(14) = 1	168
	GO TO 19	169
	18 IF ((A(1).NE.AI).OR.(A(2).NE.AMA).OR.(A(3).NE.AP).OR.(A(4).NE.AE))	170
	1 GO TO 22	171
	KFLAG(24) = 1	172
	I = 1	173
	CALL LEFT (N)	174
	CALL NUMBER (N,N2,X1,IX)	175
	IF (IX.LE.0) GO TO 21	176
	LZD(I) = IX	177
	N = N2+1	178
	CALL NUMBER (N,N2,X1,IX)	179
	RMAG = X1	180
	N = N2+1	181
	CALL NUMBER (N,N2,X1,IX)	182
	RDEG = X1	183
	RREAL = RMAG*COS(RDEG/RAD)	184
	RIMAG = RMAG*SIN(RDEG/RAD)	185
	ZLDD(I) = CMPLX(RREAL,RIMAG)	186
	LOAD = I	187
	IF (A(N2).EQ.RIGHT) GO TO 4	188
	IF (A(N2).NE.SLANT) GO TO 71	189
	I = I+1	190
	N = N2+1	191
	GO TO 20	192

	21	KFLAG(24) = -1 LOAD = -1 GO TO 4	193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240
C		FREQUENCY	
C	22	IF ((A(1)).NE.AF).OR.(A(2)).NE.AR).OR.(A(3)).NE.AE).OR.(A(4)).NE.AQ)) IGD TO 23 KFLAG(1) = 1 CALL LEFT (N) CALL NUMBER (N,N2,X1,IX) FMC = X1 GO TO 4	
C		PLOT	
C	23	IF ((A(1)).NE.AP).OR.(A(2)).NE.AL).OR.(A(3)).NE.AO).OR.(A(4)).NE.AT)) IGD 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 I.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 I.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 I.AK)) GO TO 71 ISCAT = 1 NBAP = 1	
C	27	DO 28 I=N,80 K = I+1 IF (A(I)).EQ.SLANT) GO TO 29	
C	28	CONTINUE	
C	29	GO TO 71 N = K IF ((A(N)).NE.AT).OR.(A(N+1)).NE.AH).OR.(A(N+2)).NE.AE).OR.(A(N+3)).NE	
		I.AT)) GO TO 30 CALL EQUAL (N) CALL NUMBER (N,N2,X1,IX) IF (NFFP.EQ.1) AFFT=X1 IF (NBIP.EQ.1) ABIT=X1 IF (NBAP.EQ.1) ABAT=X1 IF (A(N2).EQ.RIGHT) GO TO 4 IF (A(N2)).NE.SLANT) GO TO 71 N = N2+1 GO TO 24	241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288
	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 (NBIP.EQ.1) ABIP=X1 IF (NBAP.EQ.1) ABAP=X1 IF (A(N2).EQ.RIGHT) GO TO 4 IF (A(N2)).NE.SLANT) GO TO 71 N = N2+1 GO TO 24	
C		OUTPUT	
C	31	IF ((A(1)).NE.AO).OR.(A(2)).NE.AU).OR.(A(3)).NE.AT).OR.(A(4)).NE.AP)) IGD 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 I.AT)) GO TO 33 KFLAG(18) = 1 IBISC = 1 CALL EQUAL (N) CALL NUMBER (N,N2,X1,IX) PHSI = X1 N = N2+1 CALL NUMBER (N,N2,X1,IX) 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	289
		L,AF)) GO TO 34	290
		KFLAG(16) = 1	291
		IGAIN = 1	292
		CALL EQUAL (N)	293
		CALL NUMBER (N,N2,X1,IX)	294
		PHAI = X1	295
		N = N2+1	296
		CALL NUMBER (N,N2,X1,IX)	297
		PHAF = X1	298
		N = N2+1	299
		CALL NUMBER (N,N2,X1,IX)	300
		THAI = X1	301
		N = N2+1	302
		CALL NUMBER (N,N2,X1,IX)	303
		THAF = X1	304
		IF (A(N2).EQ.RIGHT) GO TO 4	305
		IF (A(N2).NE.SLANT) GO TO 71	306
		N = N2+1	307
		GO TO 32	308
			309
C	34	IF ((A(N).NE.AN).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AA).OR.(A(N+3).NE	310
		L,AR)) GO TO 40	311
		KFLAG(19) = 1	312
		INEAR = 2	313
		CALL EQUAL (N)	314
		IF (A(N).EQ.PLEFT) GO TO 35	315
		INEAR = 1	316
		I = 1	317
		GO TO 36	318
			319
C			320
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			322
	35	DO 37 L=1,50	323
		I = L	324
		N = N+1	325
	36	CALL NUMBER (N,N2,X1,IX)	326
		XNPII) = X1	327
		N = N2+1	328
		CALL NUMBER (N,N2,X1,IX)	329
		YNPII) = X1	330
		N = N2+1	331
		CALL NUMBER (N,N2,X1,IX)	332
		ZNPII) = X1	333
		IF (LINEAR.EQ.1) GO TO 39	334
		INEAR = L+1	335
		IF (A(N2).EQ.RIGHT) GO TO 38	336
		N = N2	337
	37	CONTINUE	338
			339
C			340
			341
		GO TO 71	342
	38	N2 = N2+1	343
		INEAR = INEAR-1	344
	39	IF (A(N2).EQ.RIGHT) GO TO 4	345
		IF (A(N2).NE.SLANT) GO TO 71	346
		N = N2+1	347
		GO TO 32	348
			349
C	40	IF ((A(N).NE.AB).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AC).OR.(A(N+3).NE	350
		L,AK)) GO TO 41	351
		KFLAG(17) = 1	352
		ISCAT = 1	353
		CALL EQUAL (N)	354
		CALL NUMBER (N,N2,X1,IX)	355
		PHII = X1	356
		N = N2+1	357
		CALL NUMBER (N,N2,X1,IX)	358
		PHIF = 1	359
		N = N2+1	360
		CALL NUMBER (N,N2,X1,IX)	361
		THII = X1	362
		N = N2+1	363
		CALL NUMBER (N,N2,X1,IX)	364
		THIF = X1	365
		IF (A(N2).EQ.RIGHT) GO TO 4	366
		IF (A(N2).NE.SLANT) GO TO 71	367
		N = N2+1	368
		GO TO 32	369
			370
C	41	IF ((A(N).NE.AC).OR.(A(N+1).NE.AU).OR.(A(N+2).NE.AR).OR.(A(N+3).NE	371
		L,AR)) GO TO 43	372
		KFLAG(15) = 1	373
		IWR = 1	374
			375
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			377
			378
		DO 42 K=N,80	379
		IF (A(K).EQ.RIGHT) GO TO 4	380
		N = K+1	381
		IF (A(K).EQ.SLANT) GO TO 32	382
	42	CONTINUE	383
C			384
		GO TO 71	

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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
CCC FEED POINT
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C 44 IF ((A(1).NE.AF).OR.(A(2).NE.AE).OR.(A(3).NE.AE).OR.(A(4).NE.AD))
      IGO TO 45
      KFLAG(13) = 1
      GO TO 46
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C 45 IF ((A(1).NE.AG).OR.(A(2).NE.AE).OR.(A(3).NE.AN).OR.(A(4).NE.AE))
      IGO TO 49
      KFLAG(23) = 1
      NGEN = 0
      CALL LEFT (N)
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54 READ (5,76) A                                481
   ICARD = ICARD+1                              482
   WRITE (6,77) ICARD,A                         483
   CALL BLNK (A)                                484
   N = 1                                         485
   GO TO 53                                      486
C
   INTERVAL FOR CALCULATION                    487
C
55 IF ((A(1).NE.A1).OR.(A(2).NE.AN).OR.(A(3).NE.AT).OR.(A(4).NE.AE)) 488
   IGO TO 56                                    489
   KFLAG(21) = 1                               490
   CALL LEFT (N)                                491
   CALL NUMBER (N,N2,X1,IX)                    492
   INT = IX                                     493
   IF (A(N2).EQ.RIGHT) GO TO 4                 494
   GO TO 71                                     495
C
   GROUND                                       496
C
56 IF ((A(1).NE.AG).OR.(A(2).NE.AR).OR.(A(3).NE.AO).OR.(A(4).NE.AU)) 497
   IGO TO 66                                    498
   KFLAG(25) = 1                               499
   KFLAG(26) = 1                               500
   IGRD = 2                                     501
   CALL LEFT (N)                                502
57 IF ((A(N).NE.AP).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AR).OR.(A(N+3).NE 503
   I.AF)) GO TO 58                              504
   IGRD = 1                                     505
   GO TO 64                                     506
58 IF ((A(N).NE.AS).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AD).OR.(A(N+3).NE 507
   I.AD)) GO TO 59                              508
   ER4 = 30.                                    509
   SIG4 = .02                                   510
   GO TO 64                                     511
59 IF ((A(N).NE.AP).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AD).OR.(A(N+3).NE 512
   I.AR)) GO TO 60                              513
   ER4 = 4.                                     514
   SIG4 = .001                                 515
   GO TO 64                                     516
60 IF ((A(N).NE.AS).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AA)) GO TO 61 517
   ER4 = 80.                                    518
   SIG4 = 4.                                   519
   GO TO 64                                     520
61 IF ((A(N).NE.AH).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AI).OR.(A(N+3).NE 521
   I.AG)) GO TO 62                              522
   CALL EQUAL (N)                              523
   CALL NUMBER (N,N2,X1,IX)                    524
C
   HGT = X1                                     525
   IF (A(N2).EQ.RIGHT) GO TO 4                 526
   IF (A(N2).NE.SLANT) GO TO 71                527
   N = N2+1                                    528
   GO TO 57                                    529
62 IF ((A(N).NE.AC).OR.(A(N+1).NE.AD).OR.(A(N+2).NE.AN).OR.(A(N+3).NE 530
   I.AD)) GO TO 63                              531
   CALL EQUAL (N)                              532
   CALL NUMBER (N,N2,X1,IX)                    533
   SIG4 = X1                                   534
   IF (A(N2).EQ.RIGHT) GO TO 4                 535
   IF (A(N2).NE.SLANT) GO TO 71                536
   N = N2+1                                    537
   GO TO 57                                    538
63 IF ((A(N).NE.AD).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AE).OR.(A(N+3).NE 539
   I.AI)) GO TO 71                              540
   CALL EQUAL (N)                              541
   CALL NUMBER (N,N2,X1,IX)                    542
   ER4 = X1                                   543
   IF (A(N2).EQ.RIGHT) GO TO 4                 544
   IF (A(N2).NE.SLANT) GO TO 71                545
   N = N2+1                                    546
   GO TO 57                                    547
C
64 DO 65 K=N,80                                548
   IF (A(K).EQ.RIGHT) GO TO 4                 549
   N = K+1                                     550
   IF (A(K).EQ.SLANT) GO TO 57                551
65 CONTINUE                                    552
C
   GO TO 71                                    553
C
66 IF ((A(1).NE.AS).OR.(A(2).NE.AT).OR.(A(3).NE.AD).OR.(A(4).NE.AP)) 554
   IGO TO 67                                    555
   IFLAG = 2                                   556
   RETURN                                       557
C
67 IF ((A(1).NE.AC).OR.(A(2).NE.AH).OR.(A(3).NE.AA).OR.(A(4).NE.AN)) 558
   IGO TO 68                                    559
   IFLAG = 3                                   560
   RETURN                                       561
C
68 IF ((A(1).NE.AE).OR.(A(2).NE.AN).OR.(A(3).NE.AD)) GO TO 71        562
C
   IFLAG = 1                                   563
   RETURN                                       564
69 IFLAG = 5                                   565
   RETURN                                       566
70 IFLAG = 4                                   567
   RETURN                                       568
71 MSG = 1                                     569
   KFLAG(30) = ICARD                          570
   GO TO 4                                     571
72 IF (IFLAG.NE.5) WRITE (6,78)                572
   IFLAG = 5                                   573
   RETURN                                       574
C
73 IFLAG = 6                                   575
   ICARD = ICARD-1                             576
   RETURN                                       577
C
74 FORMAT (5X,80A1)                            578
75 FORMAT (///5X,'DATA CARDS'///)              579
76 FORMAT (80A1)                               580
77 FORMAT (6X,12,2X,80A1)                      581
78 FORMAT (' ***** END CARD/STOP CARD MISSING*****') 582
   END                                          583
C
79

```

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

GPFLD

CALLS TO: NONE



```

SUBROUTINE RITE (IA,IB,INM,IWR,I1,I2,I3,MD,ND,NM,CJ,CG,IGRD)
COMPLEX CJ(I),CG(I),CJA,CJB
DIMENSION IA(I), IB(I), I1(I), I2(I), I3(I), MD(INM,4), ND(I)
AMAX = .0
C
DO 3 K=1,NM
KA = IA(K)
KB = IB(K)
CJA = (.0,.0)
CJB = (.0,.0)
NOK = NOK
C
DO 2 I1=1,NOK
I = MD(K,I1)
FI = 1.
IF (KB.EQ.I2(I1)) GO TO 1
IF (KB.EQ.I1(I1)) FI=-1.
CJA = CJA+FI*CJ(I)
GO TO 2
1 IF (KA.EQ.I3(I1)) FI=-1.
CJB = CJB+FI*CJ(I)
2 CONTINUE
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
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)
C
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
WRITE (6,6)
RETURN
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)
I)
8 FORMAT (/2146X,'*NORMALIZED',5X)/' SEG',2(' NODE',4X,'REAL',6X,'IMA
GINARY',3X,'MAGNITUDE',3X,'MAGNITUDE',3X,'PHASE')
END

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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

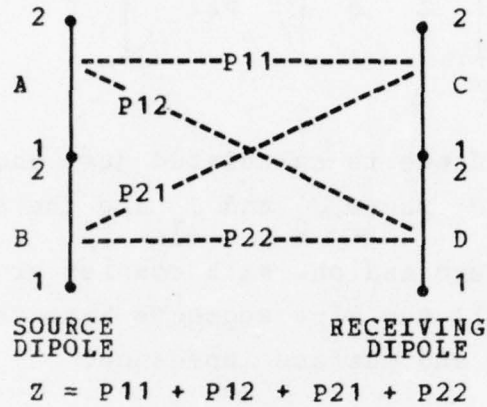
CALLS TO: NONE

```
      SUBROUTINE SART (DATAX, DATAY, N)
      DIMENSION DATAX(500), DATAY(500)
C
C     THIS ROUTINE SORTS DATA IN DATAY BY MAGNITUDE
C
      NN = N-1
      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
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SGANT

PURPOSE: to calculate the mutual impedance between filamentary monopoles.



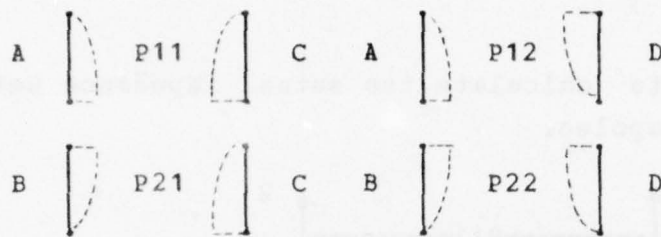
METHOD: In the induced emf formulation, the mutual impedance of coupled dipoles is

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

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.  $B_{01}$  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 dipole 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 elementary 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 elementary 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

GGG



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```

C IF (IND.EQ.0) GO TO 10
  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(
  LB),Y(LB),Z(LB),AM,DK,CGDS,SGDS,DL,SGDT,INT,ETA,GAM,P(1,1),P(1,2),
  P(2,1),P(2,2),EAR,IGRD)
  IGRD = NGRD
  GO TO 18
C
C SEGMENTS K AND L SHARE ONE POINT (THEY INTERSECT)
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))*X(JM)+Y(JP)-Y(JC))*Y(JM)-Y(JC)+Z
  (JP)-Z(JC))*Z(JM)-Z(JC))/DK*DL
  CALL GGM (0,DK,.0,DL,AM,CGDS,SGDS,SGDT,CPSI,ETA,GAM,Q(1,1),Q(1,2
  ),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)
  PI(KP,LP) = SGN*Q(KK,LL)
13 CONTINUE
C
  IGRD=NGRD
  GO TO 18
C
C (SELF REACTION OF SEGMENT K)
14 Q1 = (-0,.0)
  Q2 = (.0,.0)
  IF (CMM.LE.0.) GO TO 15
  GD = GAM*DK
  ZG = ZH(SGDS*2)
  Q1 = ZG*(SGDS*CGDS-GD)/Z.
15 Q12 = ZG*(GD*CGDS-SGDS)/Z.
  ISCK = I(SCK)
  P11 = (-0,.0)
  P12 = (.0,.0)
  IF (ISCK.EQ.0) GO TO 16
  IF (BM.LE.AM) GO TO 16
  CALL OSHELL (AM,BM,DK,CGDS,SGDS,EP2,EP,ETA,GAM,P11,P12)
16 Q11 = P11+Q11
  Q12 = P12+Q12
  CALL GGM (.0,DK,.0,DK,AM,CGDS,SGDS,SGDS,1.,ETA,GAM,P11,P12,P21,P2
  )
  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(MMM)+FI*FJ*P(15,J5)
19 CONTINUE
C
  DO 23 I=1,N
  MM = (-1)**N-(I*1-I)/2
  IJ = MM+1
  JJA = JA(I)
  JI = JJA(I)
  J2 = JJA(I)
  J1 = I(I)
  IF (I12.EQ.IB(J1)) J1=J1+MM
  JJB = JB(I)
  J2 = JJB
  IF (I12.EQ.IB(J2)) J2=J2+MM
  C(IJ) = C(IJ)+ZLD(J1)+ZLD(J2)
  JJJ = JJA
C
  DO 22 K=1,2
  NOJ = NO(JJJ)
C
  DO 21 JJ=1,NOJ
  J = NO(JJJ)
  IF (I2.EQ.1) GO TO 21
  IF (I2J1.NE.I12) GO TO 21

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      IJ = MM*J
      FI = 1
      IF (K.EQ.2) GO TO 20
      IF (I1(J).NE.I11) FI=-1
      C(IJ) = C(IJ)+FI*ZL0(J1)
      GO TO 21
20    IF (I3(J).NE.I3(I)) FI=-1.
      C(IJ) = C(IJ)+FI*ZL0(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
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**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



## 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 transformation 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: GFPLD

CALLS TO: NONE



```

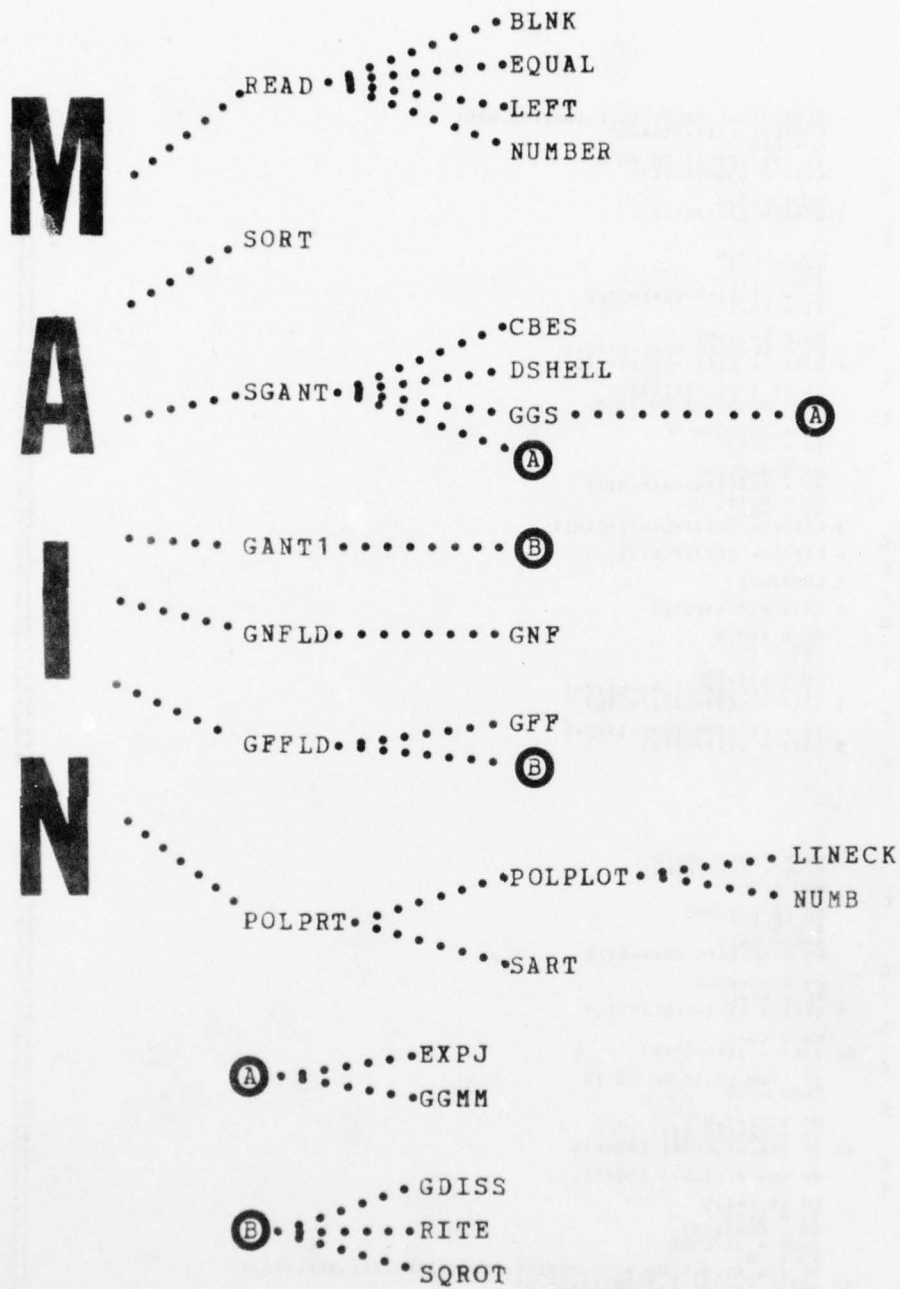
SUBROUTINE SQROT (C,S,IWR,I12,NEQ)
COMPLEX C(1),S(1),SS
N = NEQ
IF (I12.EQ.2) GO TO 6
C(1) = CSQRT(C(1))
C
DO 1 K=2,N
1 C(K) = C(K)/C(1)
C
DO 5 I=2,N
IMO = I-1
IPO = I+1
ID = (I-1)*N-(I*1-1)/2
II = ID+1
C
DO 2 L=1,IMO
LI = (L-1)*N-(L*L-1)/2+1
2 C(LI) = C(LI)-C(LI)*C(LI)
C(LI) = CSQRT(C(LI))
IF (IPO.GT.N) GO TO 5
C
DO 4 J=IPO,N
IJ = ID+J
C
DO 3 M=1,IMO
MO = (M-1)*N-(M*M-1)/2
MI = MO+1
MJ = MO+J
3 C(IJ) = C(IJ)-C(MJ)*C(MI)
C
4 C(IJ) = C(IJ)/C(LI)
C
5 CONTINUE
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-1)/2+1
7 S(LI) = S(LI)-C(LI)*S(LI)
C
II = (I-1)*N-(I*1-1)/2+1
8 S(1) = S(1)/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
KD = (K-1)*N-(K*K-K)/2
C
DO 9 L=KPO,N
KL = KD+L
9 S(K) = S(K)-C(KL)*S(L)
C
KK = KD+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 = ABS(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 = ABS(SS)
SNOR = SA/CNOR
PH = .0
12 IF (SA.GT.0.) PH = 57.29578*ATAN2(AIMAG(SS),REAL(SS))
C
WRITE (6,14) I,SNOR,SA,PH,SS
13 RETURN
C
14 FORMAT (1X,15,1F10.3,1F15.7,1F10.0,2F15.6)
15 FORMAT (1H0)
END

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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 $\gamma d$ 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 field 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 intrinsic 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  
 PHZ frequency in hertz  
 FMC frequency in megahertz  
 GAM intrinsic propagation 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 monopoles  
 INT number of integration steps

ISC	indicator for the insulation
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 dipole
JB	second segment number of a given dipole
KFLAG	print indicator
KGEM	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
NGEM	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	$\sinh \gamma d$ 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             $2\pi$  (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



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## 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. homogeneous 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 critical. 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 critical. 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. DESCRIPTION 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 maximum 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. GEOMETRY 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  $x_1, y_1, z_1$  and node 2 at  $x_2, y_2, z_2$  and node 3 at  $x_3, y_3, z_3$ , etc., the GEOMETRY CARD might appear as:

GEOMETRY( $x_1, y_1, z_1/x_2, y_2, z_2/x_3, y_3, z_3/.....$ )

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 forementioned 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 similar 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 initial, 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 specified 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 conductivity 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 rigorous closed-form impedance expressions in terms of the exponential integrals is desired, set this value to zero.

INTERVAL=value

INTE(6)

12. GENERATOR This card is similar 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 similar 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.



\*\*\*\*\*  
\* 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 \*  
 \*\*\*\*\*

DEGREE	PHI	POWER	GAIN	PHI	REAL	IMAG	THETA	MAGN	PHASE	REAL	IMAG	PHI	MAGN	PHASE
65	0	0	0	0	281E 00	159E 00	0	233E 00	150.4	245E 00	578E 00	00	592E 00	112.0
70	0	0	0	0	290E 00	198E 01	0	275E 00	160.7	243E 00	578E 00	00	592E 00	114.0
75	0	0	0	0	272E 00	358E 01	0	252E 00	171.5	243E 00	578E 00	00	592E 00	117.9
80	0	0	0	0	302E 00	170E 00	0	378E 00	150.5	243E 00	578E 00	00	592E 00	112.2
85	0	0	0	0	301E 00	106E 00	0	320E 00	160.5	243E 00	578E 00	00	592E 00	114.0
90	0	0	0	0	276E 00	219E 01	0	276E 00	175.5	243E 00	578E 00	00	592E 00	117.9



CONTINUE EXECUTION WITH THE FOLLOWING ADDITIONS AND/OR CHANGES

DATA CARDS

7 OUTPUTLIST=45,45,45,45,45/BACK=0,0,10,12)  
8 OUTPUT(CURR)  
9 CHANGE

```
*****  
* INPUT DATA *  
*****
```

ANTENNA FEEDS  
REAL VOLTS IMAGINARY  
0.10000E 01 0.0

NODE NO.  
3

```
*****  
* 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.  
FOR PHI VARYING FROM 45.0 TO 45.0 AND THETA VARYING FROM 45.0 TO 45.0  
BISTATIC SCATTERING FOR PHI VARYING IN STEPS OF 1.0 DEGREES.

\*\*\*\*\*  
 \* ANTENNA \*  
 \* CALCULATIONS \*  
 \* \*\*\*\*\*

THE INPUT IMPEDANCE AT NODE 3 IS 46.2782898 + J 26.5534973

ANTENNA BRANCH CURRENTS

SEG NODE	REAL	IMAGINARY	MAGNITUDE	PHASE	REAL	IMAGINARY	MAGNITUDE	PHASE	NORMALIZED REAL	NORMALIZED IMAGINARY	NORMALIZED MAGNITUDE	PHASE
1	0.0	0.0	0.0	0.0	0.12023E-01	-7.9175E-02	0.14396E-01	-33.4	0.12023E-01	-7.9175E-02	0.14396E-01	-33.4
2	0.12023E-01	-7.9175E-02	0.14396E-01	-33.4	0.16256E-01	-9.3276E-02	0.18742E-01	-29.8	0.16256E-01	-9.3276E-02	0.18742E-01	-29.8
3	0.16256E-01	-9.3276E-02	0.18742E-01	-29.8	0.12023E-01	-7.9175E-02	0.14396E-01	-33.4	0.12023E-01	-7.9175E-02	0.14396E-01	-33.4
4	0.12023E-01	-7.9175E-02	0.14396E-01	-33.4	0.0	0.0	0.0	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

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 \* 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

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

SEG NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
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	-.16843E-04	0.28762E-04	0.33331E-04	0.99999E 00	120.4	3	0.44958E-09	-.95513E-11	0.44958E-09	0.13488E-04	-1.2
3	0.44958E-09	-.95513E-11	0.44958E-09	0.13488E-04	-1.2	4	0.16844E-04	-.28762E-04	0.33333E-04	0.10000E 01	-59.6
4	0.16844E-04	-.28762E-04	0.33333E-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

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

SEG NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
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	-.18454E-04	0.31643E-04	0.36631E-04	0.99998E 00	120.2	3	0.53724E-09	-.15861E-09	0.56016E-09	0.15282E-04	-16.4
3	0.53724E-09	-.15861E-09	0.56016E-09	0.15282E-04	-16.4	4	0.18455E-04	-.31644E-04	0.36632E-04	0.10000E 01	-59.7
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

SEG NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE	PHASE NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
1	0.0	0.0	0.0	0.0	0.0	2	0.31775E-02	-4.9945E-03	0.32165E-02	0.73330E 00	-8.9
2	0.43373E-02	-6.5407E-03	0.43863E-02	0.73330E 00	-8.9	3	0.43373E-02	-6.5407E-03	0.43863E-02	0.10000E 01	-8.9
3	0.31775E-02	-4.9945E-03	0.32165E-02	0.73330E 00	-8.9	4	0.31775E-02	-4.9945E-03	0.32165E-02	0.73330E 00	-8.9
4	0.0	0.0	0.0	0.0	0.0	5	0.0	0.0	0.0	0.0	0.0

CURRENTS INDUCED BY THE THETA POLARIZED WAVE

SEG NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE	PHASE NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
1	0.0	0.0	0.0	0.0	0.0	2	-2.0044E-04	0.34526E-04	0.39922E-04	0.99998E 00	120.1
2	0.57514E-09	-2.6965E-09	0.63522E-09	0.15911E-04	-25.1	3	0.57514E-09	-2.6965E-09	0.63522E-09	0.15911E-04	-25.1
3	0.20045E-04	-3.4526E-04	0.39923E-04	0.10000E 01	-59.9	4	0.20045E-04	-3.4526E-04	0.39923E-04	0.10000E 01	-59.9
4	0.0	0.0	0.0	0.0	0.0	5	0.0	0.0	0.0	0.0	0.0

ELECTRIC FIELD POLARIZATION SCATTERING MATRIX (INCIDENT - SCATTERED)

INCIDENT PLANE	PHI	THETA	REAL	IMAG	PHI-PHI	REAL	IMAG	PHI-THETA	IMAG	THETA-PHI	REAL	IMAG	THETA-THETA
0.0	0.0	10.0	0.47857E-01	-1.8107E 00	-1.4901E-07	0.69849E-08	-1.9355E-07	-2.5371E-07	0.93990E-04	0.17339E-03	0.93990E-04	0.17339E-03	0.21566E-03
0.0	0.0	11.0	0.47857E-01	-1.8128E 00	-1.4901E-07	0.69849E-08	-1.9355E-07	-2.5371E-07	0.93990E-04	0.17339E-03	0.93990E-04	0.17339E-03	0.21566E-03
0.0	0.0	12.0	0.46506E-01	-1.8150E 00	-3.3528E-07	0.69849E-08	-1.9355E-07	-2.5371E-07	0.93990E-04	0.17339E-03	0.93990E-04	0.17339E-03	0.21566E-03



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

2008  
 OBSERVATION  
 POINT  
 PHI THETA  
 45.0 45.0

ELECTRIC FIELD POLARIZATION SCATTERING MATRIX  
 (INCIDENT-SCATTERED)

PHI-THETA	PHI-THETA	REAL	IMAG	THETA-THETA	THETA-THETA	REAL	IMAG
0.17345E-01	-0.12954E 00	-0.14328E-01	-0.98727E-01	0.23251E-03	-0.15151E-03	0.74103E-03	0.65082E-03

CONTINUE EXECUTION WITH THE FOLLOWING ADDITIONS AND/OR CHANGES

DATA CARDS

10 GEM{0-.25,0/0,-.125,0 /0,0,0/0,..125,0/0,..25,0}  
 11 PLOT(FAR/PHI=90)  
 13 GROUND(HEIG=.25/6000)  
 STOP

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 \* INPUT DATA \*  
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GROUND PLANE (NO/YES) YES  
 GROUND DIELECTRIC CONSTANT (RELATIVE) 0.3000E 02  
 GROUND CONDUCTIVITY (MHOS/METER) 0.2000E-01  
 ANTENNA HEIGHT (METERS) 0.2500E 00

WIRE STRUCTURE

SEG NO.	NODE NO.	X	Y	Z	NODE NO.	X	Y	Z
1	1	0.0	-0.2500E 00	0.0	1	0.0	-0.12500E 00	0.0
2	2	0.0	0.12500E 00	0.0	2	0.0	0.12500E 00	0.0
3	3	0.0	0.0	0.0	3	0.0	0.0	0.0

ANTENNA FEEDS  
 REAL VOLTS 0.1000E 01  
 IMAGINARY 0.0

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

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*
* ANTENNA
* CALCULATIONS
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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

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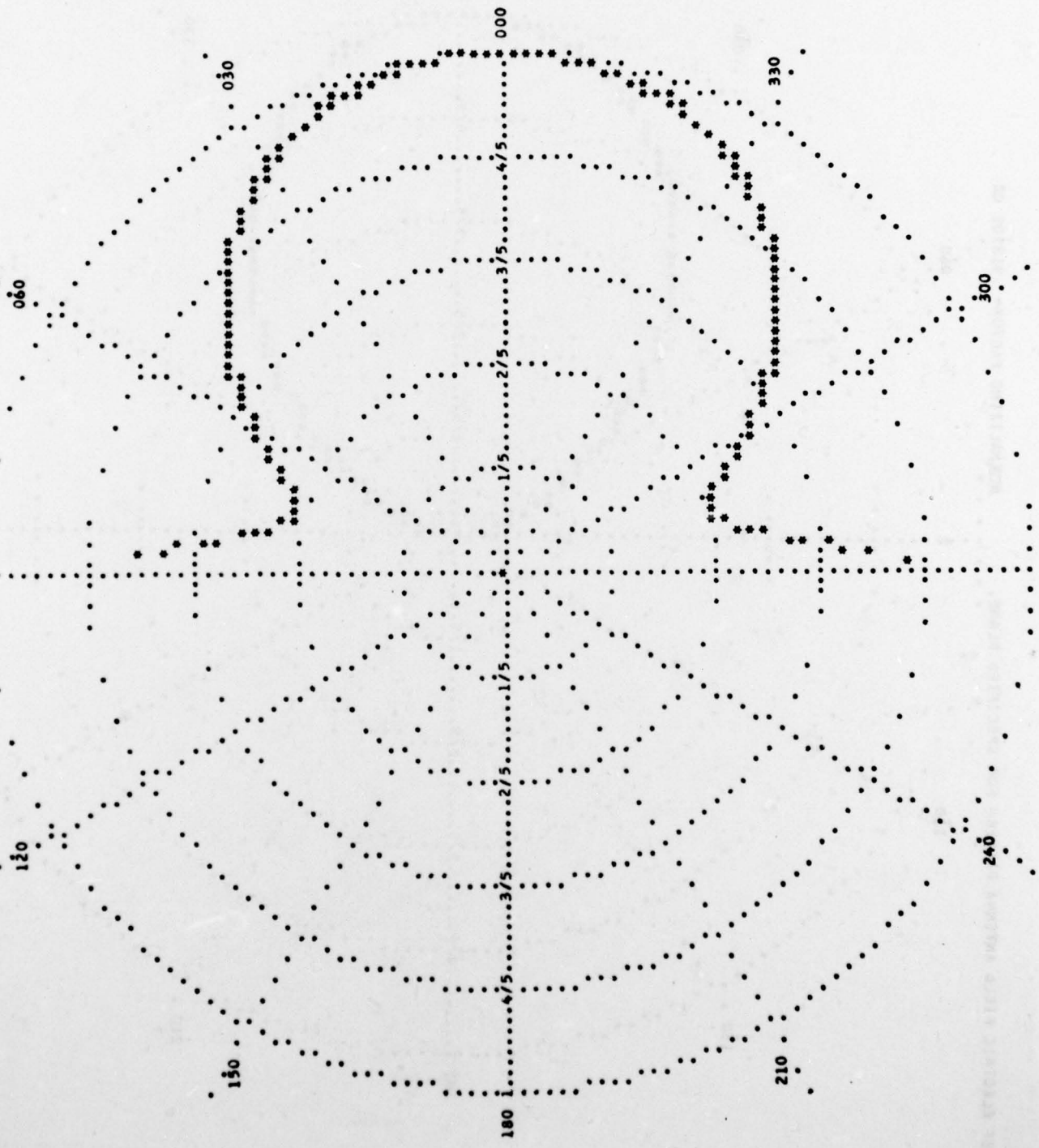
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PHI ELECTRIC FIELD ANTENNA PATTERN FOR SPECIFIED PLANE. NORMALIZING FACTOR = .28833E-06

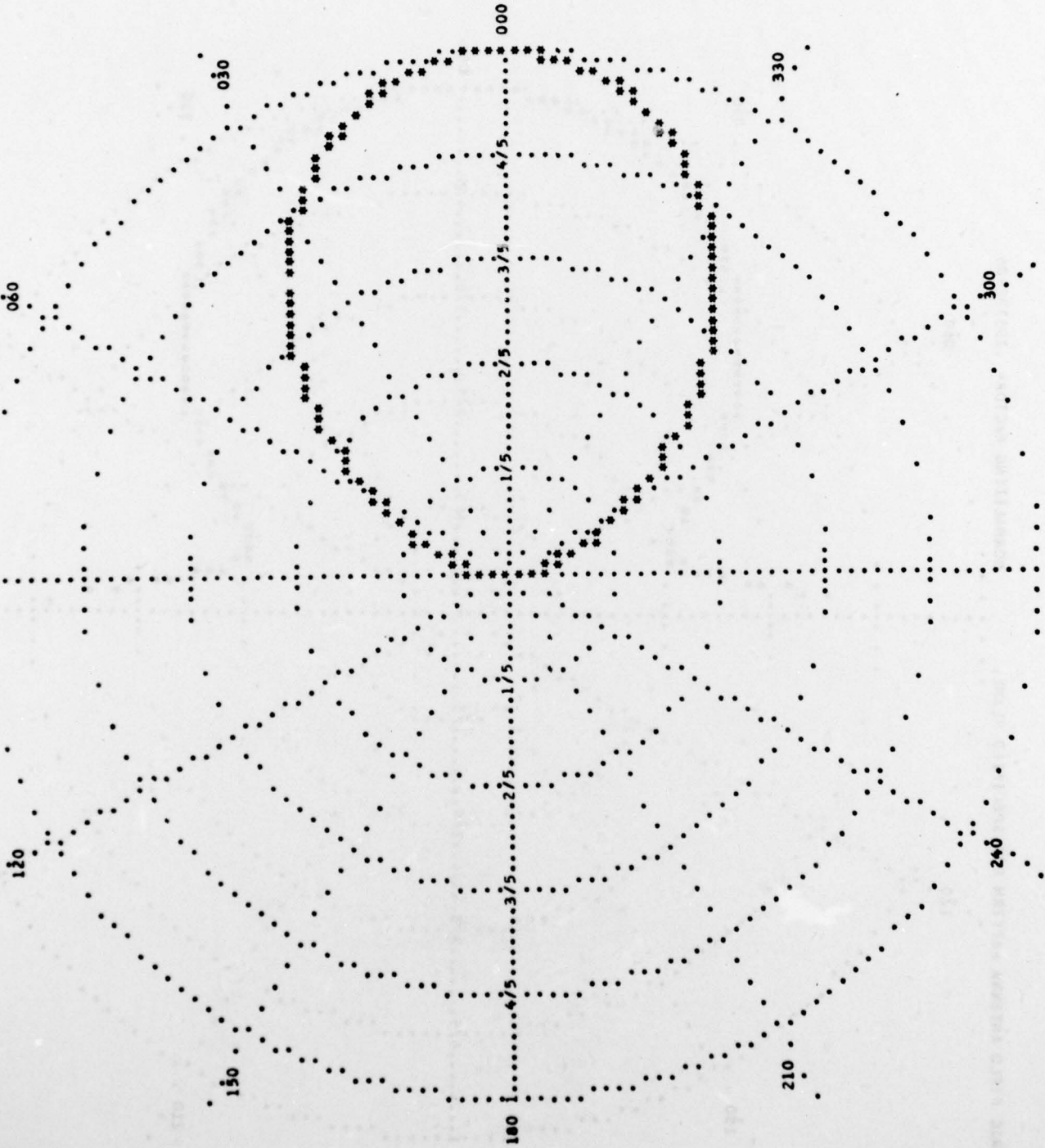
PHI ELECTRIC FIELD ANTENNA PATTERN FOR SPECIFIED PLANE.





NORMALIZING FACTOR = .91830E 00

THE ELECTRIC FIELD ANTENNA PATTERN FOR SPECIFIED PLANE.



## 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 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 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., "Mutual 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.