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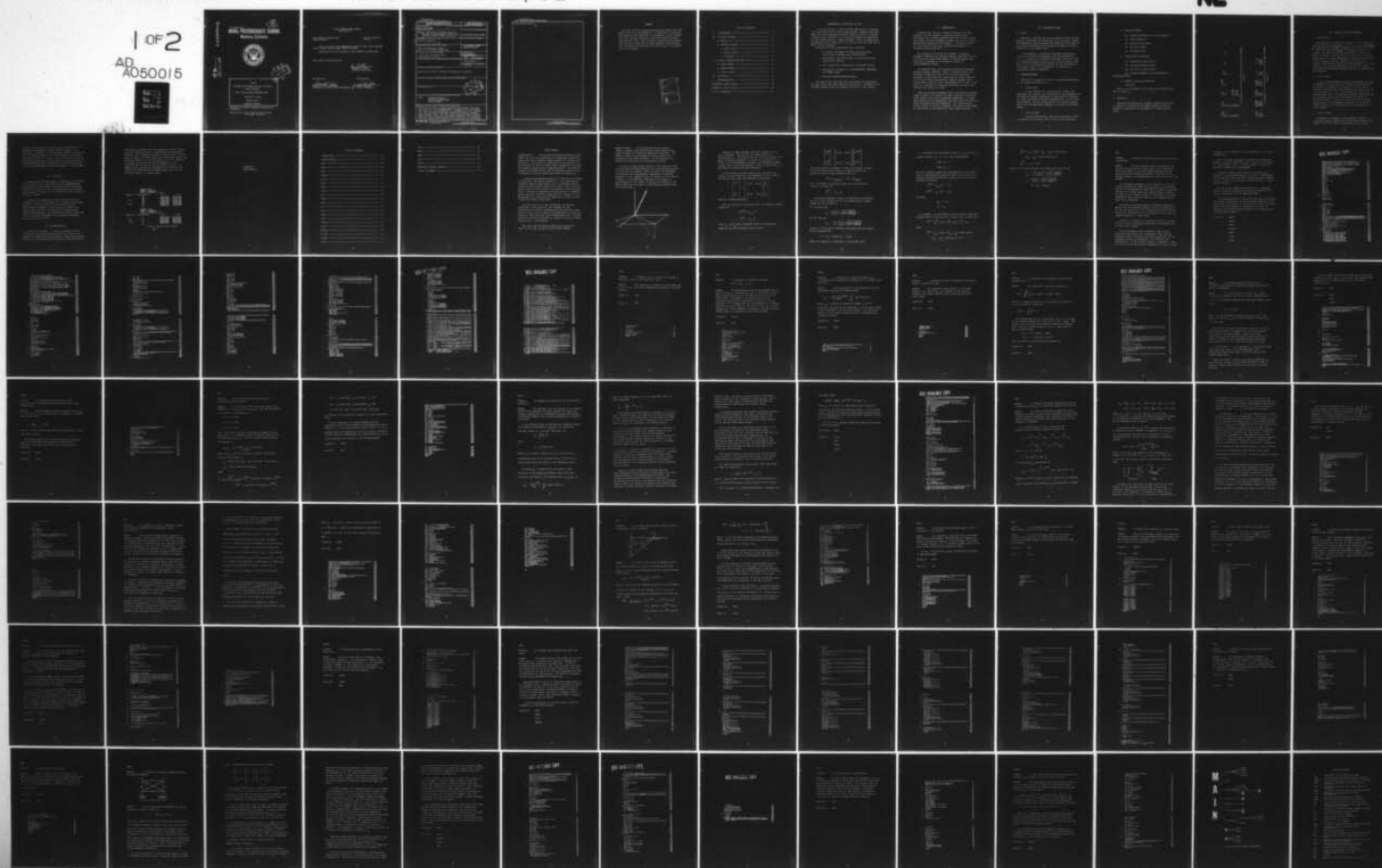
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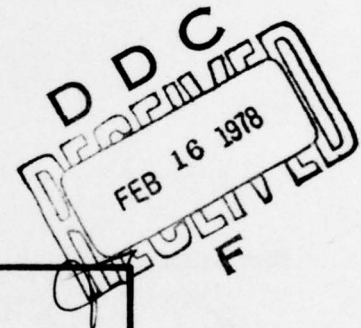
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Monterey, California



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"ASAP"

ANTENNAS-SCATTERERS ANALYSIS PROGRAM:

A USER-ORIENTED

THIN WIRE ANTENNA COMPUTER CODE

Richard W. Adler

August 1977

REVISED VERSION

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Monterey, CA

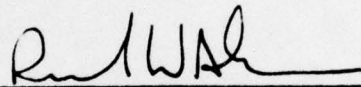
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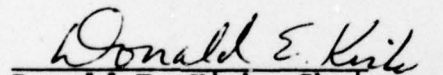
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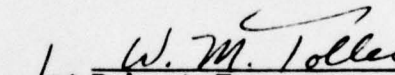


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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Previous thin-wire antenna programs have either been very specialized or all-encompassing. A beginning or occasional user does not need expertise in programming to gain insight into wire antenna structures, using this general purpose user-oriented code. The revisions contained herein correct deficiencies of handling the image problem in the original code and improve the accuracy of calculations of structures		

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over finite ground.



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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 Bevensee 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		
0.001	1.00	1.0	-1.0	0.0	
1	1	1	1	0	
300.	0.	90.	0.	90.	
1	2				3
2	3				45.
3	4				4
4	5				45.
0.	0.				5
0.	0.				
0.	0.				
0.	0.				
0.	0.				
1.	1.				

AN EXAMPLE OF THE INPUT DATA FOR THE ORIGINAL PROGRAM

TABLE 1

98.18	0.0095	82.97	43.26		
-0.091	0.080	-0.091	0.080	0.224	-0.096
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	0.069	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 3 MHZ 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 39.10	85.4+J 48.93
	.45	80.26+J 43.52	80.17+J 54.83
.00001	.25	105.20+J 57.99	115.1+J 73.89
	.30	91.83+J 41.99	94.09+J 50.69
	.35	85.90+J 40.14	86.01+J 49.83
	.45	86.78+J 43.23	80.72+J 54.63

HORIZONTAL DIPOLE FREQUENCY 3 MHZ LENGTH .5 WAVELENGTH RADIUS .001 METERS DIELECTRIC CONSTANT (RELATIVE) 10			
CONDUCTIVITY	HEIGHT/WAVELENGTH	ASAP	EXACT*
.1	.5	84.20+J 23.69	87.74+J 41.77
	.3	132.45+J 46.09	136.0+J 67.91
	.1	39.46+J 84.99	40.5+J 88.71
.001	.5	88.09+J 31.80	91.4+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

non-linear elements such as transmission lines, varactors, and wave impedance ratios, conductivity, and dielectric constant; and a frequency generation process such as a mixer or delay. One major change that would have to be made and reduce the time requirement is that of frequency. An attempt was made to utilize the frequency in the

APPENDIX A SYSTEM MANUAL

TABLE 1 RELATIONSHIP OF FREQUENCY, WAVELENGTH, AND VELOCITY			
FREQUENCY (MHz)	WAVELENGTH (m)	VELOCITY (m/sec)	PERIOD (sec)
1	300	300,000,000	3.33 x 10 ⁻⁹
10	30	300,000,000	3.33 x 10 ⁻¹⁰
100	3	300,000,000	3.33 x 10 ⁻¹¹
1000	0.3	300,000,000	3.33 x 10 ⁻¹²
10000	0.03	300,000,000	3.33 x 10 ⁻¹³
100000	0.003	300,000,000	3.33 x 10 ⁻¹⁴
1000000	0.0003	300,000,000	3.33 x 10 ⁻¹⁵
10000000	0.00003	300,000,000	3.33 x 10 ⁻¹⁶
100000000	0.000003	300,000,000	3.33 x 10 ⁻¹⁷
1000000000	0.0000003	300,000,000	3.33 x 10 ⁻¹⁸

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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.

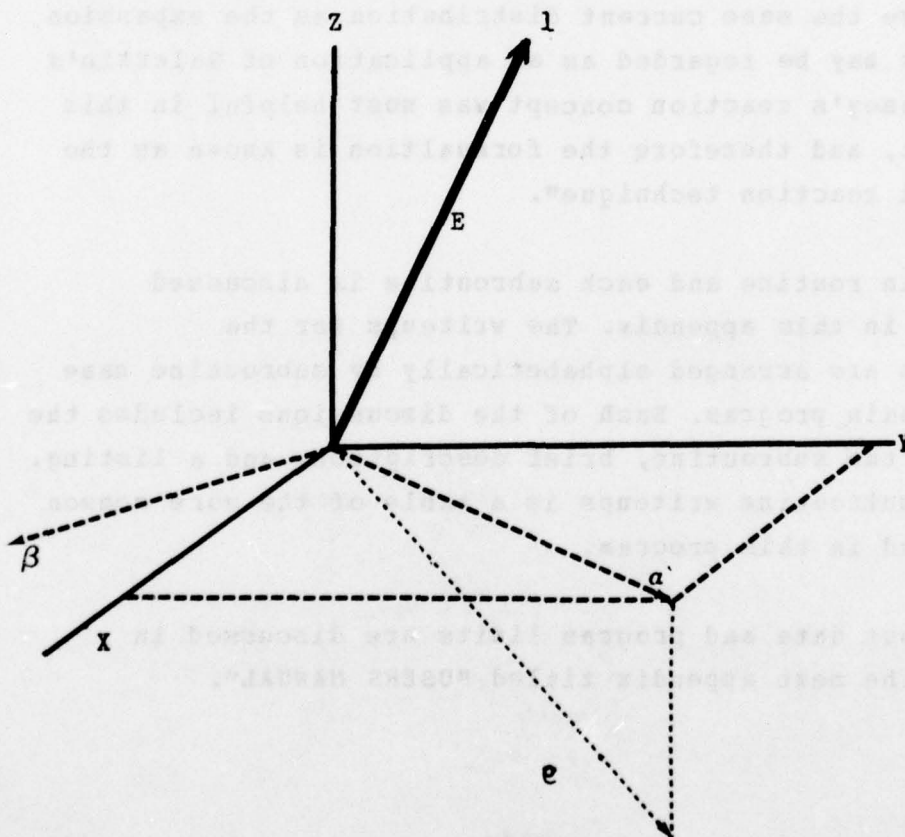
A piecewise-sinusoidal expansion is used for the current distribution. The matrix equation $ZI = V$ is generated by enforcing reaction tests with a set of sinusoidal dipoles located in the interior region of the wire. Since the test dipoles have the same current distribution as the expansion modes, this 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 (α, β, z) where α and β are parallel to the xy plane with α in the plane of incident and β perpendicular.

If the direction cosines ($\cos x$, $\cos y$, 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,

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

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 θ 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.

$$\lim_{H \rightarrow \infty} R_H = -1$$

$$\lim_{V \rightarrow \infty} R_V = +1$$

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

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

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

therefore

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

$$R_{\perp} = R_H$$

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

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

where

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

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

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

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

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)
DIMENSION I1(60), I2(60), I3(60), JA(60), JB(60), KFLAG(30)
DIMENSION DAT1(500), CTHET(500)
DIMENSION DATY1(360), DATY2(360), DATY3(360), DATY4(360)
DIMENSION D(50), IA(50), IB(50), ISC(50), MD(50.4), MD(50)
DIMENSION LZD(60), KGEN(60)
COMMON IWL
DIMENSION XNP(50), YNP(50), ZNP(50)
COMPLEX C(1830)
COMPLEX CDAT1(500), CDAT2(500), CDAT3(500), CDAT4(500)
COMPLEX CJ(60), EP(60), EPP(60), ET(60), ETT(60)
COMPLEX CGD(50), SGD(60), CG(100), VG(100), ZLD(100)
COMPLEX VOLT(60), ZLLO(60)
COMPLEX EPP5(EP,ET), EPP6(ET,ET), EX,EY,EZ
COMPLEX EP2,EP3,EP4,ERR,ETA,GAM,VII,ZII,ZS
DATA PI,TP73.14159,6.28318/
DATA EQ,UO/8.854E-12,1.2566E-6/
1 NGEN = -1
LOAD = -1
LOAD = -1
BM = -1
ICARD = 0
AM = -1
IFLAG = 0
VOLT(1) = (1.,0.)
HGT = 0.
NM = 0
NP = 0
MSG = 0
SIG2 = -1.
TD2 = -1.
SIG3 = -1
ER3 = 1
TD3 = 0.
CMM = 50.
ER2 = 1.
FMC = 300.
INM = 50
ICJ = 60
WRITE (6,74)
C DO 2 I=1,30
2 KFLAG(I) = -1
C DO 3 J=1,INM
ISC(J) = 0
VG(J) = (0.,0)

ZLD(J) = (0.,0)
JJ = J+INM
VGLJJ = (0.,0)
3 ZLD(JJ) = (0.,0)
C 4 NFFP = 0
NBIP = 0
NBAP = 0
AFFP = 1000.
AFFT = 1000.
ABIP = 1000.
ABIT = 1000.
ABAP = 1000.
ABAT = 1000.
STEP = 1.
KNM = 0
CALL READ (IA,IB,IBISC,ICARD,IGA,IN,IGRO,INEAR,INT,ISCAT,IWR,IFLAG,
1 KFLAG,KGEN,LOAD,LZD,MSG,NBAP,NBIP,NFFP,NGEN,NM,NP,ABAP,ABAT,AFFP,A
2 FFF,ABIP,ABIT,AM,BM,CMM,ER2,ER3,ER4,FMC,HGT,PHAF,PHAI,PHIF,PHII,PH
3 SF,PHSI,THAF,THAI,THIF,THII,THSF,THSI,SIG2,SIG3,SIG4,TD2,TD3,VOLT,
4 X,XNP,Y,YNP,Z,ZLLO,ZNP,STEP)
WRITE (6,56)
IF (MSG.EQ.1) GO TO 5
IF (MSG.EQ.1) WRITE (6,70) KFLAG(30)
IF (IFLAG.EQ.4) GO TO 1
5 IF (IFLAG.EQ.5) STOP
IF (AM.LT.0) WRITE (6,127)
IF (AM.LT.0) GO TO 6
IF ((INM.GT.0).AND.(NP.GT.0)) GO TO 7
WRITE (6,116)
6 IF (IFLAG.EQ.1) GO TO 1
MSG = 2
GO TO 4
7 WRITE (6,114)
WRITE (6,113)
WRITE (6,112)
IF (KFLAG(1).EQ.1) WRITE (6,83) FMC
IF (KFLAG(2).EQ.1) WRITE (6,84) AM
IF (KFLAG(3).EQ.1) WRITE (6,85) CMM
IF (KFLAG(20).NE.1) WRITE (6,87)
IF (KFLAG(4).EQ.1) WRITE (6,88) BM
IF (KFLAG(5).EQ.1) WRITE (6,89) SIG2
IF (KFLAG(6).EQ.1) WRITE (6,90) ER2
IF (KFLAG(7).EQ.1) WRITE (6,91) TD2
IF (KFLAG(8).NE.1) WRITE (6,92)
IF (KFLAG(9).EQ.1) WRITE (6,93) SIG3
IF (KFLAG(10).EQ.1) WRITE (6,94) ER3

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IF (KFLAG(11).EQ.1) WRITE (6,95) TD3
IF (KFLAG(26).NE.1) WRITE (6,122)
IF ((IGRD.GT.1).AND.(KFLAG(25).EQ.1)) WRITE (6,123)
IF ((IGRD.EQ.1).AND.(KFLAG(25).EQ.1)) WRITE (6,124)
IF ((IGRD.GT.0).AND.(KFLAG(25).EQ.1)) WRITE (6,126) HGT
IF (KFLAG(21).EQ.1) WRITE (6,121) INT
WRITE (6,111)
IF (KFLAG(12).EQ.1) WRITE (6,96) ((IA(I),X(IA(I)),Y(IA(I)),Z(IA(I)
J),JB(I),X(JB(I)),Y(JB(I)),Z(JB(I))),I=1,NM)
WRITE (6,111)
IF (KFLAG(12).GT.0) WRITE (6,119) (LZD(I),ZLLD(I),I=1,LOAD)
IF (KFLAG(14).GT.0) WRITE (6,118) (LZD(I),ZLLD(I),I=1,LOAD)
WRITE (6,111)
IF (KFLAG(23).GT.0) WRITE (6,120) (KGEN(I),VOLT(I),I=1,NGEN)
IF (KFLAG(13).GT.0) WRITE (6,97) (KGEN(I),VOLT(I),I=1,NGEN)
WRITE (6,111)
WRITE (6,114)
WRITE (6,98)
WRITE (6,112)
IF (KFLAG(22).VE.1) WRITE (6,110)
IF (KFLAG(15).EQ.1) WRITE (6,99)
IF (KFLAG(16).EQ.1) WRITE (6,100) PHA1,PHA2,THA1,THA2,STEP
IF (KFLAG(17).EQ.1) WRITE (6,101) PHI1,PHI2,THI1,THI2,STEP
IF (KFLAG(18).EQ.1) WRITE (6,102) PHS1,PHS2,THS1,THS2,STEP
IF (KFLAG(19).EQ.1) WRITE (6,103) (XNP(I),YNP(I),ZNP(I),I=1,INEAR)
IF (AFFP.LT.500.) WRITE (6,105) AFFP
IF (AFFT.LT.500.) WRITE (6,104) AFFT
IF (ABAP.LT.500.) WRITE (6,109) ABAP
IF (ABAT.LT.500.) WRITE (6,108) ABAT
IF (ABIP.LT.500.) WRITE (6,107) ABIP
IF (ABIT.LT.500.) WRITE (6,106) ABIT
IF ((ISC.GT.0).AND.(ISCAT.LT.0)) WRITE (6,73)
IF (KFLAG(4).LT.1) GO TO 129
DO 128 I=1,NM
128 ISC(I)=1
129 FHZ = FMC*1.E6
OMEGA = TP*FHZ
IF (SIG2.LT.0.) EP2=ER2*EO*CMPLX(1,-TD2)
IF (TD2.LT.0.) EP2 = CMPLX(ER2*EO,-SIG2/OMEGA)
IF (SIG3.LT.0.) EP3=ER3*EO*CMPLX(1,-TD3)
IF (TD3.LT.0.) EP3 = CMPLX(ER3*EO,-SIG3/OMEGA)
IF (IGRD.GT.1) EP4 = CMPLX(ER4*EO,-SIG4/OMEGA)
IF (IGRD.GT.1) ERR = EP4/EP3
IF (KFLAG(21).GT.0) WRITE (6,121) INT
ETA = CSQRT(UO*EP3)
GAM = OMEGA*CSQRT(-UO*EP3)
IF (KFLAG(12).NE.1) GO TO 9

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

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27

C	DO 31 I=1,360	0289
	DATY1(I) = 0	0290
	DATY2(I) = 0	0291
	DATY3(I) = 0	0292
	DATY4(I) = 0	0293
31	DATY4(I) = 0	0294
C	WRITE (6,75)	0295
	WRITE (6,79)	0296
	WRITE (6,77)	0297
	WRITE (6,82)	0298
	INC = 0	0299
	NPL = -1	0300
	IF (KFLAG(16).EQ.1) WRITE (6,69)	0301
	IF (INFP.EQ.1) GO TO 32	0302
	NPHA = (PHAF-PHAI)/STEP+1	0303
	NTHA = (THAF-THAI)/STEP+1	0304
	GO TO 34	0305
32	IF (AFFT.GT.500.) GO TO 33	0306
	NPL = 1	0307
	NPHA = 360	0308
	NTHA = 1	0309
	PHAI = 0.	0310
	THAI = AFFT	0311
	STEP = 1.	0312
	GO TO 34	0313
33	NPL = 2	0314
	NPHA = 1	0315
	NTHA = 360	0316
	PHAI = AFFP	0317
	THAI = 0.	0318
	STEP = 1.	0319
34	PH = PHAI-STEP	0320
	DO 35 K=1,NPHA	0321
	PH = PH+STEP	0322
	TH = THAI-STEP	0323
	DO 35 I=1,NTHA	0324
	PHSPH = 0.	0325
	PHSTH = 0.	0326
	TH = TH+STEP	0327
	IF ((IGRD.GT.0).AND.((TH.GT.90).AND.(TH.LT.270))) GO TO 35	0328
	CALL GFFLD (IA,IB,INC,INM,IWR,1,12,13,112,MD,N,MD,NM,AM,ACSP,ACST	0329
	1,C,CGD,CG,CJ,CMN,0,ECSP,ECST,EP,ET,EPP,ETT,EPPS,ETPS,ETTS,GT,	0330
	ZGPP,GT,PH,SGD,SCSP,SCST,SP,SPH,SPTM,STPH,STTM,TH,X,Y,Z,ZLD,ZS,ETA,G	0331
	3AM,ERR,IGRD)	0332
	ETMAG = CABS(ETTS)	0333
	EPHAG = CABS(EPPS)	0334
	IF (ETMAG.GT.1.E-32) PHSTH=57.295779*ATAN2(AIMAG(ETTS),REAL(ETTS))	0335
	IF (EPHAG.GT.1.E-32) PHSPH=57.295779*ATAN2(AIMAG(EPPS),REAL(EPPS))	0337
	IF (NPL.EQ.1) DATY1(K)=ETMAG	0338
	IF (NPL.EQ.1) DATY2(K)=ETMAG	0339
	IF (NPL.EQ.2) DATY1(I)=ETMAG	0340
	IF (NPL.EQ.2) DATY2(I)=ETMAG	0341
	IF (KFLAG(16).NE.1) GO TO 35	0342
	WRITE (6,60) TH,PH,GT,ETTS,ETMAG,PHSTH,EPPS,EPHAG,PHSPH	0343
35	CONTINUE	0344
C	WRITE (6,56)	0345
	IF (NPL.LE.0) GO TO 36	0346
	CALL POLPRT (1,DATY1)	0347
	CALL POLPRT (2,DATY2)	0348
C	BACK SCATTERING	0349
36	IF (ISCAT.LE.0) GO TO 54	0350
	WRITE (6,75)	0351
	WRITE (6,79)	0352
	WRITE (6,77)	0353
	WRITE (6,82)	0354
	L = 0	0355
	NPL = -1	0356
	INC = 1	0357
	IF (INBAP.EQ.1) GO TO 37	0358
	NPHI = (PHIF-PHI)/STEP+1	0359
	NTHI = (THIF-THI)/STEP+1	0360
	IF (IWR.LE.0) WRITE (6,62)	0361
	GO TO 39	0362
37	IF (ABAT.GT.500.) GO TO 38	0363
	NPL = 1	0364
	NPHI = 360	0365
	NTHI = 1	0366
	PHI = 0.	0367
	THI = ABAT	0368
	STEP = 1.	0369
	GO TO 39	0370
38	NPL = 2	0371
	NPHI = 1	0372
	NTHI = 360	0373
	PHI = ABAP	0374
	THI = 0.	0375
	STEP = 1.	0376
39	PH = PHI-STEP	0377
C	DO 42 K=1,NPHI	0378
	PH = PH+STEP	0379
	TH = THI-STEP	0380
C	DO 42 I=1,NTHI	0381
		0382
		0383
		0384

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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,1NC,1NM,1MR,11,12,13,112,MD,N,ND,NM,AM,ACSP,ACST
1,C,CGO,CG,CJ,CMN,O,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ETTS,GG,
2GPP,GT,PH,SGD,SCSP,SCST,SPPH,SPTM,STPH,STTH,TH,X,Y,Z,ZLD,ZS,ETA,G
3AM,ERR,IGRD)
IF (1MR.GT.0) GO TO 40
IF (NPL.LT.0) WRITE (6,63) PH,TH,SPPH,SPTM,STPH,STTH,ACSP,ACST,ECS
1P,ECST,SCSP,SCST
40 CPHI(L) = PH
CTHET(L) = TH
CDAT1(L) = EPPS
CDAT2(L) = EPTS
CDAT3(L) = ETPS
CDAT4(L) = ETTS
IF (NPL.NE.1) GO TO 41
DATY1(K) = CABS(EPPS)
DATY2(K) = CABS(EPTS)
DATY3(K) = CABS(ETPS)
DATY4(K) = CABS(ETTS)
GO TO 42
41 DATY1(K) = CABS(EPPS)
DATY2(K) = CABS(EPTS)
DATY3(K) = CABS(ETPS)
DATY4(K) = CABS(ETTS)
42 CONTINUE
C
WRITE (6,82)
IF (NPL.LE.0) GO TO 43
CALL POLPRT (7,DATY1)
CALL POLPRT (8,DATY2)
CALL POLPRT (9,DATY3)
CALL POLPRT (10,DATY4)
IF (KFLAG(17).NE.1) GO TO 45
43 WRITE (6,64)
C
DO 44 I=1,L
44 WRITE (6,65) CPHI(I),CTHET(I),CDAT1(I),CDAT2(I),CDAT3(I),CDAT4(I)
C
45 BISTATIC SCATTERING
IF (IBISC.LE.0) GO TO 54
WRITE (6,75)
WRITE (6,76)
WRITE (6,77)
WRITE (6,78)
WRITE (6,79) CPHI(L),CTHET(L)
WRITE (6,82)
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0386
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L = 0
1NC = 2
NPL = 1
IF (NBIP.EQ.1) GO TO 46
NPHS = (PHSF-PHS1)/STEP+1
NTHS = (THSF-THS1)/STEP+1
IF (1MR.LE.0) WRITE (6,67)
GO TO 48
IF (ABIT.GT.500.) GO TO 47
46 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,1NC,1NM,1MR,11,12,13,112,MD,N,ND,NM,AM,ACSP,ACST
1,C,CGO,CG,CJ,CMN,O,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ETTS,GG,
2GPP,GT,PH,SGD,SCSP,SCST,SPPH,SPTM,STPH,STTH,TH,X,Y,Z,ZLD,ZS,ETA,G
3AM,ERR,IGRD)
IF (1MR.GT.0) GO TO 49
IF (NPL.LT.0) WRITE (6,63) PH,TH,SPPH,SPTM,STPH,STTH
49 CPHI(L) = PH
CTHET(L) = TH
CDAT1(L) = EPPS
CDAT2(L) = EPTS
CDAT3(L) = ETPS
CDAT4(L) = ETTS
IF (NPL.NE.1) GO TO 50
DATY1(K) = CABS(EPPS)
DATY2(K) = CABS(EPTS)
DATY3(K) = CABS(ETPS)
DATY4(K) = CABS(ETTS)
0433
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0441
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0443
0444
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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),COAT1(I),COAT2(I),COAT3(I),COAT4(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. ' ',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,' ',F15.7/20X,'EY=',F15.7,' ',F15.7/20
   1X,'EZ=',F15.7,' ',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 (14,'FOR BISTATIC SCATTERING THE INCIDENT'/T41,'PLANE WAVE
   1 IS PHI=',F5.1,' THETA=',F5.1//)
62 FORMAT (1,'INCIDENT',T27,'ECHO AREA SIGMA',T66,'ABSORPTION',T90,'EX
   LTINCTION',T114,'SCATTERING',T1,'PLANE',T25,'(INCIDENT-SCATTERED)',1
   24X,3(5X,'CROSS SECTION',6X),T1,'WAVE',T524,3(10X,'FOR',11X),T1,'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 (154,'BACKSCATTERING',T1,'INCIDENT',T37,'ELECTRIC FIELD POLAR
   1IZATION 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),2(E11.5,2X),E11.5,3X))
66 FORMAT (154,'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
   1DENT-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
   1D/DR CHANGES//)
69 FORMAT (54X,'ELECTRIC FIELD INTENSITY',5X,'DEGREES',11X,'POWER GAI
   1N',28X,'THETA',62X,'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',F15.7//T50,3',F15.7//T50,3',F15.7//
   1 T50,3',F15.7//T50,3',F15.7//
   2 T50,3',F15.7//T50,3',F15.7//
   3 T50,3',F15.7//T50,3',F15.7//
   4 T50,3',F15.7//T50,3',F15.7//
   5 T50,3',F15.7//T50,3',F15.7//
   6 T50,3',F15.7//T50,3',F15.7//
   7 T50,3',F15.7//T50,3',F15.7//
   8 T50,3',F15.7//T50,3',F15.7//
   9 T50,3',F15.7//T50,3',F15.7//
   10 T50,3',F15.7//T50,3',F15.7//
   11 T50,3',F15.7//T50,3',F15.7//
   12 T50,3',F15.7//T50,3',F15.7//
   13 T50,3',F15.7//T50,3',F15.7//
   14 T50,3',F15.7//T50,3',F15.7//
   15 T50,3',F15.7//T50,3',F15.7//
   16 T50,3',F15.7//T50,3',F15.7//
   17 T50,3',F15.7//T50,3',F15.7//
   18 T50,3',F15.7//T50,3',F15.7//
   19 T50,3',F15.7//T50,3',F15.7//
   20 T50,3',F15.7//T50,3',F15.7//
   21 T50,3',F15.7//T50,3',F15.7//
   22 T50,3',F15.7//T50,3',F15.7//
   23 T50,3',F15.7//T50,3',F15.7//
   24 T50,3',F15.7//T50,3',F15.7//
   25 T50,3',F15.7//T50,3',F15.7//
   26 T50,3',F15.7//T50,3',F15.7//
   27 T50,3',F15.7//T50,3',F15.7//
   28 T50,3',F15.7//T50,3',F15.7//
   29 T50,3',F15.7//T50,3',F15.7//
   30 T50,3',F15.7//T50,3',F15.7//
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   33 T50,3',F15.7//T50,3',F15.7//
   34 T50,3',F15.7//T50,3',F15.7//
   35 T50,3',F15.7//T50,3',F15.7//
   36 T50,3',F15.7//T50,3',F15.7//
   37 T50,3',F15.7//T50,3',F15.7//
   38 T50,3',F15.7//T50,3',F15.7//
   39 T50,3',F15.7//T50,3',F15.7//
   40 T50,3',F15.7//T50,3',F15.7//
   41 T50,3',F15.7//T50,3',F15.7//
   42 T50,3',F15.7//T50,3',F15.7//
   43 T50,3',F15.7//T50,3',F15.7//
   44 T50,3',F15.7//T50,3',F15.7//
   45 T50,3',F15.7//T50,3',F15.7//
   46 T50,3',F15.7//T50,3',F15.7//
   47 T50,3',F15.7//T50,3',F15.7//
   48 T50,3',F15.7//T50,3',F15.7//
   49 T50,3',F15.7//T50,3',F15.7//
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   54 T50,3',F15.7//T50,3',F15.7//
   55 T50,3',F15.7//T50,3',F15.7//
   56 T50,3',F15.7//T50,3',F15.7//
   57 T50,3',F15.7//T50,3',F15.7//
   58 T50,3',F15.7//T50,3',F15.7//
   59 T50,3',F15.7//T50,3',F15.7//
   60 T50,3',F15.7//T50,3',F15.7//
   61 T50,3',F15.7//T50,3',F15.7//
   62 T50,3',F15.7//T50,3',F15.7//
   63 T50,3',F15.7//T50,3',F15.7//
   64 T50,3',F15.7//T50,3',F15.7//
   65 T50,3',F15.7//T50,3',F15.7//
   66 T50,3',F15.7//T50,3',F15.7//
   67 T50,3',F15.7//T50,3',F15.7//
   68 T50,3',F15.7//T50,3',F15.7//
   69 T50,3',F15.7//T50,3',F15.7//
   70 T50,3',F15.7//T50,3',F15.7//
   71 T50,3',F15.7//T50,3',F15.7//
   72 T50,3',F15.7//T50,3',F15.7//
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   79 T50,3',F15.7//T50,3',F15.7//
   80 T50,3',F15.7//T50,3',F15.7//
   81 T50,3',F15.7//T50,3',F15.7//
   82 T50,3',F15.7//T50,3',F15.7//
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   91 T50,3',F15.7//T50,3',F15.7//
   92 T50,3',F15.7//T50,3',F15.7//
   93 T50,3',F15.7//T50,3',F15.7//
   94 T50,3',F15.7//T50,3',F15.7//
   95 T50,3',F15.7//T50,3',F15.7//
   96 T50,3',F15.7//T50,3',F15.7//
   97 T50,3',F15.7//T50,3',F15.7//
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   100 T50,3',F15.7//T50,3',F15.7//

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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(
1**)
78 FORMAT (T50,**,9X,'NEAR FIELD',T78,**)
79 FORMAT (T50,**,9X,'FAR FIELD',T78,**)
80 FORMAT (T50,**,7X,'BACKSCATTERING',T78,**)
81 FORMAT (T50,**,4X,'BISTATIC SCATTERING',T78,**)
82 FORMAT (////)
83 FORMAT (T30,'FREQUENCY (MHZ)',T81,E11.5)
84 FORMAT (T30,'WIRE RADIUS (METERS)',T81,E11.5)
85 FORMAT (T30,'WIRE CONDUCTIVITY (MEGAMHOS/METER)',T81,E11.5)
86 FORMAT (T30,'WIRE INSULATED (NO/YES)',T85,'YES')
87 FORMAT (T30,'WIRE INSULATED (NO/YES)',T85,'NO')
88 FORMAT (T30,'INSULATION RADIUS (METERS)',T81,E11.5)
89 FORMAT (T30,'INSULATION CONDUCTIVITY (MHOS/METER)',T81,E11.5)
90 FORMAT (T30,'INSULATION DIELECTRIC CONSTANT (RELATIVE)',T81,E11.5)
91 FORMAT (T30,'INSULATION LOSS TANGENT',T81,E11.5)
92 FORMAT (T30,'EXTERIOR MEDIUM',T81,'FREE SPACE')
93 FORMAT (T30,'EXTERIOR MEDIUM CONDUCTIVITY (MHOS/METER)',T81,E11.5)
94 FORMAT (T30,'EXTERIOR MEDIUM DIELECTRIC CONSTANT (RELATIVE)',T81,
1 E11.5)
95 FORMAT (T30,'EXTERIOR MEDIUM LOSS TANGENT',T81,E11.5)
96 FORMAT (T50,'WIRE STRUCTURE',T20,'SEG',4X,2I,'NODE',19X,'LOCATION',
1,18X)/T21,'NO.',3X,2I,'NO.',9X,'X',13X,'Y',13X,'Z',7X)/T21,12,5X,
2,12,5X,E11.5,4X,E11.5,4X,E11.5,1X)
97 FORMAT (T50,'ANTENNA FEEDS',T40,'NODE',16X,'VOLTS',T41,'NO.',12X,
1,'REAL',7X,'IMAGINARY',/T41,12,6X,2(4X,E11.5))
98 FORMAT (T50,**,6X,'OUTPUT REQUESTED',T78,**)
99 FORMAT (T30,'STRUCTURE CURRENTS')
100 FORMAT (T30,'FAR FIELDS FOR PHI VARYING FROM',1X,F5.1,' TO ',F5.1,
1,' AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
2,T50,' IN STEPS OF ',F5.1,' DEGREES.')
101 FORMAT (T30,'BACKSCATTERING FOR PHI VARYING FROM ',F5.1,' TO ',F5.
1,' AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
2,T50,' IN STEPS OF ',F5.1,' DEGREES.')
102 FORMAT (T30,'BISTATIC SCATTERING FOR PHI VARYING FROM ',F5.1,' TO
1,'F5.1,' AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
2,T50,' IN STEPS OF ',F5.1,' DEGREES.')
103 FORMAT (T30,'NEAR FIELDS FOR FOLLOWING POINTS (X,Y,Z)'/90(T40,3(E1
1,5,5X))
104 FORMAT (T30,'PLOT FOR FAR FIELD THETA=',F5.1)
105 FORMAT (T30,'PLOT FOR FAR FIELD PHI=',F5.1)
106 FORMAT (T30,'PLOT FOR BISTATIC SCATTERING FOR THETA=',F5.1)

107 FORMAT (T30,'PLOT FOR BISTATIC SCATTERING FOR PHI=',F5.1)
108 FORMAT (T30,'PLOT FOR BACKSCATTERING THETA=',F5.1)
109 FORMAT (T30,'PLOT FOR BACKSCATTERING PHI=',F5.1)
110 FORMAT (T30,'NO OUTPUT OR PLOTS REQUESTED')
111 FORMAT (//)
112 FORMAT (T50,**,T78,**/T50,29(**))
113 FORMAT (T50,**,8X,'INPUT DATA ',T78,**)
114 FORMAT (T50,29(**)/T50,**,T78,**)
115 FORMAT (10X,'SINCE THIS DATA BLOCK DOES NOT HAVE A TERMINATION CAR
10 A CHANGE CARD IS ASSUMED')
116 FORMAT (//10X,40I(**)/10X,'THE DESCRIPTION AND THE GEOMETRY OF THE
1 STRUCTURE',/10X,'MUST BE STATED IN THE FIRST DATA BLOCK',/10X,***
2* EXECUTION STOPPED ***)
117 FORMAT (//10X,'NO PART OF THE WIRE STRUCTURE CAN LIE BELOW THE GRO
1 UND PLANE',/10X,****EXECUTION STOPPED****)
118 FORMAT (T50,'STRUCTURE LOADS',T40,'NODE',16X,'OHMS',/T41,'NO.',12X
1,'REAL',7X,'IMAGINARY',/T41,12,6X,2(4X,E11.5))
119 FORMAT (T50,'STRUCTURE LOADS',T39,'SEGMENT',16X,'OHMS',/T41,'NO.',12
1X,'REAL',7X,'IMAGINARY',/T41,12,6X,2(4X,E11.5))
120 FORMAT (T50,'ANTENNA FEEDS',T39,'SEGMENT',14X,'VOLTS',/T41,'NO.',12
1X,'REAL',7X,'IMAGINARY',/T41,12,6X,2(4X,E11.5))
121 FORMAT (//T30,'THE NUMBER OF INTERVALS FOR CALCULATING THE ELEMENT
1S',/T30,'IN THE IMPEDANCE MATRIX WITH SIMPSON'S-RULE INTEGRATION IS'
2,/T30,13,' IF CLOSED FORM INTEGRATION IS REQUIRED SET INT=0'//)
122 FORMAT (T30,'GROUND PLANE (NO/YES)',T85,'NO')
123 FORMAT (T30,'GROUND PLANE (NO/YES)',T85,'YES')
124 FORMAT (T30,'GROUND DIELECTRIC CONSTANT (RELATIVE)',T81,E11.5/
1 T30,'GROUND CONDUCTIVITY (MHOS/METER)',T81,E11.5)
125 FORMAT (T30,'GROUND PLANE',T83,'PERFECT')
126 FORMAT (T30,'ANTENNA HEIGHT (METERS)',T81,E11.5)
127 FORMAT (//10X,40I(**)/10X,'THE WIRE RADIUS MUST BE STATED',/10X,40I
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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
C     J = I-K
C     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.,1.)*Z
    EX = CEXP(ARG)
    CC = EX+1./EX
    CS = (0.,1.)*(EX-1./EX)
    B01 = (CS*CC)/(CS-CC)
    RETURN
  5 B01 = (0.,-1.)
    IF (Y.LT.0.) B01 = (0.,1.)
    RETURN
END

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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

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

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

CALLED BY: SGANT

CALLS TO: NONE

```
SUBROUTINE DSHELL (AM,BM,DK,CGDS,SGDS,EP2,EP,ETA,GAM,P11,P12)
COMPLEX CGDS,SGDS,EP2,EP,ETA,GAM,P11,P12,GO,CST
DATA PI/3.14159/
GO = GAM*DK
CST = (EP2-EP)*ETA*ALOG(BM/AM)/(4.*PI*EP2*SGDS*SGDS)
P11 = -CST*(GO*SGDS*CGDS)
P12 = CST*(GO*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)	0001
	INTEGER A, EQULS	0002
	COMMON /A/ A(80)	0003
	DATA EQULS/'=' /	0004
	K = N	0005
C	DO 1 I=K,80	0006
	N = I+1	0007
	IF (A(I).EQ.EQULS) GO TO 2	0008
1	CONTINUE	0009
C		0010
	N = 1	0011
2	RETURN	0012
	END	0013
		0014

EXPJ

PURPOSE: to calculate the exponential integral with complex limits.

METHOD: The exponential integral is defined as:

$$w_{12} = \int_{v_1}^{v_2} \frac{e^{-v}}{v} dv = E_1(v_1) - E_1(v_2) + j2\pi n ,$$

where the integration path is the straight line from v_1 to v_2 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 v_1 to v_2 the v plane. The integer n is zero unless this path intersects the negative real v axis at a point between v_1 and v_2 . When there is such an intersection,

a) $n = 1$ if $\text{Im}(v_1) > \text{Im}(v_2)$

b) $n = -1$ if $\text{Im}(v_1) < \text{Im}(v_2)$.

The term $j2\pi n$ is calculated below statement 12.

CALLED BY: GGMM

CALLS TO: NONE

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```

SUBROUTINE EXPJ (V1,V2,W12)
  COMPLEX FC,E15,S,T,UC,VC,V1,V2,W12,Z
  DIMENSION V1(21), W12(1), D(16), E(16)
  DATA V1/.2284657E00,0.1188931E01,0.29927363E01,0.57751436E01,0.9
18374674E01,0.15782874E02,0.93307812E-01,0.49269174E00,0.12155954E0
21,0.22699495E01,0.36676227E01,0.54253366E01,0.75659162E01,0.101202
32E02,0.13130292E02,0.16654408E02,0.20776479E02,0.25623894E02,0.31
4407519E02,0.38530683E02,0.48026086E02/
  DATA W1/.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
3.2106957E01,0.22046490E01,0.89728244E01/
  DATA E/0.21193107E02,0.31959787E03,-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 J1=1,2
    X = REAL(Z)
    Y = AIMAG(Z)
    E15 = (1.0,0)
    AB = CABS(Z)
    IF (AB.EQ.0.) GO TO 11
    IF (X.GE.0.) AND (AB.GT.10.) GO TO 10
    Y = ABS(Y)
    IF (X.LE.0.) AND (Y.GT.10.) GO TO 10
    IF (Y<X.GE.17.5.OR.YA.GE.6.5.OR.X*Y.A.GE.5.5.OR.X.GE.3.) GO TO 2
    IF (X<Y.GE.-9.) GO TO 6
    IF (Y<X.GE.-2.5) GO TO 7
    IF (X<Y.A.GE.-1.5) GO TO 3
    N = 0.3*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
C
  4 S = (0.,0)
  5 YS = Y*Y
C
  DO 5 I=J1,J2
    XI = V1(I)*X
    CF = W1(I)/(XI*XI+YS)
    5 S = S+CMPLX(XI*CF,-Y*CF)
C
  GO TO 9
  6 T3 = X*X-Y*Y
  7 T4 = 2.*X*Y
  8 T5 = X*T3-Y*A*T4
  9 T6 = X*T4+Y*A*T3
  10 UC = CMPLX(D(11)*D(12)*X*D(13)*T3+T5-E(12)*Y-A-E(13)*T4,E(11)*E(12)
  11 X*E(13)+T3+T6+D(12)*Y+A+D(13)*T4)
  12 VC = CMPLX(D(14)*D(15)*X*D(16)*T3+T5-E(15)*Y-A-E(16)*T4,E(14)*E(15)
  13 X*E(16)+T3+T6+D(15)*Y+A+D(16)*T4)
  GO TO 8
  7 T3 = X*X-Y*Y
  8 T4 = 2.*X*Y
  9 T5 = X*T3-Y*A*T4
  10 T6 = X*T4+Y*A*T3
  11 T7 = X*T5-Y*A*T6
  12 T8 = X*T6+Y*A*T5
  13 T9 = X*T7-Y*A*T8
  14 T10 = X*T8+Y*A*T7
  15 UC = CMPLX(D(11)*D(2)*X*D(3)*T3+D(4)*T5+D(5)*T7+T9-E(12)*Y-A-E(13)*T4
  16 E(14)+T6+E(15)*T8,E(11)+E(2)*X*E(3)+T3+E(4)*T5+E(5)*T7+T10+D(2)*Y+A
  17 2*D(3)*T4+D(4)*T6+D(5)*T8)
  18 VC = CMPLX(D(6)*D(7)*X*D(8)*T3+D(9)*T5+D(10)*T7+T9-E(7)*Y-A-E(8)*T
  19 14+E(9)*T6+E(10)*T8,E(6)+E(7)*X*E(8)+T3+E(9)*T5+E(10)*T7+T10+D(7)
  20 2*Y+A+D(8)*T4+D(9)*T6+D(10)*T8)
  8 EC = UC/VC
  9 EX = EXPL-X)
  10 T = EX*CMPLX(COS(YA),-SIN(YA))
  11 E15 = S*T
  12 IF (Y<LT.0.) E15 = CONJG(E15)
  GO TO 11
  10 E15 = 409319/(Z+.193044)+.421831/(Z+.1.02666)+.147126/(Z+.2.56788)+
  21 1.206335E-1/(Z+.4.900351)+.107401E-2/(Z+.8.182151)+.158654E-4/(Z+.12.734
  22 21+.317031E-7/(Z+.19.3957)
  11 E15 = E15*CEXP(-Z)
  12 IF (J1.EQ.1) W12 = E15
  13 Z = V2
C
  Z = V2/V1
  TH = ATAN2(AIMAG(Z),REAL(Z))-ATAN2(AIMAG(V2),REAL(V2))+ATAN2(AIMAG
  1(V1),REAL(V1))
  AB = ABS(TH)
  IF (AB<LT.1.) TH = 0
  IF (TH<GT.1.) TH = 6.2831853
  IF (TH<LT.-1.) TH = -6.2831853
  W12 = 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,MO,N,NO,NM,AN,C
1,CJ,CG,CMH,D,EFF,GAM,GG,CGD,SGD,VG,Y11,Z11,ZLD,ZS,IGRD)
COMPLEX YY,CGEN
DIMENSION C(1),CJ(1),CGD(1),SGD(1),VG(1),ZLD(1),Y11,Z11,ZS,GAM,CG(1)
DIMENSION I1(1),I2(1),I3(1),JA(1),JB(1)
COMMON IWL
DO 3 I=1,N
CJ(I) = (.0,.0)
K = JA(I)
DO 2 KK=1,2
KA = IA(K)
KB = IB(K)
J = K
Z1 = 1.
IF (KB.EQ.I2(1)) GO TO 1
IF (KB.EQ.I1(1)) FI=-1.
CJ(I) = CJ(I)+FI*VG(JJ)
GO TO 2
1 IF (KA.EQ.I3(1)) FI=-1.
JJ = K+NM
CJ(I) = CJ(I)+FI*VG(JJ)
2 K = JB(I)
3 CONTINUE
DO 4 I=1,N
4 CG(I) = CJ(I)
CALL SQROT (C,CJ,O,I12,N)
I12 = 2
Y11 = (.0,.0)
NNN = N
IF (IGRD.GT.0) NNN = (N+IWL)/2
DO 6 I=1,NNN
NN = IA(JB(I))
CGEN = CG(I)
IF (I.LE.IWL) CGEN=CGEN/2.
YY = CJ(I)*CONJG(CGEN)
IF (CABS(YY).LT.1.E-20) GO TO 5
Z11 = (1./YY)*(CABS(CGEN)**2)
WRITE (6,8) NN,Z11
5 Y11 = Y11+YY
6 CONTINUE
IF (IMR.GT.0) WRITE (6,7)
CALL RITE (IA,IB,INM,IMR,I1,I2,I3,MO,NO,NM,CJ,CG,IGRD)
GG = REAL(Y11)
IF (IGRD.GT.0) GG=2.*REAL(Y11)
PIN = GG
CALL GDISS (AN,CG,CMH,D,DISS,GAM,NN,SGD,ZLD,ZS)
PRAD = PIN-DISS
EFF = 100.*PRAD/PIN
RETURN
7 FORMAT (50X,'ANTENNA BRANCH CURRENTS')
8 FORMAT (10X,'THE INPUT IMPEDANCE AT NODE ',I3,' IS',F15.7,' + J',
1F15.7)
END

```

GDISS

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

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

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

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

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

CALLED BY: GANT1

CALLS TO: NONE

```

SUBROUTINE GOISS (AM,CG,CMM,D,DISS,GAM,NM,SGD,ZLD,ZS)
COMPLEX CG(1),SGD(1),ZLD(1),CJA,CJB,GAM,ZS
DIMENSION D(1)
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 = D(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)
1)**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

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

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

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

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

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

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

CALLED BY: GFFLD

CALLS TO: NONE

SUBROUTINE GFF (XA,YA,ZA,XB,YB,ZB,D,CGD,SGD,CTH,STH,CPH,SPH,GAM,ET	0001
1 A ET1,ET2,EP1,EP2,IGRD,ERR,EX,EY,EZ,EE	0002
COMPLEX FAR,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
XAB = XB-XA	0009
YAB = YB-YA	0010
ZAB = 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.-GK	0016
ET2 = (1.-GK)	0017
EP1 = (1.-GK)	0018
EP2 = (1.-GK)	0019
IF (GK.LT..001) GO TO 2	0020
FA = (XAB*CPH+YAB*SPH)*STH+ZAB*CTH	0021
FB = (XAB*CPH+YAB*SPH)*STH+ZAB*CTH	0022
EGFA = CEXP(GAM*FA)	0023
EGFB = CEXP(GAM*FB)	0024
EGGD = CEXP(GAM*GD)	0025
CST = ETA/IGK*SGD*FP	0026
ESA = CST*EGFA*(EGGD-G*SGD-CGD)	0027
ESB = CST*EGFB*(1./EGGD+G*SGD-CGD)	0028
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(1-RR*STH*STH)	0033
RV = (1-RR*CTH*CTH)/(1-RR*CTH*CTH)	0034
RH = (1-RR*CTH*CTH)/(1-RR*CTH*CTH)	0035
1 EX = CA*ESA	0036
EX = CB*ESA	0037
EX = CG*ESA	0038
EX = (EX*SPH-EY*CPH)*(RH-RV)	0039
EX = EX*RV+EY*SPH	0040
EX = EX*RV+EY*CPH	0041
EX = EX*RV	0042
EX = EX*CA-EY*CB+EZ*CG	0043
EX = CA*ESA	0044
EX = CB*ESA	0045
EX = CG*ESA	0046
EX = (EX*SPH-EY*CPH)*(RH-RV)	0047
EX = EX*RV+EY*SPH	0048
EX = EX*RV+EY*CPH	0049
EX = EX*RV	0050
EX = EX*CA-EY*CB+EZ*CG	0051
2 T = (CA*CPH+CB*SPH)*CTH+CG*STH	0052
T = (CA*CPH+CB*SPH)*CTH+CG*STH	0053
T = (CA*CPH+CB*SPH)*CTH+CG*STH	0054
ET1 = T*ESA	0055
ET2 = T*ESB	0056
EP1 = P*ESA	0057
EP2 = P*ESB	0058
3 CONTINUE	0059
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, θ_0, ϕ_0) , the excitation voltages induced by a incident plane wave are

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

where

$$\vec{E}_i = \vec{E}_0 \exp(\gamma \vec{r} \cdot \vec{r}_0)$$

where $\vec{E}_0$ 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 $\vec{E}_m$ is generated by test dipole m when radiating in the homogeneous medium. Using the vector potential, the field at the distance point (r_0, θ_0, ϕ_0) is

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

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

$$V_m = - \frac{4\pi r_0}{j\omega u} e^{jkr_0} e_0 e_m.$$

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. GGG denotes the time-average power density of the incident wave at the origin. $ACSP$ and $ACST$ denote the absorption cross sections for the phi and theta polarizations.

PIN and TIN denote the time-average power input to the wire structure, delivered by the equivalent voltage generators VP and VT at the terminals. PIN and TIN apply for the phi and theta polarizations, 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

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

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_{tt} 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,CJ,CM,D,ECSP,ECST,EP,ET,EPP,EPT,ETPS,ETPA,ET
2  TS,GG,CPA,GTT,PH,SGD,SCSP,SCST,SAPM,SAPH,STPH,STTM,TH,X,Y,Z,ZLD,ZS
3  ,ETA,GAM,ERR,IGRD)
C
C COMPLEX ERR
C COMPLEX CJ1,ET1,ET2,EPI,EP2,EPPS,ETTS,EPTS,ETPS,ZS,VP,VT
C COMPLEX C11,CJ11,EPI1,EP11,EPP11,ET11,ET21,ZLD11
C COMPLEX ETA,GAM,CGO11,SGD11,CJ111,EPP111,ET111,ZLD111
C
C DIMENSION IA(1),IB(1),11(1),12(1),13(1),MD(1),ND(1),NM(4)
C DIMENSION D(1),X(1),Y(1),Z(1),13(1),MD(1),ND(1),NM(4)
C DATA PI,TP/3.14159,0.20318/
C CJ1 = -4.*PI/(ETA*GAM)
C GG = REAL(1./ETA)
C THR = 0.174533*TH
C CTM = COS(THR)
C STM = SIN(THR)
C PHR = 0.174533*PH
C CPH = COS(PHR)
C SPH = SIN(PHR)
C
C DO 1 I=1,N
C   ET1(I) = (0.0,0)
C   EPP1(I) = (0.0,0)
C
C   DO 3 K=1,NM
C     KA = IA(K)
C     KB = IB(K)
C     NGRD = IGRD
C     IF (K.LE.NM/2) IGRD=-1
C     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)
C     IGRD = NGRD
C     NOK = ND(K)
C
C     DO 3 I1=1,NOK
C       I = MD(K,I1)
C       F1 = 1.
C       IF (KB.EQ.12(I)) GO TO 2
C       IF (KB.EQ.11(I)) F1=-1.
C       EPP1(I) = EPP1(I)*F1*EPI
C       ET1(I) = ET1(I)*F1*ET1
C       GO TO 3
C     2 IF (KA.EQ.13(I)) F1=-1.
C       EPP1(I) = EPP1(I)*F1*EP2
C       ET1(I) = ET1(I)*F1*ET2
C     3 CONTINUE
C
C   EPPS = (0.0,0)
C   ETTS = (0.0,0)
C   IF (INC.EQ.0) GO TO 8
C   IF (INC.EQ.2) GO TO 6
C
C   DO 4 I=1,N
C     ET(I) = ET1(I)*CJ1
C     EPP(I) = EPP1(I)*CJ1
C
C   CALL SCROT (C,EP,0,112,N)
C   112 = 2
C   CALL SCROT (C,ET,0,112,N)
C   IF (IMR.GT.0) WRITE (6,10) PH,TH
C   IF (IMR.GT.0) WRITE (6,11)
C   CALL RTE (IA,IB,INM,IMR,11,12,13,MD,ND,NM,EP,CG,IGRD)
C   CALL GOISS (AM,CG,CM,D,POIS,GAM,NM,SGD,ZLD,ZS)
C   IF (IMR.GT.0) WRITE (6,12)
C   CALL RTE (IA,IB,INM,IMR,11,12,13,MD,ND,NM,ET,CG,IGRD)
C   CALL GOISS (AM,CG,CM,D,TOIS,GAM,NM,SGD,ZLD,ZS)
C   ACSP = POIS/GGG
C   ACST = TOIS/GGG
C   PIN = 0
C   TIN = 0
C
C   DO 5 I=1,N
C     VP = CJ1*EPP(I)
C     VT = CJ1*ET(I)
C     PIN = PIN+REAL(VP*CONJG(EP(I)))
C     TIN = TIN+REAL(VT*CONJG(ET(I)))
C
C   ECSP = PIN/GGG
C   ECST = TIN/GGG
C   SCSP = ECSP-ACSP
C   SCST = ECST-ACST
C   EPTS = (0.0,0)
C   ETPS = (0.0,0)
C
C   DO 7 I=1,N
C     EPPS = EPPS+EPI*EPP(I)
C     EPTS = EPTS+EPI*ET1(I)
C     ETTS = ETTS+ET1*ET1(I)
C     ETPS = ETPS+ET1*EPP(I)
C
C   SPPH = 2.*TP*(CABS(EPPS)**2)
C   SPM = 2.*TP*(CABS(EPTS)**2)
C   STPM = 2.*TP*(CABS(ETPS)**2)
C   STTM = 2.*TP*(CABS(ETTS)**2)
C   RETURN
C
C   DO 9 I=1,N
C     ETTS = ETTS+CJ111*ET111
C     EPPS = EPPS+CJ111*EPP111
C
C   APP = CABS(EPPS)
C   ATT = CABS(ETTS)
C   GPP = 4.*PI*APP*APP*GGG/GG
C   GTT = 4.*PI*ATT*ATT*GGG/GG
C   RETURN
C
C   10 FORMAT (10X,'BRANCH CURRENTS ASSOCIATED WITH PLANE-WAVE SCATTERING
11 FOR THE INCIDENT ANGLES PHI=',FS.1,' AND THETA=',FS.1//)
C   11 FORMAT (44X,'CURRENTS INDUCED BY THE PHI POLARIZED WAVE')
C   12 FORMAT (44X,'CURRENTS INDUCED BY THE THETA POLARIZED WAVE')
C   END

```


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:

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

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

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

The functions F_{ik} are defined by:

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

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:

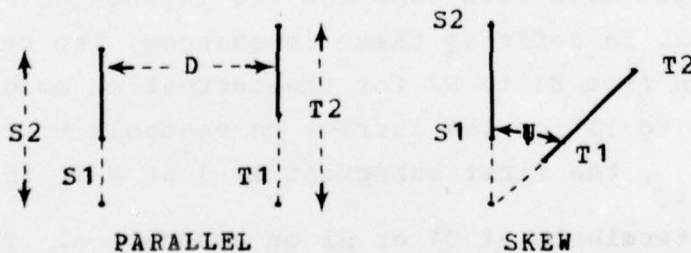
$$G_{ik} = E(R_2 + qz_2 + q't - jq'') + E(R_2 + qz_2 + q't + jq'') \\ - E(R_1 + qz_1 + q't - jq'') - E(R_1 + qz_1 + q't + jq'')$$

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

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

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

where a and q'' are real quantities with dimensions of length, a is a function of t , $a_1 = a(t_1)$, $a_2 = a(t_2)$ and $\gamma = j\omega \sqrt{\mu\epsilon}$. 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 ψ tends to zero or π . Therefore, if the monopoles are within 4.5° of being parallel, they are approximated by parallel dipoles.

CALLED BY: GGS

SGANT

CALLS TO: EXPJ

```

SUBROUTINE GGMM (S1,S2,T1,T2,D,CGDS,SGD1,SGD2,CPSI,ETA,GAM,P11,P12
1,P21,P22)
1
2  DOUBLE PRECISION R1,R2,DPQ,SIS,TS1,TS2,ST1,ST2,CD,HD,CPSS,SK,TL1,T
3
4  IL2,T01,T02,S01,DPS1,CD,Z0
5  COMPLEX CGDS,SGDS,SGDT,SGD1,SGD2,ETA,GAM,P11,P12,P21,P22
6  COMPLEX CS1,EB,EC,EK,EL,EKL,EGZ1,ES1,ES2,ET1,ET2,EXPA,EXPB
7  COMPLEX EG2(2,2),GM(2,2),GP(2)
8  DATA PI/3.14159/
9  DSQ = D*D
10 SGD = SGD1
11 IF (S2.LT.S1) SGD = -SGD1
12 SGD1 = SGD2
13 IF (T2.LT.T1) SGDT = -SGD2
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 DPS1 = CPSI
21 T01 = T1
22 T02 = T2
23 CPSS = DPS1*DPS1
24 CD = DD/DSQRT(1.00-CPSS)
25 C = CD
26 BD = CD*DPS1
27 B = BD
28 EB = CEXP(GAM*CMPLX(.0,B))
29 EC = CEXP(GAM*CMPLX(.0,C))
30
31 DO 1 K=1,2
32
33 DO 1 L=1,2
34
35 I E(K,L) = (.0,.0)
36
37 TS1 = T01*T01
38 TS2 = T02*T02
39 DPQ = DD*DD
40 SI = S1
41
42 DO 4 I=1,2
43 FI = (-1)**I
44 S01 = S1
45 SIS = S01*S01
46 ST1 = 2.*S01*T01*DPS1
47 ST2 = 2.*S01*T02*DPS1
48 RI = DSQRT(DPQ*SIS+TS1-ST1)

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RZ = DSQRT(DPQ+SIS+TS2-ST2)
EK = ER
C
DO 3 K=1,2
FK = (-1)**K
SK = FK*SDI
EL = EC
C
DO 2 L=1,2
FL = (-1)**L
EKL = EK*EL
XX = FK*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)+F1*(EXPA*EKL+EXPB/EKL)
2 EL = 1./EC
C
3 EK = 1./EB
C
ZD = SDI*OPSI
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(1,1) = Z*SGDS*EXPA/EGZ1
F(1,2) = 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 IF (CPSI.LT.0.) GO TO 6
TA = T1

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TB = T2
GO TO 1
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.LT.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)
11/EGZ(1,2)))
P12 = CST*(-GM(2)*EGZ(2,1)-GP(2)/EGZ(2,1)+CGDS*(GM(1)*EGZ(1,1)+GP(
11/EGZ(1,1)))
P21 = CST*(GM(1)*EGZ(1,2)+GP(1)/EGZ(1,2)-CGDS*(GM(2)*EGZ(2,2)+GP(2)
11/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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GGG

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) . DS and DT denote the lengths of monopoles s and t , respectively, CAS , CBS and CGS are the direction cosines of monopole s , and CA , CB and CG are the direction cosines of monopole t .

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

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

Since the point (X, Y, Z) of subroutine GNF lies on the expansion monopole t , T is the integration variable and is measured from (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 $\vec{S}$ denote a unit vector in the direction from (X_A, Y_A, Z_A) toward (X_B, Y_B, Z_B) . Also let $\vec{T}$ denote a unit vector from (X_1, Y_1, Z_1) toward (X_2, Y_2, Z_2) . Then $\vec{S} \cdot \vec{T} = \cos \theta = CC$ where θ is the angle formed by the axes of the two monopoles. Let monopole s lie in one plane P_s and monopole t lie in another parallel plane P_t . CAD, CBD and CGD are the direction cosines of the unit vector $\vec{d} = \vec{T} \times \vec{S} / \sin \theta$ which is perpendicular to both planes. To obtain the distance DK between the two planes, a vector $\vec{R}_{11}$ is constructed from (X_A, Y_A, Z_A) to (X_1, Y_1, Z_1) and take $DK = \vec{R}_{11} \cdot \vec{d}$.

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 $\vec{S} \times \vec{d}$ 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_s . This line is parallel with $\vec{d}$ and has length DK.

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,DT,SGDT,INT,ETA,GAM,P11,P12,P21,P22,ERR,IGRD) 0002
COMPLEX EX,EY,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,RH1,RV1,RH2,RV2,RH3,RV3,RH4,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 (CC.LE..003).AND.(CGS.LE..003).AND.(IGRD.GT.0) GO TO 1 0018
IF (ABS(CC).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
IP = INS+1 0024
DELT = DT/INS 0025
E = .0 0026
DSZ = CC*DELT 0027
P11 = (.0,.0) 0028
P12 = (.0,.0) 0029
P21 = (.0,.0) 0030
P22 = (.0,.0) 0031
AMS = AM*AM 0032
SGN = -1. 0033
C 0034
C 0035
DO 5 IN=1,IP 0036
YY1 = 3Y 0037
XXY = X1+DS 0038
YYZ = Y1+DS 0039
ZZZ = Z1+DS 0040
RS = XXZ**2+YYZ**2+ZZZ**2 0041
R1 = SQRT(RS+ZZZ**2) 0042
EJA = CEXP(-GAM*R1) 0043
EJ1 = EJA/R1 0044
R2 = SQRT(RS+ZZZ**2) 0045
EJB = CEXP(-GAM*R2) 0046
EJ2 = EJB/R2 0047
0048

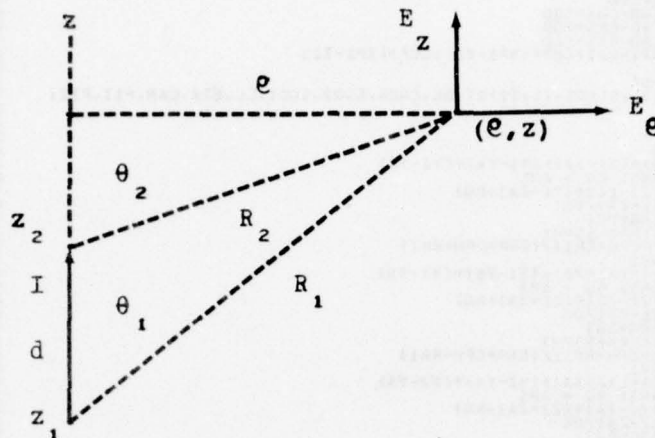
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ZZ = ZA+SZ*CGS	0145
XP1 = X1-DK*CAO	0146
YP1 = Y1-DK*CAD	0147
ZP1 = Z1-DK*CGD	0148
CAP = CBS*CGD-CGS*CBD	0149
CBP = CGS*CAD-CAS*CGD	0150
CGP = CAS*CBD-CBS*CAD	0151
P1 = CAP*(XP1-XZ)+CBP*(YP1-YZ)+CGP*(ZP1-ZZ)	0152
T1 = P1/SS	0153
S1 = T1*CC-SZ	0154
CALL GMM (S1,S1+DS,T1,T1+DT,DK,CGDS,SGDS,SGDT,CC,ETA,GAM,P11,P12,	0155
IP21,P22)	0156
RETURN	0157
C	0158
8 AMS = AM*AM	0159
RG = (X1-XA)*(X1-XA)+(Y1-YA)*(Y1-YA)	0160
IF (RG.LT.AMS) RG = AMS	0161
DG = SQRT((Z1-ZA)*(Z1-ZA)+RG)	0162
CPH = ABS(Z1-ZA)/DG	0163
SSPH = RG/(DG*DG)	0164
RR1 = CSQRT(ERR-SSPH)	0165
RV1 = -(ERR*CPH-RR1)/(ERR*CPH+RR1)	0166
P11 = -P1*RV1	0167
RG = (X1-XB)*(X1-XB)+(Y1-YB)*(Y1-YB)	0168
IF (RG.LT.AMS) RG = AMS	0169
DG = SQRT((Z1-ZB)*(Z1-ZB)+RG)	0170
CPH = ABS(Z1-ZB)/DG	0171
SSPH = RG/(DG*DG)	0172
RR1 = CSQRT(ERR-SSPH)	0173
RV1 = -(ERR*CPH-RR1)/(ERR*CPH+RR1)	0174
P12 = -P2*RV1	0175
RG = (X2-XA)*(X2-XA)+(Y2-YA)*(Y2-YA)	0176
IF (RG.LT.AMS) RG = AMS	0177
DG = SQRT((Z2-ZA)*(Z2-ZA)+RG)	0178
CPH = ABS(Z2-ZA)/DG	0179
SSPH = RG/(DG*DG)	0180
RR1 = CSQRT(ERR-SSPH)	0181
RV1 = -(ERR*CPH-RR1)/(ERR*CPH+RR1)	0182
P21 = -P1*RV1	0183
RG = (X2-XB)*(X2-XB)+(Y2-YB)*(Y2-YB)	0184
IF (RG.LT.AMS) RG = AMS	0185
DG = SQRT((Z2-ZB)*(Z2-ZB)+RG)	0186
CPH = ABS(Z2-ZB)/DG	0187
SSPH = RG/(DG*DG)	0188
RR1 = CSQRT(ERR-SSPH)	0189
RV1 = -(ERR*CPH-RR1)/(ERR*CPH+RR1)	0190
P22 = -P2*RV1	0191
RETURN	0192
END	0193

GNF

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



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

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

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

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

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

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

These expressions exclude the field contributions from the point 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 ρ , and RS denote ρ^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 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 EE = (EX1*SPH-EY1*CPH)*(RH1-RV1)
63 EX1 = -EX1*RV1+EY1*SPH
64 EY1 = -EY1*RV1-EY1*CPH
65 EZ1 = (-RV1)
66 EE = (EX2*SPH-EY2*CPH)*(RH2-RV2)
67 EX2 = -EX2*RV2+EY2*SPH
68 EY2 = -EY2*RV2-EY2*CPH
69 EZ2 = (-RV2)
70 RETURN
71 END

```

GNFLD

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

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

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

CALLED BY: MAIN

CALLS TO: GPF

```

SUBROUTINE GNFLD (IA,IB,INM,I1,I2,I3,MO,N,ND,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(1),CGD(1),SGD(1) 0005
DIMENSION IA(1),IB(1),I1(1),I2(1),I3(1),D(1),X(1),Y(1),Z(1 0006
1) 0007
DIMENSION MO(INM,4),ND(1) 0008
DATA PI,TP/3.14159,6.28318/ 0009
EX = (0.0,0) 0010
EY = (0.0,0) 0011
EZ = (0.0,0) 0012
C 0013
DO 2 K=1,NM 0014
KA = IA(K) 0015
KB = IB(K) 0016
NGRD = IGRD 0017
IF (K,LE,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 = ND(K) 0022
C 0023
DO 2 II=1,NOK 0024
FI = MO(K,II) 0025
FI = 1. 0026
IF (KB,EQ,I2(1)) GO TO 1 0027
IF (KB,EQ,I1(1)) FI=-1. 0028
EX = EX+FI*EX1* CJ(1) 0029
EY = EY+FI*EY1* CJ(1) 0030
EZ = EZ+FI*EZ1* CJ(1) 0031
GO TO 2 0032
1 IF (KA,EQ,I3(1)) FI=-1. 0033
EX = EX+FI*EX2* CJ(1) 0034
EY = EY+FI*EY2* CJ(1) 0035
EZ = EZ+FI*EZ2* CJ(1) 0036
2 CONTINUE 0037
C 0038
RETURN 0039
END 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 = INT(X)
I = IABS(I)
Z = ABS(X)
IF ((Z-1).GT.0.5) I=I+1
IF (Z.LT.10.0-0.5-2.GT.111.0) GO TO 2
LINE(1) = ISYM(2)
LINE(60) = ISYM(3)
LINE(62) = ISYM(3)
K = K+1
IF (K.EQ.2) GO TO 2
I = IZ-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 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

```
C
C
C      SUBROUTINE NUMB (Y)
C      THIS SUBROUTINE PUTS DEGREE NUMBERS ON POLAR GRID
C      COMMON ISYM,LINE
C      INTEGER Y
C      DIMENSION ISYM(14), LINE(130)
C      IF (Y.NE.37) GO TO 1
C      LINE(33) = ISYM(7)
C      LINE(34) = ISYM(8)
C      LINE(35) = ISYM(6)
C      LINE(87) = ISYM(6)
C      LINE(88) = ISYM(12)
C      LINE(89) = ISYM(6)
C 1    IF (Y.NE.21) GO TO 2
C      LINE(12) = ISYM(7)
C      LINE(13) = ISYM(11)
C      LINE(14) = ISYM(6)
C      LINE(108) = ISYM(6)
C      LINE(109) = ISYM(9)
C      LINE(110) = ISYM(6)
C 2    IF (Y.NE.0) GO TO 3
C      LINE(7) = ISYM(7)
C      LINE(8) = ISYM(13)
C      LINE(9) = ISYM(6)
C      LINE(113) = ISYM(6)
C      LINE(114) = ISYM(6)
C      LINE(115) = ISYM(6)
C 3    IF (Y.NE.-21) GO TO 4
C      LINE(12) = ISYM(8)
C      LINE(13) = ISYM(7)
C      LINE(14) = ISYM(6)
C      LINE(108) = ISYM(9)
C      LINE(109) = ISYM(9)
C      LINE(110) = ISYM(6)
C 4    IF (Y.NE.-37) GO TO 5
C      LINE(33) = ISYM(8)
C      LINE(34) = ISYM(10)
C      LINE(35) = ISYM(6)
C      LINE(87) = ISYM(9)
C      LINE(88) = ISYM(6)
C      LINE(89) = ISYM(6)
C 5    CONTINUE
C      RETURN
C      END
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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(80)
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
2 IF (ISET.EQ.1) II = II+1
C
3 DO 3 K=1,10
  IF (A(I).EQ.B(K)) GO TO 4
3 CONTINUE
C
4 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

```

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, DATAY, and X, the input data, Y, is scanned to determine the normalizing factor. If this normalizing factor is less than $1.E-32$, an error statement is printed and the plotting is 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) = 0*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,5)
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

```


	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
C	IF (AMAG.GT.DIM) GO TO 6	101
C	OK IS THE FINAL LINE POSITION FOR THE '**	102
	OK = DATAX(JJ)*5*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
C	PRINT OUT ONE LINE OF PLOT	114
C	WRITE (6,14) LINE	115
8	CONTINUE	116
C	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	1 10X,1A4,'-',1A4,' (INCIDENT-SCATTERED) IS LESS THAN '/	122
2	2 10X, ' 1.E-30.) POLAR PLOT NOT CALLED.'//)	123
11	FORMAT ('',1A4,' ELECTRIC FIELD ANTENNA PATTERN FOR SPECIFIED PLA	124
INE	11 '9X,'NORMALIZING FACTOR=',E10.5)	125
12	FORMAT ('',1A4,' BISTATIC SCATTERING PATTERN FOR',1A4,'-',1A4,'(INCIDENT-	126
13	12 SCATTERED) POLARIZATION.',9X,'NORMALIZING FACTOR=',E10.5)	127
13	13 FORMAT ('',1A4,' BACKSCATTERING PATTERN FOR',1A4,'-',1A4,'(INCIDENT-SCATT	128
14	14 ERED) POLARIZATION.',9X,'NORMALIZING FACTOR=',E10.5)	129
	END	130
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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

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


```

10 IF ((A(1).NE.AW).OR.(A(2).NE.AI).OR.(A(3).NE.AR).OR.(A(4).NE.AE)) 97
    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 13 IF ((A(1).NE.AC).OR.(A(2).NE.AX).OR.(A(3).NE.AT).OR.(A(4).NE.AE)) 120
    GO TO 17 121
    KFLAG(8) = 1 122
    CALL LEFT (N) 123
C 14 IF ((A(N).NE.AC).OR.(A(N+1).NE.AD).OR.(A(N+2).NE.AN).OR.(A(N+3).NE 124
    1.AD)) GO TO 15 125
    KFLAG(9) = 1 126
    CALL EQUAL (N) 127
    CALL NUMBER (N,N2,X1,IX) 128
    SIG3 = X1 129
    IF (A(N2).EQ.RIGHT) GO TO 4 130
    IF (A(N2).NE.SLANT) GO TO 71 131
    N = N2+1 132
    GO TO 14 133
C 15 IF ((A(N).NE.AD).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AE).OR.(A(N+3).NE 134
    1.A1)) GO TO 16 135
    KFLAG(10) = 1 136
    CALL EQUAL (N) 137
    CALL NUMBER (N,N2,X1,IX) 138
    ER3 = X1 139
    IF (A(N2).EQ.RIGHT) GO TO 4 140
    IF (A(N2).NE.SLANT) GO TO 71 141
    N = N2+1 142
    GO TO 14 143
C 16 IF ((A(N).NE.AL).OR.(A(N+1).NE.AD).OR.(A(N+2).NE.AS).OR.(A(N+3).NE 144
    1.AS)) GO TO 71 145
    KFLAG(11) = 1 146
    CALL EQUAL (N) 147
    CALL NUMBER (N,N2,X1,IX) 148
    TD3 = X1 149
    IF (A(N2).EQ.RIGHT) GO TO 4 150
    IF (A(N2).NE.SLANT) GO TO 71 151
    N = N2+1 152
    GO TO 14 153
C 17 IF ((A(1).NE.AL).OR.(A(2).NE.AD).OR.(A(3).NE.AA).OR.(A(4).NE.AD)) 154
    GO TO 18 155
    KFLAG(14) = 1 156
    GO TO 19 157
C 18 IF ((A(1).NE.AI).OR.(A(2).NE.AMA).OR.(A(3).NE.AP).OR.(A(4).NE.AE)) 158
    GO TO 22 159
    KFLAG(24) = 1 160
    I = 1 161
    CALL LEFT (N) 162
    CALL NUMBER (N,N2,X1,IX) 163
    IF (IX.LE.0) GO TO 21 164
    LZD(I) = IX 165
    N = N2+1 166
    CALL NUMBER (N,N2,X1,IX) 167
    RMAG = X1 168
    N = N2+1 169
    CALL NUMBER (N,N2,X1,IX) 170
    RDEG = X1 171
    RREAL = RMAG*COS(RDEG/RAD) 172
    RIMAG = RMAG*SIN(RDEG/RAD) 173
    ZLDD(I) = CMPLX(RREAL,RIMAG) 174
    LOAD = 1 175
    IF (A(N2).EQ.RIGHT) GO TO 4 176
    IF (A(N2).NE.SLANT) GO TO 71 177
    I = I+1 178
    N = N2+1 179
    GO TO 20 180
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21 KFLAG(24) = -1
LOAD = -1
GO TO 4
C
C
C
FREQUENCY
22 IF ((A(1).NE.AF).OR.(A(2).NE.AR).OR.(A(3).NE.AE).OR.(A(4).NE.AQ))
IGOTO 23
KFLAG(1) = 1
CALL LEFT (N)
CALL NUMBER (N,N2,X1,IX)
FMC = X1
GO TO 4
C
C
C
PLOT
23 IF ((A(1).NE.AP).OR.(A(2).NE.AL).OR.(A(3).NE.AO).OR.(A(4).NE.AT))
IGOTO 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
C
C
27 DO 28 I=N,80
K = I+1
IF (A(I).EQ.SLANT) GO TO 29
28 CONTINUE
C
C
C
GO TO 71
29 N = K
IF (A(N).NE.AT).OR.(A(N+1).NE.AH).OR.(A(N+2).NE.AE).OR.(A(N+3).NE
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
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) AFFT=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
C
C
OUTPUT
31 IF ((A(1).NE.AO).OR.(A(2).NE.AU).OR.(A(3).NE.AT).OR.(A(4).NE.AP))
IGOTO 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

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C 33 IF ((A(N).NE.AF).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AR).OR.(A(N+3).NE
1,AF)) GO TO 34
KFLAG(16) = 1
IGAIN = 1
CALL EQUAL (N)
CALL NUMBER (N,N2,X1,IX)
PHAI = X1
N = N2+1
CALL NUMBER (N,N2,X1,IX)
PHAF = X1
N = N2+1
CALL NUMBER (N,N2,X1,IX)
THAI = X1
N = N2+1
CALL NUMBER (N,N2,X1,IX)
THAF = X1
IF (A(N2).EQ.RIGHT) GO TO 4
IF (A(N2).NE.SLANT) GO TO 71
N = N2+1
GO TO 32
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C 34 IF ((A(N).NE.AN).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AA).OR.(A(N+3).NE
1,AN)) GO TO 40
KFLAG(19) = 1
INEAR = 2
CALL EQUAL (N)
IF (A(N).EQ.PLEFT) GO TO 35
I = 1
GO TO 36
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C 35 DO 37 L=1,50
I = L
N = N+1
36 CALL NUMBER (N,N2,X1,IX)
XNPII = X1
N = N2+1
CALL NUMBER (N,N2,X1,IX)
YNPII = X1
N = N2+1
CALL NUMBER (N,N2,X1,IX)
INPII = X1
IF (INEAR.EQ.1) GO TO 39
INEAR = L+1
IF (A(N2).EQ.RIGHT) GO TO 38
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C 37 CONTINUE
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C 38 N2 = N2+1
INEAR = INEAR-1
39 IF (A(N2).EQ.RIGHT) GO TO 4
IF (A(N2).NE.SLANT) GO TO 71
N = N2+1
GO TO 32
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C 40 IF ((A(N).NE.AB).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AC).OR.(A(N+3).NE
1,AB)) GO TO 41
KFLAG(17) = 1
ISCAT = 1
CALL EQUAL (N)
CALL NUMBER (N,N2,X1,IX)
PHII = X1
N = N2+1
CALL NUMBER (N,N2,X1,IX)
PHIF = X1
N = N2+1
CALL NUMBER (N,N2,X1,IX)
THII = X1
N = N2+1
CALL NUMBER (N,N2,X1,IX)
THIF = X1
IF (A(N2).EQ.RIGHT) GO TO 4
IF (A(N2).NE.SLANT) GO TO 71
N = N2+1
GO TO 32
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C 41 IF ((A(N).NE.AC).OR.(A(N+1).NE.AU).OR.(A(N+2).NE.AR).OR.(A(N+3).NE
1,AR)) GO TO 43
KFLAG(15) = 1
IWR = 1
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C 42 CONTINUE
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	385
	1.AP)) GO TO 71	386
	CALL EQUAL (N)	387
	CALL NUMBER (N,N2,X1,IX)	388
	STEP = X1	389
	IF (A(N2).EQ.RIGHT) GO TO 4	390
	IF (A(N2).NE.SLANT) GO TO 71	391
	N = N2+1	392
	GO TO 32	393
C	FEED POINT	394
C		395
	44 IF ((A(1).NE.AF).OR.(A(2).NE.AE).OR.(A(3).NE.AE).OR.(A(4).NE.AD))	396
	IGO TO 45	397
	KFLAG(13) = 1	398
	GO TO 46	399
	45 IF ((A(1).NE.AG).OR.(A(2).NE.AE).OR.(A(3).NE.AN).OR.(A(4).NE.AE))	400
	IGO TO 49	401
	KFLAG(23) = 1	402
	NGEN = 0	403
	CALL LEFT (N)	404
	47 CALL NUMBER (N,N2,X1,IX)	405
	NGEN = NGEN+1	406
	KGEN(NGEN) = IX	407
	IF (A(N2).EQ.RIGHT) GO TO 4	408
	N = N2+1	409
	CALL NUMBER (N,N2,X1,IX)	410
	VMAG = X1	411
	N = N2+1	412
	CALL NUMBER (N,N2,X1,IX)	413
	VDEG = X1	414
	VREAL = VMAG*COS(VDEG/RAD)	415
	VIMAG = VMAG*SIN(VDEG/RAD)	416
	VOLT(NGEN) = CMPLX(VREAL,VIMAG)	417
	IF (A(N2).EQ.RIGHT) GO TO 4	418
	IF (A(N2).NE.SLANT) GO TO 71	419
	IF ((A(N2).EQ.SLANT).AND.(A(N2+1).EQ.BLANK)) GO TO 48	420
	N = N2+1	421
	GO TO 47	422
	48 READ (5,76) A	423
	ICARD = ICARD+1	424
	WRITE (6,77) ICARD,A	425
	N = 1	426
	CALL BLNK (A)	427
	GO TO 47	428
C		429
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C	DESCRIPTION	433
C		434
	49 IF ((A(1).NE.AD).OR.(A(2).NE.AE).OR.(A(3).NE.AS).OR.(A(4).NE.AC))	435
	IGO TO 52	436
	KFLAG(12) = 1	437
	J = 0	438
	CALL LEFT (N)	439
	CALL NUMBER (N,N2,X1,IX)	440
	J = J+1	441
	NM = J	442
	IA(J) = IX	443
	N = N2+1	444
	CALL NUMBER (N,N2,X1,IX)	445
	IB(J) = IX	446
	IF (A(N2).EQ.RIGHT) GO TO 4	447
	IF (A(N2).NE.SLANT) GO TO 71	448
	IF ((A(N2).EQ.SLANT).AND.(A(N+1).EQ.BLANK)) GO TO 51	449
	N = N2+1	450
	GO TO 50	451
	51 READ (5,76) A	452
	ICARD = ICARD+1	453
	CALL BLNK (A)	454
	WRITE (6,77) ICARD,A	455
	N = 1	456
	GO TO 50	457
C	GEOMETRY	458
C		459
	52 IF ((A(1).NE.AG).OR.(A(2).NE.AE).OR.(A(3).NE.AD).OR.(A(4).NE.AMA))	460
	IGO TO 55	461
	KFLAG(12) = 1	462
	JJ = 0	463
	CALL LEFT (N)	464
	CALL NUMBER (N,N2,X1,IX)	465
	JJ = JJ+1	466
	NP = JJ	467
	X(JJ) = X1	468
	N = N2+1	469
	CALL NUMBER (N,N2,X1,IX)	470
	Y(JJ) = X1	471
	N = N2+1	472
	CALL NUMBER (N,N2,X1,IX)	473
	Z(JJ) = X1	474
	IF (A(N2).EQ.RIGHT) GO TO 4	475
	IF (A(N2).NE.SLANT) GO TO 71	476
	IF ((A(N2).EQ.SLANT).AND.(A(N+1).EQ.BLANK)) GO TO 54	477
	N = N2+1	478
	GO TO 53	479
		480

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
	1GO 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
	1GO 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
	1,AF)) GO TO 58	504
	IGRD = 1	505
	GO TO 64	506
	58 IF ((A(N).NE.AG).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AO).OR.(A(N+3).NE	507
	1,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.AO).OR.(A(N+3).NE	512
	1,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.A1).OR.(A(N+3).NE	521
	1,AG)) GO TO 62	522
	CALL EQUAL (N)	523
	CALL NUMBER (N,N2,X1,IX)	524
		525
	HGT = X1	526
	IF (A(N2).EQ.RIGHT) GO TO 4	527
	IF (A(N2).NE.SLANT) GO TO 71	528
	N = N2+1	529
	GO TO 57	530
	62 IF ((A(N).NE.AC).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AN).OR.(A(N+3).NE	531
	1,AD)) GO TO 63	532
	CALL EQUAL (N)	533
	CALL NUMBER (N,N2,X1,IX)	534
	SIG4 = X1	535
	IF (A(N2).EQ.RIGHT) GO TO 4	536
	IF (A(N2).NE.SLANT) GO TO 71	537
	N = N2+1	538
	GO TO 57	539
	63 IF ((A(N).NE.AO).OR.(A(N+1).NE.A1).OR.(A(N+2).NE.AE).OR.(A(N+3).NE	540
	1,AL)) GO TO 71	541
	CALL EQUAL (N)	542
	CALL NUMBER (N,N2,X1,IX)	543
	ER4 = X1	544
	IF (A(N2).EQ.RIGHT) GO TO 4	545
	IF (A(N2).NE.SLANT) GO TO 71	546
	N = N2+1	547
	GO TO 57	548
C	64 DO 65 K=N,80	549
	IF (A(K).EQ.RIGHT) GO TO 4	550
	N = K+1	551
	IF (A(K).EQ.SLANT) GO TO 57	552
	65 CONTINUE	553
C		554
C	GO TO 71	555
C		556
C	66 IF ((A(1).NE.AS).OR.(A(2).NE.AT).OR.(A(3).NE.AO).OR.(A(4).NE.AP))	557
	1GO TO 67	558
	IFLAG = 2	559
	RETURN	560
C	67 IF ((A(1).NE.AC).OR.(A(2).NE.AH).OR.(A(3).NE.AA).OR.(A(4).NE.AN))	561
	1GO TO 68	562
	IFLAG = 3	563
	RETURN	564
C	68 IF ((A(1).NE.AE).OR.(A(2).NE.AN).OR.(A(3).NE.AO)) GO TO 71	565
		566
	IFLAG = 1	567
	RETURN	568
	69 IFLAG = 5	569
	RETURN	570
	70 IFLAG = 4	571
	RETURN	572
	71 MSG = 1	573
	KFLAG(30) = ICARD	574
	GO TO 4	575
	72 IF (IFLAG.NE.5) WRITE (6,78)	576
	IFLAG = 5	577
	RETURN	578
C	73 IFLAG = 6	579
	ICARD = ICARD-1	580
	RETURN	581
C		582
C	74 FORMAT (5X,80A1)	583
	75 FORMAT (///5X,'DATA CARDS'///)	584
	76 FORMAT (80A1)	585
	77 FORMAT (6X,12,2X,80A1)	586
	78 FORMAT (' ***** END CARD/STOP CARD MISSING*****')	587
	END	588
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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(1), IB(1), I1(1), I2(1), I3(1), MD(INM,4), ND(1)
AMAX = .0
C
DO 3 K=1,NM
KA = IA(K)
KB = IB(K)
CJA = (.0,.0)
CJB = (.0,.0)
NOK = NO(K)
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)
1)
8 FORMAT (/2(46X,'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

```

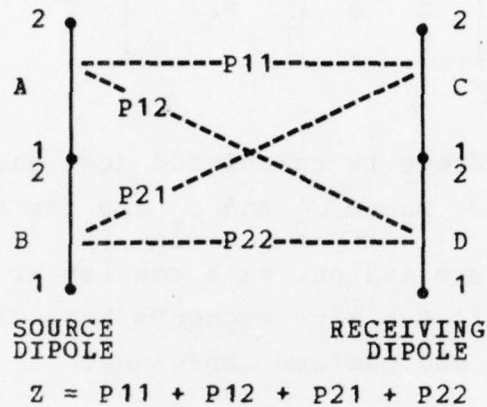
C      SUBROUTINE SART (DATA, DATAY, N)
C      DIMENSION DATA(500), DATAY(500)
C      THIS ROUTINE SORTS DATA IN DATAY BY MAGNITUDE
C      NN = N-1
C      DO 2 I=1, NN
C      NM = I+1
C      DO 1 J=NM, N
C      IF (DATAY[I], GE, DATAY[J]) GO TO 1
C      STOR = DATAY[I]
C      DATA Y(I) = DATAY[J]
C 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

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SGANT

PURPOSE: to calculate the mutual impedance between filamentary monopoles.



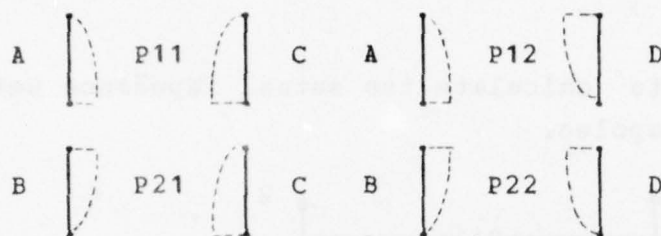
METHOD: In the induced emf formulation, the mutual impedance of coupled dipoles is

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

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

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

At statement 5, the program selects a segment K, and a few statements below this it selects another segment L. K is a segment of test 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 filamentary electric monopoles. These monopoles are parallel and have the same length. Monopole K is positioned on the axis of the wire segment, and monopole L is on the surface of the same wire segment. Thus, the displacement is equal to the wire radius. The two monopoles are side-by-side with no stagger.

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

CALLED BY: MAIN

CALLS TO: CBES

DSHELL

GGMM

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	IJ = MM+J	193
	FI = 1	194
	IF (K.EQ.2) GO TO 20	195
	IF (I1(J).NE.I1) FI=-1	196
	C(IJ) = C(IJ)+FI*ZLD(IJ)	197
	GO TO 21	198
20	IF (I3(J).NE.I3(I)) FI=-1.	199
21	C(IJ) = C(IJ)+FI*ZLD(J2)	200
C	CONTINUE	201
C	22 JJJ = JJB	202
C	23 CONTINUE	203
C	RETURN	204
C		205
	24 FORMAT (3X,'AM = ',E10.3,3X,'OMAX = ',E10.3,3X,'DMIN = ',E10.3)	206
	25 FORMAT (1,'WARNING *****')	207
	1,' THIS PROBLEM EXCEED LIMIT OF THIN WIRE CONDITION, THE RESULTS	208
	2' ARE NOT CORRECT')	209
	END	210
		211
		212
		213

SORT

PURPOSE: to define the set of dipole modes.

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

CALLED BY: MAIN

CALLS TO: NONE

	* SUBROUTINE SORT (IA,IB,I1,I2,I3,JA,JB,MD,ND,NM,NP,N,MAX,MIN,ICJ,IN	1
	1M)	2
	DIMENSION JSP(20)	3
	DIMENSION I1(1), I2(1), I3(1), JA(1), JB(1)	4
	DIMENSION IA(1), IB(1), ND(1), MD(1NM,4)	5
	I = 0	6
C	DO 3 K=1,NP	7
	NJK = 0	8
C	DO 1 J=1,NM	9
	IND = (IA(J)-K)*(IB(J)-K)	10
	IF (IND.NE.0) GO TO 1	11
	NJK = NJK+1	12
	JSP(NJK) = J	13
1	CONTINUE	14
C	MOD = NJK-1	15
	IF (MOD.LE.0) GO TO 3	16
C	DO 2 IMD=1,MOD	17
	I = I+1	18
	IF (I.GT.ICJ) GO TO 2	19
	IPD = IMD+1	20
	JAI = JSP(IPD)	21
	JBI = JSP(JAI)	22
	I1(I) = IA(JAI)	23
	IF (IA(JAI).EQ.K) I1(I)=IB(JAI)	24
	I2(I) = K	25
	I3(I) = IA(JBI)	26
	IF (IA(JBI).EQ.K) I3(I)=IB(JBI)	27
2	CONTINUE	28
C	3 CONTINUE	29
C	N = I	30
C	DO 4 J=1,NM	31
	ND(J) = 0	32
C	DO 4 K=1,4	33
4	MD(J,K) = 0	34
C	I1I = N	35
	IF (N.GT.ICJ) I1I = ICJ	36
C		37
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C	DO 7 L=1,2	53
	ND(J) = ND(J)+1	54
	K = 1	55
	M = 0	56
5	NJK = MD(J,K)	57
	IF (NJK.NE.0) GO TO 6	58
	M = 1	59
	MD(J,K) = 1	60
6	K = K+1	61
	IF (K.GT.4) GO TO 7	62
	IF (M.EQ.0) GO TO 5	63
7	J = JB(I)	64
C	8 CONTINUE	65
C	MIN = 100	66
	MAX = 0	67
C	DO 9 J=1,NM	68
	NDJ = ND(J)	69
	IF (NDJ.GT.MAX) MAX=NDJ	70
9	IF (NDJ.LT.MIN) MIN=NDJ	71
C	RETURN	72
	END	73
		74
		75
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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: GFFLD

CALLS TO: NONE

```

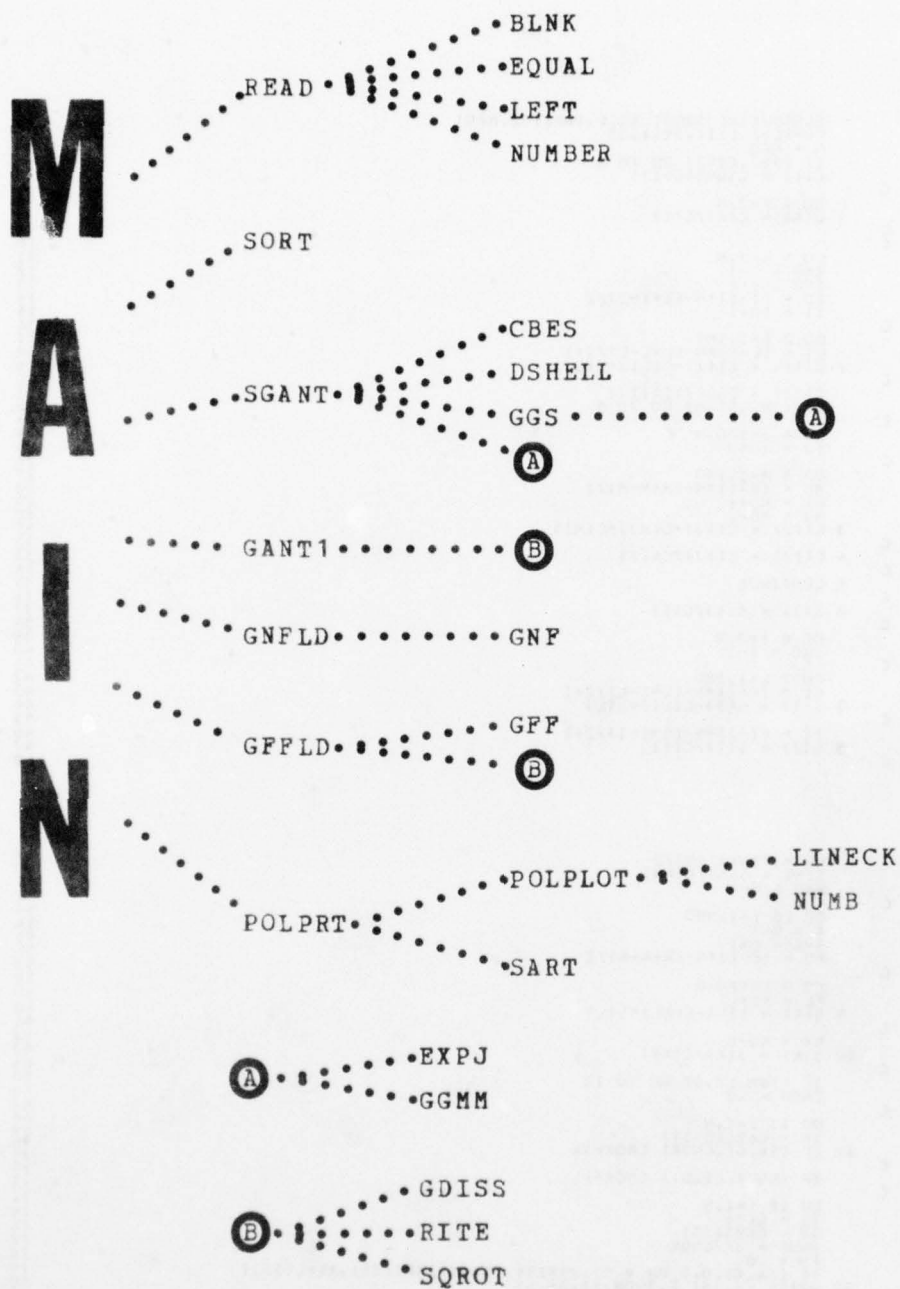
SUBROUTINE SQROT (C,S,IWR,I12,NEQ)
COMPLEX C(1),S(1),SS
N = NEQ
IF (I12.EQ.2) GO TO 6
C(1) = CSQRT(C(1))
C
DO 1 K=2,N
1 C(K) = C(K)/C(1)
C
DO 5 I=2,N
IMO = I-1
IPO = I+1
ID = (I-1)*N-(I+1-1)/2
II = ID+1
C
DO 2 L=1,IMO
LI = (L-1)*N-(L+1-1)/2+1
2 C(LI) = C(LI)-C(LI)*C(LI)
C(LI) = CSQRT(C(LI))
IF (IPO.GT.N) GO TO 5
C
DO 4 J=IPO,N
IJ = ID+J
C
DO 3 M=1,IMO
MO = (M-1)*N-(M+1-1)/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+1-1)/2+1
7 S(LI) = S(LI)-C(LI)*S(LI)
C
II = (I-1)*N-(I+1-1)/2+1
8 S(II) = S(II)/C(LI)
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 = CABS(S(I))
11 IF (SA.GT.CNOR) CNOR=SA
C
IF (CNOR.LE.0.) CNOR=1.
C
DO 12 I=1,N
SS = S(I)
SA = CABS(SS)
SNOR = SA/CNOR
PH = .0
IF (SA.GT.0.) PH = 57.29578*ATAN2(AIMAG(SS),REAL(SS))
12 WRITE (6,14) I,SNOR,SA,PH,SS
C
13 RETURN
C
14 FORMAT (1X,15,1F10.3,1F15.7,1F10.0,2F15.6)
15 FORMAT (1X,15)
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 γd for a given segment
CJ	loop currents for the structure
CMM	conductivity of the wire
D	length of a given segment
ECSP	extinction cross section for phi polarization
ECST	extinction cross section for theta polarization
EFF	radiation efficiency
EP	loop currents induced by a phi polarized wave
EPP	phi-polarized far-zone feild of the dipole mode
EPPS	scattered electric field in the phi direction due to a phi polarized wave
EPTS	scattered electric field in the theta direction due to a phi polarized wave
EP2	complex permittivity of insulation
EP3	complex permittivity of ambient medium
EP4	complex permittivity of ground
ERR	$EP4/EP3$
ER2	relative dielectric constant of insulation

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

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

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

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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 similiar to the initial one; that is, repeat the word "FEED". If only one voltage source is applied to the structure, only the node number must be stated. In the dipole example, if the drive is at node 3, the FEED CARD might appear as:

FEED(3)

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

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

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

LOAD(-1)

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

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

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

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

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

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

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

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

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

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

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

```
FREQ(12.5)
```

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

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

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

```

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

```

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


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

DATA CARDS

```
1 WIRE(RADI=1M)
2 GEOM(10,-.18,18/0,-.09,+.09/0,0.0/0,-.09,.09/0,-.18,.18)
3 DESC(1-2/2-3/3-4/4-5)
4 FEED(1)
5 OUTPI(ARF=45,50,65,80/STEP=5)
6 CHANGE
```

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

```
WIRE RADIUS (METERS) 0.10000E-02
WIRE INSULATED (NO/YES) NO
WIRE EXTERIOR MEDIUM NO
GROUND PLANE (NO/YES) NO
```

SEG NO.	WIRE NO.	LOCATION	Y	X	NO.	WIRE NO.	LOCATION	Y	X	NO.
1	1	-0.18000E-01	0.0	0.0	2	1	-0.18000E-01	0.0	0.0	2
2	2	-0.90000E-01	0.0	0.0	3	2	-0.90000E-01	0.0	0.0	3
3	3	0.0	0.0	0.0	4	3	0.0	0.0	0.0	4
4	4	0.90000E-01	0.0	0.0	5	4	0.90000E-01	0.0	0.0	5

```
ANTENNA FEEDS
REAL VOLTS 0.10000E 01
IMAGINARY 0.0
```

```
*****
* OUTPUT REQUESTED
*****
```

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

```

*****
*               *
*   ANTENNA     *
*   CALCULATIONS *
*               *
*****

```

THE INPUT IMPEDANCE AT NODE 3 IS 46.2782898 + J 26.5534973

THE RADIATION EFFICIENCY IS 99.5343018

THE TIME-AVERAGE POWER INPUT IS 0.0162564

THE ANTENNA IMPEDANCE IS 46.2782898 + J 26.5534973

 * FAR FIELD *
 * CALCULATIONS *

DEGREES		POWER GAIN		ELECTRIC FIELD INTENSITY		PHASE		MAGN		PHI		MAGN		PHI	
THETA	PHI	THETA	PHI	REAL	IMAG	THETA	PHI	REAL	IMAG	THETA	PHI	REAL	IMAG	THETA	PHI
65.00	45.00	0.2149E+00	0.6635E+00	-.2811E+00	-.1596E-01	0.00	0.00	-.2811E+00	-.1596E-01	0.00	0.00	-.2811E+00	-.1596E-01	0.00	0.00
75.00	45.00	0.1915E+00	0.6635E+00	-.2723E+00	-.3989E-01	0.00	0.00	-.2723E+00	-.3989E-01	0.00	0.00	-.2723E+00	-.3989E-01	0.00	0.00
85.00	45.00	0.1554E+00	0.6635E+00	-.2571E+00	-.1987E-01	0.00	0.00	-.2571E+00	-.1987E-01	0.00	0.00	-.2571E+00	-.1987E-01	0.00	0.00
95.00	45.00	0.1198E+00	0.6635E+00	-.2302E+00	-.1710E-01	0.00	0.00	-.2302E+00	-.1710E-01	0.00	0.00	-.2302E+00	-.1710E-01	0.00	0.00
105.00	45.00	0.0819E+00	0.6635E+00	-.2017E+00	-.1066E-01	0.00	0.00	-.2017E+00	-.1066E-01	0.00	0.00	-.2017E+00	-.1066E-01	0.00	0.00
115.00	45.00	0.0581E+00	0.6635E+00	-.1767E+00	-.4190E-01	0.00	0.00	-.1767E+00	-.4190E-01	0.00	0.00	-.1767E+00	-.4190E-01	0.00	0.00

CONTINUE EXECUTION WITH THE FOLLOWING ADDITIONS AND/OR CHANGES

DATA CARDS

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

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

```

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

```

```
*****
*                               *
*      OUTPUT REQUESTED        *
*                               *
*****
```

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

 *
 * ANTENNA *
 * CALCULATIONS *
 *

THE INPUT IMPEDANCE AT NODE 3 IS 46.2782898 + J 26.5534973

 *
 * ANTENNA BRANCH CURRENTS *
 *

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

THE RADIATION EFFICIENCY IS 99.5343018

THE TIME-AVERAGE POWER INPUT IS 0.0162564

THE ANTENNA IMPEDANCE IS 46.2782898 + J 26.5534973

 BACKSCATTERING
 CALCULATIONS

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

CURRENTS INDUCED BY THE PHI POLARIZED WAVE

SEG	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
1	1	0.0	0.0	0.0	0.0	0.0	2	0.3177E-02	-4.9074E-03	0.32149E-02	0.73326E-00	-8.8
2	2	0.3177E-02	-4.9074E-03	0.32149E-02	0.73326E-00	-8.8	3	0.43371E-02	-6.4178E-03	0.43844E-02	0.10000E-01	-8.8
3	3	0.43371E-02	-6.4178E-03	0.43844E-02	0.10000E-01	-8.8	4	0.3177E-02	-4.9074E-03	0.32149E-02	0.73326E-00	-8.8
4	4	0.3177E-02	-4.9074E-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	1	0.0	0.0	0.0	0.0	0.0	2	-1.6843E-04	0.28762E-04	0.33331E-04	0.99999E-00	120.4
2	2	-1.6843E-04	0.28762E-04	0.33331E-04	0.99999E-00	120.4	3	0.44948E-09	-9.5513E-11	0.44958E-09	0.13488E-04	-1.2
3	3	0.44948E-09	-9.5513E-11	0.44958E-09	0.13488E-04	-1.2	4	0.16844E-04	-2.8762E-04	0.33332E-04	0.10000E-01	-59.6
4	4	0.16844E-04	-2.8762E-04	0.33332E-04	0.10000E-01	-59.6	5	0.0	0.0	0.0	0.0	0.0

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

CURRENTS INDUCED BY THE PHI POLARIZED WAVE

SEG	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
1	1	0.0	0.0	0.0	0.0	0.0	2	0.3177E-02	-4.9499E-03	0.32156E-02	0.73328E-00	-8.5
2	2	0.3177E-02	-4.9499E-03	0.32156E-02	0.73328E-00	-8.5	3	0.43372E-02	-6.4765E-03	0.43853E-02	0.10000E-01	-8.9
3	3	0.43372E-02	-6.4765E-03	0.43853E-02	0.10000E-01	-8.9	4	0.3177E-02	-4.9499E-03	0.32156E-02	0.73328E-00	-8.5
4	4	0.3177E-02	-4.9499E-03	0.32156E-02	0.73328E-00	-8.5	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	1	0.0	0.0	0.0	0.0	0.0	2	-1.9434E-04	0.31643E-04	0.36631E-04	0.99998E-00	120.2
2	2	-1.9434E-04	0.31643E-04	0.36631E-04	0.99998E-00	120.2	3	0.53724E-09	-1.5861E-09	0.56016E-09	0.15282E-04	-16.7
3	3	0.53724E-09	-1.5861E-09	0.56016E-09	0.15282E-04	-16.7	4	0.18435E-04	-3.1644E-04	0.36632E-04	0.10000E-01	-59.7
4	4	0.18435E-04	-3.1644E-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	-0.49965E-03	0.32165E-02	0.73330E-00	-8.9
2	0.31775E-02	-0.49965E-03	0.32165E-02	0.73330E-00	-8.9	3	0.43373E-02	-0.65407E-03	0.43863E-02	0.10000E-01	-8.9
3	0.43373E-02	-0.65407E-03	0.43863E-02	0.10000E-01	-8.9	4	0.31775E-02	-0.49964E-03	0.32165E-02	0.73330E-00	-8.9
4	0.31775E-02	-0.49964E-03	0.32165E-02	0.73330E-00	-8.9	5	0.0	0.0	0.0	0.0	0.0

CURRENTS INDUCED BY THE THETA POLARIZED WAVE

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	-0.20044E-04	0.34526E-04	0.39922E-04	0.99998E-00	120.1
2	-0.20044E-04	0.34526E-04	0.39922E-04	0.99998E-00	120.1	3	0.57514E-09	-0.26965E-09	0.63522E-09	0.15911E-04	-25.1
3	0.57514E-09	-0.26965E-09	0.63522E-09	0.15911E-04	-25.1	4	0.20045E-04	-0.34526E-04	0.39923E-04	0.10000E-01	-59.9
4	0.20045E-04	-0.34526E-04	0.39923E-04	0.10000E-01	-59.9	5	0.0	0.0	0.0	0.0	0.0

ELECTRIC FIELD POLARIZATION SCATTERING MATRIX											
BACKSCATTERING POLARIZATION SCATTERING MATRIX (INCIDENT-SCATTERED)						THETA-PHI					
INCIDENT PLANE	THETA	PHI	PHI-PHI	PHI-THETA	PHI-THETA	REAL	IMAG	REAL	IMAG	THETA-THETA	THETA-THETA
0.0	10.0	0.0	0.47852E-01	-0.1807E-01	-0.1807E-01	0.18626E-08	-1.4901E-07	0.69849E-08	-1.9355E-07	0.93990E-04	0.17382E-03
0.0	11.0	0.0	0.47001E-01	-0.18150E-01	-0.18150E-01	0.25511E-08	-1.4901E-07	0.69849E-08	-1.9355E-07	0.93990E-04	0.17382E-03
0.0	12.0	0.0	0.46506E-01	-0.18150E-01	-0.18150E-01	0.25511E-08	-1.4901E-07	0.69849E-08	-1.9355E-07	0.93990E-04	0.17382E-03

 * BISTATIC SCATTERING *
 * CALCULATIONS *

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

OBSERVATION		ELECTRIC FIELD POLARIZATION SCATTERING MATRIX				THETA-THETA			
POINT		(INCIDENT-SCATTERED)				REAL			
PHI	THETA	PHI-THETA	PHI-THETA	THETA-PHI	THETA-PHI	REAL	IMAG		
45.0	45.0	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 GEOM(0=-25.0/0.0,-125.0 /0.0,0/0.0..125.0/0.0..25.0)
11 PLOT(FAR/PHI=90.0)
13 GROUND(HEIGHT=.25/6000)
13 STOP
```

```
*****
* INPUT DATA *
*****
GROUND PLANE (NO/YES)
GROUND DIELECTRIC CONSTANT (RELATIVE)
GROUND CONDUCTIVITY (MHOS/METER)
ANTENNA HEIGHT (METERS)
```

YES
0.3000E 02
0.2000E-01
0.2500E 00

WIRE STRUCTURE

SEG NO.	NODE NO.	X	Y	Z	LOCATION	NODE NO.	X	Y	Z	LOCATION
1	1	0.0	-2500E 00	0.0	-2500E 00	1	0.0	-12500E 00	0.0	-12500E 00
2	2	0.0	-12500E 00	0.0	-12500E 00	2	0.0	0.0	0.0	0.0
3	3	0.0	0.0	0.0	0.0	3	0.0	0.0	0.0	0.0

ANTENNA FEEDS
REAL VOLTS
0.1000E 01
IMAGINARY
0.0

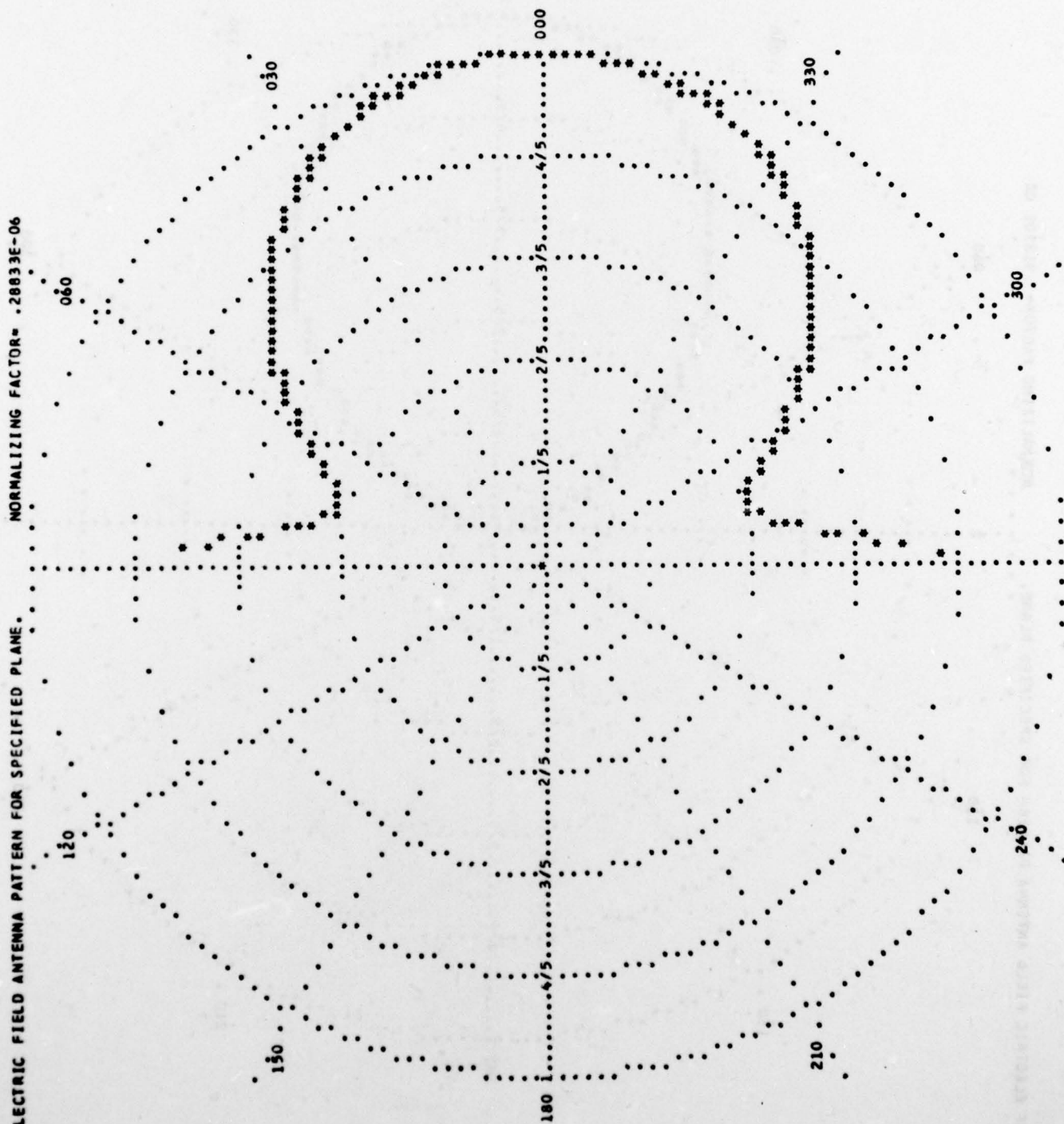
```
*****
* OUTPUT REQUESTED *
*****
PLOT FOR FAR FIELD PHI= 90.0
```

ANTENNA
CALCULATIONS

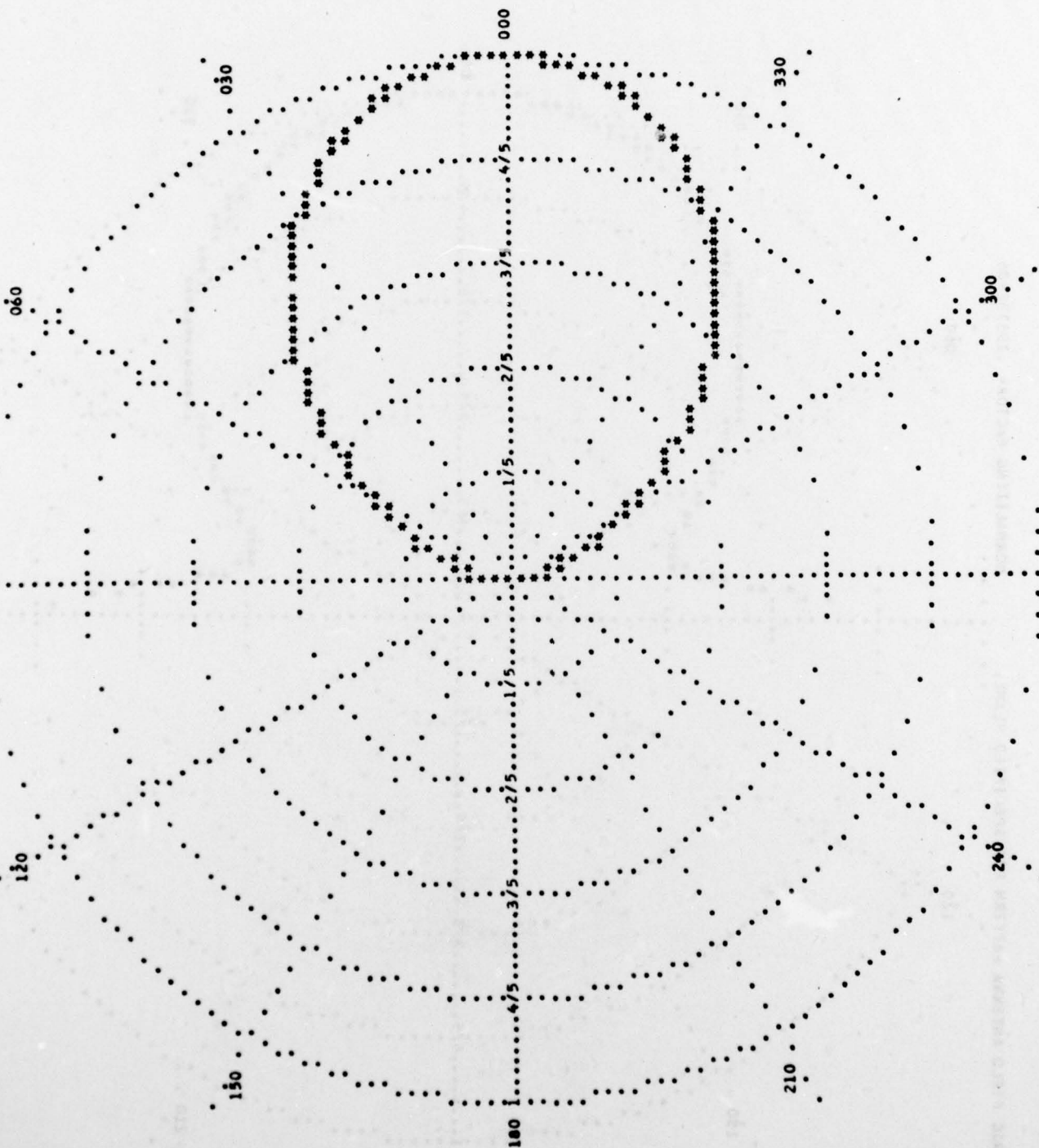
THE INPUT IMPEDANCE AT NODE 3 IS 97.1284332 + J 68.7537079
THE RADIATION EFFICIENCY IS 99.7729645
THE TIME-AVERAGE POWER INPUT IS 0.0137177
THE ANTENNA IMPEDANCE IS 97.1284332 + J 68.7537079

PHI ELECTRIC FIELD ANTENNA PATTERN FOR SPECIFIED PLANE.

NORMALIZING FACTOR = .28833E-06



THEY 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.