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A Users Manual for the Method of Moments Aircraft Modeling Code (AMC): Version II

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16. Abstract (Limit: 200 words)

This report serves as a user's manual for Version II of the "Aircraft Modelling Code" or AMC. AMC is a user-oriented computer code, based on the method of moments (MM), for the analysis of the radiation and/or scattering from geometries consisting of a main body or fuselage shape with attached wings and fins. The shape of the main body is described by defining its cross section at several stations along its length. Wings, fins, rotor blades, and radiating monopoles can then be attached to the main body. Although AMC was specifically designed for aircraft or helicopter shapes, it can also be applied to missiles, ships, submarines, jet inlets, automobiles, spacecraft, etc. The problem geometry and run control parameters are specified via a two character command language input format. This report describes the input command language and also includes several examples which illustrate typical code inputs and outputs.

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Chapter 1

Introduction

This report serves as a user's manual for Version II of the "Aircraft Modelling Code" or AMC. AMC is a user-oriented computer code, based on the method of moments (MM) [1, 2], for the analysis of certain radiation and/or scattering problems. Basically, AMC is designed to allow a user to conveniently describe a perfectly conducting surface, consisting of a main body or fuselage plus a number of attached wings or fins. As such, AMC is ideal for analyzing helicopter, aircraft, or missile type shapes. AMC can compute the radar cross section (RCS) of this winged body, or one can place a small monopole antenna on the winged body and compute the far zone gain.

Version II of AMC is similar to the original AMC [3] except for a few minor input data format changes, and the following more significant additions:

1. all wire to plate and attachment to plate mutual impedances are computed using full surface plate test modes.

2. when requested, the LU decomposed impedance matrix is saved instead of the actual impedance matrix.

3. the allowance of an *attachment mode* at the monopole source for better coupling of the antenna to the main body.

4. the ability to treat material plates modeled by either a sheet impedance or a surface impedance.

5. the ability to input arbitrary plates and wires for defining unusual geometry details.

AMC is a special purpose version of the "Electromagnetic Surface Patch" or ESP code. ESP is a user-oriented computer code, based upon the MM, for analyzing an almost arbitrary interconnection of thin wires and perfectly conducting polygonal plates [4]. Much of the theoretical basis for the ESP code is described in the literature [5]-[15]. The main difference between the ESP and AMC codes is that AMC contains special software to allow the user to conveniently describe the winged body geometry. The main body or fuselage is defined by specifying its cross section at various stations from the nose to the tail. Wings, fins, rotor blades, etc can then be attached to the fuselage. AMC translates the input geometry, specified by the user, into a number of polygonal plates and wires which approximate the winged body geometry. All plates making up the main body and the wings or fins must be perfectly conducting plates. In addition to plates, AMC can include two special wire geometries. For antenna problems a radiating monopole can be included as part of the geometry. Also, for helicopter shapes a four blade rotor, modelled by wires, can be included.

The interconnection of thin wires and polygonal plates which model the winged body can be analyzed as in the ESP code. In brief, ESP is based upon a MM solution of an electric field integral equation (EFIE) for the currents on the wires and plates [5]-[15]. The main advantages of MM solutions are high accuracy and the ability to treat geometrically complex or realistic shapes. The accuracy is a result of the fact that the MM is a direct numerical solution of the essentially exact integral equation for the current on the body. The main limitation of the method is that the required computer storage and CPU time both increase as the electrical size of the antenna or scatterer increases. Thus, AMC is a low frequency code, applicable when the body is not too large electrically. On a main frame computer, such as the VAX 8550, one can reasonably treat bodies up to about 20 λ^2 of surface area. Larger bodies are probably best run on a supercomputer with a vectorized matrix solver.

AMC can perform a wide variety of electromagnetic calculations on the specified geometry. AMC can perform near or far zone backscatter, bistatic scatter and forward

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scattering calculations. When a radiating monopole is specified, AMC can compute near or far zone radiation patterns. AMC also allows the user to easily and efficiently [14] obtain data versus frequency. That is, one can obtain input impedance, gain, or radar cross-section (RCS) versus frequency.

When the AMC code is supplied outside The Ohio State University, it will include the following three FORTRAN files:

ESP4N = the main program and all required subroutines for AMC, written in standard FORTRAN 77.

ESP4GM = a program using the GKS language [16] to plot the wire and plate geometry (see Section 5.2).

ESP4PT = a program using the GKS language [16] to plot the radiation and scattering patterns (see Section 5.3).

In order to provide CPU run times, the AMC main program contains several calls to the function GETCP(I), where I is the clock time in hundredths of a second. However, since this is not standard FORTRAN 77, these lines have been essentially removed by making them COMMENT lines (i.e., putting a "C" in column 1). If possible a user should replace this function by a comparable clock routine on his system. As delivered, the ESP code will print 0.0 for the CPU time. The plotting programs ESP4GM and ESP4PT contain one subroutine which is not standard GKS, and must be supplied by the user. This is subroutine GKHGCI. The main purpose of GKHGCI is to supply the integer JCONID, which is the third and last parameter in the GKHGCI window. JCONID is a logical device number which is then supplied as the second parameter in the window of GKS subroutine GOPWK.

The AMC code can compute all of the usual quantities of interest such as:

1. current distribution

2. input impedance or admittance and radiation efficiency

3. near or far zone radiation or gain patterns (both polarizations)

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Table 1.1: Files Used by AMC

Logical Unit Number	File Name	Description
1	ZMAT.DAT	Impedance matrix file
3	PATCHI.DAT	Patch current file
55	INFIL.DAT	Input file
66	OUTFIL.DAT	Output file
8	PTPLOT.DAT	Pattern plotting file
9	GMPLOT.DAT	Geometry plotting file
10	FSWEEP.DAT	Frequency sweep file

4. plane wave back or bistatic or forward scattering patterns in the near or far zone (complete scattering matrix).

The excitation can be either a one volt generator in the monopole (i.e., the antenna problem) or a plane wave (i.e., the scattering problem). The perfectly conducting polygonal plates are considered to have zero thickness. The thin wires are perfectly conducting with a finite radius of 0.001λ.

The AMC code uses several input and output data files as shown in Table 1.1. The file names shown are merely the choice of the author. By making a logical unit assignment the user may change the file names. A name suggesting the file description is recommended. However, the logical unit numbers corresponding to the various files are fixed by the READ and WRITE statements within the AMC code. The input file, INFIL.DAT, is the only file generated by the user. The remaining files are generated by AMC.

The input file, INFIL.DAT, contains all the commands to the AMC code. There are two types of commands, i.e., run control commands and geometry commands. These commands specify the type of electromagnetic calculations to be made and define the geometry of interest.

The run control commands, which are described in Chapter 2 specify the type of electromagnetic calculation to be made and also control the output of data. The geometry commands define the geometrical shape of the body of interest and are described in Chapter 3. Chapter 4 presents several example problems which illustrate AMC inputs and outputs. These examples should help the user to provide for a better understanding of the input commands and the code outputs. Finally, Chapter 5 gives a brief description of array DIMENSIONS and how to change them. Chapter 5 also describes three output files produced by AMC which can be used to plot the wire/plate geometry and the near and far zone radiation and scattering patterns.

1.1 Sheet Impedance Model for Thin Dielectric Plates

Consider a homogeneous thin dielectric plate of complex permittivity ϵ and thickness T which is immersed in free space with permittivity ϵ_0. In order for the sheet impedance approximation to this thin dielectric slab to be valid, it is required that

1. The slab is sufficiently thin that the electric field is essentially uniform throughout its thickness. This will be the case provided $|k_d|T \ll 1$, where $k_d = \omega\sqrt{\mu_0\epsilon}$ is the wavenumber of the dielectric.

2. The dominant polarization of the electric field in the dielectric slab is parallel to the broad surfaces of the slab.

The sheet admittance, Y_s, or sheet impedance, Z_s, of this thin dielectric plate is

$$Y_s = 1/Z_s = j\omega(\epsilon - \epsilon_0)T \qquad (1.1)$$

where ω is the radian frequency. Z_s has the dimension of ohms, sometimes written as $\Omega/\square$ (read as ohms per square). If the dielectric is so lossy that the imaginary part of ϵ dominates its real part, the Z_s is pure real and given by

$$Z_s = \frac{1}{\sigma T} \qquad (1.2)$$

where σ is the conductivity of the lossy dielectric. Equation (1.2) is the familiar equation for a resistance card.

Using the sheet impedance approximation, the extension to a layered dielectric plate is trivial. Essentially, in a multi-layered dielectric plate, the layers appear to be in parallel. For example, consider a two-layer dielectric plate. Layer 1 has permittivity ϵ_1 and thickness T_1. Layer 2 has permittivity ϵ_2 and thickness T_2. The sheet admittance or impedance of the two-layer plate is

$$Y_s = 1/Z_s = j\omega(\epsilon_1 - \epsilon_0)T_1 + j\omega(\epsilon_2 - \epsilon_0)T_2. \tag{1.3}$$

1.2 Surface Impedance Model

The AMC code also allows certain plates to have a surface impedance. However, as the theory is implemented, only plates making up a closed body may be assigned a surface impedance value. For example, plates making up a closed aircraft fuselage may be assigned a surface impedance values, whereas plates making up wings attached to the aircraft fuselage may not be assigned a surface impedance value. Typical examples of surface impedances are material coated bodies or highly conductive bodies at least a few skin depths in thickness.

The surface impedance is defined as

$$Z_{surf} = \frac{E_{tan}}{H_{tan}} \tag{1.4}$$

where E_{tan} and H_{tan} are the tangential electric and magnetic fields at the surface, defined by

$$E_{tan} = \mathbf{E} \times \hat{n} \qquad \text{and} \tag{1.5}$$

$$H_{tan} = \hat{n} \times (\hat{n} \times \mathbf{H}) \tag{1.6}$$

and $\hat{n}$ is the outward directed normal to the plate on the closed body.

Consider a PEC body coated with a material of thickness T, characteristic impedance Z_1, and complex propagation constant γ_1. The surface impedance for such a body can be determined from transmission line methods as the input impedance,

and is given by

$$Z_{suef} = Z_1 \tanh(\gamma_1 T).$$
(1.7)

Next, consider a highly conducting body at least several skin depths thick. For this case, the surface impedance reduces to the characteristic impedance of the conductor, given as

$$Z_{surf} = \sqrt{\frac{j\omega\mu_1}{\sigma_1 + j\omega\epsilon_1}}$$
(1.8)

where μ_1, σ_1 and ϵ_1 are the permeability, conductivity and permittivity of the highly conductive body.

Chapter 2

Run Control Commands

The run control commands to the Aircraft Modelling Code (AMC) are described in this section. The run control commands define the type of computation to be made and also control the output. Each run control command requires either one or two lines of input. A typical command has the form:

CM: COMMAND DESCRIPTION
Parameter List

Here CM is the command. All commands are length two character strings. Following the command is a colon (:) and then a brief description of the command. The colon and the description are ignored by the code. They are included simply to make the input file easier to read and understand. Some commands have a number of associated input parameters. These parameters, separated by spaces or commas, are placed on a single line following the command. The commands, and associated parameter lists, are read on logical unit 5 from a file normally denoted INFIL.DAT. Following the run control commands are the geometry commands (see Chapter 3).

Not all commands need be executed on a given run. The NC or "end of run control" command is the only run control command which must be executed on a given run. If a particular command is not executed, then the input parameters associated with that command *may* be defined by their default values. The default value is the value a parameter is assigned if the command which normally defines that parameter is not executed. The default value, if any, is shown in parenthesis following the parameter list. For example, if a parameter list is shown as

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P1 P2 P3

(0.0) (1.0) (-1.0)   (Defaults)

then parameter P1 has a default value of 0.0, parameter P2 has a default value of
1.0, and parameter P3 has a default value of -1.0.

2.1   EX: The Execute Command

The "execute" command (EX) tells AMC to perform a complete run. A complete
run means AMC will set up the problem geometry, perform the MM computation,
and then output the desired data. These data runs can require an hour or more of
CPU time. If the EX command is not invoked then AMC will only set up and print
out the problem geometry. These runs typically require only a few seconds of CPU
time. It is strongly suggested that initial runs be made without invoking EX so that
the user can verify the accuracy of the problem geometry before a lengthy data run
is performed.

Form of the command:

EX: Execute
Default status: Set up and print out problem geometry but do not perform any
electromagnetic computations.

2.2   WR: The Write Command

The "write" command (WR) controls whether or not a detailed description of the wire
and plate geometry is written to the output file. The WR command also controls
whether or not the current vector and the impedance matrix are written to the output
file. The MM matrix equation is of the form

$$[Z]I = V \tag{2.1}$$

where $[Z]$ is the $N \times N$ impedance matrix, V is the length N voltage vector, and I
is the length N current vector. N is the total number of MM modes of the problem

geometry.

Form of the command:

WR: Write

NPRINT, IWR, IWRZT

   (0)   (0)   (0)   (Defaults)

NPRINT = indicator for printing a detailed description of the wire and plate geometry to the output file.

= 0 implies print nothing.

= 1 implies print the detailed description of the wire and plate geometry. This detailed description includes the coordinates of every plate and wire segment and the description of the MM modes. Typically, the user will set NPRINT = 0.

IWR = indicator for writing the current vector to the output file.

= 0 implies do not write the current vector to the output file.

= 1 implies write the current vector plus the wire and plate modal geometry to the output file. Note that for backscatter and forward scatter patterns, setting IWR = 1 will cause the current vector to be written out at every angle and can produce a very large output file.

IWRZT = indicator for writing the impedance matrix to the output file.

= 0 implies do not write the impedance matrix to the output file.

= 1 implies write the impedance matrix to the output file. Caution: this will result in N^2 lines of output where N = the total number of MM modes.

2.3 IN: The Integration Command

Computation of the impedance matrix elements in the MM solution requires numerical integrations. The "integration" command (IN) sets integration parameters used

in the calculation of the impedance matrix elements.

Form of the command:

IN: Integration

INT, INTP, INTD

(4)   (6)   (18)   (Defaults)

INT = the number of Simpson's rule integration intervals used for the evaluation of the wire-to-wire impedances. INT is always an even integer, typically equal to 4.

= 0 implies all wire-to-wire impedance calculations are to be done using the exact closed form expression. Self or overlapping wire impedances are always calculated by the closed form expression because it is more accurate than numerical integration. However, the closed form expression is more time consuming than the INT = 4 numerical integration.

INTP = the number of Simpson's rule integration intervals used in integrating over the surface patch monopoles. INTP is always an even integer, typically chosen as 6.

INTD = the number of Simpson's rule integration intervals used in integrating over the attachment disk monopoles. INTD is always an even integer, typically chosen as 18.

2.4   TM: The Test Mode Command

The "test mode" command (TM) specifies the type of plate test modes used in the MM solution. Two types of plate test modes are available in AMC, full surface patch test modes and filamentary plate test modes. Full surface patch test modes may increase the accuracy of the MM solution, but will also increase the CPU time. Substantial CPU time can be saved, without significantly compromising the accuracy of

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the solution, by using filamentary plate test modes. Note that all wire to plate and attachment to plate mutual impedances are computed using full surface testing.

Form of the command:

TM: Test Mode
IFIL

(1)   (Default)

IFIL = indicator for choosing the type of plate test modes.

= 0 implies full surface patch plate test modes.

= 1 implies filamentary plate test modes.

Generally filamentary testing is used to reduce run time.

2.5   NZ: The Near Zone Command

AMC is capable of computing both near and far zone patterns. The "near zone" command (NZ) specifies the radius of the field point used in the computation of all radiated or scattered fields.

Form of the command:

NZ: Near Zone
RF

(-1.0)   (Default)

RF = radius in meters for the field point in the computation of all radiated or scattered fields. If RF < 0.0, then far zone fields will be computed.

Near zone patterns can be computed by specifying RF = the finite radius of the pattern. Far zone patterns can be obtained by either not invoking the NZ command (AMC defaults to a far zone computation) or by setting RF = -1.0

(or any other negative number). See reference [4] for a description of near zone gain and RCS.

2.6 FS: The Frequency Sweep Command

The "frequency sweep" command (FS) defines the parameters of a frequency sweep computation. This command is used when one wishes to compute gain or RCS versus frequency. In order to perform a frequency sweep computation, the dimension indicator IDMZI, defined near the top of the FORTRAN code, must be set to 1 (see section 5.1). When AMC is delivered IDMZI normally is set to 0.

Form of the command:

FS: Frequency Sweep

INDZI, FMC1, FMC2, DFZI, DFF, IRS12, THRD, PHRD, THINC, PHINC   (0)

(Default, none of the other parameters have meaning when INDZI = 0.)

INDZI = indicator to make a frequency sweep computation.

= 0 implies do not make frequency sweep computation.

= 1 implies make frequency sweep computation using the straight quadratic impedance matrix interpolation method.

= 2 implies make frequency sweep computation using the "improved" impedance matrix interpolation method.

FMC1 = beginning frequency in Mhz for the frequency sweep.

FMC2 = ending frequency in Mhz for the frequency sweep.

DFZI = step size in Mhz at which the impedance matrix is to be computed.

DFF = step size in Mhz at which the MM computation of currents, fields, etc., are to be made.

IRS12 = indicator as to whether this is a radiation (i.e. antenna) or scattering problem.

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= 1 implies a radiation problem.

= 2 implies a scattering problem.

THRD, PHRD $= (\theta, \phi)$ angle in degrees for computing the radiated field in the computation of gain (IRS12 = 1) or the scattered field in the computation of RCS (IRS12 = 2).

THINC, PHINC $= (\theta_i, \phi_i)$ angle in degrees of the incident plane wave for scattering problems (IRS12 = 2).

Figure 2.1 shows the coordinate system used by AMC.

It should be noted that if the FS command is invoked then neither the RE, RA, SE nor SA commands (Section 2.7-Section 2.10) should be invoked. Essentially this means that, on a given run, one can not mix frequency sweep and pattern computations. In the event that the FS command and one or more of the above commands are invoked then AMC will write an error message to the output file and a complete run involving electromagnetic computations will not be made. Note that the gain or RCS can be either near or far zone, depending upon the value of RF defined by the NZ command (Section 2.5).

When making frequency sweep computations, AMC employs an impedance matrix interpolation scheme to reduce CPU time. This method is described in references [4, 14]. We have found that if straight quadratic interpolation is used (INDZI= 1), typically the frequency step size is DFZI = $\Delta f_M/2$, where

$$\Delta f_M = \frac{300}{2L} \quad \text{Mhz.} \tag{2.2}$$

Here L is the maximum dimension (meters) of the body being analyzed, that is the maximum distance in meters between any two points on the body. If improved interpolation is used, DFZI typically can be increased to Δf_M or more. As DFZI increases, the CPU run times decreases, however, the $[Z]$ matrix interpolation error increases.

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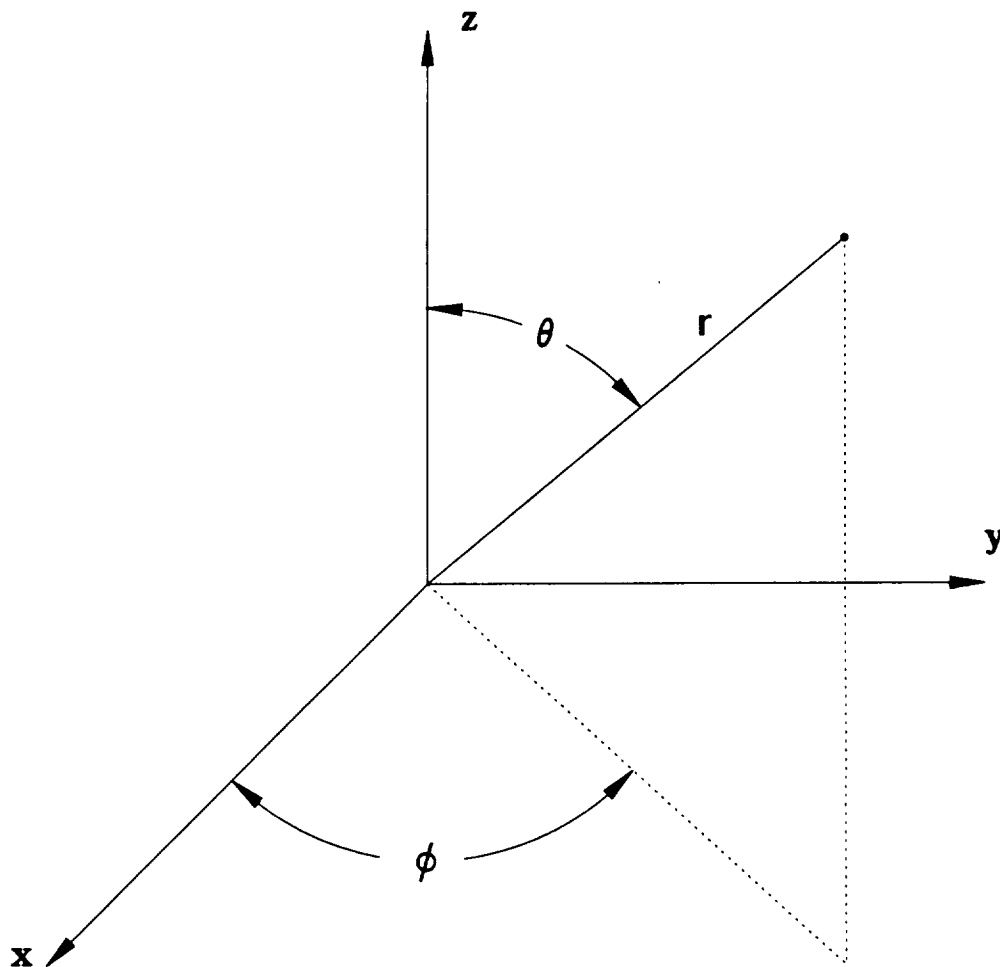
Figure 2.1: The standard coordinate system used by AMC for pattern specification.

2.7   RE: The Radiation Pattern Command (Elevation Plane)

The "radiation pattern (elevation plane)" command (RE) defines a radiation pattern in an elevation plane. An elevation plane means ϕ is fixed and θ is varied where θ and ϕ refer to the usual spherical coordinates. Figure 2.1 shows the coordinate system used by AMC.

Form of the command:

RE: Radiation Pattern (Elevation Plane)

IPFE, FNDFE, PHFE

IPFE = indicator to output a file on logical unit 8 which can be used to plot the near or far zone radiation pattern in the elevation plane.

= 0 implies do not output pattern plotting file.

= 1 implies output pattern plotting file.

FNDFE = angle increment in degrees for near or far zone radiation pattern in the elevation plane. FNDFE (and all other angle increments) must be evenly divisible into 360. Due to the length 1441 dimensioning of various arrays which store the patterns, FNDFE (and all other angle increments) can not be smaller than 0.25.

PHFE = constant ϕ angle in degrees for near or far zone radiation pattern in the elevation plane.

Note that if the RE command is invoked then neither the FS command (Section 2.6) nor the SE nor SA commands (Section 2.9-Section 2.10) should be invoked. Essentially this means that, on a given run, one can not mix radiation and scattering patterns, nor can one mix radiation pattern and frequency sweep computations. In the event that the RE command and one or more of the above commands are invoked then AMC will write an error message to the output file and a complete run involving electromagnetic computations will not be made.

2.8   RA: The Radiation Pattern Command (Azimuthal Plane)

The "radiation pattern (azimuthal plane)" command (RA) defines a radiation pattern in an azimuthal plane. An azimuthal plane means θ is fixed and ϕ is varied where θ and ϕ refer to the usual spherical coordinates. Figure 2.1 shows the coordinate system used by AMC.

Form of the command:

RA: Radiation Pattern (Azimuthal Plane)

IPFA, FNDFA, THFA

IPFA = indicator to output a file on logical unit 8 which can be used to plot the near or far zone radiation pattern in the azimuthal plane.

= 0 implies do not output pattern plotting file.

= 1 implies output pattern plotting file.

FNDFA = angle increment in degrees for near or far zone radiation pattern in the azimuthal plane.

THFA = constant θ angle in degrees for near or far zone radiation pattern in the azimuthal plane.

Note that if the RA command is invoked then neither the FS command (Section 2.6) nor the SE nor SA commands (Section 2.9-Section 2.10) should be invoked. In the event that the RA command and one or more of the above commands are invoked then AMC will write an error message to the output file and a complete run involving electromagnetic computations will not be made.

2.9 SE: The Scattering Pattern Command (Elevation Plane)

The "scattering pattern (elevation plane)" command (SE) defines a scattering pattern in the elevation plane. The scattering pattern may be a backscatter, bistatic scatter or forward scatter pattern.

Form of the command:

SE: Scattering Pattern (Elevation Plane)

ISE, IPSE, FNDSE, PHSE, THIN, PHIN

ISE = indicator for calculating the near or far zone elevation plane scattering pattern. Scattering implies either backscattering (ISE = 1) or bistatic scattering (ISE = 2) or forward scattering (ISE = 3).

= 0 implies do not compute near or far zone scattering pattern in the elevation plane.

= 1 implies compute backscatter pattern in the elevation plane.

= 2 implies compute bistatic scattering pattern in the elevation plane.

= 3 implies compute forward scattering pattern in the elevation plane.

IPSE = indicator to output a file on logical unit 8 which can be used to plot the near or far zone scattering pattern in the elevation plane.

= 0 implies do not output pattern plotting file.

= 1 implies output pattern plotting file.

FNDSE = angle increment in degrees for near or far zone scattering pattern in the elevation plane.

PHSE = constant ϕ angle in degrees for near or far zone scattering pattern in the elevation plane.

THIN = θ angle in degrees of the incident wave for bistatic scattering calculations (i.e., ISE = 2 or ISA = 2).

PHIN = ϕ angle in degrees of the incident wave for bistatic scattering calculations (i.e., ISE = 2 or ISA = 2).

It should be noted that the parameters THIN and PHIN appear in both the SE command and the SA command (see Section 2.10). If only one of these commands appears in the input file, then THIN and PHIN will be defined by that command. However, if both the SE and the SA commands appear in the input file, then THIN and PHIN are defined by the command that appears later in the input file.

Note that if the SE command is invoked then neither the FS command (Section 2.6) nor the RE nor RA commands (Section 2.7-Section 2.8) should be invoked. Essentially this means that, on a given run, one can not mix radiation and scattering

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patterns, nor can one mix scattering pattern and frequency sweep computations. In the event that the SE command and one or more of the above commands are invoked then AMC will write an error message to the output file and a complete run involving electromagnetic computations will not be made.

2.10 SA: The Scattering Pattern Command (Azimuthal Plane)

The "scattering pattern (azimuthal plane)" command (SA) defines a scattering pattern in the azimuthal plane. The scattering pattern may be a backscatter, bistatic scatter or forward scatter pattern.

Form of the command:

SA: Scattering Pattern (Azimuthal Plane)

ISA, IPSA, FNDSA, THSA, THIN, PHIN

ISA = indicator for calculating the near or far zone azimuthal plane scattering pattern.

= 0 implies do not compute near or far zone scattering pattern in the azimuthal plane.

= 1 implies compute backscatter pattern in the azimuthal plane.

= 2 implies compute bistatic scattering pattern in the azimuthal plane.

= 3 implies compute forward scattering pattern in the azimuthal plane.

IPSA = indicator to output a file on logical unit 8 which can be used to plot the near or far zone scattering pattern in the azimuthal plane.

= 0 implies do not output pattern plotting file.

= 1 implies output pattern plotting file.

FNDSA = angle increment in degrees for near or far zone scattering pattern in the azimuthal plane.

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THSA = constant θ angle in degrees for near or far zone scattering pattern in the azimuthal plane.

THIN = θ angle in degrees of the incident wave for bistatic scattering calculations (i.e., ISE = 2 or ISA = 2).

PHIN = ϕ angle in degrees of the incident wave for bistatic scattering calculations (i.e., ISE = 2 or ISA = 2).

It should be noted that the parameters THIN and PHIN appear in both the SE and the SA commands. If only one of these commands appears in the input file, then THIN and PHIN will be defined by that command. However, if both the SE and the SA commands appear in the input file, then THIN and PHIN are defined by the command that appears later in the input file.

Note that if the SA command is invoked then neither the FS command (Section 2.6) nor the RE nor RA commands (Section 2.7-Section 2.8) should be invoked. In the event that the SA command and one or more of the above commands are invoked then AMC will write an error message to the output file and a complete run involving electromagnetic computations will not be made.

2.11 FR: The Frequency Command

The "frequency" command (FR) defines the frequency in megahertz at which field computations are to be made.

Form of the command:

FM: Frequency
FMC
(300.0)   (Default)

FMC = frequency in megahertz.

If a frequency sweep calculation is to be performed by invoking the FS command, then the frequency range is defined by the FS command and the FM command is meaningless. The FM command is meaningful only when used with the RE, RA, SE and SA commands.

2.12   ZM: The Impedance Matrix Command

The "impedance matrix" command (ZM) makes it possible to save the impedance matrix for use on future runs or to reuse the impedance matrix calculated and saved during a previous run. (Note that actually the LU decomposed impedance matrix is saved, when requested. This results in a savings in the CPU time.) The user may wish to utilize the ZM command when analyzing several consecutive problems for which the impedance matrix either does not change or only certain blocks of the impedance matrix change. For example, the impedance matrix will not change if different near or far-zone patterns are computed or if different angles of incidence are used in a bistatic scattering calculation. Obviously, in these cases it would be extremely wasteful to recompute the entire impedance matrix. At other times the geometry may change only slightly from one run to the other. For example, consider the problem of locating a monopole on an aircraft such that a desired pattern is achieved. In order to solve this problem one would construct a plate model of the aircraft. A few wire modes would be used to model the monopole. The user would then analyze this configuration for many monopole locations in search of the optimum location. The impedance matrix of this (and in general any) MM problem can be visualized as shown in Figure 2.2. It consists of nine blocks corresponding to coupling between wire (W), attachment (A), and plate (P) modes. As the monopole location changes, the P/P block of the matrix does not change, since the plate geometry does not change. Thus, a considerable savings in time will result if on the first run the entire (LU decomposed) impedance matrix is stored on a disk file, i.e., the impedance matrix file on logical unit 1. On subsequent runs the stored LU decomposed matrix is read in and only the blocks involving wires and attachments are recomputed.

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$$
\left[
\begin{array}{c|c|c}
W/W & W/A & W/P \\
\hline
A/W & A/A & A/P \\
\hline
P/W & P/A & P/P
\end{array}
\right]
$$

```
W  =  WIRE
A  =  ATTACHMENT
P  =  PLATE
```

Figure 2.2: Symbolic representation of the four blocks of the moment method impedance matrix.

Form of the command:

ZM: Impedance Matrix

IWRZM, IRDZM

   (0)   (0)   (Default)

IWRZM = indicator for writing the LU decomposed impedance matrix onto logical unit 1, a disk file denoted here by ZMAT.DAT, i.e., the impedance matrix file.

= 0 implies do not write out the LU decomposed impedance matrix.

= 1 implies write out the LU decomposed impedance matrix.

IRDZM = indicator for reading in the LU decomposed impedance matrix calculated during a previous run.

= 0 implies do not read in the previous matrix. Thus, the entire impedance matrix will be computed.

= 1 implies read in the previous matrix and compute the new matrix except for the W/W, W/A, A/W and A/A blocks. Use this option when the wire and attachment geometry is identical to the run on which IWRZM = 1.

= 2 implies read in the previous matrix and compute the new matrix except for the P/P block. Use this option when the plate geometry is identical to the run on which IWRZM = 1.

= 3 implies read in the previous matrix and use it as the new matrix, i.e., do not calculate any impedance matrix elements. Use this option when the entire wire/plate geometry is identical to the run on which IWRZM = 1.

Thus IRDZM = 2 if the plate geometry is unchanged, IRDZM = 1 if the wire and attachment geometry is unchanged, and IRDZM = 3 if the entire geometry is unchanged. By unchanged it is meant unchanged from the run on which IWRZM = 1. Whenever IRDZM > 0 the following should be true:

1. IWRZM must have been 1 on a previous or first run,

2. the number of wire and plate modes is identical to the IWRZM = 1 run,

3. the frequency is the same as the IWRZM = 1 run.

The LU decomposed impedance matrix is written to and read from logical unit 1, which is a disk file termed ZMAT.DAT by the authors. If IWRZM = 1, and INDZI = 1 or 2 (see Section 2.6), then the LU decomposed impedance matrix at several frequencies from FMC1 to FMC2 will be written onto the disk file ZMAT.DAT. It is suggested that any time a long and costly run is made, the user should invoke the ZM command and set IWRZM = 1.

2.13   NC: The End of Control Command

The "end of control" command (NC) indicates to AMC that the run control commands have all been read. Thus, the NC command is the last run control command read from the input file. The NC command absolutely must appear in the input file. The geometry commands follow the NC command in the input file.

Form of the command:

NC: End of Control

2.14   Input File Comment Lines

The user may wish to include comment lines (lines ignored by AMC) in the input file. For example, the user may wish to add notes in the input file to help remember things, or to temporarily disable a previously executed command. This can be accomplished if the first two characters on an input file line are either "%%" or "   " (two blank spaces).

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Chapter 3

Geometry Commands

The geometry commands to the Aircraft Modelling Code (AMC) are explained in this section. The geometry commands define the geometrical shape of the body of interest. There are several basic building blocks used by AMC to model a body and the geometry commands are used to implement these building blocks.

Basically, the shape of the main body or fuselage is defined by its cross sections along several stations. Figure 3.1 shows an arbitrarily shaped main body. The shape is defined by a polygonal approximation to the main body along five stations from the front ($y = 0$) to the rear of the main body. For the example in Figure 3.1, each cross section is approximated by a 10 sided polygon. Plates are fit over the contours defined by the cross sections from one cross section to the next until the entire surface of the main body is made up of plates. Endcap plates may or may not be placed at either end. As the number of cross sections is increased, and as the number of sides in the polygon approximation to each cross section is increased, the accuracy of the plate model increases, however, so does the number of plates. Typically, (but not always), as the number of plates increases, the computer CPU time and storage for the MM solution increases. The main body must be positioned along the y axis, i.e., the axial length of the main body is parallel to the y axis. Once the main body has been defined, other attachments to the main body (such as wings, tail wings, rotors, etc.) are added. These attachments are modelled as either plates or wires.
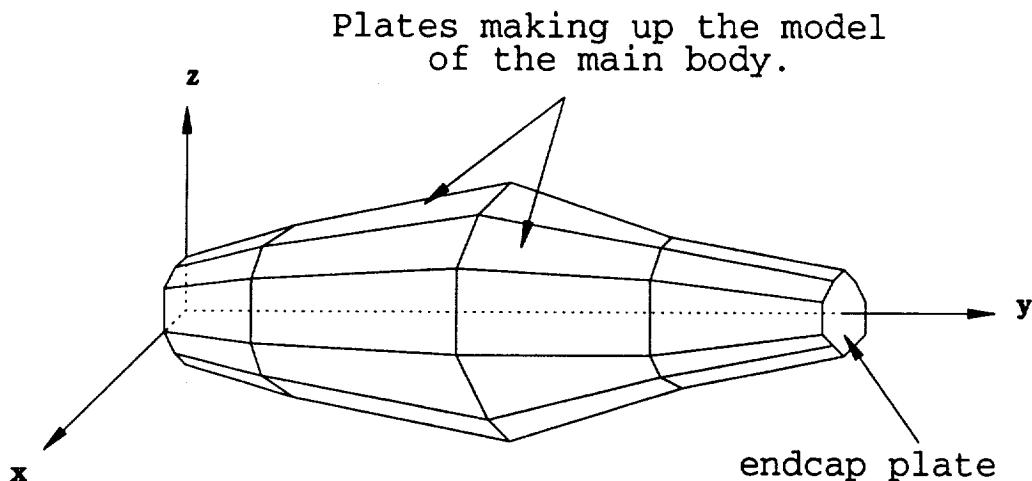
Figure 3.1: Plate model of an arbitrarily shaped body.

In general the quadrilateral plates connecting the cross sections will not be planar. Thus, it was necessary to augment the ESP code [4] so that it could treat nonplanar plates.

For radiation patterns a source monopole must be specified at the desired location. Then the radiation patterns specified by the RE and/or RA commands (see Sections 2.7 and 2.8) are computed. For scattering patterns no source monopole is needed, and the patterns specified by the SE and/or SA commands (see Sections 2.9 and 2.10) are computed.

The geometry commands follow an input format similar to the run control commands in Chapter 2. The first line is a two character abbreviation of the command. The second line, if required, lists various parameters which are input as part of the command. The geometry commands are contained in the same input file as the run control commands on logical unit 5. They immediately follow the run control commands. Therefore, the first geometry command is on the line immediately after the NC command (indicating the end of the run control commands) in the input file on logical unit 5. Logical unit 5 is referred to as INFIL.DAT.

3.1 SG: The Segmentation Command

All plates and wires that make up the body of interest must be segmented into modes. The "segmentation" command (SG) defines the maximum segment size (in wavelengths) of the plate and wire modes.

Form of the command:

SG: Segmentation

SGM

(0.2)   (Default)

SGM = the maximum segment size (in wavelengths) of the surface patch monopoles on all plates and the wire monopoles on all wires. SGM should not exceed 0.25 and is typically chosen as 0.2 or 0.25. If more accuracy is needed SGM can be chosen less than 0.2 with a substantial increase in computation time and storage since the number of MM modes increases.

Note that the maximum segment size is specified in wavelengths, regardless of the UN command (see Section 3.4). Thus, as the frequency is changed, the segmentation of the plates into surface patch modes and wires into wire modes is automatically adjusted to maintain the same segment size in wavelengths and thus comparable accuracy. This "frequency independent" method of specifying the segmentation of the plates and wires allows the user to make runs at different frequencies by only changing the frequency (see Section 2.6 or Section 2.11). If INDZI = 0 then SGM is in wavelengths at frequency FMC. If INDZI = 1 or 2, then SGM is in wavelengths at frequency FMC2.

3.2 NS: The Number of Sides Command

As discussed above, the shape of the main body is defined by cross sections. Plates are fit over the contours described by the cross sections (see Figure 3.1). To insure

that plates line up correctly all the cross sections must have the same number of points. This means that the main body defined by the cross sections will have a fixed number of sides. The "number of sides" command (NS) defines the number of sides for each cross section defining the main body. Thus, the NS command defines the number of points used to define each cross section.

Form of the command:

NS: Number of Sides

NSIDE

   (8)   (Default)

NSIDE $=$ the number of sides for each (and every) cross section in the main body. This is exactly the same as the number of points used to define each cross section.

Although not an absolute requirement, it is suggested that NSIDE be chosen as an even number, and that points 1 and (NSIDE/2 $+$ 1) be on the plane $x = 0$. It is important that NSIDE be set great enough to accurately describe the shape of the main body. However, as NSIDE is increased the number of plates increases and hence the number of modes increases. Thus, computation time and storage space increase.

Note that every cross section must have NSIDE points. However, for the case that the main body is symmetric, the input may be simplified as seen in the next section.

3.3   SM: The Symmetry Command

In many problems symmetry exists about a plane passing through the main body. If the main body can be positioned such that symmetry exists about the $x = 0$ plane, then the description of each cross section in the input file can be simplified. In this case the number of points needed to define each symmetric cross section is NSIDE/2 $+$ 1 where NSIDE is the number of sides of the main body (see Section 3.2). The "symmetry" command (SM) tells AMC that symmetry of the main body exists about

the $x = 0$ plane.

If the SM command is invoked then NSIDE must be an even number, and cross section points 1 and NSIDE/2 + 1 must be in the plane $x = 0$.

Form of the command:

SM: Symmetry

Default status: AMC will assume that cross sections are not symmetric.

Note that if the SM command is being invoked then it must appear earlier in the input file than the CS commands used to define cross sections (see Section 3.5). This is so AMC will know to read in the correct number of points needed to define the cross sections. If the SM command is invoked then NSIDE/2 + 1 points will be needed in the input file to describe each cross section. Otherwise, NSIDE points will be needed.

3.4   UN: The Units Command

The user may wish to specify all linear dimensions in a certain unit. The "units" command (UN) allows the user to specify all linear input dimensions in one of five different units. Dimensions may be in wavelengths, meters, centimeters, feet or inches.

Form of the command:

UN: Units
IUNITS
   (1)   (Default)

IUNITS = indicator for the type of units of all linear dimensions in the input file.

   = 0 implies all dimensions will be in wavelengths.

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= 1 implies all dimensions will be in meters.

= 2 implies all dimensions will be in centimeters.

= 3 implies all dimensions will be in feet.

= 4 implies all dimensions will be in inches.

It should be noted that the parameter RF (set by the NZ command for near zone calculations) must always be input in meters regardless of the UN command. The UN command need not precede commands, such as CS, TS, WG, etc., which input linear dimensions.

3.5   CS: The Cross Section Command

As illustrated in Figure 3.1, the main body or fuselage is defined by a number of cross sections. Plates are fit from one cross section to the next until the entire contour defined by the cross sections is made up of plates. Thus, plates are fit over the contour described by the cross sections. The "cross section" command (CS) defines one or two cross sections making up the surface contour of the main body. The axial length of the main body must be positioned along the y axis. A cross section is defined by its position along the y axis and by the x and z coordinates of its NSIDE (see command NS) points. Each cross section is in a plane parallel to the xz plane.

Although the user specifies the cross section at a particular y value, AMC also allows for moving the cross section to a different y value or adding a new cross section at a different y value. The moved or added cross section is determined by interpolating the present cross section with either the previous cross section or with the next cross section. If a new cross section is added by interpolation, then the CS command defines two cross sections. Otherwise, the CS command defines only one cross section.

Sometimes the user may wish to define a plate that "caps off" a cross section. For example, the user may define a fuselage by a few cross sections and wish to cap off one or both ends with plates. Referring to Figure 3.1, either one or both ends of the body may have endcaps. Cross sections can be capped off by simply setting an

indicator as part of the CS command. It really only makes sense to cap off the first and last cross sections of the fuselage.

If there is a discontinuity in the contour of the main body then two cross sections may be required at one particular y value. One contour would define the cross section on one side of the discontinuity, while a second contour would define the cross section on the other side of the discontinuity. Both cross sections would be at the same y coordinate. When two cross sections are defined at exactly the same position (i.e., they both have the same y value), the user must specify so when defining the first of the two cross sections. Furthermore, if a cross section is moved so that it is at the same position as another cross section, the user also must specify so when defining the first cross section.

Form of the command:

CS: Cross Section

YCSI(J), YPL(J), IPCI(J), IECI(J), ICSI(J)

XCSI(1,J), ZCSI(1,J)

XCSI(2,J), ZCSI(2,J)

XCSI(3,J), ZCSI(3,J)

$\vdots$

XCSI(N,J), ZCSI(N,J)

where J is the number of the cross section and N is the number of points or (x, z) pairs needed to define the cross section shape. N = NSIDE (see Section 3.2) if the main body has not been specified as symmetric and N = NSIDE/2 + 1 if the main body has been specified as symmetric. J is a counter that is incremented by 1 each time a new cross section is defined by the CS command.

YCSI(J) = the value of y for the Jth cross section. The Jth cross section is positioned at y = YCSI(J).

YPL(J) = the y value for a moved or added cross section. If the Jth cross section is moved then it is positioned at y = YPL(J). If a new cross section is added then the new cross section is positioned at y = YPL(J). See IPCI(J) below.

IPCI(J) = indicator for placement of the Jth cross section. This indicator is used for moving a cross section or adding a new cross section.

= 0 implies place the Jth cross section at YCSI(J) (usual case).

= -1 implies place the Jth section at YPL(J) by interpolating the Jth cross section and the previous cross section.

= 1 implies place the Jth cross section at YPL(J) by interpolating the Jth cross section and the next cross section.

= -2 implies place the Jth cross section at YCSI(J) and in addition place a new cross section at YPL(J) by interpolating the Jth cross section and the previous cross section.

= 2 implies place the Jth cross section at YCSI(J) and in addition place a new cross section at YPL(J) by interpolating the Jth cross section and the next cross section.

IECI(J) = indicator for capping off the Jth cross section.

= 0 implies do not cap off the Jth cross section.

= 1 implies cap off the Jth cross section with an endcap plate.

ICSI(J) = indicator for multiple cross sections at YCSI(J) or YPL(J).

= 0 implies the Jth cross section or a moved cross section is at a different location than the next cross section.

= 1 implies the Jth cross section or a moved cross section is at the same location as the next cross section.

XCSI(I,J), ZCSI(I,J) = the x and z values of the Ith point on the Jth cross section. If the main body is not specified as symmetric (see Section 3.3) then $I \in \{1,2,3,\ldots,\text{NSIDE}\}$. If the main body is specified as symmetric then I

$\in \{1, 2, 3, \ldots, \text{NSIDE}/2 + 1\}$. Furthermore, if the main body is specified as symmetric then the 1st point and the $(\text{NSIDE} / 2 + 1)^{th}$ point must be in the $x = 0$ plane, i.e., XCSI(1,J) = 0 and XCSI(NSIDE / 2 + 1,J) = 0.

The shape of the main body is defined by cross sections. This makes the order in which the cross sections are defined by the CS command in the input file very important. AMC fits plates over the contour defined by the cross sections. The plates are fitted from one cross section to the next in exactly the order they are defined in the input file. This implies that the y values of the cross sections will usually increase in order. If the y values do not increase in order, AMC prints a warning to the output file but the run goes on as normal. The specific order of the points defining a cross section also is very important. The plates making up the contour of the main body are constructed by connecting the Ith point on one cross section to the Ith point on the next cross section ($\text{I} \in \{1, 2, 3, \ldots, \text{NSIDE}\}$).

If the main body is symmetric about the $x = 0$ plane and the SM command is invoked (see Section 3.3), then two restrictions must be considered in defining the cross sections in the input file. First, the number of sides must be an even number, i.e., NSIDE defined by the NS command (see Section 3.2) must be even. Second, the points must be ordered as shown in Figure 3.2. Note that the first and last points are in the $x = 0$ plane.

3.6 TS: The Tail Section Command

All MM solutions have difficulty treating two perfectly conducting surfaces which are parallel (or nearly parallel) and are separated by only a few hundredths of a wavelength or less. This problem is often encountered in the modelling of the the tail sections of aircraft or helicopters. The simplest solution is to replace the electrically thin tail section by a zero thickness section, i.e., a flat plate.

The "tail section" command (TS) defines a thin tail section, modelled by a zero thickness flat plate. Typically, the thin tail section will extend to the right of the main body. The thin tail section is defined by exactly six points. The coordinates
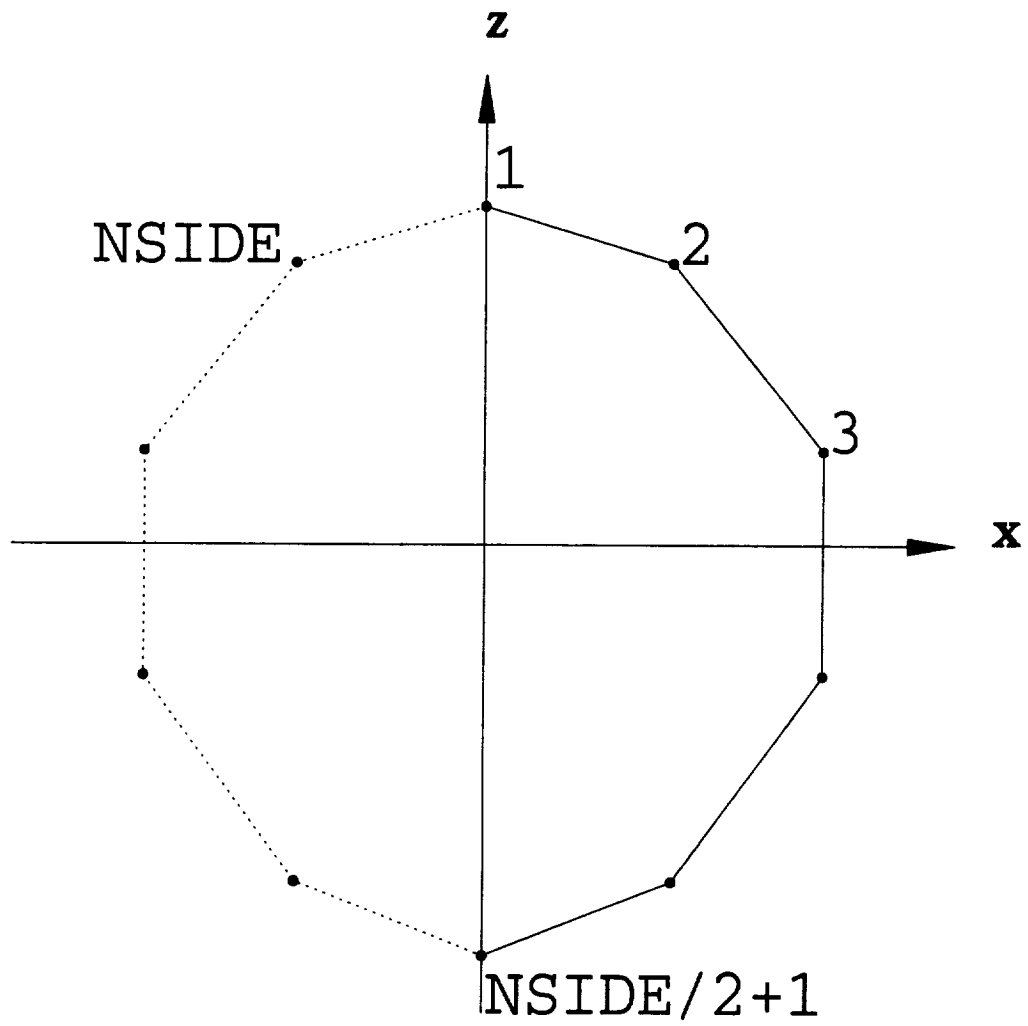
Figure 3.2: Cross section for a symmetric body.
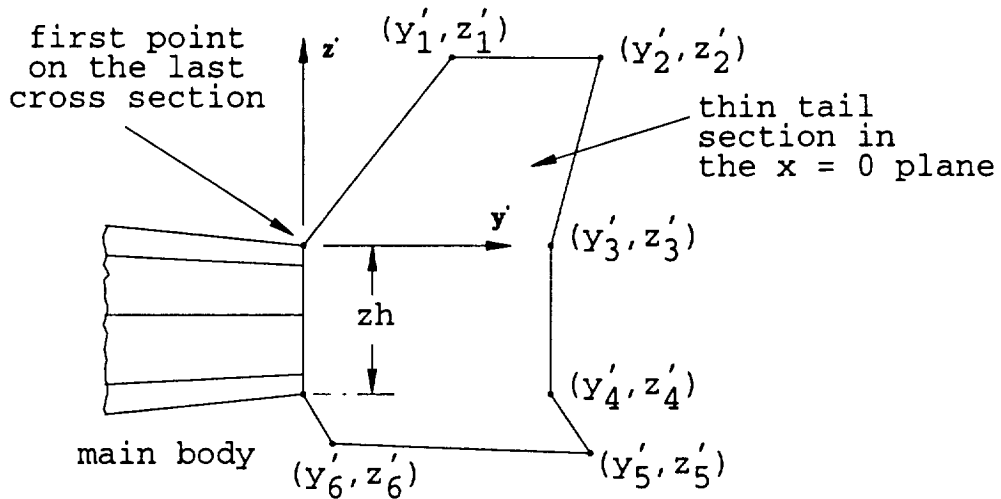
y'_i = YTSCN(I) ; i = I = 1,2,3,4,5,6

z'_i = ZTSCN(I) ; i = I = 1,2,5,6

z'_3 = 0

z'_4 = -zh

} these are not specified by the user

Figure 3.3: Geometry of the thin tail section.

of the six points are the input parameters of the TS command. The six points are referenced to the first point on the last cross section. Figure 3.3 shows the geometry of the thin tail section and the dimension parameters associated with it.

Form of the command:

TS: Tail Section

ZSHTTS

YTSCN(1), ZTSCN(1)

YTSCN(2), ZTSCN(2)

YTSCN(3)

YTSCN(4)

YTSCN(5), ZTSCN(5)

YTSCN(6), ZTSCN(6)

ZSHTTS = the complex sheet impedance in ohms per square for the thin tail section. For a perfectly conducting tail section set ZSHTTS = (0.0,0.0).

YTSCN(J) = the y value of the Jth point describing the thin tail section (J=1,2,3,4,5,6).

ZTSCN(J) = the z value of the Jth point describing the thin tail section (J=1,2,5,6).

YTSCN(J) and ZTSCN(J) are with respect to the (y', z') coordinate system shown in Figure 3.3. The (y', z') system is the basic (y, z) system translated to the first point on the last cross section. Notice that there are no z values input for points for J = 3 or 4. These values take on exactly the same as the z values as the 1st and (NSIDE/2 + 1)th point on the last cross section (NSIDE must be an even number). This is illustrated in Figure 3.3. This convention allows AMC to define the correct geometry in the event that a tail wing is specified (see Section 3.6).

The thin tail section connects to the main body at the 1st and (NSIDE/2 + 1)th points on the last cross section. The thin tail section must be in the $x = 0$ plane. Thus, if the TS command is invoked, the 1st and (NSIDE/2 + 1)th points on the last cross section must be in the plane $x = 0$. As mentioned above, it is generally recommended that NSIDE be an even number and the points 1 and (NSIDE/2 + 1) be in the $x = 0$ plane. Usually an endcap plate is specified on the last cross section (see Section 3.5) if a thin tail section is used. In this case, the thin tail section is in electrical contact with the end cap plate.

3.7 WG: The Wing Command

The geometry of interest may contain wings which attach to the main body. Wings are modelled by quadrilateral plates which make electrical contact with the main body. The "wing" command (WG) defines the shape and position of a wing or symmetric pair of wings. If the body has a pair of symmetric wings then they both can be specified in just one implementation of the WG command. Figures 3.4 and 3.5 show the geometry of a wing and the various parameters associated with the WG command.

The AMC code, and the ESP code on which it is based, is capable of treating intersecting plates only if they intersect along common edges. AMC or ESP can

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symmetric wing
(if specified)

cross section
NWSEC(1,I)

cross section
NWSEC(2,I)

point NWPT(I)

wing

(x_1', y_1', z_1') (x_2', y_2', z_2')

$x_1' = \mathrm{XWCN}(1,I)$ $x_2' = \mathrm{XWCN}(2,I)$

$y_1' = \mathrm{YWCN}(1,I)$ $y_2' = \mathrm{YWCN}(2,I)$

$z_1' = \mathrm{ZWCN}(1,I)$ $z_2' = \mathrm{ZWCN}(2,I)$
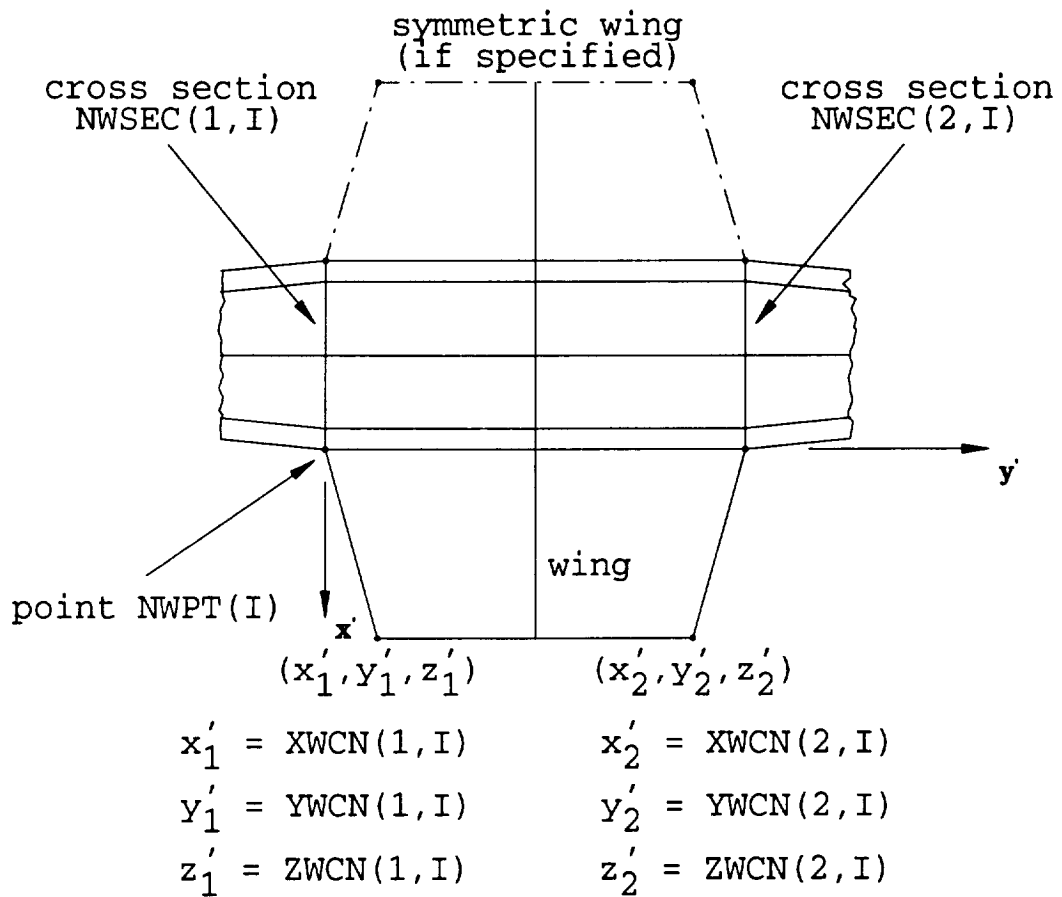
Figure 3.4: Top view of wing geometry.

point NWPT(I)

symmetric wing
(if specified)
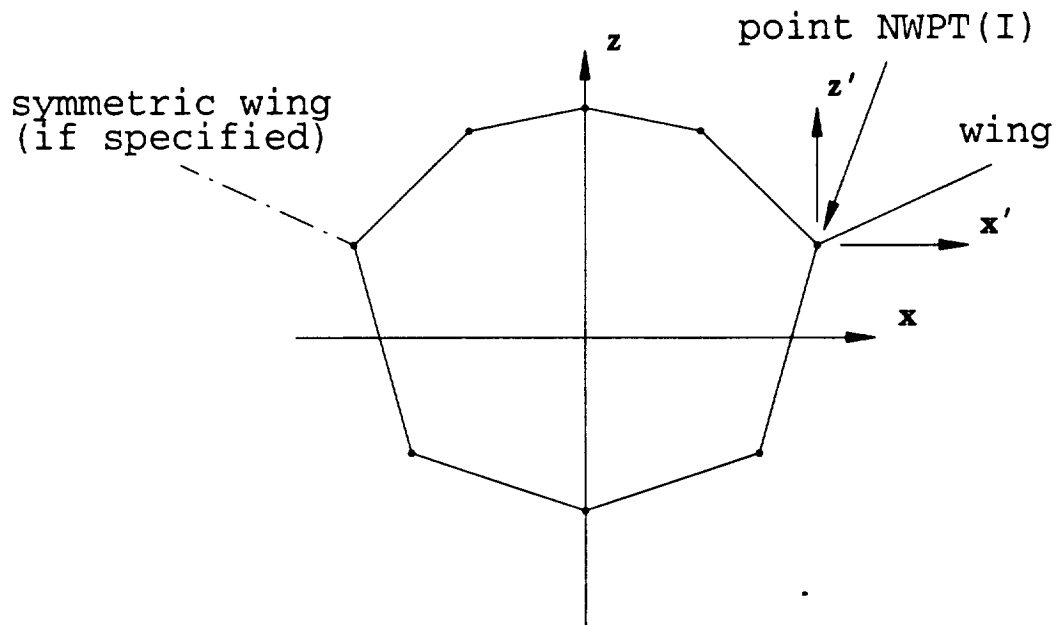
wing

Figure 3.5: End view of wing geometry.

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not treat the case where the edge of one plate intersects the planar surface of a second plate. Thus, in order to connect the wing plates to the main body plates, it is necessary that the wing and main body plates have common edges. Referring to Figures 3.4,3.5, or 4.19, a common edge between the wing plates and the main body plates can be guaranteed if the edge of the wing adjacent to the main body follows a line from point K on cross section I to point K on cross section I + 1, to point K on cross section I + 2, etc. In this case, the wing will be modelled by a quadrilateral plate extending from cross section I to cross section I + 1, a second quadrilateral plate extending from cross section I + 1 to cross section I + 2, etc. If the wing spans N cross sections, then it will be modelled by N-1 quadrilateral plates. These N-1 plates will form a planar surface only if points K on the wing cross sections have the same z values.

Form of the command:

WG: Wing
NWSEC(1,I), NWSEC(2,I), NWPT(I), NWSYM(I), ZSHTWG(I)
XWCN(1,I), YWCN(1,I), ZWCN(1,I), XWCN(2,I), YWCN(2,I), ZWCN(2,I)
where I = the number of the wing or pair of wings. I is a counter that is incremented by 1 each time a new wing or pair of wings is defined by the WG command.

NWSEC(1,I) = the number of the cross section that the Ith wing starts on.

NWSEC(2,I) = the number of the cross section that the Ith wing ends on.

NWPT(I) = the number of the cross section point that the Ith wing is placed at. If a pair of wings is defined the opposite wing will be placed at the corresponding opposite cross section point.

NWSYM(I) = indicator for wing symmetry of the Ith wing. This indicating parameter is used to specify a wing symmetric to the wing given, i.e., when a pair of symmetric wings exist.

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= 0 implies do not add a wing symmetric to the wing given.

= 1 implies add a wing symmetric to the wing given.

ZSHTWG(I) = the complex sheet impedance in ohms per square for the Ith wing(s). For a perfectly conducting wing set ZSHTWG(I) = (0.0,0.0).

XWCN(1,I), YWCN(1,I), ZWCN(1,I) = the x',y' and z' values of the first point out away from the main body of the Ith wing.

XWCN(2,I), YWCN(2,I), ZWCN(2,I) = the x',y' and z' values of the second point out away from the main body of the Ith wing.

NWSEC(1,I), NWSEC(2,I) and NWPT(I) are used to describe the location of the Ith wing. If the user anticipates placing a wing at a desired location then the cross sections must be defined accordingly. This is because point NWPT(I) on cross sections NWSEC(1,I), NWSEC(2,I), and all cross sections in between, will be the points where the wing attaches to the main body. In order for the Ith wing to be planar, the NWPT(I)th point on cross sections NWSEC(1,I) through NWSEC(2,I) must have the same z coordinate. Note that XWCN(1,I), YWCN(1,I), ZWCN(1,I), XWCN(2,I), YWCN(2,I) and ZWCN(2,I) are referenced to the point at which the Ith wing starts. In other words, they are referenced to the (x',y',z') coordinate system with origin at point NWPT(I) on cross section number NWSEC(1,I) (see Figure 3.4). Note that NWSEC(1,I) and NWSEC(2,I) must be set to the cross section number *after* any new cross sections have been added via interpolation using the CS command (see Section 3.5).

3.8   TW: The Tail Wing Command

A tail wing is like a wing (see Section 3.7) except that it attaches to the the thin tail section (see Section 3.6) instead of to the main body. A tail wing is modelled as a single quadrilateral plate and cannot be rotated, i.e., it must be horizontal. The "tail wing" command (TW) defines the shape and position of a tail wing or pair of tail wings. Figures 3.6 and 3.7 show the geometry of a tail wing and the dimension and

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placement parameters associated with it.

Form of the command:

TW: Tail Wing
YTWS, ZTWS, YTWL, ITWSYM, ZSHTTW
XTWCN(1), YTWCN(1), XTWCN(2), YTWCN(2)

YTWS = the y directed distance from the last cross section to the first point of the tail wing. Note that YTWS must be a positive number.

ZTWS = the z directed height of the tail wing with respect to point 1 of the last cross section. If ZTWS > 0, then the tail wing will be above point 1 of the last cross section. If ZTWS < 0, then the tail wing will be below point 1 of the last cross section.

YTWL = the horizontal length of the tail wing.

ITWSYM = indicator for tail wing symmetry. This indicator is used to specify a symmetric tail wing.
= 0 implies do not add a tail wing symmetric to the tail wing given.
= 1 implies add a tail wing symmetric to the tail wing given.

ZSHTTW = the complex sheet impedance in ohms per square for the tail wing(s). For a perfectly conducting tail wing(s) set ZSHTTW = (0.0,0.0).

XTWCN(1), YTWCN(1) = the x' and y' values of the first point out away from the thin tail section of the tail wing.

XTWCN(2), YTWCN(2) = the x' and y' values of the second point out away from the thin tail section of the tail wing.

Note that XTWCN(1), YTWCN(1), XTWCN(2) and YTWCN(2) are referenced to the (x', y') coordinate system whose origin is at the first point of the tail wing (see Figure 3.6).
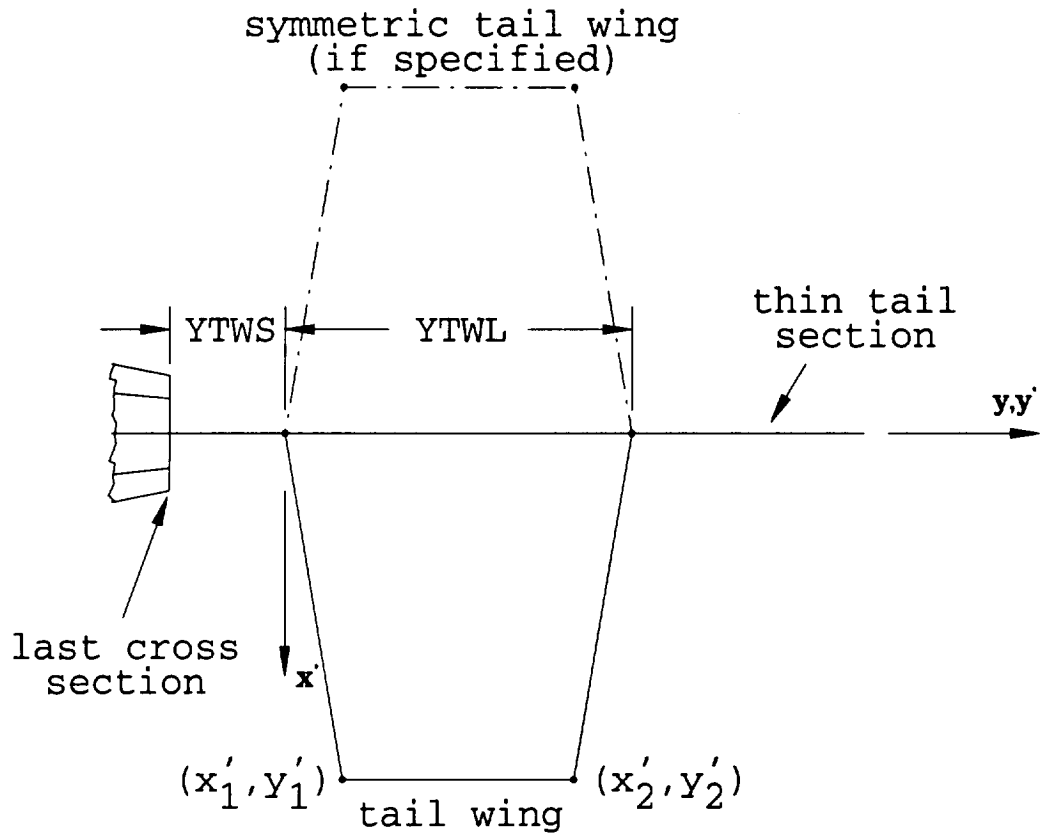
$$x_1' = \text{XTWCN}(1)$$

$$y_1' = \text{YTWCN}(1)$$

$$x_2' = \text{XTWCN}(2)$$

$$y_2' = \text{YTWCN}(2)$$

Figure 3.6: Top view of tail wing geometry.
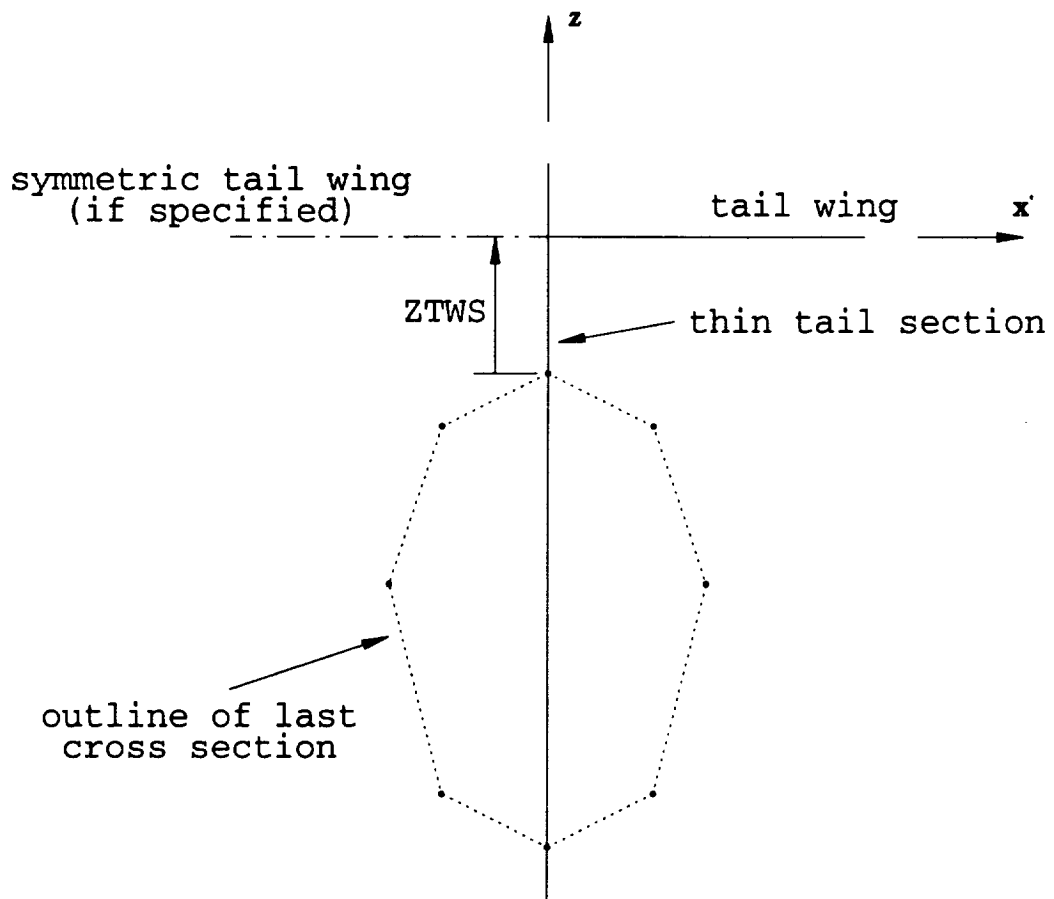
Figure 3.7: End view of tail wing geometry.

```
At this point:
   x = Xrot
   y = Yrot
   z = Zrot
```
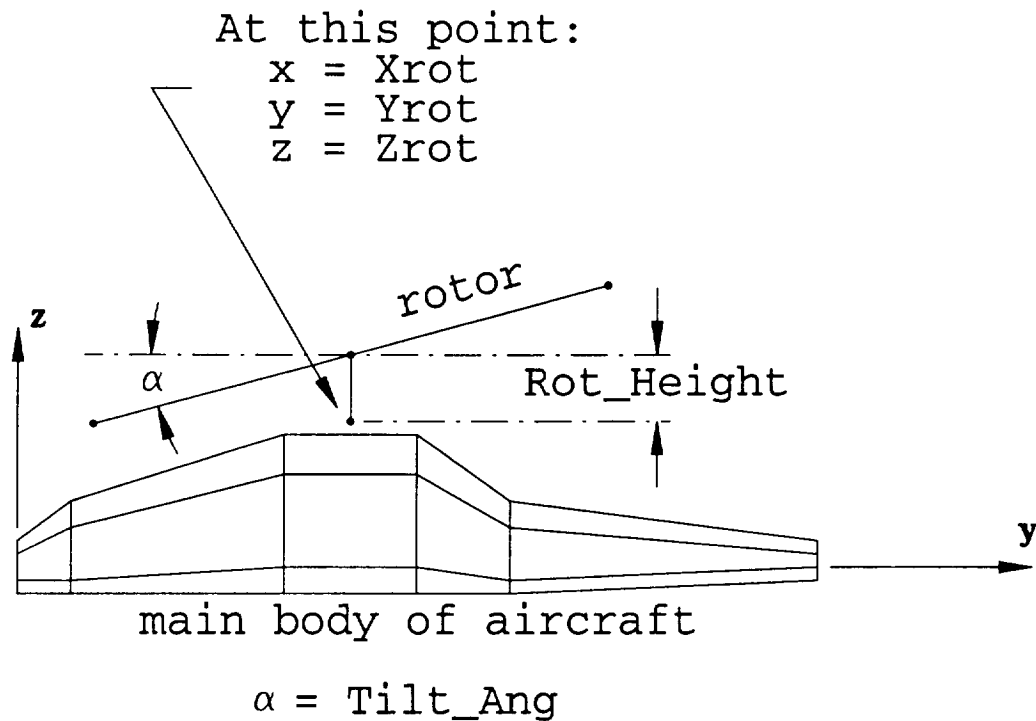
Figure 3.8: Side view of rotor geometry.

3.9   RX: The Rotor Command

If the body of interest is a helicopter the user may wish to include a rotor as part of the geometry. The "rotor" command (RX) defines the diameter, placement, and angle of rotation of a rotor with an arbitrary number of rotor blades. Figures 3.8 and 3.9 show the geometry of a four blade rotor and the dimension and placement parameters associated with it. The rotor blades are defined by two straight sections with a specified angle between them. Also, the rotor may be tilted forward or backward, i.e. it may be tilted skew to the xy plane. Note that the rotor is modelled by thin wires, and thus the width of the rotor blades must be small in terms of a wavelength.

Form of the command:

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α = Ang_Blade
β = Rotation_Ang
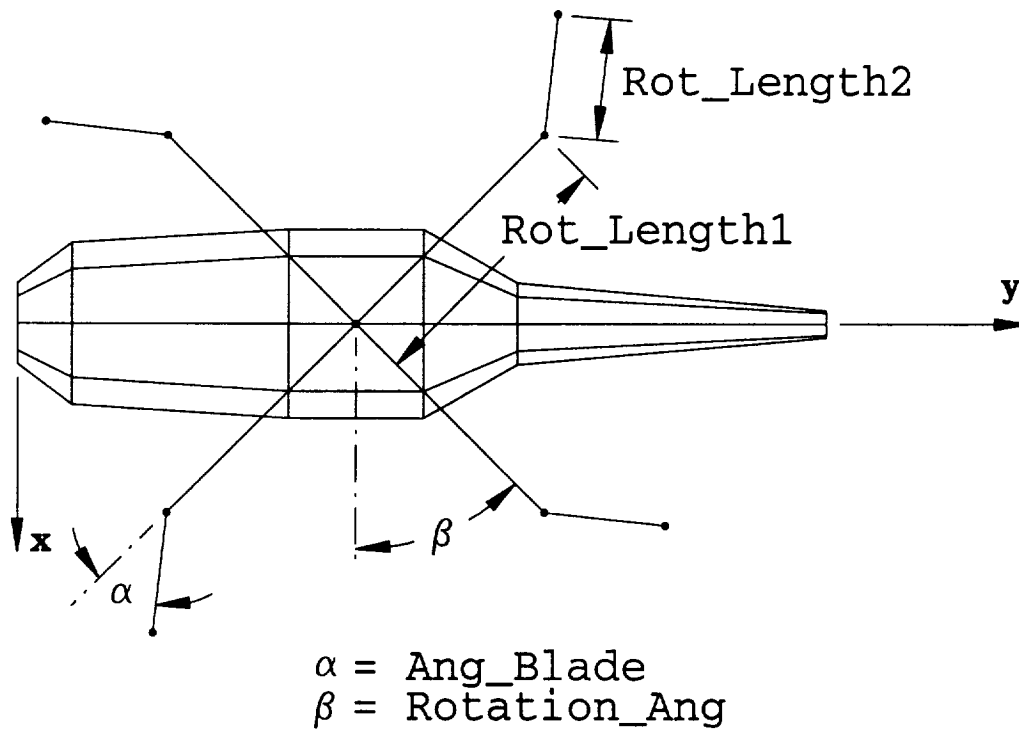
Figure 3.9: Top view of rotor geometry.

RX: Rotor

Num_Blades,Rot_Length1, Rot_Length2, Ang_Blade, Rot_Height

Xrot, Yrot, Zrot, Rotation_Ang, Tilt_Angle

Num_Blades = the number of rotor blades.

Rot_Length1 = the length of the first straight section of a rotor blade.

Rot_Length2 = the length of the second straight section of a rotor blade.

Ang_Blade = the angle of the rotor blade bend, measured from the $+x$ axis.

Rot_Height = the height of the rotor above the main body or fuselage.

Xrot = the x displacement of the rotor.

Yrot = the y displacement of the rotor.

Zrot = the z displacement of the rotor.

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Rotation_Ang = the rotation angle of the rotor, measured from the $+x$ axis.

Tilt_Ang = the tilt angle of the rotor; positive = forward tilt.

Note that Num_Blades, Rot_Length1, Rot_Length2, Ang_Blade and Rot_Height define the size and shape of the rotor, while Xrot, Yrot, Zrot, Rotation_Ang and Tilt_Ang define its position and orientation.

3.10   SC: The Source Command

In order to compute a radiation (as opposed to a scattering) pattern it is necessary to specify a source monopole. The "source" command (SC) defines the length and placement of this source. Figure 3.10 shows the geometry of the source monopole and the dimension and location parameters associated with it. Note that although two monopole sources are shown in Figure 3.10 (one above and one below the aircraft body) the user can only specify one monopole source at a time.

Form of the command:

SC: Source
Source_Length, Xsource, Ysource, Zsource, Source_Ang_Ph, Source_Ang_Th

Source_Length = the length of the source monopole.

Xsource = the x displacement of the monopole source.

Ysource = the y displacement of the monopole source.

Zsource = the z displacement of the monopole source.

Source_Ang_Ph = the ϕ angle of the monopole source.

Source_Ang_Th = the θ angle of the monopole source.

These parameters must be defined so that the source monopole does not touch or penetrate the main body.
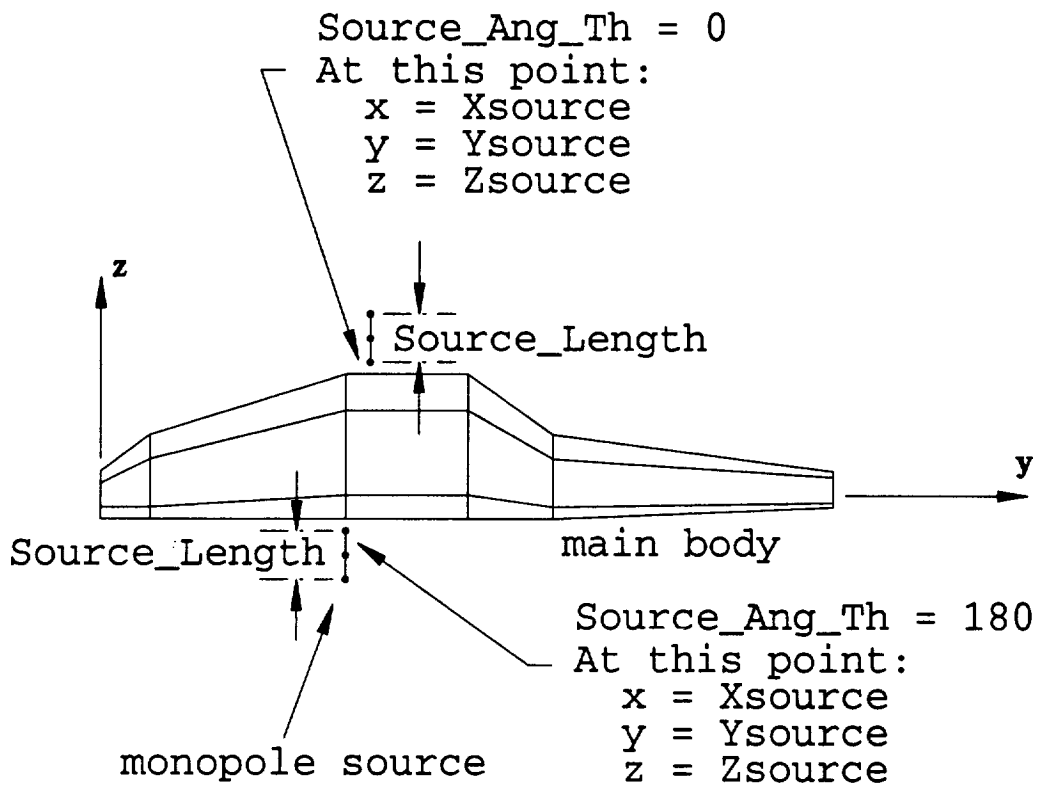
Figure 3.10: Side view of monopole source geometry.

The SC command automatically sets up a 1 volt generator at the center of the source monopole which induces currents to flow on the monopole and on the adjacent body. These currents produce the radiated fields.

The source monopole can be used to model a monopole antenna which uses the main body as its ground plane. By contrast, the wire antenna specified by the SC command does not contact the main body. However, if the distance from the end of the wire to the surface of the body is approximately $2\lambda/100$, then the far zone pattern will be essentially the same as for a true monopole antenna. It is the responsibility of the user to specify correct placement of the source monopole.

If a radiation pattern is requested, by invoking the RE and/or the RA commands (see Sections 2.7 and 2.8), then a source monopole must be specified. If a source monopole is not requested, AMC will print an error message to the output file and a complete run will not be made.

3.11   AT: The Attachment Mode Command

If a monopole source is specified by the user, there exists the option of also including an attachment mode for the monopole. As stated in Section 3.10, the source monopole does not physically contact the body of the aircraft, and thus currents cannot flow outward from the source monopole at the end nearest the aircraft body. The "attachment mode" command (AT) can specify a circular attachment mode disk which can allow for the outward flow of current from the monopole near the aircraft body. This circular disk of current is slightly removed from the aircraft body, but may allow for better coupling of the monopole to the aircraft body. Figure 3.11 shows the geometry of the attachment mode. Note that the monopole source and the attachment mode disk normal need not be in the same direction.

Form of the command:

AT: Attachment Mode
Xnorm, Ynorm, Znorm, Atrad

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```
                          ┌─ At this point:
         Aircraft           │   x = Xsource
          Body              │   y = Ysource
                            │   z = Zsource
```

```
                              a
    Monopole                       Attachment
    Source                         Mode Disk

                          n̂
```
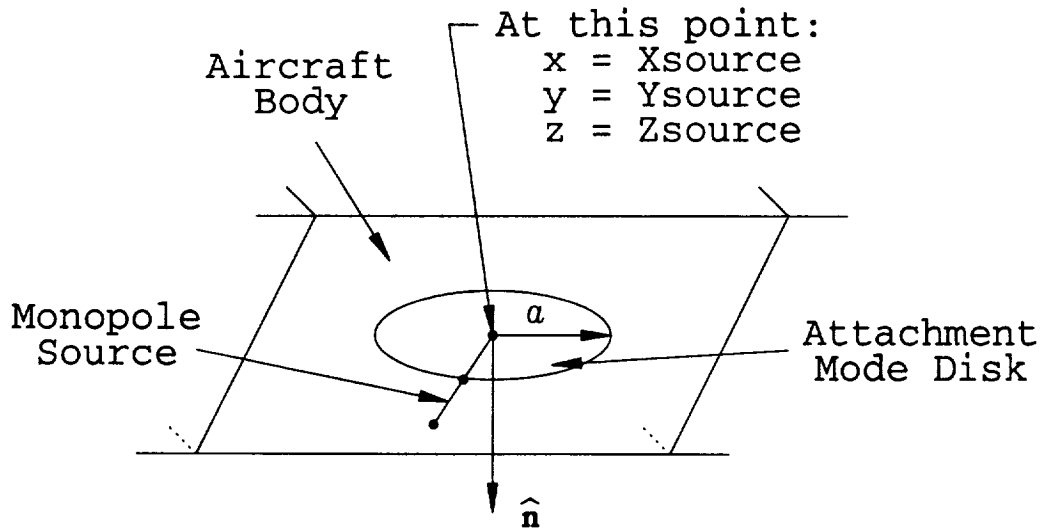
a = Atrad = Att. Mode Disk Radius

n̂ = Normal Vector to Att. Mode Disk
    Defined by Xnorm, Ynorm and Znorm

Figure 3.11: The attachment mode geometry.

Xnorm = the x direction normal to the aircraft body at the monopole source location.

Ynorm = the y direction normal to the aircraft body at the monopole source location.

Znorm = the z direction normal to the aircraft body at the monopole source location.

Atrad = the radius of the attachment mode disk monopole.

Basically, the AT command sets up an attachment mode of radius Atrad that is perpendicular to the direction specified by Xnorm, Ynorm and Znorm, with the wire portion extending onto the source monopole. Xnorm, Ynorm and Znorm do not need to be normalized by the user, but must specify the direction of the normal vector. The center of the attachment mode disk is at the location specified for the monopole source via the SC command, i.e., it is at the point (Xsource, Ysource, Zsource) (see Section 3.10).

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Experience has shown that the disk radius (Atrad) should be set between 0.1λ and 0.25λ. A good average choice is 0.2λ. Note that the disk radius should not extend beyond the aircraft body. Also, the aircraft body should be relatively flat at the monopole source location. Thus, if an attachment mode is specified, this flat section should extend at least a distance of Atrad away from the monopole source location in all radial directions. Also, the attachment mode disk must not physically penetrate or intersect with the aircraft body, and it is the responsibility of the user to insure that this requirement is satisfied.

3.12   AW: The Arbitrary Wires Command

Occasionally the user may wish to analyze a geometry that contains physical aspects which can be modelled by wires, but that is not definable through the other standard AMC commands. For example, the user may wish to specify an antenna geometry different from the usual short monopole source. The "arbitrary wire" command (AW) allows the user to input such wire geometries. The format is similar to the ESP code format, on which AMC is based, with the significant exception being that the user does NOT need to insure that the wires are segmented into modes. This is done automatically by AMC, with the user specifying the segment size that all wires input via the AW command are segmented into.

Form of the command:

AW: Arbitrary Wires
NPAW, NMAW, NATAW, SGMAW, NGNAW, IABAW
XAW(1), YAW(1), ZAW(1)
XAW(2), YAW(2), ZAW(2)
XAW(3), YAW(3), ZAW(3)
          $\vdots$
XAW(NPAW), YAW(NPAW), ZAW(NPAW)
IAAW(1), IBAW(1)

IAAW(2), IBAW(2)

IAAW(3), IBAW(3)

$\vdots$

IAAW(NMAW), IBAW(NMAW)

NPTAW(1), XNAW(1), YNAW(1), ZNAW(1), ARDAW(1)

NPTAW(2), XNAW(2), YNAW(2), ZNAW(2), ARDAW(2)

NPTAW(3), XNAW(3), YNAW(3), ZNAW(3), ARDAW(3)

$\vdots$

NPTAW(NATAW), XNAW(NATAW), YNAW(NATAW), ZNAW(NATAW), ARDAW(NATAW)

NPAW = the number of points in the arbitrary wire geometry.

NMAW = the number of segments in the arbitrary wire geometry.

NATAW = the number of wire to plate attachment points in the arbitrary wire geometry.

SGMAW = the maximum segment size in wavelengths which the arbitrary wire geometry is segmented into.

NGNAW = the segment number which contains a 1 volt generator.

= 0 implies arbitrary wire geometry contains no generator.

IABAW = indicator for generator location.

= 0 implies generator is at endpoint A of segment NGNAW.

= 1 implies generator is at endpoint B of segment NGNAW.

XAW(I) = x coordinate of wire point I.

YAW(I) = y coordinate of wire point I.

ZAW(I) = z coordinate of wire point I.

IAAW(J) = endpoint A of wire segment J.

IBAW(J) = endpoint B of wire segment J.

NPTAW(K) = attachment point K. Note that only one segment is allowed at an attachment point.

XNAW(K) = x direction normal to aircraft body at attachment point K.

YNAW(K) = y direction normal to aircraft body at attachment point K.

ZNAW(K) = z direction normal to aircraft body at attachment point K.

ARDAW(K) = attachment mode disk radius of attachment mode K.

Note that all wire point coordinates and attachment mode disk radii must be in the units indicated by the UN command (see Section 3.4.)

3.13 AP: The Arbitrary Plate Command

In analogy to what was mentioned for the AW command (Section 3.12) the user may wish to analyze a geometry that can be modelled by plates, but that is not definable through the other standard AMC commands. For example, the user may wish to specify an unusual wing or tail section shape. The "arbitrary plate" command (AP) allows the user to input such plate geometries. The format is similar to the ESP code format, on which AMC is based, with the exception that a 4–sided plate may be slightly non–planar.

Form of the command:

AP: Arbitrary Plates
NPLTSAP
NCNRS(1), IREC(1), IPN(1), IGS(1), IPLN(1), IZTP(1), ZSPL(1)
PCN(1,1,1), PCN(2,1,1), PCN(3,1,1)
PCN(1,2,1), PCN(2,2,1), PCN(3,2,1)
PCN(1,3,1), PCN(2,3,1), PCN(3,3,1)

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$$\vdots$$

PCN(1,NCNRS(1),1), PCN(2,NCNRS(N),1), PCN(3,NCNRS(1),1)

NCNRS(2), IREC(2), IPN(2), IGS(2), IPLN(2), IZTP(2), ZSPL(2)

PCN(1,1,2), PCN(2,1,2), PCN(3,1,2)

PCN(1,2,2), PCN(2,2,2), PCN(3,2,2)

PCN(1,3,2), PCN(2,3,2), PCN(3,3,2)

$$\vdots$$

PCN(1,NCNRS(2),2), PCN(2,NCNRS(2),2), PCN(3,NCNRS(2),2)

NCNRS(3), IREC(3), IPN(3), IGS(3), IPLN(3), IZTP(3), ZSPL(3)

PCN(1,1,3), PCN(2,1,3), PCN(3,1,3)

PCN(1,2,3), PCN(2,2,3), PCN(3,2,3)

PCN(1,3,3), PCN(2,3,3), PCN(3,3,3)

$$\vdots$$

PCN(1,NCNRS(3),3), PCN(2,NCNRS(3),3), PCN(3,NCNRS(3),3)

$$\vdots$$

$$\vdots$$

NCNRS(NPLTSAP), IREC(NPLTSAP), IPN(NPLTSAP), IGS(NPLTSAP),
    IPLN(NPLTSAP), IZTP(NPLTSAP), ZSPL(NPLTSAP)

PCN(1,1,NPLTSAP), PCN(2,1,NPLTSAP), PCN(3,1,NPLTSAP)

PCN(1,2,NPLTSAP), PCN(2,2,NPLTSAP), PCN(3,2,NPLTSAP)

PCN(1,3,NPLTSAP), PCN(2,3,NPLTSAP), PCN(3,3,NPLTSAP)

$$\vdots$$

PCN(1,NCNRS(NPLTSAP),NPLTSAP), PCN(2,NCNRS(NPLTSAP),NPLTSAP),
    PCN(3,NCNRS(NPLTSAP),NPLTSAP)

For the user who is familiar with ESP and the numbering of plates, it may be worthwhile to note that the plates defined via the AP command are the lowest numbered plates. Note that the segment size for all the plates defined via the AP command is SGM as defined by the SG command (see Section 3.1). Also, all plate point coordinates must be in the units indicated by the UN command (see Section 3.4.)

For the following description, it is understood that NPL takes on the values NPL = 1,2,3,...,NPLTSAP, and NCNR takes on the values NCNR = 1,2,3,...,NCNRS(NPL).

NPLTSAP = the total number of arbitrary plates.

NCNRS(NPL) = the number of corners on plate NPL.

IREC(NPL) = indicator for plate NPL being rectangular or polygonal.

    = 0 implies plate NPL is polygonal.

    = 1 implies plate NPL is rectangular.

IPN(NPL) = current mode polarization indicator.

    = 0 implies place no modes on plate NPL.

    = 1 implies modes are to be placed on plate NPL to cover polarization one only.

    = 2 implies modes are to be placed on plate NPL to cover polarization two only.

    = 3 implies both polarizations are to be placed on plate NPL. This is the usual value.

IGS(NPL) = the generating side indicator used to generate modes.

    = 0 implies AMC will choose the generating side. This is the usual value.

IPLN(NPL) = indicator for plate NPL being planar or non-planar.

    = 0 implies plate NPL is planar.

    = 1 implies plate NPL is non-planar. Note that if plate NPL is non-planar, then it must have exactly 4 sides.

IZTP(NPL) = indicator for the interpretation of impedance ZSPL.

    = 1 implies ZSPL is the sheet impedance of plate NPL in ohms per square.

    = 2 implies ZSPL is the surface impedance of plate NPL in ohms.

ZSPL(NPL) = the complex impedance for plate NPL. See IZTP(NPL) above for the correct interpretation of ZSPL(NPL). For a perfectly conducting plate set ZSPL = (0.0,0.0).

PCN(1,NCNR,NPL) = x coordinate of corner NCNR of plate NPL.

PCN(2,NCNR,NPL) = y coordinate of corner NCNR of plate NPL.

PCN(3,NCNR,NPL) = z coordinate of corner NCNR of plate NPL.

3.14 ZS: The Fuselage Sheet/Surface Impedance Command

The geometry of interest may contain fuselage sections that may be more accurately modelled as either sheet impedance plates, or plates with a surface impedance boundary condition. See Sections 1.1 and 1.2 for a more detailed description of the two impedance types. The "fuselage sheet/surface impedance" command (ZS) defines regions on the main body or fuselage where the plates have a specified impedance value. The ZS command can be invoked several times to define different impedances over different regions of the fuselage.

Form of the command:

ZS: Fuselage Sheet/Surface Impedance
NCSZS(I,1), NCSZS(I,2), NPTZS(I,1), NPTZS(I,2)
ITYPZS(I), ZSCS(I)

NCSZS(I,1) = the number of the cross section that the Ith fuselage impedance section starts on.

NCSZS(I,2) = the number of the cross section that the Ith fuselage impedance section ends on.

NPTZS(I,1) = the number of the point that the Ith fuselage impedance section starts on.

NPTZS(I,12 = the number of the point that the Ith fuselage impedance section ends on.

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ITYPZS(I) = indicator for what type of impedance ZSCS(I) is.

  = 1 implies ZSCS(I) is a sheet impedance, in ohms per square.

  = 2 implies ZSCS(I) is a surface impedance, in ohms.

ZSCS(I) = the complex impedance value of the I^{th} fuselage impedance section.

NCSZS(I,1), NCSZS(I,2), NPTZS(I,1) and NPTZS(I,2) are used to define the I^{th} fuselage impedance section. If the user anticipates defining an impedance section at a desired location then the cross sections must be defined accordingly. Note that NCSZS(I,1) and NCSZS(I,2) must be set to the cross section number *after* any new cross sections have been added via interpolation using the CS command (see Section 3.5).

3.15   ZE: The Endcap Sheet/Surface Impedance Command

Earlier, with the description of the CS command, (Section 3.5) it was mentioned that endcap plates can be used to cap off the fuselage or main body. The "endcap sheet/surface impedance" command (ZE) allows for the user to specify an impedance value on endcap plates. It only makes sense to define an endcap plate at the first and last cross sections defining the fuselage, and thus the ZE command can only be invoked twice. Note that the endcap plate must be specified by the CS command, i.e., the ZS command does not in itself define an endcap plate.

Form of the command:

ZE: Endcap Sheet/Surface Impedance
NECZS(I), ITPEZS(I), ZSEC(I)

NECZS(I) = the number of the cross section with the impedance endcap plate.

ITPEZS(I) = indicator for what type of impedance ZSEC(I) is.

  = 1 implies ZSEC(I) is a sheet impedance, in ohms per square.

  = 2 implies ZSEC(I) is a surface impedance, in ohms.

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ZSEC(I) = the complex impedance value of the endcap plate.

3.16 DG: The Detailed Geometry Command

The "detailed geometry" command (DG) requests that AMC writes a detailed description of the problem geometry to the output file. A detailed description of the problem geometry includes the following:

1. symmetry of the cross sections if they are symmetric.

2. cross section location, cross section points, and other important cross section information for each cross section.

3. thin tail section shape and position if a thin tail section has been defined.

4. wing shape and position for each wing that has been defined.

5. tail wing shape and position if a tail wing has been defined.

6. rotor geometry if a rotor has been defined.

7. source monopole geometry if a source monopole has been defined.

8. attachment mode geometry if an attachment mode has been defined.

9. arbitrary wire geometry if any arbitrary wires have been defined.

10. arbitrary plate geometry if any arbitrary plates have been defined.

11. fuselage sheet/surface impedance sections if any impedance sections have been defined.

Form of the command:

DG: Detailed Geometry

Default status: AMC will not write the detailed geometry to the output file.

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Invoking the DG command causes AMC to write out the individual "building blocks" that make up the body of interest. This gives the user the opportunity to verify the accuracy of the geometry.

3.17 NG: The End of Geometry Command

The "end of geometry" command (NG) indicates to AMC that the geometry commands have all been read. Thus, the NG command is the last command read from the input file. The NG command absolutely must appear in the input file. Any data following the NG command are ignored.

Form of the command:

NG: End of Geometry

3.18 Input File Comment Lines

As was mentioned in Section 2.14, the user can include comment lines (lines ignored by AMC) in the input file by making the first two characters on an input file line are either "%%" or "   " (two blank spaces.)

Chapter 4

Examples

In this chapter several examples are presented illustrating the use of the AMC computer code. The examples involve analyzing problems suitable for the AMC code. These example runs are designed to:

1. illustrate the input data,

2. illustrate the output data, and

3. provide trial or debugging runs for a new user.

Running any problem is a two step process. The first step is to insure that the problem geometry has been correctly defined. Even for relatively simple geometries, experience has shown that one is likely to make some errors in setting up the input file. Complicated geometries may require several runs before the geometry has been correctly defined. To avoid the time and expense of computing the impedance matrix and finding currents and fields when the geometry is incorrect, the EX command should not be invoked (see Section 2.1) until the user is sure the geometry has been specified correctly. If the EX command is not invoked, then the code reads in the geometry and then outputs a printout of the geometry. However, no moment method or electromagnetic field calculations are made. If the EX command is not invoked, the run typically requires only a few seconds of CPU time. When the user is reasonably confident that the input geometry is correct, then the actual data run is made by simply invoking the EX command. As described in Section 5.2, when the EX command is not invoked, the code also outputs a file on logical unit 9 which

can be used to provide plots of the geometry. These include a three view plot of the wire/plate geometry and, if desired, a detailed plot of the surface patch dipole modes on each plate as well as the overlap modes connecting intersecting plates. In the examples to follow, samples of these geometry plots will be given. Although all input files are shown with the EX command, it should be understood that the geometry plots were obtained by an initial run without the EX command. We strongly urge all AMC users to obtain these geometry plots, since on a complicated problem they are the best method of verifying that the geometry is correct. They can also be used to verify that the polygonal plates have (or have not) been properly segmented into surface patch modes. Finally, they provide a convenient pictorial documentation of the geometry.

The examples shown here were run on a VAX 8550, which is about 6 times faster than a VAX 11/780. It should be mentioned that running the examples on a computer other than the VAX 8550 may produce some changes in the output.

4.1   Example 1:   Backscattering From A Short Cylinder

Example 1 involves the computation of the far-zone elevation backscatter pattern, in the plane $\phi = 0°$, for the 6-sided open ended cylinder shown in Figure 4.1. The cylinder has a symmetric and uniform cross section. The frequency is 50.0 MHz.

The input file for Example 1 is shown in Figure 4.2. The run control commands appear first in the input file. The EX command specifies a complete run involving electromagnetic calculations. The WR command requests that the MM impedance matrix elements be written to the output file. For larger problem geometries this could result in a very large output file. However, Example 1 is relatively small with only 18 MM modes so the impedance matrix is printed out here to show typical values and to provide documentation for testing or debugging. The SE command defines an elevation backscatter pattern in the plane $\phi = 0°$ with a 5 degree step size. Since IPSE = 1, an output file on logical unit 8 containing the patterns will be produced

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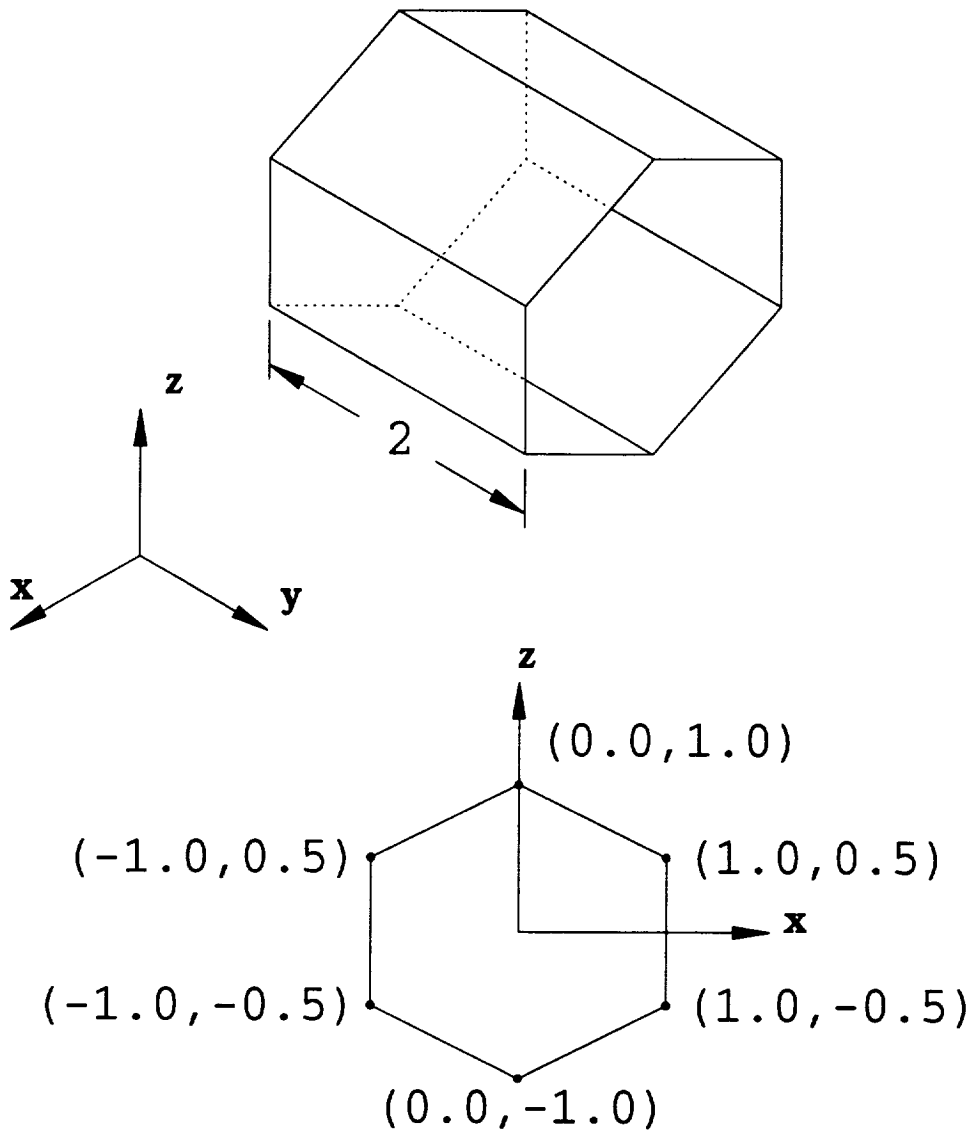
Cross Section Of Cylinder

NOTE: All dimensions are in meters.

Figure 4.1: The geometry for Example 1 is an open ended 6-sided cylinder.

```
EX : EXECUTE
WR : WRITE
0 0 1
SE : DEFINE SCATTERING ELEVATION PATTERN
1 1 5.0 0.0 0.0 0.0
FR : DEFINE FREQUENCY
50.0
NC : END OF RUN CONTROL COMMANDS
SG : DEFINE MAXIMUM SEGMENT SIZE
0.25
NS : DEFINE NUMBER OF SIDES
6
SM : SYMMETRIC FUSELAGE
DG : PRINT OUT DETAILED GEOMETRY
CS : DEFINE CROSS SECTION
0.0 0.0 0 0 0
0.0  1.0
1.0  0.5
1.0 -0.5
0.0 -1.0
CS : DEFINE CROSS SECTION
2.0 0.0 0 0 0
0.0  1.0
1.0  0.5
1.0 -0.5
0.0 -1.0
NG : END OF GEOMETRY DATA
```

Figure 4.2: The input file for Example 1.

for plotting purposes. The FR command sets the frequency to 50.0 MHz. The NC command indicates the end of the run control commands.

The geometry commands appear after the run control commands. Since the UN command was not invoked, all input dimensions will be in the default unit of length which is meters. The SG command defines the maximum segment size as 0.25 wavelengths. The NS command defines the cylinder as 6-sided. The SM command specifies symmetric cross sections. Thus, each cross section will be defined by NSIDE/2 + 1 = 4 points. The DG command requests a detailed printout of the geometry. The two CS commands define the cross sections. The first cross section is defined at $y = 0.0$ and the second cross section is defined at $y = 2.0$. No endcap plates, moved or added cross sections, or multiple cross sections at a single y value have been specified. The NG command indicates the end of the geometry commands and thus the end of the input file.

Figure 4.3 shows a three view plot of the 6-sided cylinder geometry. This plot is obtained from the geometry plotting file created on a previous run made without invoking the EX command as described in Section 5.2. The legend indicates that the moment method solution will use 18 plate modes and zero wire modes. A scale or tick mark is shown of length 0.122λ which permits one to estimate the electrical size of the geometry.

The output file for Example 1 is shown in Appendix A. The first part of the output file lists the run control commands and the parameters they have defined. This information is "echo printed" which means it is printed to the output file immediately after it has been read from the input file. The second part of the output file lists the geometry commands and the parameters they have defined. This information is also echo printed. The third part contains a detailed printout of the geometry. This part is printed only when the DG command is invoked. The fourth part of the output file lists a summary of the array dimensions (see Section 5.1) and a summary of the model geometry and modes. In Example 1 there are 6 plates and no wires. There are 18 plate modes and no wire modes. This ends the specification of the input geometry and would be the end of the output file if the EX command is not invoked.

EXAMPLE 1
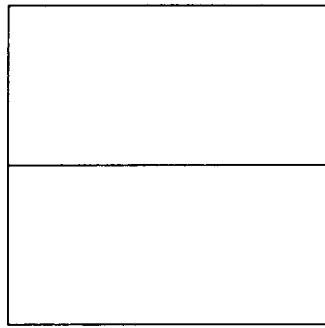
Z AXIS VIEW

0 WIRE MODES
18 PLATE MODES
0 ATTACH. MODES
18 TOTAL MODES
SCALE = 0.122 λ
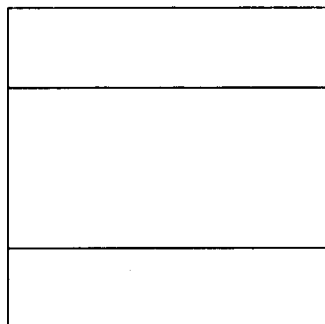
X AXIS VIEW

Y AXIS VIEW

Figure 4.3: A three view sketch of the geometry for Example 1.

Since the EX command was invoked the code proceeds to make the desired MM computations. Since the WR command was invoked setting IWRZT = 1, the impedance matrix (in volt-amps) is printed. Normally the impedance matrix is not printed because it can be very large, however, here it was printed to document typical values. The last part of the output file contains the desired patterns. The backscatter pattern in the plane $\phi = 0°$ is shown. The backscatter cross section magnitudes are given in dB over a square meter. Also, the phase in degrees of the far zone scattered electric field is given, with the usual e^{-jkr} factor removed. For all scattering patterns, the phase of the incident wave is zero at the origin of the coordinate system used to define the wire/plate geometry. The notation for the polarization of the incident and scattered wave is:

STTM = cross section for θ incident and θ scattered

SPPM = cross section for ϕ incident and ϕ scattered

STPM = cross section for θ incident and ϕ scattered

SPTM = cross section for ϕ incident and θ scattered

Since IPSE = 1 in the execution of the SE command, the code outputs a file on logical unit 8 which can be used to plot the far zone patterns (see Section 5.3). The STTM and SPPM patterns for Example 1 are plotted in Figures 4.4 and 4.5. In each case the legend indicates the frequency, the type of pattern, and the polar chart normalization. The scale of the polar chart is 10 dB/division. From reciprocity it can be shown that for *backscatter* patterns STPM should be identical to SPTM. However, due to numerical problems, or to the method for segmenting the plates into modes representing the orthogonal polarizations of current on the plates, there is always some difference in these patterns computed by the MM. If STPM is not reasonably close to SPTM (for backscatter) a severe problem is indicated. The STPM and SPTM patterns are zero due to problem symmetry in Example 1 so they have not been plotted in this report. Note that a cross section shown as -99.9 dB/m^2 should be interpreted as essentially zero.

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EXAMPLE 1
FREQUENCY =   50.00 MHZ.
BACKSCATTER
POLARIZATION: Θ-IN   Θ-OUT
ELEV. PLANE: Φ =   0°   R = ∞
MAXIMUM =   11.5 DB/M^2 10 DB/DIV.
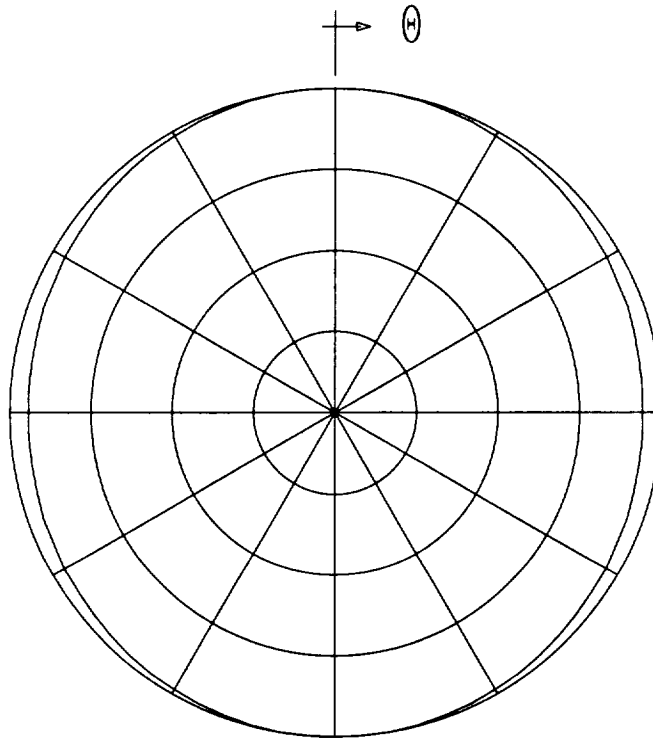
Figure 4.4: Backscatter pattern for Example 1 in the elevation plane $\phi = 0°$ and for polarization θ incident and θ scattered.

EXAMPLE 1
FREQUENCY = 50.00 MHZ.
BACKSCATTER
POLARIZATION: Φ-IN   Φ-OUT
ELEV. PLANE: Φ = 0°   R = ∞
MAXIMUM = 9.4 DB/M² 10 DB/DIV.
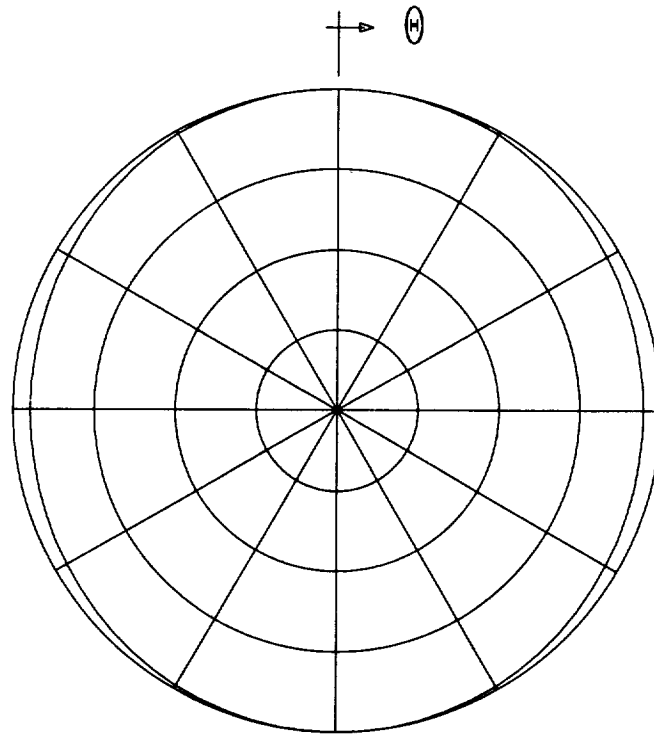
Figure 4.5: Backscatter pattern for Example 1 in the elevation plane $\phi = 0°$ and for polarization ϕ incident and ϕ scattered.

4.2 Example 2: Radiation From a Source Monopole on a Cylinder With Wings

Example 2 illustrates the computation of the far zone radiated patterns, in the plane $\phi = 0°$, for the geometry shown in Figure 4.6. The geometry consists of a symmetric six sided body which can be defined by four cross sections. The ends of the body, at cross section B, are not capped. A pair of symmetric wings is attached to the body. The source monopole is positioned below the body. The body is in the range $0 \leq y \leq 6m$.

The input file for Example 2 is shown in Figure 4.7. The run control commands appear first in the input file. The EX command specifies a complete run involving electromagnetic calculations. The RE command defines an elevation radiation pattern in the plane $\phi = 0°$. Calculations are made every 5 degrees and a pattern plotting file will be produced. The FR command sets the frequency to 50.0 MHz. The NC command indicates the end of the run control commands.

The geometry commands appear after the run control commands. All input dimensions will default to meters. The SG command defines the maximum segment size as 0.25 wavelengths. The NS command defines the cylinder as NSIDE = 6-sided. The SM command specifies symmetric cross sections. Thus, each cross section will be defined by NSIDE/2 + 1 = 4 points. The DG command requests a detailed printout of the geometry. The four CS commands define the cross sections. The cross sections are located at $y = 0.0$, $y = 2.0$, $y = 4.0$ and $y = 6.0$ meters. Note that IECI(1) = IECI(4) = 0, and thus the ends are not capped. The WG command defines the wing. Note that the wing is defined in a primed coordinate system. The wing goes from cross section 2 to cross section 3 and is located at point 3. A symmetric wing is also included. The wing is not rotated. The SC command defines the monopole source. The monopole is of length $\lambda/10 = 0.6$ meters and is positioned $2\lambda/100 = 0.12$ meters away from the surface of the cylinder. The NG command indicates the end of the geometry commands. Figure 4.8 shows a three view plot of the six sided body used in Example 2.
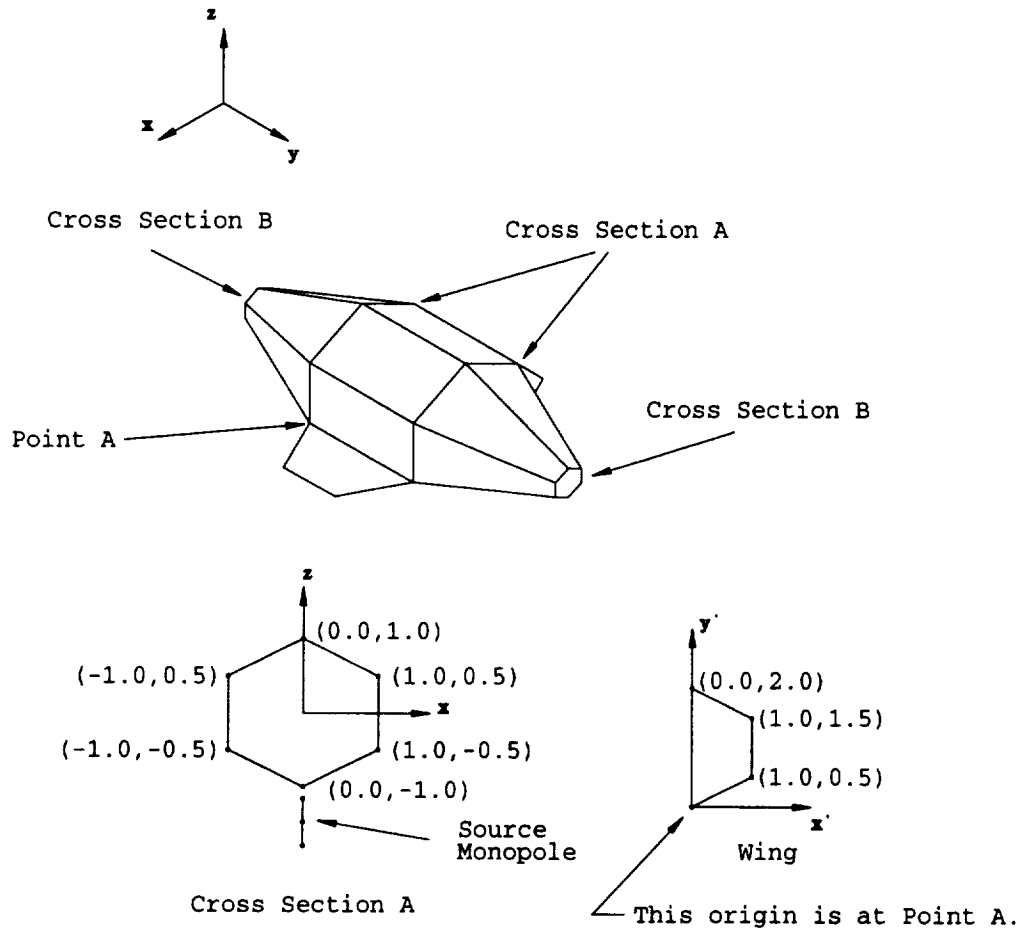
Figure 4.6: The geometry for Example 2 is a six sided body with a pair of wings and a radiating source monopole.

```
EX  :  EXECUTE
RE  :  DEFINE RADIATION ELEVATION PATTERN
1 5.0 0.0
FR: DEFINE FREQUENCY
50.0
NC  :  END OF RUN CONTROL COMMANDS
SG  :  DEFINE MAXIMUM SEGMENT SIZE
0.25
NS  :  DEFINE NUMBER OF SIDES
6
SM  :  SYMMETRIC FUSELAGE
DG  :  PRINT OUT DETAILED GEOMETRY
CS  :  DEFINE CROSS SECTION
0.0 0.0 0 0 0
0.00   0.250
0.25   0.125
0.25  -0.125
0.00  -0.250
CS  :  DEFINE CROSS SECTION
2.0 0.0 0 0 0
0.0   1.0
1.0   0.5
1.0  -0.5
0.0  -1.0
CS  :  DEFINE CROSS SECTION
4.0 0.0 0 0 0
0.0   1.0
1.0   0.5
1.0  -0.5
0.0  -1.0
CS  :  DEFINE CROSS SECTION
6.0 0.0 0 0 0
0.00   0.250
0.25   0.125
0.25  -0.125
0.00  -0.250
WG  :  DEFINE WINGS
2 3 3 1 (0.0,0.0)
1.0 0.5 0.0 1.0 1.5 0.0
SC  :  DEFINE SOURCE MONOPOLE
0.6 0.0 3.0 -1.12 0.0 180.0
NG  :  END OF GEOMETRY DATA
```

Figure 4.7: The input file for Example 2.

EXAMPLE 2
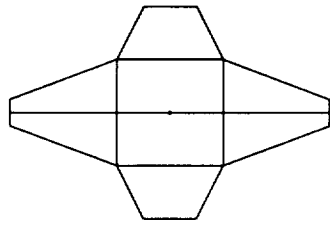
1 WIRE MODES
72 PLATE MODES
0 ATTACH. MODES
73 TOTAL MODES
SCALE = 0.367λ

Z AXIS VIEW
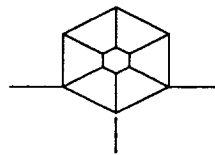
X AXIS VIEW   Y AXIS VIEW

Figure 4.8: A three view sketch of the geometry for Example 2.

The output file for Example 2 is shown in Appendix B. The run control commands and the geometry commands have been echo printed. The detailed printout of the geometry has also been included since the DG command was invoked. In Example 2 there are 20 plates and 2 wire segments made from 3 wire points. There are 72 surface patch plate modes and 1 wire mode. This ends the specification of the input geometry.

The MM computations follow the geometry specification in the output file. Since this is a radiation problem (as opposed to a scattering problem) the input admittance, input impedance, and radiation efficiency are printed. The generator feeding the monopole source is of strength 1 volt. The efficiency is 100% because there is no loading. In the AMC code the user can not specify loading. Next the elevation plane pattern in the plane $\phi = 0°$ is printed. The far zone patterns include the gain (as opposed to the directive gain) for θ and ϕ polarizations in dB and phase of the far zone radiated field in degrees. Since IPFE = 1 in the execution of the RE command, the code outputs a pattern plotting file on logical unit 8. The elevation plane pattern gain plot for the $\hat{\theta}$ polarization in the plane $\phi = 0°$ is shown in Figure 4.9. The legend in the plot indicates that the frequency is 50.0 MHz, the pattern is far zone gain (i.e. $R = \infty$), and that the polarization is θ. The $\hat{\phi}$ polarized gain is zero so it has not been included in this report.

4.3   Example 3: Radiation From a Source Monopole on a Cylinder With Endcap Plates and a Thin Tail Section and Tail Wings

Example 3 illustrates the computation of the far zone radiated patterns, in the azimuth plane $\theta = 90°$, for the geometry shown in Figures 4.10 and 4.11. A 3-D sketch of this geometry is also shown in Figure 4.12. The geometry consists of a symmetric six sided body which can be defined by three cross sections. The cross sections on the ends of the body have endcap plates. A thin tail section is added to the cylindrical body. Also, a symmetric pair of tail wings is attached to the thin tail section.

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EXAMPLE 2
FREQUENCY =   50.00 MHZ.
GAIN
POLARIZATION: Θ
ELEV. PLANE: Φ =   0°   R = ∞
MAXIMUM =   3.4 DB   10 DB/DIV.
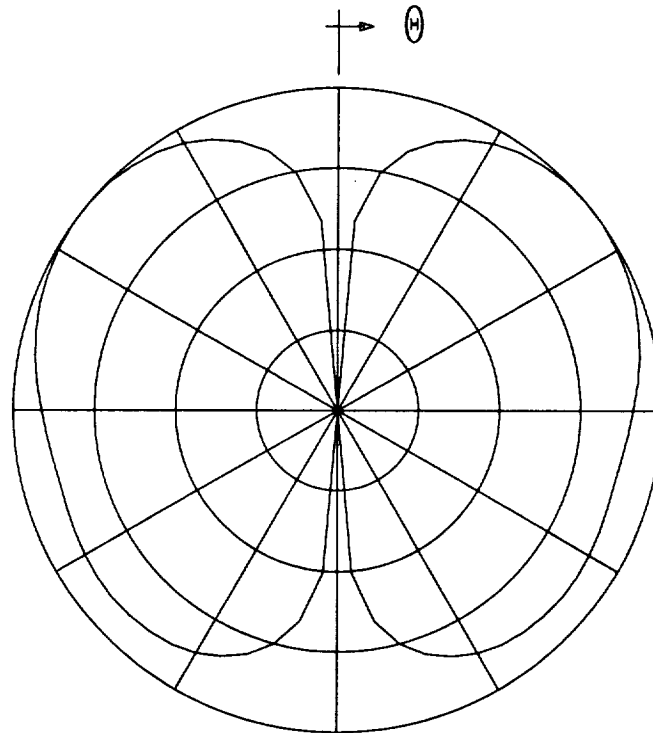
Figure 4.9: θ polarized gain in the elevation plane φ = 0° for Example 2.
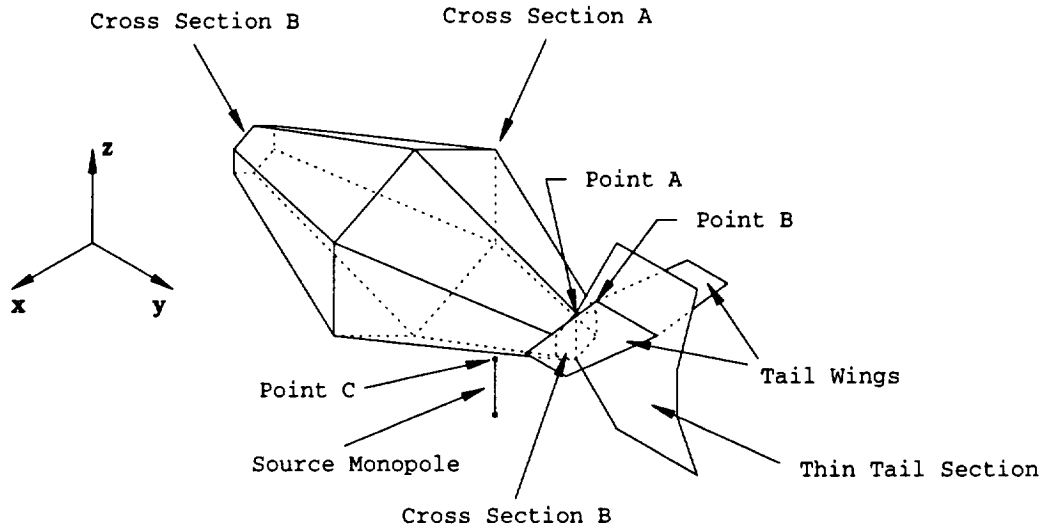
Figure 4.10: The geometry for Example 3 is a six sided body with a thin tail section, a pair of symmetric tail wings, and a radiating source monopole.
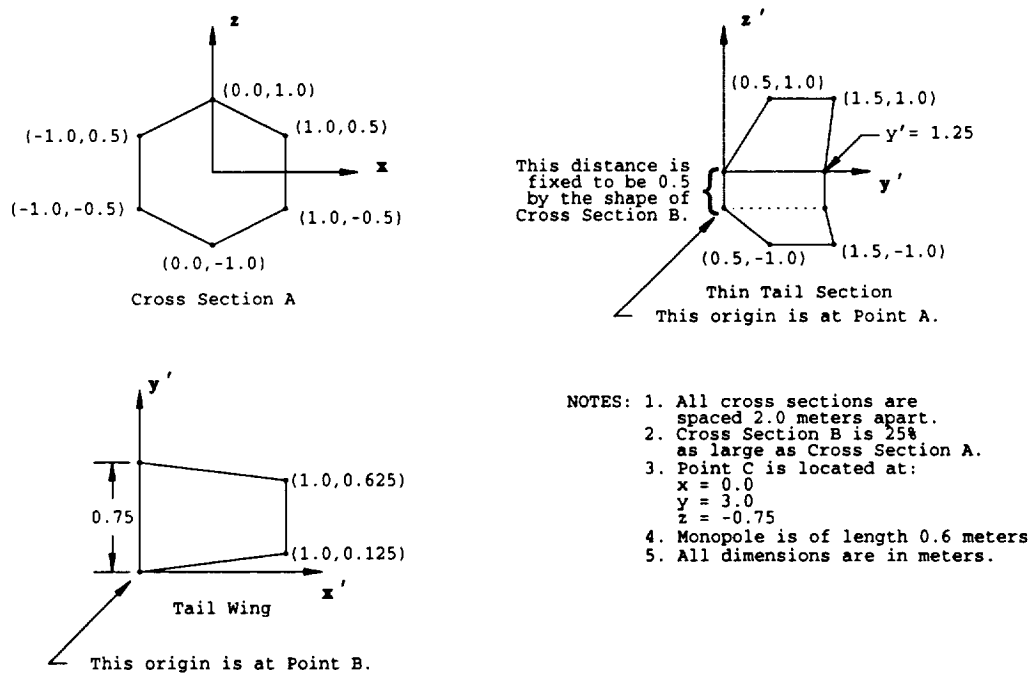
Figure 4.11: Detailed drawings of the cross sections, thin tail section and tail wings involved in Example 3.

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EXAMPLE 3

```
ROTATION ANGLE :
     PHI  =  35.0   DEG
   THETA  =  60.0   DEG
```
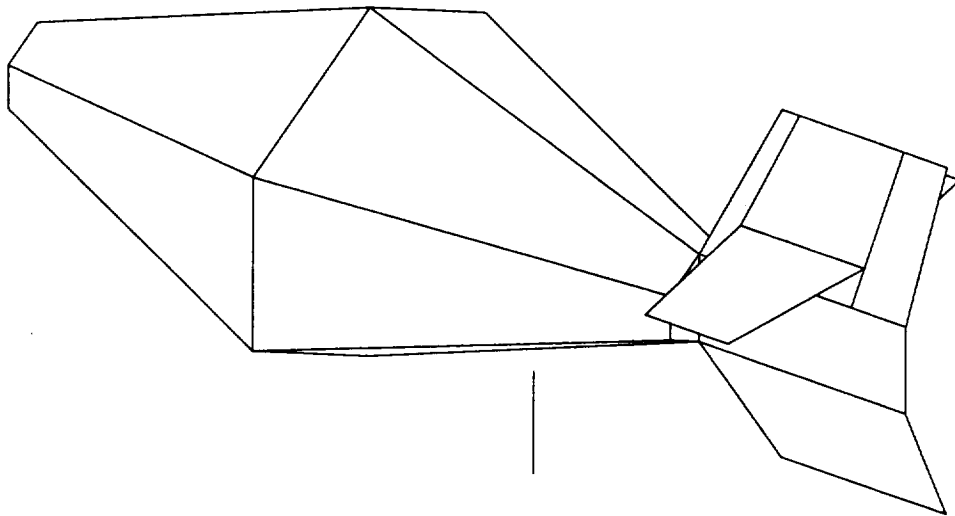
Figure 4.12: A 3-D sketch showing the geometry analyzed in Example 3.

The input file for Example 3 is shown in Figure 4.13. The run control commands appear first in the input file. The EX command specifies a complete run involving electromagnetic calculations. The RA command defines an azimuthal radiation pattern in the plane $\theta = 90°$. The pattern will be made at 5 degrees intervals, and a pattern plotting file will be produced. The FR command sets the frequency to 50.0 MHz. The NC command indicates the end of the run control commands.

The geometry commands appear after the run control commands. The SG command defines the maximum segment size as 0.25 wavelengths. The NS command defines the cylinder as NSIDE = 6-sided. The SM command specifies symmetric cross sections. Thus, each cross section will be defined by NSIDE/2 + 1 = 4 points. The UN command sets IUNITS = 2, which implies that all input dimensions will be in centimeters. Figure 4.11 shows dimensions in meters, but in Example 3 the dimensions are input in centimeters to illustrate the use of the UN command. The DG command requests a detailed printout of the geometry. The dimensions will be printed in meters rather than centimeters. The three CS commands define the cross sections. The cross sections are located at $y = 0$cm, $y = 200$cm and $y = 400$cm. Note that the cross sections on the ends of the body (those located at $y = 0$cm and $y = 400$cm) are specified to have endcap plates. The TS command defines a thin tail section. Note that the thin tail section is defined in a primed coordinate system with its origin located at point 1 on the last cross section. The thin tail section lies entirely in the $x = 0$ plane. Next, the TW command defines the tail wings. One tail wing is defined in a primed coordinate system with its origin located a y directed distance of 25cm beyond the last cross section and a z directed distance of 25cm from the first point on the last cross section. The tail wing spans a distance of 75cm along the thin tail section. A symmetric tail wing is also specified, thus making a pair of tail wings. The SC command defines the monopole source. The monopole is of length $\lambda/10 = 60$cm and is positioned $2\lambda/100 = 12$cm away from the surface of the cylinder at $y = 300$ meters. The NG command indicates the end of the geometry commands. Figure 4.14 shows a three view plot of the geometry for Example 3. This plot was generated from the geometry plotting file output on logical unit 9.

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```
EX : EXECUTE
RA : DEFINE RADIATION AZIMUTHAL PATTERN
1 5.0 90.0
FR : DEFINE FREQUENCY
50.0
NC : END OF RUN CONTROL COMMANDS
SG : DEFINE MAXIMUM SEGMENT SIZE
0.25
NS : DEFINE NUMBER OF SIDES
6
SM : SYMMETRIC FUSELAGE
UN : DEFINE UNITS
2
DG : PRINT OUT DETAILED GEOMETRY
CS : DEFINE CROSS SECTION
0.0 0.0 0 1 0
00.0   25.0
25.0   12.5
25.0 -12.5
00.0 -25.0
CS : DEFINE CROSS SECTION
200.0 0.0 0 0 0
000.0   100.0
100.0   050.0
100.0 -050.0
000.0 -100.0
CS : DEFINE CROSS SECTION
400.0 0.0 0 1 0
00.0   25.0
25.0   12.5
25.0 -12.5
00.0 -25.0
TS : DEFINE THIN TAIL SECTION
(0.0,0.0)
050.0   100.0
150.0   100.0
125.0
125.0
150.0 -100.0
050.0 -100.0
TW : DEFINE TAIL WING
25.0 25.0 75.0 1 (0.0,0.0)
100.0 12.5 100.0 62.5
SC : DEFINE SOURCE MONOPOLE
60.0 0.0 300.0 -75.0 0.0 180.0
NG : END OF GEOMETRY DATA
```

Figure 4.13: The input file for Example 3.

EXAMPLE 3

1 WIRE MODES
83 PLATE MODES
0 ATTACH. MODES
84 TOTAL MODES
SCALE = 0.336λ
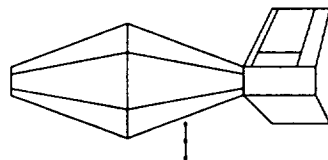
Z AXIS VIEW

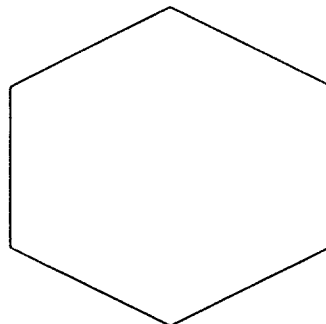X AXIS VIEW   Y AXIS VIEW

Figure 4.14: A three view sketch of the geometry for Example 3.

The output file for Example 3 is shown in Appendix C. The run control commands and the geometry commands have been echo printed. Note that the dimension parameters associated with the geometry commands have been printed in centimeters. Recall that in the input file the UN command was invoked to specify that all input dimensions (for the geometry commands) would be in centimeters. The detailed printout of the geometry has also been included since the DG command was invoked. Note that all dimensions in this part of the output file are in meters. In Example 3 there are 23 plates and 2 wire segments made from 3 wire points. There are 83 plate modes and 1 wire mode. This ends the specification of the input geometry.

The MM computations follow the geometry specification in the output file. The input admittance, input impedance, and radiation efficiency are printed. The generator feeding the monopole source is of strength 1 volt. The efficiency is 100% because there is no loading. Next the azimuthal plane pattern in the plane $\theta = 90°$ is printed. The far zone patterns include the gain (as opposed to the directive gain) for θ and ϕ polarizations in dB and phase of the far zone radiated field in degrees. Since IPFA = 1 in the execution of the RA command the code outputs a pattern plotting file on logical unit 8. The azimuthal plane pattern gain plots for the $\hat{\theta}$ polarization and the $\hat{\phi}$ polarization in the plane $\theta = 90°$ are shown in Figures 4.15 and 4.16. The legend in the plots indicates that the frequency is 50.0 MHz, the pattern is far zone gain (i.e. $R = \infty$), and the polarization ($\hat{\theta}$ and $\hat{\phi}$).

4.4   Example 4: Scattering From a Winged Body.

Example 4 shows in detail how to add a wing onto a body. The geometry of this body is shown in Figures 4.17 and 4.18. It is desired to obtain a backscatter pattern in the azimuth plane $\theta = 90°$.

The geometry consists of a circular cylinder with a circular nose cone. A symmetric pair of tail wings is attached to this body. The wings cross the junction between the nose cone and the cylinder but they do not start and end on simple cross sections. Thus, two new cross sections are needed so that the wings start and end at the correct location. Recall that a wing must start and end at a cross section. Furthermore, these

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EXAMPLE 3
FREQUENCY =   50.00 MHZ.
GAIN
POLARIZATION: θ
AZIM. PLANE:θ = 90°   R = ∞
MAXIMUM =   2.2 DB   10 DB/DIV.

φ
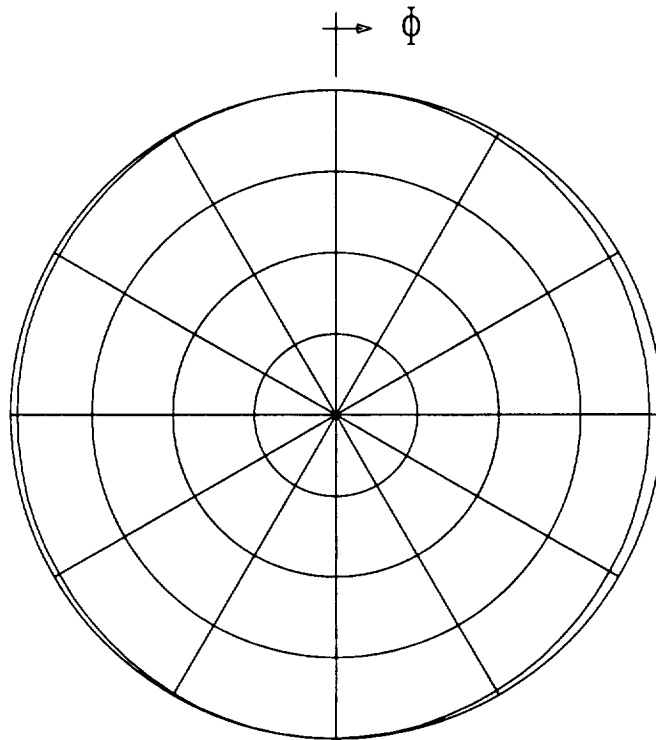
Figure 4.15: θ polarized gain in the azimuthal plane $\theta = 90°$ for Example 3.

EXAMPLE 3
FREQUENCY =   50.00 MHZ.
GAIN
POLARIZATION: φ
AZIM. PLANE: θ = 90°   R = ∞
MAXIMUM =   -3.0 DB   10 DB/DIV.

Figure 4.16: φ polarized gain in the azimuthal plane θ = 90° for Example 3.
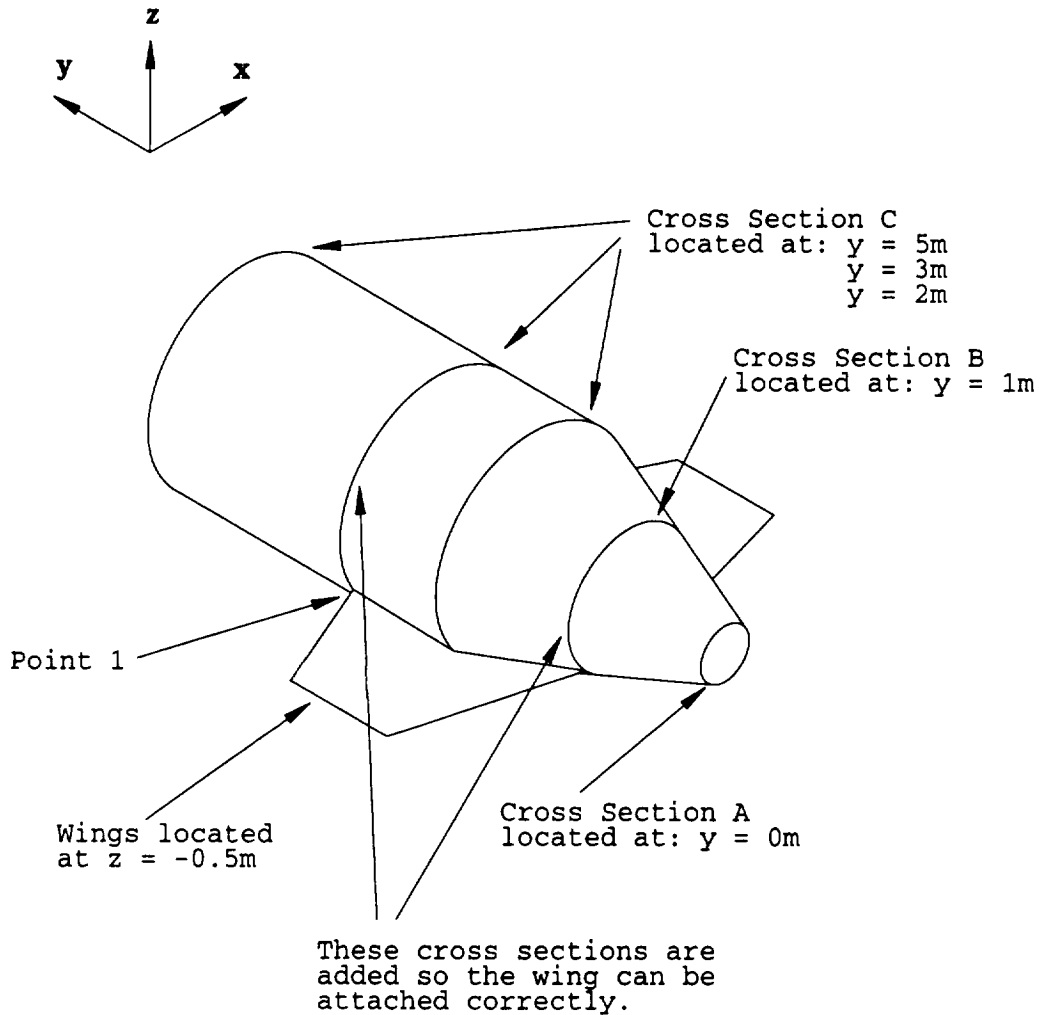
Figure 4.17: The geometry for Example 4 is a winged body.

new cross sections must be defined in such a way that keeps the wing horizontal. Thus, z values of the point the wing is placed at must be the same for each cross section that the wing spans. All circular cross sections will be approximated by 8 sided polygons. Thus, the model will have 8 sides. A 3-D sketch of the geometry of Example 4 is shown in Figure 4.19.

The input file for Example 4 is shown in Figure 4.20. The run control commands appear first in the input file. The EX command specifies a complete run involving electromagnetic calculations. The SA command defines an azimuthal backscatter pattern in the plane $\theta = 90°$. The pattern will be made at 2 degrees intervals, and a

(0.0,0.25)
(0.177,0.177)
(0.25,0.0)
(0.177,-0.177)
(0.0,-0.25)

Cross Section A

(0.0,0.625)
(0.442,0.442)
(0.625,0.0)
(0.375,-0.5)
(0.0,-0.625)

Cross Section B

(0.0,1.0)
(0.707,0.707)
(1.0,0.0)
(0.866,-0.5)
(0.0,-1.0)

Cross Section C

Outline of main body
where wing attaches

Point 1

y'

(0.5,1.5)   (1.5,1.5)

x'   Wing
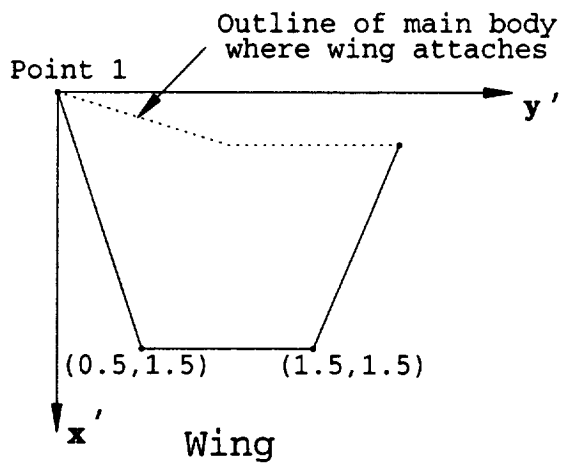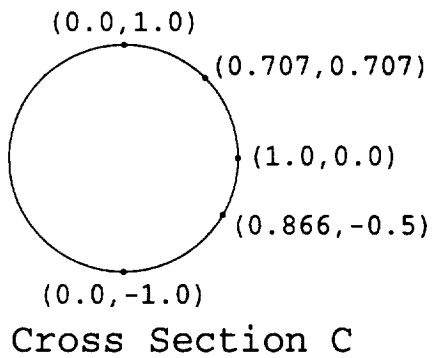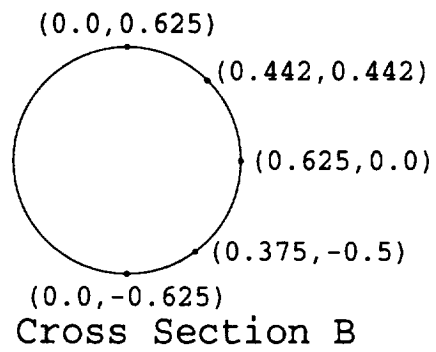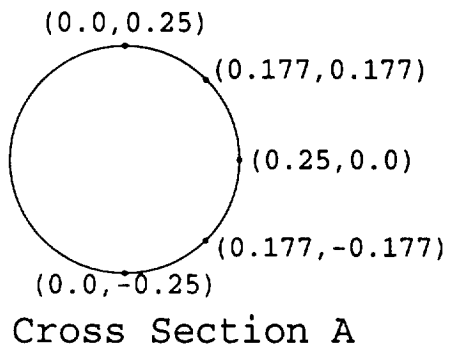
NOTE: All dimensions are in meters.

Figure 4.18: The cross sections and wing for Example 4.

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EXAMPLE 4

```
ROTATION ANGLE :
    PHI = 320.0   DEG
  THETA =  60.0   DEG
```
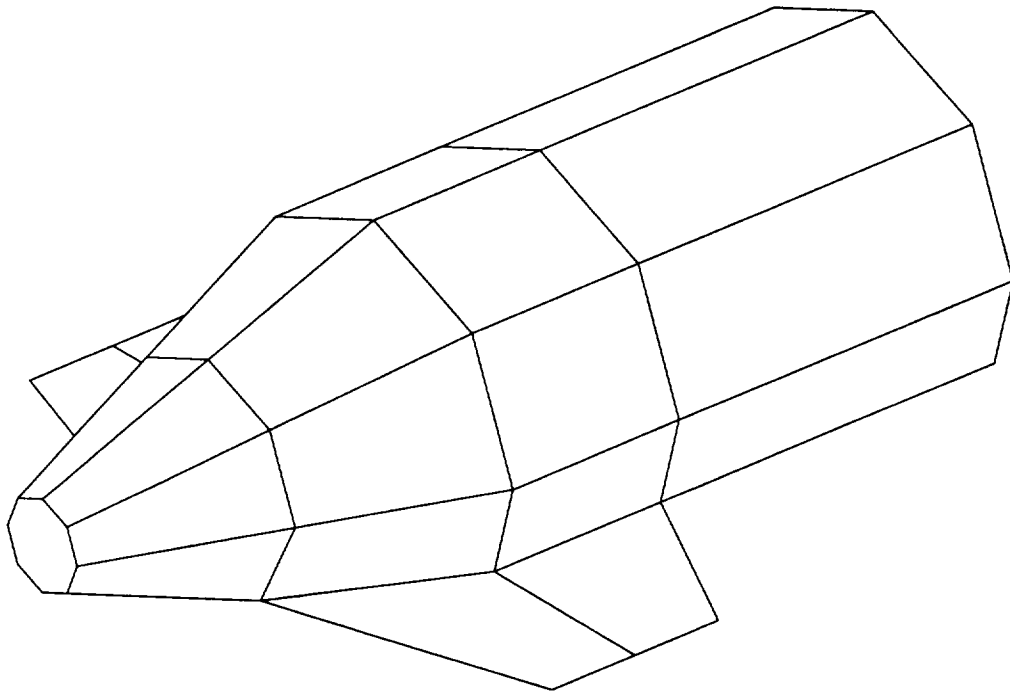
Figure 4.19: A 3-D sketch showing the geometry analyzed in Example 4.

pattern plotting file will be produced. The FR command sets the frequency to 70.0 MHz. The NC command indicates the end of the run control commands.

The geometry commands appear after the run control commands. The SG command defines the maximum segment size as 0.25 wavelengths. The cross sections each have 8 sides so the NS command need not be executed since the default is NSIDE = 8. The SM command specifies symmetric cross sections. Thus, each cross section will be defined by NSIDE/2 + 1 = 5 points. All input dimensions will be in the default unit of meters. The DG command requests a detailed printout of the geometry. The four CS commands define the five cross sections. The cross sections are located at $y = 0$m, $y = 1$m, $y = 2$m, $y = 3$m and $y = 5$m. Note that the cross section at $y = 3$m is interpolated from the cross sections defined by the 3rd and 4th CS commands. Also, note that the cross sections on the ends of the body (those located at $y = 0$m and $y = 5$m) are specified to have endcap plates. The WG command defines a wing. The wing goes from cross section 2 to cross section 4 and is located at point 4. Note that cross section 4 was placed at $y = 3$m so the wing ends there. Recall that a wing is defined such that it starts and ends at a cross section. Also, note that the z values of point 4 on cross sections 2, 3, 4 and 5 are all the same. This insures that the wing will is horizontal. A symmetric wing is also included and the wing is not rotated. As always when defining a wing, the wing is defined in a primed coordinate system. For Example 4 the origin of this primed coordinate system is located at point 4 on cross section 2. The NG command indicates the end of the geometry commands. Figure 4.21 shows a three view plot of the geometry for Example 4. This plot was generated from the geometry plotting file output on logical unit 9.

The output file for Example 4 is shown in Appendix D. The run control commands and the geometry commands have been echo printed. The dimension parameters associated with the geometry commands have been printed in meters. The detailed printout of the geometry has also been included since the DG command was invoked. In comparing the echo printed geometry commands to the detailed printout of the model geometry it can be seen that the new cross section has been added. The interpolated cross section has been included in the detailed printout. The wing is

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```
EX : EXECUTE
SA : DEFINE SCATTERING AZIMUTH PATTERN
1 1 2.0 90.0 0.0 0.0
FR : DEFINE FREQUENCY
70.0
NC : END OF RUN CONTROL COMMANDS
SG : DEFINE MAXIMUM SEGMENT SIZE
0.25
SM : SYMMETRIC FUSELAGE
DG : PRINT OUT DETAILED GEOMETRY
CS : DEFINE CROSS SECTION
0.000 0.000 0 1 0
0.000  0.250
0.177  0.177
0.250  0.000
0.177 -0.177
0.000 -0.250
CS : DEFINE CROSS SECTION
1.000 0.000 0 0 0
0.000  0.625
0.442  0.442
0.625  0.000
0.375 -0.500
0.000 -0.625
CS : DEFINE CROSS SECTION
2.000 3.000 2 0 0
0.000  1.000
0.707  0.707
1.000  0.000
0.866 -0.500
0.000 -1.000
CS : DEFINE CROSS SECTION
5.000 0.000 0 1 0
0.000  1.000
0.707  0.707
1.000  0.000
0.866 -0.500
0.000 -1.000
WG : DEFINE WINGS
2 4 4 1 (0.0,0.0)
1.500 0.500 0.000 1.500 1.500 0.000
NG : END OF GEOMETRY DATA
```

Figure 4.20: The input file for Example 4.

EXAMPLE 4
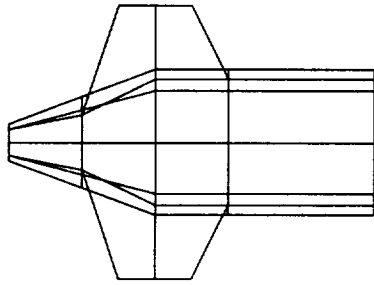
0 WIRE MODES
145 PLATE MODES
0 ATTACH. MODES
145 TOTAL MODES
SCALE = 0.428λ
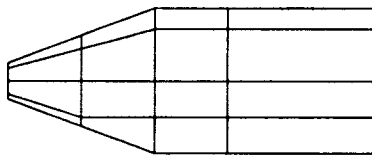
Z AXIS VIEW
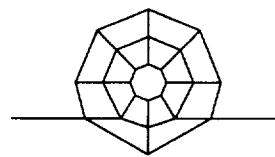
X AXIS VIEW   Y AXIS VIEW

Figure 4.21: A three view sketch of the geometry for Example 4.

attached at point 4 on the 2^{nd} and the 4^{th} cross sections. The symmetric wing is also included. The 4^{th} cross section was added using interpolation. The geometry of Example 4 conta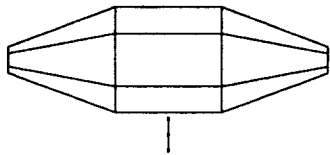ins 38 plates and no wires. There are 145 plate modes and no wire modes. This ends the specification of the input geometry.

The MM computations follow the geometry specification in the output file. The backscatter pattern in the azimuth plane $\theta = 90°$ is printed. All four combinations of polarizations of the incident and scattered wave are given. See Example 1 for a full description of backscatter polarizations. The backscatter cross section magnitudes are given in dB over a square meter. Also, the phase in degrees of the far zone scattered electric field is given, with the usual e^{-jkr} factor removed. Since IPSA = 1 in the execution of the SA command, the code outputs a file on logical unit 8 which can be used to plot the far zone patterns (see Section 5.3). The patterns for Example 4 are plotted in Figures 4.22, 4.23, 4.24 and 4.25. The cross polarized patterns (STPM and SPTM) are reasonably close, as they should be for backscatter problems.

4.5 Example 5: Radiation From a Source Monopole on a Model of a Helicopter

The geometry of Example 5 consists of a helicopter. Example 5 is included as the final example to illustrate how the AMC code can be used to analyze a practical, complicated geometry. A 3-D sketch of the helicopter showing all its features is shown in Figure 4.26. Almost every capability of the AMC geometry commands is involved in this example. The helicopter is defined by 11 cross sections. However, two new cross sections are added using interpolation, making a total of 13 cross sections. The new cross sections are added so that a pair of wings can be positioned at the y values of these new cross sections. Furthermore, multiple cross sections (cross sections having the same y value) are defined to account for the discontinuous shape of the helicopter being analyzed. In addition to a pair of wings, the helicopter also contains a thin tail section, a pair of tail wings and a monopole source.

The input file for Example 5 is included in Appendix E. The run control commands appear first in the input file. The EX command specifies a complete run. The RE

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EXAMPLE 4
FREQUENCY =   70.00 MHZ.
BACKSCATTER
POLARIZATION: θ-IN   θ-OUT
AZIM. PLANE: θ = 90°   R = ∞
MAXIMUM =   13.3 DB/M²   10 DB/DIV.
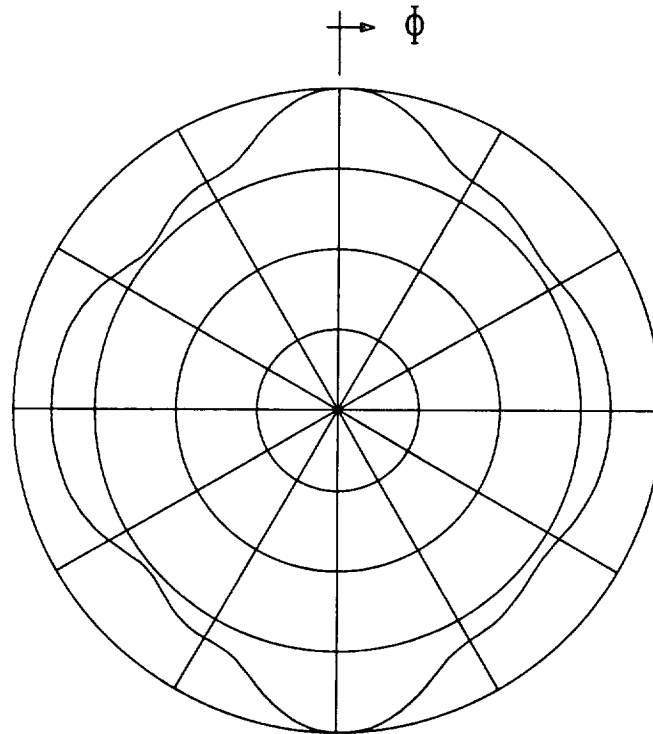
Figure 4.22: Backscatter pattern for Example 4 in the azimuth plane $\theta = 90°$ and for polarization θ incident and θ scattered.

C-2.

EXAMPLE 4
FREQUENCY =   70.00 MHZ.
BACKSCATTER
POLARIZATION: Φ-IN   Φ-OUT
AZIM. PLANE: θ =   90°   R = ∞
MAXIMUM =   17.0 DB/M²   10 DB/DIV.
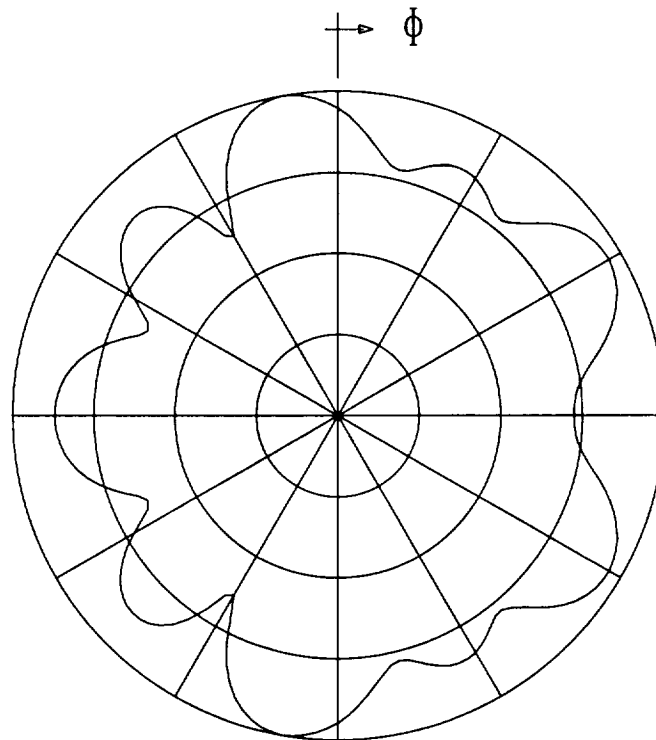
Figure 4.23: Backscatter pattern for Example 4 in the azimuth plane $\theta = 90°$ and for polarization ϕ incident and ϕ scattered.

EXAMPLE 4
FREQUENCY =   70.00 MHZ.
BACKSCATTER
POLARIZATION: Θ-IN   Φ-OUT
AZIM. PLANE: Θ = 90°   R = ∞
MAXIMUM =   2.2 DB/M²   10 DB/DIV.
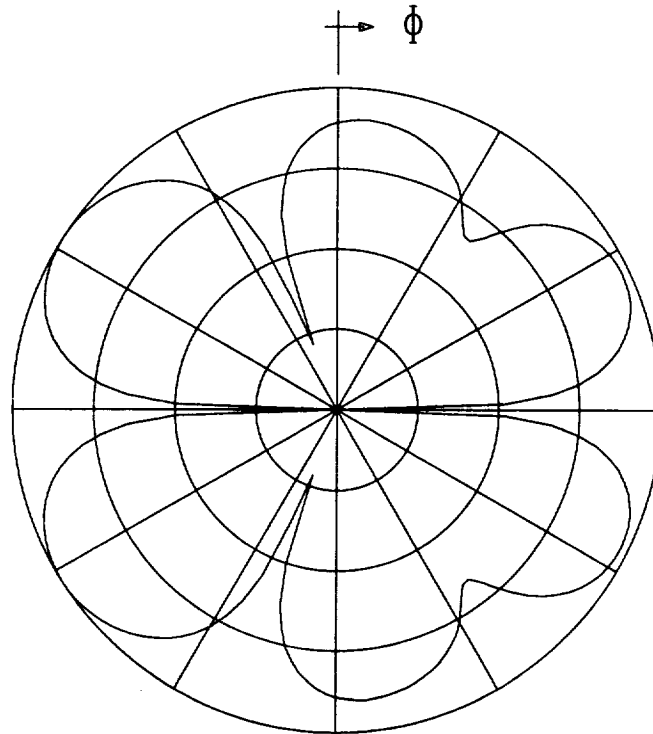
Figure 4.24: Backscatter pattern for Example 4 in the azimuth plane $\theta = 90°$ and for polarization θ incident and ϕ scattered.

EXAMPLE 4
FREQUENCY =   70.00 MHZ.
BACKSCATTER
POLARIZATION: Φ-IN   Θ-OUT
AZIM. PLANE: Θ =   90°   R = ∞
MAXIMUM =   2.4 DB/M²   10 DB/DIV.
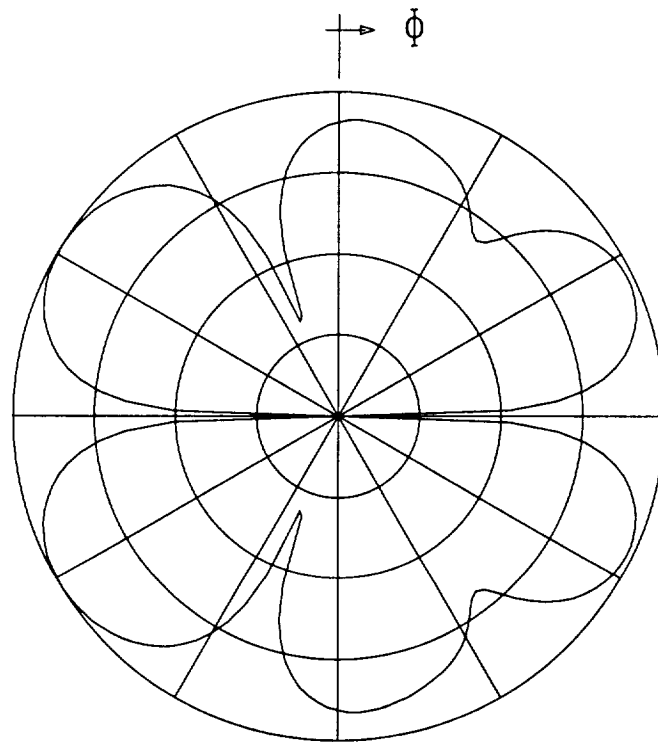
Figure 4.25: Backscatter pattern for Example 4 in the azimuth plane $\theta = 90°$ and for polarization ϕ incident and θ scattered.

EXAMPLE 5

ROTATION ANGLE :
    PHI = 45.0   DEG
  THETA = 55.0   DEG
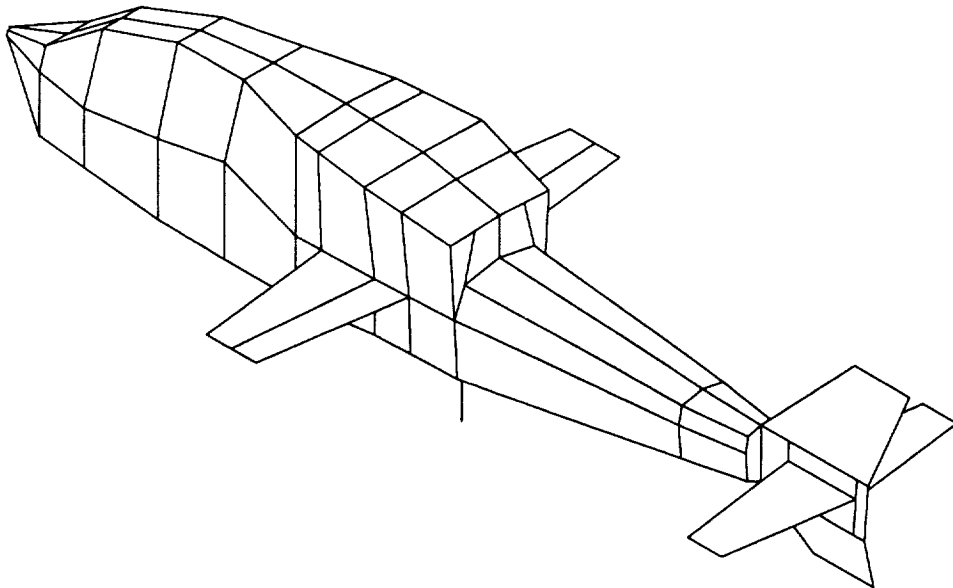
Figure 4.26: A 3-D sketch showing the helicopter analyzed in Example 5.

command defines a radiation pattern in the elevation plane $\phi = 0.0°$. It also specifies to perform pattern calculations every 1 degree and to produce a pattern plotting file. The FR command defines the frequency as 200.0 MHz. The ZM command specifies to save the impedance matrix. This is a large problem so it is wise to save the impedance matrix. The NC command specifies the end of the run control commands.

The geometry commands come next in the input file. The SG command specifies the maximum segment size as 0.25 wavelengths. The NS command defines the number of sides as 8, i.e., NSIDE = 8. The NS command could have been omitted because the number of sides defaults to NSIDE = 8. The SM command specifies symmetric cross sections. Thus, each cross section will be defined by NSIDE$/2 + 1 = 5$ points. The DG command requests a detailed printout of the problem geometry. The UN command sets IUNITS = 2 so all dimensions will be input in centimeters. The CS commands define all the cross sections. Note that the 6^{th} and 7^{th} CS commands specify that new cross sections be added by interpolation. The first new cross section will be placed at $y = 69.82$cm by interpolating the cross sections defined by the 6^{th} and 7^{th} CS commands. Similarly, the second new cross section will be placed at $y = 86.48$cm by interpolating the cross sections defined by the 7^{th} and 8^{th} CS commands. These new cross sections have been added so that a wing pair can be placed from the first newly added cross section to the second newly added cross section. Also, the 8^{th} CS command specifies that this cross section is at the same y value as the next cross section. Note that the cross sections defined by the 8^{th} and 9^{th} CS commands have the same y value. Finally, note that the cross section defined by the last CS command is specified to have an endcap plate. The TS command defines a thin tail section. This thin tail section extends beyond the last cross section. The WG command defines a symmetric pair of wings. These wings are attached at point 3 on the 7^{th} and the 9^{th} cross section. Note that the 7^{th} and the 9^{th} cross sections are the two cross sections that were added using interpolation. The TW command defines a symmetric pair of tail wings that are attached to the thin tail section. The SC command defines a source monopole of length 10.0cm. The source monopole extends downward (IUPDN = 2) from the point $x = 0.0$cm, $y = 87.63$cm and $z = -15.0$cm. The NC command

indicates the end of the geometry commands and hence the end of the input file. Figure 4.27 shows a three view plot of the geometry for Example 5. This plot was generated from the geometry plotting file on logical unit 9.

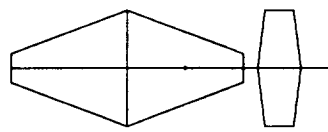The output file for Example 5 is shown in Appendix F. The run control commands and the geometry commands have been echo printed. The dimension parameters associated with the geometry commands have been printed in centimeters. The detailed printout of the geometry has also been included since the DG command was invoked. All dimensions in this part of the output file are in meters. In comparing the echo printed geometry commands to the detailed printout of the helicopter model geometry it can be seen that two new cross sections have been added. The interpolated cross sections have been included in the detailed printout. Also, note that the pair of wings are attached at point 3 on the 7^{th} and the 9^{th} cross sections. These are the two added cross sections. The geometry of Example 5 contains 106 plates and 2 wire segments made from 3 wire points. There are 234 plate modes and 1 wire mode. Since this is a fairly large number of modes, it is wise to save the impedance matrix. This ends the specification of the input geometry.

The MM computations follow the geometry specification in the output file. The input admittance, input impedance, and radiation efficiency are printed. The generator feeding the monopole source is of strength 1 volt. The efficiency is 100% because there is no loading. Next the elevation plane pattern in the plane $\phi = 0°$ is printed. The far zone patterns include the gain for θ and ϕ polarizations in dB and phase of the far zone radiated field in degrees. Since IPFE $= 1$ in the execution of the RE command the code outputs a pattern plotting file on logical unit 8. The elevation plane pattern gain plots for the $\hat{\theta}$ polarization and the $\hat{\phi}$ polarization in the plane $\phi = 0°$ are shown in Figures 4.28 and 4.29. The legend in the plots indicates that the frequency is 200.0 MHz, the pattern is far zone gain (i.e. $R = \infty$), and the polarization ($\hat{\theta}$ and $\hat{\phi}$).

Measured results were also obtained on a physical model of the helicopter [17]. A comparison of the measured and computed roll plane patterns calculated in Example 5 are shown in Figures 4.30 and 4.31. Also shown are comparisons of the other
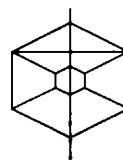
EXAMPLE 5
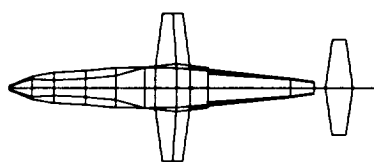
1 WIRE MODES
234 PLATE MODES
0 ATTACH. MODES
235 TOTAL MODES
SCALE = 0.428λ
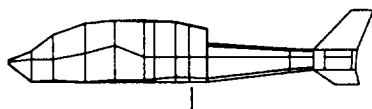
Z AXIS VIEW

X AXIS VIEW   Y AXIS VIEW

Figure 4.27: A three view sketch of the geometry for Example 5.

principle plane patterns in Figures 4.32 - 4.35. The computation of these patterns was not part of Example 5, but they are included here for documentation. Note that the MM patterns of Figures 4.30 - 4.35 were computed using the original version of AMC, and as a result they are not exactly the same as results from AMC: Version II.

The measured patterns have been normalized by a constant to the AMC computed patterns. This constant was the same for each of the six patterns. The normalization constant was the average of the values needed to make the maximum of each measured pattern coincide with the corresponding AMC computed pattern. The elevation plane cross polarization pattern was not included in this average because of the immense difference in patterns. Due to symmetry considerations the elevation plane cross polarization pattern should be zero. Note that the AMC computed pattern is on the order of -90 dB, while the measured pattern is on the order of -20 dB. All of the other five normalization values were within 1.0 dB of each other. Thus, except for the elevation plane cross polarization pattern of Figure 4.33, the measurements and AMC computations are in good agreement.

```
EXAMPLE 5
FREQUENCY =  200.00 MHZ.
GAIN
POLARIZATION:  θ
ELEV. PLANE: φ =    0°   R = ∞
MAXIMUM =    1.8 DB     10 DB/DIV.
```
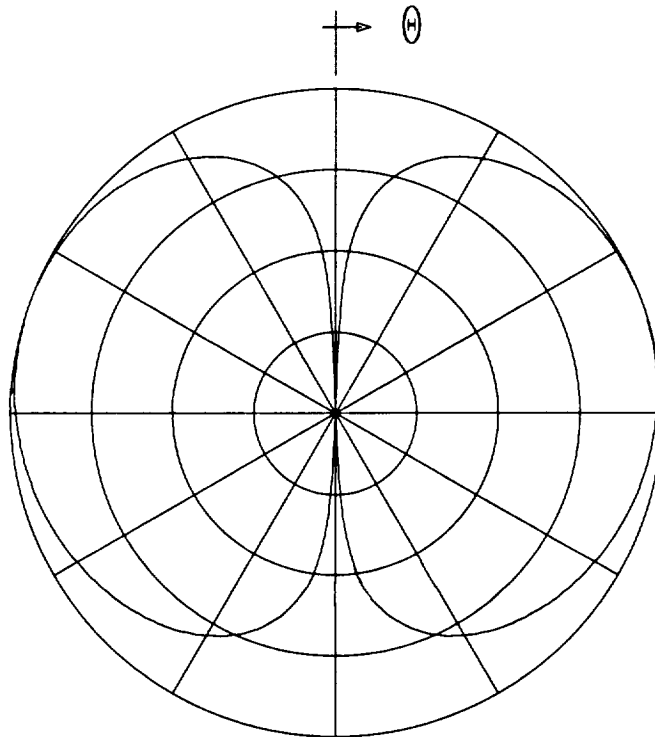
Figure 4.28: θ polarized gain in the elevation plane $\phi = 0°$ for Example 5.

EXAMPLE 5
FREQUENCY = 200.00 MHZ.
GAIN
POLARIZATION: ϕ
ELEV. PLANE: ϕ = 0° R = ∞
MAXIMUM = -9.9 DB 10 DB/DIV.
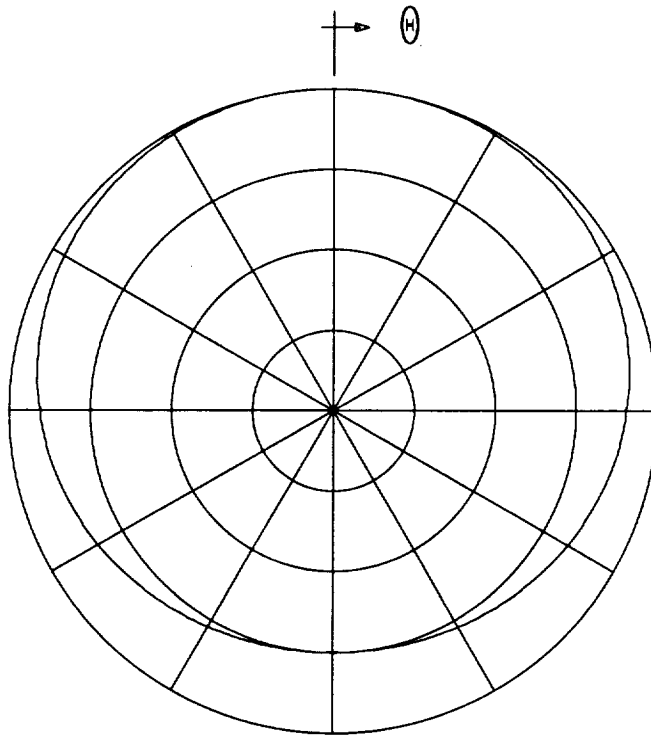
Figure 4.29: ϕ polarized gain in the elevation plane $\phi = 0°$ for Example 5.

Figure 4.30: A comparison of the AMC computed pattern to measured pattern for the θ polarized gain in the plane $\phi = 0.0°$ for Example 5.

Figure 4.31: A comparison of the AMC computed pattern to measured pattern for the ϕ polarized gain in the plane $\phi = 0.0°$ for Example 5.

Elevation Plane ($\phi = 90\degree$)
Co Pol. (θ)
——————— MM calculation
- - - - - - - - measurement
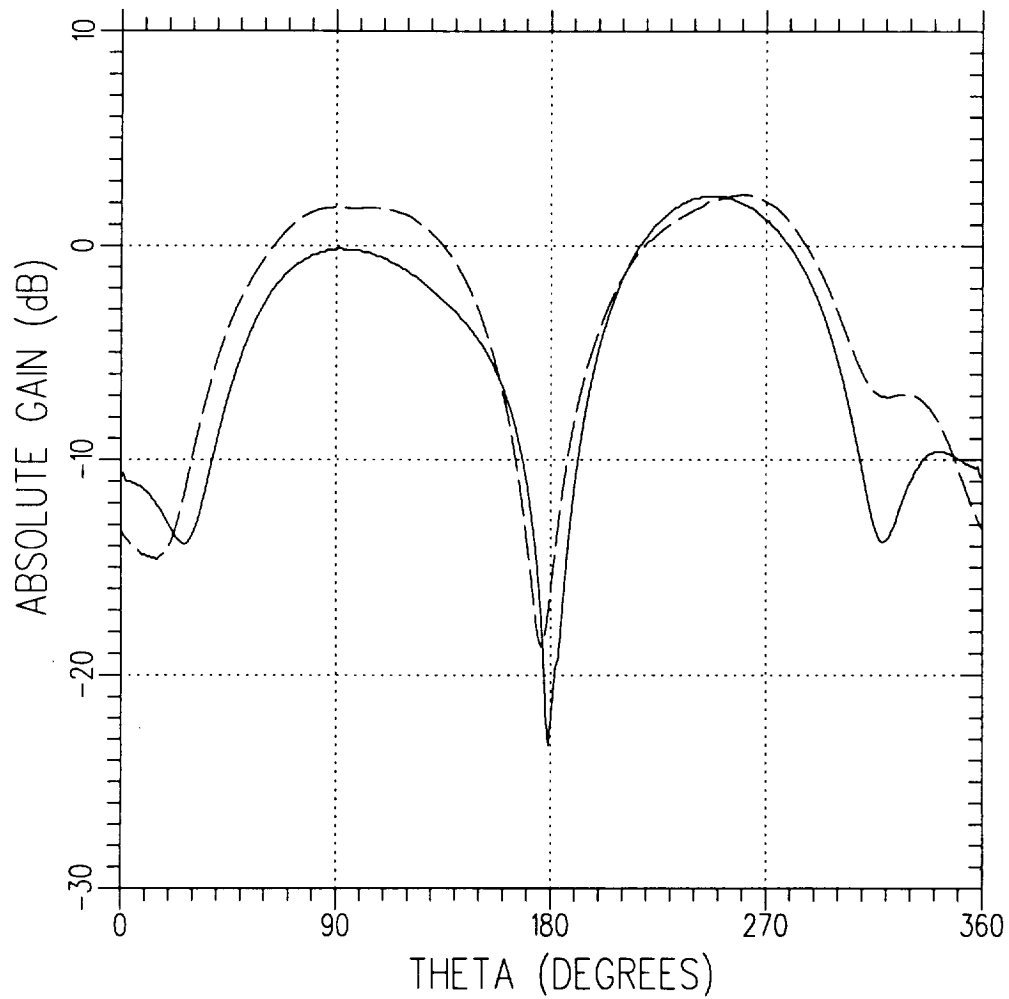
Figure 4.32: A comparison of the AMC computed pattern to measured pattern for the θ polarized gain in the plane $\phi = 90.0\degree$.
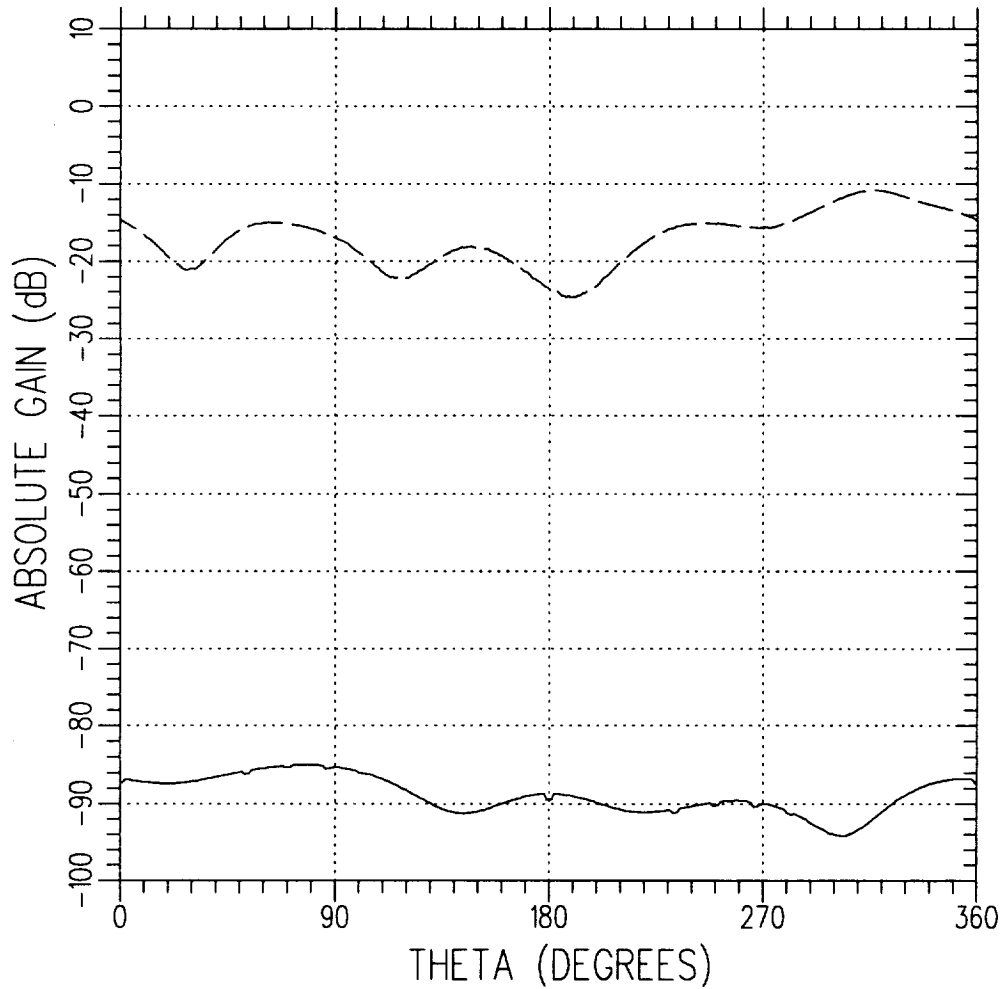
Figure 4.33: A comparison of the AMC computed pattern to measured pattern for the ϕ polarized gain in the plane $\phi = 90.0°$.

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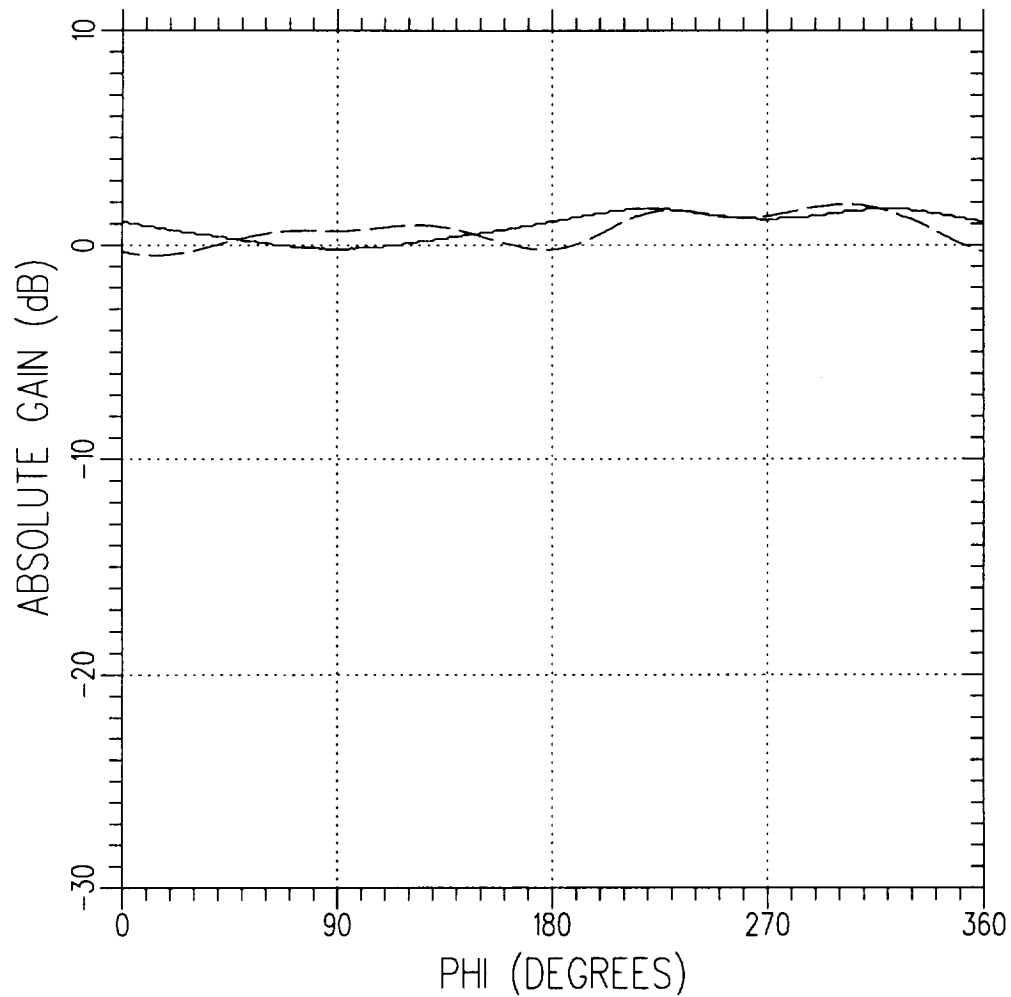
Figure 4.34: A comparison of the AMC computed pattern to measured pattern for the θ polarized gain in the plane $\theta = 90.0°$.
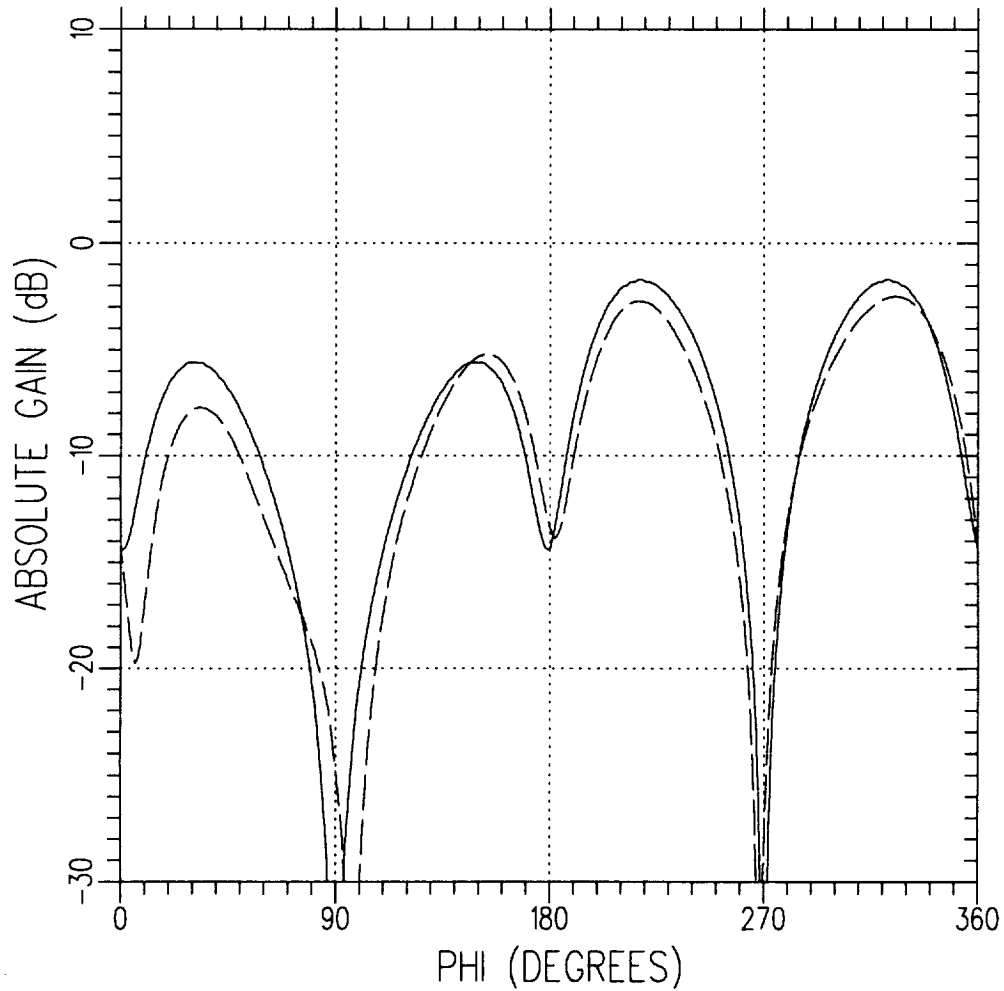
Figure 4.35: A comparison of the AMC computed pattern to measured pattern for the ϕ polarized gain in the plane $\theta = 90.0°$.

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Chapter 5

Array Dimensions and Data for Plotting

The size of the problem, i.e., the number of points, segments, modes, etc., which can be treated by the AMC code is determined by the dimensions specified for various arrays. A description of these arrays and their dimensions is given in this chapter.

The amount of data generated by the AMC code is so large that in most cases it can be best understood when it is properly plotted, rather than printed in tabular fashion. In particular this data includes the wire/plate geometry, the detailed layout of surface patch modes on the plates, near or far zone radiation and scattering patterns, and frequency sweep data. This plotting capability has proven to be extremely valuable to the authors. In order to make AMC more transportable we have separated the plotting from the main AMC code. The AMC code outputs three data files which can be used to generate the plots. The three data files generated by AMC are:

1. a file containing the wire/plate geometry on logical unit 9 (GMPLOT.DAT)

2. a file containing the pattern data on logical unit 8 (PTPLOT.DAT)

3. a file containing the frequency sweep data on logical unit 10 (FSWP.DAT).

With knowledge of the contents and format of these data files one can use any available graphics software to write programs which display the data. This section describes the contents and format of these three data files.

Two plotting programs have been written to accompany the AMC code. The first (ESP4GM) reads in the geometry data file and plots the geometry while, the second

(ESP4PT) reads in the pattern data file and plots the patterns. These two plotting codes are written in FORTRAN and use the "Graphical Kernel System (GKS)" plotting software [16]. When AMC is supplied outside The Ohio State University, these two plotting programs are normally supplied as separate files. The plotting codes were written to be used interactively, and provide prompts which hopefully make their use self explanatory. If a user does not have GKS on his system then we strongly urge that he write his own plotting software which reads in and then plots the data files produced by AMC. This section will provide a description of the data files produced by the AMC code.

5.1 Array Dimensions

The size of the problem, i.e., the number of plates, points, segments, modes, etc., which can be treated by the AMC code is determined by the dimensions specified for various arrays. All arrays whose dimensions may change from problem to problem are dimensioned near the top of the main program. Arrays dimensioned by the same parameters are grouped together. The array dimensions are specified by DIMENSION and COMPLEX statements. All arrays have either fixed dimensions, independent of the geometry being run, or are dimensioned according to one of the following dimension indicators.

IDWR = maximum number of wire points, wire segments, or wire modes. Although in a complex wire geometry the number of wire points (NP), segments (NM) and modes (NWR) are in general different, they are always of comparable magnitude. Thus it is easier to dimension all arrays dealing with the wire geometry by the single dimension indicator, IDWR.

IPL = maximum number of plates.

ICN = maximum number of corners on a polygonal plate. Most of the plates used by AMC are quadrilateral or 4 sided plates. The main exception is when endcap plates are specified by the CS command. Also, arrays holding the cross sections

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describing the main body are dimensioned in such a way that ICN must be greater than or equal to NSIDE.

IAT = maximum number of wire-to-plate attachments. This is set to 1 in AMC because AMC does not treat wire-to-plate attachments.

ITOT = maximum number of modes (wire + plate + attachment).

IDZT = maximum length of the one dimensional array ZT which is used to store the symmetric impedance matrix for full surface testing and is used for temporary storage of the symmetric wire/wire block of the impedance matrix for filament testing. Thus, the value for IDZT is dependent upon whether filament (default: IFIL = 1) or full surface (the TM command set IFIL = 0) testing is being used. If IFIL = 0, set IDZT $\geq$ (ITOT*ITOT + ITOT)/2. If IFIL = 1, IDZT can be reduced to (IDWR*IDWR + IDWR)/2 to save storage. IDZT must be at least 1.

IDZTF = dimension of the two dimensional array ZTF, used to store the impedance matrix when filament testing is being used, i.e., IFIL = 1 (default status). If IFIL = 1, then set IDZTF $\geq$ ITOT. If IFIL = 0, then IDZTF can be reduced to 1 to save storage.

IDWR2 = twice the maximum number of wire points, segments or modes IDWR2 = 2*IDWR.

ITW2 = the larger of IDWR2 and ITOT.

IDMZI = indicator as to whether or not a frequency sweep computation is being made. See the INDZI parameter specified by invoking the FS command.
= 0 implies no frequency sweep (INDZI = 0).
= 1 frequency sweep being done (INDZI = 1 or 2).

IERVSR has to do with wire-to-plate attachments. Thus, IERVSR is always set to 1 in AMC because AMC does not treat wire-to-plate attachments.

ISEC = the maximum number of cross sections that can be used to describe a body.

IWING = the maximum number of wings or wing pairs that the main body can have attached to it.

The dimension indicators are defined in PARAMETER statements at the top of the MAIN program. In addition to the nine dimension indicators defined above, we also define the parameters IDFIL and IDSUR which indicate whether filament of full surface testing is to be used. Specifically, these parameters are defined by:

IDFIL = indicator to dimension for filament testing.

= 1 implies dimension for filament testing (usual case).

= 0 implies do not dimension for filament testing.

IDSUR = indicator to dimension for full surface testing.

= 1 implies dimension for full surface testing.

= 0 implies do not dimension for full surface testing (usual case).

Either IDFIL or IDSUR must be 1. If IFIL = 1 (default status), then IDFIL must be 1. If the TM command sets IFIL = 0, then IDSUR must be 1. It is always valid to set IDFIL and IDSUR to 1. If IDFIL and IDSUR are both 1, then the arrays will be properly dimensions for IFIL = 0 or 1, however, considerable storage may be wasted. It is never valid to set IDFIL and IDSUR to 0. The AMC code is normally set up to run with filament testing since it is faster than full surface testing. Normally, the TM command is not executed, IFIL defaults to 1, and one sets the parameters IDFIL = 1, and IDSUR = 0.

The AMC code stores the impedance matrix in different arrays, depending on whether full surface (IFIL=0) or filament testing (IFIL=1) is used. If IFIL = 0, then the impedance matrix is stored in the one dimensional complex array ZT, while if IFIL = 1 the impedance matrix is stored in the two-dimensional complex array ZTF. When full surface testing is used, the impedance matrix is symmetric. Thus, for IFIL = 0, an N by N symmetric matrix would result in only $(N * N + N)/2$ elements in the one dimensional array ZT. When IFIL = 1, the ZT array is also used as temporary

storage for the symmetric wire/wire block of the impedance matrix. Clearly it is wasteful of storage to have both the ZT and ZTF arrays dimensioned large enough to hold the entire impedance matrix. If IFIL = 0, storage can be saved by setting IDFIL = 0 and IDSUR = 1. If IFIL = 1, storage can be saved by setting IDSUR = 0 and IDFIL = 1.

When AMC is supplied outside The Ohio State University, typically the dimension indicators are set to:

IDFIL = 1

IDSUR = 0

IDWR = 200

IPL = 120

ICN = 12

IAT = 1

ITOT = 600

ISEC = 20

IWING = 4

IDZT = MAX0((IDWR*IDWR+IDWR)/2,IDSUR*(ITOT*ITOT+ITOT)/2,1)

IDZTF = MAX0(IDFIL*ITOT,1)

IDWR2 = 2*IDWR

ITW2 = MAX0(ITOT,IDWR2)

IDMZI = 0

IERVSR = 1.

The function MAX0 takes the maximum value of its arguments. In standard FORTRAN 77 one can not have a function subroutine in a PARAMETER statement. Therefore, in the AMC code we have replaced the MAX0 function by arithmetic statements which perform the same function. In the above case the code can treat filament testing problems with up to IPL = 120 polygonal plates, each having up to ICN = 12 corners. Also, the cross sections describing the main body may be defined by up to NSIDE = 12 points. No wire-to-plate attachments can be used in AMC. The number of wire points, segments or modes can not exceed IDWR = 200. The total number of modes can be up to ITOT = 600. IDMZI is set to 0 and thus a frequency sweep computation can not be made.

If it is desired to change array dimensions, then one must only change the corresponding PARAMETER statements at the top of the main program. For example, if one wished to run a problem involving 200 plates, 1000 modes (all but a few being plate modes), and where the cross sections can have up to NSIDE = 20 sides, then one should set:

IPL = 200

ITOT = 1000

ICN = 20.

When changing dimensions, the user need only change the first nine of the above dimension indicators. The remaining four will automatically be adjusted.

5.2   Geometry Data

When the EX command is not invoked (EX does not appear in the input file) then AMC will write a data file on logical unit 9 which contains the wire/plate geometry and the detailed layout of surface patch modes on the plates. Let GMPLOT.DAT be the name of the file assigned to unit 9. The geometry data mainly consists of:

1. the coordinates of the corners of the plates,

2. the coordinates of the endpoints of the wire segments,

3. the coordinates of the corners of all quadrilateral
   surface patch monopoles.

The coordinates are in the x, y, z rectangular system in meters. File GMPLOT.DAT contains all the data necessary to draw the three view plot of the wire/plate geometry, the surface patch modal layout on each plate, and the overlap surface patch modal layout of intersecting plates. The plots can be used to check the accuracy of the input geometry and also serve as an excellent record of the problem geometry.

Appendix G provides the code that reads in and stores all the geometry data contained in file GMPLOT.DAT. The IF-THEN blocks are included to test whether the data arrays are of sufficient lengths to store all the data contained in file GM-PLOT.DAT. If an array is too small the program ends after telling the user how to re-dimension that array. The following list defines all geometry variable names whose values are read from GMPLOT.DAT via the code of Appendix G .

NPLTS = the total number of plates

NPLTM = the total number of surface patch modes including overlap modes

NM = the total number of wire segments

NP = the total number of wire points

NWR = the total number of wire modes

NAT = the total number of wire/plate attachment points or modes
   (NAT = 0 always in the AMC code)

WV = the wavelength in meters

NOPL = the total number of overlap plate pairs; an overlap plate pair is a set of 2
   plates that share a common edge and are connected by overlap modes

NOVT = the total number of overlap modes

X(I),Y(I),Z(I) = the x, y, z coordinates in meters of the I^{th} wire endpoint, where I $\in \{1, 2, \ldots, NP\}$

IA(I),IB(I) = the endpoints A and B, respectively, of wire segment I where I $\in \{1, 2, \ldots, NM\}$ and IA, IB $\in \{1, 2, \ldots, NP\}$.

NCNRS(NPL) = the number of corners on plate NPL

NPL11(NPL) = the total number of surface patch modes covering the first current polarization on plate NPL (does not count overlap modes)

NPL22(NPL) = the total number of surface patch modes on plate NPL (does not count overlap modes)

NDNPLT(NPL) = the total number of surface patch modes covering plates 1 through and including NPL, i.e., the number of the last surface patch mode on plate NPL (does not include overlap modes)

IPN(NPL) = the polarization indicator for plate NPL
  IPN = 1 $\Rightarrow$ 1^{st} polarization only
  IPN = 2 $\Rightarrow$ 2^{nd} polarization only
  IPN = 3 $\Rightarrow$ both polarizations are present
  IPN = 0 $\Rightarrow$ no polarizations

PA(I, J, K) = x, y, z coordinates (K=1,2,3) in meters of the J^{th} corner of monopole A of the I^{th} surface patch mode. J $\in \{1, 2, 3, 4\}$, I $\in \{1, 2, \ldots, NPLTM\}$.

PB(I, J, K) is analogous to PA(I, J, K) but for monopole B.

PCN(K, NC, NPL) = x, y, z coordinates (K=1,2,3) in meters of the NC^{th} corner of plate NPL where NC $\in \{1, 2, \ldots, NCNRS(NPL)\}$ and NPL $\in \{1, 2, \ldots, NPLTS\}$

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IOVT(I, J) specifies the 2 plates and the common side which define overlap plate
pair I where I $\in \{1, 2, \ldots, NOPL\}$.

IOVT(I,1) = plate A of pair I

IOVT(I,2) = junction side of plate A of pair I

IOVT(I,3) = plate B of pair I

IOVT(I,4) = junction side of plate B of pair I

where IOVT(I,1), IOVT(I,3) $\in \{1, 2, \ldots, NPLTS\}$

and IOVT(I,1) $\neq$ IOVT(I,3),

IOVT(I,2) $\in \{1, 2, \ldots, NCNRS[IOVT(I,1)]\}$, and

IOVT(I,4) $\in \{1, 2, \ldots, NCNRS[IOVT(I,3)]\}$.

By "junction side" of plate A it is meant that side of plate A which contacts a
side of plate B. Side 1 connects corners 1 and 2, side 2 connects corners 2 and
3, ..., and side NCNRS(NPL) connects corners NCNRS(NPL) and 1.

ITK(I) = the number of overlap modes in overlap plate pair I

A surface patch dipole mode is made up of two surface patch monopoles, termed
A and B. The geometry of the A and B monopoles are contained in the PA and PB
arrays, respectively. We will describe these arrays with the help of Figure 5.1, which
shows the PA or PB array numbering scheme for a geometry consisting of 3 plates
among which there are 2 overlap plate pairs. In this figure the vertical dimension
represents the index I, which (see above) corresponds to the mode number. The
following observations may be helpful to the user.

- There are NPL22(N) modes on plate N. Of these, NPL11(N) are for polarization
  one and NPL22(N) - NPL11(N) for polarization two.

- The last mode on plate N is mode number
  NDNPLT(N) = NDNPLT(N-1) + NPL22(N).

- If there are NPLTS plates, then the first overlap mode is
  NDNPLT(NPLTS) + 1. The first overlap pair of plates involves modes ND-
  NPLT(NPLTS) + 1 through NDNPLT(NPLTS) + ITK(1). The second overlap

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pair involves modes NDNPLT(NPLTS) + ITK(1) + 1 through NDNPLT(NPLTS) + ITK(1) + ITK(2).

- The last overlap mode is mode number NPLTM = NDNPLT(NPLTS) + NOVT.

- Overlap pair P involves side IOVT(P,2) of plate IOVT(P,1) contacting side IOVT(P,4) of plate IOVT(P,3).

A typical surface patch dipole mode (or overlap mode) is shown in Figure 5.2 in which corner numbers are circled. The corner and side numbering scheme of a monopole is shown. The arrow indicates that the current of a dipole is always referenced as positive in the direction from monopole A to monopole B. Note also that corner number 1 of monopole A always coincides with corner number 1 of monopole B, and corner number 4 of monopole A always coincides with corner number 4 of monopole B. In other words monopoles A and B of surface patch mode I share side 4. The x, y, z coordinates of each of the four corners are contained in the PA and PB arrays. For example the x, y, z coordinates of PA1, which is the same as PB1 is given by:

$$PA1 = PB1 = (\ PA(I,1,1), \ PA(I,1,2), \ PA(I,1,3) \ )$$

$$= (\ PB(I,1,1), \ PB(I,1,2), \ PB(I,1,3) \ ).$$

Similarly, the coordinates of PB3 are:

$$PB3 = (\ PB(I,3,1), \ PB(I,3,2), \ PB(I,3,3) \ ).$$

The above information should be sufficient to allow a user to obtain geometry plots similar to those shown in the previous chapter.

5.3 Pattern Data

The RE, RA, SE, and SA commands define the radiation and scattering patterns. If in these commands, IPFE, IPFA, IPSE, or IPSA, respectively, are set to 1, then then corresponding pattern will be output on logical unit 8. Let PTPLOT.DAT be the name of the file assigned to unit 8. The data sent to PTPLOT.DAT consists of

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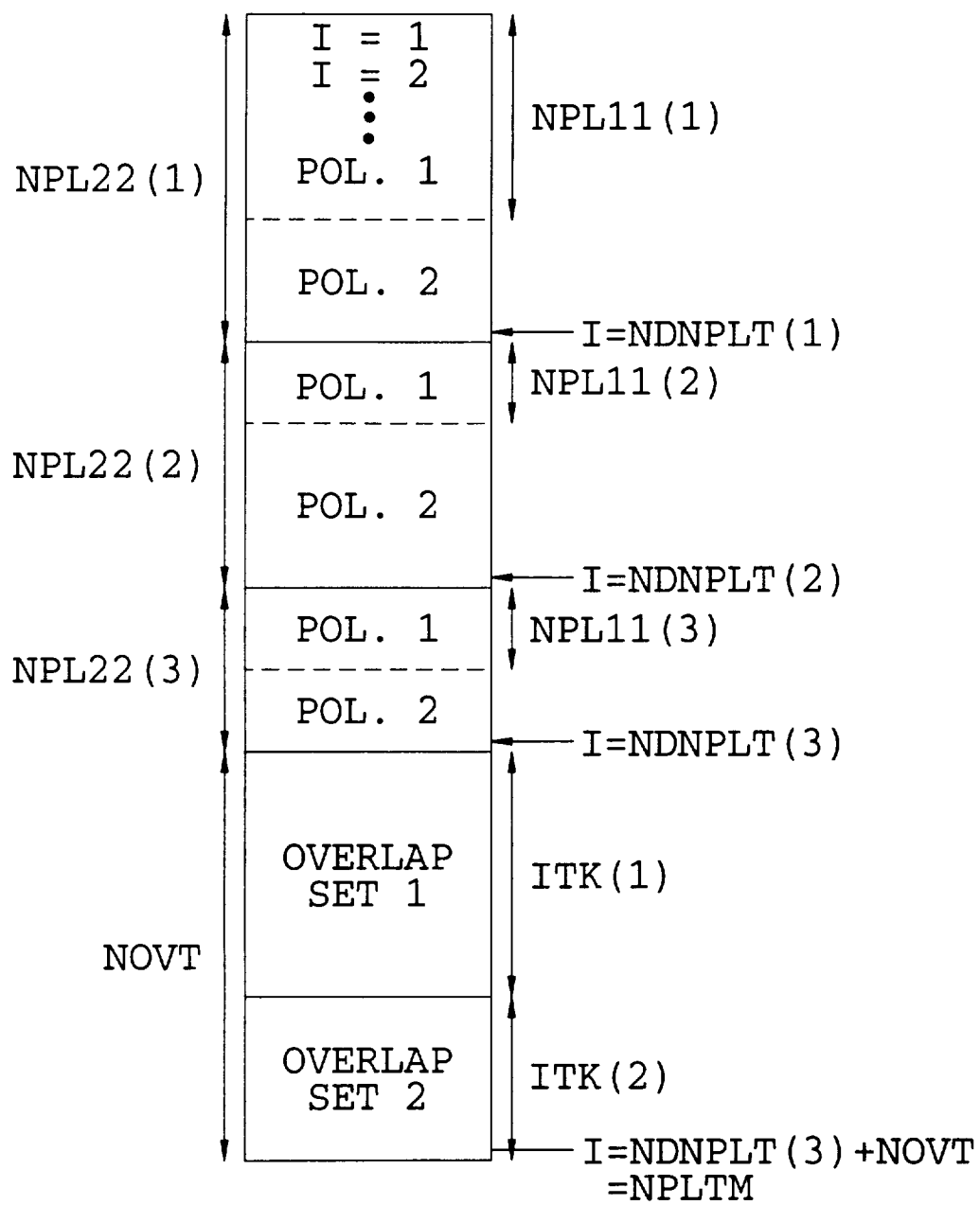
Figure 5.1: Numbering scheme for the PA or PB arrays for a geometry with NPLTS = 3 plates and NOPL = 2 overlap sets.

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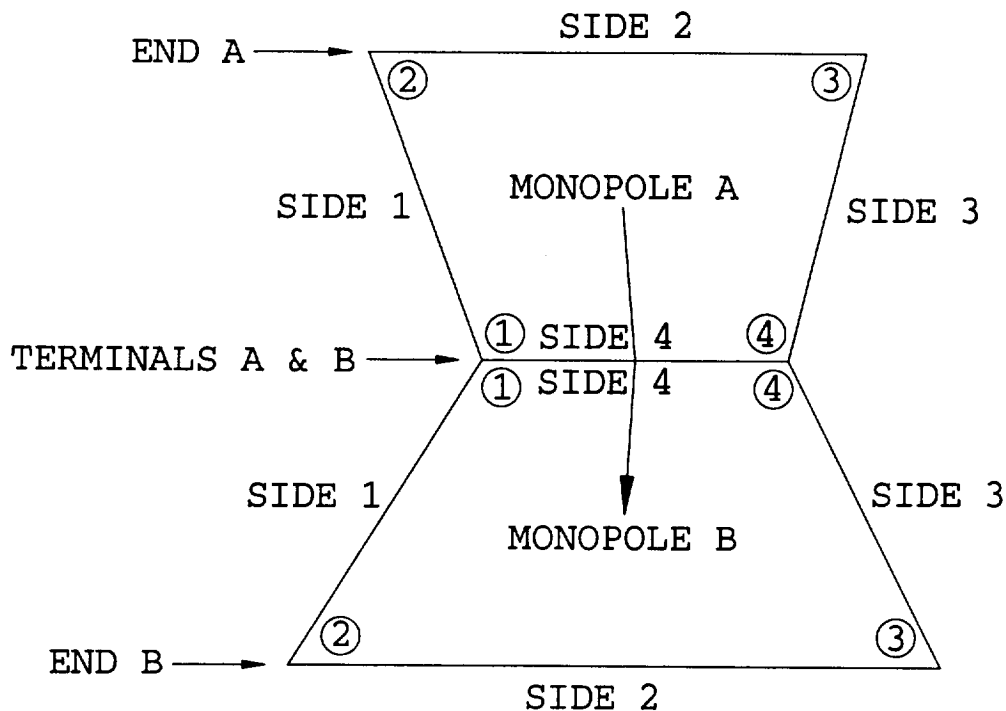
Figure 5.2: A typical dipole surface patch mode or overlap mode.

the radiated or scattered field magnitude in dB, its phase in degrees, as well as other miscellaneous parameters describing the pattern. Appendix H shows a code to read and store the pattern data of file PTPLOT.DAT. The IF-THEN blocks are included to test whether the data arrays are of sufficient lengths to store all the data contained in file PTPLOT.DAT. If an array is too small the program ends after telling the user how to re-dimension that array. The following list defines all pattern variable names whose values are read from PTPLOT.DAT via the code of Appendix H .

NPATS = the number of pattern cuts. The different polarizations computed on a single pattern cut do not count as additional patterns in specifying NPATS.

IRS12 = the pattern type indicator

= 1 for a radiation pattern

= 2 for a scattering pattern.

FMC = frequency in megahertz.

RF = radius of near zone pattern in meters.

< 0 implies a far zone pattern $(r \rightarrow \infty)$.

IEA(I) = pattern plane indicator for pattern I

where I $\in \{1, 2, \ldots, \text{NPATS}\}$

IEA(I) = 1 for an elevation plane pattern

IEA(I) = 2 for an azimuth plane pattern.

NPTS(I) = the number of pattern data points in pattern I

where I $\in \{1, 2, \ldots, \text{NPATS}\}$.

CANG(I) = constant or fixed angle for pattern I

= fixed angle ϕ ($^\circ$) for elevation patterns (IEA(I) = 1)

= fixed angle θ ($^\circ$) for azimuth patterns (IEA(I) = 2).

ISCAT(I) = the pattern type for pattern I

= 0 for radiation pattern

= 1 for backscatter pattern

= 2 for bistatic scatter pattern

= 3 for forward scatter pattern.

THIN(I), PHIN(I) = θ and ϕ angles in degrees specifying the bistatic incident wave direction for pattern I. As seen in Appendix H, these values are only written to PTPLOT.DAT for scatter patterns.

RADPO(I,J,K) = Absolute gain (not in dB) of data point J $(1 \leq J \leq \text{NPTS(I)})$ of radiation pattern I $(1 \leq I \leq \text{NPATS})$ with polarization K:

K = 1 for θ polarization

K = 2 for ϕ polarization

K = 3 for r polarization.

SCATPO(I,J,K) = Radar cross section (meter^2) of data point J $(1 \leq J \leq \text{NPTS(I)})$ of scattering pattern I $(1 \leq I \leq \text{NPATS})$ with polarization K:

K = 1 for θ in θ out polarization

K = 2 for ϕ in ϕ out polarization

K = 3 for θ in ϕ out polarization

K = 4 for ϕ in θ out polarization

K = 5 for θ in r out polarization

K = 6 for ϕ in r out polarization

The contents of pattern data file PTPLOT.DAT have been described. Appendix H shows a code which will read PTPLOT.DAT and store the values in the above described variables and arrays. Simple programs can then be written using this information to draw the desired patterns with any available graphics software.

5.4   Frequency Sweep Data

When a frequency sweep computation is being made (the FS command is invoked) AMC outputs the data for plotting on logical unit 10. This data file is referred to as FSWP.DAT. For antenna problems, FSWP.DAT is a tabulation of input impedance, radiation efficiency and gain versus frequency. For scattering problems, FSWP.DAT is a tabulation of RCS versus frequency. Appendix I shows a FORTRAN code to read FSWP.DAT and store the data in arrays for subsequent plotting or further analysis. Comments define the meaning of all parameters.

Chapter 6

Summary

This report serves as a user's manual for the "Aircraft Modelling Code" (AMC). AMC is a general purpose computer code based on the method of moments (MM) solution for electromagnetic radiation and scattering from wires and polygonal plates. The AMC code is well suited for analyzing helicopter or aircraft shapes, but it can treat other geometries as well. AMC is basically a special purpose version of the "Electromagnetic Surface Patch Code" (ESP) which contains a special software to aid in the description of the aircraft geometry. The main body or fuselage is described by defining its cross section at several stations from the nose to the tail. Wings, fins, rotor blades and radiating antennas can then be attached to this main body.

The major advantage of the AMC code is accuracy and the ability to model complex shapes. The accuracy is a result of the fact that the MM is a direct numerical solution of the exact integral equation for the currents on the wires and plates modelling the geometry of interest. The ability to model complex shapes is a result of the simplified method for inputting the geometry. The main limitation of the AMC code is that it is a low frequency code. The computation time and storage requirements are roughly proportional to the square of the number of MM modes. The number of MM modes is proportional to the electrical length of the wires and the electrical surface area of the plates. As the frequency is increased, the number of MM modes increases, and at some point the required computer CPU time and storage become prohibitive. Thus, the program is limited to treating bodies which are not too large electrically.

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Appendix A

Output File for Example 1

THE OHIO STATE UNIVERSITY AIRCRAFT MODELLING CODE

****

************** RUN CONTROL COMMANDS **************

EX: EXECUTE
NGO   = 1

WR: WRITE
NPRINT = 0
IWR   = 0
IWRZT = 1

SE: SCATTERING PATTERN (ELEVATION)
ISE   = 1
IPSE = 1
FNDSE =   5.000
PHSE =   0.000
THIN =   0.000
PHIN =   0.000

FR: FREQUENCY
FMC   =   50.000

************ GEOMETRY INPUT DATA ************

SG: SEGMENTATION
SGM = 0.25000

NS: NUMBER OF SIDES
NSIDE =   6

CS: CROSS SECTION
CROSS SECTION NUMBER 1:
    YCSI(J) =   0.00000
    YPL(J) =   0.00000
    IPCI(J) = 0
    IECI(J) = 0
    ICSI(J) = 0

NSIDE	XCSI(I,J)	ZCSI(I,J)
1	0.00000	1.00000
2	1.00000	0.50000
3	1.00000	-0.50000
4	0.00000	-1.00000
5	-1.00000	-0.50000
6	-1.00000	0.50000

CS: CROSS SECTION
CROSS SECTION NUMBER 2:
    YCSI(J) =   2.00000
    YPL(J) =   0.00000
    IPCI(J) = 0
    IECI(J) = 0
    ICSI(J) = 0

NSIDE	XCSI(I,J)	ZCSI(I,J)
1	0.00000	1.00000
2	1.00000	0.50000
3	1.00000	-0.50000
4	0.00000	-1.00000
5	-1.00000	-0.50000
6	-1.00000	0.50000

******* DETAILED DESCRIPTION OF GEOMETRY *******

CROSS SECTION GEOMETRY:
CROSS SECTIONS ARE SYMMETRIC.

CROSS SECTION NUMBER 1:
    LOCATED AT Y =   0.00000 meters.
    CROSS SECTION COORDINATES (meters)

NSIDE	XCS(I,J)	ZCS(I,J)
1	0.00000	1.00000
2	1.00000	0.50000
3	1.00000	-0.50000
4	0.00000	-1.00000
5	-1.00000	-0.50000
6	-1.00000	0.50000

```
CROSS SECTION NUMBER  2:
     LOCATED AT Y =        2.00000 meters.
        CROSS SECTION COORDINATES (meters)
          NSIDE      XCS(I,J)      ZCS(I,J)
          -----      --------      --------
            1         0.00000       1.00000
            2         1.00000       0.50000
            3         1.00000      -0.50000
            4         0.00000      -1.00000
            5        -1.00000      -0.50000
            6        -1.00000       0.50000
```

********* SUMMARY OF ARRAY DIMENSIONS **********

```
IDWR   =  200
ITW2   = 2250
ICN    =   16
IPL    =  450
IAT    =   10
ITOT   = 2250
IDZT   =    20100
IDZTF  = 2250
IDMI   =    1
IDZTI  =         1
IDZTFI =    1
IDMZI  =  0
```

********** SUMMARY OF MODEL GEOMETRY ***********

```
NUMBER OF PLATES =    6
NUMBER OF POINTS ON THE WIRES =    0
NUMBER OF SEGMENTS ON THE WIRES =    0


   NWR = NUMBER OF WIRE MODES =     0
   NPLTM = NUMBER OF PLATE MODES =    18
   NAT = NUMBER OF ATTACHMENT MODES =     0
```

******** RESULTS OF THE MM COMPUTATION *********

```
   IMPEDANCE MATRIX AT      50.000 (MHZ)

   I    J            Z(I,J)

   1    1    0.25065E+02   -0.53274E+02
   2    1    0.20807E+02   -0.10508E+02
```

3	1	0.14076E+02	-0.11695E+02
4	1	0.10047E+02	-0.13090E+02
5	1	0.11829E+02	-0.12456E+02
6	1	0.19885E+02	-0.10305E+02
7	1	0.50346E+00	0.52696E+02
8	1	-0.50346E+00	-0.52696E+02
9	1	-0.64657E+00	-0.55407E+02
10	1	0.64657E+00	0.55407E+02
11	1	0.89010E+00	0.16153E+02
12	1	-0.89010E+00	-0.16153E+02
13	1	0.56259E+00	0.25119E+01
14	1	-0.56259E+00	-0.25119E+01
15	1	-0.25560E+00	-0.11503E+01
16	1	0.25560E+00	0.11503E+01
17	1	-0.10575E+01	-0.15487E+02
18	1	0.10575E+01	0.15487E+02
1	2	0.20878E+02	-0.10167E+02
2	2	0.25182E+02	-0.57808E+02
3	2	0.20878E+02	-0.10167E+02
4	2	0.11848E+02	-0.12525E+02
5	2	0.74574E+01	-0.13567E+02
6	2	0.11848E+02	-0.12525E+02
7	2	-0.55247E+00	-0.58497E+02
8	2	0.55247E+00	0.58497E+02
9	2	-0.11942E+01	-0.18060E+02
10	2	0.11942E+01	0.18060E+02
11	2	0.55247E+00	0.58497E+02
12	2	-0.55247E+00	-0.58497E+02
13	2	0.11942E+01	0.18060E+02
14	2	-0.11942E+01	-0.18060E+02
15	2	0.63116E+00	0.21762E+01
16	2	-0.63116E+00	-0.21762E+01
17	2	-0.63116E+00	-0.21762E+01
18	2	0.63116E+00	0.21762E+01
1	3	0.14076E+02	-0.11695E+02
2	3	0.20807E+02	-0.10508E+02
3	3	0.25065E+02	-0.53274E+02
4	3	0.19885E+02	-0.10305E+02
5	3	0.11829E+02	-0.12456E+02
6	3	0.10047E+02	-0.13090E+02
7	3	-0.89010E+00	-0.16153E+02
8	3	0.89010E+00	0.16153E+02
9	3	-0.56259E+00	-0.25119E+01
10	3	0.56259E+00	0.25119E+01
11	3	-0.50346E+00	-0.52696E+02
12	3	0.50346E+00	0.52696E+02
13	3	0.64657E+00	0.55407E+02
14	3	-0.64657E+00	-0.55407E+02
15	3	0.10575E+01	0.15487E+02
16	3	-0.10575E+01	-0.15487E+02
17	3	0.25560E+00	0.11503E+01
18	3	-0.25560E+00	-0.11503E+01
1	4	0.10047E+02	-0.13090E+02
2	4	0.11829E+02	-0.12456E+02

3	4	0.19885E+02	-0.10305E+02
4	4	0.25065E+02	-0.53274E+02
5	4	0.20807E+02	-0.10508E+02
6	4	0.14076E+02	-0.11695E+02
7	4	-0.25560E+00	-0.11503E+01
8	4	0.25560E+00	0.11503E+01
9	4	0.56259E+00	0.25119E+01
10	4	-0.56259E+00	-0.25119E+01
11	4	-0.10575E+01	-0.15487E+02
12	4	0.10575E+01	0.15487E+02
13	4	-0.64657E+00	-0.55407E+02
14	4	0.64657E+00	0.55407E+02
15	4	0.50346E+00	0.52696E+02
16	4	-0.50346E+00	-0.52696E+02
17	4	0.89010E+00	0.16153E+02
18	4	-0.89010E+00	-0.16153E+02
1	5	0.11848E+02	-0.12525E+02
2	5	0.74574E+01	-0.13567E+02
3	5	0.11848E+02	-0.12525E+02
4	5	0.20878E+02	-0.10167E+02
5	5	0.25182E+02	-0.57808E+02
6	5	0.20878E+02	-0.10167E+02
7	5	0.63116E+00	0.21762E+01
8	5	-0.63116E+00	-0.21762E+01
9	5	0.11942E+01	0.18060E+02
10	5	-0.11942E+01	-0.18060E+02
11	5	-0.63116E+00	-0.21762E+01
12	5	0.63116E+00	0.21762E+01
13	5	-0.11942E+01	-0.18060E+02
14	5	0.11942E+01	0.18060E+02
15	5	-0.55247E+00	-0.58497E+02
16	5	0.55247E+00	0.58497E+02
17	5	0.55247E+00	0.58497E+02
18	5	-0.55247E+00	-0.58497E+02
1	6	0.19885E+02	-0.10305E+02
2	6	0.11829E+02	-0.12456E+02
3	6	0.10047E+02	-0.13090E+02
4	6	0.14076E+02	-0.11695E+02
5	6	0.20807E+02	-0.10508E+02
6	6	0.25065E+02	-0.53274E+02
7	6	0.10575E+01	0.15487E+02
8	6	-0.10575E+01	-0.15487E+02
9	6	0.64657E+00	0.55407E+02
10	6	-0.64657E+00	-0.55407E+02
11	6	0.25560E+00	0.11503E+01
12	6	-0.25560E+00	-0.11503E+01
13	6	-0.56259E+00	-0.25119E+01
14	6	0.56259E+00	0.25119E+01
15	6	-0.89010E+00	-0.16153E+02
16	6	0.89010E+00	0.16153E+02
17	6	-0.50346E+00	-0.52696E+02
18	6	0.50346E+00	0.52696E+02
1	7	0.50745E+00	0.53356E+02
2	7	-0.54970E+00	-0.57577E+02

3	7	-0.87950E+00	-0.10102E+02
4	7	-0.24263E+00	-0.89510E+00
5	7	0.61613E+00	0.20016E+01
6	7	0.10498E+01	0.98202E+01
7	7	0.21462E+02	-0.52950E+02
8	7	0.17072E+02	-0.92336E+01
9	7	-0.11911E+02	-0.67091E+01
10	7	-0.14785E+02	-0.73177E+02
11	7	0.97926E+01	0.74336E+02
12	7	0.79719E+01	0.77045E+01
13	7	-0.40142E+01	0.31398E+02
14	7	-0.22716E+01	0.15589E+02
15	7	-0.66735E+01	0.15819E+02
16	7	-0.40118E+01	0.14348E+02
17	7	0.39115E+00	0.28846E+02
18	7	0.11126E+01	0.13366E+02
1	8	-0.50745E+00	-0.53356E+02
2	8	0.54970E+00	0.57577E+02
3	8	0.87950E+00	0.10102E+02
4	8	0.24263E+00	0.89510E+00
5	8	-0.61613E+00	-0.20016E+01
6	8	-0.10498E+01	-0.98202E+01
7	8	0.17072E+02	-0.92336E+01
8	8	0.21462E+02	-0.52950E+02
9	8	-0.14785E+02	-0.73177E+02
10	8	-0.11911E+02	-0.67091E+01
11	8	0.79719E+01	0.77045E+01
12	8	0.97926E+01	0.74336E+02
13	8	-0.22716E+01	0.15589E+02
14	8	-0.40142E+01	0.31398E+02
15	8	-0.40118E+01	0.14348E+02
16	8	-0.66735E+01	0.15819E+02
17	8	0.11126E+01	0.13366E+02
18	8	0.39115E+00	0.28846E+02
1	9	-0.65102E+00	-0.55277E+02
2	9	-0.11865E+01	-0.12167E+02
3	9	-0.55429E+00	-0.22976E+01
4	9	0.55429E+00	0.22976E+01
5	9	0.11865E+01	0.12167E+02
6	9	0.65103E+00	0.55277E+02
7	9	-0.11899E+02	-0.67967E+01
8	9	-0.14780E+02	-0.73057E+02
9	9	0.26810E+02	-0.43433E+02
10	9	0.21312E+02	-0.96883E+01
11	9	0.22644E+01	-0.15560E+02
12	9	0.40000E+01	-0.31407E+02
13	9	0.74417E+01	-0.17792E+02
14	9	0.11110E+02	-0.19514E+02
15	9	0.22644E+01	-0.15560E+02
16	9	0.40000E+01	-0.31407E+02
17	9	-0.11899E+02	-0.67967E+01
18	9	-0.14780E+02	-0.73057E+02
1	10	0.65103E+00	0.55277E+02
2	10	0.11865E+01	0.12167E+02

3	10	0.55429E+00	0.22976E+01
4	10	-0.55429E+00	-0.22976E+01
5	10	-0.11865E+01	-0.12167E+02
6	10	-0.65102E+00	-0.55277E+02
7	10	-0.14780E+02	-0.73057E+02
8	10	-0.11899E+02	-0.67967E+01
9	10	0.21312E+02	-0.96883E+01
10	10	0.26810E+02	-0.43433E+02
11	10	0.40000E+01	-0.31407E+02
12	10	0.22644E+01	-0.15560E+02
13	10	0.11110E+02	-0.19514E+02
14	10	0.74417E+01	-0.17792E+02
15	10	0.40000E+01	-0.31407E+02
16	10	0.22644E+01	-0.15560E+02
17	10	-0.14780E+02	-0.73057E+02
18	10	-0.11899E+02	-0.67967E+01
1	11	0.87950E+00	0.10102E+02
2	11	0.54970E+00	0.57577E+02
3	11	-0.50745E+00	-0.53356E+02
4	11	-0.10498E+01	-0.98202E+01
5	11	-0.61613E+00	-0.20016E+01
6	11	0.24263E+00	0.89510E+00
7	11	0.97926E+01	0.74336E+02
8	11	0.79719E+01	0.77045E+01
9	11	0.22716E+01	-0.15589E+02
10	11	0.40142E+01	-0.31398E+02
11	11	0.21462E+02	-0.52950E+02
12	11	0.17072E+02	-0.92336E+01
13	11	0.14785E+02	0.73177E+02
14	11	0.11911E+02	0.67091E+01
15	11	0.39115E+00	0.28846E+02
16	11	0.11126E+01	0.13366E+02
17	11	-0.66735E+01	0.15819E+02
18	11	-0.40118E+01	0.14348E+02
1	12	-0.87950E+00	-0.10102E+02
2	12	-0.54970E+00	-0.57577E+02
3	12	0.50745E+00	0.53356E+02
4	12	0.10498E+01	0.98202E+01
5	12	0.61613E+00	0.20016E+01
6	12	-0.24263E+00	-0.89510E+00
7	12	0.79719E+01	0.77045E+01
8	12	0.97926E+01	0.74336E+02
9	12	0.40142E+01	-0.31398E+02
10	12	0.22716E+01	-0.15589E+02
11	12	0.17072E+02	-0.92336E+01
12	12	0.21462E+02	-0.52950E+02
13	12	0.11911E+02	0.67091E+01
14	12	0.14785E+02	0.73177E+02
15	12	0.11126E+01	0.13366E+02
16	12	0.39115E+00	0.28846E+02
17	12	-0.40118E+01	0.14348E+02
18	12	-0.66735E+01	0.15819E+02
1	13	0.55429E+00	0.22976E+01
2	13	0.11865E+01	0.12167E+02

3	13	0.65102E+00	0.55277E+02
4	13	-0.65103E+00	-0.55277E+02
5	13	-0.11865E+01	-0.12167E+02
6	13	-0.55429E+00	-0.22976E+01
7	13	-0.40000E+01	0.31407E+02
8	13	-0.22644E+01	0.15560E+02
9	13	0.74417E+01	-0.17792E+02
10	13	0.11110E+02	-0.19514E+02
11	13	0.14780E+02	0.73057E+02
12	13	0.11899E+02	0.67967E+01
13	13	0.26810E+02	-0.43433E+02
14	13	0.21312E+02	-0.96883E+01
15	13	0.14780E+02	0.73057E+02
16	13	0.11899E+02	0.67967E+01
17	13	-0.40000E+01	0.31407E+02
18	13	-0.22644E+01	0.15560E+02
1	14	-0.55429E+00	-0.22976E+01
2	14	-0.11865E+01	-0.12167E+02
3	14	-0.65103E+00	-0.55277E+02
4	14	0.65102E+00	0.55277E+02
5	14	0.11865E+01	0.12167E+02
6	14	0.55429E+00	0.22976E+01
7	14	-0.22644E+01	0.15560E+02
8	14	-0.40000E+01	0.31407E+02
9	14	0.11110E+02	-0.19514E+02
10	14	0.74417E+01	-0.17792E+02
11	14	0.11899E+02	0.67967E+01
12	14	0.14780E+02	0.73057E+02
13	14	0.21312E+02	-0.96883E+01
14	14	0.26810E+02	-0.43433E+02
15	14	0.11899E+02	0.67967E+01
16	14	0.14780E+02	0.73057E+02
17	14	-0.22644E+01	0.15560E+02
18	14	-0.40000E+01	0.31407E+02
1	15	-0.24263E+00	-0.89510E+00
2	15	0.61613E+00	0.20016E+01
3	15	0.10498E+01	0.98202E+01
4	15	0.50745E+00	0.53356E+02
5	15	-0.54970E+00	-0.57577E+02
6	15	-0.87950E+00	-0.10102E+02
7	15	-0.66735E+01	0.15819E+02
8	15	-0.40118E+01	0.14348E+02
9	15	0.22716E+01	-0.15589E+02
10	15	0.40142E+01	-0.31398E+02
11	15	0.39115E+00	0.28846E+02
12	15	0.11126E+01	0.13366E+02
13	15	0.14785E+02	0.73177E+02
14	15	0.11911E+02	0.67091E+01
15	15	0.21462E+02	-0.52950E+02
16	15	0.17072E+02	-0.92336E+01
17	15	0.97926E+01	0.74336E+02
18	15	0.79719E+01	0.77045E+01
1	16	0.24263E+00	0.89510E+00
2	16	-0.61613E+00	-0.20016E+01

3	16	-0.10498E+01	-0.98202E+01
4	16	-0.50745E+00	-0.53356E+02
5	16	0.54970E+00	0.57577E+02
6	16	0.87950E+00	0.10102E+02
7	16	-0.40118E+01	0.14348E+02
8	16	-0.66735E+01	0.15819E+02
9	16	0.40142E+01	-0.31398E+02
10	16	0.22716E+01	-0.15589E+02
11	16	0.11126E+01	0.13366E+02
12	16	0.39115E+00	0.28846E+02
13	16	0.11911E+02	0.67091E+01
14	16	0.14785E+02	0.73177E+02
15	16	0.17072E+02	-0.92336E+01
16	16	0.21462E+02	-0.52950E+02
17	16	0.79719E+01	0.77045E+01
18	16	0.97926E+01	0.74336E+02
1	17	-0.10498E+01	-0.98202E+01
2	17	-0.61613E+00	-0.20016E+01
3	17	0.24263E+00	0.89510E+00
4	17	0.87950E+00	0.10102E+02
5	17	0.54970E+00	0.57577E+02
6	17	-0.50745E+00	-0.53356E+02
7	17	0.39115E+00	0.28846E+02
8	17	0.11126E+01	0.13366E+02
9	17	-0.11911E+02	-0.67091E+01
10	17	-0.14785E+02	-0.73177E+02
11	17	-0.66735E+01	0.15819E+02
12	17	-0.40118E+01	0.14348E+02
13	17	-0.40142E+01	0.31398E+02
14	17	-0.22716E+01	0.15589E+02
15	17	0.97926E+01	0.74336E+02
16	17	0.79719E+01	0.77045E+01
17	17	0.21462E+02	-0.52950E+02
18	17	0.17072E+02	-0.92336E+01
1	18	0.10498E+01	0.98202E+01
2	18	0.61613E+00	0.20016E+01
3	18	-0.24263E+00	-0.89510E+00
4	18	-0.87950E+00	-0.10102E+02
5	18	-0.54970E+00	-0.57577E+02
6	18	0.50745E+00	0.53356E+02
7	18	0.11126E+01	0.13366E+02
8	18	0.39115E+00	0.28846E+02
9	18	-0.14785E+02	-0.73177E+02
10	18	-0.11911E+02	-0.67091E+01
11	18	-0.40118E+01	0.14348E+02
12	18	-0.66735E+01	0.15819E+02
13	18	-0.22716E+01	0.15589E+02
14	18	-0.40142E+01	0.31398E+02
15	18	0.79719E+01	0.77045E+01
16	18	0.97926E+01	0.74336E+02
17	18	0.17072E+02	-0.92336E+01
18	18	0.21462E+02	-0.52950E+02

BACKSCATTERING, ISCAT =   1
FAR-ZONE PATTERN

(DEG)		** CROSS	SECTION	(DB/M**2) **	******	PHASE	(DEG)	******	
TH	PHI	STTM	SPPM	STPM	SPTM	STTM	SPPM	STPM	SPTM
0.0	0.0	11.53	9.44	-99.90	-99.90	-39.8	-42.9	71.2	137.5
5.0	0.0	11.52	9.43	-99.90	-99.90	-39.7	-42.9	91.2	-133.8
10.0	0.0	11.46	9.39	-99.90	-99.90	-39.6	-42.9	61.8	-128.4
15.0	0.0	11.37	9.32	-99.90	-99.90	-39.5	-42.9	48.3	-156.0
20.0	0.0	11.25	9.23	-99.90	-99.90	-39.2	-42.9	36.8	-150.3
25.0	0.0	11.10	9.11	-99.90	-99.90	-38.8	-42.9	28.1	171.2
30.0	0.0	10.94	8.96	-99.90	-99.90	-38.4	-42.9	-47.8	-164.8
35.0	0.0	10.77	8.79	-99.90	-99.90	-37.8	-43.0	26.8	173.3
40.0	0.0	10.59	8.60	-99.90	-99.90	-37.1	-43.1	40.2	-142.3
45.0	0.0	10.40	8.40	-99.90	-99.90	-36.4	-43.2	22.4	-166.3
50.0	0.0	10.22	8.20	-99.90	-99.90	-35.7	-43.4	-17.6	-69.0
55.0	0.0	10.04	8.01	-99.90	-99.90	-34.9	-43.6	29.6	-117.0
60.0	0.0	9.87	7.82	-99.90	-99.90	-34.2	-43.7	65.9	-136.6
65.0	0.0	9.64	7.66	-99.90	-99.90	-33.9	-43.8	-16.5	-51.3
70.0	0.0	9.55	7.52	-99.90	-99.90	-33.1	-43.8	100.5	-22.6
75.0	0.0	9.43	7.41	-99.90	-99.90	-32.8	-43.9	35.1	161.6
80.0	0.0	9.33	7.33	-99.90	-99.90	-32.5	-43.9	63.7	-62.2
85.0	0.0	9.27	7.29	-99.90	-99.90	-32.3	-43.9	5.0	166.0
90.0	0.0	9.25	7.27	-99.90	-99.90	-32.3	-43.9	64.8	-152.8
95.0	0.0	9.27	7.29	-99.90	-99.90	-32.3	-43.9	33.9	-157.4
100.0	0.0	9.33	7.33	-99.90	-99.90	-32.5	-43.9	71.5	-82.1
105.0	0.0	9.43	7.41	-99.90	-99.90	-32.8	-43.9	82.6	-121.4
110.0	0.0	9.55	7.52	-99.90	-99.90	-33.1	-43.8	120.2	170.2
115.0	0.0	9.64	7.66	-99.90	-99.90	-33.9	-43.8	-97.2	-145.0
120.0	0.0	9.87	7.82	-99.90	-99.90	-34.2	-43.7	53.7	-162.9
125.0	0.0	10.04	8.01	-99.90	-99.90	-34.9	-43.6	63.8	-152.5
130.0	0.0	10.22	8.20	-99.90	-99.90	-35.7	-43.4	109.7	-133.8
135.0	0.0	10.40	8.40	-99.90	-99.90	-36.4	-43.2	-27.5	-122.4
140.0	0.0	10.59	8.60	-99.90	-99.90	-37.1	-43.1	-123.9	-106.6
145.0	0.0	10.77	8.79	-99.90	-99.90	-37.8	-43.0	80.4	-122.6
150.0	0.0	10.94	8.96	-99.90	-99.90	-38.4	-42.9	-155.4	-154.6
155.0	0.0	11.10	9.11	-99.90	-99.90	-38.8	-42.9	136.6	-150.9
160.0	0.0	11.25	9.23	-99.90	-99.90	-39.2	-42.9	-4.3	-104.6
165.0	0.0	11.37	9.32	-99.90	-99.90	-39.5	-42.9	-155.3	-7.1
170.0	0.0	11.46	9.39	-99.90	-99.90	-39.6	-42.9	146.0	-143.1
175.0	0.0	11.52	9.43	-99.90	-99.90	-39.7	-42.9	172.3	-130.6
180.0	0.0	11.53	9.44	-99.90	-99.90	-39.8	-42.9	154.2	-153.4
175.0	180.0	11.52	9.43	-99.90	-99.90	-39.7	-42.9	111.2	131.6
170.0	180.0	11.46	9.39	-99.90	-99.90	-39.6	-42.9	-120.5	-30.3
165.0	180.0	11.37	9.32	-99.90	-99.90	-39.5	-42.9	164.5	-33.1
160.0	180.0	11.25	9.23	-99.90	-99.90	-39.2	-42.9	-86.3	-14.4
155.0	180.0	11.10	9.11	-99.90	-99.90	-38.8	-42.9	163.2	0.0
150.0	180.0	10.94	8.96	-99.90	-99.90	-38.4	-42.9	-80.7	9.2
145.0	180.0	10.77	8.79	-99.90	-99.90	-37.8	-43.0	-110.3	-2.9
140.0	180.0	10.59	8.60	-99.90	-99.90	-37.1	-43.1	10.8	28.7
135.0	180.0	10.40	8.40	-99.90	-99.90	-36.4	-43.2	35.4	-14.0
130.0	180.0	10.22	8.20	-99.90	-99.90	-35.7	-43.4	-17.2	-91.2
125.0	180.0	10.04	8.01	-99.90	-99.90	-34.9	-43.6	-88.6	-44.3

120.0	180.0	9.87	7.82	-99.90	-99.90	-34.2	-43.7	-57.6	-70.0
115.0	180.0	9.64	7.66	-99.90	-99.90	-33.9	-43.8	-95.8	90.0
110.0	180.0	9.55	7.52	-99.90	-99.90	-33.1	-43.8	52.3	2.0
105.0	180.0	9.43	7.41	-99.90	-99.90	-32.8	-43.9	-58.8	26.6
100.0	180.0	9.33	7.33	-99.90	-99.90	-32.5	-43.9	24.2	-97.6
95.0	180.0	9.27	7.29	-99.90	-99.90	-32.3	-43.9	162.2	69.4
90.0	180.0	9.25	7.27	-99.90	-99.90	-32.3	-43.9	-112.8	-23.6
85.0	180.0	9.27	7.29	-99.90	-99.90	-32.3	-43.9	-122.5	-170.7
80.0	180.0	9.33	7.33	-99.90	-99.90	-32.5	-43.9	-157.5	-14.8
75.0	180.0	9.43	7.41	-99.90	-99.90	-32.8	-43.9	-120.8	-124.6
70.0	180.0	9.55	7.52	-99.90	-99.90	-33.1	-43.8	72.6	166.0
65.0	180.0	9.64	7.66	-99.90	-99.90	-33.9	-43.8	-93.6	-18.2
60.0	180.0	9.87	7.82	-99.90	-99.90	-34.2	-43.7	176.4	46.6
55.0	180.0	10.04	8.01	-99.90	-99.90	-34.9	-43.6	129.5	-142.5
50.0	180.0	10.22	8.20	-99.90	-99.90	-35.7	-43.4	96.3	146.6
45.0	180.0	10.40	8.40	-99.90	-99.90	-36.4	-43.2	71.1	176.4
40.0	180.0	10.59	8.60	-99.90	-99.90	-37.1	-43.1	169.1	-140.7
35.0	180.0	10.77	8.79	-99.90	-99.90	-37.8	-43.0	115.1	-162.3
30.0	180.0	10.94	8.96	-99.90	-99.90	-38.4	-42.9	104.9	-156.8
25.0	180.0	11.10	9.11	-99.90	-99.90	-38.8	-42.9	108.9	-153.4
20.0	180.0	11.25	9.23	-99.90	-99.90	-39.2	-42.9	114.8	-129.8
15.0	180.0	11.37	9.32	-99.90	-99.90	-39.5	-42.9	80.6	-135.0
10.0	180.0	11.46	9.39	-99.90	-99.90	-39.6	-42.9	105.9	170.5
5.0	180.0	11.52	9.43	-99.90	-99.90	-39.7	-42.9	149.2	-155.2
0.0	180.0	11.53	9.44	-99.90	-99.90	-39.8	-42.9	115.2	-178.6

CPU RUN TIME FOR RUN   1 GEOMETRY   1 =   10.00 SECONDS

TOTAL CPU RUN TIME =   10.00 SECONDS

Appendix B

Output File for Example 2

THE OHIO STATE UNIVERSITY AIRCRAFT MODELLING CODE

****

************ RUN CONTROL COMMANDS *************

EX: EXECUTE
NGO = 1

RE: RADIATION PATTERN (ELEVATION)
IPFE = 1
FNDFE =   5.000
PHFE =   0.000

FR: FREQUENCY
FMC   =   50.000

************ GEOMETRY INPUT DATA *************

SG: SEGMENTATION
SGM = 0.25000

NS: NUMBER OF SIDES
NSIDE = 6

CS: CROSS SECTION
CROSS SECTION NUMBER 1:
    YCSI(J) =   0.00000
    YPL(J) =   0.00000
    IPCI(J) = 0
    IECI(J) = 0
    ICSI(J) = 0
        NSIDE   XCSI(I,J)   ZCSI(I,J)

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-----	---------	---------
1	0.00000	0.25000
2	0.25000	0.12500
3	0.25000	-0.12500
4	0.00000	-0.25000
5	-0.25000	-0.12500
6	-0.25000	0.12500

CS: CROSS SECTION
CROSS SECTION NUMBER 2:
    YCSI(J) =   2.00000
    YPL(J) =   0.00000
    IPCI(J) = 0
    IECI(J) = 0
    ICSI(J) = 0

NSIDE	XCSI(I,J)	ZCSI(I,J)
-----	---------	---------
1	0.00000	1.00000
2	1.00000	0.50000
3	1.00000	-0.50000
4	0.00000	-1.00000
5	-1.00000	-0.50000
6	-1.00000	0.50000

CS: CROSS SECTION
CROSS SECTION NUMBER 3:
    YCSI(J) =   4.00000
    YPL(J) =   0.00000
    IPCI(J) = 0
    IECI(J) = 0
    ICSI(J) = 0

NSIDE	XCSI(I,J)	ZCSI(I,J)
-----	---------	---------
1	0.00000	1.00000
2	1.00000	0.50000
3	1.00000	-0.50000
4	0.00000	-1.00000
5	-1.00000	-0.50000
6	-1.00000	0.50000

CS: CROSS SECTION
CROSS SECTION NUMBER 4:
    YCSI(J) =   6.00000
    YPL(J) =   0.00000
    IPCI(J) = 0
    IECI(J) = 0
    ICSI(J) = 0

NSIDE	XCSI(I,J)	ZCSI(I,J)
-----	---------	---------
1	0.00000	0.25000
2	0.25000	0.12500
3	0.25000	-0.12500
4	0.00000	-0.25000
5	-0.25000	-0.12500

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```
             6          -0.25000        0.12500
```

WG: WING
WING NUMBER 1:
    NWSEC(1,I) = 2
    NWSEC(2,I) = 3
    NWPT(I)   = 3
    NWSYM(I)   = 1
    ZSHTWG(I) =   0.000+J   0.000
    XWCN(1,I) =   1.00000
    YWCN(1,I) =   0.50000
    ZWCN(1,I) =   0.00000
    XWCN(2,I) =   1.00000
    YWCN(2,I) =   1.50000
    ZWCN(2,I) =   0.00000

SC: SOURCE
SOURCE GEOMETRY:
    Source_Length =   0.60000
    Xsource   =   0.00000
    Ysource   =   3.00000
    Zsource   =   -1.12000
    Source_Ang_Th =   180.00000 degrees
    Source_Ang_Ph =   0.00000 degrees

******* DETAILED DESCRIPTION OF GEOMETRY *******

CROSS SECTION GEOMETRY:
CROSS SECTIONS ARE SYMMETRIC.

CROSS SECTION NUMBER 1:
    LOCATED AT Y =   0.00000 meters.
       CROSS SECTION COORDINATES (meters)
        NSIDE   XCS(I,J)   ZCS(I,J)

        -----   --------   ---------
          1   0.00000   0.25000
          2   0.25000   0.12500
          3   0.25000   -0.12500
          4   0.00000   -0.25000
          5   -0.25000   -0.12500
          6   -0.25000   0.12500

CROSS SECTION NUMBER 2:
    LOCATED AT Y =   2.00000 meters.
       CROSS SECTION COORDINATES (meters)
        NSIDE   XCS(I,J)   ZCS(I,J)

        -----   --------   ---------
          1   0.00000   1.00000
          2   1.00000   0.50000
          3   1.00000   -0.50000

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```
          4          0.00000      -1.00000
          5         -1.00000      -0.50000
          6         -1.00000       0.50000


CROSS SECTION NUMBER  3:
     LOCATED AT Y =        4.00000 meters.
        CROSS SECTION COORDINATES (meters)
          NSIDE      XCS(I,J)       ZCS(I,J)

          -----     --------       ---------
          1          0.00000       1.00000
          2          1.00000       0.50000
          3          1.00000      -0.50000
          4          0.00000      -1.00000
          5         -1.00000      -0.50000
          6         -1.00000       0.50000


CROSS SECTION NUMBER  4:
     LOCATED AT Y =        6.00000 meters.
        CROSS SECTION COORDINATES (meters)
          NSIDE      XCS(I,J)       ZCS(I,J)

          -----     --------       ---------
          1          0.00000       0.25000
          2          0.25000       0.12500
          3          0.25000      -0.12500
          4          0.00000      -0.25000
          5         -0.25000      -0.12500
          6         -0.25000       0.12500


WING GEOMETRY:

WING NUMBER  1:
THIS WING IS AT POINT  3 AND GOES FROM CROSS SECTION  2
TO CROSS SECTION  3.
A SYMMETRIC WING IS ALSO INCLUDED.
THE WING COORDINATES ARE REFERENCED TO POINT  3 ON CROSS SECTION  2.
THE WING SHEET IMPEDANCE IS        0.000+J        0.000 (OHMS / SQ.)
        WING COORDINATES (meters)
         XWCN(1,1) =        1.00000
         YWCN(1,1) =        0.50000
         ZWCN(1,1) =        0.00000
         XWCN(2,1) =        1.00000
         YWCN(2,1) =        1.50000
         ZWCN(2,1) =        0.00000


SOURCE MONOPOLE GEOMETRY:
LENGTH OF THE SOURCE MONOPOLE =        0.60000 meters.
X DISPLACEMENT OF THE SOURCE MONOPOLE =       0.00000 meters.    ·
Y DISPLACEMENT OF THE SOURCE MONOPOLE =       3.00000 meters.
Z DISPLACEMENT OF THE SOURCE MONOPOLE =      -1.12000 meters.
SOURCE MONOPOLE DIRECTION IS THETA =     180.00000 degrees.
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SOURCE MONOPOLE DIRECTION IS PHI =   0.00000 degrees.

********* SUMMARY OF ARRAY DIMENSIONS **********

IDWR   = 200
ITW2   = 2250
ICN   =   16
IPL   = 450
IAT   =   10
ITOT   = 2250
IDZT   =   20100
IDZTF = 2250
IDMI   =   1
IDZTI =   1
IDZTFI =   1
IDMZI = 0

********** SUMMARY OF MODEL GEOMETRY **********

NUMBER OF PLATES = 20
NUMBER OF POINTS ON THE WIRES =   3
NUMBER OF SEGMENTS ON THE WIRES =   2

   NWR = NUMBER OF WIRE MODES =   1
   NPLTM = NUMBER OF PLATE MODES =   72
   NAT = NUMBER OF ATTACHMENT MODES =   0

******** RESULTS OF THE MM COMPUTATION *********

  INPUT ADMITTANCE(MHOS) =   0.000003 J   0.000928
  INPUT IMPEDANCE(OHMS) =   3.609 J -1077.811
  EFFICIENCY (PERCENT) = 100.000

  ANTENNA PROBLEM, ISCAT =   0

FAR-ZONE GAIN ELEVATION PLANE PATTERN. PHI =   0.0 DEG.

(DEG)   **MAG (DB)**   *PHASE (DEG)*
THETA GTHETA   GPHI   GTHETA   GPHI

  0.0 -99.90 -99.90   -19.6   10.2
  5.0 -13.06 -99.90 -106.5   -1.2

10.0	-6.79	-99.90	-105.0	-5.3
15.0	-3.41	-99.90	-103.8	-7.3
20.0	-1.17	-99.90	-102.3	-16.5
25.0	0.41	-99.90	-100.4	-19.1
30.0	1.56	-99.90	-98.2	-22.5
35.0	2.38	-99.90	-95.4	-17.4
40.0	2.94	-99.90	-92.2	-17.9
45.0	3.28	-99.90	-88.6	-19.6
50.0	3.43	-99.90	-84.4	-20.6
55.0	3.41	-99.90	-79.6	-11.1
60.0	3.23	-99.90	-74.2	-14.2
65.0	2.90	-99.90	-68.3	-13.7
70.0	2.47	-99.90	-61.2	-13.1
75.0	1.92	-99.90	-53.3	-11.2
80.0	1.28	-99.90	-44.4	-8.1
85.0	0.60	-99.90	-34.1	-10.1
90.0	-0.06	-99.90	-22.6	-5.2
95.0	-0.62	-99.90	-9.8	-4.8
100.0	-1.01	-99.90	3.8	-4.8
105.0	-1.18	-99.90	17.6	5.8
110.0	-1.14	-99.90	30.9	5.1
115.0	-0.94	-99.90	43.4	3.7
120.0	-0.73	-99.90	53.5	7.4
125.0	-0.53	-99.90	62.6	7.5
130.0	-0.42	-99.90	70.4	11.8
135.0	-0.46	-99.90	77.0	19.6
140.0	-0.67	-99.90	82.5	18.0
145.0	-1.11	-99.90	87.1	23.4
150.0	-1.83	-99.90	91.0	29.1
155.0	-2.88	-99.90	94.1	31.8
160.0	-4.40	-99.90	96.7	36.8
165.0	-6.59	-99.90	98.6	40.3
170.0	-9.96	-99.90	100.2	43.9
175.0	-16.38	-99.90	102.0	48.6
180.0	-99.90	-99.90	101.3	55.9
185.0	-16.38	-99.90	102.0	-111.9
190.0	-9.96	-99.90	100.2	-108.6
195.0	-6.59	-99.90	98.6	-111.6
200.0	-4.40	-99.90	96.7	-103.3
205.0	-2.88	-99.90	94.1	-96.7
210.0	-1.83	-99.90	91.0	-90.8
215.0	-1.11	-99.90	87.1	-98.4
220.0	-0.67	-99.90	82.5	-84.9
225.0	-0.46	-99.90	77.0	-88.0
230.0	-0.42	-99.90	70.4	-87.8
235.0	-0.53	-99.90	62.6	-94.3
240.0	-0.73	-99.90	53.5	-92.7
245.0	-0.94	-99.90	43.4	-99.2
250.0	-1.14	-99.90	30.9	-99.3
255.0	-1.18	-99.90	17.6	-107.2
260.0	-1.01	-99.90	3.8	-101.8
265.0	-0.62	-99.90	-9.8	-106.3
270.0	-0.06	-99.90	-22.6	-103.1
275.0	0.60	-99.90	-34.1	-111.6

```
280.0     1.28    -99.90      -44.4    -117.4
285.0     1.92    -99.90      -53.3    -113.9
290.0     2.47    -99.90      -61.2    -117.6
295.0     2.90    -99.90      -68.3    -122.6
300.0     3.23    -99.90      -74.2    -123.5
305.0     3.41    -99.90      -79.6    -122.1
310.0     3.43    -99.90      -84.4    -129.3
315.0     3.28    -99.90      -88.6    -130.4
320.0     2.94    -99.90      -92.2    -131.0
325.0     2.38    -99.90      -95.4    -135.2
330.0     1.56    -99.90      -98.2    -141.2
335.0     0.41    -99.90     -100.4    -134.3
340.0    -1.17    -99.90     -102.3    -152.2
345.0    -3.41    -99.90     -103.8    -148.8
350.0    -6.79    -99.90     -105.0    -167.5
355.0   -13.06    -99.90     -106.5    -165.7
360.0   -99.90    -99.90      159.0    -170.9
```

CPU RUN TIME FOR RUN   1 GEOMETRY   1 =   78.00 SECONDS

TOTAL CPU RUN TIME =   78.00 SECONDS

Appendix C

Output File for Example 3

THE OHIO STATE UNIVERSITY AIRCRAFT MODELLING CODE

****

************ RUN CONTROL COMMANDS *************

EX: EXECUTE
NGO   = 1

RA: RADIATION PATTERN (AZIMUTHAL)
IPFA = 1
FNDFA =   5.000
THFA =   90.000

FR: FREQUENCY
FMC   =   50.000

************ GEOMETRY INPUT DATA *************

SG: SEGMENTATION
SGM = 0.25000

NS: NUMBER OF SIDES
NSIDE = 6

UN: UNITS
IUNITS = 2 (CENTIMETERS)

CS: CROSS SECTION
CROSS SECTION NUMBER 1:
     YCSI(J) =   0.00000
     YPL(J) =   0.00000
     IPCI(J) = 0

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```
        IECI(J) =  1
        ICSI(J) =  0
           NSIDE      XCSI(I,J)      ZCSI(I,J)

           -----      ---------      ---------
             1          0.00000       25.00000
             2         25.00000       12.50000
             3         25.00000      -12.50000
             4          0.00000      -25.00000
             5        -25.00000      -12.50000
             6        -25.00000       12.50000


CS: CROSS SECTION
CROSS SECTION NUMBER  2:
        YCSI(J) =    200.00000
        YPL(J)  =      0.00000
        IPCI(J) =  0
        IECI(J) =  0
        ICSI(J) =  0
           NSIDE      XCSI(I,J)      ZCSI(I,J)

           -----      ---------      ---------
             1          0.00000      100.00000
             2        100.00000       50.00000
             3        100.00000      -50.00000
             4          0.00000     -100.00000
             5       -100.00000      -50.00000
             6       -100.00000       50.00000


CS: CROSS SECTION
CROSS SECTION NUMBER  3:
        YCSI(J) =    400.00000
        YPL(J)  =      0.00000
        IPCI(J) =  0
        IECI(J) =  1
        ICSI(J) =  0
           NSIDE      XCSI(I,J)      ZCSI(I,J)

           -----      ---------      ---------
             1          0.00000       25.00000
             2         25.00000       12.50000
             3         25.00000      -12.50000
             4          0.00000      -25.00000
             5        -25.00000      -12.50000
             6        -25.00000       12.50000


TS: TAIL SECTION
TAIL SECTION GEOMETRY:
ZSHTTS =        0.000+J        0.000
POINTS ON TAIL SECTION:
     J       YTSCN(J)       ZTSCN(J)

     -       --------       --------
     1        50.00000      100.00000
     2       150.00000      100.00000
     3       125.00000
     4       125.00000
     5       150.00000     -100.00000
```

```
        6       50.00000     -100.00000

TW: TAIL WING
TAIL WING GEOMETRY:
    YTWS     =      25.00000
    ZTWS     =      25.00000
    YTWL     =      75.00000
    ITWSYM   =  1
    ZSHTTW  =       0.000+J       0.000
    XTWCN(1) =     100.00000
    YTWCN(1) =      12.50000
    XTWCN(2) =     100.00000
    YTWCN(2) =      62.50000


SC: SOURCE
SOURCE GEOMETRY:
    Source_Length =      60.00000
    Xsource       =       0.00000
    Ysource       =     300.00000
    Zsource       =     -75.00000
    Source_Ang_Th =     180.00000 degrees
    Source_Ang_Ph =       0.00000 degrees



******* DETAILED DESCRIPTION OF GEOMETRY *******



CROSS SECTION GEOMETRY:
CROSS SECTIONS ARE SYMMETRIC.



CROSS SECTION NUMBER  1:
    LOCATED AT Y =       0.00000 meters.
    HAS AN ENDCAP PLATE.
        CROSS SECTION COORDINATES (meters)
        NSIDE      XCS(I,J)      ZCS(I,J)

        -----      --------      ---------
          1         0.00000       0.25000
          2         0.25000       0.12500
          3         0.25000      -0.12500
          4         0.00000      -0.25000
          5        -0.25000      -0.12500
          6        -0.25000       0.12500


CROSS SECTION NUMBER  2:
    LOCATED AT Y =       2.00000 meters.
        CROSS SECTION COORDINATES (meters)
        NSIDE      XCS(I,J)      ZCS(I,J)

        -----      --------      ---------
          1         0.00000       1.00000
          2         1.00000       0.50000
          3         1.00000      -0.50000
          4         0.00000      -1.00000
```

```
             5       -1.00000     -0.50000
             6       -1.00000      0.50000


CROSS SECTION NUMBER  3:
     LOCATED AT Y =       4.00000 meters.
     HAS AN ENDCAP PLATE.
        CROSS SECTION COORDINATES (meters)
         NSIDE      XCS(I,J)     ZCS(I,J)

         -----      --------     --------
           1        0.00000      0.25000
           2        0.25000      0.12500
           3        0.25000     -0.12500
           4        0.00000     -0.25000
           5       -0.25000     -0.12500
           6       -0.25000      0.12500


TAIL SECTION GEOMETRY:
THE TAIL SECTION COORDINATES ARE REFERENCED TO POINT 1
ON CROSS SECTION NUMBER  3
THE TAIL SECTION SHEET IMPEDANCE IS       0.000+J       0.000 (OHMS / SQ.)
        TAIL SECTION COORDINATES (meters.)
         J       YTSCN(J)     ZTSCN(J)

         -       --------     --------
         1        0.50000      1.00000
         2        1.50000      1.00000
         3        1.25000      0.00000
         4        1.25000     -0.50000
         5        1.50000     -1.00000
         6        0.50000     -1.00000


TAIL WING GEOMETRY:
THE TAIL WING IS       0.75000 meters LONG ALONG THE TAIL SECTION.
THE TAIL WING IS REFERENCED TO THE POINT Y =       0.25000 meters
AND Z =       0.25000 meters.
A SYMMETRIC TAIL WING IS ALSO INCLUDED.
THE TAIL WING SHEET IMPEDANCE IS       0.000+J       0.000 (OHMS / SQ.)
        TAIL WING COORDINATES (meters).
            XTWCN(1) =       1.00000
            YTWCN(1) =       0.12500
            XTWCN(2) =       1.00000
            YTWCN(2) =       0.62500


SOURCE MONOPOLE GEOMETRY:
LENGTH OF THE SOURCE MONOPOLE =       0.60000 meters.
X DISPLACEMENT OF THE SOURCE MONOPOLE =       0.00000 meters.
Y DISPLACEMENT OF THE SOURCE MONOPOLE =       3.00000 meters.
Z DISPLACEMENT OF THE SOURCE MONOPOLE =      -0.75000 meters.
SOURCE MONOPOLE DIRECTION IS THETA =     180.00000 degrees.
SOURCE MONOPOLE DIRECTION IS  PHI  =       0.00000 degrees.
```

```
********* SUMMARY OF ARRAY DIMENSIONS **********


IDWR   =  200
ITW2   = 2250
ICN    =   16
IPL    =  450
IAT    =   10
ITOT   = 2250
IDZT   =   20100
IDZTF  = 2250
IDMI   =    1
IDZTI  =        1
IDZTFI =    1
IDMZI  =  0


********** SUMMARY OF MODEL GEOMETRY ***********


NUMBER OF PLATES =  24
NUMBER OF POINTS ON THE WIRES =   3
NUMBER OF SEGMENTS ON THE WIRES =   2


   NWR = NUMBER OF WIRE MODES =    1
   NPLTM = NUMBER OF PLATE MODES =   88
   NAT = NUMBER OF ATTACHMENT MODES =    0




******** RESULTS OF THE MM COMPUTATION *********

  INPUT ADMITTANCE(MHOS) =   0.000003 J   0.000927
  INPUT IMPEDANCE(OHMS) =      3.598 J  -1078.687
  EFFICIENCY (PERCENT) = 100.000



  ANTENNA PROBLEM, ISCAT =     0




  FAR-ZONE GAIN AZIMUTH PLANE PATTERN.  THETA =  90.0 DEG.

 (DEG)   **MAG (DB)**   *PHASE (DEG)*
  PHI   GTHETA   GPHI   GTHETA    GPHI


  0.0    2.20  -10.86   -25.7  -129.8
  5.0    2.14   -7.87    -9.2  -115.5
 10.0    2.06   -5.90     7.7  -101.0
```

15.0	1.95	-4.56	24.7	-86.6
20.0	1.84	-3.68	41.7	-72.5
25.0	1.72	-3.16	58.5	-58.9
30.0	1.59	-2.95	74.8	-45.8
35.0	1.47	-3.01	90.4	-33.4
40.0	1.36	-3.31	105.2	-21.8
45.0	1.25	-3.85	119.0	-11.1
50.0	1.14	-4.60	131.6	-1.4
55.0	1.04	-5.58	143.0	7.3
60.0	0.94	-6.82	153.0	14.9
65.0	0.86	-8.35	161.5	21.4
70.0	0.78	-10.09	168.6	25.5
75.0	0.72	-12.77	174.1	30.9
80.0	0.68	-16.31	178.1	33.9
85.0	0.65	-22.34	-179.5	35.6
90.0	0.64	-99.90	-178.7	82.1
95.0	0.65	-22.34	-179.5	-144.4
100.0	0.68	-16.31	178.1	-146.1
105.0	0.72	-12.77	174.1	-149.1
110.0	0.78	-10.09	168.6	-154.5
115.0	0.86	-8.35	161.5	-158.6
120.0	0.94	-6.82	153.0	-165.1
125.0	1.04	-5.58	143.0	-172.7
130.0	1.14	-4.60	131.6	178.6
135.0	1.25	-3.85	119.0	168.9
140.0	1.36	-3.31	105.2	158.2
145.0	1.47	-3.01	90.4	146.6
150.0	1.59	-2.95	74.8	134.2
155.0	1.72	-3.16	58.5	121.1
160.0	1.84	-3.68	41.7	107.5
165.0	1.95	-4.56	24.7	93.4
170.0	2.06	-5.90	7.7	79.0
175.0	2.14	-7.87	-9.2	64.5
180.0	2.20	-10.86	-25.7	50.2
185.0	2.23	-15.92	-41.8	36.8
190.0	2.23	-30.06	-57.2	35.5
195.0	2.20	-20.31	-72.0	179.6
200.0	2.14	-13.42	-85.9	168.7
205.0	2.06	-10.02	-99.1	156.3
210.0	1.97	-7.97	-111.3	144.1
215.0	1.88	-6.70	-122.6	132.5
220.0	1.79	-5.98	-133.0	121.6
225.0	1.70	-5.68	-142.6	111.7
230.0	1.63	-5.74	-151.1	102.7
235.0	1.57	-6.14	-158.8	94.6
240.0	1.53	-6.89	-165.5	87.6
245.0	1.50	-8.01	-171.3	81.7
250.0	1.47	-9.36	-176.0	77.7
255.0	1.46	-11.84	-179.8	73.0
260.0	1.45	-15.18	177.5	70.3
265.0	1.44	-21.10	175.9	68.7
270.0	1.44	-98.94	175.4	-55.9
275.0	1.44	-21.10	175.9	-111.3
280.0	1.45	-15.18	177.5	-109.7

```
285.0    1.46   -11.84   -179.8   -107.0
290.0    1.47    -9.36   -176.0   -102.3
295.0    1.50    -8.01   -171.3    -98.3
300.0    1.53    -6.89   -165.5    -92.4
305.0    1.58    -6.14   -158.8    -85.4
310.0    1.63    -5.74   -151.1    -77.3
315.0    1.70    -5.68   -142.6    -68.3
320.0    1.79    -5.98   -133.0    -58.4
325.0    1.88    -6.70   -122.6    -47.5
330.0    1.97    -7.97   -111.3    -35.9
335.0    2.06   -10.02    -99.1    -23.7
340.0    2.14   -13.43    -85.9    -11.3
345.0    2.20   -20.31    -72.0     -0.4
350.0    2.23   -30.06    -57.2   -144.5
355.0    2.23   -15.92    -41.8   -143.2
360.0    2.20   -10.86    -25.7   -129.8
```

CPU RUN TIME FOR RUN   1 GEOMETRY   1 =   155.00 SECONDS

TOTAL CPU RUN TIME =   155.00 SECONDS

Appendix D

Output File for Example 4

THE OHIO STATE UNIVERSITY AIRCRAFT MODELLING CODE

****

************* RUN CONTROL COMMANDS *************

EX: EXECUTE
NGO   = 1

SA: SCATTERING PATTERN (AZIMUTHAL)
ISA   = 1
IPSA = 1
FNDSA =   2.000
THSA =   90.000
THIN =   0.000
PHIN =   0.000

FR: FREQUENCY
FMC   =   70.000

************ GEOMETRY INPUT DATA *************

SG: SEGMENTATION
SGM = 0.25000

CS: CROSS SECTION
CROSS SECTION NUMBER 1:
    YCSI(J) =   0.00000
    YPL(J) =   0.00000
    IPCI(J) = 0
    IECI(J) = 1
    ICSI(J) = 0
        NSIDE   XCSI(I,J)   ZCSI(I,J)

-----	---------	---------
1	0.00000	0.25000
2	0.17700	0.17700
3	0.25000	0.00000
4	0.17700	-0.17700
5	0.00000	-0.25000
6	-0.17700	-0.17700
7	-0.25000	0.00000
8	-0.17700	0.17700

CS: CROSS SECTION
CROSS SECTION NUMBER 2:

    YCSI(J) =   1.00000
    YPL(J) =   0.00000
    IPCI(J) = 0
    IECI(J) = 0
    ICSI(J) = 0

NSIDE	XCSI(I,J)	ZCSI(I,J)
-----	---------	---------
1	0.00000	0.62500
2	0.44200	0.44200
3	0.62500	0.00000
4	0.37500	-0.50000
5	0.00000	-0.62500
6	-0.37500	-0.50000
7	-0.62500	0.00000
8	-0.44200	0.44200

CS: CROSS SECTION
CROSS SECTION NUMBER 3:

    YCSI(J) =   2.00000
    YPL(J) =   3.00000
    IPCI(J) = 2
    IECI(J) = 0
    ICSI(J) = 0

NSIDE	XCSI(I,J)	ZCSI(I,J)
-----	---------	---------
1	0.00000	1.00000
2	0.70700	0.70700
3	1.00000	0.00000
4	0.86600	-0.50000
5	0.00000	-1.00000
6	-0.86600	-0.50000
7	-1.00000	0.00000
8	-0.70700	0.70700

CS: CROSS SECTION
CROSS SECTION NUMBER 4:

    YCSI(J) =   5.00000
    YPL(J) =   0.00000
    IPCI(J) = 0
    IECI(J) = 1
    ICSI(J) = 0

NSIDE	XCSI(I,J)	ZCSI(I,J)

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-----	--------	--------
1	0.00000	1.00000
2	0.70700	0.70700
3	1.00000	0.00000
4	0.86600	-0.50000
5	0.00000	-1.00000
6	-0.86600	-0.50000
7	-1.00000	0.00000
8	-0.70700	0.70700

WG: WING
WING NUMBER 1:
    NWSEC(1,I) = 2
    NWSEC(2,I) = 4
    NWPT(I)   = 4
    NWSYM(I)   = 1
    ZSHTWG(I) =   0.000+J   0.000
    XWCN(1,I) =   1.50000
    YWCN(1,I) =   0.50000
    ZWCN(1,I) =   0.00000
    XWCN(2,I) =   1.50000
    YWCN(2,I) =   1.50000
    ZWCN(2,I) =   0.00000

******* DETAILED DESCRIPTION OF GEOMETRY *******

CROSS SECTION GEOMETRY:
CROSS SECTIONS ARE SYMMETRIC.

CROSS SECTION NUMBER 1:
    LOCATED AT Y =   0.00000 meters.
    HAS AN ENDCAP PLATE.
        CROSS SECTION COORDINATES (meters)
        NSIDE   XCS(I,J)   ZCS(I,J)

NSIDE	XCS(I,J)	ZCS(I,J)
-----	--------	---------
1	0.00000	0.25000
2	0.17700	0.17700
3	0.25000	0.00000
4	0.17700	-0.17700
5	0.00000	-0.25000
6	-0.17700	-0.17700
7	-0.25000	0.00000
8	-0.17700	0.17700

CROSS SECTION NUMBER 2:
    LOCATED AT Y =   1.00000 meters.
        CROSS SECTION COORDINATES (meters)
        NSIDE   XCS(I,J)   ZCS(I,J)

NSIDE	XCS(I,J)	ZCS(I,J)
-----	--------	---------
1	0.00000	0.62500

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2	0.44200	0.44200
3	0.62500	0.00000
4	0.37500	-0.50000
5	0.00000	-0.62500
6	-0.37500	-0.50000
7	-0.62500	0.00000
8	-0.44200	0.44200

CROSS SECTION NUMBER 3:
    LOCATED AT Y =   2.00000 meters.
      CROSS SECTION COORDINATES (meters)

NSIDE	XCS(I,J)	ZCS(I,J)
-----	--------	--------
1	0.00000	1.00000
2	0.70700	0.70700
3	1.00000	0.00000
4	0.86600	-0.50000
5	0.00000	-1.00000
6	-0.86600	-0.50000
7	-1.00000	0.00000
8	-0.70700	0.70700

CROSS SECTION NUMBER 4:
    LOCATED AT Y =   3.00000 meters.
    THIS CROSS SECTION WAS PLACED HERE BY INTERPOLATION.
      CROSS SECTION COORDINATES (meters)

NSIDE	XCS(I,J)	ZCS(I,J)
-----	--------	--------
1	0.00000	1.00000
2	0.70700	0.70700
3	1.00000	0.00000
4	0.86600	-0.50000
5	0.00000	-1.00000
6	-0.86600	-0.50000
7	-1.00000	0.00000
8	-0.70700	0.70700

CROSS SECTION NUMBER 5:
    LOCATED AT Y =   5.00000 meters.
    HAS AN ENDCAP PLATE.
      CROSS SECTION COORDINATES (meters)

NSIDE	XCS(I,J)	ZCS(I,J)
-----	--------	--------
1	0.00000	1.00000
2	0.70700	0.70700
3	1.00000	0.00000
4	0.86600	-0.50000
5	0.00000	-1.00000
6	-0.86600	-0.50000
7	-1.00000	0.00000
8	-0.70700	0.70700

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WING GEOMETRY:

WING NUMBER 1:
THIS WING IS AT POINT 4 AND GOES FROM CROSS SECTION 2
TO CROSS SECTION 4.
A SYMMETRIC WING IS ALSO INCLUDED.
THE WING COORDINATES ARE REFERENCED TO POINT 4 ON CROSS SECTION 2.
THE WING SHEET IMPEDANCE IS   0.000+J   0.000 (OHMS / SQ.)
        WING COORDINATES (meters)
        XWCN(1,1) =   1.50000
        YWCN(1,1) =   0.50000
        ZWCN(1,1) =   0.00000
        XWCN(2,1) =   1.50000
        YWCN(2,1) =   1.50000
        ZWCN(2,1) =   0.00000

********* SUMMARY OF ARRAY DIMENSIONS **********

IDWR   =   200
ITW2   = 2250
ICN   =   16
IPL   =   450
IAT   =   10
ITOT   = 2250
IDZT   =   20100
IDZTF = 2250
IDMI   =   1
IDZTI =   1
IDZTFI =   1
IDMZI =   0

********** SUMMARY OF MODEL GEOMETRY ***********

NUMBER OF PLATES =   40
NUMBER OF POINTS ON THE WIRES =   0
NUMBER OF SEGMENTS ON THE WIRES =   0

    NWR = NUMBER OF WIRE MODES =   0
    NPLTM = NUMBER OF PLATE MODES =   148
    NAT = NUMBER OF ATTACHMENT MODES =   0

******** RESULTS OF THE MM COMPUTATION *********

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BACKSCATTERING, ISCAT =   1
FAR-ZONE PATTERN

(DEG)		** CROSS	SECTION	(DB/M**2) **		******	PHASE	(DEG)	******
TH	PHI	STTM	SPPM	STPM	SPTM	STTM	SPPM	STPM	SPTM
90.0	0.0	13.33	14.87	-2.13	-1.37	28.2	-11.9	176.7	175.4
90.0	2.0	13.34	13.95	-1.86	-1.14	44.2	3.9	-166.3	-168.1
90.0	4.0	13.21	12.90	-1.70	-1.05	60.5	20.6	-148.9	-151.0
90.0	6.0	12.96	11.73	-1.65	-1.06	77.4	38.6	-130.9	-133.3
90.0	8.0	12.60	10.50	-1.70	-1.20	94.8	58.6	-112.8	-115.4
90.0	10.0	12.11	9.37	-1.78	-1.38	112.8	81.1	-93.7	-96.2
90.0	12.0	11.53	8.54	-1.98	-1.66	131.5	105.9	-74.7	-76.9
90.0	14.0	10.84	8.22	-2.18	-1.93	151.0	132.0	-55.1	-56.8
90.0	16.0	10.08	8.45	-2.54	-2.34	171.4	157.2	-35.5	-36.6
90.0	18.0	9.28	9.02	-2.88	-2.69	-167.2	179.9	-15.7	-15.9
90.0	20.0	8.49	9.70	-3.33	-3.10	-144.7	-160.2	4.3	5.0
90.0	22.0	7.75	10.32	-3.84	-3.52	-121.2	-142.8	24.4	25.9
90.0	24.0	7.13	10.77	-4.47	-4.02	-96.8	-127.5	44.7	46.9
90.0	26.0	6.68	11.01	-5.25	-4.62	-72.1	-114.1	65.2	67.9
90.0	28.0	6.38	11.01	-6.13	-5.28	-47.5	-102.2	86.7	89.4
90.0	30.0	6.23	10.79	-7.33	-6.21	-23.5	-92.3	108.9	111.2
90.0	32.0	6.16	10.33	-8.66	-7.27	-0.3	-84.3	133.5	134.5
90.0	34.0	6.12	9.69	-10.06	-8.46	22.0	-78.9	161.9	160.3
90.0	36.0	6.06	8.98	-11.13	-9.57	43.4	-76.8	-164.6	-170.0
90.0	38.0	5.97	8.42	-11.16	-10.10	64.2	-78.3	-127.6	-136.1
90.0	40.0	5.83	8.34	-9.96	-9.57	84.4	-82.7	-93.0	-101.4
90.0	42.0	5.65	8.90	-8.17	-8.17	104.4	-87.4	-64.7	-70.7
90.0	44.0	5.42	9.93	-6.36	-6.44	124.1	-90.2	-41.9	-45.6
90.0	46.0	5.19	11.14	-4.73	-4.78	143.7	-90.0	-23.0	-25.0
90.0	48.0	4.96	12.29	-3.34	-3.31	163.2	-87.5	-6.6	-7.6
90.0	50.0	4.78	13.29	-2.17	-2.07	-177.4	-83.4	7.9	7.6
90.0	52.0	4.67	14.09	-1.20	-1.02	-158.4	-78.3	21.1	21.2
90.0	54.0	4.63	14.69	-0.41	-0.17	-139.8	-72.6	33.1	33.5
90.0	56.0	4.68	15.10	0.22	0.50	-121.9	-66.8	44.1	44.7
90.0	58.0	4.81	15.32	0.69	1.02	-104.9	-61.0	54.3	55.0
90.0	60.0	4.99	15.36	1.03	1.40	-89.0	-55.4	63.8	64.5
90.0	62.0	5.21	15.23	1.23	1.63	-74.2	-50.2	72.5	73.3
90.0	64.0	5.45	14.93	1.31	1.73	-60.6	-45.5	80.5	81.3
90.0	66.0	5.69	14.47	1.25	1.69	-48.2	-41.4	88.0	88.8
90.0	68.0	5.92	13.85	1.08	1.53	-36.9	-38.2	94.7	95.4
90.0	70.0	6.12	13.09	0.75	1.22	-26.7	-35.8	100.8	101.6
90.0	72.0	6.31	12.18	0.28	0.76	-17.5	-34.5	106.3	107.2
90.0	74.0	6.47	11.16	-0.35	0.14	-9.4	-34.6	111.3	112.1
90.0	76.0	6.61	10.06	-1.17	-0.68	-2.3	-36.3	115.6	116.4
90.0	78.0	6.72	8.94	-2.23	-1.73	3.9	-39.5	119.4	120.3
90.0	80.0	6.81	7.95	-3.56	-3.06	9.1	-44.7	122.4	123.2
90.0	82.0	6.88	7.10	-5.32	-4.81	13.3	-50.5	125.1	125.9
90.0	84.0	6.94	6.52	-7.67	-7.16	16.6	-56.6	127.1	128.0
90.0	86.0	6.98	6.19	-11.08	-10.57	19.0	-61.9	128.6	129.4
90.0	88.0	7.00	6.04	-17.04	-16.53	20.4	-65.3	₺29.4	130.3
90.0	90.0	7.01	6.00	-99.90	-99.90	20.8	-66.5	21.9	-134.1
90.0	92.0	7.00	6.04	-17.04	-16.53	20.4	-65.3	-50.6	-49.7
90.0	94.0	6.98	6.19	-11.08	-10.57	19.0	-61.9	-51.4	-50.6

90.0	96.0	6.94	6.52	-7.67	-7.16	16.6	-56.6	-52.9	-52.0
90.0	98.0	6.88	7.10	-5.32	-4.81	13.3	-50.5	-54.9	-54.1
90.0	100.0	6.81	7.95	-3.56	-3.06	9.1	-44.7	-57.6	-56.8
90.0	102.0	6.72	8.94	-2.23	-1.73	3.9	-39.5	-60.6	-59.7
90.0	104.0	6.61	10.06	-1.17	-0.68	-2.3	-36.3	-64.4	-63.6
90.0	106.0	6.47	11.16	-0.35	0.14	-9.4	-34.6	-68.7	-67.9
90.0	108.0	6.31	12.18	0.28	0.76	-17.5	-34.5	-73.7	-72.8
90.0	110.0	6.12	13.09	0.75	1.22	-26.7	-35.8	-79.2	-78.4
90.0	112.0	5.92	13.85	1.08	1.53	-36.9	-38.2	-85.3	-84.6
90.0	114.0	5.69	14.47	1.25	1.69	-48.2	-41.4	-92.0	-91.2
90.0	116.0	5.45	14.93	1.31	1.73	-60.6	-45.5	-99.5	-98.7
90.0	118.0	5.21	15.23	1.23	1.63	-74.2	-50.2	-107.5	-106.7
90.0	120.0	4.99	15.36	1.03	1.40	-89.0	-55.4	-116.2	-115.5
90.0	122.0	4.81	15.32	0.69	1.02	-104.9	-61.0	-125.7	-125.0
90.0	124.0	4.68	15.10	0.22	0.50	-121.9	-66.8	-135.9	-135.3
90.0	126.0	4.63	14.69	-0.41	-0.17	-139.8	-72.6	-146.9	-146.5
90.0	128.0	4.67	14.09	-1.20	-1.02	-158.4	-78.3	-158.9	-158.8
90.0	130.0	4.78	13.29	-2.17	-2.07	-177.4	-83.4	-172.1	-172.4
90.0	132.0	4.96	12.29	-3.34	-3.31	163.2	-87.5	173.4	172.4
90.0	134.0	5.19	11.14	-4.73	-4.78	143.7	-90.0	157.0	155.0
90.0	136.0	5.42	9.93	-6.36	-6.44	124.1	-90.2	138.1	134.4
90.0	138.0	5.65	8.90	-8.17	-8.17	104.4	-87.4	115.3	109.3
90.0	140.0	5.83	8.34	-9.96	-9.57	84.4	-82.7	87.0	78.6
90.0	142.0	5.97	8.42	-11.16	-10.10	64.2	-78.3	52.4	43.9
90.0	144.0	6.06	8.98	-11.13	-9.57	43.4	-76.8 ·	15.4	10.0
90.0	146.0	6.12	9.69	-10.06	-8.46	22.0	-78.9	-18.1	-19.7
90.0	148.0	6.16	10.33	-8.66	-7.27	-0.3	-84.3	-46.5	-45.5
90.0	150.0	6.23	10.79	-7.33	-6.21	-23.5	-92.3	-71.1	-68.8
90.0	152.0	6.38	11.01	-6.13	-5.28	-47.5	-102.2	-93.3	-90.6
90.0	154.0	6.68	11.01	-5.25	-4.62	-72.1	-114.1	-114.8	-112.1
90.0	156.0	7.13	10.77	-4.47	-4.02	-96.8	-127.5	-135.3	-133.1
90.0	158.0	7.75	10.32	-3.84	-3.52	-121.2	-142.8	-155.6	-154.1
90.0	160.0	8.49	9.70	-3.33	-3.10	-144.7	-160.2	-175.7	-175.0
90.0	162.0	9.28	9.02	-2.88	-2.69	-167.2	179.9	164.3	164.1
90.0	164.0	10.08	8.45	-2.54	-2.34	171.4	157.2	144.5	143.4
90.0	166.0	10.84	8.22	-2.18	-1.93	151.0	132.0	124.9	123.2
90.0	168.0	11.53	8.54	-1.98	-1.66	131.5	105.9	105.3	103.1
90.0	170.0	12.11	9.37	-1.78	-1.38	112.8	81.1	86.3	83.8
90.0	172.0	12.60	10.50	-1.70	-1.20	94.8	58.6	67.2	64.6
90.0	174.0	12.96	11.73	-1.65	-1.06	77.4	38.6	49.1	46.7
90.0	176.0	13.21	12.90	-1.70	-1.05	60.5	20.6	31.1	29.0
90.0	178.0	13.34	13.95	-1.86	-1.14	44.2	3.9	13.7	11.9
90.0	180.0	13.33	14.87	-2.13	-1.37	28.2	-11.9	-3.3	-4.6
90.0	182.0	13.21	15.62	-2.54	-1.74	12.8	-27.1	-19.8	-20.6
90.0	184.0	12.95	16.21	-3.10	-2.28	-2.1	-42.0	-35.8	-36.1
90.0	186.0	12.57	16.64	-3.85	-3.01	-16.4	-56.6	-51.2	-51.1
90.0	188.0	12.06	16.87	-4.76	-3.90	-30.1	-71.1	-66.6	-66.1
90.0	190.0	11.43	16.95	-6.08	-5.19	-43.0	-85.3	-80.7	-79.8
90.0	192.0	10.69	16.81	-7.64	-6.69	-54.9	-99.5	-95.2	-94.0
90.0	194.0	9.87	16.49	-9.94	-8.89	-65.9	-113.3	-108.3	-107.0
90.0	196.0	9.00	15.91	-12.68	-11.44	-75.5	-127.2	-122.9	-121.6
90.0	198.0	8.13	15.09	-17.70	-15.92	-83.8	-140.3	-137.1	-136.1
90.0	200.0	7.35	13.97	-29.29	-24.50	-90.9	-152.9	-163.4	-160.3
90.0	202.0	6.73	12.49	-22.92	-25.14	-97.1	-164.4	33.7	48.7

90.0	204.0	6.32	10.56	-15.31	-16.01	-103.0	-174.0	17.4	24.1
90.0	206.0	6.10	8.06	-11.32	-11.63	-109.4	-180.0	5.6	10.8
90.0	208.0	6.02	5.00	-8.67	-8.81	-116.9	-178.0	-5.5	-0.9
90.0	210.0	6.01	2.48	-6.62	-6.67	-125.7	-160.9	-15.4	-11.3
90.0	212.0	5.98	3.14	-5.03	-5.01	-135.9	-137.5	-25.1	-21.3
90.0	214.0	5.90	5.68	-3.71	-3.66	-147.5	-128.4	-34.4	-30.9
90.0	216.0	5.74	7.94	-2.61	-2.53	-160.4	-130.5	-43.3	-40.2
90.0	218.0	5.49	9.59	-1.67	-1.58	-174.4	-137.4	-52.0	-49.1
90.0	220.0	5.17	10.74	-0.86	-0.77	170.3	-146.6	-60.4	-57.8
90.0	222.0	4.81	11.48	-0.17	-0.07	153.9	-156.8	-68.5	-66.1
90.0	224.0	4.46	11.89	0.41	0.52	136.5	-167.5	-76.4	-74.2
90.0	226.0	4.16	12.02	0.91	1.02	118.0	-178.5	-84.0	-82.0
90.0	228.0	3.99	11.88	1.32	1.43	99.0	170.3	-91.4	-89.5
90.0	230.0	3.98	11.51	1.64	1.77	79.8	159.1	-98.5	-96.7
90.0	232.0	4.14	10.89	1.89	2.03	61.0	147.6	-105.3	-103.6
90.0	234.0	4.46	10.04	2.07	2.21	43.1	135.8	-111.8	-110.1
90.0	236.0	4.87	8.92	2.17	2.33	26.5	123.4	-118.1	-116.4
90.0	238.0	5.34	7.55	2.19	2.38	11.2	109.7	-124.0	-122.3
90.0	240.0	5.81	5.95	2.14	2.35	-2.7	93.8	-129.6	-127.9
90.0	242.0	6.26	4.25	2.01	2.24	-15.3	74.1	-134.9	-133.2
90.0	244.0	6.68	2.90	1.79	2.06	-26.7	49.4	-139.8	-138.2
90.0	246.0	7.05	2.59	1.49	1.78	-37.1	21.4	-144.4	-142.7
90.0	248.0	7.37	3.41	1.10	1.43	-46.4	-4.1	-148.7	-147.1
90.0	250.0	7.64	4.86	0.59	0.95	-54.8	-23.3	-152.6	-150.9
90.0	252.0	7.87	6.34	-0.03	0.36	-62.3	-37.1	-156.1	-154.5
90.0	254.0	8.06	7.64	-0.79	-0.37	-69.0	-47.2	-159.3	-157.7
90.0	256.0	8.22	8.73	-1.72	-1.28	-74.9	-54.8	-162.1	-160.5
90.0	258.0	8.34	9.64	-2.86	-2.39	-79.9	-60.6	-164.5	-162.9
90.0	260.0	8.44	10.31	-4.28	-3.79	-84.2	-65.0	-166.8	-165.2
90.0	262.0	8.51	10.90	-6.08	-5.57	-87.7	-68.4	-168.3	-166.8
90.0	264.0	8.56	11.31	-8.48	-7.95	-90.4	-70.8	-169.7	-168.1
90.0	266.0	8.60	11.60	-11.92	-11.39	-92.3	-72.5	-170.6	-169.1
90.0	268.0	8.62	11.78	-17.90	-17.36	-93.4	-73.5	-171.2	-169.7
90.0	270.0	8.63	11.83	-99.90	-99.90	-93.8	-73.8	116.8	-118.0
90.0	272.0	8.62	11.78	-17.90	-17.36	-93.4	-73.5	8.8	10.3
90.0	274.0	8.60	11.60	-11.92	-11.39	-92.3	-72.5	9.4	10.9
90.0	276.0	8.56	11.31	-8.48	-7.95	-90.4	-70.8	10.3	11.9
90.0	278.0	8.51	10.90	-6.08	-5.57	-87.7	-68.4	11.7	13.2
90.0	280.0	8.44	10.31	-4.28	-3.79	-84.2	-65.0	13.2	14.8
90.0	282.0	8.34	9.64	-2.86	-2.39	-79.9	-60.6	15.5	17.1
90.0	284.0	8.22	8.73	-1.72	-1.28	-74.9	-54.8	17.9	19.5
90.0	286.0	8.06	7.64	-0.79	-0.37	-69.0	-47.2	20.7	22.3
90.0	288.0	7.87	6.34	-0.03	0.36	-62.3	-37.1	23.9	25.5
90.0	290.0	7.64	4.86	0.59	0.95	-54.8	-23.3	27.4	29.1
90.0	292.0	7.37	3.41	1.10	1.43	-46.4	-4.1	31.3	32.9
90.0	294.0	7.05	2.59	1.49	1.78	-37.1	21.4	35.6	37.3
90.0	296.0	6.68	2.90	1.79	2.06	-26.7	49.4	40.2	41.8
90.0	298.0	6.26	4.25	2.01	2.24	-15.3	74.1	45.1	46.8
90.0	300.0	5.81	5.95	2.14	2.35	-2.7	93.8	50.4	52.1
90.0	302.0	5.34	7.55	2.19	2.38	11.2	109.7	56.0	57.7
90.0	304.0	4.87	8.92	2.17	2.33	26.5	123.4	61.9	63.6
90.0	306.0	4.46	10.04	2.07	2.21	43.1	135.8	68.2	69.9
90.0	308.0	4.14	10.89	1.89	2.03	61.0	147.6	74.7	76.4
90.0	310.0	3.98	11.51	1.64	1.77	79.8	159.1	81.5	83.3

90.0	312.0	3.99	11.88	1.32	1.43	99.0	170.3	88.6	90.5
90.0	314.0	4.16	12.02	0.91	1.02	118.0	-178.5	96.0	98.0
90.0	316.0	4.46	11.89	0.41	0.52	136.5	-167.5	103.6	105.8
90.0	318.0	4.81	11.48	-0.17	-0.07	153.9	-156.8	111.5	113.9
90.0	320.0	5.17	10.74	-0.86	-0.77	170.3	-146.6	119.6	122.2
90.0	322.0	5.49	9.59	-1.67	-1.58	-174.4	-137.4	128.0	130.9
90.0	324.0	5.74	7.94	-2.61	-2.53	-160.4	-130.5	136.7	139.8
90.0	326.0	5.90	5.68	-3.71	-3.66	-147.5	-128.4	145.6	149.1
90.0	328.0	5.98	3.14	-5.03	-5.01	-135.9	-137.5	154.9	158.7
90.0	330.0	6.01	2.48	-6.62	-6.67	-125.7	-160.9	164.6	168.7
90.0	332.0	6.02	5.00	-8.67	-8.81	-116.9	-178.0	174.5	179.1
90.0	334.0	6.10	8.06	-11.32	-11.63	-109.4	-180.0	-174.4	-169.2
90.0	336.0	6.32	10.56	-15.31	-16.01	-103.0	-174.0	-162.6	-155.9
90.0	338.0	6.73	12.49	-22.92	-25.14	-97.1	-164.4	-146.3	-131.3
90.0	340.0	7.35	13.97	-29.29	-24.50	-90.9	-152.9	16.6	19.7
90.0	342.0	8.13	15.09	-17.70	-15.92	-83.8	-140.3	42.9	43.9
90.0	344.0	9.00	15.91	-12.68	-11.44	-75.5	-127.2	57.1	58.4
90.0	346.0	9.87	16.49	-9.94	-8.89	-65.9	-113.3	71.7	73.0
90.0	348.0	10.69	16.81	-7.64	-6.69	-54.9	-99.5	84.8	86.0
90.0	350.0	11.43	16.95	-6.08	-5.19	-43.0	-85.3	99.3	100.2
90.0	352.0	12.06	16.87	-4.76	-3.90	-30.1	-71.1	113.4	113.9
90.0	354.0	12.57	16.64	-3.85	-3.01	-16.4	-56.6	128.8	128.9
90.0	356.0	12.95	16.21,	-3.10	-2.28	-2.1	-42.0	144.2	143.9
90.0	358.0	13.21	15.62	-2.54	-1.74	12.8	-27.1	160.2	159.4
90.0	360.0	13.33	14.87	-2.13	-1.37	28.2	-11.9	176.7	175.4

CPU RUN TIME FOR RUN   1 GEOMETRY   1 =   309.00 SECONDS

TOTAL CPU RUN TIME =   309.00 SECONDS

Appendix E

Input File For Example 5

```
EX : EXECUTE
RE : DEFINE RADIATION ELEVATION PATTERN
1 1.0 0.0
FR : DEFINE FREQUENCY
200.0
ZM : SAVE [Z] MATRIX
1 0
NC : END OF RUN CONTROL COMMANDS
SG : DEFINE MAXIMUM SEGMENT SIZE
0.25
NS : DEFINE NUMBER OF SIDES
8
SM : SYMMETRIC FUSELAGE
DG : PRINT OUT DETAILED GEOMETRY
UN : DEFINE UNITS
2
CS : DEFINE CROSS SECTION
0.0 0.0 0 0 0
0.0 -1.5
0.7 -1.8
1.0 -2.5
0.7 -3.2
0.0 -3.5
CS : DEFINE CROSS SECTION
10.92 0.0 0 0 0
0.0    2.7
4.3    2.7
5.5   -1.2
5.5 -11.8
0.0 -11.8
CS : DEFINE CROSS SECTION
21.34 0.0 0 0 0
```

```
0.0  10.5
3.7  10.5
7.3  -1.2
7.3 -11.2
0.0 -11.9
CS : DEFINE CROSS SECTION
36.58 0.0 0 0 0
0.0  16.0
4.4  16.0
8.2   1.7
8.2 -12.0
0.0 -12.0
CS : DEFINE CROSS SECTION
50.85 0.0 0 0 0
0.0  17.4
5.8  17.4
9.5   5.4
9.5 -11.0
0.0 -12.0
CS : DEFINE CROSS SECTION
64.92 69.82 2 0 0
0.0  17.6
9.7  17.0
9.7   0.0
9.7 -11.0
0.0 -12.0
CS : DEFINE CROSS SECTION
80.01 86.46 2 0 0
 0.0  16.9
11.5  16.6
 9.4   0.0
 9.4  -9.6
 0.0 -12.0
CS : DEFINE CROSS SECTION
94.97 0.0 0 0 1
0.0  13.6
9.6  13.1
8.8   0.0
8.2 -10.2
0.0 -12.0
CS : DEFINE CROSS SECTION
94.97 0.0 0 0 0
0.0   6.5
6.8   5.1
8.8   0.0
```

```
8.2 -10.2
0.0 -12.0
CS : DEFINE CROSS SECTION
134.62 0.0 0 0 0
0.0   3.8
4.0   3.0
4.6   0.0
4.2 -5.8
0.0 -7.4
CS : DEFINE CROSS SECTION
146.02 0.0 0 1 0
0.0   3.4
2.5   2.7
2.9   0.0
2.6 -4.9
0.0 -6.2
TS : DEFINE TAIL SECTION
(0.0,0.0)
18.3   19.0
28.9   19.0
21.0
20.3
22.1 -16.5
10.4 -16.5
WG : DEFINE WINGS
7 9 3 1 (0.0,0.0)
25.78 3.50 0.00 25.78 13.15 0.00
TW : DEFINE TAIL WINGS
5.38 -3.40 13.21 1 (0.0,0.0)
-22.86 3.30 -22.86 9.90
SC : DEFINE SOURCE MONOPOLE
10.0 0.0 87.63 -15.0 0.0 180.0
NG : END OF GEOMETRY
```

Appendix F

Output File for Example 5

THE OHIO STATE UNIVERSITY AIRCRAFT MODELLING CODE

****

************ RUN CONTROL COMMANDS *************

EX: EXECUTE
NGO   = 1

RE: RADIATION PATTERN (ELEVATION)
IPFE = 1
FNDFE =   1.000
PHFE =   0.000

FR: FREQUENCY
FMC   = 200.000

ZM: IMPEDANCE MATRIX
IWRZM = 1
IRDZM = 0

************ GEOMETRY INPUT DATA *************

SG: SEGMENTATION
SGM = 0.25000

NS: NUMBER OF SIDES
NSIDE = 8

UN: UNITS
IUNITS = 2 (CENTIMETERS)

```
CS: CROSS SECTION
CROSS SECTION NUMBER  1:
    YCSI(J) =      0.00000
    YPL(J)  =      0.00000
    IPCI(J) =  0
    IECI(J) =  0
    ICSI(J) =  0
        NSIDE     XCSI(I,J)     ZCSI(I,J)

        -----     ---------     ---------
          1         0.00000      -1.50000
          2         0.70000      -1.80000
          3         1.00000      -2.50000
          4         0.70000      -3.20000
          5         0.00000      -3.50000
          6        -0.70000      -3.20000
          7        -1.00000      -2.50000
          8        -0.70000      -1.80000


CS: CROSS SECTION
CROSS SECTION NUMBER  2:
    YCSI(J) =     10.92000
    YPL(J)  =      0.00000
    IPCI(J) =  0
    IECI(J) =  0
    ICSI(J) =  0
        NSIDE     XCSI(I,J)     ZCSI(I,J)

        -----     ---------     ---------
          1         0.00000       2.70000
          2         4.30000       2.70000
          3         5.50000      -1.20000
          4         5.50000     -11.80000
          5         0.00000     -11.80000
          6        -5.50000     -11.80000
          7        -5.50000      -1.20000
          8        -4.30000       2.70000


CS: CROSS SECTION
CROSS SECTION NUMBER  3:
    YCSI(J) =     21.34000
    YPL(J)  =      0.00000
    IPCI(J) =  0
    IECI(J) =  0
    ICSI(J) =  0
        NSIDE     XCSI(I,J)     ZCSI(I,J)

        -----     ---------     ---------
          1         0.00000      10.50000
          2         3.70000      10.50000
          3         7.30000      -1.20000
          4         7.30000     -11.20000
          5         0.00000     -11.90000
          6        -7.30000     -11.20000
          7        -7.30000      -1.20000
          8        -3.70000      10.50000
```

```
CS: CROSS SECTION
CROSS SECTION NUMBER  4:
    YCSI(J) =      36.58000
    YPL(J)  =       0.00000
    IPCI(J) =  0
    IECI(J) =  0
    ICSI(J) =  0
        NSIDE     XCSI(I,J)     ZCSI(I,J)

        -----     ---------     ---------
          1        0.00000      16.00000
          2        4.40000      16.00000
          3        8.20000       1.70000
          4        8.20000     -12.00000
          5        0.00000     -12.00000
          6       -8.20000     -12.00000
          7       -8.20000       1.70000
          8       -4.40000      16.00000

CS: CROSS SECTION
CROSS SECTION NUMBER  5:
    YCSI(J) =      50.85000
    YPL(J)  =       0.00000
    IPCI(J) =  0
    IECI(J) =  0
    ICSI(J) =  0
        NSIDE     XCSI(I,J)     ZCSI(I,J)

        -----     ---------     ---------
          1        0.00000      17.40000
          2        5.80000      17.40000
          3        9.50000       5.40000
          4        9.50000     -11.00000
          5        0.00000     -12.00000
          6       -9.50000     -11.00000
          7       -9.50000       5.40000
          8       -5.80000      17.40000

CS: CROSS SECTION
CROSS SECTION NUMBER  6:
    YCSI(J) =      64.92000
    YPL(J)  =      69.82000
    IPCI(J) =  2
    IECI(J) =  0
    ICSI(J) =  0
        NSIDE     XCSI(I,J)     ZCSI(I,J)

        -----     ---------     ---------
          1        0.00000      17.60000
          2        9.70000      17.00000
          3        9.70000       0.00000
          4        9.70000     -11.00000
          5        0.00000     -12.00000
          6       -9.70000     -11.00000
          7       -9.70000       0.00000
          8       -9.70000      17.00000
```

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```
CS: CROSS SECTION
CROSS SECTION NUMBER  7:
    YCSI(J) =     80.01000
    YPL(J)  =     86.46000
    IPCI(J) = 2
    IECI(J) = 0
    ICSI(J) = 0
        NSIDE      XCSI(I,J)      ZCSI(I,J)

        -----      ---------      ---------
          1          0.00000       16.90000
          2         11.50000       16.60000
          3          9.40000        0.00000
          4          9.40000       -9.60000
          5          0.00000      -12.00000
          6         -9.40000       -9.60000
          7         -9.40000        0.00000
          8        -11.50000       16.60000


CS: CROSS SECTION
CROSS SECTION NUMBER  8:
    YCSI(J) =     94.97000
    YPL(J)  =      0.00000
    IPCI(J) = 0
    IECI(J) = 0
    ICSI(J) = 1
        NSIDE      XCSI(I,J)      ZCSI(I,J)

        -----      ---------      ---------
          1          0.00000       13.60000
          2          9.60000       13.10000
          3          8.80000        0.00000
          4          8.20000      -10.20000
          5          0.00000      -12.00000
          6         -8.20000      -10.20000
          7         -8.80000        0.00000
          8         -9.60000       13.10000

CS: CROSS SECTION
CROSS SECTION NUMBER  9:
    YCSI(J) =     94.97000
    YPL(J)  =      0.00000
    IPCI(J) = 0
    IECI(J) = 0
    ICSI(J) = 0
        NSIDE      XCSI(I,J)      ZCSI(I,J)

        -----      ---------      ---------
          1          0.00000        6.50000
          2          6.80000        5.10000
          3          8.80000        0.00000
          4          8.20000      -10.20000
          5          0.00000      -12.00000
          6         -8.20000      -10.20000
          7         -8.80000        0.00000
          8         -6.80000        5.10000
```

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```
CS: CROSS SECTION
CROSS SECTION NUMBER 10:
    YCSI(J) =    134.62000
    YPL(J)  =      0.00000
    IPCI(J) =  0
    IECI(J) =  0
    ICSI(J) =  0
        NSIDE     XCSI(I,J)      ZCSI(I,J)

        -----     ---------      ---------
          1         0.00000        3.80000
          2         4.00000        3.00000
          3         4.60000        0.00000
          4         4.20000       -5.80000
          5         0.00000       -7.40000
          6        -4.20000       -5.80000
          7        -4.60000        0.00000
          8        -4.00000        3.00000


CS: CROSS SECTION
CROSS SECTION NUMBER 11:
    YCSI(J) =    146.02000
    YPL(J)  =      0.00000
    IPCI(J) =  0
    IECI(J) =  1
    ICSI(J) =  0
        NSIDE     XCSI(I,J)      ZCSI(I,J)

        -----     ---------      ---------
          1         0.00000        3.40000
          2         2.50000        2.70000
          3         2.90000        0.00000
          4         2.60000       -4.90000
          5         0.00000       -6.20000
          6        -2.60000       -4.90000
          7        -2.90000        0.00000
          8        -2.50000        2.70000


TS: TAIL SECTION
TAIL SECTION GEOMETRY:
ZSHTTS =        0.000+J        0.000
POINTS ON TAIL SECTION:
      J       YTSCN(J)       ZTSCN(J)

      -       --------       --------
      1       18.30000       19.00000
      2       28.90000       19.00000
      3       21.00000
      4       20.30000
      5       22.10000      -16.50000
      6       10.40000      -16.50000


WG: WING
WING NUMBER  1:
    NWSEC(1,I) =  7
    NWSEC(2,I) =  9
    NWPT(I)    =  3
```

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```
        NWSYM(I)   =   1
        ZSHTWG(I) =          0.000+J        0.000
        XWCN(1,I) =         25.78000
        YWCN(1,I) =          3.50000
        ZWCN(1,I) =          0.00000
        XWCN(2,I) =         25.78000
        YWCN(2,I) =         13.15000
        ZWCN(2,I) =          0.00000


TW: TAIL WING
TAIL WING GEOMETRY:
        YTWS       =          5.38000
        ZTWS       =         -3.40000
        YTWL       =         13.21000
        ITWSYM     =   1
        ZSHTTW =          0.000+J        0.000
        XTWCN(1) =        -22.86000
        YTWCN(1) =          3.30000
        XTWCN(2) =        -22.86000
        YTWCN(2) =          9.90000


SC: SOURCE
SOURCE GEOMETRY:
        Source_Length =        10.00000
        Xsource       =         0.00000
        Ysource       =        87.63000
        Zsource       =       -15.00000
        Source_Ang_Th =       180.00000 degrees
        Source_Ang_Ph =         0.00000 degrees


******* DETAILED DESCRIPTION OF GEOMETRY *******


CROSS SECTION GEOMETRY:
CROSS SECTIONS ARE SYMMETRIC.


CROSS SECTION NUMBER  1:
        LOCATED AT Y =        0.00000 meters.
        CROSS SECTION COORDINATES (meters)
          NSIDE      XCS(I,J)      ZCS(I,J)

          -----      --------      ---------
            1         0.00000      -0.01500
            2         0.00700      -0.01800
            3         0.01000      -0.02500
            4         0.00700      -0.03200
            5         0.00000      -0.03500
            6        -0.00700      -0.03200
            7        -0.01000      -0.02500
            8        -0.00700      -0.01800


CROSS SECTION NUMBER  2:
```

```
        LOCATED AT Y =      0.10920 meters.
          CROSS SECTION COORDINATES (meters)
          NSIDE      XCS(I,J)      ZCS(I,J)

          -----      --------      --------
            1        0.00000       0.02700
            2        0.04300       0.02700
            3        0.05500      -0.01200
            4        0.05500      -0.11800
            5        0.00000      -0.11800
            6       -0.05500      -0.11800
            7       -0.05500      -0.01200
            8       -0.04300       0.02700


CROSS SECTION NUMBER  3:
        LOCATED AT Y =      0.21340 meters.
          CROSS SECTION COORDINATES (meters)
          NSIDE      XCS(I,J)      ZCS(I,J)

          -----      --------      --------
            1        0.00000       0.10500
            2        0.03700       0.10500
            3        0.07300      -0.01200
            4        0.07300      -0.11200
            5        0.00000      -0.11900
            6       -0.07300      -0.11200
            7       -0.07300      -0.01200
            8       -0.03700       0.10500


CROSS SECTION NUMBER  4:
        LOCATED AT Y =      0.36580 meters.
          CROSS SECTION COORDINATES (meters)
          NSIDE      XCS(I,J)      ZCS(I,J)

          -----      --------      --------
            1        0.00000       0.16000
            2        0.04400       0.16000
            3        0.08200       0.01700
            4        0.08200      -0.12000
            5        0.00000      -0.12000
            6       -0.08200      -0.12000
            7       -0.08200       0.01700
            8       -0.04400       0.16000


CROSS SECTION NUMBER  5:
        LOCATED AT Y =      0.50850 meters.
          CROSS SECTION COORDINATES (meters)
          NSIDE      XCS(I,J)      ZCS(I,J)

          -----      --------      --------
            1        0.00000       0.17400
            2        0.05800       0.17400
            3        0.09500       0.05400
            4        0.09500      -0.11000
            5        0.00000      -0.12000
```

```
                    6        -0.09500       -0.11000
                    7        -0.09500        0.05400
                    8        -0.05800        0.17400


CROSS SECTION NUMBER  6:
     LOCATED AT Y =        0.64920 meters.
        CROSS SECTION COORDINATES (meters)
           NSIDE      XCS(I,J)      ZCS(I,J)

           -----     ---------    ---------
            1         0.00000       0.17600
            2         0.09700       0.17000
            3         0.09700       0.00000
            4         0.09700      -0.11000
            5         0.00000      -0.12000
            6        -0.09700      -0.11000
            7        -0.09700       0.00000
            8        -0.09700       0.17000


CROSS SECTION NUMBER  7:
     LOCATED AT Y =        0.69820 meters.
     THIS CROSS SECTION WAS PLACED HERE BY INTERPOLATION.
        CROSS SECTION COORDINATES (meters)
           NSIDE      XCS(I,J)      ZCS(I,J)

           -----     ---------    ---------
            1         0.00000       0.17373
            2         0.10284       0.16870
            3         0.09603       0.00000
            4         0.09603      -0.10545
            5         0.00000      -0.12000
            6        -0.09603      -0.10545
            7        -0.09603       0.00000
            8        -0.10284       0.16870


CROSS SECTION NUMBER  8:
     LOCATED AT Y =        0.80010 meters.
        CROSS SECTION COORDINATES (meters)
           NSIDE      XCS(I,J)      ZCS(I,J)

           -----     ---------    ---------
            1         0.00000       0.16900
            2         0.11500       0.16600
            3         0.09400       0.00000
            4         0.09400      -0.09600
            5         0.00000      -0.12000
            6        -0.09400      -0.09600
            7        -0.09400       0.00000
            8        -0.11500       0.16600


CROSS SECTION NUMBER  9:
     LOCATED AT Y =        0.86460 meters.
     THIS CROSS SECTION WAS PLACED HERE BY INTERPOLATION.
```

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```
CROSS SECTION COORDINATES (meters)
   NSIDE      XCS(I,J)      ZCS(I,J)

   -----      --------      --------
     1         0.00000       0.15477
     2         0.10681       0.15091
     3         0.09141       0.00000
     4         0.08883      -0.09859
     5         0.00000      -0.12000
     6        -0.08883      -0.09859
     7        -0.09141       0.00000
     8        -0.10681       0.15091


CROSS SECTION NUMBER 10:
   LOCATED AT Y =      0.94970 meters.
   THIS CROSS SECTION IS AT THE SAME LOCATION AS THE NEXT ONE.
   CROSS SECTION COORDINATES (meters)
   NSIDE      XCS(I,J)      ZCS(I,J)

   -----      --------      --------
     1         0.00000       0.13600
     2         0.09600       0.13100
     3         0.08800       0.00000
     4         0.08200      -0.10200
     5         0.00000      -0.12000
     6        -0.08200      -0.10200
     7        -0.08800       0.00000
     8        -0.09600       0.13100


CROSS SECTION NUMBER 11:
   LOCATED AT Y =      0.94970 meters.
   CROSS SECTION COORDINATES (meters)
   NSIDE      XCS(I,J)      ZCS(I,J)

   -----      --------      --------
     1         0.00000       0.06500
     2         0.06800       0.05100
     3         0.08800       0.00000
     4         0.08200      -0.10200
     5         0.00000      -0.12000
     6        -0.08200      -0.10200
     7        -0.08800       0.00000
     8        -0.06800       0.05100


CROSS SECTION NUMBER 12:
   LOCATED AT Y =      1.34620 meters.
   CROSS SECTION COORDINATES (meters)
   NSIDE      XCS(I,J)      ZCS(I,J)

   -----      --------      --------
     1         0.00000       0.03800
     2         0.04000       0.03000
     3         0.04600       0.00000
     4         0.04200      -0.05800
     5         0.00000      -0.07400
```

```
              6        -0.04200       -0.05800
              7        -0.04600        0.00000
              8        -0.04000        0.03000


CROSS SECTION NUMBER 13:
    LOCATED AT Y =      1.46020 meters.
    HAS AN ENDCAP PLATE.
        CROSS SECTION COORDINATES (meters)
          NSIDE      XCS(I,J)      ZCS(I,J)

          -----      --------      --------
            1         0.00000       0.03400
            2         0.02500       0.02700
            3         0.02900       0.00000
            4         0.02600      -0.04900
            5         0.00000      -0.06200
            6        -0.02600      -0.04900
            7        -0.02900       0.00000
            8        -0.02500       0.02700


TAIL SECTION GEOMETRY:
THE TAIL SECTION COORDINATES ARE REFERENCED TO POINT 1
ON CROSS SECTION NUMBER 13
THE TAIL SECTION SHEET IMPEDANCE IS      0.000+J      0.000 (OHMS / SQ.)
        TAIL SECTION COORDINATES (meters.)
          J       YTSCN(J)      ZTSCN(J)

          -       --------      --------
          1        0.18300       0.19000
          2        0.28900       0.19000
          3        0.21000       0.00000
          4        0.20300      -0.09600
          5        0.22100      -0.16500
          6        0.10400      -0.16500


WING GEOMETRY:

WING NUMBER  1:
THIS WING IS AT POINT  3 AND GOES FROM CROSS SECTION  7
TO CROSS SECTION  9.
A SYMMETRIC WING IS ALSO INCLUDED.
THE WING COORDINATES ARE REFERENCED TO POINT  3 ON CROSS SECTION  7.
THE WING SHEET IMPEDANCE IS      0.000+J      0.000 (OHMS / SQ.)
        WING COORDINATES (meters)
          XWCN(1,1) =      0.25780
          YWCN(1,1) =      0.03500
          ZWCN(1,1) =      0.00000
          XWCN(2,1) =      0.25780
          YWCN(2,1) =      0.13150
          ZWCN(2,1) =      0.00000


TAIL WING GEOMETRY:
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THE TAIL WING IS   0.13210 meters LONG ALONG THE TAIL SECTION.
THE TAIL WING IS REFERENCED TO THE POINT Y =   0.05380 meters
AND Z =   -0.03400 meters.
A SYMMETRIC TAIL WING IS ALSO INCLUDED.
THE TAIL WING SHEET IMPEDANCE IS   0.000+J   0.000 (OHMS / SQ.)
        TAIL WING COORDINATES (meters).
            XTWCN(1) =   -0.22860
            YTWCN(1) =   0.03300
            XTWCN(2) =   -0.22860
            YTWCN(2) =   0.09900

SOURCE MONOPOLE GEOMETRY:
LENGTH OF THE SOURCE MONOPOLE =   0.10000 meters.
X DISPLACEMENT OF THE SOURCE MONOPOLE =   0.00000 meters.
Y DISPLACEMENT OF THE SOURCE MONOPOLE =   0.87630 meters.
Z DISPLACEMENT OF THE SOURCE MONOPOLE =   -0.15000 meters.
SOURCE MONOPOLE DIRECTION IS THETA =   180.00000 degrees.
SOURCE MONOPOLE DIRECTION IS PHI =   0.00000 degrees.

********* SUMMARY OF ARRAY DIMENSIONS **********

IDWR   = 200
ITW2   = 2250
ICN   =   16
IPL   = 450
IAT   =   10
ITOT   = 2250
IDZT   =   20100
IDZTF = 2250
IDMI   =   1
IDZTI =   1
IDZTFI =   1
IDMZI = 0

********** SUMMARY OF MODEL GEOMETRY ***********

NUMBER OF PLATES = 106
NUMBER OF POINTS ON THE WIRES =   3
NUMBER OF SEGMENTS ON THE WIRES =   2

   NWR = NUMBER OF WIRE MODES =   1
   NPLTM = NUMBER OF PLATE MODES = 234
   NAT = NUMBER OF ATTACHMENT MODES =   0

******** RESULTS OF THE MM COMPUTATION *********

```
INPUT ADMITTANCE(MHOS) =   0.000001 J   0.000700
INPUT IMPEDANCE(OHMS) =       2.325 J  -1428.609
EFFICIENCY (PERCENT) = 100.000
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ANTENNA PROBLEM, ISCAT =   0

FAR-ZONE GAIN ELEVATION PLANE PATTERN. PHI =   0.0 DEG.

(DEG)	**MAG (DB)**		*PHASE (DEG)*	
THETA	GTHETA	GPHI	GTHETA	GPHI
0.0	-97.38	-9.85	91.9	-121.8
1.0	-37.61	-9.85	-77.9	-121.8
2.0	-30.22	-9.85	-64.4	-121.8
3.0	-23.28	-9.86	-55.6	-121.8
4.0	-19.91	-9.86	-54.6	-121.8
5.0	-17.55	-9.86	-55.2	-121.8
6.0	-15.68	-9.87	-54.9	-121.8
7.0	-14.29	-9.87	-53.8	-121.8
8.0	-13.12	-9.88	-53.0	-121.8
9.0	-12.04	-9.89	-52.9	-121.8
10.0	-11.04	-9.90	-53.5	-121.9
11.0	-10.20	-9.91	-53.4	-121.9
12.0	-9.44	-9.92	-53.3	-121.9
13.0	-8.75	-9.93	-53.2	-121.9
14.0	-8.11	-9.94	-53.0	-121.9
15.0	-7.53	-9.96	-52.9	-122.0
16.0	-6.99	-9.97	-52.8	-122.0
17.0	-6.48	-9.98	-52.6	-122.0
18.0	-6.02	-10.00	-52.4	-122.0
19.0	-5.57	-10.02	-52.3	-122.1
20.0	-5.16	-10.04	-52.1	-122.1
21.0	-4.76	-10.05	-51.9	-122.1
22.0	-4.39	-10.07	-51.8	-122.2
23.0	-4.04	-10.09	-51.6	-122.2
24.0	-3.72	-10.12	-51.4	-122.2
25.0	-3.40	-10.14	-51.1	-122.3
26.0	-3.10	-10.16	-50.9	-122.3
27.0	-2.82	-10.19	-50.7	-122.4
28.0	-2.55	-10.21	-50.5	-122.4
29.0	-2.30	-10.24	-50.2	-122.4
30.0	-2.06	-10.26	-50.0	-122.5
31.0	-1.82	-10.29	-49.7	-122.5
32.0	-1.60	-10.32	-49.4	-122.6
33.0	-1.39	-10.35	-49.1	-122.6
34.0	-1.19	-10.38	-48.8	-122.7
35.0	-1.00	-10.41	-48.5	-122.7
36.0	-0.82	-10.45	-48.2	-122.8
37.0	-0.64	-10.48	-47.9	-122.8

38.0	-0.48	-10.52	-47.6	-122.9
39.0	-0.32	-10.55	-47.2	-123.0
40.0	-0.17	-10.59	-46.9	-123.0
41.0	-0.03	-10.62	-46.5	-123.1
42.0	0.11	-10.66	-46.2	-123.1
43.0	0.24	-10.70	-45.8	-123.2
44.0	0.36	-10.74	-45.4	-123.3
45.0	0.48	-10.78	-45.0	-123.3
46.0	0.59	-10.83	-44.6	-123.4
47.0	0.69	-10.87	-44.2	-123.5
48.0	0.79	-10.91	-43.8	-123.5
49.0	0.88	-10.96	-43.3	-123.6
50.0	0.97	-11.00	-42.9	-123.7
51.0	1.05	-11.05	-42.4	-123.7
52.0	1.13	-11.10	-42.0	-123.8
53.0	1.20	-11.15	-41.5	-123.9
54.0	1.27	-11.20	-41.0	-123.9
55.0	1.33	-11.25	-40.6	-124.0
56.0	1.39	-11.30	-40.1	-124.1
57.0	1.44	-11.35	-39.5	-124.1
58.0	1.49	-11.41	-39.0	-124.2
59.0	1.54	-11.46	-38.5	-124.3
60.0	1.58	-11.52	-38.0	-124.4
61.0	1.62	-11.57	-37.4	-124.4
62.0	1.65	-11.63	-36.8	-124.5
63.0	1.68	-11.69	-36.3	-124.6
64.0	1.70	-11.75	-35.7	-124.7
65.0	1.72	-11.81	-35.1	-124.7
66.0	1.74	-11.87	-34.5	-124.8
67.0	1.75	-11.93	-33.9	-124.9
68.0	1.76	-12.00	-33.3	-124.9
69.0	1.77	-12.06	-32.7	-125.0
70.0	1.77	-12.13	-32.0	-125.1
71.0	1.77	-12.19	-31.4	-125.2
72.0	1.77	-12.26	-30.7	-125.2
73.0	1.76	-12.33	-30.1	-125.3
74.0	1.75	-12.40	-29.4	-125.4
75.0	1.74	-12.47	-28.6	-125.4
76.0	1.72	-12.54	-28.0	-125.5
77.0	1.69	-12.61	-27.3	-125.6
78.0	1.67	-12.69	-26.6	-125.6
79.0	1.65	-12.76	-25.9	-125.7
80.0	1.62	-12.84	-25.2	-125.8
81.0	1.58	-12.91	-24.5	-125.8
82.0	1.55	-12.99	-23.7	-125.9
83.0	1.51	-13.07	-22.7	-125.9
84.0	1.47	-13.15	-22.0	-126.0
85.0	1.43	-13.23	-21.4	-126.0
86.0	1.40	-13.31	-20.5	-126.1
87.0	1.32	-13.39	-19.8	-126.1
88.0	1.26	-13.47	-19.0	-126.2
89.0	1.24	-13.55	-18.0	-126.2
90.0	1.20	-13.82	-17.0	-125.8
91.0	1.11	-13.72	-16.4	-126.3

92.0	1.05	-13.81	-15.7	-126.3
93.0	0.98	-13.90	-14.9	-126.4
94.0	0.93	-13.98	-13.8	-126.4
95.0	0.85	-14.07	-13.1	-126.4
96.0	0.80	-14.16	-12.0	-126.4
97.0	0.73	-14.25	-11.1	-126.4
98.0	0.64	-14.34	-10.4	-126.5
99.0	0.55	-14.43	-9.5	-126.5
100.0	0.49	-14.52	-8.6	-126.5
101.0	0.41	-14.61	-7.6	-126.5
102.0	0.33	-14.71	-6.7	-126.5
103.0	0.24	-14.80	-5.8	-126.5
104.0	0.16	-14.89	-4.9	-126.5
105.0	0.08	-14.99	-3.9	-126.4
106.0	-0.01	-15.08	-3.0	-126.4
107.0	-0.11	-15.18	-2.0	-126.4
108.0	-0.20	-15.27	-1.1	-126.4
109.0	-0.30	-15.37	-0.1	-126.3
110.0	-0.40	-15.46	0.8	-126.3
111.0	-0.49	-15.56	1.8	-126.2
112.0	-0.59	-15.66	2.7	-126.2
113.0	-0.70	-15.75	3.7	-126.1
114.0	-0.80	-15.85	4.6	-126.0
115.0	-0.91	-15.95	5.6	-126.0
116.0	-1.01	-16.04	6.6	-125.9
117.0	-1.12	-16.14	7.5	-125.8
118.0	-1.23	-16.24	8.5	-125.7
119.0	-1.35	-16.34	9.4	-125.6
120.0	-1.46	-16.43	10.4	-125.5
121.0	-1.58	-16.53	11.3	-125.4
122.0	-1.70	-16.63	12.3	-125.3
123.0	-1.82	-16.72	13.2	-125.2
124.0	-1.95	-16.82	14.2	-125.1
125.0	-2.07	-16.91	15.1	-124.9
126.0	-2.20	-17.01	16.0	-124.8
127.0	-2.33	-17.10	16.9	-124.7
128.0	-2.47	-17.19	17.8	-124.5
129.0	-2.60	-17.29	18.7	-124.3
130.0	-2.74	-17.38	19.6	-124.2
131.0	-2.89	-17.47	20.5	-124.0
132.0	-3.03	-17.56	21.4	-123.8
133.0	-3.18	-17.65	22.2	-123.7
134.0	-3.34	-17.74	23.1	-123.5
135.0	-3.49	-17.83	23.9	-123.3
136.0	-3.66	-17.91	24.8	-123.1
137.0	-3.82	-18.00	25.6	-122.9
138.0	-3.99	-18.08	26.4	-122.7
139.0	-4.17	-18.17	27.2	-122.5
140.0	-4.35	-18.25	27.9	-122.3
141.0	-4.53	-18.33	28.7	-122.1
142.0	-4.73	-18.41	29.4	-121.9
143.0	-4.92	-18.48	30.2	-121.7
144.0	-5.13	-18.56	30.9	-121.4
145.0	-5.34	-18.63	31.6	-121.2

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146.0	-5.56	-18.70	32.2	-121.0
147.0	-5.79	-18.77	32.9	-120.8
148.0	-6.02	-18.84	33.6	-120.6
149.0	-6.26	-18.91	34.2	-120.3
150.0	-6.52	-18.97	34.8	-120.1
151.0	-6.78	-19.04	35.4	-119.9
152.0	-7.06	-19.10	35.9	-119.7
153.0	-7.35	-19.16	36.5	-119.5
154.0	-7.65	-19.22	37.0	-119.2
155.0	-7.96	-19.27	37.5	-119.0
156.0	-8.29	-19.32	38.0	-118.8
157.0	-8.63	-19.37	38.5	-118.6
158.0	-9.00	-19.42	39.0	-118.4
159.0	-9.38	-19.47	39.4	-118.2
160.0	-9.79	-19.51	39.8	-118.0
161.0	-10.22	-19.56	40.2	-117.9
162.0	-10.67	-19.60	40.6	-117.7
163.0	-11.16	-19.64	41.0	-117.5
164.0	-11.68	-19.67	41.3	-117.3
165.0	-12.23	-19.71	41.6	-117.2
166.0	-12.82	-19.74	41.8	-117.0
167.0	-13.48	-19.77	42.2	-116.9
168.0	-14.19	-19.79	42.4	-116.8
169.0	-14.97	-19.82	42.6	-116.6
170.0	-15.83	-19.84	42.8	-116.5
171.0	-16.63	-19.86	42.2	-116.4
172.0	-17.73	-19.88	42.2	-116.3
173.0	-19.21	-19.90	43.2	-116.3
174.0	-20.99	-19.91	44.5	-116.2
175.0	-23.03	-19.92	45.7	-116.1
176.0	-25.52	-19.93	44.1	-116.1
177.0	-30.28	-19.94	41.0	-116.0
178.0	-51.39	-19.95	-3.1	-116.0
179.0	-53.90	-19.96	172.9	-116.0
180.0	-99.90	-19.96	-49.3	-116.1
181.0	-53.84	-19.96	172.6	64.0
182.0	-51.43	-19.95	-2.8	64.0
183.0	-30.28	-19.94	41.1	64.0
184.0	-25.52	-19.93	44.1	63.9
185.0	-23.03	-19.92	45.7	63.9
186.0	-20.99	-19.91	44.5	63.8
187.0	-19.21	-19.90	43.2	63.7
188.0	-17.73	-19.88	42.2	63.7
189.0	-16.63	-19.86	42.2	63.6
190.0	-15.83	-19.84	42.8	63.5
191.0	-14.97	-19.82	42.6	63.4
192.0	-14.19	-19.79	42.4	63.2
193.0	-13.48	-19.77	42.2	63.1
194.0	-12.82	-19.74	41.8	63.0
195.0	-12.23	-19.71	41.6	62.8
196.0	-11.68	-19.67	41.3	62.7
197.0	-11.16	-19.64	41.0	62.5
198.0	-10.67	-19.60	40.6	62.3
199.0	-10.22	-19.56	40.3	62.1

200.0	-9.79	-19.52	39.8	62.0
201.0	-9.38	-19.47	39.4	61.8
202.0	-9.00	-19.42	39.0	61.6
203.0	-8.63	-19.37	38.5	61.4
204.0	-8.29	-19.32	38.0	61.2
205.0	-7.96	-19.27	37.6	61.0
206.0	-7.65	-19.22	37.0	60.8
207.0	-7.35	-19.16	36.5	60.5
208.0	-7.06	-19.10	35.9	60.3
209.0	-6.78	-19.04	35.4	60.1
210.0	-6.52	-18.98	34.8	59.9
211.0	-6.26	-18.91	34.2	59.7
212.0	-6.02	-18.84	33.6	59.4
213.0	-5.79	-18.78	32.9	59.2
214.0	-5.56	-18.70	32.2	59.0
215.0	-5.34	-18.63	31.6	58.8
216.0	-5.13	-18.56	30.9	58.6
217.0	-4.92	-18.48	30.2	58.3
218.0	-4.73	-18.41	29.4	58.1
219.0	-4.53	-18.33	28.7	57.9
220.0	-4.35	-18.25	27.9	57.7
221.0	-4.17	-18.17	27.2	57.5
222.0	-3.99	-18.08	26.4	57.3
223.0	-3.82	-18.00	25.6	57.1
224.0	-3.66	-17.91	24.8	56.9
225.0	-3.49	-17.83	23.9	56.7
226.0	-3.34	-17.74	23.1	56.5
227.0	-3.18	-17.65	22.2	56.3
228.0	-3.03	-17.56	21.4	56.2
229.0	-2.89	-17.47	20.5	56.0
230.0	-2.74	-17.38	19.6	55.8
231.0	-2.60	-17.29	18.7	55.7
232.0	-2.47	-17.20	17.8	55.5
233.0	-2.33	-17.10	16.9	55.3
234.0	-2.20	-17.01	16.0	55.2
235.0	-2.07	-16.91	15.1	55.1
236.0	-1.95	-16.82	14.2	54.9
237.0	-1.82	-16.72	13.2	54.8
238.0	-1.70	-16.63	12.3	54.7
239.0	-1.58	-16.53	11.3	54.6
240.0	-1.46	-16.43	10.4	54.5
241.0	-1.35	-16.34	9.4	54.4
242.0	-1.23	-16.24	8.5	54.3
243.0	-1.12	-16.14	7.5	54.2
244.0	-1.01	-16.04	6.6	54.1
245.0	-0.91	-15.95	5.6	54.0
246.0	-0.80	-15.85	4.6	54.0
247.0	-0.70	-15.75	3.7	53.9
248.0	-0.59	-15.66	2.7	53.8
249.0	-0.49	-15.56	1.8	53.8
250.0	-0.40	-15.46	0.8	53.7
251.0	-0.30	-15.37	-0.1	53.7
252.0	-0.20	-15.27	-1.1	53.6
253.0	-0.11	-15.18	-2.0	53.6

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254.0	-0.01	-15.08	-3.0	53.6
255.0	0.08	-14.99	-3.9	53.6
256.0	0.16	-14.89	-4.9	53.5
257.0	0.24	-14.80	-5.8	53.5
258.0	0.33	-14.71	-6.7	53.5
259.0	0.41	-14.61	-7.6	53.5
260.0	0.49	-14.52	-8.6	53.5
261.0	0.55	-14.43	-9.5	53.5
262.0	0.64	-14.34	-10.4	53.5
263.0	0.73	-14.25	-11.1	53.6
264.0	0.80	-14.16	-12.0	53.6
265.0	0.85	-14.07	-13.1	53.6
266.0	0.93	-13.98	-13.8	53.6
267.0	0.98	-13.90	-14.9	53.6
268.0	1.05	-13.81	-15.7	53.7
269.0	1.11	-13.72	-16.4	53.7
270.0	1.20	-13.82	-17.0	54.2
271.0	1.24	-13.55	-18.0	53.8
272.0	1.26	-13.47	-19.0	53.8
273.0	1.32	-13.39	-19.8	53.9
274.0	1.40	-13.31	-20.5	53.9
275.0	1.43	-13.23	-21.4	54.0
276.0	1.47	-13.15	-22.0	54.0
277.0	1.51	-13.07	-22.7	54.1
278.0	1.55	-12.99	-23.7	54.1
279.0	1.58	-12.91	-24.5	54.2
280.0	1.62	-12.84	-25.2	54.2
281.0	1.65	-12.76	-25.9	54.3
282.0	1.67	-12.69	-26.6	54.4
283.0	1.69	-12.61	-27.3	54.4
284.0	1.72	-12.54	-28.0	54.5
285.0	1.74	-12.47	-28.6	54.6
286.0	1.75	-12.40	-29.4	54.6
287.0	1.76	-12.33	-30.1	54.7
288.0	1.77	-12.26	-30.7	54.8
289.0	1.77	-12.20	-31.4	54.8
290.0	1.77	-12.13	-32.0	54.9
291.0	1.77	-12.06	-32.7	55.0
292.0	1.76	-12.00	-33.3	55.1
293.0	1.75	-11.93	-33.9	55.1
294.0	1.74	-11.87	-34.5	55.2
295.0	1.72	-11.81	-35.1	55.3
296.0	1.70	-11.75	-35.7	55.3
297.0	1.68	-11.69	-36.3	55.4
298.0	1.65	-11.63	-36.8	55.5
299.0	1.62	-11.57	-37.4	55.6
300.0	1.58	-11.52	-38.0	55.6
301.0	1.54	-11.46	-38.5	55.7
302.0	1.49	-11.41	-39.0	55.8
303.0	1.44	-11.35	-39.5	55.9
304.0	1.39	-11.30	-40.1	55.9
305.0	1.33	-11.25	-40.6	56.0
306.0	1.27	-11.20	-41.0	56.1
307.0	1.20	-11.15	-41.5	56.1

308.0	1.13	-11.10	-42.0	56.2
309.0	1.05	-11.05	-42.4	56.3
310.0	0.97	-11.00	-42.9	56.3
311.0	0.88	-10.96	-43.3	56.4
312.0	0.79	-10.91	-43.8	56.5
313.0	0.69	-10.87	-44.2	56.5
314.0	0.59	-10.83	-44.6	56.6
315.0	0.48	-10.78	-45.0	56.7
316.0	0.36	-10.74	-45.4	56.7
317.0	0.24	-10.70	-45.8	56.8
318.0	0.11	-10.66	-46.2	56.9
319.0	-0.03	-10.62	-46.5	56.9
320.0	-0.17	-10.59	-46.9	57.0
321.0	-0.32	-10.55	-47.2	57.0
322.0	-0.48	-10.52	-47.6	57.1
323.0	-0.64	-10.48	-47.9	57.2
324.0	-0.82	-10.45	-48.2	57.2
325.0	-1.00	-10.41	-48.5	57.3
326.0	-1.19	-10.38	-48.8	57.3
327.0	-1.39	-10.35	-49.1	57.4
328.0	-1.60	-10.32	-49.4	57.4
329.0	-1.82	-10.29	-49.7	57.5
330.0	-2.05	-10.26	-50.0	57.5
331.0	-2.30	-10.24	-50.2	57.6
332.0	-2.55	-10.21	-50.5	57.6
333.0	-2.82	-10.19	-50.7	57.6
334.0	-3.10	-10.16	-50.9	57.7
335.0	-3.40	-10.14	-51.1	57.7
336.0	-3.71	-10.12	-51.4	57.8
337.0	-4.04	-10.09	-51.6	57.8
338.0	-4.39	-10.07	-51.8	57.8
339.0	-4.76	-10.05	-51.9	57.9
340.0	-5.15	-10.04	-52.1	57.9
341.0	-5.57	-10.02	-52.3	57.9
342.0	-6.01	-10.00	-52.4	58.0
343.0	-6.48	-9.98	-52.6	58.0
344.0	-6.99	-9.97	-52.8	58.0
345.0	-7.53	-9.96	-52.9	58.0
346.0	-8.11	-9.94	-53.0	58.1
347.0	-8.75	-9.93	-53.2	58.1
348.0	-9.44	-9.92	-53.3	58.1
349.0	-10.20	-9.91	-53.4	58.1
350.0	-11.04	-9.90	-53.5	58.1
351.0	-12.04	-9.89	-52.9	58.2
352.0	-13.12	-9.88	-53.0	58.2
353.0	-14.29	-9.87	-53.8	58.2
354.0	-15.67	-9.87	-54.9	58.2
355.0	-17.55	-9.86	-55.2	58.2
356.0	-19.91	-9.86	-54.6	58.2
357.0	-23.28	-9.86	-55.6	58.2
358.0	-30.21	-9.85	-64.4	58.2
359.0	-37.59	-9.85	-78.0	58.2
360.0	-97.38	-9.85	-88.2	58.2

CPU RUN TIME FOR RUN   1 GEOMETRY   1 =   826.00 SECONDS

TOTAL CPU RUN TIME =   828.00 SECONDS

Appendix G

Code to Read Geometry Data

```
C-------DIMENSION INDICATOR ASSIGNMENTS
       PARAMETER (IPL=30)
       PARAMETER (ICN=8)
       PARAMETER (IPLM=500)
       PARAMETER (IWS=100)
       PARAMETER (IWP=100)
       PARAMETER (IOPP=100)

C-------DIMENSIONED BY IWP, THE MAX NUMBER OF WIRE POINTS
       DIMENSION X(IWP),Y(IWP),Z(IWP)

C-------DIMENSIONED BY IWS, THE MAX NUMBER OF WIRE SEGMENTS
       DIMENSION IA(IWS),IB(IWS)

C-------DIMENSIONED BY IPL
       DIMENSION NCNRS(IPL),NPL11(IPL),NPL22(IPL),NDNPLT(IPL),
      1          IPN(IPL)

C-------DIMENSIONED BY IPLM
       DIMENSION PA(IPLM,4,3),PB(IPLM,4,3)

C-------DIMENSIONED BY IOPP, THE MAX NUMBER OF OVERLAP PLATE PAIRS
       DIMENSION ITK(IOPP),IOVT(IOPP,4)

C-------DIMENSIONED BY ICN AND IPL
       DIMENSION PCN(3,ICN,IPL)
             .
             .
             .
             .

10     FORMAT(' INCREASE PARAMETER IPL  TO ',I3,'  OR GREATER')
```

```
20      FORMAT(' INCREASE PARAMETER IPLM TO ',I4,'  OR GREATER')
30      FORMAT(' INCREASE PARAMETER IWS  TO ',I3,'  OR GREATER')
40      FORMAT(' INCREASE PARAMETER IWP  TO ',I3,'  OR GREATER')
60      FORMAT(' INCREASE PARAMETER IOPP TO ',I3,'  OR GREATER')
80      FORMAT(' INCREASE PARAMETER ICN  TO ',I3,'  OR GREATER')


C-------READ IN WIRE/PLATE/OVERLAP GEOMETRY FOR GKS PLOTTING
C       MAKE SURE STORAGE ARRAYS ARE OF ADEQUATE SIZE FOR THIS
C       DATA SET.
C       IF NOT TELL THE USER WHICH DIMENSIONS TO INCREASE AND END.
C
        READ(9,*)NPLTS,NPLTM,NM,NP,NWR,NAT,WV,NOPL,NOVT
        IFLAG=0
        IF(NPLTS.GT.IPL)THEN
                WRITE(5,10)NPLTS
                IFLAG=1
        ENDIF
        IF(NPLTM.GT.IPLM)THEN
                WRITE(5,20)NPLTM
                IFLAG=1
        ENDIF
        IF(NM.GT.IWS)THEN
                WRITE(5,30)NM
                IFLAG=1
        ENDIF
        IF(NP.GT.IWP)THEN
                WRITE(5,40)NP
                IFLAG=1
        ENDIF
        IF(NOPL.GT.IOPP)THEN
                WRITE(5,60)NOPL
                IFLAG=1
        ENDIF

        IF(IFLAG.EQ.1)STOP

        DO 158 I=1,NP
        READ(9,*)X(I),Y(I),Z(I)
158     CONTINUE
        DO 159 I=1,NM
        READ(9,*)IA(I),IB(I)
159     CONTINUE
        NCMAX=0
        DO 151 NPL=1,NPLTS
```

```
      READ(9,*)NCNRS(NPL),NPL11(NPL),NPL22(NPL),NDNPLT(NPL),IPN(NPL)
      IF(NCNRS(NPL).GT.NCMAX)NCMAX=NCNRS(NPL)
151   CONTINUE
      IF(NCMAX.GT.ICN)THEN
            WRITE(5,80)NCMAX
            STOP
      ENDIF
      DO 152 I=1,NPLTM
      DO 153 J=1,4
      READ(9,*)PA(I,J,1),PA(I,J,2),PA(I,J,3),PB(I,J,1),PB(I,J,2),
    2 PB(I,J,3)
153   CONTINUE
152   CONTINUE
      DO 156 NPL=1,NPLTS
      NCNR=NCNRS(NPL)
      DO 157 NC=1,NCNR
      READ(9,*)PCN(1,NC,NPL),PCN(2,NC,NPL),PCN(3,NC,NPL)
157   CONTINUE
156   CONTINUE
      DO 166 I=1,NOPL
      READ(9,*)IOVT(I,1),IOVT(I,2),IOVT(I,3),IOVT(I,4),ITK(I)
166   CONTINUE
C-------END GEOMETRY DATA INPUT
```

Appendix H

Code to Read Pattern Plotting Data

```
C-------DIMENSION INDICATOR ASSIGNMENTS
C IPATS = MAXIMUM NUMBER OF PATTERNS
C IPNTS = MAXIMUM NUMBER OF DATA POINTS FOR A PATTERN

PARAMETER (IPATS = 5)
PARAMETER (IPNTS = 1441)

C-------DIMENSIONED BY IPATS ONLY
DIMENSION NPTS(IPATS),ISCAT(IPATS),IEA(IPATS),CANG(IPATS),
     + THIN(IPATS),PHIN(IPATS),IPLOTA(IPATS,7)


C-------DIMENSIONED BY IPNTS ONLY
DIMENSION E(IPNTS)

C-------DIMENSIONED BY IPATS AND IPNTS
DIMENSION RADPO(IPATS,IPNTS,3),
     +  SCATPO(IPATS,IPNTS,6)

FIELD(DBVAL)=10**(DBVAL/10.)


  31 FORMAT(' INCREASE PARAMETER IPATS TO ',I3,' OR GREATER')
  32 FORMAT(' INCREASE PARAMETER IPNTS TO ',I3,' OR GREATER')

C=======BEGIN READING AND STORING INPUT DATA FILE INFO.
C IF THE IPATS OR IPNTS DIMENSIONS ARE TOO SMALL
C THEN INSTRUCT USER AND STOP
C THE PATTERN DATA POINTS ARE READ IN AS
C MAGNITUDE(DB), ANGLE(DEGREES), ETC.
```

```
C
C         ie. READ(8,*)A,THA,B,PHA
C READ(8,*)A,TTA,B,PPA,C,TPA,D,PTA
C
C THE MAGNITUDE DATA ARE IMMEDIATELY CONVERTED FROM DB TO
C FIELD UNITS AND THEN STORED.
C THE ANGLE DATA ARE READ IN AND SUBSEQUENTLY DISCARDED
C SINCE THIS PROGRAM DOES NOT USE ANGLE INFORMATION.

READ(8,*) NPATS,IRS12,FMC,RF

IF(NPATS.GT.IPATS) THEN
WRITE(5,31)NPATS
STOP
ENDIF


IF(IRS12.EQ.1)THEN
DO 10 I=1,NPATS

READ(8,*)IEA(I),NPTS(I),CANG(I)
IF(NPTS(I).GT.IPNTS) THEN
WRITE(5,32)NPTS(I)
STOP
ENDIF
DO 20 J=1,NPTS(I)
READ(8,*)THM,THA,PHM,PHA,RM,RA
RADPO(I,J,1)=FIELD(THM)
RADPO(I,J,2)=FIELD(PHM)
RADPO(I,J,3)=FIELD(RM)
 20 CONTINUE
 10 CONTINUE
ELSEIF(IRS12.EQ.2)THEN
DO 30 I=1,NPATS
  READ(8,*)IEA(I),NPTS(I),ISCAT(I),CANG(I),THIN(I)
     2 ,PHIN(I)
IF(NPTS(I).GT.IPNTS) THEN
WRITE(5,32)NPTS(I)
STOP
ENDIF
DO 40 J=1,NPTS(I)
READ(8,*)TTM,TTA,PPM,PPA,TPM,TPA,PTM,PTA,TRM,TRA,PRM,PRA
SCATPO(I,J,1)=FIELD(TTM)
SCATPO(I,J,2)=FIELD(PPM)
SCATPO(I,J,3)=FIELD(TPM)
```

```
SCATPO(I,J,4)=FIELD(PTM)
SCATPO(I,J,5)=FIELD(TRM)
SCATPO(I,J,6)=FIELD(PRM)
 40 CONTINUE
 30 CONTINUE
ENDIF
C=======FINISHED READING INPUT DATA FILE
```

Appendix I

Code to Read Frequency Sweep Data

```
C INPUT FREQUENCY SWEEP DATA
C
C READ DESCRIPTION OF FREQUENCY SWEEP (SEE READS 1 AND 1A)
C
C RF = RADIUS OF PATTERN FIELD POINT IN METERS
C    < 0 IMPLIES FAR ZONE.
C THRD,PHRD = THETA,PHI ANGLE OF RADIATED/SCATTERED WAVE IN DEGREES
C THINC,PHINC = THETA,PHI ANGLE OF INCIDENT WAVE IN DEGREES
C IRS12 = 1 IMPLIES AN ANTENNA/RADIATION COMPUTATION
C       = 2 IMPLIES A SCATTERING COMPUTATION
C NFF = NUMBER OF FREQUENCIES AT WHICH DATA IS COMPUTED
C NFZI = NUMBER OF FREQUENCIES AT WHICH [Z] IS COMPUTED
C INDZI = 1 IMPLIES STANDARD QUADRATIC INTERPOLATION OF [Z]
C       = 2 IMPLIES IMPROVED QUADRATIC INTERPOLATION OF [Z]
C
        READ(10,3210)RF,THRD,PHRD,THINC,PHINC,IRS12,NFF,NFZI,INDZI
C
C READ IN ANTENNA/RADIATION FREQUENCY SWEEP DATA
C NOTE: GAIN IS IN DB OVER A SQUARE METER
C PHASE IS PHASE OF THE ELECTRIC FIELD IN DEGREES
C
C FMC = FREQUENCY IN MHZ
C ZIN = INPUT IMPEDANCE IN OHMS
C EFF = RADIATION EFFICIENCY IN PERCENT
C DBAET = GAIN FOR THETA POLARIZATION
C DBAEP = GAIN FOR PHI POLARIZATION
C DBAER = GAIN FOR R POLARIZATION
C PET = PHASE OF THE THETA POLARIZED ELECTRIC FIELD
C PEP = PHASE OF THE PHI POLARIZED ELECTRIC FIELD
C PER = PHASE OF THE R POLARIZED ELECTRIC FIELD
```

```
C
IF(IRS12.EQ.1)THEN
DO100N=1,NFF
C FAR ZONE DATA
        IF(RF.LT.0.0)READ(10,3125)FMC(N),ZIN(N),EFF(N),DBAET(N),
     2 DBAEP(N),PET(N),PEP(N)
C NEAR ZONE DATA
        IF(RF.GE.0.0)READ(10,3126)FMC(N),ZIN(N),EFF(N),DBAET(N),
     2  DBAEP(N),DBAER(N),PET(N),PEP(N),PER(N)
  100 CONTINUE
        ENDIF
C
C READ IN SCATTERING FREQUENCY SWEEP DATA
C NOTE: RCS IS IN DB OVER A SQUARE METER
C PHASE IS PHASE OF THE ELECTRIC FIELD IN DEGREES
C
C FMC = FREQUENCY IN MHZ
C STTM = RCS FOR THETA IN AND THETA OUT
C SPPM = RCS FOR PHI IN AND PHI OUT
C STPM = RCS FOR THETA IN AND PHI OUT
C SPTM = RCS FOR PHI IN AND THETA OUT
C STRM = RCS FOR THETA IN AND R OUT
C SPRM = RCS FOR PHI IN AND R OUT
C PHTT = PHASE OF ELECTRIC FIELD FOR THETA IN AND THETA OUT
C PHPP = PHASE OF ELECTRIC FIELD FOR PHI IN AND PHI OUT
C PHTP = PHASE OF ELECTRIC FIELD FOR THETA IN AND PHI OUT
C PHPT = PHASE OF ELECTRIC FIELD FOR PHI IN AND THETA OUT
C PHTR = PHASE OF ELECTRIC FIELD FOR THETA IN AND R OUT
C PHPR = PHASE OF ELECTRIC FIELD FOR PHI IN AND R OUT
C
IF(IABS(IRS12).EQ.2)THEN
DO110N=1,NFF
C FAR ZONE DATA
IF(RF.LT.0.0)READ(10,3195)FMC(N),STTM(N),SPPM(N),STPM(N),
     2 SPTM(N),PHTT(N),PHPP(N),PHTP(N),PHPT(N)
C NEAR ZONE DATA
        IF(RF.GE.0.0)READ(10,3196)FMC(N),STTM(N),SPPM(N),STPM(N),
     2 SPTM(N),STRM(N),SPRM(N),PHTT(N),PHPP(N),PHTP(N),PHPT(N),
     3 PHTR(N),PHPR(N)
  110 CONTINUE
ENDIF
C
C MISC. FORMATS
C
 3210    FORMAT(1X,E11.5,4(1X,F6.1),1X,6I4)
```

```
3125    FORMAT(1X,F9.3,2X,E10.4,2X,E10.4,2X,F6.1,2(2X,F6.2),
   2    2(2X,F6.1))
3126    FORMAT(1X,F9.3,2X,E10.4,2X,E10.4,2X,F6.1,3(2X,F6.2),
   2    3(2X,F6.1))
3195    FORMAT(1X,F8.2,4(2X,F6.2),4(2X,F6.1))
3196    FORMAT(1X,F8.2,6(2X,F6.2)/9X,6(2X,F6.1))
```