



# A User's Manual for the Method of Moments Aircraft Modeling Code (AMC)

M.E. Peters and E.H. Newman

The Ohio State University  
**ElectroScience Laboratory**

Department of Electrical Engineering  
Columbus, Ohio 43212

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<b>16. Abstract (Limit: 200 words)</b>  This report serves as a user's manual for the "Aircraft Modeling 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.			<b>13. Report Type/Period Covered</b> Final Report
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# Chapter 1

## Introduction

This report serves as a user's manual for 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.

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 [3]. Much of the theoretical basis for the ESP code is described in the literature [4]-[14]. 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, modeled 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 [4]-[14]. 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  $20 \lambda^2$  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 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 [13] 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 [15] to plot the wire and plate geometry (see Section 5.2).

**ESP4PT** = a program using the GKS language [15] 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 GETTCP(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)
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  $0.001\lambda$ .

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.

Table 1.1: Files Used by AMC

Logical Unit Number	File Name	Description
1	ZMAT.DAT	Impedance matrix file
5	INFIL.DAT	Input file
6	OUTFL.DAT	Output file
8	PTPLOT.DAT	Pattern plotting file
9	GMPLOT.DAT	Geometry plotting file
10	FSWP.DAT	Frequency sweep file

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.

## 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

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

$$[Z]I = V \quad (2.1)$$

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  
(4) (6) (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.

## 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 the solution, by using filamentary plate test modes.

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 [3] 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.

= 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 [3,13]. We have found that if straight quadratic interpolation

is used (INDZI= 1), typically the frequency step size is  $DFZI = \Delta f_M/2$ , where

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

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  $\Delta f_M$  or more. As DFZI increases, the CPU run times decreases, however, the  $[Z]$  matrix interpolation error increases.

## 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  $\phi$  is fixed and  $\theta$  is varied where  $\theta$  and  $\phi$  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  $\phi$  angle in degrees for near or far zone radiation pattern in the elevation plane.

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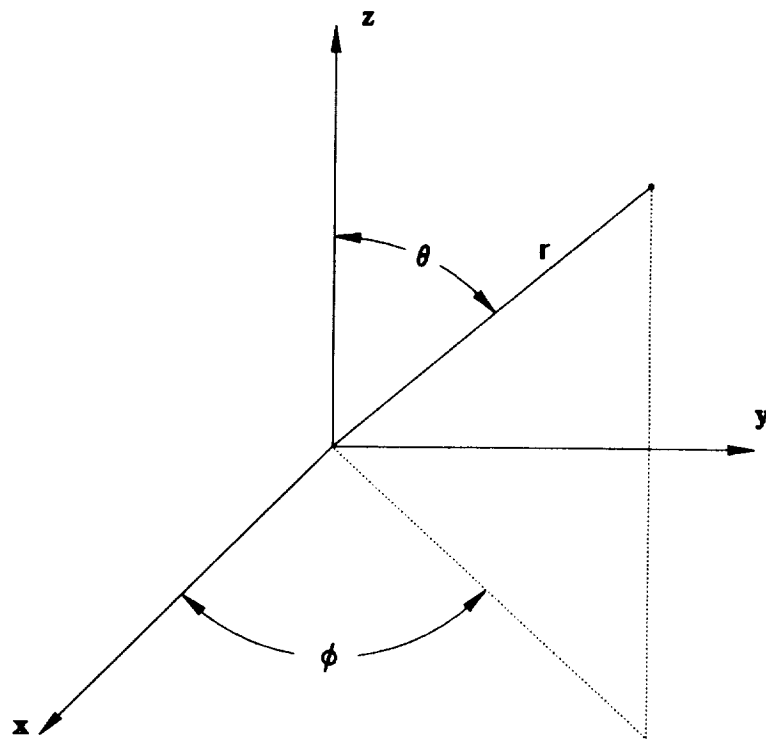


Figure 2.1: The standard coordinate system used by AMC for pattern specification.

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  $\theta$  is fixed and  $\phi$  is varied where  $\theta$  and  $\phi$  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, FNDFFA, 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.

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

**THFA** = constant  $\theta$  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  $\phi$  angle in degrees for near or far zone scattering pattern in the elevation plane.

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



**PHIN** =  $\phi$  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 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.

**THSA** = constant  $\theta$  angle in degrees for near or far zone scattering pattern in the azimuthal plane.

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

**PHIN** =  $\phi$  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. 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 four blocks corresponding to coupling between wire (W) 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 impedance matrix is stored on a disk file, i.e., the impedance matrix file on logical unit 1. On

subsequent runs the stored matrix is read in and only the blocks involving wires are recomputed.

Form of the command:

ZM: Impedance Matrix

IWRZM, IRDZM

(0) (0) (Default)

**IWRZM** = indicator for writing the 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 impedance matrix.

= 1 implies write out the impedance matrix.

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

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

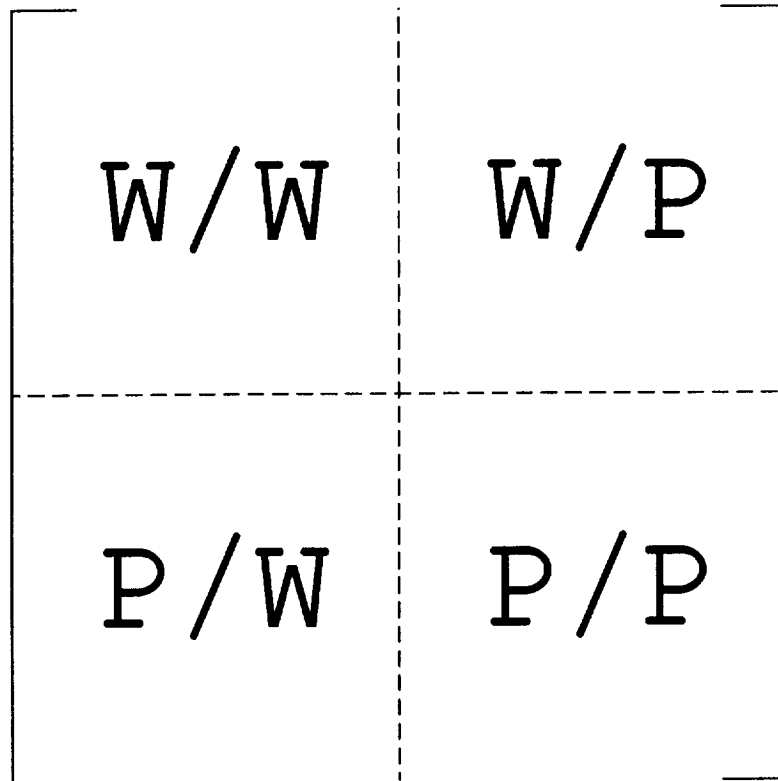
= 1 implies read in the previous matrix and compute the new matrix except for the W/W block. Use this option when the wire geometry is identical to the run on which IWRZM = 1.

= 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 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 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,



W = WIRE  
P = PLATE

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

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

The 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 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

## 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.

In general the quadrilateral plates connecting the cross sections will not be planar. Thus, it was necessary to augment the ESP code [3] so that it

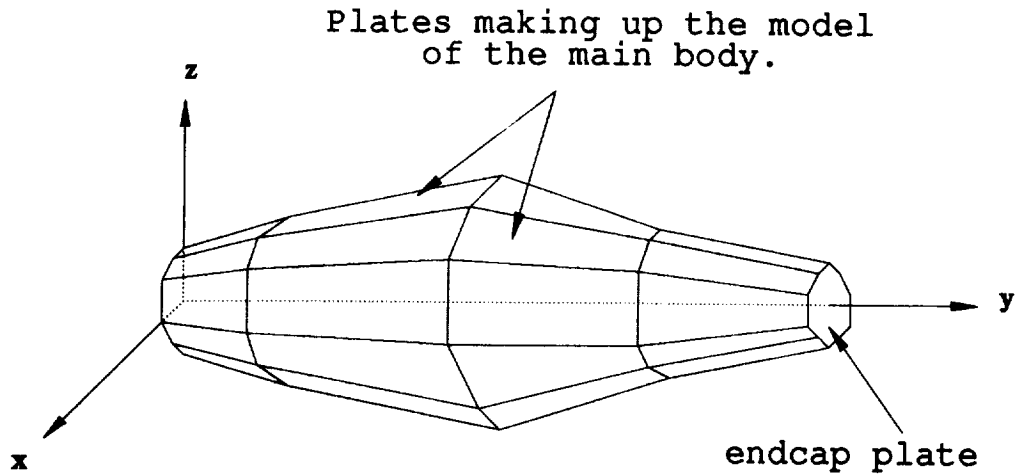


Figure 3.1: Plate model of an arbitrarily shaped body.

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  $(\text{NSIDE}/2 + 1)$  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  $\text{NSIDE}/2 + 1$  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  $\text{NSIDE}/2 + 1$  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.

= 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

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)

⋮

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.  $N = \text{NSIDE}$  (see Section 3.2) if the main body has not been specified as symmetric and  $N = \text{NSIDE}/2 + 1$  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  $J^{\text{th}}$  cross section. The  $J^{\text{th}}$  cross section is positioned at  $y = \text{YCSI}(J)$ .

**YPL(J)** = the y value for a moved or added cross section. If the  $J^{\text{th}}$  cross section is moved then it is positioned at  $y = \text{YPL}(J)$ . If a new cross section is added then the new cross section is positioned at  $y = \text{YPL}(J)$ . See **IPCI(J)** below.

**IPCI(J)** = indicator for placement of the  $J^{\text{th}}$  cross section. This indicator is used for moving a cross section or adding a new cross section.

- = 0 implies place the  $J^{\text{th}}$  cross section at  $\text{YCSI}(J)$  (usual case).
- = -1 implies place the  $J^{\text{th}}$  section at  $\text{YPL}(J)$  by interpolating the  $J^{\text{th}}$  cross section and the previous cross section.
- = 1 implies place the  $J^{\text{th}}$  cross section at  $\text{YPL}(J)$  by interpolating the  $J^{\text{th}}$  cross section and the next cross section.
- = -2 implies place the  $J^{\text{th}}$  cross section at  $\text{YCSI}(J)$  and in addition place a new cross section at  $\text{YPL}(J)$  by interpolating the  $J^{\text{th}}$  cross section and the previous cross section.
- = 2 implies place the  $J^{\text{th}}$  cross section at  $\text{YCSI}(J)$  and in addition place a new cross section at  $\text{YPL}(J)$  by interpolating the  $J^{\text{th}}$  cross section and the next cross section.

**IECI(J)** = indicator for capping off the  $J^{\text{th}}$  cross section.

- = 0 implies do not cap off the  $J^{\text{th}}$  cross section.

= 1 implies cap off the  $J^{\text{th}}$  cross section with an endcap plate.

**ICSI(J)** = indicator for multiple cross sections at **YCSI(J)** or **YPL(J)**.  
= 0 implies the  $J^{\text{th}}$  cross section or a moved cross section is at a different location than the next cross section.  
= 1 implies the  $J^{\text{th}}$  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  $I^{\text{th}}$  point on the  $J^{\text{th}}$  cross section. If the main body is not specified as symmetric (see Section 3.3) then  $I \in \{1, 2, 3, \dots, \text{NSIDE}\}$ . If the main body is specified as symmetric then  $I \in \{1, 2, 3, \dots, \text{NSIDE}/2 + 1\}$ . Furthermore, if the main body is specified as symmetric then the  $1^{\text{st}}$  point and the  $(\text{NSIDE} / 2 + 1)^{\text{th}}$  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  $I^{\text{th}}$  point on one cross section to the  $I^{\text{th}}$  point on the next cross section ( $I \in \{1, 2, 3, \dots, \text{NSIDE}\}$ ).

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.

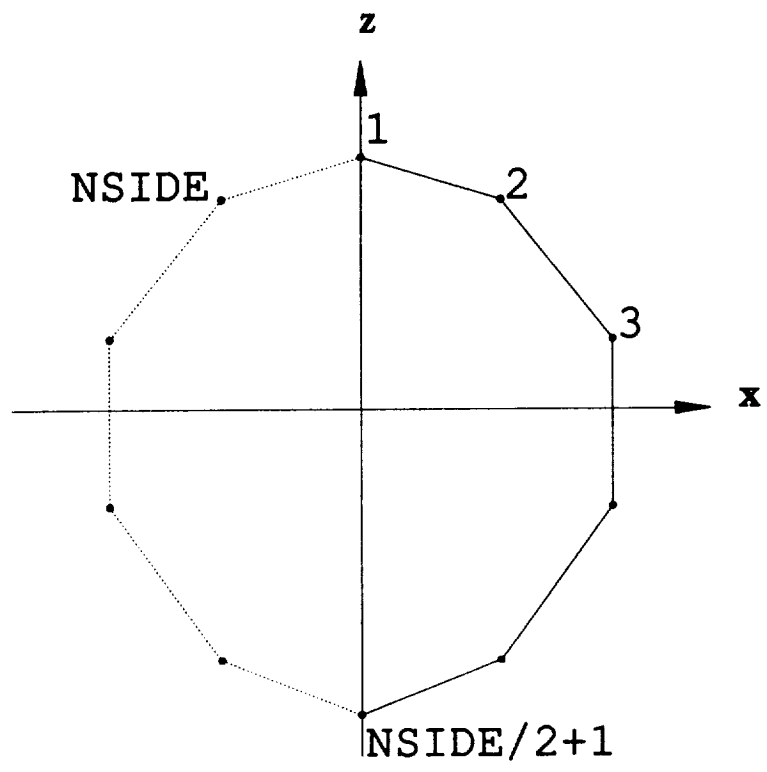


Figure 3.2: Cross section for a symmetric body.

## 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 modeling 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, modeled 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 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:

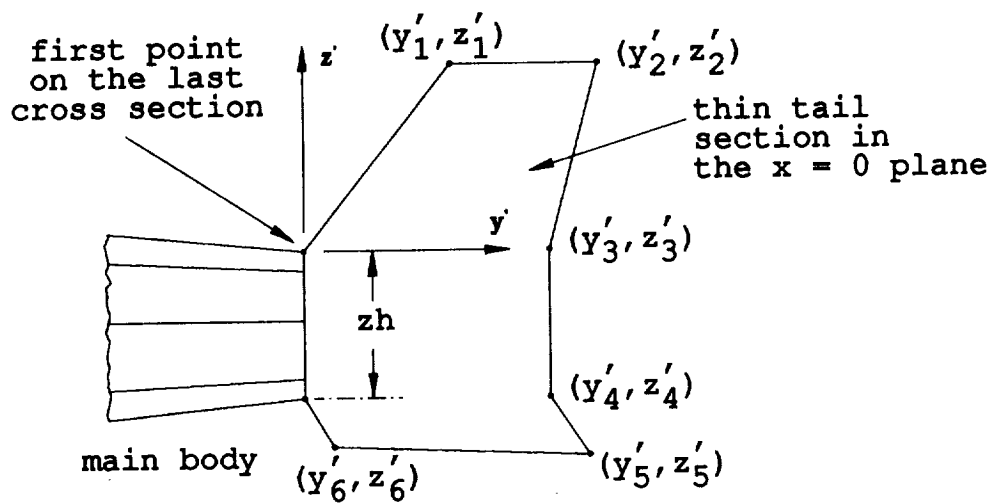
```
TS: Tail Section
YTSCN(1), ZTSCN(1)
YTSCN(2), ZTSCN(2)
YTSCN(3)
YTSCN(4)
YTSCN(5), ZTSCN(5)
YTSCN(6), ZTSCN(6)
```

**YTSCN(J)** = the  $y$  value of the  $J^{\text{th}}$  point describing the thin tail section  
( $J=1,2,3,4,5,6$ ).

**ZTSCN(J)** = the  $z$  value of the  $J^{\text{th}}$  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  $1^{\text{st}}$  and  $(\text{NSIDE}/2 + 1)^{\text{th}}$  point on the last cross section (NSIDE must be an even number). This is illustrated in Figure 3.3.





$$\begin{aligned}
 y'_i &= \text{YTSCN}(I) ; i = I = 1, 2, 3, 4, 5, 6 \\
 z'_i &= \text{ZTSCN}(I) ; i = I = 1, 2, 5, 6 \\
 z'_3 &= 0 \\
 z'_4 &= -zh
 \end{aligned}
 \left. \vphantom{\begin{aligned} y'_i \\ z'_i \\ z'_3 \\ z'_4 \end{aligned}} \right\} \text{these are not specified by the user}$$

Figure 3.3: Geometry of the thin tail section.

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 1<sup>st</sup> and (NSIDE/2 + 1)<sup>th</sup> 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 1<sup>st</sup> and (NSIDE/2 + 1)<sup>th</sup> 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 modeled 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 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 modeled 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 modeled 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.

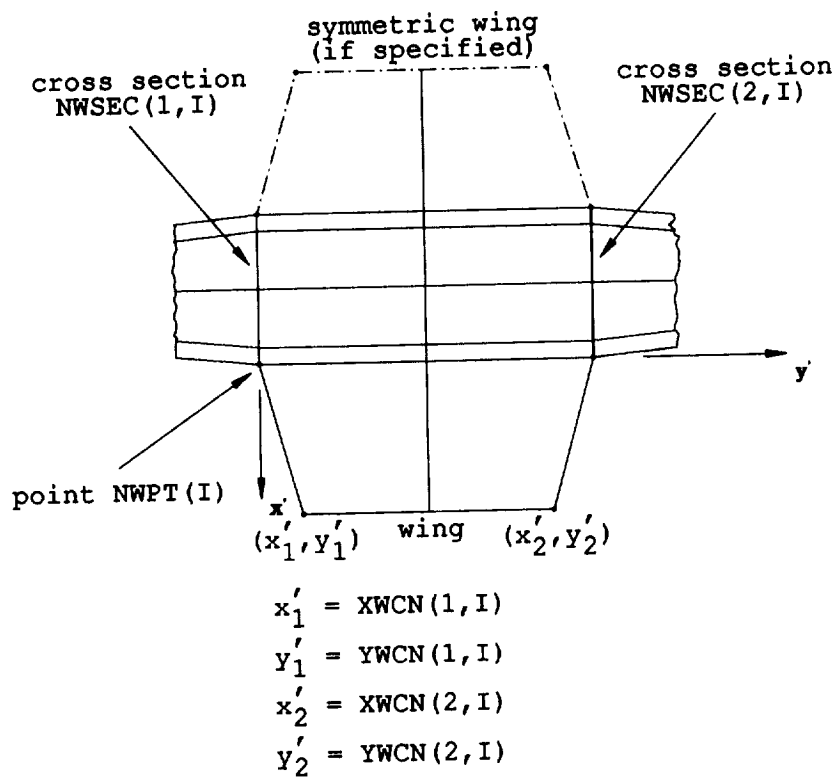
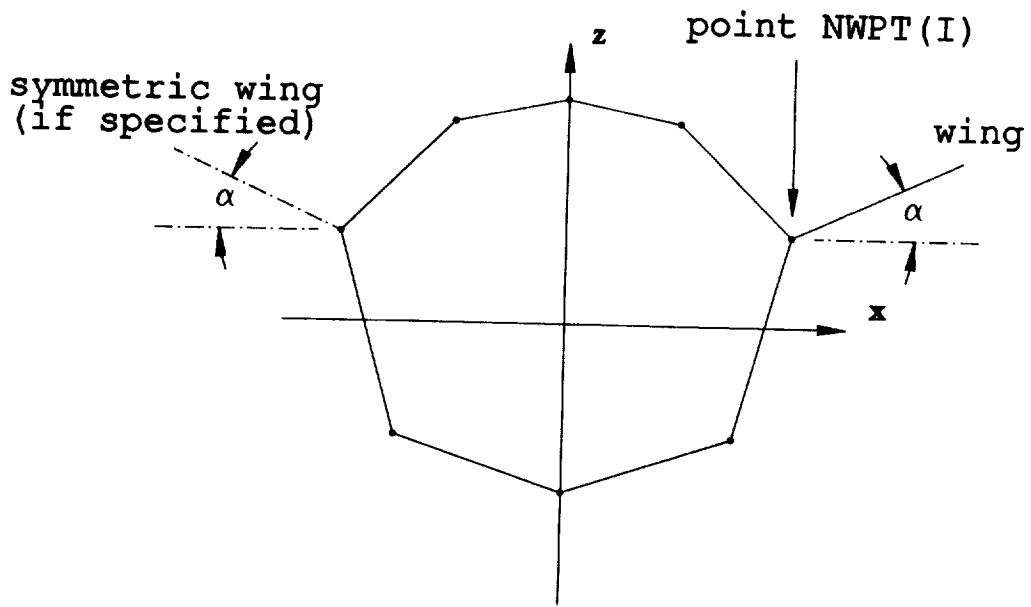


Figure 3.4: Top view of wing geometry.



$\alpha = \text{AWR}(I) = \text{angle of wing rotation}$

Figure 3.5: End view of wing geometry.

Form of the command:

WG: Wing

NWSEC(1,I), NWSEC(2,I), NWPT(I), NWSYM(I), AWR(I)

XWCN(1,I), YWCN(1,I), XWCN(2,I), YWCN(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 I<sup>th</sup> wing starts on.

NWSEC(2,I) = the number of the cross section that the I<sup>th</sup> wing ends on.

NWPT(I) = the number of the cross section point that the I<sup>th</sup> 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 I<sup>th</sup> wing. This indicating parameter is used to specify a wing symmetric to the wing given, i.e., when a pair of symmetric wings exist.

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

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

AWR(I) = angle of rotation in degrees (measured clockwise from the positive x axis) of the I<sup>th</sup> wing.

XWCN(1,I), YWCN(1,I) = the x' and y' values of the first point out away from the main body of the I<sup>th</sup> wing.

XWCN(2,I), YWCN(2,I) = the x' and y' values of the second point out away from the main body of the I<sup>th</sup> wing.

NWSEC(1,I), NWSEC(2,I) and NWPT(I) are used to describe the location of the I<sup>th</sup> 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  $I^{\text{th}}$  wing to be planar, the  $\text{NWPT}(I)^{\text{th}}$  point on cross sections  $\text{NWSEC}(1,I)$  through  $\text{NWSEC}(2,I)$  must have the same  $z$  coordinate. Note that  $\text{XWCN}(1,I)$ ,  $\text{YWCN}(1,I)$ ,  $\text{XWCN}(2,I)$  and  $\text{YWCN}(2,I)$  are referenced to the point at which the  $I^{\text{th}}$  wing starts. In other words, they are referenced to the  $(x',y')$  coordinate system with origin at point  $\text{NWPT}(I)$  on cross section number  $\text{NWSEC}(1,I)$  (see Figure 3.4).

### 3.8 TW: The Tail Wing Command

A tail wing is like a wing (see Section 3.7) except that it attaches to the thin tail section (see Section 3.6) instead of to the main body. A tail wing is modeled 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 placement parameters associated with it.

Form of the command:

**TW:** Tail Wing

**YTWS**, **ZTWS**, **YTWL**, **ITWSYM**

**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.

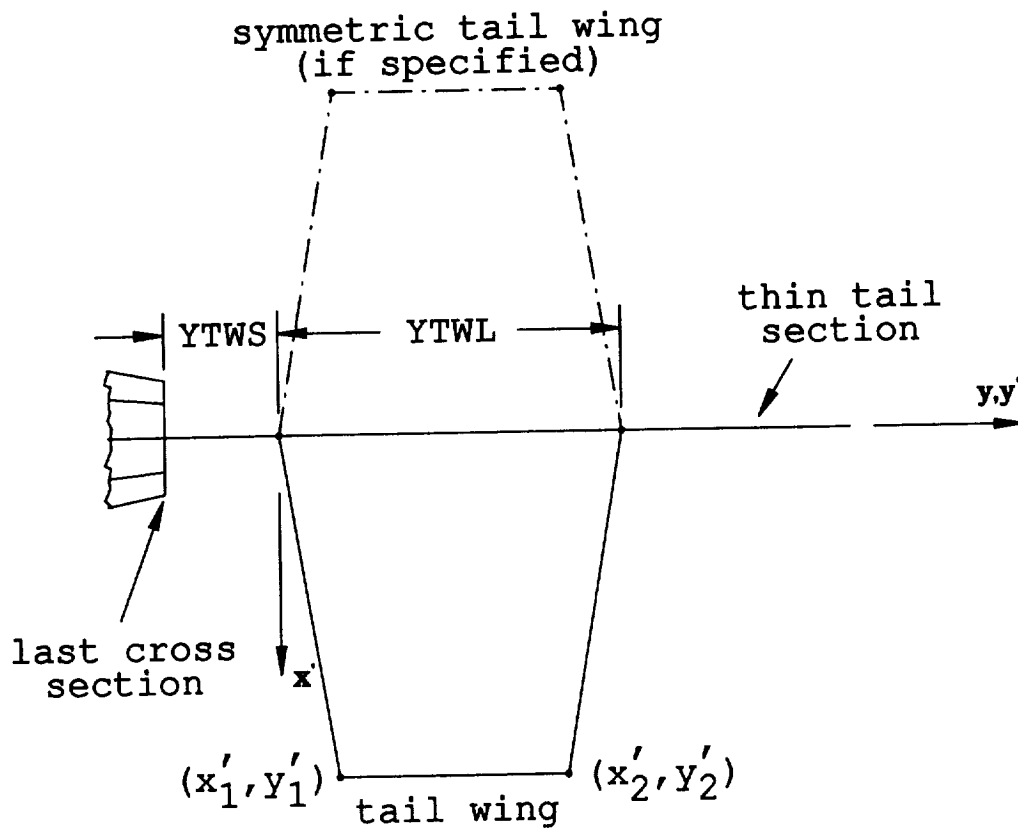
**ZTWS** = the  $z$  directed height of the tail wing with respect to point 1 of the last cross section. If **ZTWS**  $> 0$ , then the tail wing will be above point 1 of the last cross section. If **ZTWS**  $< 0$ , then the tail wing will be below point 1 of the last cross section.

**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.



$$x'_1 = XTWCN(1)$$

$$y'_1 = YTWCN(1)$$

$$x'_2 = XTWCN(2)$$

$$y'_2 = YTWCN(2)$$

Figure 3.6: Top view of tail wing geometry.

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OF POOR QUALITY

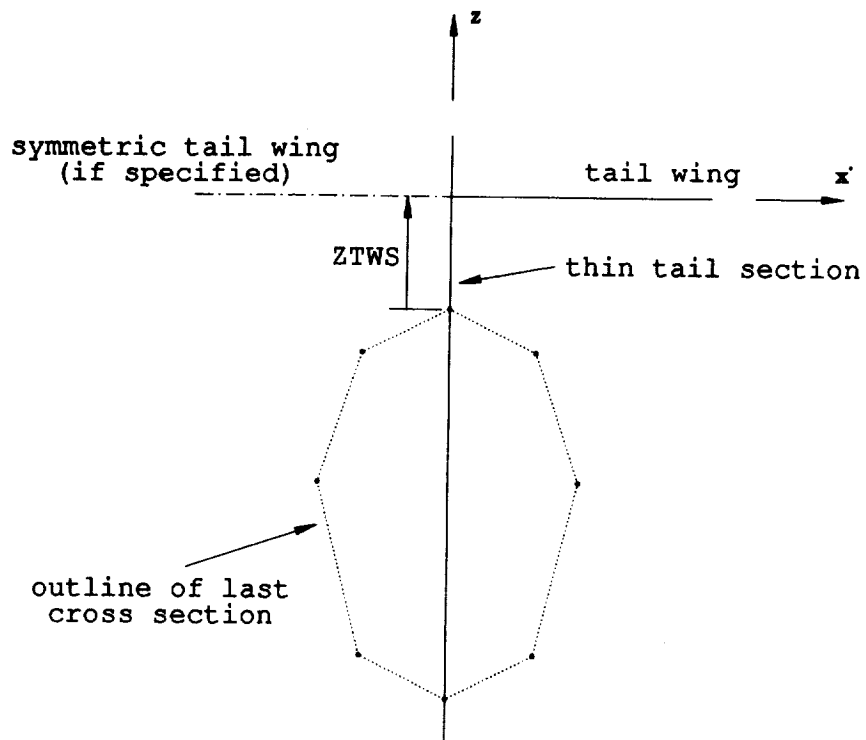


Figure 3.7: End view of tail wing geometry.



**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).

### **3.9 RT: 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 (RT) defines the diameter, placement, and angle of rotation of a four blade rotor. Figures 3.8 and 3.9 show the geometry of a four blade rotor and the dimension and placement parameters associated with it. Note that the rotor is modeled by thin wires, and thus the width of the rotor blades must be small in terms of a wavelength.

Form of the command:

RT: Rotor  
XLR, HT, ALPHA, DXR, DYR, DZR

**XLR** = the radius of the span of the rotor.

**HT** = the height of the rotor above the main body or fuselage.

**ALPHA** = the angle in degrees of the rotation of the rotor.

**DXR** = the  $x$  displacement of the rotor.

**DYR** = the  $y$  displacement of the rotor.

**DZR** = the  $z$  displacement of the rotor.

Note that **XLR, HT** and **ALPHA** define the size and orientation of the four blade rotor, while **DXR, DYR** and **DZR** define its position.

At this point:

$x = DXR$

$y = DZR$

$z = DZR$

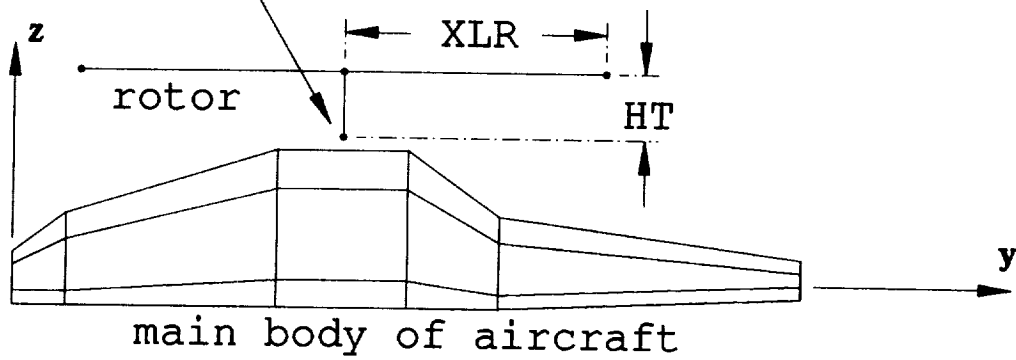
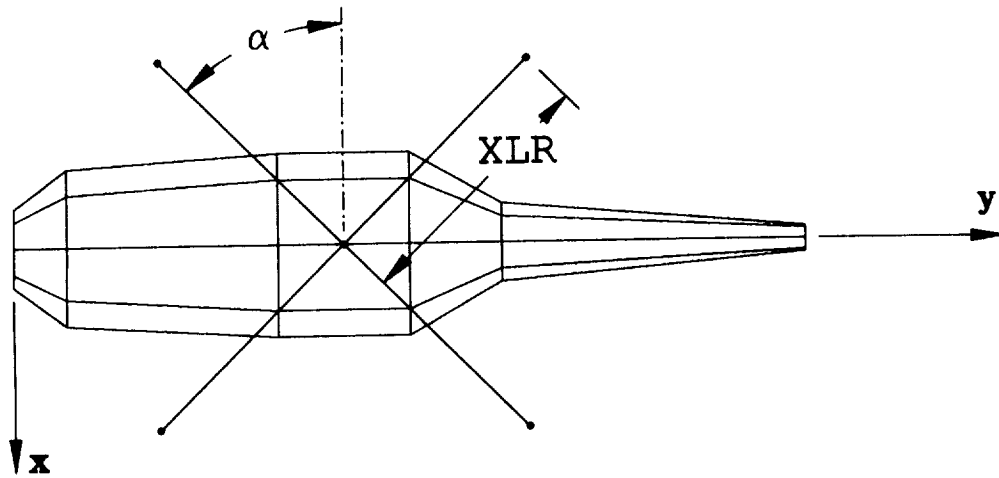


Figure 3.8: Side view of rotor geometry.



$\alpha = \text{ALPHA} = \text{angle of rotation}$

Figure 3.9: Top view of rotor geometry.

### 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.

Form of the command:

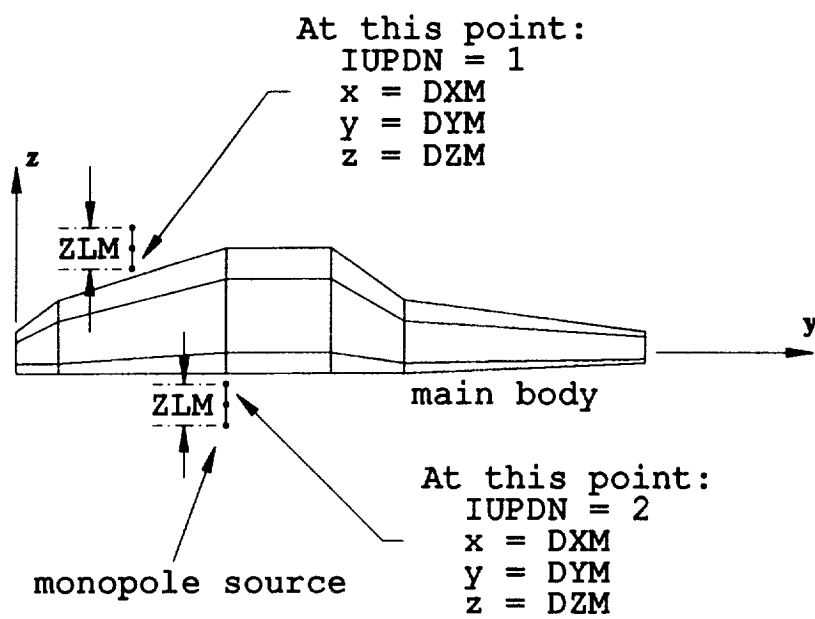
SC: Source  
IUPDN, ZLM, DXM, DYM, DZM

**IUPDN** = indicator for whether the source monopole goes up or down from the point  $(x, y, z) = (DXM, DYM, DZM)$ .

= 1 implies the source monopole goes up from  $(DXM, DYM, DZM)$ .

= 2 implies the source monopole goes down from  $(DXM, DYM, DZM)$ .

**ZLM** = the length of the source monopole.



NOTE: The user can specify only one monopole source location.

Figure 3.10: Side view of monopole source geometry.

**DXM** = the  $x$  displacement of the monopole source.

**DYM** = the  $y$  displacement of the monopole source.

**DZM** = the  $z$  displacement of the monopole source.

These parameters must be defined so that the source monopole does not touch or penetrate the main body.

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.

It should be noted that if IUPDN = 1 then the source monopole will extend a distance of ZLM upward (in the positive  $z$  direction) from the point (DXM,DYM,DZM). Likewise, if IUPDN = 2 then the source monopole will extend a distance of ZLM downward (in the negative  $z$  direction) from the point (DXM,DYM,DZM). Figure 3.10 shows the source monopole geometry for both cases. However, only one source monopole may be specified.

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 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.

Form of the command:

DG: Detailed Geometry

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

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.

### **3.12 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

# 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.

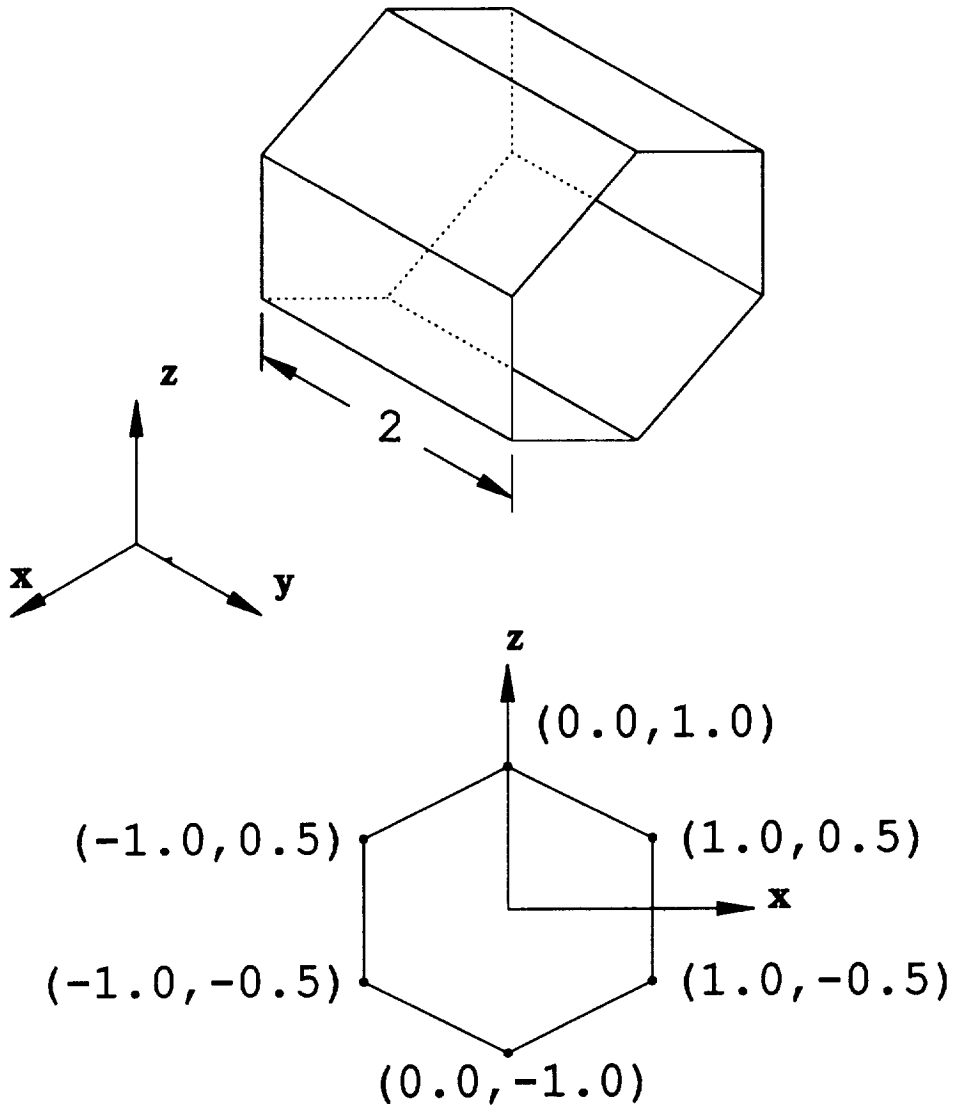
The examples shown here were run on a VAX 8550, which is about 6 times faster than a VAX 11/780. It should be mentioned that running the examples on a computer other than the VAX 8550 may produce some changes in the output.

## 4.1 Example 1: Backscattering From A Short Cylinder

Example 1 involves the computation of the far-zone elevation backscatter pattern, in the plane  $\phi = 0^\circ$ , 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  $\phi = 0^\circ$  with a 5 degree step size. Since IPSE = 1, an output file on logical unit 8 containing the patterns will be produced for plotting purposes. The FR command sets the frequency to 50.0 MHz. The NC command indicates the end of the run





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.

control commands.

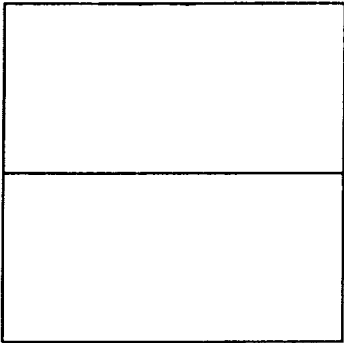
The geometry commands appear after the run control commands. Since the UN command was not invoked, all input dimensions will be in the default unit of length which is meters. The SG command defines the maximum segment size as 0.25 wavelengths. The NS command defines the cylinder as 6-sided. The SM command 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  $0.122\lambda$  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.

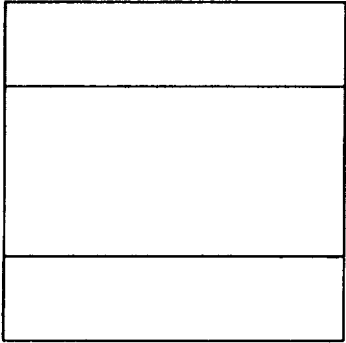
Since the EX command was invoked the code proceeds to make the desired MM computations. Since the WR command was invoked setting  $IWRZT = 1$ , the impedance matrix (in volt-amps) is printed. Normally the impedance matrix is not printed because it can be very large, however, here it was printed to document typical values. The last part of the output

# EXAMPLE 1

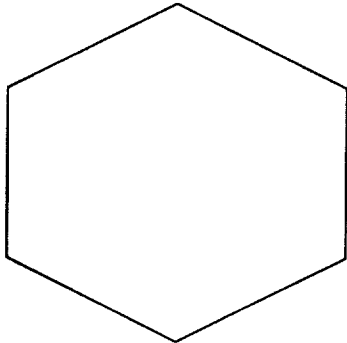


Z AXIS VIEW

0 WIRE MODES  
18 PLATE MODES  
0 ATTACH. MODES  
18 TOTAL MODES  
SCALE =  $0.122\lambda$



X AXIS VIEW



Y AXIS VIEW

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

file contains the desired patterns. The backscatter pattern in the plane  $\phi = 0^\circ$  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  $\theta$  incident and  $\theta$  scattered

**SPPM** = cross section for  $\phi$  incident and  $\phi$  scattered

**STPM** = cross section for  $\theta$  incident and  $\phi$  scattered

**SPTM** = cross section for  $\phi$  incident and  $\theta$  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<sup>2</sup> should be interpreted as essentially zero.

## 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  $\phi = 0^\circ$ , for the geometry shown in Figure 4.6. The geometry consists of a symmetric six sided body which can be defined by four cross

**EXAMPLE 1 PATTERNS**

FREQUENCY = 50.00 MHZ.

BACKSCATTER

POLARIZATION:  $\theta$ -IN  $\theta$ -OUT

ELEV. PLANE:  $\phi = 0^\circ$   $R = \infty$

MAXIMUM = 11.5 DB/M<sup>2</sup> 10 DB/DIV.

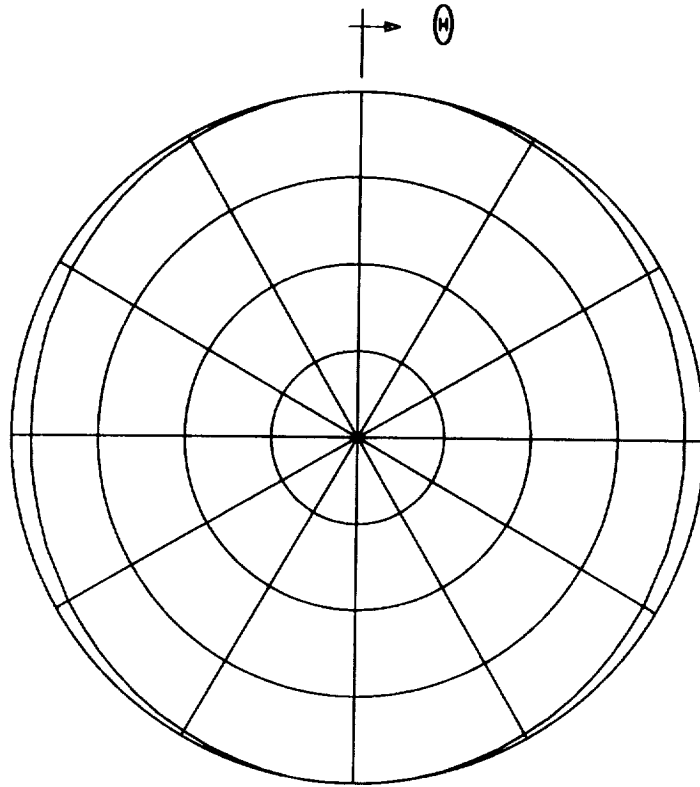


Figure 4.4: Backscatter pattern for Example 1 in the elevation plane  $\phi = 0^\circ$  and for polarization  $\theta$  incident and  $\theta$  scattered.

### EXAMPLE 1 PATTERNS

FREQUENCY = 50.00 MHZ.

BACKSCATTER

POLARIZATION:  $\phi$ -IN  $\phi$ -OUT

ELEV. PLANE:  $\phi = 0^\circ$   $R = \infty$

MAXIMUM = 9.4 DB/M<sup>2</sup> 10 DB/DIV.

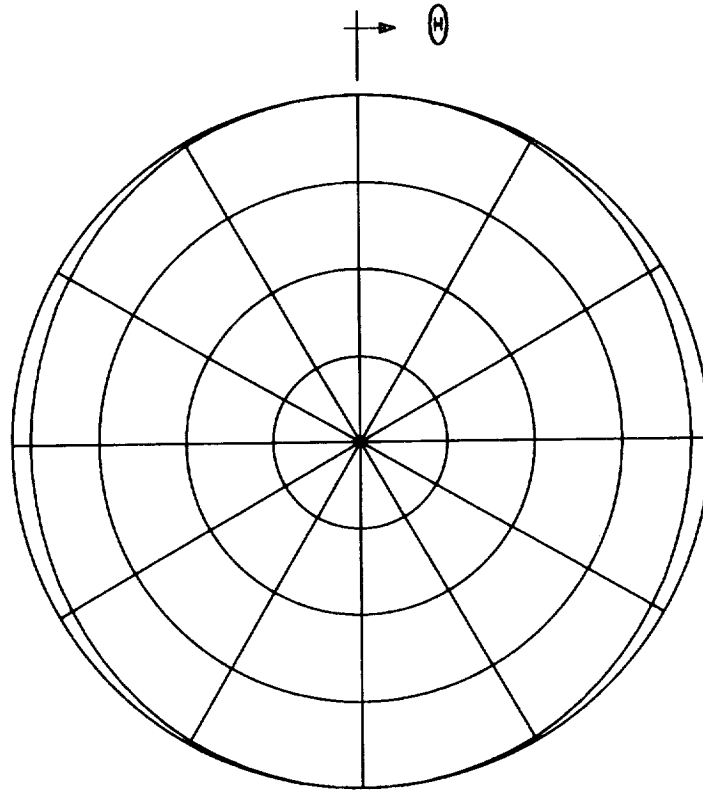


Figure 4.5: Backscatter pattern for Example 1 in the elevation plane  $\phi = 0^\circ$  and for polarization  $\phi$  incident and  $\phi$  scattered.

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  $0 \leq y \leq 6\text{m}$ .

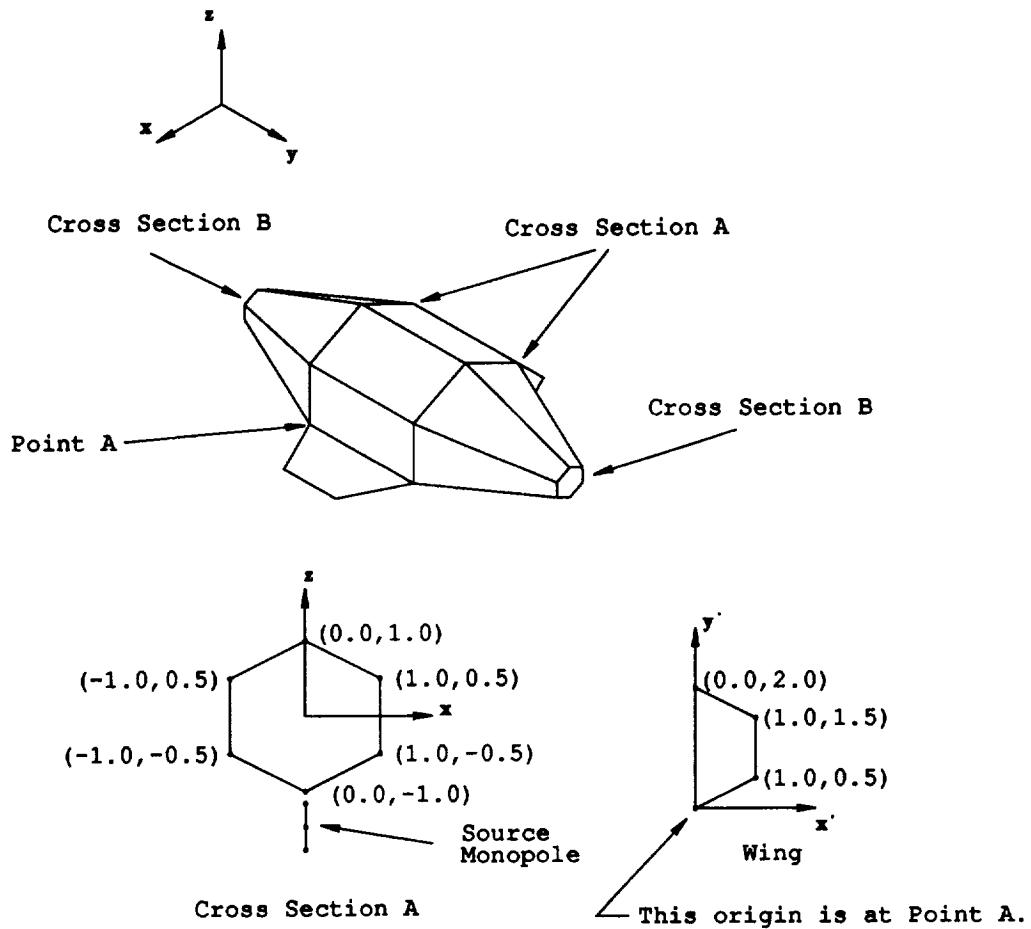
The input file for Example 2 is shown in Figure 4.7. The run control commands appear first in the input file. The EX command specifies a complete run involving electromagnetic calculations. The RE command defines an elevation radiation pattern in the plane  $\phi = 0^\circ$ . Calculations are made every 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.

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





- NOTES: 1. Cross Section B is 25% as large as Cross Section A.  
 2. All cross sections are spaced 2.0 meters apart.  
 3. The Source Monopole is located at  $y = 3.0$  meters.  
 4. All dimensions are in meters.

Figure 4.6: The geometry for Example 2 is a six sided body with a pair of wings and a radiating source monopole.

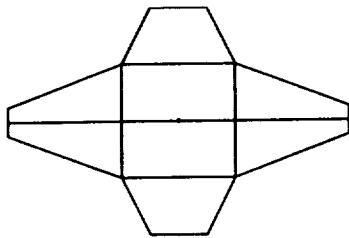
```

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
0.0 0.25
0.25 0.125
0.25 -0.125
0.0 -0.25
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
0.0 0.25
0.25 0.125
0.25 -0.125
0.0 -0.25
WG :DEFINE WING
2 3 3 1 0.0
1.0 0.5 1.0 1.5
SC :DEFINE SOURCE MONOPOLE
2 0.6 0.0 3.0 -1.12
NG :END OF GEOMETRY DATA

```

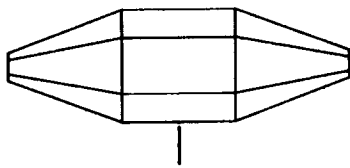
Figure 4.7: The input file for Example 2.

## EXAMPLE 2

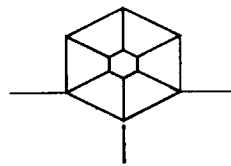


Z AXIS VIEW

1 WIRE MODES  
72 PLATE MODES  
0 ATTACH. MODES  
73 TOTAL MODES  
SCALE =  $0.367\lambda$



X AXIS VIEW



Y AXIS VIEW

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

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  $\phi = 0^\circ$  is printed. The far zone patterns include the gain (as opposed to the directive gain) for  $\theta$  and  $\phi$  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  $\phi = 0^\circ$  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  $\theta$ . 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  $\theta = 90^\circ$ , 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.

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  $\theta = 90^\circ$ . 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

**EXAMPLE 2 PATTERN**

FREQUENCY = 50.00 MHZ.

GAIN

POLARIZATION:  $\theta$

ELEV. PLANE:  $\phi = 0^\circ$   $R = \infty$

MAXIMUM = 3.1 DB 10 DB/DIV.

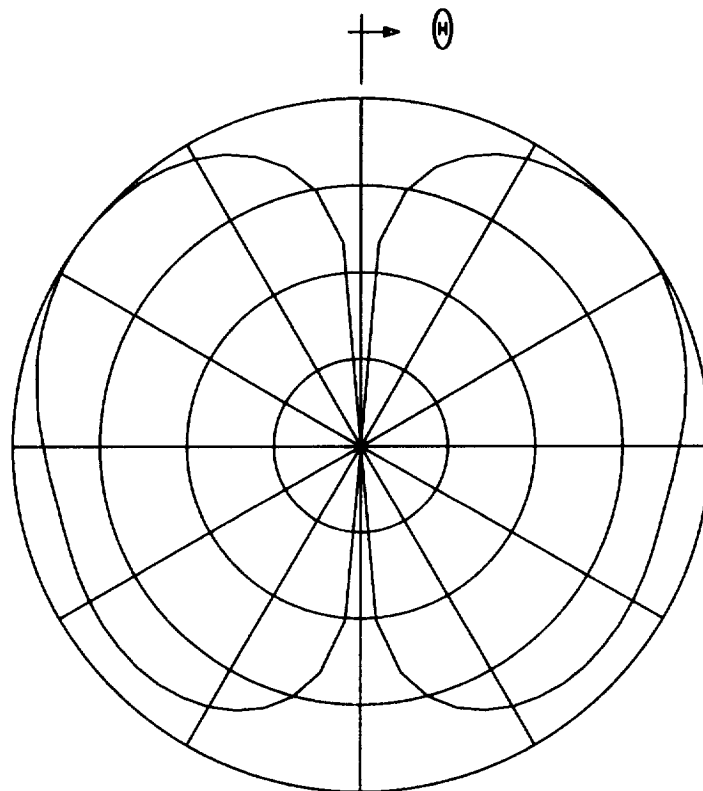


Figure 4.9:  $\theta$  polarized gain in the elevation plane  $\phi = 0^\circ$  for Example 2.

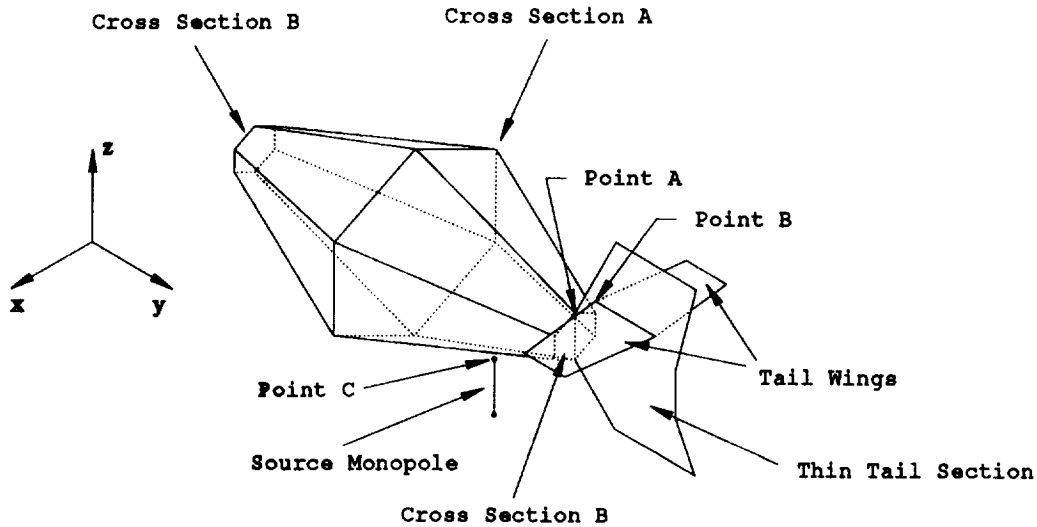
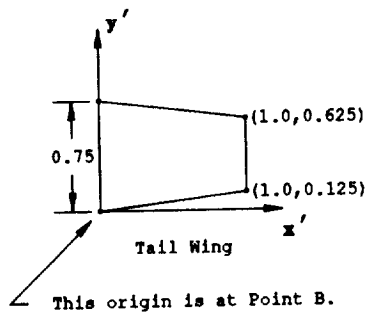
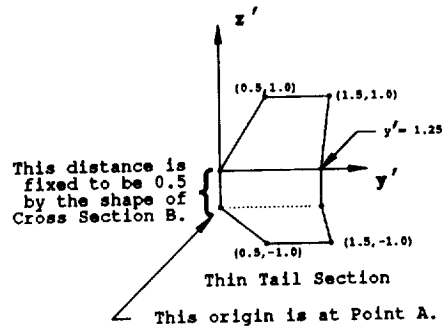
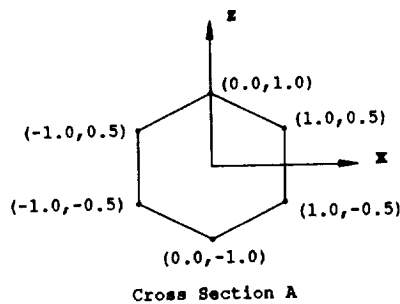


Figure 4.10: The geometry for Example 3 is a six sided body with a thin tail section, a pair of symmetric tail wings, and a radiating source monopole.

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  $y = 0\text{cm}$ ,  $y = 200\text{cm}$  and  $y = 400\text{cm}$ . Note that the cross sections on the ends of the body (those located at  $y = 0\text{cm}$  and  $y = 400\text{cm}$ ) 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

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- NOTES: 1. All cross sections are spaced 2.0 meters apart.  
 2. Cross Section B is 25% as large as Cross Section A.  
 3. Point C is located at:  
 $x = 0.0$   
 $y = 3.0$   
 $z = -0.75$   
 4. Monopole is of length 0.6 meters  
 5. All dimensions are in meters.

Figure 4.11: Detailed drawings of the cross sections, thin tail section and tail wings involved in Example 3.

### EXAMPLE 3

ROTATION ANGLE :  
PHI = 35.0 DEG  
THETA = 60.0 DEG

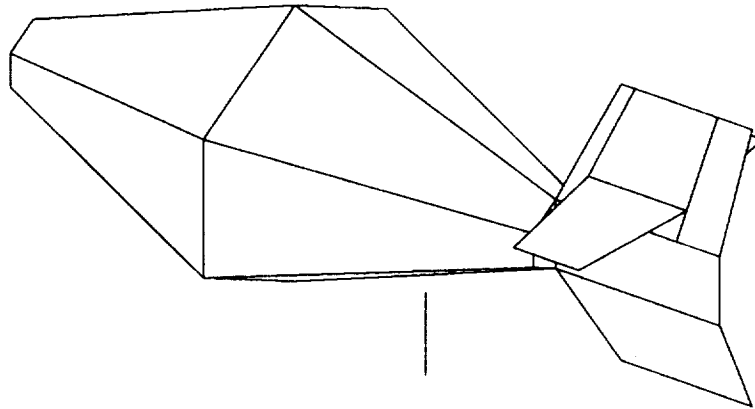


Figure 4.12: A 3-D sketch showing the geometry analyzed in Example 3.



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  $\lambda/10 = 60\text{cm}$  and is positioned  $2\lambda/100 = 12\text{cm}$  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.

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  $\theta = 90^\circ$  is printed. The far zone patterns include the gain (as opposed to the directive gain) for  $\theta$  and  $\phi$  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  $\theta = 90^\circ$  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  $\hat{\phi}$ ).

```

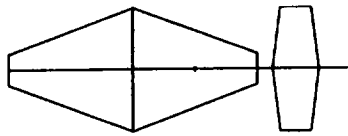
EX :EXECUTE
RA :DEFINE RADIATION AZIMUTHAL PATTERN
1 5.0 90.0
FR :DEFINE FREQUENCY
50.0
NC :END OF RUN CONTROL COMMANDS
SG :DEFINE MAXIMUM SEGMENT SIZE
0.25
NS :DEFINE NUMBER OF SIDES
6
SM :SYMMETRIC FUSELAGE
UN :DEFINE UNITS
2
DG :PRINT OUT DETAILED GEOMETRY
CS :DEFINE CROSS SECTION
0.0 0.0 0 1 0
0.0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

```

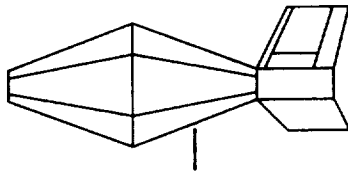
Figure 4.13: The input file for Example 3.

### EXAMPLE 3

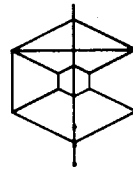
1 WIRE MODES  
83 PLATE MODES  
0 ATTACH. MODES  
84 TOTAL MODES  
SCALE =  $0.336 \lambda$



Z AXIS VIEW



X AXIS VIEW



Y AXIS VIEW

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

### EXAMPLE 3 PATTERNS

FREQUENCY = 50.00 MHZ.

GAIN

POLARIZATION:  $\theta$

AZIM. PLANE:  $\theta = 90^\circ$   $R = \infty$

MAXIMUM = 3.2 DB 10 DB/DIV.

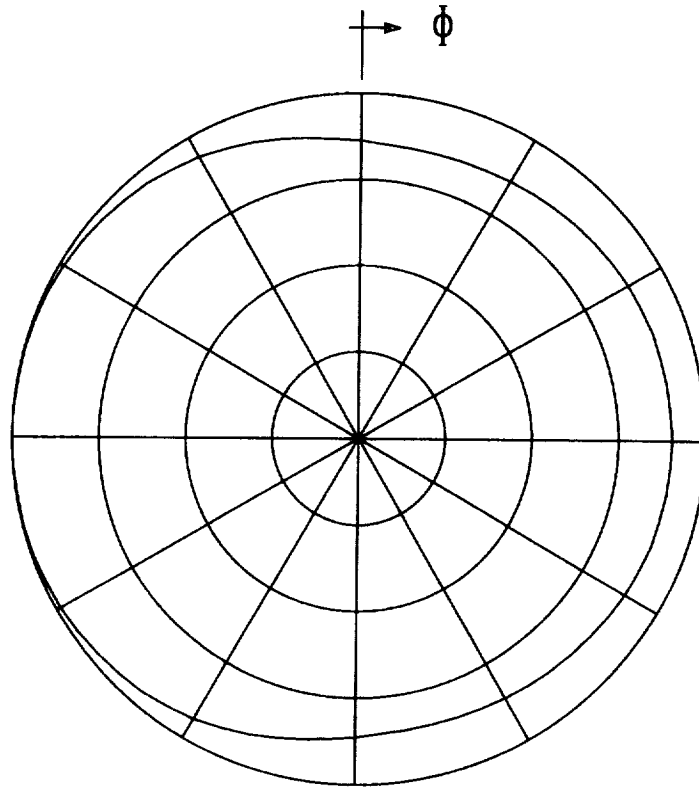


Figure 4.15:  $\theta$  polarized gain in the azimuthal plane  $\theta = 90^\circ$  for Example 3.

**EXAMPLE 3 PATTERNS**

FREQUENCY = 50.00 MHZ.

GAIN

POLARIZATION:  $\phi$

AZIM. PLANE:  $\theta = 90^\circ$   $R = \infty$

MAXIMUM = -6.6 DB 10 DB/DIV.

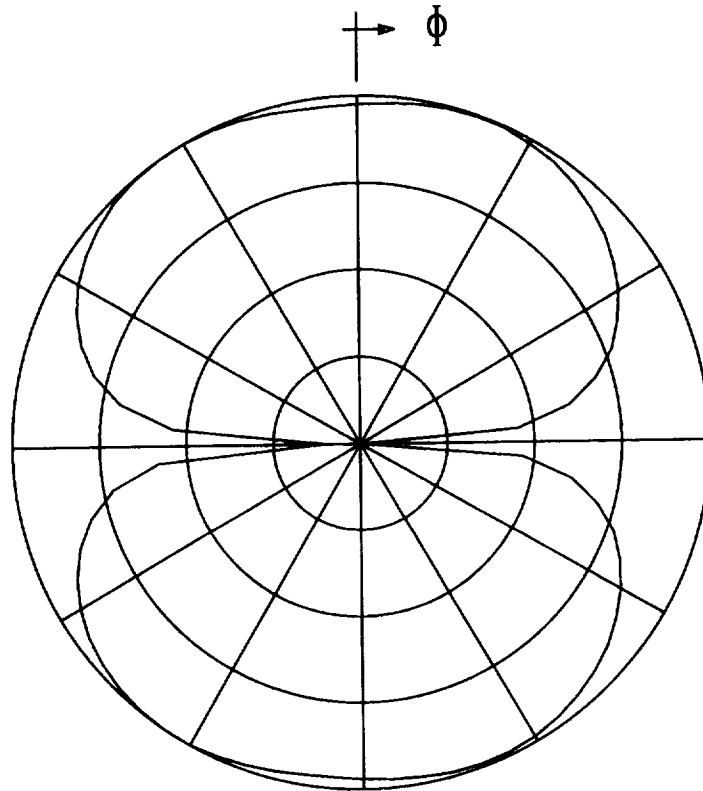


Figure 4.16:  $\phi$  polarized gain in the azimuthal plane  $\theta = 90^\circ$  for Example 3.

## 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  $\theta = 90^\circ$ .

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 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  $\theta = 90^\circ$ . The pattern will be made at 2 degree intervals, and a 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  $\text{NSIDE}/2 + 1 = 5$  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  $y = 0\text{m}$ ,  $y = 1\text{m}$ ,  $y = 2\text{m}$ ,  $y = 3\text{m}$  and  $y = 5\text{m}$ . Note that the cross section at  $y = 3\text{m}$  is interpolated from the cross sections defined by the 3<sup>rd</sup> and 4<sup>th</sup> CS commands. Also, note that the cross sections on the ends of the body (those located at  $y = 0\text{m}$  and  $y = 5\text{m}$ ) are specified to have

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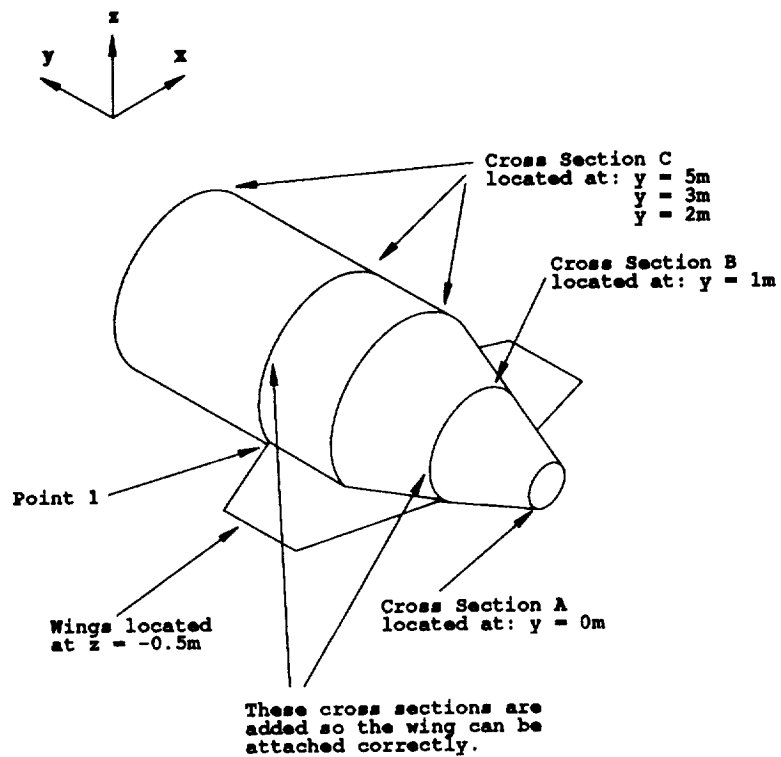
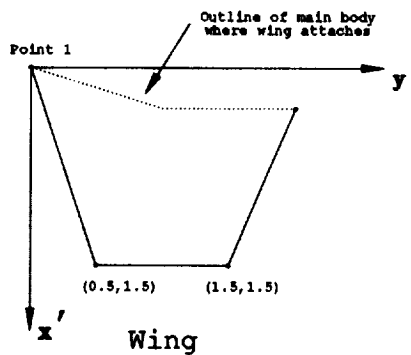
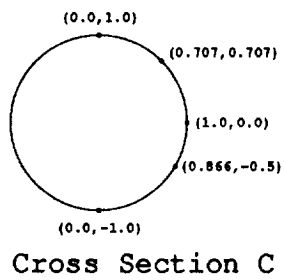
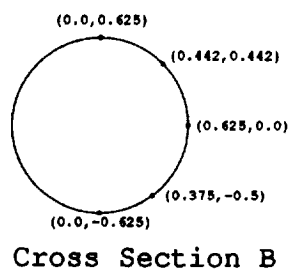
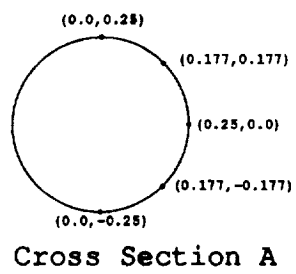


Figure 4.17: The geometry for Example 4 is a winged body.

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NOTE: All dimensions are in meters.

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



# EXAMPLE 4

ROTATION ANGLE :  
PHI = 320.0 DEG  
THETA = 60.0 DEG

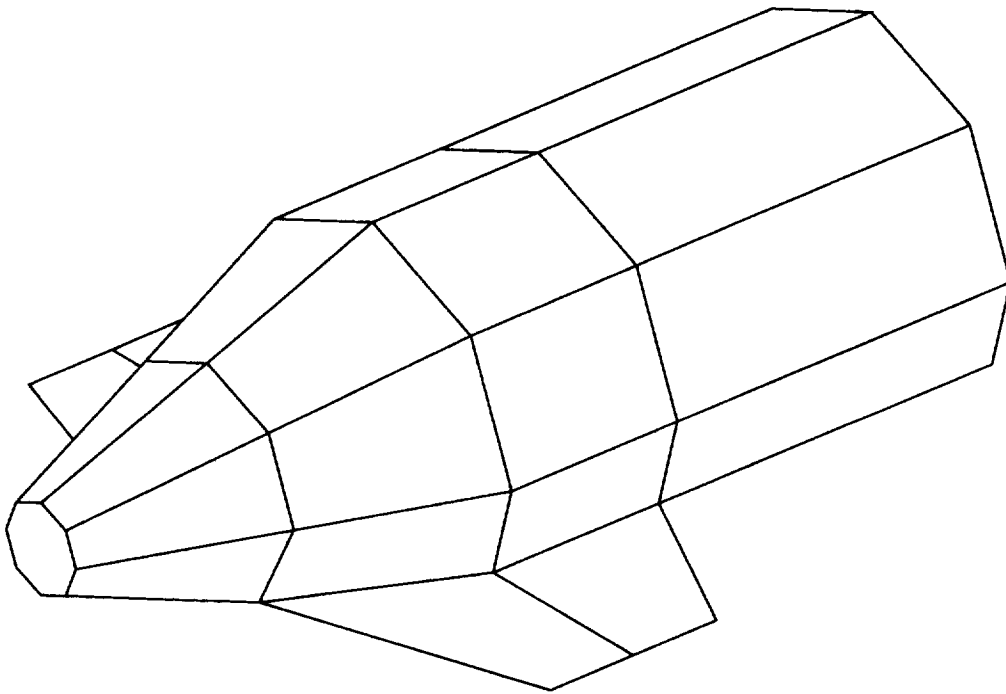


Figure 4.19: A 3-D sketch showing the geometry analyzed in Example 4.

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  $y = 3\text{m}$  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 be 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 attached at point 4 on the 2<sup>nd</sup> and the 4<sup>th</sup> cross sections. The symmetric wing is also included. The 4<sup>th</sup> cross section was added using interpolation. The geometry of Example 4 contains 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  $\theta = 90^\circ$  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  $\text{IPSA} = 1$  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.

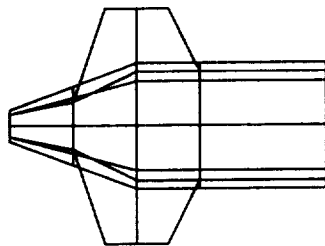
```

EX: EXECUTE
SA: DEFINE SCATTERING AZIMUTH PLANE
1 1 2.0 90.0 0.0 0.0
FR: 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 WING
2 4 4 1 0.000
1.500 0.500 1.500 1.500
NG: END OF GEOMETRY DATA

```

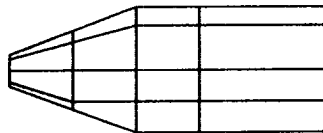
Figure 4.20: The input file for Example 4.

## EXAMPLE 4

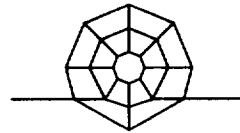


Z AXIS VIEW

0 WIRE MODES  
145 PLATE MODES  
0 ATTACH. MODES  
145 TOTAL MODES  
SCALE<sub>1</sub> = 0.428λ



X AXIS VIEW



Y AXIS VIEW

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

**EXAMPLE 4 PATTERNS**

FREQUENCY = 70.00 MHZ.

BACKSCATTER

POLARIZATION:  $\theta$ -IN  $\theta$ -OUT

AZIM. PLANE:  $\theta = 90^\circ$   $R = \infty$

MAXIMUM = 13.4 DB/M<sup>2</sup> 10 DB/DIV.

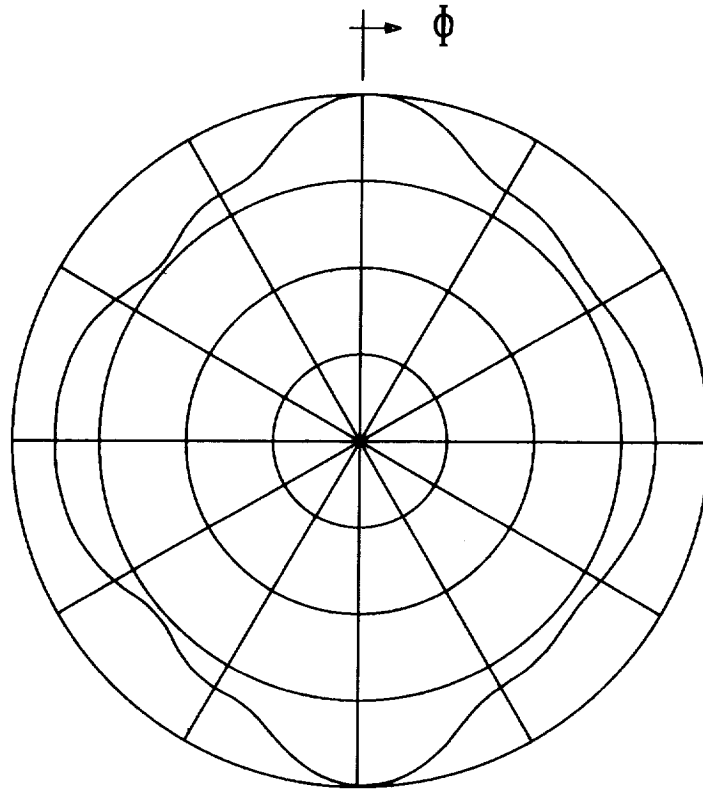


Figure 4.22: Backscatter pattern for Example 4 in the azimuth plane  $\theta = 90^\circ$  and for polarization  $\theta$  incident and  $\theta$  scattered.

**EXAMPLE 4 PATTERNS**

FREQUENCY = 70.00 MHZ.

BACKSCATTER

POLARIZATION:  $\phi$ -IN  $\phi$ -OUT

AZIM. PLANE:  $\theta = 90^\circ$   $R = \infty$

MAXIMUM = 16.8 DB/M<sup>2</sup> 10 DB/DIV.

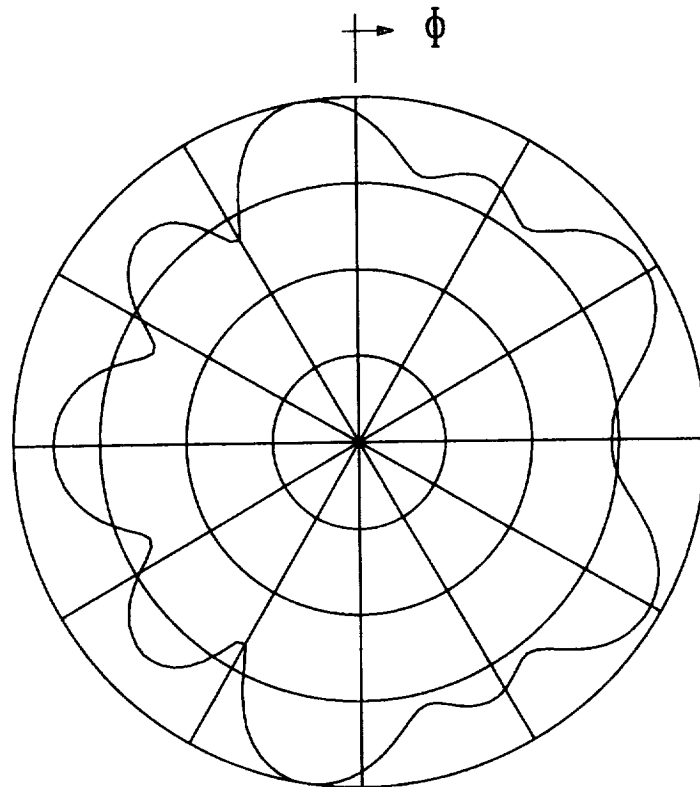


Figure 4.23: Backscatter pattern for Example 4 in the azimuth plane  $\theta = 90^\circ$  and for polarization  $\phi$  incident and  $\phi$  scattered.

**EXAMPLE 4 PATTERNS**

FREQUENCY = 70.00 MHZ.

BACKSCATTER

POLARIZATION:  $\theta$ -IN  $\phi$ -OUT

AZIM. PLANE:  $\theta = 90^\circ$   $R = \infty$

MAXIMUM = 2.8 DB/M<sup>2</sup> 10 DB/DIV.

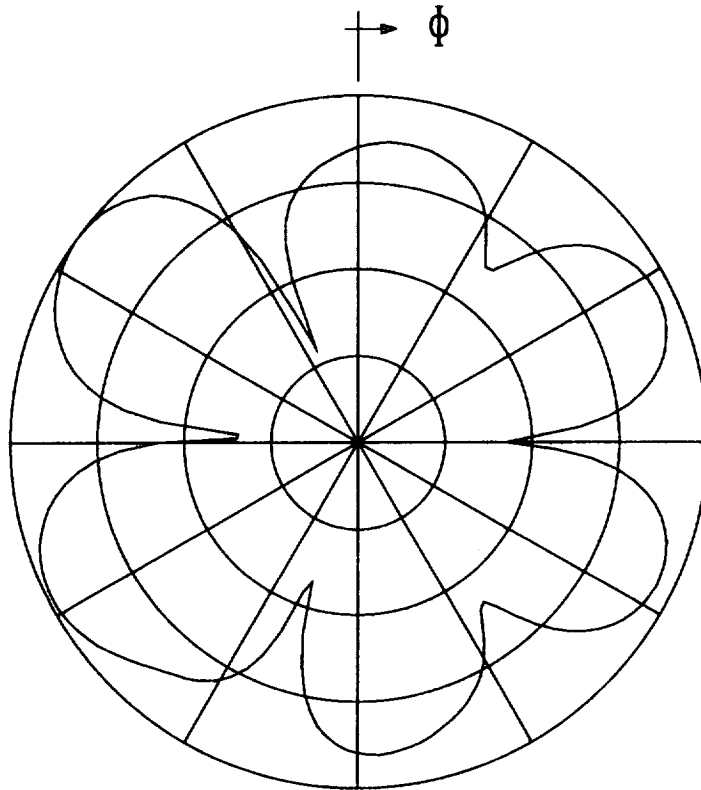


Figure 4.24: Backscatter pattern for Example 4 in the azimuth plane  $\theta = 90^\circ$  and for polarization  $\theta$  incident and  $\phi$  scattered.

#### EXAMPLE 4 PATTERNS

FREQUENCY = 70.00 MHZ.

BACKSCATTER

POLARIZATION:  $\phi$ -IN  $\theta$ -OUT

AZIM. PLANE:  $\theta = 90^\circ$   $R = \infty$

MAXIMUM = 3.4 DB/M<sup>2</sup> 10 DB/DIV.

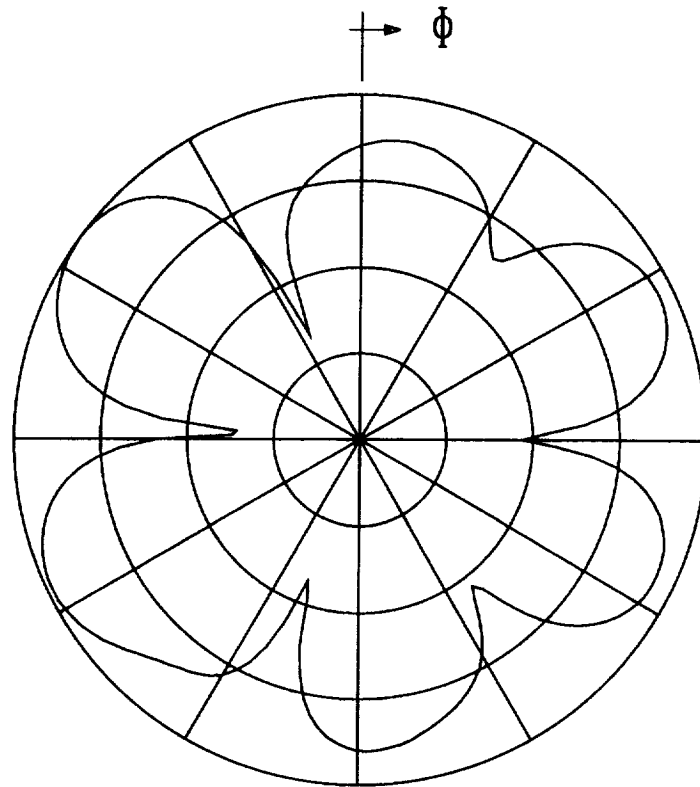


Figure 4.25: Backscatter pattern for Example 4 in the azimuth plane  $\theta = 90^\circ$  and for polarization  $\phi$  incident and  $\theta$  scattered.



## 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 command defines a radiation pattern in the elevation plane  $\phi = 0.0^\circ$ . 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  $\text{NSIDE}/2 + 1 = 5$  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<sup>th</sup> and 7<sup>th</sup> CS commands specify that new cross sections be added by interpolation. The first new cross section will be placed at  $y = 69.82\text{cm}$  by interpolating the cross sections defined by the 6<sup>th</sup> and 7<sup>th</sup> CS commands. Similarly, the second new cross section will be placed at  $y = 86.48\text{cm}$  by interpolating the cross sections defined by the

## EXAMPLE 5

ROTATION ANGLE :  
PHI = 45.0 DEG  
THETA = 55.0 DEG

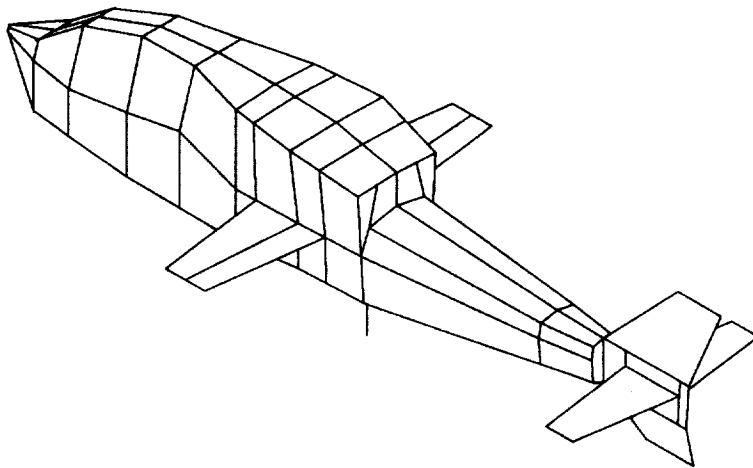


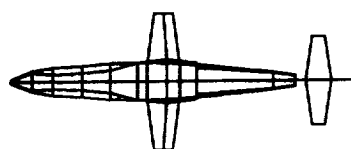
Figure 4.26: A 3-D sketch showing the helicopter analyzed in Example 5.

7<sup>th</sup> and 8<sup>th</sup> 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<sup>th</sup> 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<sup>th</sup> and 9<sup>th</sup> 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<sup>th</sup> and the 9<sup>th</sup> cross section. Note that the 7<sup>th</sup> and the 9<sup>th</sup> 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  $x = 0.0\text{cm}$ ,  $y = 87.63\text{cm}$  and  $z = -15.0\text{cm}$ . 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<sup>th</sup> and the 9<sup>th</sup> 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

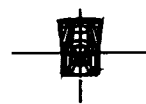
## EXAMPLE 5



Z AXIS VIEW



X AXIS VIEW



Y AXIS VIEW

1 WIRE MODES  
234 PLATE MODES  
0 ATTACH. MODES  
235 TOTAL MODES  
SCALE =  $0.428\lambda$

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

pattern in the plane  $\phi = 0^\circ$  is printed. The far zone patterns include the gain for  $\theta$  and  $\phi$  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  $\phi = 0^\circ$  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 [16]. 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 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.

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 PATTERNS**

FREQUENCY = 200.00 MHZ.

GAIN

POLARIZATION:  $\theta$

ELEV. PLANE:  $\phi = 0^\circ$   $R = \infty$

MAXIMUM = 1.7 DB 10 DB/DIV.

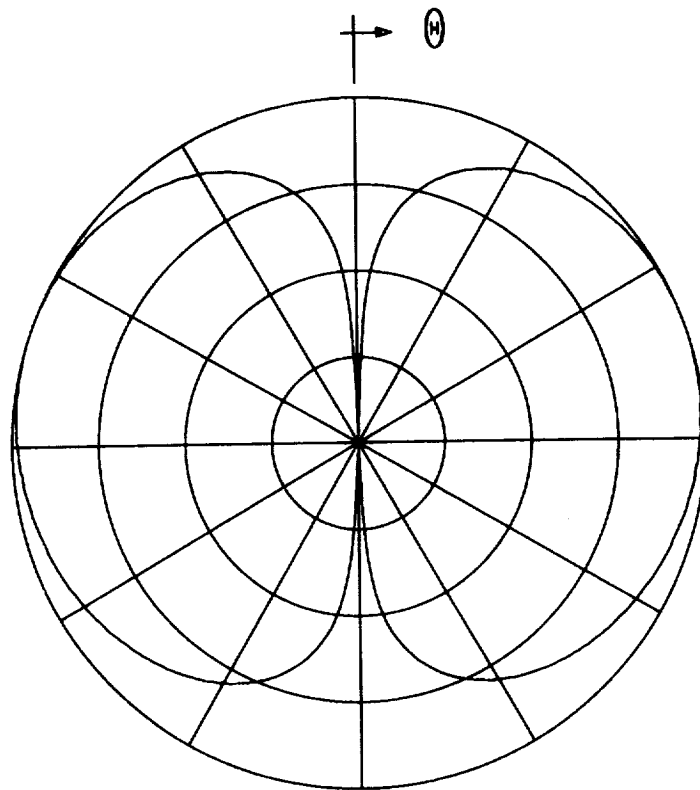


Figure 4.28:  $\theta$  polarized gain in the elevation plane  $\phi = 0^\circ$  for Example 5.

**EXAMPLE 5 PATTERNS**

FREQUENCY = 200.00 MHZ.

GAIN

POLARIZATION:  $\phi$

ELEV. PLANE:  $\phi = 0^\circ$   $R = \infty$

MAXIMUM = -10.8 DB 10 DB/DIV.

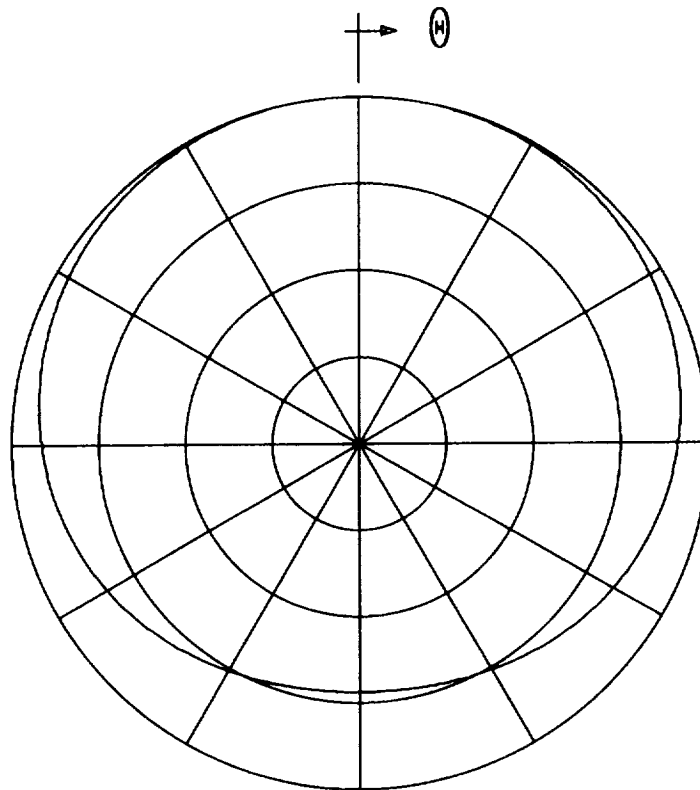


Figure 4.29:  $\phi$  polarized gain in the elevation plane  $\phi = 0^\circ$  for Example 5.

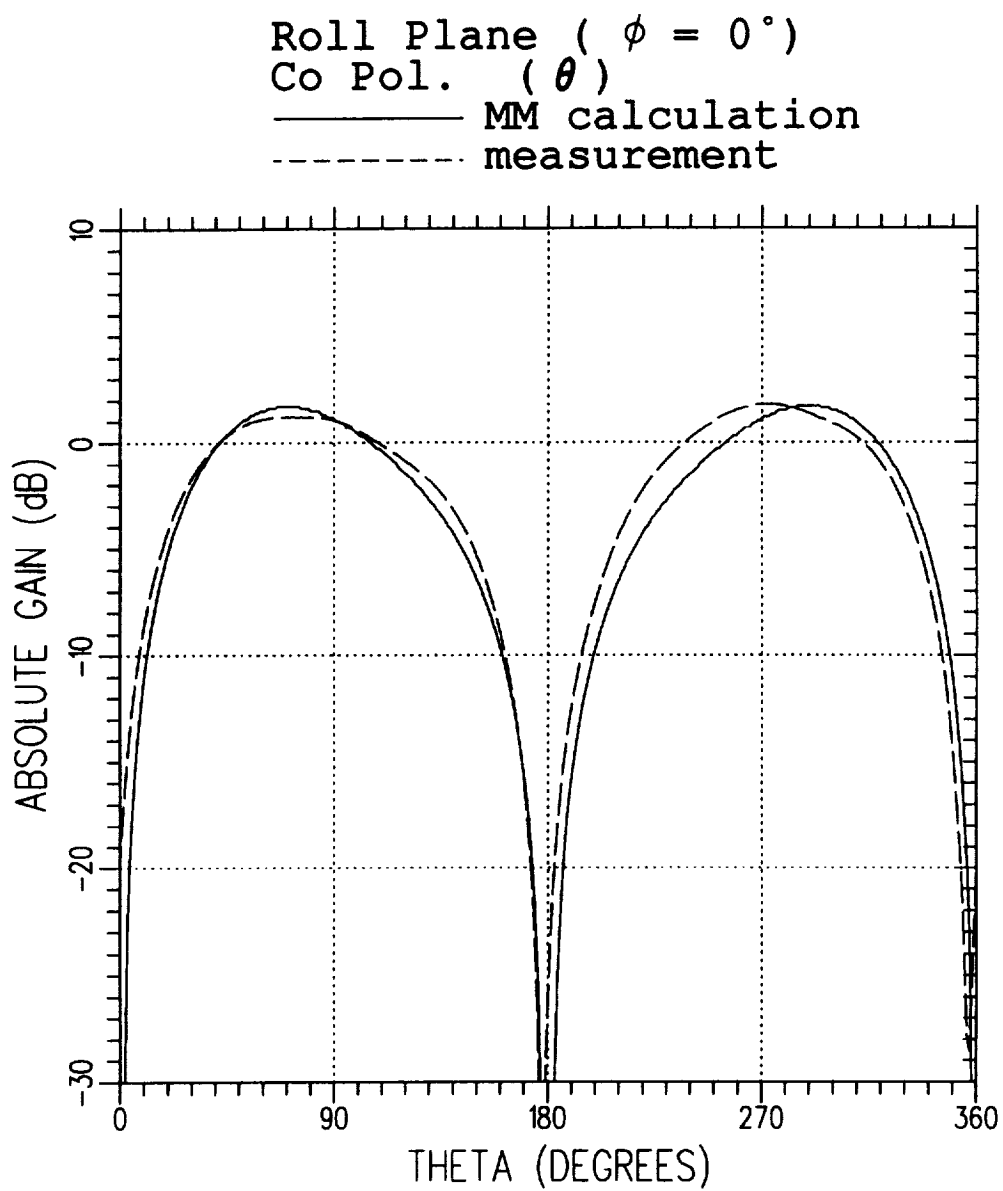


Figure 4.30: A comparison of the AMC computed pattern to measured pattern for the  $\theta$  polarized gain in the plane  $\phi = 0.0^\circ$  for Example 5.



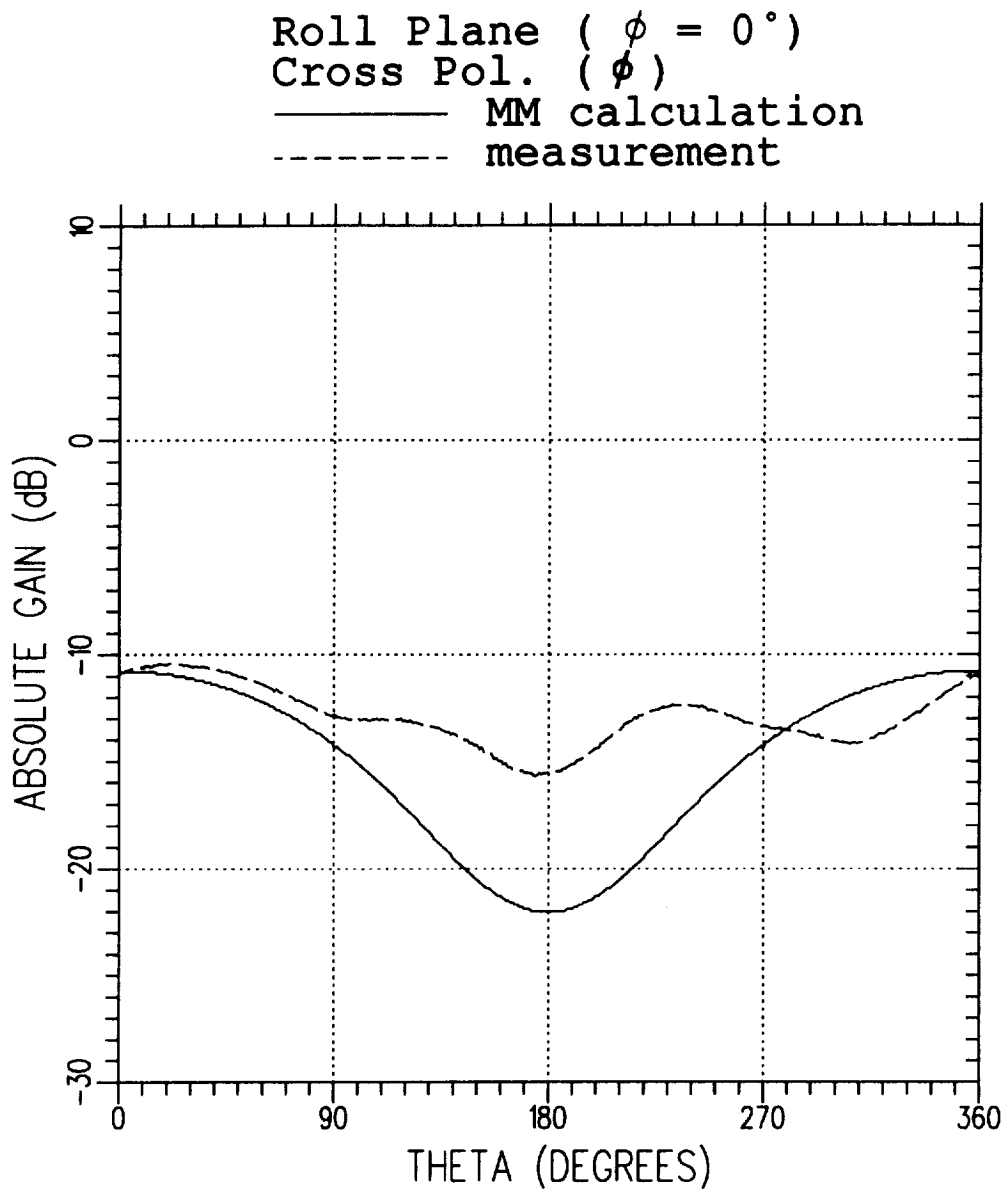


Figure 4.31: A comparison of the AMC computed pattern to measured pattern for the  $\phi$  polarized gain in the plane  $\phi = 0.0^\circ$  for Example 5.

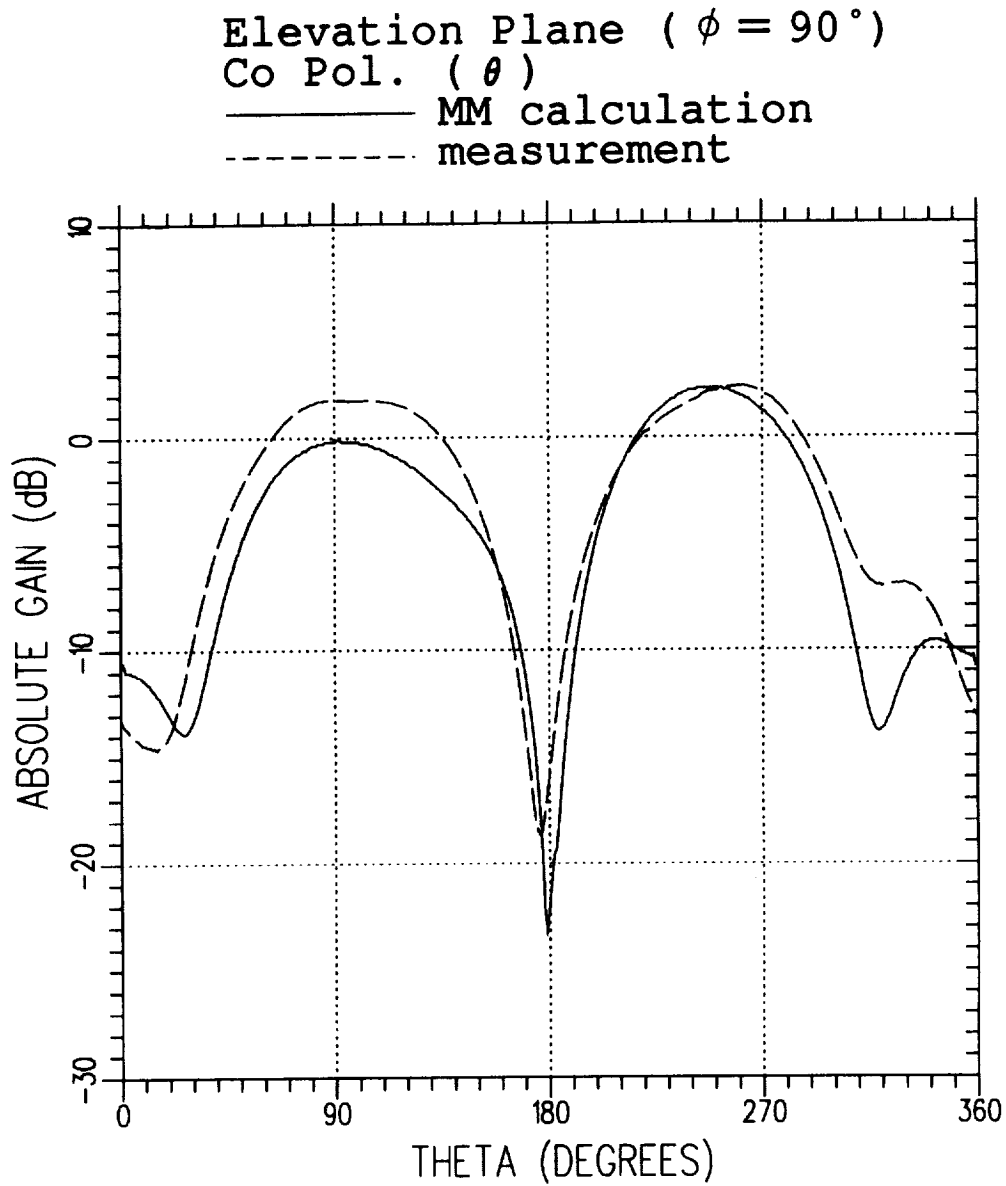


Figure 4.32: A comparison of the AMC computed pattern to measured pattern for the  $\theta$  polarized gain in the plane  $\phi = 90.0^\circ$ .

Elevation Plane ( $\phi = 90^\circ$ )  
Cross Pol. ( $\phi$ )  
—— MM calculation  
- - - - measurement

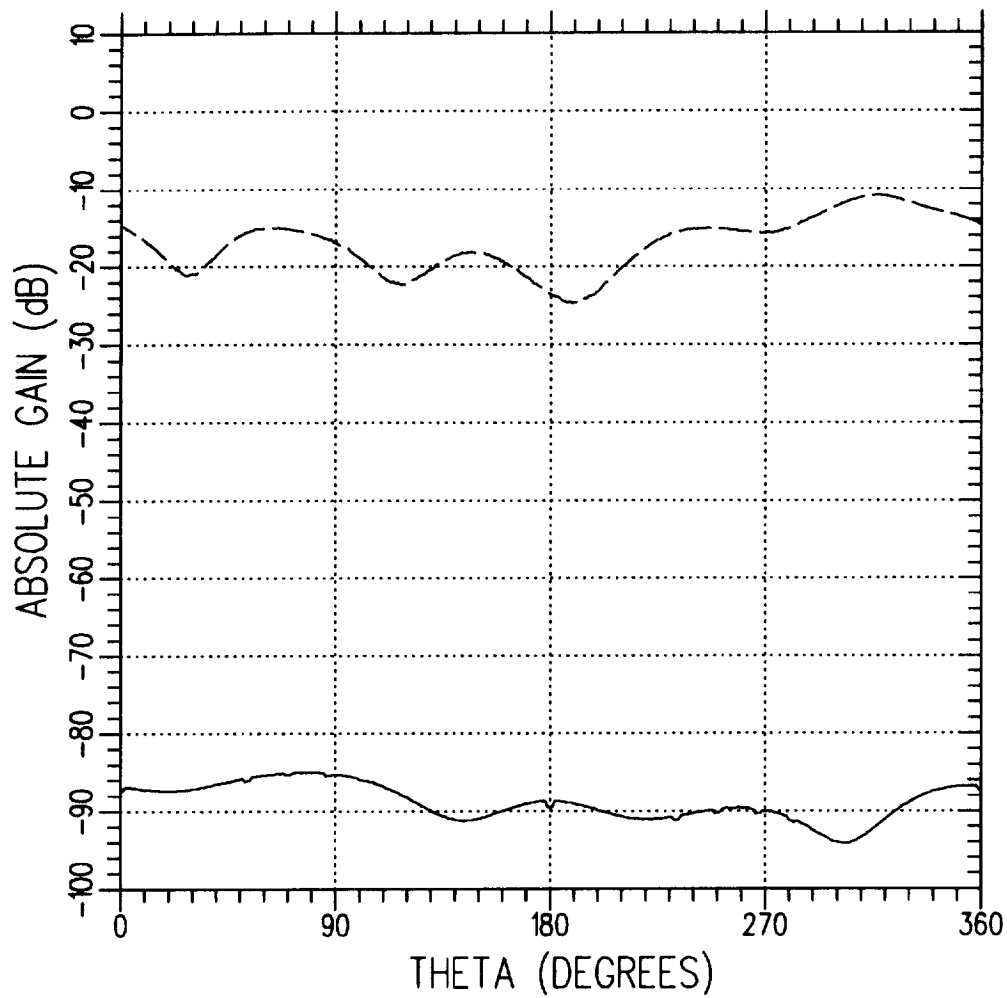


Figure 4.33: A comparison of the AMC computed pattern to measured pattern for the  $\phi$  polarized gain in the plane  $\phi = 90.0^\circ$ .

Azimuth Plane ( $\theta = 90^\circ$ )

Co Pol. ( $\theta$ )

———— MM calculation

----- measurement

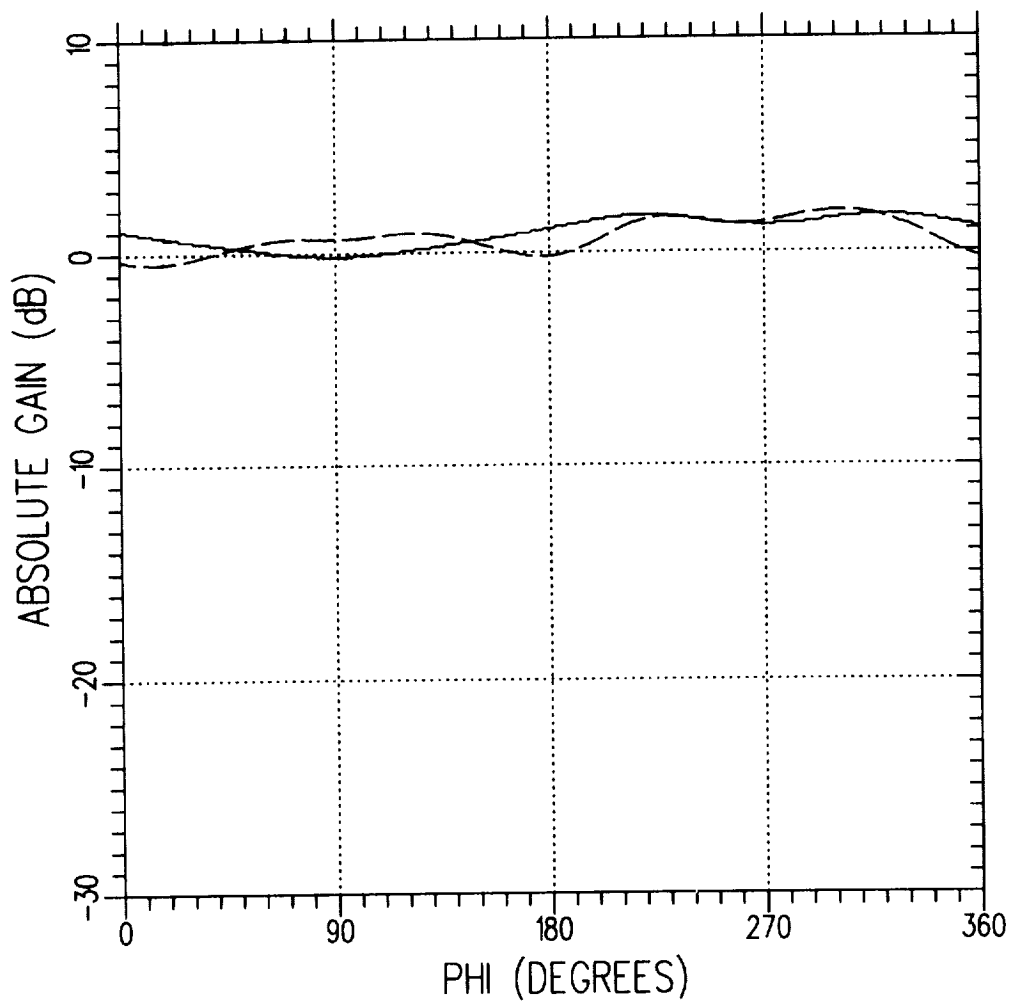


Figure 4.34: A comparison of the AMC computed pattern to measured pattern for the  $\theta$  polarized gain in the plane  $\theta = 90.0^\circ$ .

Azimuth Plane ( $\theta = 90^\circ$ )

Cross Pol. ( $\phi$ )

———— MM calculation

----- measurement

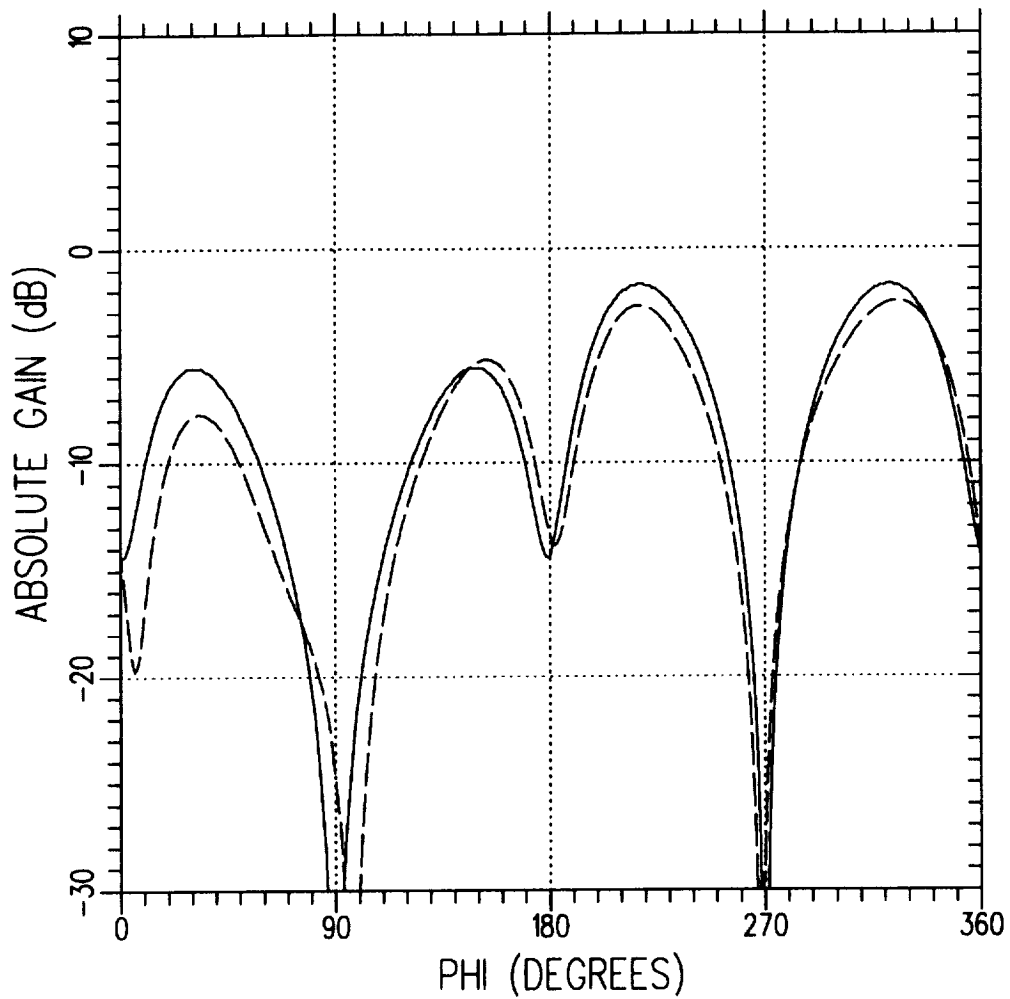


Figure 4.35: A comparison of the AMC computed pattern to measured pattern for the  $\phi$  polarized gain in the plane  $\theta = 90.0^\circ$ .

## 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 (GM-PLOT.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 [15]. 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 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).

**IERSR** has to do with wire-to-plate attachments. Thus, IERSR 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 or 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 **IDFIL** = 1 (default status), then **IDSUR** must be 1. If the **TM** command sets **IDFIL** = 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 dimensioned for **IDFIL** = 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, **IDFIL** 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 (**IDFIL**=0) or filament testing (**IDFIL**=1) is used. If **IDFIL** = 0, then the impedance matrix is stored in the one dimensional complex array **ZT**, while if **IDFIL** = 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 **IDFIL** = 0, an  $N$  by  $N$  symmetric matrix would result in only  $(N * N + N)/2$  elements in the one dimensional array **ZT**. When **IDFIL** = 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**

**IERSR = 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 GMPLLOT.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 GMPLLOT.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 GMPLLOT.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  $I \in \{1, 2, \dots, NP\}$

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

**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<sup>st</sup> polarization only

IPN = 2  $\Rightarrow$  2<sup>nd</sup> 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  $J^{\text{th}}$  corner of monopole A of the  $I^{\text{th}}$  surface patch mode.  $J \in \{1,2,3,4\}$ ,  $I \in \{1,2,\dots, \text{NPLTM}\}$ .

**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  $NC^{\text{th}}$  corner of plate NPL where  $NC \in \{1,2,\dots, \text{NCNRS(NPL)}\}$  and  $NPL \in \{1,2,\dots, \text{NPLTS}\}$

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

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  $\text{IOVT(I,1)}, \text{IOVT(I,3)} \in \{1,2,\dots, \text{NPLTS}\}$

and  $\text{IOVT(I,1)} \neq \text{IOVT(I,3)}$ ,

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

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

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  $\text{NCNRS(NPL)}$  connects corners  $\text{NCNRS(NPL)}$  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  $NDNPLT(NPLTS) + 1$  through  $NDNPLT(NPLTS) + ITK(1)$ . The second overlap 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:

$$\begin{aligned} \text{PA1} = \text{PB1} &= ( \text{PA}(I,1,1), \text{PA}(I,1,2), \text{PA}(I,1,3) ) \\ &= ( \text{PB}(I,1,1), \text{PB}(I,1,2), \text{PB}(I,1,3) ). \end{aligned}$$

Similarly, the coordinates of PB3 are:

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

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 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.

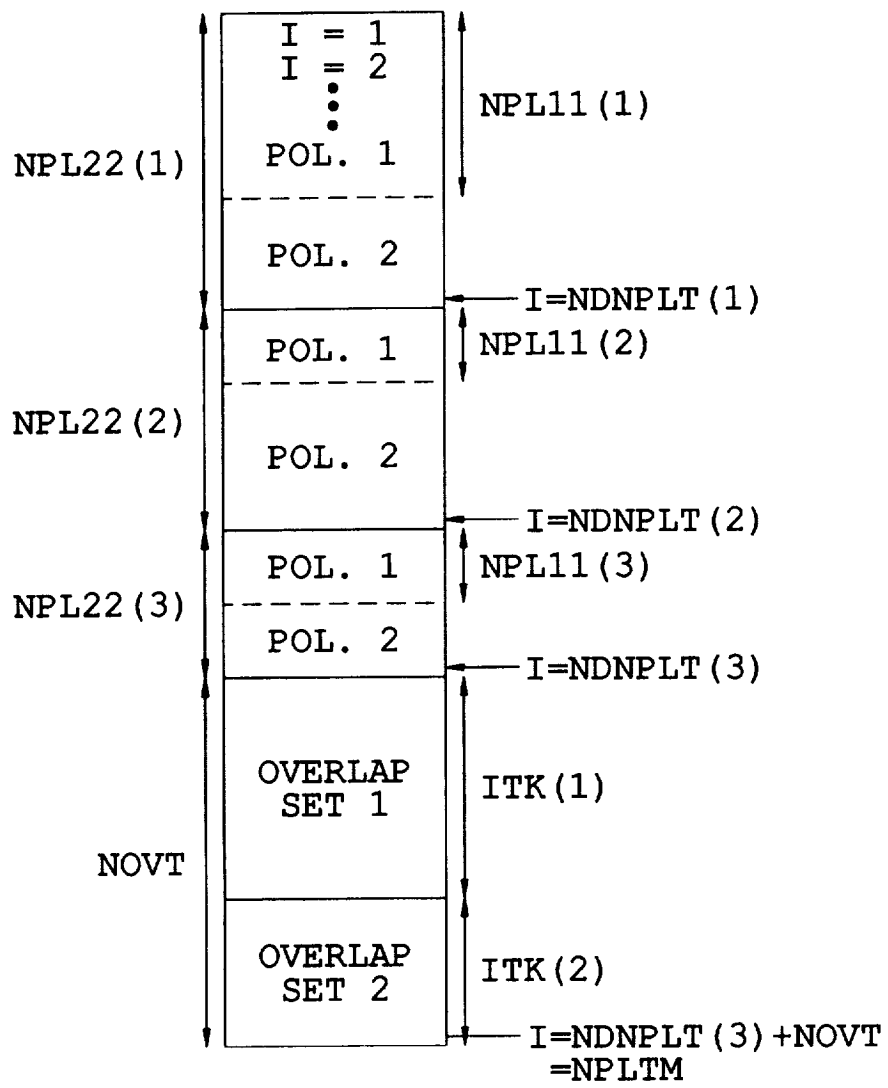


Figure 5.1: Numbering scheme for the PA or PB arrays for a geometry with NPLTS = 3 plates and NOPL = 2 overlap sets.



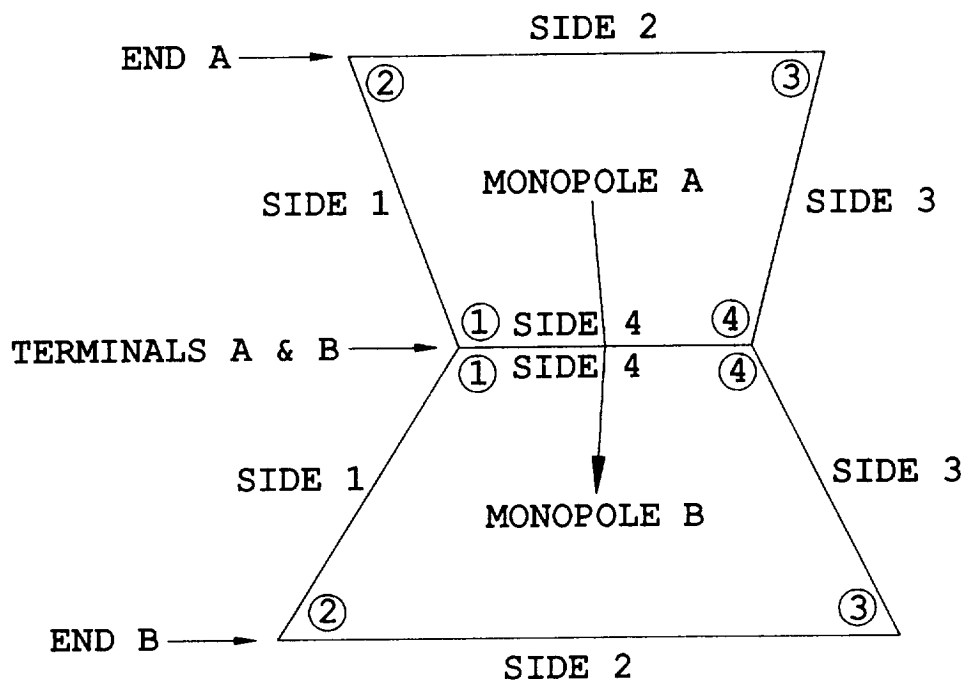


Figure 5.2: A typical dipole surface patch mode or overlap mode.

**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  $I \in \{1, 2, \dots, \text{NPATS}\}$   
**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  $I \in \{1, 2, \dots, \text{NPATS}\}$ .

**CANG(I)** = constant or fixed angle for pattern I  
= fixed angle  $\phi$  ( $^\circ$ ) for elevation patterns (**IEA(I) = 1**)  
= fixed angle  $\theta$  ( $^\circ$ ) 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)** =  $\theta$  and  $\phi$  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  $\theta$  polarization  
K = 2 for  $\phi$  polarization  
K = 3 for  $r$  polarization.

**SCATPO(I,J,K)** = Radar cross section ( $\text{meter}^2$ ) 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  $\theta$  in  $\theta$  out polarization  
K = 2 for  $\phi$  in  $\phi$  out polarization  
K = 3 for  $\theta$  in  $\phi$  out polarization  
K = 4 for  $\phi$  in  $\theta$  out polarization

K = 5 for  $\theta$  in  $r$  out polarization  
K = 6 for  $\phi$  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 modeling 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 = 600  
ICN = 12  
IPL = 120  
IAT = 1  
ITOT = 600  
IDZT = 20100  
IDZTF = 600

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	0.50347E+00	0.52696E+02
8	1	-0.50347E+00	-0.52696E+02
9	1	-0.64657E+00	-0.55407E+02
10	1	0.64657E+00	0.55407E+02
11	1	0.89011E+00	0.16153E+02
12	1	-0.89011E+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	-0.89011E+00	-0.16153E+02
8	3	0.89011E+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	0.64658E+00	0.55407E+02
14	3	-0.64658E+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	0.50347E+00	0.52696E+02
16	4	-0.50347E+00	-0.52696E+02
17	4	0.89011E+00	0.16153E+02
18	4	-0.89011E+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	0.64658E+00	0.55407E+02
10	6	-0.64658E+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	-0.89011E+00	-0.16153E+02
16	6	0.89011E+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	0.39116E+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	0.39116E+00	0.28846E+02
1	9	-0.65103E+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	-0.43434E+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	0.65102E+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	-0.43434E+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	0.39116E+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	0.39116E+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	-0.65102E+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	-0.43434E+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	0.65103E+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	-0.43434E+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	0.39116E+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	0.39116E+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	0.39116E+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	0.39116E+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	-15.0	98.7
5.0	0.0	11.52	9.43	-99.90	-99.90	-39.7	-42.9	64.0	53.1
10.0	0.0	11.46	9.39	-99.90	-99.90	-39.6	-42.9	77.9	30.6
15.0	0.0	11.37	9.32	-99.90	-99.90	-39.5	-42.9	69.5	-20.0
20.0	0.0	11.25	9.23	-99.90	-99.90	-39.2	-42.9	35.6	62.6
25.0	0.0	11.10	9.11	-99.90	-99.90	-38.8	-42.9	37.0	60.4
30.0	0.0	10.94	8.96	-99.90	-99.90	-38.4	-42.9	82.1	0.4
35.0	0.0	10.77	8.79	-99.90	-99.90	-37.8	-43.0	108.0	76.4
40.0	0.0	10.59	8.60	-99.90	-99.90	-37.1	-43.1	64.5	127.6
45.0	0.0	10.40	8.40	-99.90	-99.90	-36.4	-43.2	-105.2	50.9
50.0	0.0	10.22	8.20	-99.90	-99.90	-35.7	-43.4	29.1	82.0
55.0	0.0	10.04	8.01	-99.90	-99.90	-34.9	-43.6	-132.9	25.0
60.0	0.0	9.87	7.82	-99.90	-99.90	-34.2	-43.7	151.0	84.6
65.0	0.0	9.64	7.66	-99.90	-99.90	-33.9	-43.8	-30.6	37.8
70.0	0.0	9.55	7.52	-99.90	-99.90	-33.1	-43.8	24.7	-2.6
75.0	0.0	9.43	7.41	-99.90	-99.90	-32.8	-43.9	-78.6	130.3
80.0	0.0	9.33	7.33	-99.90	-99.90	-32.5	-43.9	-52.5	153.4
85.0	0.0	9.27	7.29	-99.90	-99.90	-32.3	-43.9	-19.6	71.6
90.0	0.0	9.25	7.27	-99.90	-99.90	-32.3	-43.9	-21.5	-90.0
95.0	0.0	9.27	7.29	-99.90	-99.90	-32.3	-43.9	-35.6	-97.6
100.0	0.0	9.33	7.33	-99.90	-99.90	-32.5	-43.9	-75.5	-75.7
105.0	0.0	9.43	7.41	-99.90	-99.90	-32.8	-43.9	-49.8	-114.0
110.0	0.0	9.55	7.52	-99.90	-99.90	-33.1	-43.8	-77.4	-84.8
115.0	0.0	9.64	7.66	-99.90	-99.90	-33.9	-43.8	-175.3	-73.7
120.0	0.0	9.87	7.82	-99.90	-99.90	-34.2	-43.7	-88.1	-20.4
125.0	0.0	10.04	8.01	-99.90	-99.90	-34.9	-43.6	-7.8	-152.3
130.0	0.0	10.22	8.20	-99.90	-99.90	-35.7	-43.4	71.6	-74.6
135.0	0.0	10.40	8.40	-99.90	-99.90	-36.4	-43.2	25.3	-3.4
140.0	0.0	10.59	8.60	-99.90	-99.90	-37.1	-43.1	86.9	-151.1
145.0	0.0	10.77	8.79	-99.90	-99.90	-37.8	-43.0	95.6	-151.9
150.0	0.0	10.94	8.96	-99.90	-99.90	-38.4	-42.9	65.2	27.7
155.0	0.0	11.10	9.11	-99.90	-99.90	-38.8	-42.9	131.2	119.7
160.0	0.0	11.25	9.23	-99.90	-99.90	-39.2	-42.9	72.7	-178.7
165.0	0.0	11.37	9.32	-99.90	-99.90	-39.5	-42.9	77.0	15.9
170.0	0.0	11.46	9.39	-99.90	-99.90	-39.6	-42.9	62.0	171.6
175.0	0.0	11.52	9.43	-99.90	-99.90	-39.7	-42.9	127.4	-155.9

180.0	0.0	11.53	9.44	-99.90	-99.90	-39.8	-42.9	7.4	141.8
175.0	180.0	11.52	9.43	-99.90	-99.90	-39.7	-42.9	94.5	-86.6
170.0	360.0	11.46	9.39	-99.90	-99.90	-39.6	-42.9	149.9	-90.0
165.0	180.0	11.37	9.32	-99.90	-99.90	-39.5	-42.9	42.7	178.6
160.0	360.0	11.25	9.23	-99.90	-99.90	-39.2	-42.9	156.9	-18.4
155.0	180.0	11.10	9.11	-99.90	-99.90	-38.8	-42.9	-129.0	98.1
150.0	360.0	10.94	8.96	-99.90	-99.90	-38.4	-42.9	77.2	-64.4
145.0	180.0	10.77	8.79	-99.90	-99.90	-37.8	-43.0	121.7	-98.9
140.0	360.0	10.59	8.60	-99.90	-99.90	-37.1	-43.1	176.1	-42.4
135.0	180.0	10.40	8.40	-99.90	-99.90	-36.4	-43.2	96.7	139.2
130.0	360.0	10.22	8.20	-99.90	-99.90	-35.7	-43.4	-47.3	-99.9
125.0	180.0	10.04	8.01	-99.90	-99.90	-34.9	-43.6	-157.3	144.7
120.0	360.0	9.87	7.82	-99.90	-99.90	-34.2	-43.7	-53.0	-61.6
115.0	180.0	9.64	7.66	-99.90	-99.90	-33.9	-43.8	5.9	-158.8
110.0	360.0	9.55	7.52	-99.90	-99.90	-33.1	-43.8	-74.4	-69.7
105.0	180.0	9.43	7.41	-99.90	-99.90	-32.8	-43.9	116.7	93.5
100.0	360.0	9.33	7.33	-99.90	-99.90	-32.5	-43.9	-24.4	-102.9
95.0	180.0	9.27	7.29	-99.90	-99.90	-32.3	-43.9	136.1	161.4
90.0	360.0	9.25	7.27	-99.90	-99.90	-32.3	-43.9	-62.1	-36.2
85.0	180.0	9.27	7.29	-99.90	-99.90	-32.3	-43.9	116.2	142.8
80.0	360.0	9.33	7.33	-99.90	-99.90	-32.5	-43.9	-98.0	166.0
75.0	180.0	9.43	7.41	-99.90	-99.90	-32.8	-43.9	-154.0	72.9
70.0	360.0	9.55	7.52	-99.90	-99.90	-33.1	-43.8	32.5	-62.6
65.0	180.0	9.64	7.66	-99.90	-99.90	-33.9	-43.8	-27.6	4.2
60.0	360.0	9.87	7.82	-99.90	-99.90	-34.2	-43.7	51.3	-68.2
55.0	180.0	10.04	8.01	-99.90	-99.90	-34.9	-43.6	-31.3	157.7
50.0	360.0	10.22	8.20	-99.90	-99.90	-35.7	-43.4	54.6	-94.8
45.0	180.0	10.40	8.40	-99.90	-99.90	-36.4	-43.2	-6.2	179.3
40.0	360.0	10.59	8.60	-99.90	-99.90	-37.1	-43.1	118.4	-27.5
35.0	180.0	10.77	8.79	-99.90	-99.90	-37.8	-43.0	-58.0	76.2
30.0	360.0	10.94	8.96	-99.90	-99.90	-38.4	-42.9	-155.7	57.3
25.0	180.0	11.10	9.11	-99.90	-99.90	-38.8	-42.9	-39.4	-83.5
20.0	360.0	11.25	9.23	-99.90	-99.90	-39.2	-42.9	140.3	60.6
15.0	180.0	11.37	9.32	-99.90	-99.90	-39.5	-42.9	-97.2	0.0
10.0	360.0	11.46	9.39	-99.90	-99.90	-39.6	-42.9	25.5	28.7
5.0	180.0	11.52	9.43	-99.90	-99.90	-39.7	-42.9	93.4	33.7
0.0	360.0	11.53	9.44	-99.90	-99.90	-39.8	-42.9	100.3	76.8

CPU RUN TIME FOR RUN 1 GEOMETRY 1 = 17.74 SECONDS

TOTAL CPU RUN TIME = 17.93 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)
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
6	-0.25000	0.12500

WG: WING

WING NUMBER 1:

NWSEC(1,I) = 2  
 NWSEC(2,I) = 3  
 NWPT(I) = 3  
 NWSYM(I) = 1  
 AWR(I) = 0.000 degrees  
 XWCN(1,I) = 1.00000  
 YWCN(1,I) = 0.50000  
 XWCN(2,I) = 1.00000  
 YWCN(2,I) = 1.50000

SC: SOURCE

MONOPOLE SOURCE GEOMETRY:

IUPDN = 2  
 ZLM = 0.60000  
 DXM = 0.00000  
 DYM = 3.00000  
 DZM = -1.12000

\*\*\*\*\* 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
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.

WING IS ROTATED 0.000 degrees CCW FROM THE HORIZONTAL.

WING COORDINATES (meters)

XWCN(1,1) =	1.00000
YWCN(1,1) =	0.50000
XWCN(2,1) =	1.00000
YWCN(2,1) =	1.50000

SOURCE MONOPOLE GEOMETRY:

MONOPOLE SOURCE GOES DOWN FROM (DXM,DYM,DZM).

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.

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

IDWR	=	200
ITW2	=	600
ICN	=	12
IPL	=	120



IAT = 1  
ITOT = 600  
IDZT = 20100  
IDZTF = 600  
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 0.000927  
INPUT IMPEDANCE(OHMS) = 3.343 J 100.000  
EFFICIENCY (PERCENT) =

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	42.3	-105.5
5.0	-13.43	-99.90	-108.2	-110.6
10.0	-7.14	-99.90	-106.5	-102.2

15.0	-3.75	-99.90	-105.2	-102.7
20.0	-1.51	-99.90	-103.7	-106.3
25.0	0.08	-99.90	-101.8	-101.4
30.0	1.22	-99.90	-99.4	-97.0
35.0	2.04	-99.90	-96.6	-97.6
40.0	2.59	-99.90	-93.4	-101.8
45.0	2.93	-99.90	-89.6	-103.7
50.0	3.08	-99.90	-85.3	-107.3
55.0	3.05	-99.90	-80.4	-103.7
60.0	2.88	-99.90	-74.8	-101.7
65.0	2.54	-99.90	-68.7	-109.9
70.0	2.11	-99.90	-61.4	-116.8
75.0	1.56	-99.90	-53.3	-117.7
80.0	0.93	-99.90	-44.1	-143.5
85.0	0.26	-99.90	-33.6	-166.9
90.0	-0.39	-99.90	-21.7	-179.2
95.0	-0.92	-99.90	-8.7	152.9
100.0	-1.27	-99.90	5.1	23.8
105.0	-1.40	-99.90	19.0	116.3
110.0	-1.33	-99.90	32.2	76.2
115.0	-1.09	-99.90	44.6	88.2
120.0	-0.88	-99.90	54.7	68.7
125.0	-0.67	-99.90	63.7	75.5
130.0	-0.57	-99.90	71.4	68.5
135.0	-0.61	-99.90	78.0	70.0
140.0	-0.83	-99.90	83.5	75.3
145.0	-1.28	-99.90	88.1	65.8
150.0	-1.99	-99.90	91.9	75.3
155.0	-3.06	-99.90	95.1	67.9
160.0	-4.58	-99.90	97.6	83.0
165.0	-6.77	-99.90	99.6	76.2
170.0	-10.15	-99.90	101.1	84.5
175.0	-16.61	-99.90	103.1	90.3
180.0	-99.90	-99.90	-27.7	85.5
185.0	-16.61	-99.90	103.1	-88.7
190.0	-10.15	-99.90	101.1	-71.2
195.0	-6.77	-99.90	99.6	-63.8
200.0	-4.58	-99.90	97.6	-65.4
205.0	-3.06	-99.90	95.1	-56.1
210.0	-1.99	-99.90	91.9	-51.8
215.0	-1.28	-99.90	88.1	-44.8
220.0	-0.83	-99.90	83.5	-34.1
225.0	-0.61	-99.90	78.0	-24.1
230.0	-0.57	-99.90	71.4	-7.9

235.0	-0.67	-99.90	63.7	-16.3
240.0	-0.88	-99.90	54.7	-0.3
245.0	-1.09	-99.90	44.6	1.5
250.0	-1.33	-99.90	32.2	4.4
255.0	-1.40	-99.90	19.0	10.8
260.0	-1.27	-99.90	5.1	20.3
265.0	-0.92	-99.90	-8.7	19.2
270.0	-0.39	-99.90	-21.7	33.7
275.0	0.26	-99.90	-33.6	41.8
280.0	0.93	-99.90	-44.1	34.9
285.0	1.56	-99.90	-53.3	42.9
290.0	2.11	-99.90	-61.4	53.7
295.0	2.54	-99.90	-68.7	51.9
300.0	2.88	-99.90	-74.8	57.3
305.0	3.05	-99.90	-80.4	61.2
310.0	3.08	-99.90	-85.3	61.4
315.0	2.93	-99.90	-89.6	71.4
320.0	2.59	-99.90	-93.4	71.4
325.0	2.04	-99.90	-96.6	67.5
330.0	1.22	-99.90	-99.4	69.3
335.0	0.08	-99.90	-101.8	73.8
340.0	-1.51	-99.90	-103.7	73.0
345.0	-3.75	-99.90	-105.2	68.6
350.0	-7.14	-99.90	-106.5	75.6
355.0	-13.43	-99.90	-108.2	78.5
360.0	-99.90	-99.90	-138.2	77.0

CPU RUN TIME FOR RUN 1 GEOMETRY 1 = 132.68 SECONDS

TOTAL CPU RUN TIME = 133.04 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

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:

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
XTWCN(1)	=	100.00000
YTWCN(1)	=	12.50000
XTWCN(2)	=	100.00000
YTWCN(2)	=	62.50000

SC: SOURCE

MONOPOLE SOURCE GEOMETRY:

IUPDN	=	2
ZLM	=	60.00000
DXM	=	0.00000
DYM	=	300.00000
DZM	=	-75.00000

\*\*\*\*\* 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)
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

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 = 0.25000meters.  
 A SYMMETRIC TAIL WING IS ALSO INCLUDED.

TAIL WING COORDINATES (meters).	
XTWCN(1) =	1.00000
YTWCN(1) =	0.12500
XTWCN(2) =	1.00000
YTWCN(2) =	0.62500

SOURCE MONOPOLE GEOMETRY:  
 MONOPOLE SOURCE GOES DOWN FROM (DXM,DYM,DZM).  
 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.

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

IDWR	=	200
ITW2	=	600
ICN	=	12
IPL	=	120
IAT	=	1



ITOT = 600  
IDZT = 20100  
IDZTF = 600  
IDMI = 1  
IDZTI = 1  
IDZTFI = 1  
IDMZI = 0

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

NUMBER OF PLATES = 23  
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 = 83  
NAT = NUMBER OF ATTACHMENT MODES = 0

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

INPUT ADMITTANCE(MHOS) = 0.000003 J 0.000926  
INPUT IMPEDANCE(OHMS) = 3.791 J 100.000  
EFFICIENCY (PERCENT) =

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	-2.32	-7.58	-22.3	-92.4
5.0	-2.56	-7.38	-10.9	-89.1
10.0	-2.68	-7.13	0.8	-84.7

15.0	-2.69	-6.92	13.2	-79.0
20.0	-2.61	-6.81	26.0	-72.2
25.0	-2.48	-6.85	39.2	-64.7
30.0	-2.30	-7.05	52.6	-56.7
35.0	-2.10	-7.44	66.0	-48.5
40.0	-1.88	-8.01	79.0	-40.3
45.0	-1.67	-8.76	91.4	-32.4
50.0	-1.47	-9.71	103.0	-24.9
55.0	-1.28	-10.87	113.6	-17.9
60.0	-1.11	-12.25	123.1	-11.6
65.0	-0.97	-13.91	131.3	-6.1
70.0	-0.85	-15.79	138.2	-1.0
75.0	-0.76	-18.56	143.6	2.0
80.0	-0.69	-22.21	147.5	4.1
85.0	-0.65	-28.42	149.8	3.9
90.0	-0.64	-51.07	150.6	-111.0
95.0	-0.65	-27.85	149.8	-169.1
100.0	-0.69	-21.97	147.5	-172.5
105.0	-0.76	-18.45	143.6	-176.0
110.0	-0.85	-15.75	138.2	-179.6
115.0	-0.97	-13.94	131.3	174.8
120.0	-1.11	-12.32	123.1	168.9
125.0	-1.28	-10.97	113.6	162.3
130.0	-1.46	-9.84	103.0	155.1
135.0	-1.67	-8.91	91.4	147.3
140.0	-1.88	-8.17	79.0	139.1
145.0	-2.09	-7.61	66.0	130.8
150.0	-2.29	-7.24	52.7	122.4
155.0	-2.47	-7.04	39.3	114.3
160.0	-2.60	-7.02	26.1	106.7
165.0	-2.68	-7.14	13.3	99.8
170.0	-2.67	-7.36	1.0	94.1
175.0	-2.55	-7.62	-10.8	89.7
180.0	-2.32	-7.83	-22.2	86.6
185.0	-1.96	-7.90	-33.2	84.4
190.0	-1.51	-7.78	-44.3	82.4
195.0	-0.98	-7.52	-55.4	79.9
200.0	-0.42	-7.18	-66.6	76.6
205.0	0.13	-6.86	-77.9	72.2
210.0	0.66	-6.64	-89.2	67.0
215.0	1.14	-6.56	-100.3	61.2
220.0	1.56	-6.66	-111.1	55.2
225.0	1.93	-6.96	-121.3	49.1
230.0	2.24	-7.46	-131.0	43.3

235.0	2.49	-8.18	-139.8	37.8
240.0	2.69	-9.17	-147.8	32.9
245.0	2.85	-10.47	-154.7	28.5
250.0	2.97	-12.17	-160.5	25.3
255.0	3.06	-14.45	-165.1	21.6
260.0	3.12	-17.74	-168.4	19.0
265.0	3.15	-23.28	-170.4	16.2
270.0	3.16	-42.70	-171.1	-12.4
275.0	3.15	-25.02	-170.4	-156.7
280.0	3.12	-18.59	-168.4	-157.5
285.0	3.06	-15.01	-165.1	-156.1
290.0	2.97	-12.58	-160.5	-152.9
295.0	2.85	-10.77	-154.7	-150.2
300.0	2.69	-9.40	-147.8	-146.0
305.0	2.49	-8.36	-139.9	-141.2
310.0	2.24	-7.58	-131.0	-135.9
315.0	1.93	-7.04	-121.4	-130.2
320.0	1.57	-6.71	-111.1	-124.2
325.0	1.15	-6.56	-100.3	-118.3
330.0	0.66	-6.60	-89.2	-112.6
335.0	0.14	-6.77	-78.0	-107.4
340.0	-0.42	-7.04	-66.7	-103.0
345.0	-0.98	-7.33	-55.5	-99.5
350.0	-1.50	-7.56	-44.4	-96.9
355.0	-1.96	-7.66	-33.4	-94.7
360.0	-2.32	-7.58	-22.3	-92.4

CPU RUN TIME FOR RUN 1 GEOMETRY 1 = 241.97 SECONDS

TOTAL CPU RUN TIME = 242.42 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)
  -----
    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
AWR(I) = 0.000 degrees
XWCN(1,I) = 1.50000
YWCN(1,I) = 0.50000
XWCN(2,I) = 1.50000
YWCN(2,I) = 1.50000

```

\*\*\*\*\* 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	0.17700	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)
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

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

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.  
WING IS ROTATED 0.000 degrees CCW FROM THE HORIZONTAL.

WING COORDINATES (meters)  
XWCN(1,1) = 1.50000  
YWCN(1,1) = 0.50000  
XWCN(2,1) = 1.50000  
YWCN(2,1) = 1.50000

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

IDWR = 200  
ITW2 = 600  
ICN = 12  
IPL = 120  
IAT = 1  
ITOT = 600  
IDZT = 20100  
IDZTF = 600  
IDMI = 1  
IDZTI = 1  
IDZTFI = 1  
IDMZI = 0

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

NUMBER OF PLATES = 38  
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 = 145  
NAT = NUMBER OF ATTACHMENT MODES = 0

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

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	13.40	14.98	-3.12	-2.51	27.3	-13.1	-177.7	-179.9
90.0	2.0	13.42	14.13	-2.81	-2.16	43.3	2.8	-162.5	-164.4
90.0	4.0	13.32	13.12	-2.59	-1.91	59.7	19.7	-146.3	-148.0
90.0	6.0	13.08	11.98	-2.45	-1.76	76.7	38.0	-129.3	-130.5
90.0	8.0	12.73	10.75	-2.41	-1.73	94.2	58.2	-111.8	-112.7
90.0	10.0	12.26	9.59	-2.40	-1.73	112.3	80.9	-93.0	-93.4
90.0	12.0	11.68	8.70	-2.52	-1.88	131.1	106.2	-74.1	-74.0
90.0	14.0	11.01	8.30	-2.63	-2.02	150.7	132.9	-54.5	-53.8
90.0	16.0	10.26	8.45	-2.92	-2.35	171.2	158.7	-34.8	-33.5
90.0	18.0	9.48	8.97	-3.20	-2.66	-167.2	-177.9	-14.8	-12.7
90.0	20.0	8.71	9.59	-3.60	-3.09	-144.6	-157.6	5.5	8.3
90.0	22.0	8.01	10.14	-4.09	-3.60	-121.0	-140.0	25.7	29.3
90.0	24.0	7.43	10.51	-4.72	-4.23	-96.7	-124.7	46.1	50.5
90.0	26.0	7.01	10.67	-5.54	-5.03	-72.1	-111.4	66.7	72.1
90.0	28.0	6.75	10.58	-6.50	-5.92	-47.7	-100.0	88.2	94.6
90.0	30.0	6.62	10.27	-7.84	-7.15	-23.9	-90.7	110.5	118.1
90.0	32.0	6.56	9.75	-9.39	-8.48	-1.0	-83.7	135.6	144.3
90.0	34.0	6.53	9.09	-11.08	-9.79	21.1	-79.7	165.5	174.6
90.0	36.0	6.49	8.46	-12.31	-10.56	42.3	-79.3	-157.7	-150.3
90.0	38.0	6.41	8.15	-12.06	-10.18	62.8	-82.3	-117.1	-113.7
90.0	40.0	6.29	8.42	-10.38	-8.78	82.8	-87.0	-81.8	-81.1
90.0	42.0	6.12	9.28	-8.27	-7.01	102.5	-90.7	-54.5	-54.6
90.0	44.0	5.91	10.45	-6.32	-5.30	121.9	-91.8	-33.1	-33.1
90.0	46.0	5.70	11.66	-4.66	-3.79	141.1	-90.3	-15.2	-14.9
90.0	48.0	5.48	12.76	-3.28	-2.50	160.2	-86.8	0.3	1.0
90.0	50.0	5.31	13.68	-2.14	-1.43	179.1	-82.1	14.1	15.1
90.0	52.0	5.18	14.40	-1.21	-0.54	-162.3	-76.6	26.6	28.0
90.0	54.0	5.13	14.93	-0.46	0.17	-144.1	-70.7	38.2	39.8
90.0	56.0	5.15	15.28	0.12	0.74	-126.6	-64.8	48.8	50.6
90.0	58.0	5.25	15.44	0.56	1.16	-110.0	-59.0	58.7	60.7
90.0	60.0	5.39	15.43	0.86	1.45	-94.3	-53.4	67.9	70.1
90.0	62.0	5.58	15.26	1.03	1.62	-79.7	-48.3	76.5	78.8
90.0	64.0	5.78	14.92	1.07	1.66	-66.2	-43.7	84.4	86.8
90.0	66.0	6.00	14.43	0.98	1.57	-53.8	-39.7	91.9	94.4
90.0	68.0	6.20	13.77	0.78	1.37	-42.5	-36.7	98.6	101.2
90.0	70.0	6.40	12.99	0.42	1.03	-32.3	-34.5	105.0	107.7

90.0	72.0	6.58	12.05	-0.07	0.54	-23.2	-33.5	110.8	113.6
90.0	74.0	6.73	11.01	-0.74	-0.12	-15.0	-33.9	116.1	119.1
90.0	76.0	6.87	9.90	-1.59	-0.95	-7.8	-35.8	121.1	124.2
90.0	78.0	6.98	8.79	-2.68	-2.02	-1.6	-39.4	125.9	129.1
90.0	80.0	7.08	7.82	-4.06	-3.37	3.6	-45.0	130.1	133.7
90.0	82.0	7.16	7.00	-5.85	-5.11	7.9	-51.1	134.9	138.9
90.0	84.0	7.22	6.47	-8.23	-7.39	11.3	-57.5	140.5	145.1
90.0	86.0	7.27	6.18	-11.59	-10.54	13.8	-62.8	149.0	154.5
90.0	88.0	7.30	6.06	-16.66	-14.96	15.3	-66.3	169.4	175.4
90.0	90.0	7.31	6.02	-20.10	-17.86	15.9	-67.5	-126.8	-131.2
90.0	92.0	7.32	6.05	-14.62	-13.75	15.6	-66.3	-82.2	-87.6
90.0	94.0	7.30	6.17	-10.26	-9.69	14.3	-62.8	-70.0	-73.0
90.0	96.0	7.28	6.45	-7.32	-6.82	12.1	-57.4	-66.0	-67.7
90.0	98.0	7.23	6.99	-5.20	-4.72	9.0	-51.0	-65.0	-66.0
90.0	100.0	7.17	7.80	-3.57	-3.11	5.0	-44.8	-65.8	-66.3
90.0	102.0	7.09	8.78	-2.34	-1.89	0.0	-39.2	-67.4	-67.7
90.0	104.0	6.99	9.91	-1.34	-0.92	-5.9	-35.7	-70.3	-70.3
90.0	106.0	6.86	11.02	-0.58	-0.17	-12.8	-33.7	-73.8	-73.7
90.0	108.0	6.71	12.07	0.01	0.40	-20.7	-33.4	-78.1	-77.9
90.0	110.0	6.54	13.01	0.43	0.80	-29.6	-34.4	-83.0	-82.7
90.0	112.0	6.34	13.80	0.71	1.05	-39.5	-36.6	-88.7	-88.3
90.0	114.0	6.13	14.46	0.84	1.15	-50.4	-39.7	-94.9	-94.3
90.0	116.0	5.91	14.96	0.86	1.13	-62.5	-43.7	-101.9	-101.3
90.0	118.0	5.68	15.30	0.74	0.96	-75.7	-48.3	-109.5	-108.7
90.0	120.0	5.46	15.49	0.48	0.65	-90.0	-53.5	-117.8	-116.9
90.0	122.0	5.27	15.50	0.09	0.20	-105.4	-59.1	-126.9	-125.7
90.0	124.0	5.13	15.35	-0.45	-0.42	-121.9	-65.0	-136.6	-135.3
90.0	126.0	5.04	15.01	-1.15	-1.20	-139.3	-71.0	-147.2	-145.7
90.0	128.0	5.04	14.49	-2.02	-2.18	-157.5	-76.9	-158.6	-156.9
90.0	130.0	5.10	13.78	-3.10	-3.40	-176.2	-82.5	-171.2	-169.2
90.0	132.0	5.23	12.87	-4.40	-4.88	164.7	-87.5	174.9	177.1
90.0	134.0	5.40	11.78	-5.98	-6.70	145.3	-91.2	159.2	161.5
90.0	136.0	5.58	10.57	-7.87	-8.93	125.8	-93.0	140.7	142.7
90.0	138.0	5.76	9.37	-10.05	-11.59	106.1	-92.3	117.9	118.4
90.0	140.0	5.92	8.45	-12.29	-14.28	86.2	-88.9	87.8	83.6
90.0	142.0	6.03	8.09	-13.68	-15.29	65.9	-84.3	49.0	37.4
90.0	144.0	6.09	8.32	-13.21	-13.73	45.2	-81.1	8.1	-4.9
90.0	146.0	6.12	8.90	-11.55	-11.49	23.7	-81.1	-25.7	-35.6
90.0	148.0	6.13	9.55	-9.77	-9.55	1.4	-84.7	-52.7	-59.6
90.0	150.0	6.18	10.07	-8.23	-8.01	-21.8	-91.4	-75.6	-80.5
90.0	152.0	6.30	10.39	-6.90	-6.74	-46.0	-100.5	-96.4	-99.8
90.0	154.0	6.56	10.48	-5.94	-5.84	-70.7	-111.8	-116.7	-119.1
90.0	156.0	7.00	10.33	-5.06	-5.02	-95.7	-124.9	-136.3	-137.9
90.0	158.0	7.61	9.96	-4.34	-4.34	-120.3	-140.1	-155.8	-156.8

90.0	160.0	8.34	9.42	-3.72	-3.75	-144.1	-157.5	-175.2	-175.8
90.0	162.0	9.14	8.81	-3.16	-3.18	-166.9	-177.8	165.2	165.1
90.0	164.0	9.95	8.30	-2.69	-2.70	171.5	158.9	145.7	145.8
90.0	166.0	10.72	8.16	-2.19	-2.16	150.9	133.2	126.3	126.7
90.0	168.0	11.42	8.57	-1.84	-1.76	131.3	106.6	106.7	107.4
90.0	170.0	12.02	9.47	-1.50	-1.35	112.5	81.3	87.5	88.4
90.0	172.0	12.50	10.65	-1.26	-1.04	94.5	58.6	68.1	69.1
90.0	174.0	12.87	11.89	-1.08	-0.76	77.0	38.5	49.5	50.7
90.0	176.0	13.11	13.06	-1.01	-0.59	60.1	20.2	30.7	32.1
90.0	178.0	13.23	14.09	-1.06	-0.55	43.8	3.4	12.3	13.7
90.0	180.0	13.22	14.96	-1.25	-0.64	27.9	-12.5	-6.0	-4.4
90.0	182.0	13.07	15.68	-1.62	-0.90	12.6	-27.7	-24.1	-22.4
90.0	184.0	12.80	16.22	-2.18	-1.35	-2.2	-42.5	-41.9	-40.2
90.0	186.0	12.40	16.60	-2.99	-2.04	-16.3	-57.0	-59.7	-57.9
90.0	188.0	11.88	16.79	-4.03	-2.95	-29.8	-71.3	-77.7	-76.0
90.0	190.0	11.24	16.83	-5.60	-4.35	-42.4	-85.3	-95.3	-93.5
90.0	192.0	10.50	16.66	-7.55	-6.08	-54.0	-99.2	-114.1	-112.1
90.0	194.0	9.70	16.31	-10.56	-8.74	-64.5	-112.7	-134.3	-131.7
90.0	196.0	8.87	15.72	-14.35	-12.01	-73.7	-126.1	-160.4	-155.5
90.0	198.0	8.08	14.91	-20.21	-17.39	-81.7	-138.8	147.8	165.0
90.0	200.0	7.41	13.80	-18.69	-19.30	-88.7	-150.9	67.4	87.1
90.0	202.0	6.90	12.37	-13.51	-14.14	-95.1	-161.6	29.7	36.1
90.0	204.0	6.59	10.55	-10.24	-10.44	-101.5	-170.4	8.7	11.5
90.0	206.0	6.44	8.27	-8.05	-8.02	-108.7	-175.6	-7.0	-5.8
90.0	208.0	6.38	5.65	-6.55	-6.40	-117.0	-173.5	-20.6	-20.3
90.0	210.0	6.35	3.63	-5.45	-5.24	-126.6	-160.1	-31.8	-32.3
90.0	212.0	6.30	3.94	-4.66	-4.44	-137.5	-141.9	-41.8	-42.7
90.0	214.0	6.18	5.89	-4.05	-3.87	-149.6	-133.3	-50.3	-51.6
90.0	216.0	5.98	7.85	-3.54	-3.43	-163.0	-134.2	-57.6	-59.0
90.0	218.0	5.70	9.38	-3.08	-3.05	-177.4	-140.1	-63.7	-65.1
90.0	220.0	5.36	10.48	-2.60	-2.65	167.1	-148.4	-69.0	-70.0
90.0	222.0	4.99	11.21	-2.07	-2.17	150.5	-158.0	-73.9	-74.2
90.0	224.0	4.63	11.63	-1.49	-1.61	132.9	-168.2	-78.5	-78.2
90.0	226.0	4.34	11.77	-0.88	-0.98	114.5	-178.9	-83.3	-82.2
90.0	228.0	4.18	11.67	-0.27	-0.32	95.6	170.3	-88.2	-86.6
90.0	230.0	4.18	11.34	0.32	0.34	76.6	159.3	-93.5	-91.4
90.0	232.0	4.34	10.77	0.86	0.95	58.2	148.0	-99.0	-96.6
90.0	234.0	4.64	9.98	1.33	1.50	40.6	136.3	-104.7	-102.1
90.0	236.0	5.03	8.96	1.72	1.96	24.3	123.9	-110.5	-107.8
90.0	238.0	5.46	7.71	2.02	2.33	9.3	110.2	-116.2	-113.5
90.0	240.0	5.90	6.27	2.23	2.60	-4.4	94.3	-121.9	-119.3
90.0	242.0	6.31	4.80	2.34	2.76	-16.8	75.0	-127.5	-124.9
90.0	244.0	6.70	3.67	2.34	2.82	-28.1	51.5	-132.8	-130.4
90.0	246.0	7.04	3.43	2.24	2.77	-38.4	25.6	-137.9	-135.6

90.0	248.0	7.34	4.15	2.05	2.62	-47.6	1.6	-142.7	-140.6
90.0	250.0	7.59	5.45	1.73	2.34	-56.0	-17.1	-147.1	-145.1
90.0	252.0	7.80	6.83	1.30	1.94	-63.4	-31.1	-151.2	-149.3
90.0	254.0	7.98	8.07	0.74	1.42	-70.0	-41.4	-154.9	-153.2
90.0	256.0	8.13	9.14	0.04	0.75	-75.9	-49.3	-158.2	-156.6
90.0	258.0	8.24	10.03	-0.82	-0.09	-80.9	-55.4	-161.1	-159.5
90.0	260.0	8.33	10.70	-1.88	-1.12	-85.1	-60.0	-163.7	-162.1
90.0	262.0	8.41	11.28	-3.19	-2.40	-88.6	-63.6	-165.5	-164.0
90.0	264.0	8.46	11.69	-4.82	-4.01	-91.3	-66.2	-167.0	-165.4
90.0	266.0	8.50	11.98	-6.92	-6.08	-93.2	-68.1	-167.8	-166.1
90.0	268.0	8.52	12.14	-9.79	-8.91	-94.4	-69.2	-167.7	-165.7
90.0	270.0	8.54	12.18	-14.17	-13.22	-94.8	-69.6	-165.8	-162.8
90.0	272.0	8.54	12.10	-23.27	-21.82	-94.4	-69.4	-153.6	-146.8
90.0	274.0	8.53	11.91	-23.40	-22.26	-93.3	-68.4	-11.7	-19.0
90.0	276.0	8.50	11.59	-14.34	-13.48	-91.5	-66.7	1.4	-1.1
90.0	278.0	8.46	11.15	-10.02	-9.17	-88.8	-64.3	4.9	3.6
90.0	280.0	8.40	10.54	-7.22	-6.35	-85.4	-60.9	7.2	6.4
90.0	282.0	8.32	9.83	-5.18	-4.31	-81.2	-56.5	9.7	9.3
90.0	284.0	8.22	8.89	-3.59	-2.72	-76.3	-50.7	12.1	11.9
90.0	286.0	8.08	7.78	-2.31	-1.44	-70.5	-43.1	14.8	14.9
90.0	288.0	7.91	6.47	-1.26	-0.40	-63.9	-33.0	17.9	18.3
90.0	290.0	7.71	5.01	-0.39	0.47	-56.5	-19.4	21.4	22.0
90.0	292.0	7.46	3.58	0.36	1.21	-48.3	-0.7	25.2	26.2
90.0	294.0	7.16	2.76	0.97	1.80	-39.1	23.9	29.6	30.9
90.0	296.0	6.81	2.98	1.50	2.30	-28.9	50.8	34.4	35.9
90.0	298.0	6.42	4.18	1.93	2.70	-17.7	74.9	39.7	41.5
90.0	300.0	5.99	5.75	2.26	3.00	-5.3	94.3	45.5	47.6
90.0	302.0	5.54	7.26	2.52	3.22	8.3	110.0	51.8	54.2
90.0	304.0	5.08	8.56	2.68	3.34	23.3	123.5	58.7	61.4
90.0	306.0	4.66	9.63	2.76	3.36	39.6	135.8	66.1	69.1
90.0	308.0	4.32	10.45	2.73	3.29	57.2	147.2	74.0	77.3
90.0	310.0	4.12	11.04	2.61	3.10	75.8	158.3	82.5	86.0
90.0	312.0	4.09	11.40	2.36	2.80	95.0	169.2	91.5	95.3
90.0	314.0	4.22	11.53	2.00	2.36	114.2	179.8	101.0	105.1
90.0	316.0	4.49	11.42	1.49	1.77	132.9	-169.8	111.0	115.3
90.0	318.0	4.84	11.04	0.81	1.01	150.7	-159.7	121.4	126.1
90.0	320.0	5.20	10.36	-0.05	0.05	167.5	-150.3	132.3	137.4
90.0	322.0	5.54	9.34	-1.13	-1.16	-176.8	-142.2	143.7	149.1
90.0	324.0	5.81	7.91	-2.48	-2.66	-162.3	-136.5	155.6	161.4
90.0	326.0	5.99	6.11	-4.17	-4.55	-149.0	-135.5	167.9	174.3
90.0	328.0	6.10	4.37	-6.34	-6.99	-136.9	-142.9	-179.1	-171.9
90.0	330.0	6.13	4.03	-9.22	-10.31	-126.1	-158.7	-165.0	-156.2
90.0	332.0	6.14	5.76	-13.43	-15.34	-116.7	-171.3	-148.3	-135.1
90.0	334.0	6.19	8.21	-20.33	-23.18	-108.8	-173.8	-120.2	-84.0

90.0	336.0	6.35	10.41	-25.23	-20.08	-102.0	-169.3	-11.7	12.0
90.0	338.0	6.69	12.22	-16.96	-14.47	-96.0	-160.9	37.1	42.3
90.0	340.0	7.25	13.65	-12.71	-11.27	-90.0	-150.5	55.9	59.2
90.0	342.0	7.99	14.76	-10.30	-9.35	-83.2	-138.7	70.5	73.1
90.0	344.0	8.84	15.59	-8.55	-7.91	-75.2	-126.2	82.8	84.6
90.0	346.0	9.72	16.20	-7.46	-7.01	-65.9	-112.9	95.9	96.9
90.0	348.0	10.57	16.56	-6.45	-6.09	-55.3	-99.5	106.6	106.8
90.0	350.0	11.34	16.75	-5.72	-5.40	-43.6	-85.7	118.4	117.7
90.0	352.0	12.00	16.73	-5.02	-4.67	-30.8	-71.8	129.4	127.9
90.0	354.0	12.55	16.56	-4.48	-4.08	-17.2	-57.6	141.9	140.0
90.0	356.0	12.96	16.20	-3.96	-3.48	-3.0	-43.1	154.5	152.3
90.0	358.0	13.24	15.68	-3.50	-2.96	11.9	-28.3	167.9	165.6
90.0	360.0	13.40	14.98	-3.12	-2.51	27.3	-13.1	-177.7	-179.9

CPU RUN TIME FOR RUN 1 GEOMETRY 1 = 499.71 SECONDS

TOTAL CPU RUN TIME = 500.51 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 :DEFINES TAIL SECTION  
18.3 19.0  
28.9 19.0  
21.0  
20.3

22.1 -16.5  
10.4 -16.5  
WG :DEFINE WING  
7 9 3 1 0.0  
25.78 3.50 25.78 13.15  
TW :DEFINE TAIL WING  
5.38 -3.40 13.21 1  
-22.86 3.30 -22.86 9.90  
SC :DEFINE MONOPOLE  
2 10.0 0.0 87.63 -15.0  
NG :END OF GEOMETRY DATA

# 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

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

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:

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  
NWSYM(I) = 1  
AWR(I) = 0.000 degrees  
XWCN(1,I) = 25.78000  
YWCN(1,I) = 3.50000  
XWCN(2,I) = 25.78000  
YWCN(2,I) = 13.15000

TW: TAIL WING

TAIL WING GEOMETRY:

YTWS = 5.38000  
ZTWS = -3.40000  
YTWL = 13.21000  
ITWSYM = 1  
XTWCN(1) = -22.86000  
YTWCN(1) = 3.30000  
XTWCN(2) = -22.86000  
YTWCN(2) = 9.90000

SC: SOURCE

MONOPOLE SOURCE GEOMETRY:

IUPDN = 2  
ZLM = 10.00000  
DXM = 0.00000  
DYM = 87.63000  
DZM = -15.00000

\*\*\*\*\* 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.

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

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.

WING IS ROTATED 0.000 degrees CCW FROM THE HORIZONTAL.

WING COORDINATES (meters)

XWCN(1,1) = 0.25780

YWCN(1,1) = 0.03500

XWCN(2,1) = 0.25780

YWCN(2,1) = 0.13150

TAIL WING GEOMETRY:

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 = -0.03400meters.

A SYMMETRIC TAIL WING IS ALSO INCLUDED.

TAIL WING COORDINATES (meters).

XTWCN(1) = -0.22860

YTWCN(1) = 0.03300

XTWCN(2) = -0.22860

YTWCN(2) = 0.09900

SOURCE MONOPOLE GEOMETRY:

MONOPOLE SOURCE GOES DOWN FROM (DXM,DYM,DZM).

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.

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

IDWR = 200

ITW2 = 600

ICN = 12

IPL = 120

IAT = 1

ITOT = 600  
IDZT = 20100  
IDZTF = 600  
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) = 2.290 J 100.000  
EFFICIENCY (PERCENT) =

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	-87.29	-10.75	156.7	-122.9
1.0	-37.21	-10.75	-87.7	-122.9
2.0	-30.03	-10.75	-65.7	-122.9
3.0	-23.24	-10.75	-58.8	-122.9



4.0	-19.94	-10.76	-55.7	-122.9
5.0	-17.63	-10.76	-54.9	-122.9
6.0	-15.75	-10.77	-54.5	-123.0
7.0	-14.33	-10.77	-54.9	-123.0
8.0	-13.16	-10.78	-54.4	-123.0
9.0	-12.07	-10.78	-54.0	-123.0
10.0	-11.08	-10.79	-54.4	-123.1
11.0	-10.24	-10.80	-54.2	-123.1
12.0	-9.48	-10.81	-54.1	-123.2
13.0	-8.79	-10.82	-54.0	-123.2
14.0	-8.16	-10.83	-53.9	-123.3
15.0	-7.57	-10.84	-53.7	-123.3
16.0	-7.03	-10.85	-53.6	-123.4
17.0	-6.53	-10.87	-53.4	-123.5
18.0	-6.06	-10.88	-53.3	-123.5
19.0	-5.61	-10.89	-53.1	-123.6
20.0	-5.20	-10.91	-53.0	-123.7
21.0	-4.82	-10.93	-52.8	-123.7
22.0	-4.44	-10.94	-52.6	-123.8
23.0	-4.09	-10.96	-52.4	-123.9
24.0	-3.76	-10.98	-52.2	-124.0
25.0	-3.45	-11.00	-51.9	-124.1
26.0	-3.15	-11.02	-51.7	-124.2
27.0	-2.87	-11.04	-51.5	-124.3
28.0	-2.60	-11.06	-51.2	-124.4
29.0	-2.35	-11.09	-51.0	-124.5
30.0	-2.11	-11.11	-50.7	-124.6
31.0	-1.88	-11.13	-50.4	-124.7
32.0	-1.66	-11.16	-50.2	-124.8
33.0	-1.45	-11.18	-49.9	-124.9
34.0	-1.25	-11.21	-49.6	-125.0
35.0	-1.05	-11.24	-49.3	-125.1
36.0	-0.87	-11.27	-48.9	-125.3
37.0	-0.70	-11.30	-48.6	-125.4
38.0	-0.54	-11.33	-48.3	-125.5
39.0	-0.38	-11.36	-47.9	-125.6
40.0	-0.23	-11.39	-47.6	-125.7
41.0	-0.09	-11.42	-47.2	-125.9
42.0	0.05	-11.46	-46.8	-126.0
43.0	0.18	-11.49	-46.5	-126.1
44.0	0.30	-11.53	-46.1	-126.3
45.0	0.41	-11.57	-45.7	-126.4
46.0	0.52	-11.60	-45.2	-126.5
47.0	0.63	-11.64	-44.8	-126.7

48.0	0.73	-11.68	-44.4	-126.8
49.0	0.82	-11.72	-43.9	-126.9
50.0	0.90	-11.76	-43.5	-127.1
51.0	0.98	-11.80	-43.1	-127.2
52.0	1.06	-11.85	-42.6	-127.3
53.0	1.14	-11.89	-42.0	-127.5
54.0	1.20	-11.94	-41.6	-127.6
55.0	1.26	-11.98	-41.1	-127.7
56.0	1.32	-12.03	-40.6	-127.9
57.0	1.37	-12.08	-40.0	-128.0
58.0	1.42	-12.13	-39.5	-128.1
59.0	1.47	-12.17	-39.0	-128.3
60.0	1.51	-12.23	-38.4	-128.4
61.0	1.54	-12.28	-37.9	-128.6
62.0	1.58	-12.33	-37.3	-128.7
63.0	1.60	-12.38	-36.7	-128.8
64.0	1.63	-12.44	-36.1	-129.0
65.0	1.65	-12.49	-35.5	-129.1
66.0	1.66	-12.55	-34.9	-129.2
67.0	1.68	-12.61	-34.3	-129.4
68.0	1.69	-12.67	-33.6	-129.5
69.0	1.69	-12.73	-33.0	-129.6
70.0	1.69	-12.79	-32.4	-129.7
71.0	1.69	-12.85	-31.7	-129.9
72.0	1.69	-12.91	-31.0	-130.0
73.0	1.68	-12.98	-30.3	-130.1
74.0	1.67	-13.04	-29.6	-130.2
75.0	1.66	-13.11	-28.9	-130.3
76.0	1.64	-13.17	-28.2	-130.5
77.0	1.62	-13.24	-27.5	-130.6
78.0	1.59	-13.31	-26.8	-130.7
79.0	1.56	-13.38	-26.0	-130.8
80.0	1.53	-13.45	-25.3	-130.9
81.0	1.49	-13.53	-24.7	-131.0
82.0	1.47	-13.60	-23.8	-131.1
83.0	1.46	-13.67	-22.8	-131.2
84.0	1.41	-13.75	-22.0	-131.3
85.0	1.33	-13.83	-21.6	-131.4
86.0	1.34	-13.90	-20.5	-131.5
87.0	1.24	-13.98	-19.8	-131.6
88.0	1.19	-14.06	-18.9	-131.7
89.0	1.16	-14.15	-18.0	-131.8
90.0	1.10	-14.37	-17.0	-131.8
91.0	1.04	-14.31	-16.3	-131.9

92.0	0.97	-14.40	-15.6	-132.0
93.0	0.91	-14.48	-14.8	-132.0
94.0	0.88	-14.57	-13.6	-132.1
95.0	0.75	-14.66	-12.9	-132.2
96.0	0.74	-14.75	-11.9	-132.2
97.0	0.69	-14.84	-11.0	-132.3
98.0	0.56	-14.93	-10.2	-132.3
99.0	0.47	-15.02	-9.3	-132.3
100.0	0.41	-15.11	-8.3	-132.4
101.0	0.34	-15.21	-7.4	-132.4
102.0	0.26	-15.30	-6.4	-132.4
103.0	0.19	-15.40	-5.5	-132.4
104.0	0.10	-15.50	-4.6	-132.5
105.0	0.02	-15.59	-3.6	-132.5
106.0	-0.07	-15.69	-2.6	-132.5
107.0	-0.17	-15.79	-1.7	-132.4
108.0	-0.26	-15.90	-0.7	-132.4
109.0	-0.35	-16.00	0.3	-132.4
110.0	-0.44	-16.10	1.2	-132.4
111.0	-0.54	-16.21	2.2	-132.4
112.0	-0.64	-16.31	3.2	-132.3
113.0	-0.74	-16.42	4.1	-132.3
114.0	-0.84	-16.52	5.1	-132.2
115.0	-0.94	-16.63	6.1	-132.1
116.0	-1.05	-16.74	7.1	-132.1
117.0	-1.15	-16.85	8.0	-132.0
118.0	-1.26	-16.96	9.0	-131.9
119.0	-1.37	-17.07	10.0	-131.8
120.0	-1.49	-17.18	11.0	-131.7
121.0	-1.60	-17.29	11.9	-131.6
122.0	-1.72	-17.41	12.9	-131.5
123.0	-1.84	-17.52	13.8	-131.3
124.0	-1.96	-17.63	14.8	-131.2
125.0	-2.08	-17.75	15.7	-131.0
126.0	-2.21	-17.86	16.6	-130.9
127.0	-2.32	-17.98	17.6	-130.7
128.0	-2.46	-18.09	18.5	-130.5
129.0	-2.61	-18.21	19.4	-130.3
130.0	-2.75	-18.32	20.3	-130.2
131.0	-2.88	-18.44	21.2	-129.9
132.0	-3.02	-18.55	22.1	-129.7
133.0	-3.17	-18.67	22.9	-129.5
134.0	-3.32	-18.78	23.8	-129.3
135.0	-3.47	-18.89	24.6	-129.0

136.0	-3.63	-19.01	25.5	-128.8
137.0	-3.79	-19.12	26.3	-128.5
138.0	-3.96	-19.23	27.1	-128.3
139.0	-4.13	-19.35	27.9	-128.0
140.0	-4.31	-19.46	28.6	-127.7
141.0	-4.49	-19.57	29.4	-127.4
142.0	-4.68	-19.68	30.1	-127.1
143.0	-4.88	-19.78	30.9	-126.8
144.0	-5.08	-19.89	31.6	-126.5
145.0	-5.29	-19.99	32.3	-126.2
146.0	-5.50	-20.10	32.9	-125.9
147.0	-5.73	-20.20	33.6	-125.5
148.0	-5.96	-20.30	34.2	-125.2
149.0	-6.20	-20.40	34.9	-124.9
150.0	-6.45	-20.49	35.5	-124.5
151.0	-6.71	-20.59	36.1	-124.2
152.0	-6.99	-20.68	36.6	-123.9
153.0	-7.27	-20.77	37.2	-123.5
154.0	-7.57	-20.86	37.7	-123.2
155.0	-7.88	-20.94	38.2	-122.8
156.0	-8.21	-21.03	38.7	-122.5
157.0	-8.55	-21.11	39.2	-122.2
158.0	-8.91	-21.18	39.6	-121.8
159.0	-9.31	-21.26	40.1	-121.5
160.0	-9.70	-21.33	40.5	-121.2
161.0	-10.12	-21.40	40.9	-120.9
162.0	-10.58	-21.46	41.3	-120.6
163.0	-11.07	-21.52	41.6	-120.3
164.0	-11.58	-21.58	41.9	-120.0
165.0	-12.13	-21.64	42.2	-119.8
166.0	-12.73	-21.69	42.5	-119.5
167.0	-13.38	-21.74	42.8	-119.3
168.0	-14.09	-21.78	43.0	-119.0
169.0	-14.87	-21.82	43.2	-118.8
170.0	-15.74	-21.86	43.4	-118.6
171.0	-16.55	-21.90	43.3	-118.4
172.0	-17.66	-21.93	43.8	-118.3
173.0	-19.10	-21.96	44.1	-118.1
174.0	-20.84	-21.98	42.8	-118.0
175.0	-22.86	-22.00	44.0	-117.9
176.0	-25.36	-22.02	45.0	-117.8
177.0	-30.03	-22.03	46.6	-117.7
178.0	-48.47	-22.04	22.9	-117.7
179.0	-47.59	-22.05	154.7	-117.7

180.0	-89.45	-22.06	6.8	-117.7
181.0	-47.47	-22.05	155.2	62.3
182.0	-48.63	-22.04	23.3	62.3
183.0	-30.04	-22.03	46.7	62.3
184.0	-25.37	-22.02	45.0	62.2
185.0	-22.87	-22.00	44.0	62.1
186.0	-20.85	-21.98	42.8	62.0
187.0	-19.11	-21.96	44.1	61.9
188.0	-17.67	-21.93	43.8	61.7
189.0	-16.56	-21.90	43.3	61.6
190.0	-15.74	-21.86	43.5	61.4
191.0	-14.87	-21.83	43.3	61.2
192.0	-14.09	-21.78	43.0	61.0
193.0	-13.38	-21.74	42.8	60.7
194.0	-12.74	-21.69	42.5	60.5
195.0	-12.13	-21.64	42.3	60.2
196.0	-11.59	-21.58	41.9	60.0
197.0	-11.07	-21.52	41.6	59.7
198.0	-10.58	-21.46	41.3	59.4
199.0	-10.12	-21.40	40.9	59.1
200.0	-9.71	-21.33	40.5	58.8
201.0	-9.31	-21.26	40.1	58.5
202.0	-8.92	-21.18	39.6	58.1
203.0	-8.55	-21.11	39.2	57.8
204.0	-8.21	-21.03	38.7	57.5
205.0	-7.88	-20.94	38.2	57.1
206.0	-7.57	-20.86	37.7	56.8
207.0	-7.27	-20.77	37.2	56.5
208.0	-6.99	-20.68	36.6	56.1
209.0	-6.72	-20.59	36.1	55.8
210.0	-6.45	-20.50	35.5	55.5
211.0	-6.20	-20.40	34.9	55.1
212.0	-5.96	-20.30	34.3	54.8
213.0	-5.73	-20.20	33.6	54.5
214.0	-5.50	-20.10	33.0	54.1
215.0	-5.29	-19.99	32.3	53.8
216.0	-5.08	-19.89	31.6	53.5
217.0	-4.88	-19.78	30.9	53.2
218.0	-4.68	-19.68	30.1	52.9
219.0	-4.49	-19.57	29.4	52.6
220.0	-4.31	-19.46	28.6	52.3
221.0	-4.13	-19.35	27.9	52.0
222.0	-3.96	-19.23	27.1	51.7
223.0	-3.79	-19.12	26.3	51.5

224.0	-3.63	-19.01	25.5	51.2
225.0	-3.47	-18.89	24.6	50.9
226.0	-3.32	-18.78	23.8	50.7
227.0	-3.17	-18.67	22.9	50.5
228.0	-3.02	-18.55	22.1	50.2
229.0	-2.88	-18.44	21.2	50.0
230.0	-2.75	-18.32	20.3	49.8
231.0	-2.61	-18.21	19.4	49.6
232.0	-2.46	-18.09	18.5	49.4
233.0	-2.32	-17.98	17.6	49.3
234.0	-2.21	-17.86	16.6	49.1
235.0	-2.08	-17.75	15.7	48.9
236.0	-1.96	-17.63	14.8	48.8
237.0	-1.84	-17.52	13.8	48.7
238.0	-1.72	-17.41	12.9	48.5
239.0	-1.60	-17.30	11.9	48.4
240.0	-1.49	-17.18	11.0	48.3
241.0	-1.37	-17.07	10.0	48.2
242.0	-1.26	-16.96	9.0	48.1
243.0	-1.15	-16.85	8.0	48.0
244.0	-1.05	-16.74	7.1	47.9
245.0	-0.94	-16.63	6.1	47.8
246.0	-0.84	-16.52	5.1	47.8
247.0	-0.74	-16.42	4.1	47.7
248.0	-0.64	-16.31	3.2	47.7
249.0	-0.54	-16.21	2.2	47.6
250.0	-0.44	-16.10	1.2	47.6
251.0	-0.35	-16.00	0.3	47.6
252.0	-0.26	-15.90	-0.7	47.6
253.0	-0.17	-15.79	-1.7	47.5
254.0	-0.07	-15.69	-2.6	47.5
255.0	0.02	-15.59	-3.6	47.5
256.0	0.10	-15.50	-4.6	47.5
257.0	0.19	-15.40	-5.5	47.5
258.0	0.26	-15.30	-6.4	47.6
259.0	0.34	-15.21	-7.4	47.6
260.0	0.41	-15.11	-8.3	47.6
261.0	0.46	-15.02	-9.3	47.6
262.0	0.56	-14.93	-10.2	47.7
263.0	0.69	-14.84	-11.0	47.7
264.0	0.74	-14.75	-11.9	47.8
265.0	0.75	-14.66	-12.9	47.8
266.0	0.88	-14.57	-13.6	47.9
267.0	0.91	-14.48	-14.8	47.9

268.0	0.97	-14.40	-15.6	48.0
269.0	1.04	-14.31	-16.3	48.1
270.0	1.10	-14.37	-17.0	48.2
271.0	1.16	-14.15	-18.0	48.2
272.0	1.19	-14.06	-18.9	48.3
273.0	1.24	-13.98	-19.8	48.4
274.0	1.34	-13.91	-20.5	48.5
275.0	1.33	-13.83	-21.6	48.6
276.0	1.41	-13.75	-22.0	48.7
277.0	1.46	-13.67	-22.8	48.8
278.0	1.47	-13.60	-23.8	48.9
279.0	1.49	-13.53	-24.7	49.0
280.0	1.53	-13.45	-25.3	49.1
281.0	1.56	-13.38	-26.0	49.2
282.0	1.59	-13.31	-26.8	49.3
283.0	1.62	-13.24	-27.5	49.4
284.0	1.64	-13.17	-28.2	49.5
285.0	1.66	-13.11	-28.9	49.6
286.0	1.67	-13.04	-29.6	49.8
287.0	1.68	-12.98	-30.3	49.9
288.0	1.69	-12.91	-31.0	50.0
289.0	1.69	-12.85	-31.7	50.1
290.0	1.69	-12.79	-32.4	50.3
291.0	1.69	-12.73	-33.0	50.4
292.0	1.69	-12.67	-33.6	50.5
293.0	1.68	-12.61	-34.3	50.6
294.0	1.66	-12.55	-34.9	50.8
295.0	1.65	-12.49	-35.5	50.9
296.0	1.63	-12.44	-36.1	51.0
297.0	1.60	-12.38	-36.7	51.2
298.0	1.58	-12.33	-37.3	51.3
299.0	1.54	-12.28	-37.9	51.4
300.0	1.51	-12.23	-38.4	51.6
301.0	1.47	-12.18	-39.0	51.7
302.0	1.42	-12.13	-39.5	51.9
303.0	1.38	-12.08	-40.0	52.0
304.0	1.32	-12.03	-40.6	52.1
305.0	1.28	-11.98	-41.1	52.3
306.0	1.20	-11.94	-41.6	52.4
307.0	1.14	-11.89	-42.0	52.5
308.0	1.06	-11.85	-42.6	52.7
309.0	0.98	-11.81	-43.0	52.8
310.0	0.90	-11.76	-43.5	52.9
311.0	0.82	-11.72	-43.9	53.1

312.0	0.73	-11.68	-44.4	53.2
313.0	0.63	-11.64	-44.8	53.3
314.0	0.52	-11.60	-45.2	53.5
315.0	0.41	-11.57	-45.7	53.6
316.0	0.30	-11.53	-46.1	53.7
317.0	0.18	-11.49	-46.5	53.9
318.0	0.05	-11.46	-46.8	54.0
319.0	-0.09	-11.43	-47.2	54.1
320.0	-0.23	-11.39	-47.6	54.3
321.0	-0.38	-11.36	-47.9	54.4
322.0	-0.54	-11.33	-48.3	54.5
323.0	-0.70	-11.30	-48.6	54.6
324.0	-0.87	-11.27	-48.9	54.7
325.0	-1.05	-11.24	-49.3	54.9
326.0	-1.24	-11.21	-49.6	55.0
327.0	-1.44	-11.19	-49.9	55.1
328.0	-1.65	-11.16	-50.2	55.2
329.0	-1.87	-11.13	-50.4	55.3
330.0	-2.11	-11.11	-50.7	55.4
331.0	-2.35	-11.09	-51.0	55.5
332.0	-2.60	-11.06	-51.2	55.6
333.0	-2.87	-11.04	-51.5	55.7
334.0	-3.15	-11.02	-51.7	55.8
335.0	-3.45	-11.00	-51.9	55.9
336.0	-3.76	-10.98	-52.2	56.0
337.0	-4.09	-10.96	-52.4	56.1
338.0	-4.44	-10.94	-52.6	56.2
339.0	-4.81	-10.93	-52.8	56.3
340.0	-5.20	-10.91	-53.0	56.3
341.0	-5.61	-10.89	-53.1	56.4
342.0	-6.06	-10.88	-53.3	56.5
343.0	-6.53	-10.87	-53.4	56.5
344.0	-7.03	-10.85	-53.6	56.6
345.0	-7.57	-10.84	-53.7	56.7
346.0	-8.16	-10.83	-53.9	56.7
347.0	-8.79	-10.82	-54.0	56.8
348.0	-9.48	-10.81	-54.1	56.8
349.0	-10.24	-10.80	-54.2	56.9
350.0	-11.08	-10.79	-54.4	56.9
351.0	-12.07	-10.78	-54.0	57.0
352.0	-13.15	-10.78	-54.4	57.0
353.0	-14.33	-10.77	-54.9	57.0
354.0	-15.75	-10.77	-54.5	57.0
355.0	-17.62	-10.76	-54.9	57.1



356.0	-19.94	-10.76	-55.7	57.1
357.0	-23.23	-10.76	-58.7	57.1
358.0	-30.01	-10.75	-65.6	57.1
359.0	-37.19	-10.75	-87.3	57.1
360.0	-87.28	-10.75	-23.3	57.1

CPU RUN TIME FOR RUN 1 GEOMETRY 1 = 1416.89 SECONDS

TOTAL CPU RUN TIME = 1419.88 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
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))

```





