NASA Technical Memorandum 107679

Finite Difference Time Domain Grid Generation from AMC Helicopter Models

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September 1992

NASA

National Aeronautics and
Space Administration

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Finite Difference Time Domain Grid Generation From AMC Helicopter Models

Abstract

A simple technique is presented which forms a cubic grid model of a helicopter from an Aircraft Modeling Code (AMC) input file. The AMC input file defines the helicopter fuselage as a series of polygonal cross sections. The cubic grid model is used as an input to a Finite Difference Time Domain (FDTD) code to obtain predictions of antenna performance on a generic helicopter model. The predictions compare reasonably well with measured data.

Introduction

To investigate new methods for computationally evaluating antenna performance on helicopters, a finite difference time domain (FDTD) scattering code was obtained [1]. The FDTD method of solving Maxwell's equations involves discretizing the equations on a cubic grid of points which contains the object(s) of interest and a surrounding area. A slight modification of the code allowed for addition of radiation prediction capability to the scattering code. Unfortunately, in the original code, the model representation was actually defined explicitly in the main program, instead of being done by a preprocessor and then read in from a file. This meant the user had to assign material properties to each grid point in the problem space in the main program, a tedious job except in the simplest of cases. For a complicated helicopter configuration at a reasonable frequency, this job would be practically impossible. This also meant a recompile of the program had to be done for each different model configuration. A need was seen for a modeling utility which would provide a user with a more efficient interface to the FDTD code. The GRID code is an attempt to provide such an interface. In the first section of this report, the input file for the GRID code will be described. In the second section, the algorithm for creating the cubic grid model from the input file will be described. In the third section, some FDTD results obtained using the GRID code will be presented, and in the last section some conclusions and recommendations for future improvements to the code will be given.

Input File

The first step in creating a modeling interface was to decide in which format data were to be supplied to the program. A new modeling program developed jointly by NASA Langley and Ohio State University (OSU) has provided a convenient way for a user to input cross section and flat plate information by means of a graphics tablet. Given the tablet input, the Helicopter Antenna Radiation Program (HARP) will automatically generate input data for two of the existing helicopter antenna pattern prediction codes which have also been developed jointly by NASA and OSU. The input file format for the method of moments Aircraft Modeling Code (AMC) was chosen as the input for the GRID program. This input file format includes cross

```
FR :DEFINE FREQENCY
500.0
NS :DEFINE NUMBER OF SIDES
8
SM :SYMMETRIC FUSELAGE
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
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
0.0 3.8
4.0 3.0
4.6 0.0
4.2 -5.8
0.0 -7.4
CS :DEFINE CROSS SECTION
146.02 0.0 0 1 0
0.0 3.4
2.5 2.7
2.9 0.0
2.6 -4.9
0.0 -6.2
TS :DEFINE TAIL SECTION
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 6.0 0.0 87.63 -13.2
NG :END OF GEOMETRY DATA
```

Figure 1. Sample Input File for AMC Code

sectional data for the helicopter fuselage at different values along the fuselage axis, as well as flat plates representing the wings, tail section, and tail wings. The antenna is modeled as a wire monopole. The input file is fairly simple to create even without using a graphics tablet and the HARP code. This allows the GRID code to use much of the input/output code already written for the AMC code. The gridding technique used in the GRID code is a simple one which is designed to take advantage of the AMC input file format. The grid spacing is specified by the user by appending to the AMC input file an integer indicating how many grid spaces are spanned by the monopole antenna. In other words, the monopole is divided into an integer number of divisions to give the grid spacing. Thus, the length of the monopole antenna is always exactly modeled by the GRID program.

A sample input file for a NASA advanced attack helicopter model is shown in figure 1. As can be seen from the figure, the input file consists of two letter codes indicating which parameter is being specified, followed by an optional comment and the appropriate numbers describing the parameter. A picture of the advanced attack helicopter AMC model is shown in figure 2. Detailed description of the AMC input

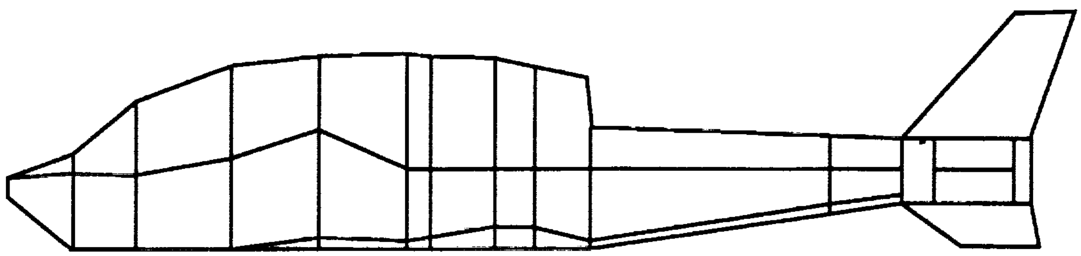

Figure 2. AMC model for NASA Advanced Attack Helicopter

file is available [2].

Algorithm for Grid Generation

Since the GRID program uses the same input file as used by the AMC program, the GRID code calls the subroutine used by the AMC program for the purpose of reading in the data. After calling this subroutine, the cross section information defining the fuselage of the helicopter is stored in arrays giving the x, y, and z locations of each point contained in a cross section, for each cross section. Note that each cross section is defined by the same number of points, so that corresponding points on adjacent cross sections can be connected by line segments to form a wireframe outline of the fuselage. The y value is constant for all the points forming a cross section, since the plane containing cross section points is parallel to the x-z plane. Arrays containing the x, y, and z coordinates of the vertices of each flat plate defining the wings, tail section, and tail wings are also initialized. For simplicity, the assumption was made that the wings and tail wings were in the $z = 0$ plane, and the tail section was at $x = 0$. Thus, the arrays contain sets of points defining planar closed polygons parallel to either the x-z (fuselage cross sections), the y-z (tail section), or the x-y (wings and tail wings) planes.

Once the arrays containing the polygons have been set up , the basic dimensions of the grid can be determined. The size of each grid cell is determined from the number specified by the user for the length of the monopole antenna in grid cells. Dividing the physical length of the monopole by this number gives the physical size of each grid cell edge. A rule of thumb for the size of the total FDTD grid is to allow a wavelength of empty grid cells on each side of the actual model. The minimum x, y, and z values for the helicopter can be obtained by searching the arrays of points described above, and the differences in the maxima and minima give the extent of the model in the three directions. The total grid size is obtained by adding two wavelengths to the model size in each direction.

The next step in computing the grid model from the lists of polygons defining the fuselage, tail section, and wings is to determine the closest points of the grid to the surface defined by the polygons. A side view of a sample fuselage overlaid with an FDTD grid is shown in figure 3. For the fuselage, the grid computation is done one section at a time, a section being the part of the fuselage between two cross sections. The basic algorithm for this process for each section is as follows:

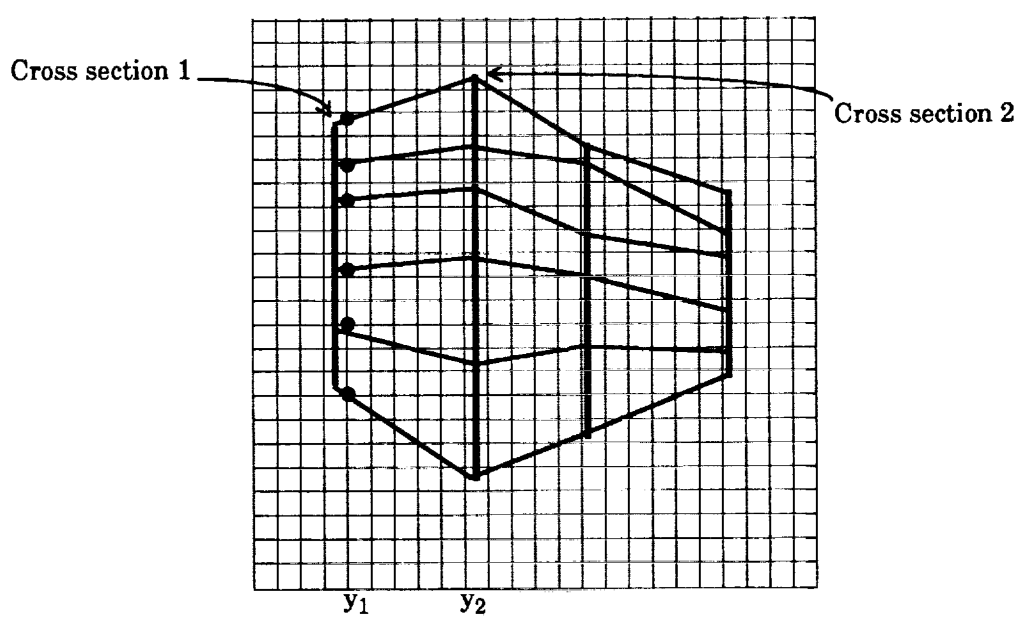

Figure 3. Side View of Sample Fuselage With Grid

Determine the y grid values closest to the y values of the two cross sections defining the section (for example, y_1 and y_2 in figure 3)

For each y grid value between y_1 and y_2:

Determine intersections of line segments between corresponding points on cross sections 1 and 2 with the current y grid plane, which form a new cross section (for example, points illustrated by heavy dots in figure 3)

Find x, z grid points which most closely approximate the new cross section in this y plane

Note that the last step in this algorithm is a two-dimensional problem involving overlaying a closed plane polygon with a two-dimensional square grid and finding the grid points which most accurately approximate the polygon. This is identical to finding the grid approximations for the wings and tail section of the helicopter model, since they are modeled by planar closed polygons. Thus, one basic algorithm has been developed to solve this specific problem. This algorithm will now be described:

For each line segment forming the side of the polygon:

Obtain a vector pointing from beginning point to ending point (for example, vector shown in figure 4))

Compute angle vector makes with the x axis

Rotate coordinate system so that new (x') axis is along vector

Find grid point closest to first endpoint of line segment to start the grid approximation to line segment (x_c, z_c in figure 4)

Find nearest neighbors to current point x_c, z_c

Find x', z' coordinates of nearest neighbors

Choose as next x_c, z_c the nearest neighbor which has positive x' value and the smallest z'

Repeat last three steps until current point becomes grid point nearest ending point of vector (see figure 5)

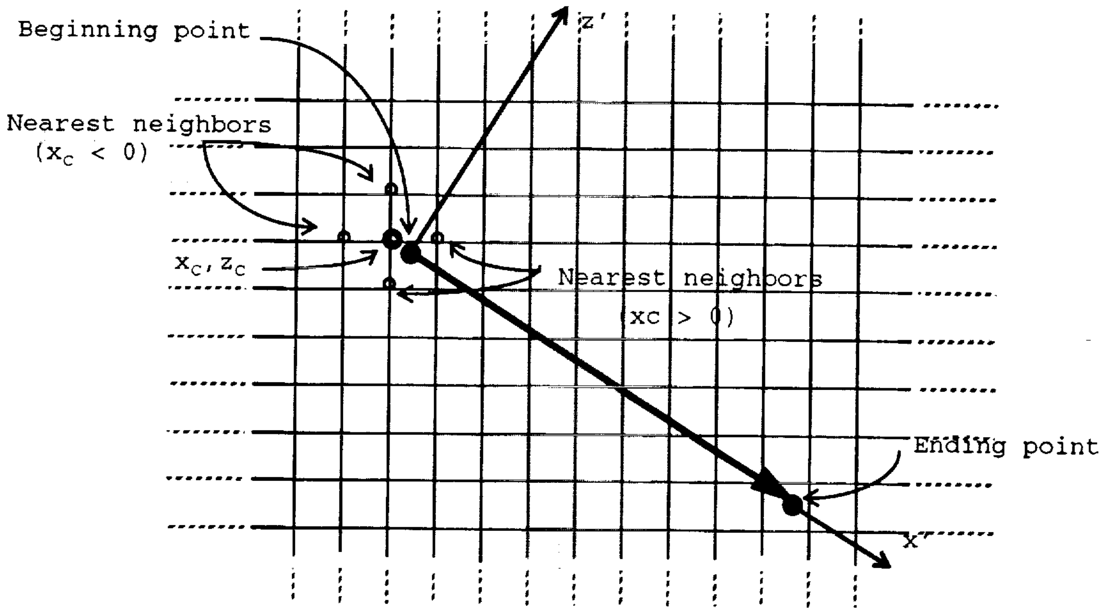

Figure 4. Two Cross Section Endpoints, x', z' Coordinates

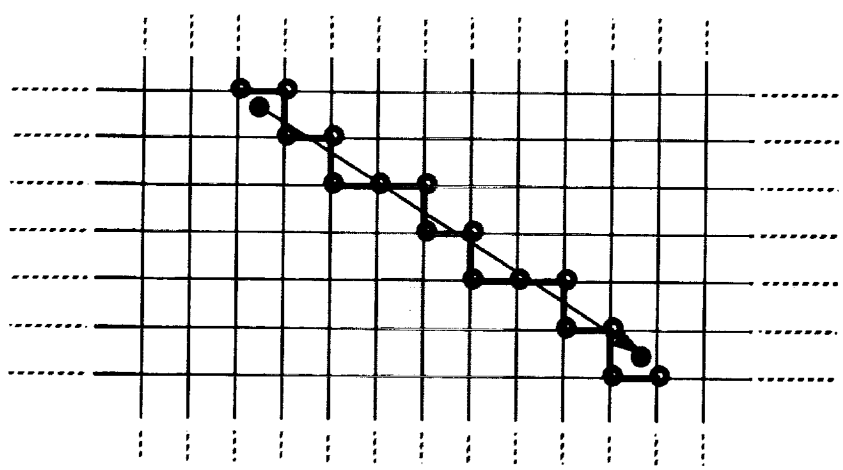

Figure 5. Grid Approximation to Line Segment Forming Cross Section Edge

Once this procedure has been performed on each side of the sample closed polygon shown in figure 6a, the resulting grid approximation looks like that in figure 6b. The grid approximation to the fuselage cross sections and the grid approximation to the plates forming the wings and tail section are then combined to give the FDTD input model for the helicopter.

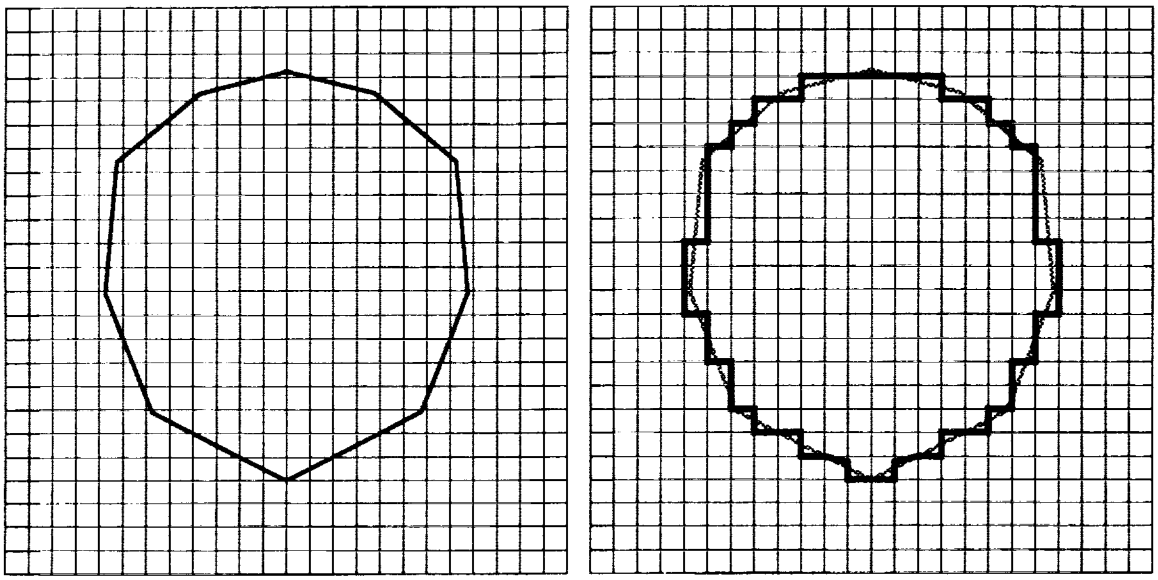

Figure 6. Grid Approximation to Cross Section

FDTD Results

In this section, a sample output from the FDTD code is shown. The input file to the FDTD code was obtained by running the GRID code for the NASA advanced attack helicopter scale model shown in figure 2, but using 29 cross sections and 50 points per cross section in the AMC model file to more accurately describe the surface. The more accurate model was obtained fairly easily using the HARP code described earlier. The test case shown is for a frequency of 500 Mhz, and the monopole, which is mounted on the bottom of the helicopter, is 6 cm long. The grid spacing for this case was chosen as 3 cm. This results in 20 grid cells per wavelength, which is the recommended spacing size for this code. A linearly polarized elevation plane radiation pattern is shown in figure 7 for both measured and FDTD computed results. The GRID code took 1.488 CPU seconds to execute on a Cray X-MP for this case.

Conclusions and Recommendations

From the pattern shown in figure 7, it can be seen that the FDTD method

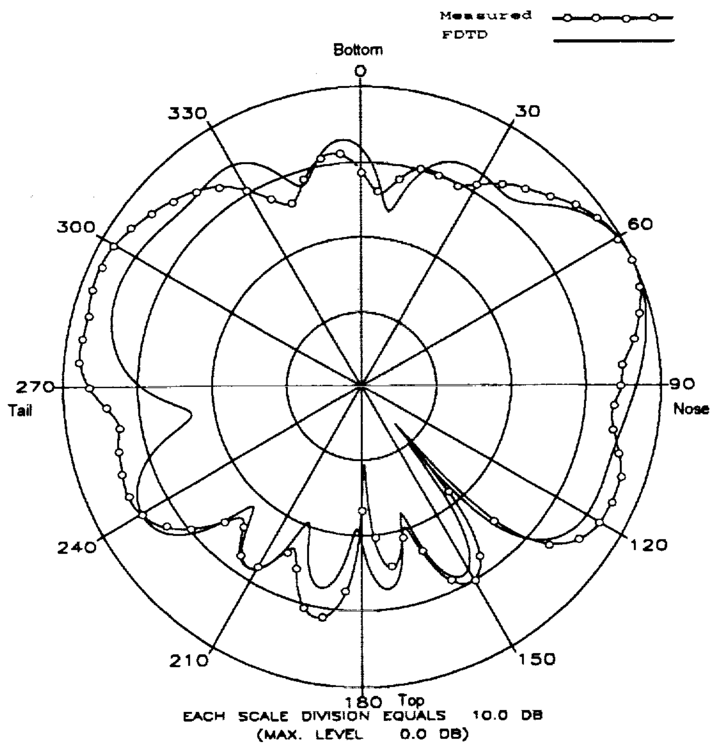

Figure 7. Computed and Measured Results

shows promise in predicting helicopter antenna patterns, especially for low to moderate frequencies. Since the number of grid cells increases roughly as the cube of the frequency, higher frequency runs (with wavelengths much smaller than the target size) are prohibitively expensive in terms of computer storage and run time. The input file for the FDTD code can be obtained from an AMC model in a simple way using the GRID code. To get the results shown, however, a fairly detailed AMC model had to be created. With the use of the HARP automated modeling code, this process is also quite easy.

The GRID code is based on a simple geometric approach to finding the intersection of a cubic grid with a cross section model of a helicopter. Future improvements could include extra parameters being taken into account in the creation of the grid, such as the conservation of surface area when going to a cubic grid model from the cross section model. This would result in a more accurate FDTD calculation. Also, research could be done in the literature for optimizing techniques to speed up execution and improve accuracy.

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2. Peters, M. E. and Newman, E. H.: A User's Manual for the Method of Moments Aircraft Modeling Code (AMC). (Ohio State University; NASA Grant NSG 1498.) NASA CR-716199-14, 1989.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
September 1992

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Finite Difference Time Domain Grid Generation from AMC Helicopter Models

5. FUNDING NUMBERS
WU 505-64-70-01

6. AUTHOR(S)
Robin L. Cravey

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA Langley Research Center
Hampton, Virginia 23681-0001

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA TM-107679

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited

Subject Category 32

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

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14. SUBJECT TERMS
Finite Difference Time Domain, Helicopter Antenna Pattern Prediction, Grid generation

15. NUMBER OF PAGES
11

16. PRICE CODE
A03

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102