Modeling 3D Wings Like Object Based On Finite-Different Time-Domain (FDTD) Method In Graphical User Interface For Radar Cross Section (RCS)

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Special dedication to my family, my kind hearted supervisor EN FAUZI BIN MOHD JOHAR and to all my dearest friends.

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ABSTRACT

This thesis focuses on the application of radar. This application is to identify patterns of Radar Cross Section (RCS) in a wide band frequency where the frequencies reflected on an object such as an airplane wing. Each airplane wing design provides a difference of Radar Cross Section (RCS) patterns where type of wing design depending on characteristics of the aircraft. By using this application, the forms of these wings can be easier studied before it is designed as a prototyping where it is very useful especially in the Air Force. This application uses the Finite Difference Time Domain method (FDTD). Whereas this method is simpler than Method of Moments (MoM) or Finite Element Method (FEM) and it is space time based domain as a result benefited to wide band frequencies application FDTD is able to compute the pattern of Radar Cross Section (RCS) as imaginary. In this method, there are other methods used to achieve the Radar Cross Section (RCS) pattern as similar as real. The method is Perfectly Matched Layer (PML), Absorbing Boundary Condition (ABC), Near Field Far Field (NFFF) and Scattering Parameters. In addition, to facilitate the wing shape is examined, Graphical User Interfaces (GUI) are used to display the Radio Cross section (RCS) depends on the chosen form of wings.

ABSTRAK

Thesis ini tertumpuan kepada aplikasi radar yang sedang digunakan pada masa kini. Aplikasi ini adalah untuk mengenal pasti corak keratan rentas radio “Radar Cross Section” (RCS) pada frekuensi jalur lebar yang terpantul pada objek seperti sayap kapal terbang. Setiap bentuk sayap kapal terbang akan memberikan corak keratan rentas radar yang berlainan dimana bentuk sayap ini memainkan peranan yang penting. Ianya bergantung pada ciri-ciri bentuk kapal terbang tersebut. Dengan menggunakan aplikasi ini, bentuk-bentuk sayap ini dapat memudahkan kajian dijalankan terhadap sayap tersebut sebelum ianya direka sebagai protaip. Ianya amat berguna terutamanya pada Angkatan Tentera Udara. Aplikasi ini menggunakan kaedah “Finite Difference Time Domain” (FDTD). Dimana, kaedah le adalah lebih mudah daripada Kaedah (MoM) atau (FEM) dan berupaya dijalankan pada lebar jalur frekuensi.FDTD ini berupaya membina corak keratan rentas radar “Radar Cross Section” (RCS) sebenar bergantung pada bentuk object tersebut. Didalam kaedah ini, terdapat beberapa kaedah lain yang digunakan bersama untuk mencapai corak keratan rentas radar (RCS) yang sebenar. Kaedah tersebut ialah kaedah ‘Perfectly Matched Layer (PML)’, ‘Absorbing Boundary Condition (ABC)’, ‘Near Field Far Field (NFFF)’ dan ‘scattering parameters’. Selain itu, bagi memudahkan bentuk sayap ini dikaji. Peranti antara muka atau dikenali sebagai ‘Graphical User Interfaces (GUI)’ digunakan untuk memaparkan corak keratan rentas radar (RCS) bergantung pada bentuk sayap yang dipilih.

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FDTD	-	Finite Difference Time Domain
RCS	-	Radar Cross Section
PML	-	Perfectly Matched Layer
CPML	-	Convolution Perfect Matched Layer
ABC	-	Absorbing Boundary Condition
NFFF	-	Near Field Far Field
GUI	-	Graphical User Interfaces (GUI)
PMC	-	Perfect Magnetic Fields
3D	-	3-Dimension
CEM	-	Electromagnetic computational model
MOM	-	Method of Moments
FEM	-	Finite Element Method
RAM	-	Absorbent Material
DFT	-	Difference Fourier Transform
TE	-	Transverse Electric Wave
TM	-	Transverse Magnetic
CST	-	Center Standard Time
HFSS	-	High Frequency Structural Simulator
EXE	-	Execute.File
IEEE	-	Institute of Electrical and Electronics Engineers

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

This chapter will explain the background of the project which is giving an introduction about this project. This chapter contains the project objectives, problem statement, scope of work, methodology project and Gantt chart in project.

1.1 Project Overview

This project is a simulation on a wing-shaped object in 3 Dimension. This simulation will use Maxwell's equations in the time domain difference Cartesian coordinates for structure modeling of electromagnetic waves. In addition, the Finite Difference Time Domain (FDTD) method is used to simplify the modeling. Thus, simulation is better in wideband frequency.

In this project, 3D FDTD is used in transverse electric wave (TE) and transverse magnetic (TM). So, the drafting of this 3D simulation will take a long time. Therefore, the NFFF (Near Field Far Field) transformation method requires a transformation method for scattered field formulation and will be integrated with the far zone plane wave source. This will reduce the simulation time. In addition, the FFT (Fast Fourier Transform) method also will be executed to evaluate the RCS (Radio Cross Section) parameters.

By changing parameter object, RCS can be visualized and studied. Finally RCS result of FDTD will be verified with commercial software either CST (Center Standard Time) or HFSS (High Frequency Structural Simulator).

1.2 Objective

The objective of this project is:

1. To model a wing-shaped object on 3D Finite-Different Time-Domain (FDTD) method in Graphical User Interface.

2. To implement MATLAB in the simulation for wing-shaped modeling object in 3 Dimension.

3. To analyze the radar cross section (RCS) pattern of the wings structure.

The main objective of this project is to design the software in which to simulate a wing-shaped model in 3D Finite-Time Domain different methods (FDTD). This simulation will collect the reflected signal resulting from the percentage of the intercepted power radiated (scattered) on the wing object when the object receives a signal from a plane wave source. At the end of the simulation, the distribution of data is computed to obtain the RCS pattern. RCS pattern will depend on the shape and direction of the incoming signal. By using the graphical User Interface (GUI), it is even easier to analyze the RCS patterns for different direction of the incoming signal without modifying the existing code.

1.3 Problem Statement

In present developing world, to design scattering parameter for any object is an important and crucial process. Originally it begins from a numerical model of learning called electromagnetic computational model (CEM). Electromagnetic computational model (CEM) algorithm is the ability to simulate the device behavior and the structure of the system before it is actually built. Besides that, the Electromagnetic Computational Model (CEM) is easier to be implemented and cost efficient.

As for the analytical methods used, the basic foundation theories and details must be sufficient to design such a structure because the study of the basic equations to develop numerical capitalization using some kind of numerical time stepping procedure to get model behavior over time required. In this method, the principle of operation can be used to for a new design, modification of existing designs, and for the development of the new configuration. Another method that can be used is experimental method, but requires the high cost, takes a long time and limited scope to modeling structure.

FDTD method is used to solve Maxwell's equations in the time domain which is used to calculate the electric and magnetic fields. Technique is based on a simple formula that does not require the asymptotic complexity and easy-to-implement parallel calculation. In addition, the FDTD method is a tool to simulate the necessary structure and easy to design that allows virtual prototype developed to avoid expensive physical prototypes.

1.4 Scope of Works

The scope of this project is to design the 3D Finite Different -Time Domain (FDTD) to Single Periodic Unit Based on Perfect Electric Conductor (PEC) / Perfect Magnetic Conductor (PMC). This project mainly focuses on software and designs the structure of the modeling boundary layer and also to model spatial filter (FFS). A unit cell is bounded by PEC, PMC and CPML. The FDTD based on curl/differential equation has the Maxwell equation and scalar curl Maxwell's equation.

1.4.1 Understanding FDTD Algorithm

The Finite-Difference Time-Domain method (FDTD) is one of the most popular techniques for the solution of electromagnetic problems. It has been successfully applied to an extremely wide variety of problems, such as scattering from metal objects and dielectrics, antennas, micro-strip circuits, and electromagnetic absorption in the human body exposed to radiation. The main reason of the success of the FDTD method resides in the fact that the method itself is extremely simple, even for programming a three-dimensional code.

This project is a simulation of scattering in model a wing-shaped object in 3 Dimension .This simulations will use Maxwell's equations in the time domain difference Cartesian coordinates for structure modeling of electromagnetic waves. This basic equation is representing vector equation in Faraday's Law and Ampere's Maxwell Law. In the equations, there are calculate magnetic field and electric field. This equation will describe more in chapter 2 as literature review part.

By using the basic equation, the electric and magnetic fields in a 3D space will derived. In 3-Dimension derivation, it is natural to specify the location of a node using three indices representing the displacement in the x, y, and z directions. So it has additional steps that will need the implementation of a three-dimensional (3D) grid and almost trivial. A 3D grid can be viewed as stacked layers of TE and TM grids. The figure 1 show Yee unit cell in 3 Dimension with z direction.

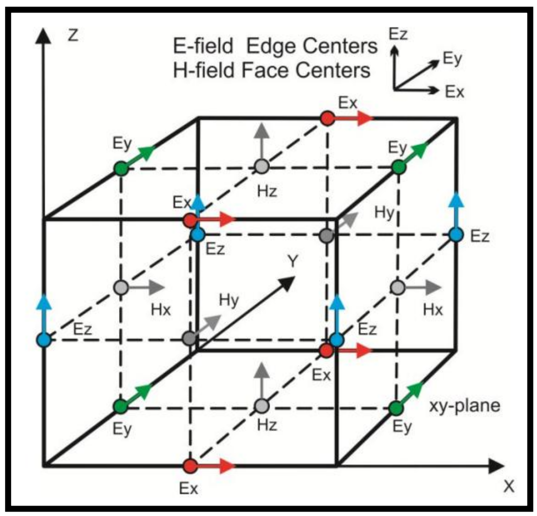

Figure 1.1: Yee unit cell in 3 Dimension [1]

The basic equation will be reduced to a system of six scalar equations in Cartesian coordinates where μ, ε and σ will assuming that are isotropic. These six coupled partial differential equations form the basic building blocks of the Yee FDTD algorithm for solving Maxwell's equations. This six equation is Scalar Maxwell's equations, it important part to develop 3 Dimension in FDTD. It will describe more in next chapter.

1.4.2 Design object in FDTD

The FDTD method has an ability to deal with problems incorporating materials with geometrical in-homogeneities. With an arrangement of the fields in the Yee, the object will be constructed. This construction uses a combination of these simple object where it uses the term ‘brick’, which has its faces parallel to the Cartesian coordinates axes and can be represented by two corner point; [1] the point with lower x, y, and z coordinates and [2] the point with upper x, y, and z. Below, Figure 2 and 3 show the measured of wing and Table 2 represent a values Cartesian Coordinates Axes for lower and upper for each brick.

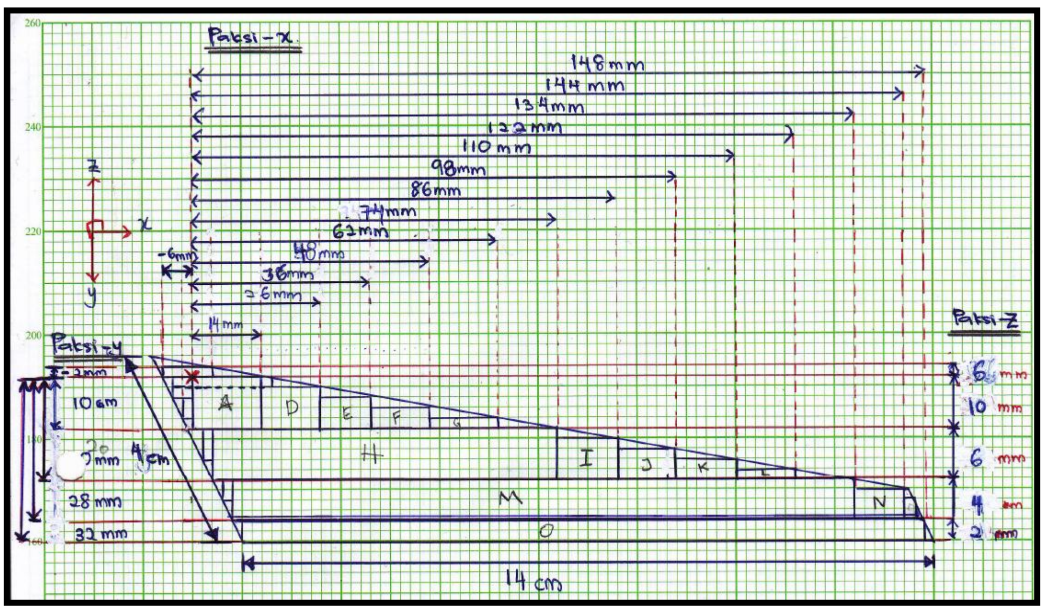

Figure 1.2: Top view measurement of wing-shaped

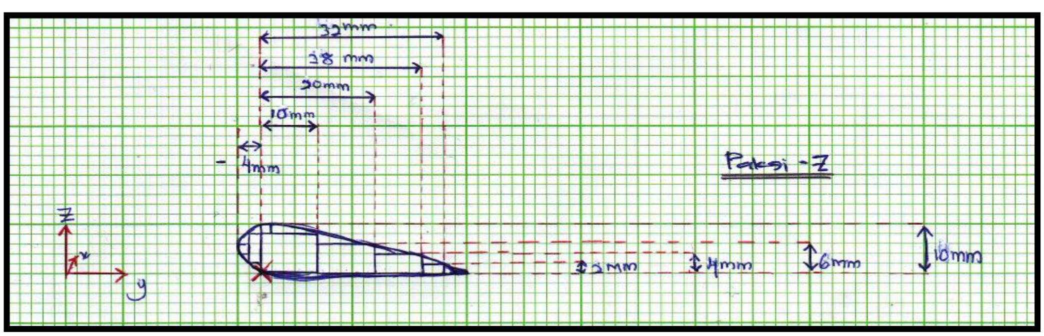

Figure 1.3: Side view measurement of wing-shaped