MODELING WIRE ANTENNA USING 3D FINITE DIFFERENCE-TIME DOMAIN (FDTD) METHOD IN GRAPHICAL USER INTERFACE (GUI) FOR RADIATION PETTERN EVALUATION

SITI NURSYUHADA BINTI MAT NASIR

This Report Is Submitted In Partial Fulfillment Of Requirement For The Degree of Bachelor In Electronic Engineering (Telecommunication Electronic)

Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer

Universiti Teknikal Malaysia Melaka

JUNE 2013

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : MODELING WIRE ANTENNA USING 3D FINITE DIFFERENCE-TIME DOMAIN (FDTD) METHOD IN GRAPHICAL USER INTERFACE (GUI) FOR RADIATION PATTERN EVALUATION.

Sesi Pengajian : 2012/2013

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No.309 Felda Kemahang 2,17500
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FAUZI BIN MOHD JOHAR
Pensyarah
Fakulti Kejuruteraan Elektronik Dan Kejuruteraan Komputer
Universiti Teknikal Malaysia Melaka (UTeM)
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

Tarikh: 11th JUNE 2013

Tarikh: 11th JUNE 2013

"I hereby declare that this report is the result of my own work except for quotes as cited in the references"

Signature :..

Author :SITI NURSYUHADA BINTI MAT NASIR

Date : 11th JUNE 2013

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Signature	:..
Supervisor's Name	: ENCIK FAUZI BIN MOHD JOHAR
Date	: 11th JUNE 2013

It is only befitting that I dedicated this humble work to the noble and illustrious prophet, Muhamad SallallahuAlaihiWasallam, addressed by Allah SubhanahuWata'ala as the "Unlettered" Prophet, yet, the Master of the most extensive knowledge, foretold in previous scriptures, and the Mercy for the Worlds.

Special dedication to my loving parents, Mat Nasir bin Zakaria and Hasnira binti Abdullah, also to all my supported siblings, my kind hearted Encik Fauzi bin Mohd Johar and special thank you to my dearest friends.

ACKNOWLEDGEMENT

Alhamdulillah, all praise to thank to Allah SWT the almighty for giving me the Rahmah to finish my Project Sarjana Muda II successfully. Thanks to Ilahi for the opportunity given and helped make easier the entire task project given as long as this semester. After work hard for whole semester, finally I finished my Project Sarjana Muda II with fully satisfaction.

Special thanks to my kind hearted supervisors Mr. Fauzi bin Mohd Johar, for the opportunity given to me to do this project. Thank a lots for the her endless support and ideas, during which he has been patiently supervising my progress and encouraged me to do this project in the right way. He never tired to teach me step by step until I can do it independently. With full of hope, Allah SWT bless him and family.

Then, I would like to thanks for my family, especially my loving parents Mat Nasir bin Zakaria and Hasnira binti Abdullah and my siblings because always be behind me. Thank you for the support and encouragement. They are always advising me to perform the best in any field that I involve. Without them, I wouldn’t to complete my thesis project with successful.

Lastly, to everybody that has been involved in my project directly or indirectlty, thanks a lots. Without all supporters, I wouldn’t to complete my thesis project with successful.

ABSTRACT

The Finite-Difference Time-Domain (FDTD) method is one of known electromagnetic numerical tool that used for design and analysis the antenna. 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. The purpose of project is to develop a simulator based on 3D-FDTD method for wire antenna. Hence the type of antenna, frequencies, types of source, and time iteration are directly entered by user into the MATLAB based-graphical user interface (GUI) menu which is user friendly and attractive. As a result of simulation the antenna electric field radiation are displayed into three (3) different planes. That radiation patterns can be partly drawn in xy, yz and xz plane at particular frequency. Since this software designed for three (3) dimensional antenna structure than two (2) dimensions, therefore higher computational cost. From this project, we had able create our own specific antenna software toward learning how commercial software such as that CST or HFSS developed. As well as learning tool to motivate for students keeps involving in development of antenna simulator or tool. Normally, prices of electromagnetic software packages especially antenna is quite expensive and license per year basis. Finally, this project also relevant and parallels with the latest technology in antenna design.

ABSTRAK

Kaedah ″Finite-Difference Time-Domain″ (FDTD) merupakan salah satu perkakasan numerikal elektromagnetik yang digunakan untuk merekabentuk dan menganalisa antena. Di mana kaedah ini lebih ringkas daripada ″Method of Moments″ (MoM) atau ″Finite Element Method″ (FEM) dan ianya berdasarkan ruang masa domain hasilnya memudahkan untuk aplikasi frekuensi jalur lebar. Tujuan projek ialah membangunkan simulator berasaskan kaedah 3D-FDTD untuk antena wayar. Di sini bentuk antena, frekuensi, jenis sumber dan masa lelaran dimasukan terus oleh pengguna ke dalam menu paparan muka pengguna grafik (GUI) MATLAB yang mesra guna dan menarik itu. Hasil simulasi antena, radiasi medan elektrik dipaparkan dalam tiga (3) satah berbeza. Bentuk radiasi itu boleh digambarkan berasingan dalam satah berbeza xy, yz dan xz pada frekuensi tertentu. Oleh kerana perisian ini direkabentuk untuk struktur antena tiga (3) dimensi berbanding dua (2) dimensi, maka kos pengkomputeran lebih tinggi. Daripada projek ini, kita mampu mencipta sendiri perisian tertentu antena ke arah memahami bagaimana perisian komersial seperti CST atau HFSS itu dibangunkan. Juga sebagai alat pembelajaran bagi memotivasi pelajar sentiasa melibatkan diri dalam pembangunan alat atau simulator antena. Kebiasaannya, harga pakej perisian elektromagnetik terutamanya antena adalah sangat mahalnya dan asas kepada tahun lesen. Akhir sekali, projek ini juga relevan dan selari dengan teknologi terkini dalam rekabentuk antena.

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CHAPTER I

INTRODUCTION

This chapter elaborates the project background, project objectives, problem statements, scope of work, methodology and lastly project planning.

1.1 Project Overview

The aim of this project is to apply the differential time domain of Maxwell's equations in Cartesian coordinate for simulating wire antennas. Since the proposed structure is thin wire antenna thus Faraday's law contour path formulation based integral Faraday equation also implemented. All these equations are being used in implementation of Finite Difference Time Domain (FDTD) method for modeling full wave electromagnetic structures. The FDTD method is one of numerical solution method used in solving electromagnetic problems as well as in acoustics study. Based on finite-difference approximations of the derivative operators the differential equation is being solved. The advantage of FDTD is simple method to implement numerically and time based simulation as result better for obtaining wideband frequency response.

In order to compute the antenna radiation pattern which is in the far away region from radiated antenna the near-field to far-field (NFFF) transformation technique and also Fast Fourier Transformation (FFT) will be implemented.

1.2 Objectives

The objective of this project is:

i. To implement MATLAB in wire antenna modeling.
ii. To model straight line spiral wire antenna using 3D finite difference-time domain (FDTD).
iii. To analyze the radiation pattern of thin wire antenna.

The developed FDTD modeler is represented in graphical user interface (GUI) using MATLAB software for analyzing the radiation pattern of three wire antennas. Wire antennas are array dipole, spiral and grid spiral lines.

1.3 Problem Statement

In this world today, many people has their own creativity to upgrade the every existing software to become a new software depend on their criteria that they want. If analytical method is used, theoretical of fundamental must be strong to designing any structure required. Until now, we have assumed that all of the objects in the FDTD problem space conform to the FDTD grid. The FDTD method has gain tremendous popularity of the past decade as a tool for solving Maxwell's equations. It is based on simple formulations that do not require complex asymptotic. The FDTD technique is easy to implement using parallel computation algorithm. Besides that, these features of the FDTD method have made it the most attractive technique of computational electromagnetic for many microwave devices and antenna application. Thus, some subcell modeling techniques are develop to model geometries that do not conform to the grid or have dimensions smaller than cell dimensions. One of the most common such geometries is a thin wire that has a radius less than a cell size. Thus, we can use FDTD program to model the thin wires as a model techniques subcell. There are various techniques proposed for modeling thin wires. In this project we use is based on Faraday's law contour-path formulation. Here we can see FDTD is a very versatile modeling technique. It is a very intuitive technique, so users can easily understand how to use it, and know what to expect from a given model.

Furthermore, others problem statement that we can define is, in perspective computational methods in electromagnetic which is various methods that may be employed for the analysis of boundary value problems in electromagnetic. As shown, the analysis may be based on theoretical approach and/or experimental measurements.

i. Analysis may be used to reduce the number of costly tests on prototypes by supporting the design process.
ii. Analysis may be used to ascertain the advantages as well as limitations of a configuration by carrying out parametric studies.

iii. Analysis can provide an understanding of the operating principles that could be useful for a new design, for modification of an existing design, and for the development of new configurations.

1.4 Scope of Works

1. Understanding FDTD Algorithm

- This work presents the development of a modeling wire antenna using 3D FDTD method in graphical user interface (GUI) for radiation pattern evaluation. The formulation of the implemented FDTD algorithm is described, as well as the analysis of its fundamental properties. A description of the complementary techniques and algorithms that allow the effective implementation of a simulator for the analysis of problems of engineering value is also presented. These include a Convolutional Perfectly Matched Layer (CPML), a thin-wire model, excitation source models and a near-to-far-field transformation. The stated above techniques are implemented in a modular fashion and integrated into a graphical user interface that, besides allowing the configuration and three-dimensional visualization of the structures being analyzed, also features a non-uniform mesh generation algorithm that automatically performs the discretization of the 3D objects.

- In this project we also use techniques in computational electromagnetic (CEM), which is the collection of techniques in CEM can be classified in various ways. This classification divides CEM into two major categories namely numerical methods and high-frequency. Numerical methods are best suited for problems where the size of the structure under analysis is in the order of the wavelength to a few tens of wavelengths. These methods take into account the wave nature of the electromagnetic phenomenon and are therefore based on discretizations of differential or integral formulations of Maxwell's equations. Both integral and differential equation based numerical methods can be divided in two parts namely frequency domain and time domain.

2. Familiarize FDTD Program

In this project, the starting point for the construction of an FDTD algorithm is Maxwell's time domain equation. The time-dependent Maxwell's equations in a region of space without imposed electric or magnetic current sources, but that may have materials that absorb electric or magnetic field energy, are given in differential form, by Faraday's law and Ampere's law. Then, it converts into scalar Maxwell's equations for 3D FDTD. After make a Scalar Maxwell's equations for 3D FDTD, the Maxwell's will discretized where it analyzed related to time dependent Maxwell's equation that introduce by Yee cell.

3. Design Antenna

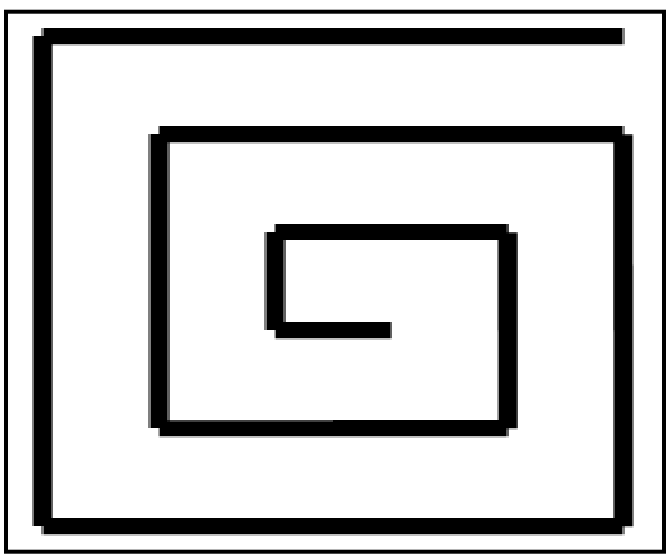

Figure 1.1 Spiral

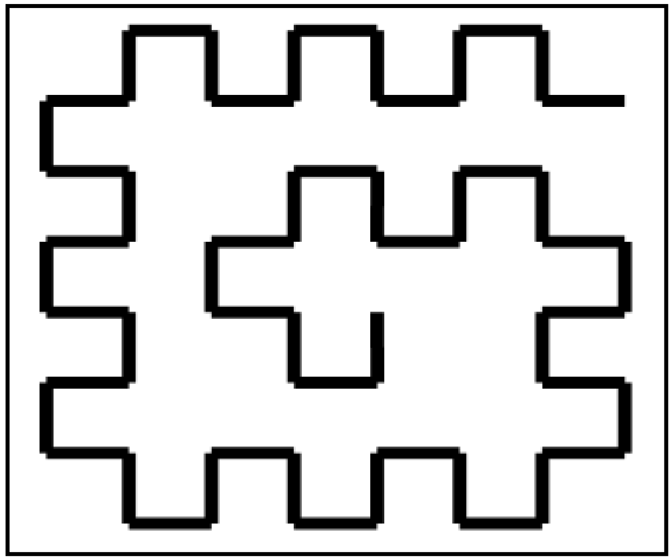

Figure 1.2 Meander Spiral

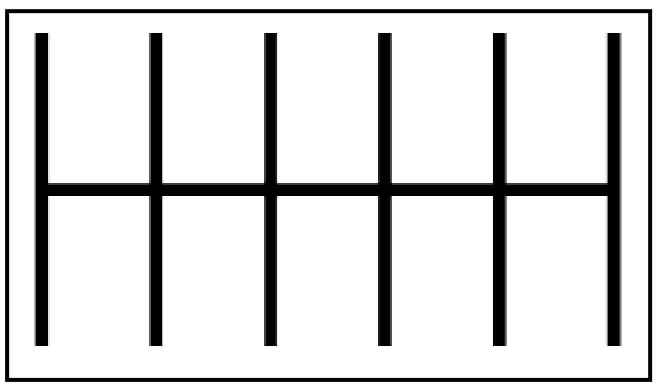

Figure 1.3 Array dipole

A simple thin wire antenna are illustrated by 3 different shaped which is spiral, meander Spiral and array dipole. The all antenna consists of metal and the E and H fields are determined at every point in space within that computational domain. The material of each cell within the computational domain must be specified. Typically, the material is either free-space (air), metal, or dielectric.

4. Develope Graphical User Interfaces (GUI)

A graphical user interface (GUI) is a graphical display in one or more windows containing controls, called components that enable a user to perform interactive tasks. The user of the GUI does not have to create a script or type commands at the command line to accomplish the tasks. Unlike coding programs to accomplish tasks, the user of a GUI need not understand the details of how the tasks are performed. However, creating a GUI can make the review of current system and equipment conditions much easier for the facility personnel.

Construction of the GUI encompasses: -

- Creating forms/background screens: A form is a graphic object that may or may not have a background image associated with it. A form without an associated background image is a blank screen onto which you can put other graphic objects. Background images are drawings made with any standard drawing tool or digital pictures from any source that are saved in or converted to BMP, PCX or JPG format.

- Attaching these forms/background images to the GUI by filename.

- Associating configured point groups with the forms/background images.

- Creating graphic objects on the forms/background images. These objects can be:

  i. Point Status boxes (Input points or Output points)
  ii. Static Text
  iii. Hot Spot Form Links
  iv. Animations
  v. Flood areas

- Configuring these objects with text descriptions, point values, links to other graphics, etc.

5. Simulate FDTD technique using Matlab.

CHAPTER II

LITERATURE REVIEW

Chapter two is about literature review regarding the project. It contains method to do research, theory used to solve problem in this project and so on.

2.1 Finite Different Time- Domain (FDTD)

In this project, the starting point for the construction of an FDTD algorithm is Maxwell's time domain equation. The time-dependent Maxwell's equations in a region of space without imposed electric or magnetic current sources, but that may have materials that absorb electric or magnetic field energy, are given in differential form, by

i. Faraday’s law

$$\frac{\partial \vec{B}}{\partial t} = -\nabla \times \vec{E} - \vec{M} \qquad (2.1.1a)$$

Where,

E= electric field strength vector in volts per meter

M= magnetic current density vector in volts per square meter

B= magnetic flux density vector in webers per square meter

ii. Ampere’s Maxwell law

$$\frac{\partial \vec{D}}{\partial t} = \nabla \times \vec{H} - \vec{J} \qquad (2.1.1b)$$

Where,

H= magnetic field strength vector in amperes per meter

J= electric current density vector in amperes per square meter

D=electric displacement vector in coulombs per square meter

Finite-Difference Time-Domain (FDTD) is a popular and very versatile electromagnetic modeling technique because it is easy to understand, easy to implement in software, and since it is a time-domain technique it can cover a wide frequency range with a single simulation run. Furthermore, the features of the FDTD method have made it the most attractive technique of computational electromagnetic for many microwave devices and antenna applications [1]. The FDTD method belongs in the general class of differential time domain numerical modeling methods. Maxwell's (differential form) equations are simply modified to central-difference equations, discritized, and implemented in software. The equations are solved in a leap-frog manner; that is, the