DEVELOPMENT OF EDUCATIONAL GRAPHICAL INTERFACES FOR RADIATION AND PROPAGATION OF RECTANGULAR PATCH ANTENNA

TAN YONG MENG

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical – Electronics and Telecommunication)

Faculty of Electrical Engineering
University Teknologi Malaysia

NOVEMBER 2009

To my beloved father, mother and sister.

ACKNOWLEDGEMENT

I would like to express my sincere appreciation and thankfulness to my final year project supervisor, Dr. You Kok Yeow, regarding his guidance, support and willingness to help throughout my final year project progress. He has provided me with his valuable advice and suggestion so that I can follow the right track in performing all necessary tasks and complete the project as well. Besides, he also acts as language supervisor to check on my documentation. I believe that without his assistance, my project will not be able to operate smoothly and complete on time.

I am also indebted to librarians for their assistance in supplying the relevant literatures. My sincere appreciation also extends to my friends who have provided assistance at various occasions. Their views and tips are useful indeed. Finally, I would like to thank my parents and sister for their encouragement and support who had helped me go through all the difficulties that I faced throughout my project.

ABSTRACT

The purpose of this project is to design an education program for radiation and propagation of rectangular patch antenna. There are many available commercial softwares to design patch antenna but besides costly and time consuming, equations involved are not clearly stated although method used is known. This developed education software is cheap, simple to use and time-savvy. This education program is generated by using MATLAB coding to deal with real situations while the graphical user interface (GUI) is designed by using Hewlett-Packard Visual Engineering Environment (HP VEE). Available electromagnetic analytical equations will be used to predict the performance of rectangular patch antenna where the results will be compared with literature data and commercial simulator results, which are expected agree with available published data. The results obtained has almost the same shape and polarization properties compares to the one simulated by using AWR Design Environment 2006. An educational software tool for microwave study is created upon the completion of this project. The existence of this software tool will ease the difficulties of designing rectangular patch antenna as it is economical, user friendly and time-saving.

ABSTRAK

Tujuan kajian ini adalah merekakan satu atucara pendidikan bagi radiasi dan propagasi antena tampalan segiempat. Terdapat banyak perisian komers untuk merekabentuk antena tampalan, tetapi masa simulasinya panjang, malahnya mahal. Tambahan pula, persamaan-persamaan dan kaedah-kaedah yang digunakan dalam perisian komers tersebut tidak diberitahu. Dalam kajian ini, perisian yang murah, menjimatkan masa dan guna mesra telah dibangunkan. Perisian pendidikan ini dijanakan dengan menggunakan pengkodan "MATLAB" untuk berinteraksi dengan situasi sebenar. Grafik antara muka pengguna telah direkakan dengan menggunakan "Hewlett-Packard Visual Engineering Environment (HP VEE)". Persamaan analisisan elektromagnet yang sedia ada telah digunakan untuk meramalkan prestasi antena tampalan segiempat dan keputusannya telah dibandingkan dengan data kajian literatur dan keputusan pensimulasi komers. Keputusan yang diperolehi mempunyai bentuk dan pengutuban yang seakan sama berbanding dengan keputusan yang dipeolehi daripada "AWR Design Environment 2006". Satu alat perisian pendidikan bagi pengkajian mikrogelombang berjaya dicipta dengan sesiapnya kajian ini. Dengan alat perisian ini akan memudahkan kerumitan merekabentuk antena tampalan segiempat kerana murah, menjimatkan masa dan guna mesra.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AWR	-	Microwave Office
CAD	-	Computer Aided Design
CEM	-	Computational Electromagnetic
ERBFG	-	Epoxy Resin Bonded Glass Fabric
FDTD	-	Finite Difference Time-Domain
FEM	-	Finite Element Method
GUI	-	Graphical User Interface
HP VEE	-	Hewlett-Packard Visual Engineering Environment
MOM	-	Method of Moments
NEC-2	-	Numerical Electromagnetic Code
R & D	-	Research and Development
PCB	-	Printed Circuit Board
PDE	-	Partial Differential Equation
RAM	-	Random Access Memory
RF	-	Radio Frequency
UTM	-	Universiti Teknologi Malaysia
TM	-	Transverse Magnetic

LISTS OF SYMBOLS

E_θ	-	Radiation pattern
$J_i(x)$	-	*i*th-order Bessel function of the first kind
L	-	Length
$L_{eff}(f)$	-	Actual length
W	-	Width
$W_{eff}(0)$	-	Static effective width
$W_{eff}(f)$	-	Actual width
$Y_i(x)$	-	*i*th-order Bessel function of the second kind
Y_m	-	Mutual-admittance between the radiating slot
Y_0	-	Characteristic admittance
Y_s	-	Self-admittance of the radiating slot
Z	-	Impedance
$\vec{B}$	-	Magnetic flux density
$\vec{D}$	-	Electric flux density
$\vec{E}$	-	Electric field intensity
$\vec{H}$	-	Magnetic field intensity
$\vec{J}$	-	Current density
Y_{in}	-	Input admittance
c_0	-	Speed of light in free space
d	-	Diameter probe
f	-	Frequency

h	-	Substrate thickness
$\varepsilon_{reff}(0)$	-	Static effective relative permittivity
$\varepsilon_{reff}(f)$	-	Frequency-dependent effective relative permittivity
α	-	Attenuation constant
β	-	Phase constant
ζ	-	Euler's constant
x_f	-	X feed position
y_f	-	Y feed position
$\tan\delta$	-	Loss tangent of the dielectric
ε_r	-	Dielectric constant
λ_0	-	Wavelength
ε_r	-	Relative permittivity
ε_{eff}	-	Effective permittivity of substrate
σ_s	-	Conductance of the patch
σ_g	-	Conductance of the ground plane
Δ_s	-	Rms surface roughness of the patch
Δ_g	-	Rms surface roughness of the ground plane
^{o}	-	Degree

CHAPTER 1

INTRODUCTION

Education software is a student oriented program and acts as an aid in the process of learning and it plays a vital part to lecturers in delivering lectures. Students will have an enthusiasm towards the process of learning if they make use with the education software. In the same time, it will become easier for lecturers when preparing lecturing material with the implementing of this educational software. Education software is developed to help the users in reducing the effort and time in getting the knowledge.

1.1 Project Background

In general, the term of microwave refers to alternate current signals with frequencies ranging from 300 MHz to 300 GHz with electrical wavelength of 1mm to 1m respectively (Pozar, 2005).

Trends of moving towards Computer Aided Design (CAD) are not happening recently. It has been exist for quite some times in many fields such as education, Research and Development (R & D), testing, manufacturing and so on. CAD itself has become a compulsory subject in most of the universities in Malaysia to equip the students with such knowledge in order to face the outside world.

This project is to design an education program for radiation and propagation of rectangular patch antenna by using MATLAB coding to deal with the real situation in the outside world. The Graphical User Interface (GUI) of this education program is designed by using Hewlett-Packard Visual Engineering Environment (HP VEE). Available electromagnetic analytical equations will be used to predict the performance of rectangular patch antenna where the result of rectangular patch antenna will be compared with literature data and commercial simulator results, which are expected agree with the available published data.

1.2 Objectives

Below are the objectives of the project:

a) To create and develop a graphical user interface (GUI) of microwave educational tool for undergraduate study.
b) To develop a graphical user interface (GUI) tool for rectangular patch antenna practical design.
c) To practice the designing procedure for rectangular patch antenna without actual building it.

1.3 Problem Statements

There are lots of commercial softwares to calculate the parameters required to design an antenna and simulate the radiation pattern and propagation of antennas. Users do not know what exact equations are used in commercial software because all equations involved are not clearly stated although method used is known. Besides, they are not user friendly because commercial software is complicated to use. Worse still, those of the commercial simulators are expensive and time consuming. However, this education software is cheap and simple. In addition, it is user friendly and rapid in simulating the radiation pattern and propagation of antennas.

This education software tool developed is less accurate compare to some commercialized softwares. This education software is only capable to simulate rectangular patch antenna as it is using analytical equations. Besides, the graphics produced in this software is not that attractive.

1.4 Thesis Outline

This thesis contains five chapters. The first chapter is about the introduction of the project. This chapter includes overview, project background, project objectives and problem statements. Chapter 2 focuses on the literature review of the project. It is mainly about the overview of Hewlett Packard Visual Engineering Environment (HP VEE), various antennas which include microstrip line antenna and rectangular patch antenna. In addition, this chapter will also show the theory of each aspect of the projects.

Chapter 3 of this thesis explains the project methodology. Here, the entire steps of study work are shown and explained in details. Chapter 4 analyses and discusses the result simulations which are in visual engineering environment interface. In this thesis, chapter 5 summaries this work of project. Besides, this chapter also describes the future work and suggestions for the project.

REFERENCES

Annapurna, D., and Sisir, K., D. (2000). *Microwave Engineering.* New Delhi: Tata McGraw-Hill.

Bahl, I. J. and Bhartia, P. (1980). *Microstrip Antennas.* Norwood, MA: Artech House.

Balanis, C. A. (1992). Antenna Theory: A Review. *IEEE Invited Paper*. 80(1): 7-8.

Balanis, C. A. (2005). *Antenna Theory Analysis And Design.* (3rd ed.) N.J.: John Wiley & Sons.

Booton, R. C. (1992). *Computational Methods for Electromagnetics and Microwaves.* N.J.: John Wiley & Sons.

Chen, Z. N., and Chia, M. Y. W (2006). *Broadband Planar Antennas: Design and Applications.* Chichester: John Wiley & Sons.

Davidson, D. B. (2005). *Computational Electromagnetics for RF and Microwave Engineering.* Cambridge: Cambridge University Press.

Dearnley, R. W. (1989). A Broadband Transmission Line Model for a Rectangular Microstrip Antenna. *IEEE Trans. on Antennas and Propagation*. 37(1): 6-12.

Dey, S., Aanandan, C. K., and Mohanan, P. (1993). Modified Circular Patch Antenna. *IEE*. 29(12): 1126-1127.

F. Sagnard. (2004). Educational Graphical Interface to learn About Radiation and Propagation of Electromagnetic Waves. *IEEE Trans. Educaion.* 47(5): 389-396.

Hirasawa, K., and Haneishi, M. (1992). *Analysis, Design, And Measurement Of Small And Low-Profile Antennas.* Boston: Artech House.

Hubregt, J. V. (2009). *Approximate Antenna Analysis for CAD.* Wiltshire: John Wiley & Sons.

IEEE Std. (1993). IEEE Standard Definitions of Terms for Antennas. *IEEE Srandard Board*. 143: 4-20.

Lu, J., and Thiel, D. V. (2000). Computational and Visual Electromagnetics Using an Integrated Programming Language for Undergraduate Engineering Students. *IEEE Trans. on Magnetics.* 4(9): 1000-1003.

Luk, K. M., Chair, R., and Lee, K. F. (1998). Small Rectangular Patch Antenna. *Electronics Letters*. 34(25): 2366-2367.

McAllister, D., Smith, J, R., and Diserens N. J. (1985). *Computer Modelling in Electrostatics.* Hertfordshire: John Wiley & Sons.

Paris, D. T., and Hurd, F. K. (1969). *Basic Electromagnetic Theory*. New York: McGraw-Hill.

Pozar, D. M. (2005). *Microwave Engineering.* New Jersey: John Wiley & Sons.

Ramesh, G., Prakash, B. and Inder, B. (2001). *Microstrip Antenna Design Handbook*. MA: Artech House.

Sadiku, M. N. O. (1992). *Numerical Techniques in Electromagnetics*. Florida: CRC Press.

Thiel, D. V., and Smith, S. (2002). *Switched Parasitic Antennas for Cellular Communications.* MA: Artech House.

Waterhouse, R. B. (2003). *Microstrip Patch Antennas: A Designer's Guide*. Boston: Kluwer Academic Publishers.

Wood, C. (1981). Analysis of Microstrip Circular Patch Antennas. *IEE Proc.* 128(2): 69-76.