

**AN INVESTIGATION OF ELECTROMAGNETIC EFFECT ON HUMAN  
CELL**

**NUR HAZWANI JANUDIN**

**This Report Is Submitted In Partial Fulfilment Of Requirement For The  
Bachelor Degree of Electronic Engineering (Computer Engineering)**

**Faculty of Electronic and Computer Engineering  
Universiti Teknikal Malaysia Melaka**

**JUNE 2013**



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**  
**FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER**

**BORANG PENGESAHAN STATUS LAPORAN**  
**PROJEK SARJANA MUDA II**

**Tajuk Projek** : AN INVESTIGATION OF ELECTROMAGNETIC EFFECT ON HUMAN CELL  
**Sesi Pengajian** : SESI 2012/2013

Saya NUR HAZWANI JANUDIN mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (  ) :

**SULIT\***

\*(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

**TERHAD\*\***

\*\*\*(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

**TIDAK TERHAD**

Disahkan oleh:

Hz  
 (NUR HAZWANI JANUDIN)



Tarikh: 11/6/13

Tarikh: 11/6/13

“I hereby declare that this is the results of my own paper except for quotes as cited in  
the references.”

Signature :   
Author : NUR HAZWANI JANUDIN  
Date : 11 JUNE 2013

“I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of Bachelor Degree of Electronic and Computer Engineering (Computer engineering) with Honours.”

Signature :   
Supervisor's Name : ENGR MOHD MUZAFAR BIN ISMAIL  
Date : 11 JUNE 2013

This project and research work is dedicated to any beloved parents for their devoted caring throughout my life, my loving brother and sister, also my friends for their encouragement and love.

## ACKNOWLEDGEMENT

First and foremost, I want to thank the god because without his grace I will not be able to complete this Final Year Project (FYP) and report for the session 2013 as well as possible. Here, I would like to thank my University Teknikal Malaysia Melaka (UTeM) coordinator/supervisor Engr.. Mohd Muzafar Ismail who advised and guided me to complete the Final Year Project and report in time. During the completion of this Final Year Project (FYP) and report, I faced many problems and difficulties. However, I managed to overcome them all with patience and completed it properly. The journey in completing the Final Year Project (FYP) and report really taught me in terms of leadership, proper time management, communication skills, technical knowledge, soft skills and so many more. The advice and encouragement from the supervisor were really motivating me to do the best. In addition, my family members and friends also became a part of completing the Final Year Project (FYP) and report, which helped me in giving some rational ideas and supports. Finally, I would like to thank those involved directly and indirectly in completing the Final Year Project (FYP) and report successfully. Thank you very much to you all.

## ABSTRACT

Electromagnetic radiation (EM radiation or EMR) is a form of energy emitted and absorbed by charged particles which exhibits wave-like behavior as it travels through space. EMR has both electric and magnetic field components. The effect of EMR upon biological systems depends both upon the radiation's power and frequency. It is difficult to verify the effect of electromagnetic wave on human cell experimentally. Some of mathematical models which available today still can't be proved in order to relate them with electromagnetic wave on human being. The Finite Different Time Domain was used as numerical method to represent the wave equation of interaction among electromagnetic waves and human cell. The interaction was representing the contour color in the MATLAB. The purpose of this project is to analyze the interaction and effect on human cell when exposed to electromagnetic wave. Other than that is to develop an accurate simulation using FDTD method and MATLAB for studying the wave propagation properties. The outcome of this project will give an understanding about propagation of electromagnetic wave in human skin cell. The Maxwell equations will be used as the basis of the modeling in this project with the aid of numerical method approaches specifically Finite Difference Time Domain (FDTD) techniques.

## ABSTRAK

Sinaran elektromagnet (EM radiasi atau EMR) adalah satu bentuk tenaga yang dipancarkan dan diserap oleh zarah bercas yang mempamerkan tingkah laku seperti gelombang kerana ia bergerak melalui ruang. EMR mempunyai kedua-dua komponen medan elektrik dan magnet. Kesan EMR kepada sistem biologi bergantung kepada kedua-dua kuasa sinaran dan frekuensi. Ia adalah sukar untuk mengesahkan kesan gelombang elektromagnet pada sel manusia yang diujikaji. Beberapa model matematik yang ada hari ini masih tidak dapat dibuktikan dalam usaha untuk mengaitkan mereka dengan gelombang elektromagnet pada manusia. Finite Difference Time Domain yang berbeza telah digunakan sebagai kaedah berangka untuk mewakili persamaan gelombang interaksi antara gelombang elektromagnet dan sel manusia. Interaksi mewakili warna kontur dalam MATLAB. Tujuan projek ini adalah untuk menganalisis interaksi dan kesan ke atas sel manusia apabila terdedah kepada gelombang elektromagnet. Selain daripada itu adalah untuk mendapatkan simulasi tepat dengan menggunakan kaedah FDTD dan MATLAB untuk mengkaji ciri-ciri penyebaran gelombang. Hasil daripada projek ini akan memberi kefahaman tentang penyebaran gelombang elektromagnet di dalam sel kulit manusia melalui Persamaan Maxwell yang digunakan sebagai asas model dalam projek ini dengan bantuan kaedah berangka pendekatan khusus Finite Difference Time Domain (FDTD) teknik.



## TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	<b>DECLARATION</b>	ii
	<b>DEDICATION</b>	iii
	<b>ACKNOWLEDGEMENT</b>	vi
	<b>ABSTRACT</b>	vii
	<b>ABSTRAK</b>	viii
	<b>TABLE OF CONTENT</b>	ix
	<b>LIST OF TABLES</b>	xii
	<b>LIST OF FIGURES</b>	xiii
	<b>LIST OF SYMBOL</b>	xv
	<b>LIST OF APPENDICES</b>	xvii
<b>1</b>	<b>INTRODUCTION</b>	1
	1.1 Background	1
	1.2 Objectives	2
	1.3 Problem Statement	2
	1.4 Scope of the work	3
	1.5 Importance and Motivation of the work	3
	1.6 Methodology	4
	1.7 Structure of the thesis	8

<b>2</b>	<b>LITERATURE REVIEW</b>	<b>9</b>
2.1	Human cell	9
2.2	The structure of plasma membrane	10
2.3	Human skin cell structure and size	11
2.4	Cell membrane effect	11
2.5	Cell nucleus effect	11
2.6	Biochemical reaction effect	12
2.7	Electromagnetic effect	12
2.8	Electric field and magnetic field interaction with single cell	13
2.9	Dielectric properties of the human body	13
2.10	Interaction of electromagnetic wave and human cell analysis technique	14
2.11	Numerical solutions for human cell	15
2.12	Other researcher approach	16
<b>3</b>	<b>MATHEMATICAL ANALYSIS</b>	<b>17</b>
3.1	Overview of numerical method	17
3.2	Boundary Condition	19
3.3	Finite Difference Time Domain Method (FDTD)	19
3.4	Numerical methods solve Maxwell's equation	24
3.5	Relation FDTD and Matlab	29
3.6	Introduction of Matlab software	30
3.7	Component of Matlab software	32
3.8	Assumptions	34
3.9	Parameter considered in Matlab	34
3.10	Project Experiment	35

<b>4</b>	<b>RESULT, ANALYSIS AND DISCUSSION</b>	<b>38</b>
4.1	Cell structure	38
4.2	Movement of E-Field	39
4.3	The value of E-field in MATLAB simulation	41
4.4	Relationship between $E_0$ value and attenuation	42
4.5	Skin depth and $\delta$ value	44
4.6	Comparison with total attenuation at membrane Cell with skin depth	46
4.7	Comparison with references	48
	4.7.1 Value of attenuation	48
	4.7.2 Skin Depth	49
4.8	Project experiment	50
4.9	Discussion	51
<b>5</b>	<b>CONCLUSION AND FUTURE WORKS</b>	<b>54</b>
5.1	Conclusion	54
5.2	Future works	55
	<b>REFERENCES</b>	<b>56</b>
	Appendix	58

## LIST OF TABLES

TABLE NO.	TITLE	PAGE
1.1	Gantt chart for Project PSM 1	7
1.1	Gantt chart for Project PSM 2	7
2.1	Human Skin Cell size from NIGMS	11
2.2	Material Properties at membrane cell	14
2.3	Other researcher approach	16
3.1	Input parameter	33
3.2	Data processing	33
3.3	Final output	33
3.4	The value of permittivity and conductivity taken from the engineering source	34
4.1	Comparison E-Field value from different frequencies	41
4.2	Attenuation value	43
4.3	Skin depth value	46
4.4	Value of all parameter and attenuation	47
4.5	Comparison with others references	48

## LIST OF FIGURES

NO.	TITLE	PAGE
1.1	Project Flow	5
1.2	Flow Chart of Project	6
2.1	Structure of Plasma Membrane	10
3.1	Yee Cell	18
3.2	A typical finite difference mesh for an integrated wave propagation.	21
3.3	Locating nodes on centre of a mesh cell and on mesh points.	21
3.4	Cross section area	26
3.5	Overview of Matlab flow	31
3.6	Flowchart of programming process	32
3.7	Experiment methodology	35
3.8	Modified anechoic chamber	36
3.9	Experiment illustration	36
4.1	Cell design in 2D dimension	38
4.2	Three layer of membrane	39
4.3	Movement of E-Field at 3 different frequencies	40
4.4	E-Field value	41
4.5	Graph of Comparison E-field value for different frequencies	42
4.6	Graph of Attenuation vs 3 layer at different frequencies	44
4.7	The value of skin depth at 2.4 GHz	45
4.8	The value of skin depth at 4.5 GHz	45
4.9	The value of skin depth at 9 GHz	45
4.10	Graph of total attenuation vs frequency	47

4.11	Graph of skin depth vs frequency	48
4.12	Comparison with other researchers	49
4.13	Comparison of skin depth	49
4.14	Frequency setting	50
4.15	Experiment setup	50

## LIST OF SYMBOLS

$b$	-	Normalized propagation constant
$c$	-	Speed of light; Phase velocity [m/s]
$B$	-	Magnetic flux-density complex amplitude [Wb/m <sup>2</sup> ]
$d$	-	Differential
div	-	Divergence
$D$	-	Electric flux density [C/m <sup>2</sup> ]
$E$	-	Electric field [V/m]
$F$	-	Force [kgms <sup>-2</sup> ]
$H$	-	Magnetic-field complex amplitude [A/m]
$H$	-	Magnetic field [A/m]
$j$	-	$(-1)^{1/2}$ integer
$J$	-	Electric current density [A/m <sup>2</sup> ]
$k_0$	-	Free space propagation constant [rad/m]
$l$	-	length [m]
$m$	-	number of modes
$M$	-	Magnetization density [A/m]
$n$	-	Refractive index
$\rho$	-	Electric polarization density [C/m <sup>2</sup> ]
$Q$	-	Electric charge [C]
$T$	-	Time [s]
TE	-	Transverse electric wave
TM	-	Transverse magnetic wave
TEM	-	Transverse electromagnetic wave
$\varphi$	-	Total internal reflection phase shift [rad]
$V$	-	Voltage [V]
$\beta$	-	Propagation constant [rad/m]

$\epsilon$	-	Electric permittivity of medium [F/m]
$\epsilon_0$	-	Electric permittivity of a free space [F/m]
$\epsilon_r$	-	Relative dielectric constant of the material[F/m]
$\theta$	-	Angle
$\theta_c$	-	Critical angle
$\lambda$	-	Wavelength [m]
$\lambda_0$	-	Free space wavelength [m]
$\mu$	-	Magnetic permeability [H/m]
$\mu_0$	-	Magnetic permeability of free space [H/m]
$\Phi$	-	Angle in a cylindrical coordinate system
$\omega$	-	Angular frequency [rad/s]
$\partial$	-	Partial differential
$\nabla$	-	Gradient operator
$\nabla \cdot$	-	Divergence operator
$\nabla \times$	-	Curl operator
$\nabla^2$	-	Laplacian operator
$\sigma$	-	Conductivity
$\sigma_{\text{eff}}$	-	Conductivity effective



## CHAPTER 1

### INTRODUCTION

#### 1.1 Background

Nowadays, more electrical and electronic equipment produced and each device will emit electromagnetic waves intentionally or unintentionally. It threatens the world during the 24 hours when using a mobile phone, computer, electrical items and equipment that emits waves. Long exposures to low-power electromagnetic waves have the potential to effect human health. The impact will not appear immediately because these may affect human cells in the future if exposed for too long. When radiation enters human cell, the component of the cell will react through kinetic energy.

Three phenomena can be considered as the effects of the interaction of electromagnetic radiation with biological tissues such as the EM wave's penetration into the living system and their propagation into it. Besides that, the possible secondary effects induced by the primary interaction and the primary interaction of the waves with biological tissues [3].

The purpose of this project is to analyze the interaction and effect on human cell when exposed to electromagnetic wave and how we can prove it experimentally. Some of mathematical models which available today still can't be proved in order to relate them with electromagnetic wave on human being. Matlab and GUI is used to assist the understanding on how electromagnetic wave effecting human cell. The Maxwell equation will be used as the basic of the modelling in this project with the aid of numerical method approaches especially Finite Difference Time Domain technique.

## 1.2 Objective

- i. To analyze the interaction and effect on human cell when exposed to electromagnetic wave.
- ii. To develop an accurate simulation using FDTD method and MATLAB for studying the wave propagation properties. . The numerical method used is the finite-difference time-domain (FDTD) because it has successfully applied in various engineering fields.

## 1.3 Problem Statement

It is difficult to verify the effect of electromagnetic wave on human cell experimentally. Some of mathematical models which available today still can't be proved in order to relate them with electromagnetic wave on human being. Matlab and GUI are used to assist the understanding on how electromagnetic wave effecting human cell. In addition, MATLAB and GUI handle all the parameters of the FDTD simulation and computes theoretical values of characteristics parameters of the wave propagation in different mediums.

## 1.4 Scope of Work

The project has three main scopes:

1. Understand the concept of human cell, interaction in a single cell and effect when exposed to electromagnetic wave.
2. Understand the Finite Difference Time Domain Method (FDTD) to develop the Maxwell equation.
3. Understand Matlab and GUI to develop simulation program for studying the wave propagation properties.

## 1.5 Importance and Motivation of Work

1. Increase the number of study done
2. To prove that electromagnetic waves effect human cell mathematically.
3. To develops public information to raise the level of understanding about potential health risks of radiation.
4. Once the cells are damaged, it can cause many diseases such as skin cancer and it is very dangerous to humans.

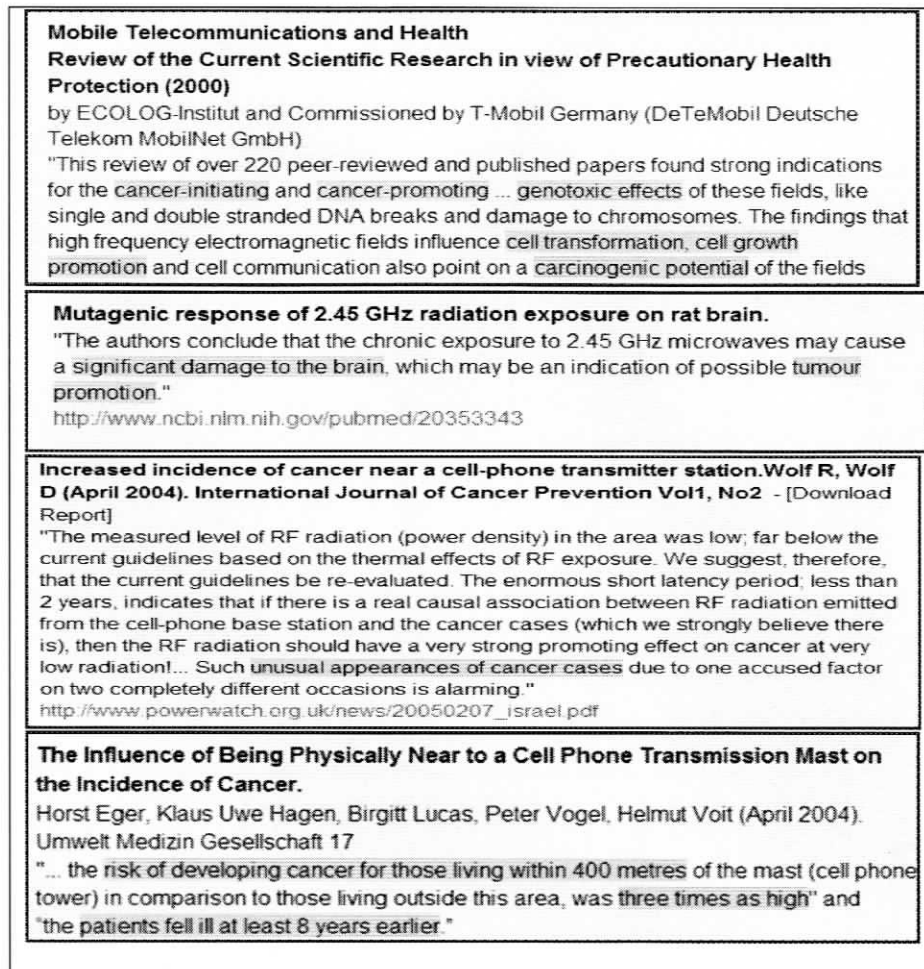


Figure 1.0: Importance and Motivation of work

## 1.6 Methodology

Implementations and works of the project are summarized into the project flow and flow chart shown below in Figure 1.1 and Figure 1.2. It shows the details of the work of the project that had been implemented in the first and second semester.

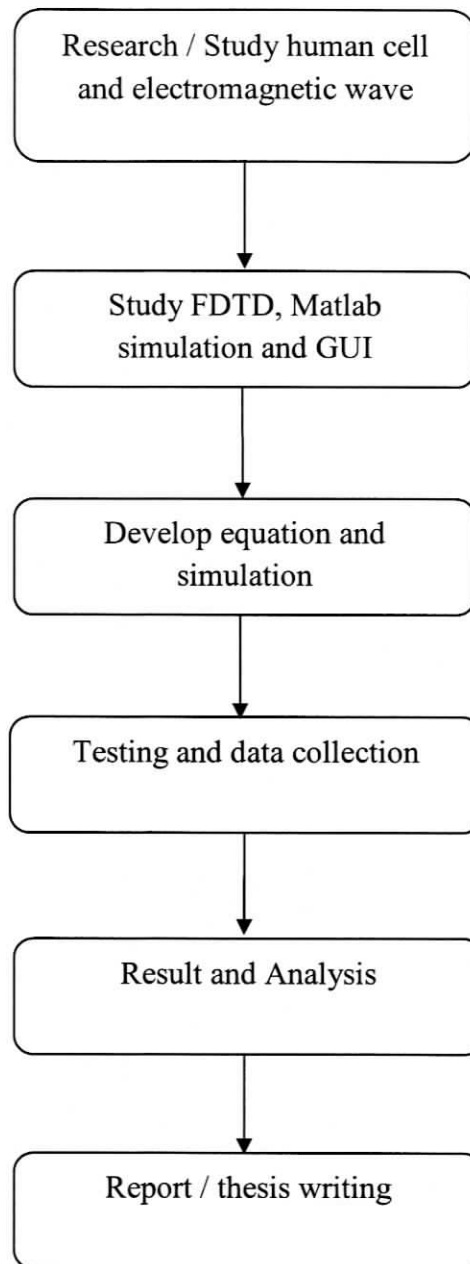


Figure 1.1: Overview of Project Flow

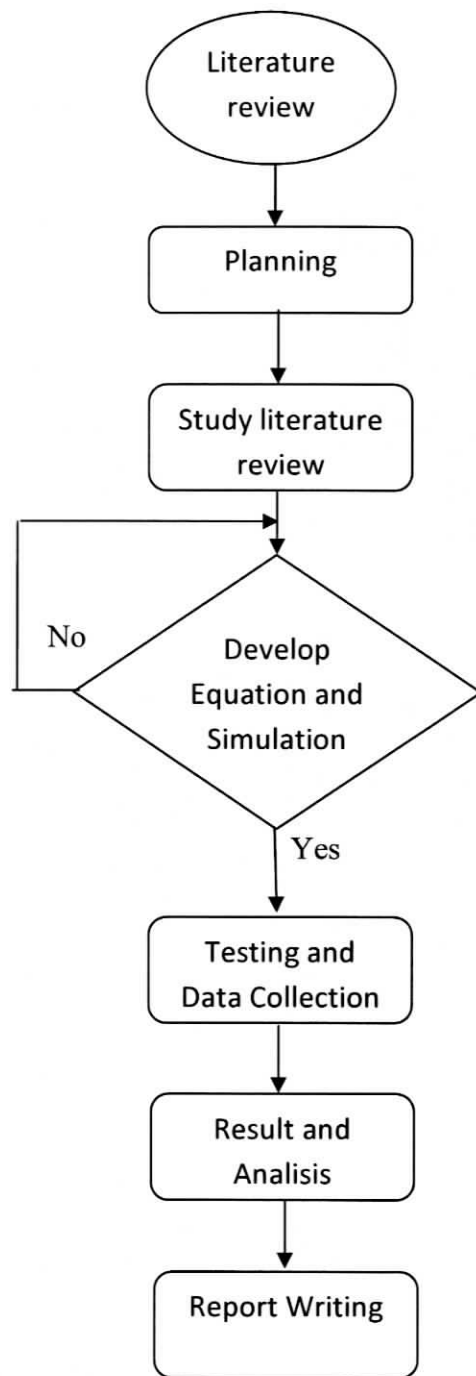


Figure 1.2: Flow Chart of Project

NO	ACTIVITY	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
01	Meeting with supervisor																
02	Thesis title confirmation																
03	Making proposal																
04	Complete and submit proposal																
05	Study human cell and interaction in cell																
06	Study Maxwell equation and FDTD																
07	Study Matlab simulation and GUI																
08	Prepare Project I seminar																
09	Project I seminar																
10	Writing final report																
11	Submit final report																

Table 1.1: Gantt chart for Project PSM 1

NO	ACTIVITY	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
01	Meeting with supervisor																
02	Thesis writing – Chapter 1																
03	Thesis writing – Chapter 2																
04	Thesis writing – Chapter 3																
05	Submit progress project																
06	Matlab simulation and modeling																
07	Result and analysis																
08	Thesis writing – Chapter 4																
09	Thesis writing – Chapter 5																
10	Thesis writing – Chapter 6																
11	Prepare Project II final seminar																
12	Project II final seminar																
13	Final check and submit final draft																
14	Submit hardcover and softcopy																

Table 1.2: Gantt chart for Project PSM 2

## 1.7 Structure of the thesis

This report represented by 3 chapters.

Chapter 1: This chapter discuss about the brief overview about the project such as project background, objective, and scope of work, problem statement and methodology.

Chapter 2: This chapter discuss about the information that have in project. This chapter discusses more about literature review for the interaction in cell when expose to electromagnetic wave. The structure of human cell also will be discussed in this chapter and its function within electromagnetic propagation. Beside that the behaviour and structure of three layers also be mentioned.

Chapter 3: This chapter discuss about the methodology of the project. Mathematical analysis will be present in this chapter. Then, the interactions have been analyzed using the numerical method based on finite difference time domain approach. The assumption is considered to design the interaction of electromagnetic wave with human cell. To obtain the result, we discuss the parameters of relative permittivity and conductivity at different frequency.

Chapter 4: In this chapter, we focused on Matlab development which it shows how mathematical equation was apply in Matlab file. The value of attenuation and skin depth are calculated using formula. The relationships between them are discussed. The result will be compared with others references.

Chapter 5: Conclusion and future work will be discuses in this chapter. The overall project will be summarized to conclude this project.