

DESIGN OF SLOT PLANAR ANTENNA

NOR SAIDATINA BINTI ABDUL LATIF

**This report submitted in the partial fulfillment of the requirement for the
award of Bachelor of Electronic Telecommunication Engineering With
Honours.**

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

April 2010



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN

PROJEK SARJANA MUDA II

Tajuk Projek : DESIGN OF SLOT PLANAR ANTENNA

Sesi Pengajian : 2009/2010

Saya NOR SAIDATINA BINTI ABDUL LATIF
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:

(TANDATANGAN PENULIS)

(COP DAN TANDATANGAN PENYELIA)

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

Signature :

Author : Nor Saidatina Binti Abdul Latif

Date :

“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 of Electronic Engineering (Telecommunication Electronics)”

Signature :

Supervisor's name : En. Mohamad Zoinol Abidin Bin Abd Aziz

Date :

To my beloved family.....

ACKNOWLEDGEMENT

First and foremost, praise to Allah the Almighty for It countless blessings and guidance throughout the hard times I have endured. Thanks also to my beloved family and friends for giving me the support and encouragement.

I would like to express my utmost gratitude to Mr. Mohamad Zoinol Abidin Abd. Aziz for the guidance and thought me many things and enthusiastic to share knowledge. The cooperation in order to give me a knowledge and explanation is very thankful appreciate. I truly have learnt a lot and all this would not be without his guidance.

Last but not least, warm thank you to my fellow friends for giving me an encouragement and pray for a great success. Additionally, to those whom their names are not mentioned here that have help me directly or indirectly, there is no such meaningful word than thank you so much.

ABSTRACT

Microstrip antennas are useful in many applications such as application in WLAN. It is because of their numerous advantages such as low profile, low cost, lightweight and easy fabrication. However microstrip has disadvantage that is narrow bandwidth. In order to solve the problem of narrow bandwidth in WLAN systems, slot planar antenna is designed. The slot antenna provides a wider bandwidth with less dependence on substrate thickness. The current of a slot antenna is distributed on a metal sheet around the slot and so less energy is stored between the antenna and ground plane. They are also superior to dipole and patch antennas since they have low cross polarization and less surface wave losses. A slot planar antenna is designed in order to obtain the required parameter responses at 5.2 GHz to be used in WLAN. This slot planar antenna is simulated by using Computer Simulation Technology (CST). From the simulation, results of gain, directivity, radiation pattern, HPBW, FNBW and return loss are obtained. This antenna is etched on a FR4 with dielectric constant of 4.9 with the height of 1.6 mm. A prototype of the slot planar antenna is built and tested by Vector Network Analyzer (VNA). The main parameters concerned are return loss, bandwidth and gain. Then the measurement result obtained would be compared to the simulation result. With these designs, impedance bandwidth of approximately 20% has been obtained.

ABSTRAK

Antena mikrojalur mempunyai banyak kegunaan antaranya dalam WLAN. Hal ini kerana ia mempunyai banyak kelebihan seperti profil rendah, kos yang rendah, ringan dan mudah difabrikasi. Walau bagaimana pun, mikrojalur mempunyai keburukan iaitu lajurlebar yang kecil. Untuk mengatasi masalah jalurlebar yang kecil dalam sistem WLAN, antenna slot planar direka. Antena slot memberikan jalurlebar yang besar dengan kurang pergantungan pada tinggi substrat. Arus antena slot diedarkan pada logam di keliling slot, oleh itu sedikit tenaga disimpan di antara antena dengan satah bumi. Antena ini juga lebih unggul dari dwikutub dan antena patch kerana mempunyai polarisasi silang dan gelombang permukaan yang rendah. Dalam projek ini, antena planar slot direka pada 5.2 GHz untuk digunakan dalam WLAN. Antena planar slot ini disimulasikan dengan menggunakan Computer Simulation Technology (CST). Melalui simulasi, hasil HPBW, FNBW, polar radiasi dan direktiviti diperolehi. Antena slot planar difabrikasikan di atas FR4 dengan pemalar dielektrik 4.5 dan tinggi 1.6 mm. Prototaip antena planar slot diukur menggunakan Vector Network Analyzer (VNA). Kemudian hasil pengukuran yang diperolehi akan dibandingkan dengan hasil simulasi. Melalui rekaan ini, jalurlebar sebanyak 20% diperolehi.

CONTENT

CHAPTER	TITLE	PAGE
	TITLE OF THE PROJECT	i
	DISCLAIMER	ii
	SUPERVISOR'S CONFIRMATION	iii
	DEDICATION	iv
	ACKNOWLEDGEMENT	v
	ABSTRACT	vi
	ABSTRAK	vii
	TABLE OF CONTENT	
	viii	
	LIST OF FIGURES	xii
	LIST OF TABLES	xv
	LIST OF ABBREVIATIONS	xvi
I	INTRODUCTION	1
	1.1 Overview	1
	1.2 Project Summary	2
	1.3 Objectives	3
	1.4 Problem Statement.	3
	1.5 Scope of Project	4
	1.6 Outline of Thesis	4
II	LITERATURE REVIEW	5
	2.1 Wireless Local Area Network (WLAN) System	5

2.2	Types of Antenna	6
2.2.1	Wire Antennas	6
2.2.2	Aperture Antennas	7
2.2.3	Microstrip Antennas	7
2.2.4	Array Antennas	8
2.2.5	Lens Antennas	9
2.3	Fundamental Parameters of Antennas	9
2.3.1	Radiation Pattern	10
2.3.2	Efficiency	11
2.3.3	Bandwidth	12
2.3.4	Directivity	12
2.3.5	Gain	12
2.4	Planar Transmission Structure	13
2.5	Slotline	13
2.6	Planar Antenna	15
2.7	Feeding Techniques	16
2.7.1	Microstrip Line	16
2.7.2	Coaxial Probe	17
2.7.3	Aperture Coupling	17
2.7.4	Proximity Coupling	18
2.8	Method of Analysis	19
2.8.1	Transmission Line Model	19
2.8.2	Cavity Model	20
2.8.3	Full-Wave Numerical Model	21
2.9	Wideband Planar Slot Antennas	24
2.9.1	Printed Dipole Antenna	24
2.9.2	Slot Dipole Antenna	25
2.9.3	Coplanar Patch-Slot Antenna	26
2.9.4	Bow-Tie Slot Antenna	26
2.10	Log Periodic Meandered Dipole Slot Antenna	27
2.10.1	The Meandered Dipole Slot Antenna	27
2.10.2	The Log Periodic Meandered Dipole Slot Antenna	28
2.11	Antenna Miniaturization Techniques	29
2.11.1	Distributed Inductive Loading (DIL)	30

III	PROJECT METHODOLOGY	32
3.1	Project Methodology	32
3.2	Design Consideration	35
3.2.1	The Dielectric Constant	35
3.2.2	Feed Line	35
3.2.3	Substrate Thickness	36
3.3	Design Specification	36
3.3.1	Design I (Coplanar Patch Antenna)	37
3.3.2	Design II (Vertical)	46
3.4	Simulation	55
3.5	Fabrication	55
3.6	Measurement Set Up	57
IV	RESULT AND DISCUSSION	58
4.1	Coplanar Patch Antenna Slot Antenna	58
4.2	Microstrip CPA	61
4.3	Strip CPA with Different Height Ground	63
4.4	Vertical Slot Planar	64
4.5	Vertical Microstrip	67
V	CONCLUSION AND RECOMMENDATION	69
5.1	Conclusion	69
5.2	Recommendation	70
	REFERENCES	71
	APPENDIX A	75

APPENDIX B	76
APPENDIX C	77
APPENDIX D	78
APPENDIX E	79
APPENDIX F	81
APPENDIX G	82
APPENDIX H	83
APPENDIX I	84
APPENDIX J	85
APPENDIX K	86
APPENDIX L	88

LIST OF FIGURES

NO	TITLE	PAGE
2.1	Wire Antenna Configurations	6
2.2	Aperture Antenna Configurations	7
2.3	Rectangular and Circular Microstrip (patch) Antennas	8
2.4	Typical Array Configurations	9
2.5	Radiation Pattern	11
2.6	Planar Transmission Lines Used in MICs	13
2.7	Slotline Configuration	14
2.8	Field Distributed in a Slotline	14
2.9	Structure of Basic Planar Antenna	15
2.10	Basic Configuration of Microstrip Line Feed	16
2.11	Basic Configuration of Coaxial Probe	17
2.12	Basic Configuration of Aperture Coupling	18
2.13	Basic Configuration of Proximity Coupling	18
2.14	Transmission Line Model of Microstrip Antenna	20
2.15	Cavity Model	21
2.16	Printed Dipole Antenna Parameters	24
2.17	Slot Dipole Geometry and Parameters	25
2.18	CPA Geometry and Parameters	26
2.19	Bow-Tie Slot Antenna Geometry	27
2.20	The Meandered Dipole Slot Antenna	28
2.21	The Log Periodic Meandered Dipole Slot Antenna ($0 < \tau < 1$)	29
2.22	The Log Periodic Meandered Dipole Slot Antenna ($\tau > 1$)	29
2.23	Photograph of a Slot Antenna Loaded with Distributed Inductive Loads. The Scale Dimensions are in Centimetres	31
3.1	Methodology	34

3.2	Parameter of Coplanar Patch Antenna	37
3.3	Different Types of Design	38
3.4	Microstrip CPA in CST	38
3.5	Graph of Frequency against L1 of Microstrip CPA	39
3.6	Graph of Frequency against w1 of Microstrip CPA	39
3.7	Strip Planar CPA in CST	40
3.8	Graph of Frequency against L1 of Strip Planar CPA	40
3.9	Strip CPA with Different Height Ground in CST	41
3.10	Graph of Frequency against g2 of Strip CPA with Different Height Ground	42
3.11	Microstrip Slot CPA in CST	42
3.12	Graph of Frequency against L1 Microstrip Slot CPA	43
3.13	Slot Planar CPA in CST	43
3.14	Graph of Frequency against L1 of Slot Planar CPA	44
3.15	Graph of Frequency against w1 of Slot Planar CPA	44
3.16	Graph of Frequency against CPW Feed Line of Slot Planar CPA	45
3.17	Slot CPA with Different Height Ground in CST	45
3.18	Graph of Frequency against g2 of Slot CPA with Different Height Ground	46
3.19	Parameter of Vertical CPA	46
3.20	Different Types of Vertical Design	47
3.21	Vertical Microstrip in CST	48
3.22	Graph of Frequency against L1 of Vertical Microstrip	48
3.23	Vertical Strip Planar in CST	49
3.24	Graph of frequency against L1 of Vertical Strip Planar	49
3.25	Vertical Strip with Different Height Ground in CST	50
3.26	Graph of Frequency against g2 of Vertical Strip with Different Height Ground	50
3.27	Vertical Slot Microstrip in CST	51
3.28	Graph of Frequency against L1 of Vertical Slot Microstrip	51
3.29	Vertical Slot Planar in CST	52
3.30	Graph of Frequency against L1 of Vertical Slot Planar	52
3.31	Graph of frequency against w1 of Vertical Slot Planar	53
3.32	Graph of Frequency against F1 of Vertical Slot Planar	53

3.33	Vertical Slot with Different Height Ground in CST	54
3.34	Graph of Frequency against g_2 of Vertical Slot with Different Height Ground	54
3.35	Prototype of Slot CPA	56
3.36	Prototype of Vertical Slot Planar	56
4.1	The parameters and geometric dimensions of Coplanar Patch Slot Antenna	58
4.2	Simulation Result of Return Loss of Slot Planar CPA	60
4.3	Measured Result of Return Loss Slot Planar CPA	60
4.4	Radiation Pattern of Slot Planar CPA	61
4.5	Simulation Result of Return Loss of Microstrip CPA	62
4.6	Radiation Pattern of Microstrip CPA	62
4.7	Simulation Result of Return Loss of Strip CPA with Different Height Ground	63
4.8	Radiation Pattern of Strip CPA with Different Height Ground	64
4.9	The parameters and geometric dimensions of Vertical Slot Planar	64
4.10	Simulation Result of Return Loss of Vertical Slot Planar	66
4.11	Measured Result of Return Loss of Vertical Slot Planar	66
4.12	Radiation pattern of Vertical Slot Planar	67
4.13	Simulation Result of Return Loss of Vertical Microstrip	68
4.14	Radiation Pattern of Vertical Microstrip	68

LIST OF TABLE

TABLES	TITLE	
PAGE		
3.1	Specification of the Design	36
4.1	Parameters of Coplanar Patch Slot Antenna	59
4.2	Parameters of Vertical Slot Planar	65

LIST OF ABBREVIATIONS

ϵ_r	-	Dielectric Constant
ADS	-	Advance Design system
BW	-	Bandwidth
CPA	-	Coplanar Patch Antenna
CPW	-	Coplanar Waveguide
CST	-	Computer Software Technology
dB	-	Decibel
DEA	-	Double-element Antenna
DIL	-	Distributed Inductive Loading
E1	-	Vertical Slot Length
F1	-	Feed Line Length
FDTD	-	Finite Difference Time Domain
FEM	-	Finite-Element Method
FNBW	-	First Null Beam Width
g2	-	Height of the Ground
GPS	-	Global Positional System
h	-	Thickness of Substrate
HPBW	-	Half Power Beam Width
HSA	-	Hybrid Slot Antenna
IEEE	-	Institute of Electrical and Electronics Engineers
L1	-	Length of the Patch
L_g	-	Lenght
MoM	-	Method of Moments
RF	-	Radio Frequency
S1, S2, S3	-	Slot Height
S4	-	Gap Width

SMA	-	SubMiniature version A
$\tan \delta$	-	Tangent Loss
VNA	-	Vector Network Analyzer
VSWR	-	Voltage Standing Wave Ratio
w_1	-	Width of the Patch
W_g	-	Width
WLAN	-	Wireless Local Area Network

CHAPTER 1

INTRODUCTION

1.1 Overview

An antenna is an element used for radiating or receiving electromagnetic wave. Although antennas may seem to be available in numerous different shapes and sizes, they all operate according to the same basic principles of electromagnetics. As a general principle, a guided wave traveling along a transmission line which opens out will radiate as a free-space wave, also known as an electromagnetic wave. When an antenna is receiving, the antenna transforms free-space propagating waves by inducing a guided electromagnetic wave within the antenna. The guided electromagnetic wave is then fed into an integrated circuit. The integrated circuit then deciphers the signal being transmitted. When an antenna is transmitting, the antenna receives the guided electromagnetic wave for transmission from a feed line and induces an electric field surrounding the antenna to form a free-space propagating electromagnetic wave. The features of antenna can be known by the parameters of operation frequency, radiation patterns, reflected loss, and antenna gain, etc.

An antenna may be that component of a personal communication device, a radio, a television, or a radar system that directs incoming and outgoing radio waves between free space and a transmission line. Antennas are usually metal and have a

wide variety of configurations, from the whip or mast like devices employed for radio and television broadcasting to the large parabolic reflectors used to receive satellite signals and the radio waves generated by distant astronomical objects. Many types of portable electronic devices, such as cellular phones, GPS receivers, palm electronic devices, pagers, laptop computers, and telematics units in vehicles, need an effective and efficient antenna for communicating wirelessly with other fixed or mobile communication units.

Advances in digital and radio electronics have resulted in the production of a new breed of personal communications equipment posing special problems for antenna designers. Personal wireless communication devices have created an increased demand for compact antennas. The increase in satellite communication has also increased the demand for antennas that are compact and provide reliable transmission. Wire antennas, such as whips and helical antennas are sensitive to only one polarization direction. As a result, they are not optimal for use in portable communication devices which require robust communications even if the device is oriented such that the antenna is not aligned with a dominant polarization mode [1].

1.2 Project Summary

The main purpose of this project is to design slot planar antenna with a certain frequency, bandwidth, gain and structure. The scopes of work are design the slot planar antenna, the simulation, fabrication and test the antenna which involve with some materials and tools. For example, the software called Computer Simulation Technology (CST) is used for the simulation and FR4 microstrip board for fabricate. The fabricated antenna will be measure and test in order to verify the performance.

1.3 Objectives

The objective of this project is to design a slot planar antenna that can operate at frequency of 5.2 GHz, broader bandwidth and suitable gain for WLAN application.

1.4 Problem Statement

Microstrip and printed antenna design have their own disadvantages such as narrow bandwidth (5% to 10% is typical without special technique), dielectric and conductor losses can be large for thin patches resulting in poor antenna efficiency and sensitivity to environmental factors such as temperature and humidity. Assessing the size of a small antenna is more difficult than it sounds because of the interaction between the antenna and its immediate environment (or the test equipment, during measurements) [1].

To overcome these problems, slot planar antenna is designed because slot antennas exhibit wider bandwidth, lower dispersion and lower radiation loss than microstrip antennas, and when feeding by a coplanar waveguide they also provide an easy means of the parallel and series connection of active and passive elements that are required for improving the impedance matching and gain. The planar antenna has the advantages of lightweight, compact size, easy manufacture, easy attachment and easy integration [7].

1.5 Scope of Project

The work scopes of this project are to design the slot planar antenna. This project is divided into four phase. The first phase involves, designing the slot planar antenna that operate at 5.2 GHz, broader bandwidth and suitable gain. Next, the simulation process will take place to simulate the antenna parameters such as radiation pattern, return loss and gain by using Computer Simulation Technology (CST) Software. Then, etching process is done to perform the fabrication on FR4

microstrip board. Finally the parameters of the antenna such as return loss, bandwidth and gain are tested by using network analyzer.

1.6 Outlines of Thesis

The outlines of the thesis are as follows:

Chapter 1: This chapter provides the introduction to the project, objective and scope of work.

Chapter 2: This chapter covers the literature review on the slot antenna, the antenna properties, and the feeding methods.

Chapter 3: This chapter covers the methodology of the project and the design guideline

Chapter 4: Chapter 4 consists of the slot planar antenna design, simulation and measurement.

Chapter 5: This chapter provides the conclusion and recommendation to the project.

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss on the antenna parameters, types of antenna and various shapes of slot design.

2.1 Wireless Local Area Network (WLAN) System

Wireless LAN can be used either to replace wired LAN, or as an extension of the wired LAN infrastructure. There are in general two types of antennas for WLAN applications, fixed WLAN base stations or access points, and the other is for mobile communication terminals.

For base station applications, impedance matching for WLAN bandwidth should be better than 1.5:1 VSWR or about 14 dB return loss [3], similar to the cellular system base station. Antenna that capable to excite circular polarization is very attractive because it can overcome the multipath fading problem, thus enhance the system performance, especially indoor WLAN operation [3].

2.2 Types of Antenna

There are various types of antenna such as wire, aperture, microstrip, array and lens antenna.

2.2.1 Wire Antennas

Wire antennas are familiar to the layman because they are seen virtually everywhere-on automobiles, buildings, ships, aircraft, spacecraft, and so on. There are various shapes of wire antennas such as a straight wire (dipole), loop, and helix. Loop antennas need not only be circular. They may take the form of a rectangle, square, ellipse, or any other configuration. The circular loop is the most common because of its simplicity in construction [8].

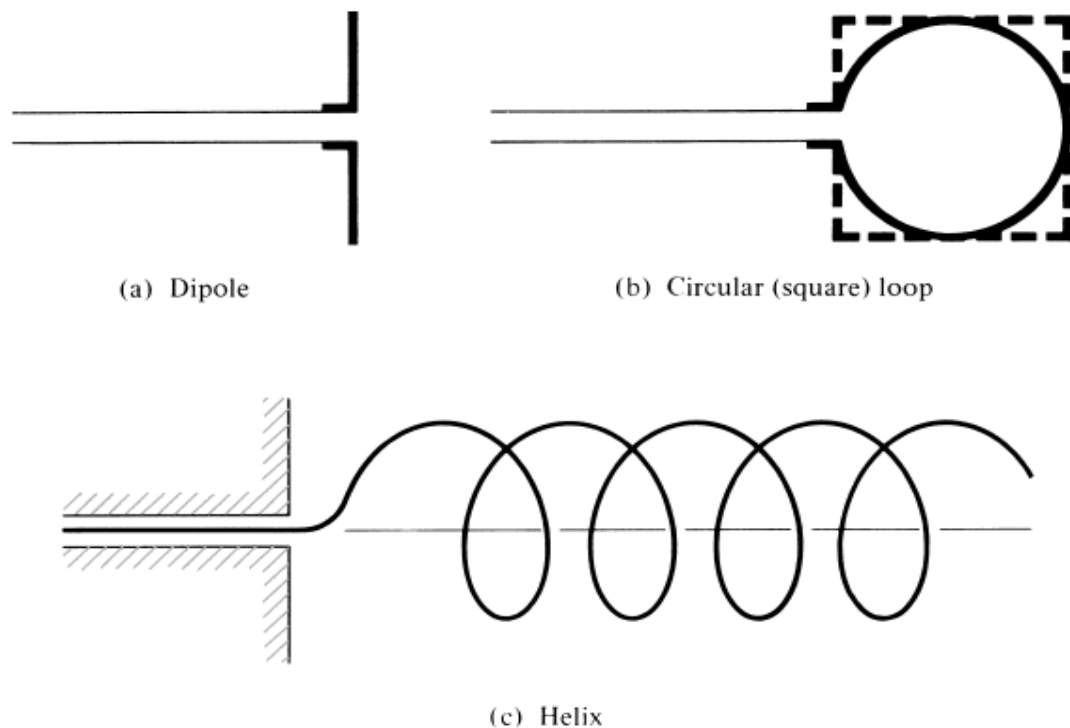


Figure 2.1: Wire Antenna Configurations [8]