

DUAL POLARIZED ANTENNA DESIGN FOR 5.8GHZ POINT TO POINT
APPLICATION

NURUL SYAHIDAH BT RAZALI

This report is submitted in partial fulfillment of the requirements for the award of
Bachelor of Electronic Engineering (Telecommunication Electronics) With Honours

Faculty of Electronic and Computer Engineering

Universiti Teknikal Malaysia Melaka

May 2009



UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : **DUAL POLARIZED ANTENNA DESIGN FOR 5.8GHZ
POINT TO POINT APPLICATION**
Sesi Pengajian : **2008/2009**

Saya **NURUL SYAHIDAH BT RAZALI**

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 () :

<input type="checkbox"/>	SULIT*	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
<input type="checkbox"/>	TERHAD*	(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
<input checked="" type="checkbox"/>	TIDAK TERHAD	

Disahkan oleh:

(TANDATANGAN PENULIS)

(COP DAN TANDATANGAN PENYELIA)

Alamat Tetap:

NO 111 KG BARU TEBING TEMBAH
23100 PAKA, DUNGUN, T'GANU.

Tarikh: 8 MEI 2009

Tarikh: 8 MEI 2009

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

Signature :.....
Author : Nurul Syahidah Bt Razali
Date : 8 Mei 2009

“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 (Telecommunications Electronics) With Honours.”

Signature :

Supervisor's Name :Mohd Zoinol Abidin B Abd Aziz.

Date : 8 Mei 2009

DEDICATION

For my beloved mom and dad

ACKNOWLEDGEMENT

Full of gratitude I have successfully completed my project. I would like to take this opportunity to express my gratitude to my supervisor, Mr Zoinol Abidin B. Abd Aziz from FKEKK, UTeM for his guidance and encouragement throughout the course of my studies. He has given me plentiful of ideas and advices in performing this project. Furthermore, I would like to thank to Master's student, Mohd Syaiful for his great guidance and in-depth discussion towards my project. Lastly, I sincerely express my appreciation to my family and Muhammad Hanafi for their support in encouraging me to further study and taking up this course.

ABSTRACT

In this thesis, a project of dual polarized antenna with resonant frequency at 5.8GHz point to point application is presented. The dual polarized antennas are traditionally characterized in terms of port-to-port isolation and co- and cross-polar patterns. The dual polarized antenna that's investigated is design to produce $+45^\circ$ and -45° electromagnetic field which its vertical and horizontal systems are equivalent with respect to their propagation efficiency that can be used with good results for transmit and receive applications. Besides, the design of dual polarized antenna is considering the ideal requirement which is small, inexpensive and unique structure. First step is by calculating the width and length of the patch. Then, the design is simulate using CST Microwave Studio software to simulate the return loss, bandwidth, radiation pattern, gain, directivity and beam width. In order to verify the results, a prototype antenna is fabricated by using chemical etching techniques. After that, the return loss is measured by using network analyzer while gain and radiation pattern is measured by using spectrum analyzer. The result obtain showed the return loss of the antenna is lower than -10dB at 5.8 GHz and produce higher bandwidth. Furthermore, the polarization of antenna is at $\pm 45^\circ$ which also has acceptable gain.

ABSTRAK

Tesis ini adalah mengenai projek dwi-pengutuban antenna dengan frekuensi resonan 5.8GHz. Antenna dwi-pengutuban dikategorikan berdasarkan '*isolation*' dari suatu pangkalan ke satu pangkalan serta berdasarkan paten '*co- and cross-polar*'. Antena ini akan menghasilkan $\pm 45^\circ$ medan elektromagnetik iaitu pengutuban menegak dan melintang antenna ini sama berdasarkan tahap efisien penyebaran dimana sesuai digunakan untuk menghantar dan menerima isyarat dengan baik. Pertama sekali, '*patch*' antenna ini di kira panjang dan lebarnya. Kemudian, antenna ini disimulasi menggunakan perisian CST Microwave Studio untuk mendapatkan kebocoran balik, jalur lebar, paten radiasi, '*gain*', '*directivity*', dan '*beamwidth*'. Prototaip antenna ini kemudiannya dihasilkan dengan kaedah teknik goresan untuk menguji kebolehnya. Kebocoran balik diukur menggunakan '*network analyzer*' manakala '*gain*' dan paten radiasi diukur menggunakan '*spectrum analyzer*'. Hasil kajian menunjukkan return loss adalah lebih kecil dari -10 dB pada frekuensi 5.8GHz dan menghasilkan jalurlebar yang besar. Selain itu, pengutuban antenna ini adalah pada sudut $\pm 45^\circ$ dan mempunyai '*gain*' yang bersesuaian.

CONTENTS

CHAPTER	TITLE	PAGE
	PROJECT TITLE	i
	AUTHENTICATION FORM	ii
	AUTHOR'S ACKNOWLEDGEMENT	iii
	SUPERVISOR'S ACKNOWLEDGEMENT	iv
	DEDICATION	v
	ACKNOWLEDGEMENT	vi
	ABSTRACT	vii
	ABSTRAK	viii
	CONTENTS	ix
	LIST OF TABLES	xiii
	LIST OF FIGURES	xv
	LIST OF ABBREVIATIONS	xix
	LIST OF APPENDICES	xxi
I	INTRODUCTION	
	1.1 Project Background	1
	1.2 Objective	2
	1.3 Problem Statement	2
	1.4 Scope of Work	2

II LITERATURE REVIEW

2.1	Basic Antenna Parameters	4
2.1.1	Antenna Polarization	4
2.1.1.1	Linear Polarization	5
2.1.1.2	Circular Polarization	7
2.1.1.3	Elliptical Polarization	7
2.1.2	Antenna Gain	8
2.1.3	Return Loss	9
2.1.4	Bandwidth	10
2.1.5	Radiation Pattern	10
2.1.6	Half Power Beamwidth	11
2.2	Microstrip Structure	12
2.3	Microstrip Rectangular Patch Antenna Design	13
2.4	Feeding Technique	15
2.4.1	Microstrip Line Feed	15
2.4.2	Coaxial Probe Feed	16
2.5	Feed Network	17
2.6	Dual Polarized Antenna	18
2.6.1	Corporate Feed Line Method	19
2.6.2	Feedforward Isolation Enhancement	19
2.6.3	Meanderline Polarizer	20
2.6.4	Folded Metal Box Dipole Broadband Antenna	21
2.6.5	Inset-Fed Microstrip Patch Antenna	22

III DUAL POLARIZED MICROSTRIP ANTENNA DESIGN

3.1	Single Patch Antenna	27
3.2	Slant $+45^\circ$ and -45°	30
3.3	1x2 Array Antenna	32

3.4	2x2 Array Antenna	34
3.5	1x4 Array Antenna	35
3.6	2x4 Array Antenna	37
3.7	Fabrication	38
3.8	Measurement Setup	40
	3.8.1 Return Loss	40
	3.8.2 Radiation Pattern	41
	3.8.3 Gain	42

IV RESULTS ANALYSIS AND DISCUSSION

4.1	Single Patch Antenna Design Result	43
	4.1.1 Analysis of Single Patch Antenna Dimension	44
	4.1.2 Results of Optimum Design	47
4.2	Single Element Slanted at $+45^\circ$ and -45° Antenna	49
	4.2.1 Analysis of Single Element Slanted at $+45^\circ$ and -45° Antenna Dimension	50
	4.2.2 Results of Optimum Design	51
4.3	Array of 1x2 Dual Polarized Antenna	53
	4.3.1 Analysis of Power Divider Dimension	54
	4.3.2 Analysis of 1x2 Dual Polarized Antenna Dimension	55
	4.3.3 Results of Optimum Design	59
4.4	Array of 2x2 Dual Polarized Antenna	61
	4.4.1 Analysis of 2x2 Dual Polarized Antenna Dimension	62
	4.4.2 Results of Optimum Design	64
4.5	Array of 1x4 Dual Polarized Antenna	67
	4.5.1 Analysis of 1x4 Dual Polarized Antenna Dimension	68

4.5.2	Results of Optimum Design	70
4.6	Array of 2x4 Dual Polarized Antenna	73
4.6.1	Analysis of 2x4 Dual Polarized Antenna Dimension	74
4.6.2	Results of Optimum Design	76

V CONCLUSION AND RECOMMENDATIONS

5.1	Conclusion	80
5.2	Recommendations	81

REFERENCES	82
-------------------	-----------

APPENDIX A	85
-------------------	-----------

LIST OF TABLES

NO	TITLE	PAGE
3.1	Properties of the Design	28
4.1	Effect width of the rectangular patch	44
4.2	Effect length of rectangular patch	45
4.3	Effect length of feedline, $\ell_{\lambda/2}$	46
4.4	Single patch parameters	47
4.5	Best performance of single patch antenna	47
4.6	Effect of varying $\ell_{\lambda/2}$	50
4.7	Effect of varying L_f	51
4.8	Slant $+45^\circ$ and -45° parameter	51
4.9	Best performance of slant 45° and -45°	52
4.10	Varying the length of 50Ω	54
4.11	Varying the feed length, L_f	55
4.12	Effect of varying the width of rectangular patch	56
4.13	Effect of varying length of rectangular patch	57
4.14	Effect of varying length of $\ell_{\lambda/2}$	58
4.15	Result of array 1x2 dual polarized antenna	61
4.16	Effect width of rectangular patch	63
4.17	Effect of varying length of rectangular patch	63
4.18	Result of array 2x2 dual polarized antenna	66
4.19	Width of rectangular patch	68
4.20	Length of rectangular patch	69

4.21	Result of array 1x4 dual polarized antenna	72
4.22	Effect width of rectangular patch	74
4.23	Effect length of rectangular patch	75
4.24	Result of array 2x4 dual polarized antenna	78
1	Via's Parameter	86

LIST OF FIGURES

NO	TITLE	PAGE
2.1	<i>E</i> -plane and <i>H</i> -plane	5
2.2	Linear Polarization	6
2.3	Circular Polarization	7
2.4	Elliptical Polarization	8
2.5	Power Pattern in dB	11
2.6	HPBW in linear scale	12
2.7	Microstrip Cross-Section	13
2.8	Embedded Microstrip Cross-Section	13
2.9	Physical and Effective Lengths of Rectangular Microstrip Patch	13
2.10	Rectangular Patch	14
2.11	Microstrip Feedline	16
2.12	Configuration of coaxial probe feed	17
2.13	Series Feed	17
2.14	Tapered Lines	18
2.15	$\lambda/4$ Transformer	18
2.16	The configuration of the 2x2 array with $W=13.5\text{mm}$	19
2.17	Dual Polarized Microstrip Patch Antenna	20
2.18	Dual Polarized Patch Antenna with Feedforward Isolation Circuit	20
2.19	Dual Polarized Antenna Assembly	21

2.20	Boxed Dipole for Dual Polarized antenna	22
2.21	Quarter-wave Transformer Impedance Matching technique	23
2.22	Layout of the 45° and -45 ° dual-polarized 1x2 array antenna	23
2.23	Layout of the -45° polarized 1x2 array antenna	23
2.24	Layout of the 45° polarized 1x2 array antenna	24
3.1	Flowchart of Design Process	26
3.2	Microstrip-line feed	27
3.3	Calculation Dimension	28
3.4	Single element patch antenna	29
3.5	CST simulation	30
3.6	Single element slanted at 45°	31
3.7	Single element slanted at -45°	31
3.8	Polarization observation	32
3.9	Slant 45° and slant -45°	32
3.10	Power divider	33
3.11	Matching	33
3.12	Combination of power divider and patch	34
3.13	Combination two array of 1x2	35
3.14	1x2 antenna slanted at +45°	36
3.15	1x2 antenna slanted at -45°	36
3.16	1x4 dual polarized antenna	37
3.17	2x4 dual polarized antenna	38
3.18	1x2 Dual polarized microstrip antenna	38
3.19	2x2 Dual polarized microstrip antenna	39
3.20	1x4 Dual polarized microstrip antenna	39
3.21	2x4 Dual polarized microstrip antenna	40
3.22	Return Loss measurement setup	40
3.23	Radiation Pattern measurement setup	41
4.1	Single Element	43

4.2	Single patch constructions	44
4.3	Return Loss	48
4.4	Radiation Pattern for E-plane and H-plane	48
4.5	Slant +45°	49
4.6	Slant -45°	49
4.7	Return Loss	52
4.8	Radiation pattern for 45° and -45° polarizations slant 45° and -45° antenna	53
4.9	Power divider	54
4.10	Array of 1x2 antenna	56
4.11	Return Loss	59
4.12	Radiation pattern for 45° and -45° polarizations 1x2 array antenna in simulation	60
4.13	Radiation pattern for 45° and -45° polarizations 1x2 array antenna in measurement	60
4.14	Array of 2x2 antenna	62
4.15	Return Loss	65
4.16	Radiation pattern for 45° and -45° polarizations 2x2 array antenna in simulation	65
4.17	Radiation pattern for 45° and -45° polarizations 2x2 array antenna in measurement	66
4.18	Array of 1x4 antenna	67
4.19	Return Loss	71
4.20	Radiation pattern for 45° and -45° polarizations 1x4 array antenna in simulation	71
4.21	Radiation pattern for 45° and -45° polarizations 1x4 array antenna in measurement	72
4.22	Array of 2x4 antenna	73
4.23	Return Loss	77
4.24	Radiation pattern for 45° and -45° polarizations 1x4 array antenna in simulation	77

4.25	Radiation pattern for 45° and -45° polarizations	78
	1x4 array antenna in measurement	
1	Back view	85
2	Cutplane view	85
3	Intersection between Via and ground plane	86
4	Build a Teflon	87
5	Teflon parameter	87
6	Teflon's Intersection	88
7	SMA ground plane	88
8	Extending the center of conductor	89
9	Waveguide port	89

LIST OF ABBREVIATIONS

CST	–	Computer Simulation Technology
IEEE	–	Institute of Electrical and Electronics Engineers
E	–	Electric Field Vector
H	–	Magnetic Field Vector
P	–	Poynting Vector
P_{Ref}	–	Receiving power of a reference antenna
P_{Test}	–	Receiving power of a test antenna
S	–	Scattering
RL	–	Return Loss
BW	–	Bandwidth
FNBW	–	First Null Beamwidth
HPBW	–	Half Power Beamwidth
ϵ_r	–	Dielectric constant
f_r	–	Resonant Frequency
$\tan \delta$	–	Tangent Loss
h	–	Height of substrate
W	–	Width
L	–	Length
ϵ_{eff}	–	Effective dielectric constant
ΔL	–	Extended incremental length
L_e	–	Effective length
R_{in}	–	Resonant input resistance
y_o	–	Inset feed-point distance

W_0	–	Width of feedline connected with the rectangular patch
$\ell_{\lambda/2}$	–	Length of feedline connected with the rectangular patch
Z_0	–	Input impedance
FR-4	–	Flame Resistant 4
ISM	–	Industrial Scientific and Medicine
L_f	–	Length of feedline
W_f	–	Width of feedline
AUT	–	Antenna Under Test
Tx	–	Transmitter
Rx	–	Receiver

LIST OF APPENDICES

NO	TITLE	PAGE
A	Coaxial Probe Feed	85

CHAPTER I

INTRODUCTION

Nowadays, the growing capacity demand from the users in communication system led to the development of antenna arrays at the base stations. This is because antenna arrays give advantages like increased coverage, diversity gain and interference suppression. If the array is equipped with the dual polarized antenna, more degrees of freedom are available. Thus, the one that investigated in this thesis may play a significant role.

1.1 Project Background

Antenna is the transitional structure between free-space and a guiding device. It is crucial elements of any wireless communication system which have various types such as helix, yagi, dipole, parabolic, horn and patch. Among of them, the patch or microstrip antenna popularly employed in many wireless communication systems. This is due to their advantages which are lightweight, low profile, easy fabrication and conformability to the mounting structure.

Dual-polarization operation has been concerned in microstrip antenna designs since it have a better chance of receiving more total signal than a singly linear polarized antenna. A dual-polarized microstrip antenna can be realized by feeding the rectangular microstrip patch at two orthogonal edges, through edge feed or probe feed, which excites TM_{01} -and TM_{10} -mode with orthogonal polarizations [1]–[4].

1.2 Objective

The objective of this project is to design dual polarized microstrip antenna for 5.8GHz point to point application. Important technical objective of this project is to get the return loss below than -10 dB, have a maximum gain and polarization at $\pm 45^\circ$. The antennas are simulated by using CST Microwave Studio software and fabricated by using chemical etching technique. Measurements are performed on the prototype in order to verify the results obtained during simulations.

1.3 Problem Statement

The growing capacity demand from the users on wireless communication system set up the development of dual polarized antenna [5]. Since dual polarized antenna is designed to divert things to have multipath, the antenna can increased the capacity on wireless communication system. Besides, many linearly polarized multipath signals with different orientation exist at the receive site. Dual polarized antenna has a better chance of receiving more total signal than a singly linearly polarized antenna.

1.4 Scope of Work

The dual polarized antenna is designed using microstrip technique for resonant frequency at 5.8GHz point to point application. Calculations are involved to determine

width and length of rectangular patch, feed line and power divider for resonant frequency 5.8GHz. A software of *CST Microwave Studio* is used in order to simulate single patch element, slant 45° and -45° and also an array for 1x2, 1x4, 2x2, and 2x4. From simulation process, return loss, bandwidth, gain, radiation pattern, directivity and beamwidth are discovered at frequency resonant 5.8GHz. The design is then fabricated by using FR-4 board and applied chemical etching technique for antenna array of 1x2, 1x4, 2x2 and 2x4. Afterward, the return loss, radiation pattern and gain of antenna are measured. Finally, simulation and measurement results are compared and analyzed.