



**Faculty of Electronic and Computer Technology and Engineering**

**OPTIMIZATION OF DUAL-BAND CPW PENTAGONAL PATCH  
ANTENNA WITH SLOTS FOR WIMAX AND WLAN  
APPLICATIONS**

اونيورسيتي تيكنيكل مليسيا ملاك  
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**Amier Hafizun bin Ab Rashid**

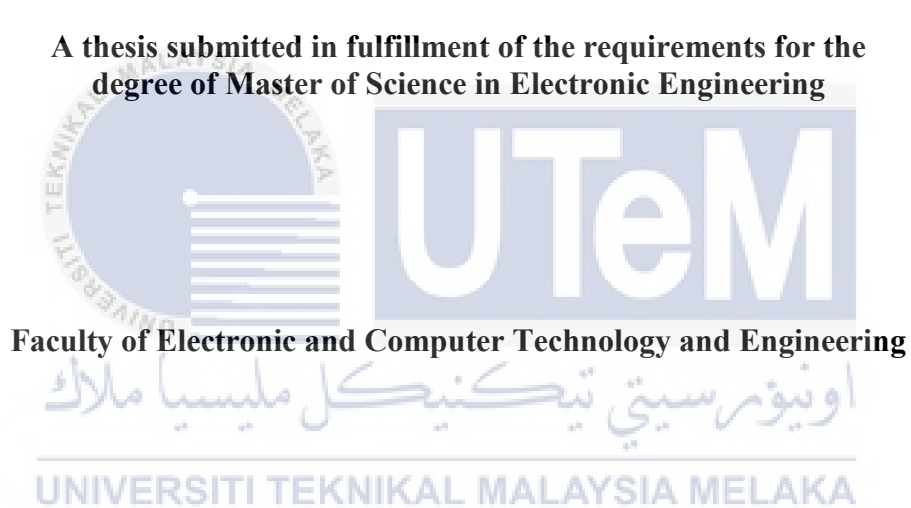
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**OPTIMIZATION OF DUAL-BAND CPW PENTAGONAL PATCH ANTENNA  
WITH SLOTS FOR WIMAX AND WLAN APPLICATIONS**

**AMIER HAFIZUN BIN AB RASHID**

**A thesis submitted in fulfillment of the requirements for the  
degree of Master of Science in Electronic Engineering**



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## DEDICATION

Dedicated to ALLAH Almighty, my loving wife, parents and all my family's members for your infinite and unfading love, sacrifice, best wishes, patience and encouragement.



## ABSTRACT

Beside low cost and easy to fabricate, there isn't enough bandwidth in any single antenna to accommodate all frequency ranges for basic rectangular antenna. The antenna with dual band frequency is proposed. This research presents various co-planar waveguide pentagonal microstrip patch antenna designs with multiple slots structure (MSS) techniques for dual-band 3.5 GHz Worldwide Interoperability for Microwave Access (WiMAX) and 5.8 GHz Wireless Local Area Networks (WLAN) application. The simulation work is applied using CST Microwave Studio software while the fabricated antenna design in laboratory using FR-4 substrate material ( $\epsilon_r = 4.4$ ,  $\tan \delta = 0.019$ ). The work started with Antenna *A* with basic square patch antenna shapes. Then the Antenna *B1*, Antenna *B2*, Antenna *B3*, Antenna *B4* with different shaped of patch including circular, triangular, square and pentagonal with co-planar waveguide (CPW) technique. Antenna *C1* and Antenna *C2* applied the first and second stage of multiple slot structure. The next stage of Antenna *D1*, Antenna *D2* and Antenna *D3* with CPW pentagonal island patch antenna with first, second and third stage of multiple slot structure. It then proceeds to the final stage of Antenna *E1* and Antenna *E2*, CPW antenna with some modifications design mini pentagonal island and multiple slot's structure. Besides that, the parametric study on a dual band CPW Pentagonal patch antenna for WiMAX and WLAN applications with multiple slot structure is presented in this work. As a result of the antenna's designs, the performance of the return loss, gain, and radiation pattern was impacted by the first and second multiple slot's structure. For the last proposed design of Antenna *E2*, it shows that, the antenna is operate at two different point at 3.5 GHz and 5.9 GHz with return losses of  $-25.662$  dB and  $-28.815$  dB, respectively. For both resonant frequency points, it shows the bandwidth performance of 1.58 GHz (from 2.57 GHz to 4.15 GHz) and 2.4 GHz (from 5.13 GHz to 7.53 GHz). For antenna gain, it shows a 2.24 dB and 4.47 dB for each resonant frequency, respectively.

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**PENGOPTIMUMAN ANTENA TAMPALAN DWI-JALUR GELOMBANG CO-PLANAR BERBENTUK PENTAGONAL DENGAN STRUKTUR SLOT BERBILANG UNTUK APLIKASI WiMAX DAN WLAN**

**ABSTRAK**

Selain kos rendah dan mudah dibuat, tidak ada lebar jalur yang mencukupi dalam mana-mana antenna tunggal untuk menampung semua julat frekuensi untuk antenna segi empat tepat asas. Antena dengan frekuensi dwi jalur dicadangkan. Kajian ini mempersembahkan pelbagai reka bentuk antenna tampalan jalur mikro pentagonal dengan teknik struktur pelbagai slot (MSS) untuk dwi-jalur 3.5 GHz Saling Kendalian Seluruh Dunia untuk Akses Gelombang Mikro (WiMAX) dan aplikasi Rangkaian Kawasan Setempat Tanpa Wayar (WLAN) 5.8 GHz. Kerja simulasi diaplikasikan menggunakan perisian CST Microwave Studio manakala reka bentuk antenna fabrikasi di makmal menggunakan bahan substrat FR-4 ( $\epsilon_r = 4.4$ ,  $\tan \delta = 0.019$ ). Kerja dimulakan dengan Antena A dengan bentuk antenna tampalan empat segi asas. Kemudian Antena B1, Antena B2, Antena B3, Antena B4 dengan bentuk tampalan yang berbeza termasuk bulatan, segi tiga, segi empat dan pentagonal dengan teknik pandu gelombang co-planar (CPW). Antena C1 dan Antena C2 menggunakan peringkat pertama dan kedua struktur slot berbilang. Peringkat seterusnya Antena D1, Antena D2 dan Antena D3 dengan antenna tampalan pulau pentagonal CPW dengan peringkat pertama, kedua dan ketiga struktur slot berbilang. Ia kemudiannya meneruskan ke peringkat akhir Antena E1 dan Antena E2, antenna CPW dengan beberapa reka bentuk pengubahsuaian pulau pentagonal mini dan struktur slot berbilang. Selain itu, kajian parametrik ke atas antenna tampalan untuk aplikasi WiMAX dan WLAN dengan struktur slot berbilang dibentangkan dalam kerja ini. Hasil daripada reka bentuk antenna, prestasi kehilangan pulangan, keuntungan dan corak sinaran telah dipengaruhi oleh struktur slot berbilang tahap yang pertama dan kedua. Untuk reka bentuk terakhir Antena E2 yang dicadangkan, ia menunjukkan bahawa, antenna beroperasi pada dua titik berbeza pada 3.5 GHz dan 5.9 GHz dengan kerugian pulangan masing-masing - 25.662 dB dan - 28.815 dB. Untuk kedua-dua titik frekuensi resonan, ia menunjukkan prestasi lebar jalur 1.58 GHz (dari 2.57 GHz hingga 4.15 GHz) dan 2.4 GHz (daripada 5.13 GHz hingga 7.53 GHz). Untuk kekuatan Antena, ia menunjukkan 2.24 dB dan 4.47 dB untuk setiap frekuensi resonans, masing-masing.

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First and foremost, I would like to thank ALLAH for giving me with strength and courage to complete this thesis. Who gave me an opportunity, courage and patience to carry out this work. I feel privileged to glory His name in the sincerest way through this small accomplishment. I seek His mercy, favor and forgiveness.

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## TABLE OF CONTENTS

	<b>PAGE</b>
<b>DECLARATION</b>	
<b>APPROVAL</b>	
<b>DEDICATION</b>	
<b>ABSTRACT</b>	<b>i</b>
<b>ABSTRAK</b>	<b>ii</b>
<b>ACKNOWLEDGEMENTS</b>	<b>iii</b>
<b>TABLE OF CONTENTS</b>	<b>iv</b>
<b>LIST OF TABLES</b>	<b>vi</b>
<b>LIST OF FIGURES</b>	<b>ix</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xvi</b>
<b>LIST OF PUBLICATIONS</b>	<b>xvii</b>

### CHAPTER

<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Research Overview	1
1.2 Research Background	2
1.3 Problem Statements	2
1.4 Objectives of the Research	6
1.5 Hypothesis	6
1.6 Scope of Research	6
1.7 Contribution of Project	7
1.8 Organization of Thesis	7
<b>2. LITERATURE REVIEW</b>	<b>9</b>
2.1 Introduction	9
2.2 Antenna Design and Application	11
2.2.1 Wireless Local Area Network (WLAN)	11
2.2.2 Worldwide Interoperability for Microwave Access (WiMAX)	13
2.3 Antenna Types	14
2.3.1 Basic Microstrip Antenna	15
2.3.2 Dual Band Antenna	17
2.3.3 CPW Antenna	19
2.3.4 Wideband Antenna	21
2.3.5 Pentagonal Microstrip Antenna	23
2.3.6 Slot on Antenna	25
2.3.7 Fractal Slots on Antenna	27
2.3.8 Pentagonal Antenna with Fractal Slots	37
2.4 Antenna Parameter	39
2.4.1 Return Loss and Resonant Frequency	40
2.4.2 Radiation pattern	42
2.4.3 Gain	42
2.4.4 Directivity	44
2.4.5 Bandwidth	44

2.5	Feeding Technique	44
2.5.1	Coaxial Probe Feed	46
2.5.2	Microstrip line feed	47
2.5.3	Aperture Coupled Feed	48
2.5.4	Proximity Coupled Microstrip Feed Line	49
2.5.5	Coplanar Wave Guide (CPW) Feeding	50
2.6	Summary	51
<b>3.</b>	<b>METHODOLOGY</b>	<b>53</b>
3.1	Background	53
3.2	Antenna Specification	55
3.3	Multiple Pentagonal Slot Design	56
3.4	Simulation Setup of Antenna	57
3.5	Simulation of Antenna Design	62
3.5.1	Antenna <i>A</i>	64
3.5.2	Antenna <i>B</i>	66
3.5.3	Antenna <i>C</i>	68
3.5.4	Antenna <i>D</i>	69
3.5.5	Antenna <i>E</i>	71
3.5.6	Antenna <i>E2</i>	72
3.6	Fabrication of Antenna Design	73
3.7	Measurement of Patch Antenna	76
3.8	Summary	77
<b>4.</b>	<b>RESULT AND DISCUSSION</b>	<b>78</b>
4.1	Introduction	78
4.2	Antenna <i>A</i>	79
4.2.1	Antenna <i>A1</i>	79
4.3	Antenna <i>B</i>	84
4.3.1	Antenna <i>B1</i>	84
4.3.2	Antenna <i>B2</i>	89
4.3.3	Antenna <i>B3</i>	92
4.3.4	Antenna <i>B4</i>	95
4.4	Antenna <i>C</i>	102
4.4.1	Antenna <i>C1</i>	102
4.4.2	Antenna <i>C2</i>	108
4.5	Antenna <i>D</i>	113
4.5.1	Antenna <i>D1</i>	113
4.5.2	Antenna <i>D2</i>	118
4.5.3	Antenna <i>D3</i>	123
4.6	Antenna <i>E</i>	128
4.6.1	Antenna <i>E1</i>	128
4.6.2	Antenna <i>E2</i>	134
4.7	Summary	140
<b>5.</b>	<b>CONCLUSION</b>	<b>141</b>
5.1	Conclusion	141
5.2	Suggestions for future work	143
	<b>REFERENCES</b>	<b>144</b>

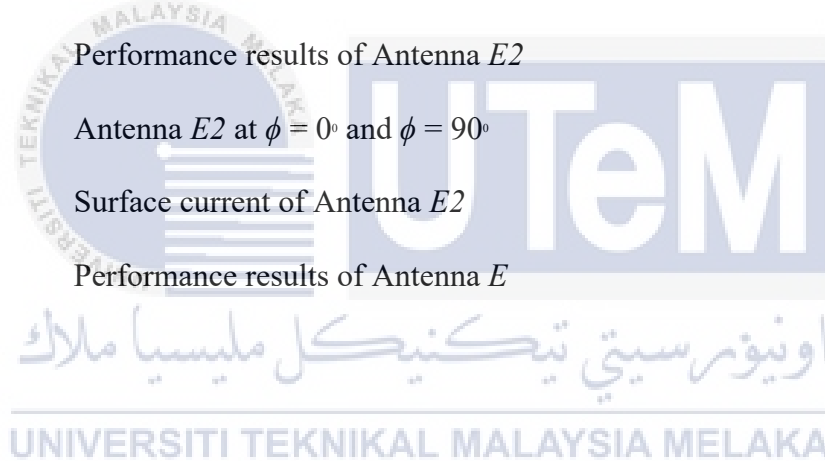


## LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Wi-Fi standards of 802.11 based on its designation	13
2.2	Example of dual band antenna of WLAN and WiMAX	18
2.3	Previous studies of CPW antenna	21
2.4	Example of wideband antenna of WLAN and WiMAX	23
2.5	Advantages and disadvantages of slot antenna technique	27
2.6	Example antenna design with Sierpienski Gasket Structure added	33
2.7	Example of antenna design with Sierpienski Carpet Structure	36
2.8	Example of Pentagonal antenna with fractal slot geometry	39
2.9	Advantages and disadvantages of feeding technique	46
3.1	Design specifications	55
3.2	Material specification of substrate	56
3.3	Multiple pentagonal slots design stage	57
3.4	Dimension of Antenna A1	66
3.5	Dimension of the Antenna B	68
3.6	Dimension of the Antenna C	69
3.7	Dimensions of Antenna D1, Antenna D2 and Antenna D3	70
3.8	Dimensions of Antenna E1	71
3.9	Dimensions of Antenna E2	72
4.1	Different performance results of Antenna A1	81

4.2	Radiation pattern of Antenna <i>A1</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	82
4.3	Surface current of Antenna <i>A1</i>	83
4.4	Different performance results of Antenna <i>B1</i>	85
4.5	Radiation pattern of Antenna <i>B1</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	87
4.6	Surface current of Antenna <i>B1</i>	88
4.7	Different performance results of Antenna <i>B2</i>	90
4.8	Radiation pattern of Antenna <i>B2</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	91
4.9	Surface current of Antenna <i>B2</i>	92
4.10	Different performance results of Antenna <i>B3</i>	94
4.11	Radiation pattern of Antenna <i>B3</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	94
4.12	Surface current of Antenna <i>B3</i> at 2.41 GHz	95
4.13	Performance results of Antenna <i>B4</i>	96
4.14	Radiation pattern of Antenna <i>B4</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	97
4.15	Surface current of Antenna <i>B4</i>	98
4.16	Performance results of Antenna <i>B</i>	101
4.17	Performance results of Antenna <i>C1</i>	104
4.18	Radiation pattern of Antenna <i>C1</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	105
4.19	Surface current of Antenna <i>C1</i>	106
4.20	Performance results of Antenna <i>C1</i>	110
4.21	Antenna <i>C2</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	111
4.22	Surface current of Antenna <i>C2</i>	112
4.23	Performance results of Antenna <i>C</i>	113
4.24	Performance results of Antenna <i>D1</i>	115
4.25	Antenna <i>D1</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	116
4.26	Surface current of Antenna <i>D1</i>	117

4.27	Performance results of Antenna <i>D2</i>	119
4.28	Radiation pattern of Antenna <i>D2</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	121
4.29	Surface current of Antenna <i>D2</i>	122
4.30	Performance results of Antenna <i>D3</i>	124
4.31	Antenna <i>D3</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	125
4.32	Surface current of Antenna <i>D3</i>	126
4.33	Performance results of Antenna <i>D</i>	128
4.34	Performance results of Antenna <i>E1</i>	130
4.35	Antenna <i>E1</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	131
4.36	Surface current of Antenna <i>E1</i>	132
4.37	Performance results of Antenna <i>E2</i>	136
4.38	Antenna <i>E2</i> at $\phi = 0^\circ$ and $\phi = 90^\circ$	137
4.39	Surface current of Antenna <i>E2</i>	138
4.40	Performance results of Antenna <i>E</i>	139



## LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Wide range application of the WiMAX and WLAN (Kim, et al., 2011)	4
1.2	Polygon MSAs design (a) Top and (b) Side views of CMSAs, (c) ETMSA, (d) SMSA, (e) P-MSA, (f) Hexagonal MSA, (g) Septagon MSA and (h) Octagon MSA (Deskmukh and Chavali, 2021)	5
2.1	Antenna concept as energy transducer, dispersing EM energy into free space or capturing it from space	11
2.2	Speed vs. mobility of wireless systems (The Potential of WiMAX : Short Trip to the Wireless World)	14
2.3	Basic shapes in the use of microstrip patch antenna	15
2.4	Microstrip patch antenna component	16
2.5	Dual band antenna of WLAN and WiMAX, (a) Naik, 2018, (b) Sonak, 2019, (c) Christydass, 2021, (d) Thanki, 2021	17
2.6	Basic coplanar waveguide (CPW structure in cross section	19
2.7	CPW antenna, (a)Daniel, 2021, (b)Alsariera, 2020, (c) Saha et al, 2020, (d)Maity et al, 2020, (e) Maity et al, 2020	20
2.8	Wideband antenna of WLAN and WiMAX	22

2.9	Example of pentagonal with dual-band and wideband effect, (a) Viraja et al, 2018, (b) Rawat et al, 2016, (c) Datta and Mukherjee, 2019, (d) Tecpoyotl - Torres et al, 2010	25
2.10	Types of slot on antenna, (a) Coaxial line, (b) waveguide, (c) two-wire feed line (Bhaysar, 2023)	26
2.11	Differentiaial current flow on the antenna, (a) microstrip antenna with slots, wire antenna (Bhaysar 2023)	26
2.12	Hexagonal Koch Fractal slots shape with a CPW-fed ultra-wideband antenna, (a) basic hexagonal, (b) 6 mini hexagons added, (c) insertion of the first iteration of the Koch fractal slots, (d) two external hexagon added, (e) first iteration of Koch is inserted in the edge of the central hexagon, 9f) the two external hexagons are groove	28
2.13	The sierpienski iteration development stage, (a) triangular, (b) square	30
2.14	Equilateral triangular Sierpinski gasket conductor structure (Puente et al., 1996)	25
2.15	Hexagonal modified Sierpinski carpet fractal slots antenna: (a) basic hexagonal form, (b) First iteration and (c) Second Iteration	31
2.16	Multiband microstrip-fed printed antenna with circular nested triangle structure fractal slots, (a) basic geometry of first-order fractal slots, (b) second order inscribed circle on the triangle gap and nest a triangular gao, (c) third order, (d) final configuration.	32

2.17	Sierpinski gasket antenna, (b) Durbhakula & rao, 2018, (b) Devesh et al, 2018	32
2.18	Step-by-step development of the Sierpinski carpet, (a) Zero iteration, (b) first iteration, (c) second iteration, (d) third iteration	34
2.19	Hexagonal fractal slots on triangular patch antenna (Chaouche et al, 2019), (a) initial triangular antenna, (b) first iteration, (c) second iteration, and (d) third iteration	34
2.20	UWB coplanar waveguide-fed modified hexagonal slots Sierpinski carpet fractal slots antenna	35
2.21	Antenna design with Sierpinski carpet structure, (a) Yadav et al., 2018, (b) Sankhe, 2018, (c) Maharana et al., 2017	36
2.22	Ring fractal antenna development stage, (a) first iteration, (b) second iteration, (c) third iteration	37
2.23	Multiband Koch pentagonal fractal slots antenna development stage, (a) pentagonal fractal slots geometry, (b) Koch embedded pentagonal fractal slots geometry	38
2.24	Pentagonal antenna with fractal slots geometry	38
2.25	Three-Dimensional Radiation pattern (Balanis, 2005)	42
2.26	Two-Dimensional Radiation Pattern, (a) Field pattern in Linear Scale, (b) Power pattern in Linear Scale, and (c) Power pattern in Decibel (Balanis, 2005)	43

2.27	Feeding technique, (a) coaxial probe feed, (b) Microstrip line feed, (c) Aperture coupled feed, (d) Proximity coupled microstrip feed line, (e) Coplanar waveguide (CPW) feeding	45
2.28	Dual-polarized microstrip Yagi antenna based on coaxial back feed (Liang et al., 2020)	47
2.29	Equilateral triangular patch antenna using AgHT-8 with copper feedline (Borah and Bezboruah, 2018)	48
2.30	Example of aperture coupled feed, (a) Brauner et al., 2003, (b) Anandkumar & Sangeta, 2020	49
2.31	Example of Proximity coupled microstrip feed line, (a) Kumari and Kumar, 2016, (b) Casula et al., 2016	50
2.32	Example of coplanar waveguide (CPW) feeding technique, Dayo et al., 2020	51
3.1	Flow chart of the research development	54
3.2	A flow chart illustrates the simulation configuration for the antenna in CST	58
3.3	The CST Microwave Studio simulation software's material collection	60
3.4	The new material creates in material library of CST	60
3.5	The antenna setp in CST Microwave Studio	61
3.6	Domain setup in CST Microwave Studio	62
3.7	Design stage of Antenna	63
3.8	Design stage of Antenna <i>A1</i>	64

3.9	Design stage of Antenna <i>B</i> , (a) Antenna <i>B1</i> , (b) Antenna <i>B2</i> , (c) Antenna <i>B3</i> , (d) Antenna <i>B4</i>	67
3.10	Design stage of Antenna <i>C</i> , (a) Antenna <i>C1</i> , (b) Antenna <i>C2</i>	68
3.11	Design stage of Antenna <i>D1</i> , Antenna <i>D2</i> , Antenna <i>D3</i>	70
3.12	Design stage of CPW pentagonal island patch antenna structure with mini pentagonal island Antenna <i>E1</i>	71
3.13	Design stage of Antenna <i>E2</i>	72
3.14	The process of fabrication antenna	73
3.15	The .dxf file printed layout, (b) Ultraviolet exposure machine	74
3.16	Developing process	74
3.17	Etching process, (a) antenna before etching, (b) etching machine	75
3.18	Soldering process	75
3.19	The return loss measurement setup, (a) vector network analyzer and coaxial cable, (b) antenna under test - Antenna <i>B4</i> , Antenna <i>C1</i> , Antenna <i>C2</i> , Antenna <i>D3</i> , Antenna <i>E1</i> and Antenna <i>E2</i>	76
3.20	Radiation pattern measurement of proposed antenna	77
4.1	Schematic diagram of Antenna <i>A1</i> : (a) front view shape and (b) side view	79
4.2	Return loss of Antenna <i>A1</i>	80
4.3	Schematic diagram of Antenna <i>B1</i> : (a) front view shape and (b) side view	84



4.4	Return loss of Antenna <i>B1</i> (simulation)	85
4.5	Schematic diagram of Antenna <i>B2</i> : (a) front view shape and (b) side view	89
4.6	Return loss of Antenna <i>B2</i> (simulation)	90
4.7	Schematic diagram of Antenna <i>B3</i> : (a) front view shape and (b) side view	93
4.8	Return loss of Antenna <i>B3</i> (simulation)	93
4.9	Schematic diagram of the Antenna <i>A4</i> : (a) front view shape and (b) side view	95
4.10	Return loss of Antenna <i>B4</i> (simulation)	96
4.11	Parametric study of return loss for Antenna <i>B4</i> with different patch length dimension	99
4.12	Parametric study of return loss for Antenna <i>B4</i> with different patch width	100
4.13	Comparison of return loss for Antenna <i>B</i>	101
4.14	Measurement of antenna <i>C1</i>	102
4.15	Return loss of Antenna <i>C1</i>	103
4.16	Parametric study of return loss for Antenna <i>C1</i> with different feedline and CPW gap dimension	107
4.17	Parametric study of return loss for of Antenna <i>C1</i> with different feedline length.	108
4.18	Parametric study of return loss for Antenna <i>C1</i> with different slot width	109
4.19	Schematic diagram of the Antenna <i>C2</i>	109
4.20	Return loss of Antenna <i>C2</i>	110

4.21	Comparison of return loss for antenna <i>C</i>	113
4.22	Schematic diagram of the Antenna <i>D1</i>	114
4.23	Return loss of Antenna <i>D1</i>	115
4.24	Schematic diagram of the Antenna <i>D2</i>	118
4.25	Return loss of Antenna <i>D2</i>	119
4.26	Schematic diagram of the Antenna <i>D3</i>	123
4.27	Return loss of Antenna <i>D3</i>	124
4.28	Comparison of return loss for Antenna <i>D</i>	127
4.29	Schematic diagram of the Antenna <i>E1</i> (a) simulation, (b) fabrication	129
4.30	Return loss of Antenna <i>E1</i>	129
4.31	Return loss of Antenna <i>E1</i> with different mini pentagonal island length dimension	133
4.32	Return loss of Antenna <i>E1</i> with different mini pentagonal island width dimension	134
4.33	Schematic diagram of the Antenna <i>E2</i> , (a) simulation, (b) fabrication	145
4.34	Return loss of Antenna <i>E2</i>	146
4.35	Comparison of return loss for Antenna <i>E</i>	109

## LIST OF ABBREVIATIONS

CPW	-	Coplanar waveguide
CST	-	Computer Simulation Technology
FCC	-	Federal Communication Commission
MSS	-	Multiple Slots structures
FSS	-	frequency selective surfaces
GPS	-	Global Positioning System
LTE	-	Long Term Evolution
PRFPA	-	pentagonal ring fractal patch antenna
RF	-	Radio Frequency
SMA	-	Sub Miniature Version A
VNA	-	Vector Network Analyser
WiMAX	-	Worldwide Interoperability for Microwave Access
WLAN	-	Wireless Local Area Network

## LIST OF PUBLICATIONS

The research papers produced and published during this research are as follows:

### 1. Journal :

1. A. H. A. Rashid, B. H. Ahmad, M. Z. A. A. Aziz, N. Hassan, 2023. CPW Fractal Antenna with Third Iteration of Pentagonal Sierpinski Gasket Island for 3.5 GHz WiMAX and 5.2 GHz WLAN Applications, *International Journal of Electrical and Computer Engineering Systems* vol. 14 (2), pp. 129-134.  
DOI: <https://doi.org/10.32985/ijeces.14.2.2>
2. A. H. A. Rashid, B. H. Ahmad, M. Z. A. A. Aziz, N. Hassan, M. Mazlan 2023. Parametric Study of CPW Pentagonal Sierpienski Gasket Fractal Patch Antenna, *Przegląd Elektrotechniczny* vol. 07/2023 , pp. 186.  
ISSN 0033-2097, R. 99 NR 7/2023 <http://pe.org.pl/articles/2023/7/34.pdf>  
DOI: 15199/48.2023.07.34

### 2. Technical Conference

3. A. H. A. Rashid, B. H. Ahmad, M. Z. A. A. Aziz and N. Hassan, 2022. Dual Band CPW Fractal Geometry Shaped of Pentagonal Island for WLAN and WiMAX, *IEEE International RF and Microwave Conference (RFM 2022), Kuala Lumpur*

4. A. H. A. Rashid, B. H. Ahmad, M. Z. A. Abd Aziz and N. Hassan, 2022. Effect of Different Dimension of CPW Pentagonal Island Antenna with Sierpinski Gasket Fractal. Presented and accepted at The *6th International Conference for Electronic Design (ICED 2022), Perlis*  
<https://doi.org/10.1063/5.0192220>
5. A. H. A. Rashid, B. H. Ahmad, M. Z. A. Aziz, N. Hassan, M. Mazalan, N. Mahmud, Dual Band CPW Pentagonal Island Antenna With Modified Sierpinski Gasket Structure At 3.5 GHz AND 5.8 GHz, Presented and accepted at 2023 *IEEE International Symposium On Antennas And Propagation (ISAP2023), Kuala Lumpur*
6. A. H. A. Rashid, B. H. Ahmad, M. Z. A. Aziz, N. Hassan, M. Mazalan, N. Mahmud, CPW Pentagonal Patch Antenna With Multiple Slots Effect For WLAN And WiMAX Applications, Presented and accepted at 2023 *IEEE International Symposium On Antennas And Propagation (ISAP2023), Kuala Lumpur*

### **3. Book Chapter**

7. A. H. A. Rashid, B. H. Ahmad, N. Hassan, Sierpinski Gasket Fractal on CPW Pentagonal Antenna Design for WiMAX and WLAN Application, 2023, Reconfigurable Antenna for Wireless Communication System, Chapter 10, Penerbit UTM

8. A. H. A. Rashid, B. H. Ahmad, M. Z. A. A. Aziz and N. Hassan, Dual Band CPW Pentagonal Sierpinski Gasket Fractal Patch Antenna for WiMAX And WLAN Applications, *Progress in Engineering technology VI 2024 (accepted)*, Springer



# CHAPTER 1

## INTRODUCTION

### 1.1 Research Overview

Due to the growing demand for efficient, low-profile, and cost-effective production in wireless frequency applications on a device, a small planar antenna is an optimal choice for dual-band frequency resonance for 3.5 GHz WiMAX and 5.8 GHz WLAN applications. Therefore, this research proposed a dual-band, pentagonal-shaped, multiple slots patch antenna. It also used an FR-4 substrate with a dielectric constant of  $\epsilon_r = 4.4$  and an electrical conductivity tangent loss of  $\tan \delta = 0.019$ . Based on the reference design of the fundamental square patch antenna, this research designed a pentagonal-shaped patch antenna.

### 1.2 Research Background

Compact, multi-functional applications, low-cost materials and components, and easy-to-fabricate antennas are always in high demand in the revolutionary era of modern technology. Even though the proposed antenna meets these standards, there is always the need to lower the antenna's size while improving performance metrics. Because technological advancement is a never-ending process, there is always room for enhancement by several techniques.

However, modern wireless communications necessitate antennas that can operate in multiple frequency bands, such as 1575.42 MHz/ 1227.60 MHz/ 1176.45 MHz for the Global Positioning System (GPS) (Mishra et al., 2019), 900/1800 MHz

for the Global System for Mobile Communication (GSM), 2.4 GHz/ 5.2 GHz/ 5.8 GHz for Wireless Local Area Networks (WLANs), 2.5 GHz/ 3.5 GHz/ 5.5 GHz for Interoperability for Microwave Access (WiMAX), and 700 MHz/ 2300 MHz/ 2600 MHz for Long Term Evolution (LTE) (Hamid et al., 2022).

Antennas with dual band or multiband and lower dimensions, such as dual-band antenna than previously conceivable, are required for current communications systems. Much attention has been focused on how much more multiband antennas are needed because the Federal Communication Commission (FCC) has made it illegal to use frequencies between 3.1 GHz and 10.6 GHz.

Each antenna has typically followed on a single, with different antennas required for different purposes (Praveena et al., 2022). This will result in difficulty with restricted material used, location of the antenna and also antenna size. To solve this difficulty, a multiband or dual band antenna can be implemented, which allows a single antenna to work across many frequency bands. Wideband impedance matching, thermal cooling, structural strength, good isolation, and low design complexity are all advantages of coplanar waveguide feed (Singhal et al, 2017).

### **1.3 Problem Statements**

Microstrip patch antennas are simple and convenient antennas for microwave communications. It provides numerous benefits, such as reduced weight, size, volume occupancy, and cost. It has long been popular in wireless applications because of its inexpensive cost and low profile, but its main drawback is its limited impedance bandwidth. In addition, there are several problems with the basic microstrip patch antenna performance. This antenna maybe can have a good performance in low frequency. However, when frequencies increase, typical patch antenna designs suffer