Faculty of Electronic and Computer Technology and Engineering

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

Amier Hafizun bin Ab Rashid

Master of Science in Electronic Engineering

2024

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

Faculty of Electronic and Computer Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

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 (ε_r = 4.4, tan δ = 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.

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 antena tunggal untuk menampung semua julat frekuensi untuk antena segi empat tepat asas. Antena dengan frekuensi dwi jalur dicadangkan. Kajian ini mempersembahkan pelbagai reka bentuk antena 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 antena fabrikasi di makmal menggunakan bahan substrat FR-4 ($\varepsilon r = 4.4$, $\tan \delta = 0.019$). Kerja dimulakan dengan Antena A dengan bentuk antena 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 antena tampalan pulau pentagonal CPW dengan peringkat pertama, kedua dan ketiga struktur slot berbilang. Ia kemudiannya meneruskan ke peringkat akhir Antena E1 dan Antena E2, antena CPW dengan beberapa reka bentuk pengubahsuaian pulau pentagonal mini dan struktur slot berbilang. Selain itu, kajian parametrik ke atas antena tampalan untuk aplikasi WiMAX dan WLAN dengan struktur slot berbilang dibentangkan dalam kerja ini. Hasil daripada reka bentuk antena, 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, antena 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.

ACKNOWLEDGEMENTS

In the Name of Allah, Most Merciful, Most Gracious,

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.

I would like to express my deepest gratitude to my Supervisor, Profesor Ir. Dr. Badrul Hisham Ahmad and Prof Madya Dr. Mohamad Zoinol Abidin Abd Aziz for his constant support, patience and constructive guidance for this project. I would also like to thank the technician at Laboratory for his support and cooperation.

Last but not least, I would like to express my appreciation to my beloved wife, Sabarina binti Ramlan, parents, and my family for the unconditional support and love that let me through the toughest days in my life. To all my who shared a lot of information and ideas to make my thesis better, I hope we can have a good grade for our effort. For those who not stated here, I would like to thank for their friendship, help and countless support to me. May Allah S.W.T. bless all of them for their kindness and support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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, *Przeglad 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. Mahmod, 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. Mahmod, 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 r = 4.4 and an electrical conductivity tangent loss of tan = 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