UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BANDWIDTH AND GAIN ENHANCED OF PATCH ANTENNA WITH METAMATERIAL WAVEGUIDE

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electronic Engineering Technology (Telecommunication) with Honours.

by

SAFIAH BINTI ABD RAZAK

B071410793

930621-14-6346

FACULTY OF ENGINEERING TECHNOLOGY

2017

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Bandwidth And Gain Enhanced Of Patch Antenna With Metamaterial Waveguide**

SESI PENGAJIAN: **2017/18 Semester 1**

Saya

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☑	TIDAK TERHAD	

Disahkan oleh:

SAFIAH BINTI ABD RAZAK

____

Cop Rasmi:

Alamat Tetap:

No. 14 Jalan Nirwana 2,

Taman Nirwana 68000

Ampang Selangor

Tarikh: ___________________________

Tarikh: 13 JANUARI 2017

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled "
Bandwidth And Gain Enhanced Of Patch Antenna With Metamaterial Waveguide"
is the results of my own research except as cited in references.

Signature	:	…………………………………………
Author's Name	:	SAFIAH BINTI ABD RAZAK
Date	:	13 JANUARI 2018

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electronic Engineering Technology (Telecommunication) with Honours. The member of the supervisory is as follow:

………………………………

(Mr. Adib Bin Othman)

ABSTRAK

Pada asasnya, antena patch microstrip (MPA) adalah antena fabrikasi yang terdiri daripada patch metalik yang dicetak pada substrat yang berasaskan. Kelebihan antena patch microstrip menawarkan profil rendah, keupayaan untuk permukaan berbentuk, kemudahan fabrikasi, profil rendah, kos rendah, struktur planar, ringan, kemudahan integrasi dan peralatan komunikasi mudah alih. Sebagai kelebihan yang dinyatakan, terdapat beberapa kelemahan antena microstrip seperti bandwidth sempit dan keuntungan yang rendah. Terdapat teknik khas untuk mengatasi masalah ini seperti menambah struktur antena tampalan gelombang metamaterial untuk meningkatkan lebar jalur dan keuntungan antena patch microstrip. Dalam projek ini, pandu gelombang yang terdiri daripada cincin alur metamaterial planar dicadangkan untuk digunakan dalam antena patch microstrip. Hasil simulasi dibandingkan antara antena patch konvensional tanpa antena metamaterial dan patch yang dimuatkan dengan pandu gelombang metamaterial. Antena patch konvensional bergema pada 4.856 GHz dengan keuntungan 3.330dB dan jalur lebar 255.42MHz (4.7505GHz-4.9759GHz). Sementara itu, antena tampalan yang dimuatkan dengan struktur gelombang pandu metamaterial, ia adalah resonansi pada 4.852GHz dengan keuntungan 4.041dB dan jalur lebar 294.19MHz (4.7036GHz - 4.9977GHz) sepadan dengan aplikasi WiMAX. Untuk nilai pengukuran dari peralatan, nilai keuntungan diukur untuk antena tampal konvensional tanpa metamaterial adalah 2.418 dB tetapi nilai keuntungan diukur untuk antena tampalan dengan metamaterial adalah 3.27 dB. Nilai bandwidth yang diukur untuk antena patch konvensional tanpa metamaterial adalah 106MHz tetapi nilai bandwidth yang diukur untuk patch antena dengan metamaterial adalah 96MHz. Dari pemerhatian, terdapat nilai kenaikan keuntungan dalam antena tampalan dengan bahan metamaterial tetapi ada juga penurunan nilai bandwidth antena patch dengan metamaterial apabila dibandingkan dengan antena patch konvensional tanpa metamaterial. Bandwidth antena patch dengan metamaterial sepatutnya meningkat lebih daripada antena patch konvensional tanpa metamaterial kerana telah terbukti dalam simulasi CST. Dari pemerhatian dan analisis, pelajar telah mengetahui bahawa terdapat faktor yang mempengaruhi jalur lebar antena patch dengan metamaterial adalah disebabkan oleh proses pematerian.

ABSTRACT

Basically, a microstrip patch antenna (MPA) is fabricate antenna which consists of a metallic patch printed on a grounded substrate. The advantages of microstrip patch antenna offers the of low profile, conformability to a shaped surface, ease of fabrication, low-profile, low cost, planar structure, light weight, ease of integration and portable communication equipment. As the advantage stated, there are some disadvantage of microstrip antenna such as narrow bandwidth and low in gain. There a special technique to overcome these problem such as adding metamaterial waveguide patch antenna structure to increase the bandwidth and gain of microstrip patch antenna. In this project, a waveguide made up from planar metamaterial squared ring is proposed to use in microstrip patch antenna. The simulation result are compared between conventional patch antenna without metamaterial and patch antenna loaded with metamaterial waveguide. The conventional patch antenna resonates at 4.856 GHz with gain of 3.330dB and bandwidth of 255.42MHz (4.7505GHz-4.9759GHz). Meanwhile, patch antenna loaded with metamaterial waveguide structure, it is resonant at 4.852GHz with gain of 4.041dB and bandwidth of 294.19MHz (4.7036GHz – 4.9977GHz) corresponds to WiMAX application. For the measurement value from equipment, the value of measured gain for conventional patch antenna without metamaterial is 2.418 dB but the value of measured gain for patch antenna with metamaterial is 3.27 dB. The value of measured bandwidth for conventional patch antenna without metamaterial is 106MHz but the value of measured bandwidth for patch antenna with metamaterial is 96MHz. From the observation, there is an increment value of gain in patch antenna with metamaterial but there is also decrement value of bandwidth in patch antenna with metamaterial when it compared with conventional patch antenna without metamaterial. The bandwidth of patch antenna with metamaterial is supposed to be increased more than conventional patch antenna without metamaterial because it has been proven in simulation CST. From the observation and analysis, student had found out that there is factor affecting bandwidth of patch antenna with metamaterial is due to the the soldering process.

DEDICATION

I dedicate this project to God Almighty my creator, my source of inspiration, wisdom, knowledge and understanding. I also dedicate my dissertation work to my family and many friends. For my mom, Norma binti Ramli, without her I would not be here and my lovely father, Abd Razak bin Ibrahim. From day one loving words, actions, and intentions have been poured out on me by their hands. Thank you. My love for you all can never be quantified.

ACKNOWLEDGEMENT

Foremost, I would like to express my sincere gratitude to my supervisor Sir Adib Bin Othman for the continuous support of my research and design, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of design and simulation of this project. I could not have imagined having a better advisor and mentor for my undergraduate project. Without his assistance and dedicated involvement in every step throughout the process, this paper would have never been accomplished. I would like to thank you very much for your support and understanding over these past one years.

I thank my classmate Affiq Saipudin and Hafizah Hanif who as a good friend was always willing to help and give his best suggestions. Besides that, for the stimulating discussions, designing and simulations, for the sleepless nights we were working together before deadlines, and for all the fun we have had in the last years. I have to appreciate the guidance given by other supervisor as well as the panels especially in our project presentation that has improved our presentation skills thanks to their comment and advices.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 Introduction

An antenna can be characterized as the changing of an RF signal flow on conductor and into an electromagnetic wave in free space [7]. At the time when the signal is flow through the antenna, the antenna will transfer the radiation to convey in space in a certain path. The implementation of an antenna can be described by different parameters for instance, radiation pattern, input impedance, return loss, bandwidth, directivity and gain, beamwidth, side lobes, polarization and other.

The microstrip patch antenna (MPA) is developed in early 1980, well known as one port device. There are four basic categories of microstrip antenna which can be list as MPA, microstrip dipoles, Printed slot antennas and microstrip travelling wave antennas. The antenna is relying on shape, dimension of patch, the thickness and dielectric constant of substrate and feeding arrangement. Furthermore, the MPA have the predominant frequency range of 1 to 6 GHz. Basically, the MPA is made up of conducting patch on half side of dielectric substrate and it also connected to grounding plane on the other side, it can be classify as resonant antenna. The matter of substrate will allow mechanical support for radiating patch element and to sustain the distance between patch and ground plane while the grounding plane is play role as lower conduction layer site while the patch is very thin metallic strip which is situated on the top of substrate. A thin substrate need more amount of dielectric constant compared to thick substrate. These days, there are a few kind of shape in patch which presumably recognized as rectangular, circular, triangular, elliptical and more. The four most standard feeding methods are the microstrip line, coaxial probe, aperture coupling and proximity coupling. There are essentially two investigation strategies for patch antennas- transmission line model and cavity model [1].

Moreover, the best way to enhance the bandwidth and gain of MPA, the antenna will be incorporate with metamaterial structure as waveguide. The metamaterial are characterized as naturally visible composites which utilize to expand execution of miniaturized (electrically small) antenna frameworks [7]. The basic electromagnetic antenna goal is to build the energy into free space. The metamaterials are known as Double Negative (DNG) materials because of the possessions of negative dielectric permittivity (ε) and magnetic permeability. The complex permittivity and permeability of the suggested structures of metamaterial had been explained by Nicolson-Ross-Weir (NRW) [2]. The metamaterial structure comprises of Split Ring Resonators (SRRs) to convey negative permeability and thin wire part to deliver negative permittivity. The SRR are including two concentric rings with a split every ring. It acts as an LC resonator with flows inductance and capacitance that will be empowered by a time-varying outside magnetic field some portion of commons direction of a resonator. There are primarily four types of metamaterial structures as antenna substrates which are 1-D Split Ring structure, Symmetrical Ring structure, Omega structure and S structure [7].

The two essential characteristic of MPA is small bandwidth and lower gain. The advantages can be incorporate and overcome by metamaterial structure. It is the ideal approach to the antenna miniaturization and to improve the efficiency, gain, bandwidth of the antenna. The numerical simulation result is obtained by simulation the antenna structure with waveguide metamaterial (WG-MTM) in CST. The waveguide metamaterial is used to reduce the mutual coupling between two neighbouring patches. The WG-MTM is a new category of effective medium proposed recently. Inserting the WG-MTM between two H-plane coupled microstrip patches has reduced the mutual coupling of those patches by 6 dB in the 10-dB bandwidth. Compared to other decoupling techniques, the proposed decoupling scheme provides good coupling suppression level for closely spaced microstrip patches and involves simple and straightforward fabrication process.

1.2 Problem Statement

The basic geometry of a MPA consists of a metallic patch printed on a grounded substrate. The advantages of MPA offers the of low profile, conformability to a shaped surface, ease of fabrication, low-profile, low cost, planar structure, ease of integration and portable communication equipment but there are some disadvantage of patch antenna such as has narrow bandwidth, lower gain and less efficiency compared to other technology. From that case, the author had figure out the special technique to overcome this problem such as adding metamaterial waveguide at patch antenna which has been proved by Jayant G. Joshi in journal of "Bandwidth Enhancement and Size Reduction of MPA with Metamaterial Waveguide" also has been proved by Xin Mi Yang in journal of "Patch Antennas With Metamaterials Waveguided" is applied to increase the bandwidth and gain MPA.

1.3 Objectives

a. To design the MPA with metamaterial waveguide
b. To enhanced the bandwidth and gain of MPA incorporate with metamaterial waveguide structure.
c. To validate the theory concept of patch antenna with metamaterial waveguide with actual prototype.

1.4 Scope of Work

The scope of work in this project is to design a compatible patch antenna incorporate with metamaterial waveguide structure. The antenna is designed on FR-4 substrate and ground plane at the bottom of substrate by using copper annealed. The type of feeding method is used microstrip feeding line fetched in the middle between port and patch structure. The metamaterial is implanted on FR-4 substrate. The patch antenna is design to be cooperated with metamaterial waveguide in frequency range of 4.8GHz-4.9GHz for the WiMAX application. The gain is measured by using network analyzer and bandwidth is measured by using spectrum analyzer meanwhile the radiation pattern is measured in an anechoic chamber.

1.5 Thesis Organization

This study is presented in five chapters. The thesis begins with an introduction brief of the project. It focused on the overview of the project, detailing the objectives, the problem statement, and work scope of the project. In chapter 2 is basically literature review about past study on MPA. Moreover, in this literature review is contained the facts or other aspect that the authors need correspond to the project that the authors had planned. The methodology is described on how the project had developed and discussed deeply in chapter 3. In this chapter, the author is included the design of conventional patch antenna without metamaterial and patch antenna with metamaterial. In chapter 4 is focused on discussion of results obtained from simulation process and hardware process. Finally, the conclusion and future recommendation for this study were briefly stated in chapter 5.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The topic, elaborate on basic of MPA and several application of MPA using metamaterial as waveguide.

2.2 Microstrip Patch Antenna

The patch antenna also is known as microstrip antenna. The MPA is developed in early 1980, well known as one port device. There are four basic categories of microstrip antenna which can be list as MPA, microstrip dipoles, Printed slot antennas and microstrip travelling wave antennas. The antenna is relying on shape, dimension of patch, the thickness and dielectric constant of substrate and feeding arrangement [6].The MPA is one of printed antenna type for narrow-band microwave. Basically, a MPA is made up of conducting patch on half side of dielectric substrate and it also connected to grounding plane on the other side, it can be classify as resonant antenna. The ones that are most alluring for good antenna execution are thick substrate whose dielectric steady is at the lower end of the range since they give better effectiveness, bigger BW and the binding fields for radiation into space is not tight. The thin substrate with the higher dielectric consistent is alluring for microwave circuitry since they require firmly bound fields to limit undesired radiation and coupling, thus it will reduce the element size. In lower value of BW will lead to larger losses, the lesser the efficiency [7]. The change of such planar cells opened the field for a scope of uses in the microwave region, especially for the antenna design.

2.2.1 Characteristic of MPA:

a. Substrate

The matter of substrate will allow mechanical support for radiating patch element and to sustain the distance between patch and ground plane while the grounding plane is play role as lower conduction layer site. The thickness of substrate in range of 0.01 to 0.05 in free space wavelength is commonly be used in MPA's construction [8]. The thickness of substrate is a lot of lesser than λ_o [6]. When it is put at the top of ground plane, the substrate is having only a small fraction of free space wavelength [9]. Commonly, the height is about 0.003 $\lambda_o \leq 0.05\ \lambda_o$ [9]. Typically, thin substrates will cause a high amount of loss that can lead to less efficiency than the thick substrate, it is because of the BW is narrow [9].

b. Patch

Patch is very thin metallic strip which is situated on the top of substrate [9]. Uniquely, the patch is consists of conduction substance which made up from copper or gold and most probably depending on wavelength. The primary dimension of patch is λ_e /2, the λ_e is an equivalent operating wavelength [6]. The radiation pattern is relying on electric current which pass out to the patch. Nowadays, many geometrical shape and dimension can be produced from this patches, there are several type of shape in patch which probably known as rectangular, circular, triangular, elliptical and etc. The rectangular patches is very often using microstrip antenna because it is simplest and highly requested. The rectangular geometries are split in nature and it analysis, so that it become less complicated while circular patch antenna has symmetric radiation pattern. The property of patch including the resonant length L, the width, the thickness t, the conductivity ζ_p and the RMS of the surface error Δ_p [6]. The length of patch is in between $\frac{\lambda o}{3} < L < \frac{\lambda o}{2}$ [9]. Normally, the feed lines are photo-etched on the substrate [7]. Ordinarily, a patch antenna has a gain in the vicinity of 5 and 6 dB and shows a 3-dB beamwidth in the vicinity of 70 and 90.

c. Dielectric

The amount of dielectric constant usually in the range of $2.2 \leq \varepsilon_r \leq 12$ [9]. A thin substrate need more amount of dielectric constant compared to thick substrate [9]. The Whole structure of the MPA is as shown in figure 2.1. The comparison of characteristic for varies types of MPA are tabulated in table 2.1

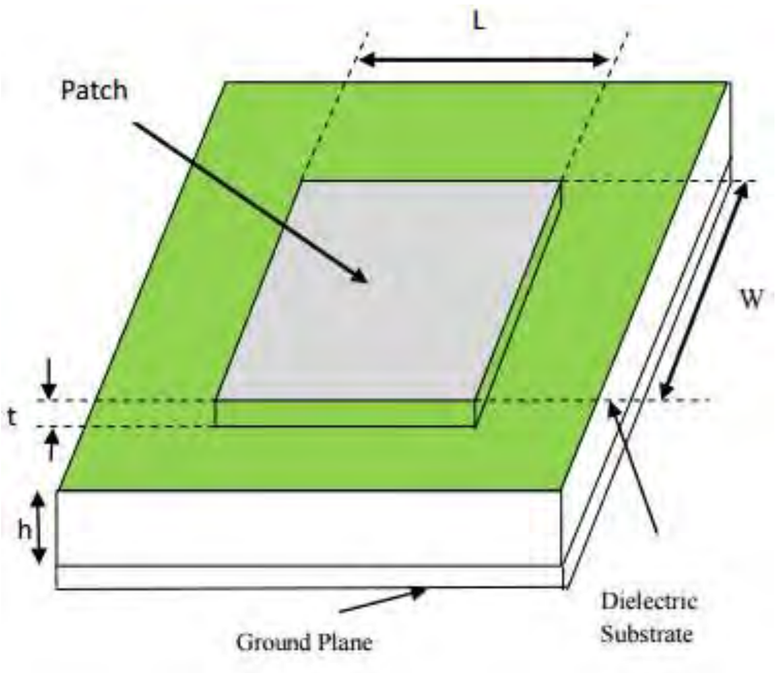

Figure 2.1: Structure of rectangular MPA [10]

Table 2.1: Comparison of Characteristic Various Types of Microstrip Antennae [10]

Characteristics	MPA	Microstrip Slot Antenna	Printed Dipole Antenna
Profile	Thin	Thin	Thin
Fabrication	Very Easy	Easy	Easy
Polarization	Both Linear And Circular	Both Linear And Circular	Linear
Dual frequency Operation	Possible	Possible	Possible
Shape Flexibility	Any Shape	Mostly Rectangular And Circular Shapes	Rectangular And Triangular
Spurious Radiation	Exists	Exists	Exists
BW	2-50%	5-30%	-30%

2.3 Type of Patch In Microstrip Antenna

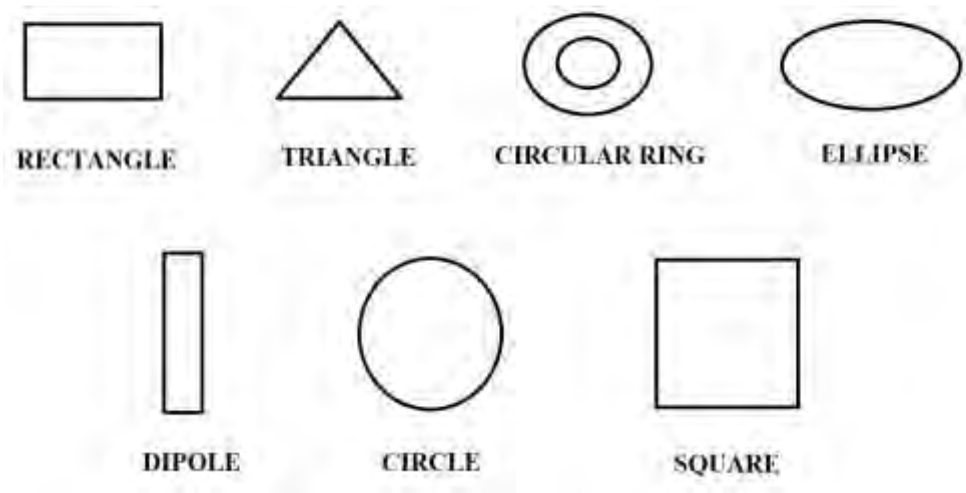

Figure 2.2: Common available shapes of MPA [11]

The figure 2.2 is shown the available shape of MPA design. In generally, the type of patch can be classified as rectangle, triangle, circular ring, ellipse, dipole, circle and square shape. The radiating element such as patch and feed lines is