U-SHAPED PATCH ANTENNA WITH RECTANGULAR PARACITIC PATCH AND PBG STRUCTURE AT 2.4GHz FOR WIMAX APPLICATION BY USING GRAPHENE

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This Report Is Submitted In Fulfillments of Requirement for the Bachelor Degree of Electronic Engineering (Wireless Communication) With Honors

Faculty of Electronic and Computer Engineering

Universiti Teknikal Malaysia Melaka

JUNE 2017

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : U-Shaped Patch Antenna With Rectangular Parasitic Patch and PBG Structure at 2.4GHz For WiMAX Application Using by Graphene

Sesi Pengajian :

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Special dedication and big thanks to my loving father, Mohd Yusoh Bin Ya'acob and my mother Rosmini Bt Ismail, my kind hearted supervisor, Mr Azman Bin Awang Teh, my siblings and to all my fellow friends.

ACKNOWLEDGMENT

Alhamdulillah with His blessing and the strengths, I am successfully completed my project and thesis. First of all, my most sincere thanks goes to my supervisor, Mr Azman Bin Awang Teh for his dedication to his student and patience in assisting me with this thesis. I would like to thank to him for his valuable advice and efforts offered during the completion of this thesis.

I also would like to thanks to my parents because still trusted me and always give an advise even them know I'm always doing wrong. Thank you both of you.

Last but not least, thanks to all my classmate and housemate for their help, and moral support. Your friendships means lot to me. Thank you.

ABSTRACT

Antenna is a very important device in telecommunication field used to transmit or receive radio frequency signal. Normally most of the antenna is built up of copper because it is suitable material for it. Recently graphene is claimed as a promising element to replace the copper. Thus, in this project graphene is use as material antenna in designing U-shaped patch antenna with rectangular parasitic patch and PBG structure that generate at 2.4 GHz for WiMAX application. The implementation of design consist the addition of square PBG structure on the ground plane. This method is applied to enhance the gain. This antenna will be design by using FR4 substrate with dielectric constant of $\varepsilon r = 4.4$, tangent loss of 0.019 and substrate height of 1.6mm. The coaxial feed will pass through substrate from patch to ground. There are two types of patch material been used; graphene and copper to identify and compare the performance. All the design and simulation will be using Computer Simulation Software (CST). From the simulation, the highest return loss obtained is -24.186dB while gain is 2.252dB and directivity is 2.702dBi. In this project, prove that graphene gives an improvement in the performance of antenna due to its high conductivity.

ABSTRAK

Antena adalah alat yang sangat penting dalam bidang telekomunikasi yang digunakan untuk menghantar atau menerima isyarat frekuensi radio. Biasanya kebanyakan antena dibina daripada tembaga kerana ia adalah bahan yang sesuai untuk itu. Baru-baru ini graphene didakwa sebagai elemen berpotensi untuk menggantikan tembaga. Oleh itu, dalam projek ini, graphene digunakan sebagai bahan dalam mereka antenna berbentuk U tampalan dengan parasit segi empat tepat dan struktur PBG pada 2.4GHz untuk aplikasi WiMAX. Kaedah ini digunakan untuk meningkatkan penguat. Antena ini akan direka bentuk dengan menggunakan FR4 substrat dengan pemalar dielektrik $\varepsilon r = 4.4$, tangen 0,019 dan ketinggian substrat 1.6 mm. Masukan sepaksi akan melalui substrat dari tampalan ke belakang. Terdapat dua jenis bahan tampalan telah digunakan; graphene dan tembaga untuk mengenal pasti dan membandingkan prestasi. Semua reka bentuk dan simulasi akan menggunakan Computer Simulation Software (CST). Dari simulasi, kehilangan pulangan tertinggi diperolehi adalah -24.186dB manakala penguat adalah 2.252dB dan 'direktiviti' adalah 2.702dBi. Dalam projek ini, terbukti bahawa graphene memberikan peningkatan dalam prestasi antena kerana kekonduksiannya yang tinggi.

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CHAPTER 1

INTRODUCTION

Antenna is a device that converts electric power into radio wave and vice versa. It usually consists or operates with an oscillate frequency current to the antenna terminals and antenna will radiate the energy from transmitter to electromagnetic waves. The microstrip patch antennas are using in number of applications like in mobile communications, satellite communication, GPS applications, wireless communication etc. The main problem associated with the microstrip patch antenna includes Low efficiency, High quality factor, Low power handling capacity, Poor polarization purity. But advantages include Low profile, Compact size, Planer configuration, Low weight, Easy to fabricate [1]. The performance of microstrip antenna mainly depends on the patch material, dimension of antenna, feeding technique.

Antenna is a transducer designed to send information as well as collect data in electromagnetic waves. It transforms electrical power into radio waves and the other way round so that performing its operation. In other words, the antenna is the transitional structure between free-space and guiding device. The guiding device or transmission line may take the form of coaxial line or a hollow waveguide, used to transport electromagnetic energy from the source to the antenna, or even from the receiver to the antenna. There are many types of antenna such as wire antennas, aperture antennas, microstrip antennas, array antennas, lens antennas and so on. Different types of antenna have different types of application.

1.1 Project Background

This project been proposed to design U-Shaped Patch Antenna with Rectangular Parasitic Patch and PBG Structure with center frequency at 2.4GHz for WiMAX application by using Graphene. Researches are made on solving the main drawback of the microstrip antenna, which is the narrow bandwidth. One of the methods is found by using Photonic Band Gap (PBG) structure [27]. The PBG structure is a periodic structure that could suppress the electromagnetic wave propagations within a particular frequency band in the antenna and gives better performance and efficiency. This is due to the photonic crystals which consist of dielectric materials to allow the electromagnetic field to propagate with low loss [27]. A PBG crystal is a structure that could manipulate beams of light [30]. The perforations in the crystal could form a complex pattern of overlapping beams which will cause the cancellation of band of wavelength in all direction to prevent the propagations. Therefore by using the PBG structure on microstrip patch antenna, it could results an increase in both the gain and bandwidth.

In this project, bandwidth of the antenna is improved by conversion of the rectangular patch antenna into a U-shaped patch microstrip antenna with a parasitic rectangular patch on top of the surface that can operates at 2.4GHz resonant frequency. On top of that, it is also found that gain is improved significantly by adding a Photonic

Band Gap (PBG) structure on the ground plane of the antenna while keeping all others parameters satisfied.

The technical standard is intended for the type approval of WiMAX equipment and it applies to wireless broadband access (BWA) equipment operating on radio frequencies identified by MCMC (Malaysian Communications and Multimedia Commission) for BWA in the frequency bands 2300 MHz to 2400 MHz; 2504 MHz to 2688 MHz; and 3400 MHz to 3600 MHz. The antenna will be design on FR-4 substrate with coaxial fed input that connect the patch and ground through substrate [2]. The design will replace the patch and ground material of copper with graphene. This research will be focused on the strength of graphene instead of copper. Graphene is a material that begins used nowadays to produce antenna structure in form of carbon layer. Graphene is a two-dimensional (2D) material, formed of a lattice of hexagonally arranged carbon atoms. Graphene is typically referred to as a single layer of graphite. Hence, by using graphene as material, it can improve radiation pattern. The graphene could potentially lead to very interesting features such as miniaturization, dynamic tuning and even optical transparency and mechanical flexibility [4][5]. As for this final year project, the analysis is about to see whether graphene is more suitable compare to copper for WiMAX application.

1.2 Problem Statement

In this recent years wireless applications undergone rapid development especially for worldwide interoperability for microwave access (WiMAX) application. However, the narrow bandwidth of the microstrip patch antenna is one of the major drawbacks for practical WiMAX application. In fact, there is an important issue exists where the WiMAX application is having a wide impedance bandwidth. There are few WiMAX operations are used, for instance, the 2.5GHz band (range 2.5GHz – 2.69GHz), 3.5 GHz band (3.3 GHz – 3.8 GHz) and 5.5 GHz band (5.25 GHz – 5.85 GHz). For a microstrip

patch antenna it have a few limitation, such as produce a narrow bandwidth, microstrip antennas with a high dielectric constant when it is fabricate and associated with a tolerance problems. Microstrip antenna is preferred due to some advantages such as efficient, low profile and electrically small to be integrated in modern wireless terminal [6]. However, when microstrip antennas are miniaturized, their gain and efficiency drop significantly [7]. Throughout this project, the material of copper for the patch and ground will be replace with graphene as an improvement. This graphene substance will increase the gain and directivity of the transmission. The conductivity of graphene is very frequency-dependent and can have completed different behavior [8]. The improvement needs to be simulated and compare the performance.

1.3 Objective

To make sure this project work as planned, a few objectives were determined where these objectives will be followed as a guide through the whole completion process of this project in order to achieve the desired output. These objectives were provided by sequence of project from beginning until the end of project. A detailed explanation for each objective will be discussed. There are several objectives that are to be achieved at the end of the project which includes:

I. To develop a U-Shaped Patch Antenna with Rectangular Parasitic Patch and PBG Structure with center frequency at 2.4GHz for WiMAX application.
II. To simulate the design by utilize the Computer Simulation Tool (CST).
III. To study the performance between copper and graphene as patch and ground material.

1.4 Scope of Work

As to ensure the completion of project achieves the stated objectives, the project shall be completed within these scopes. This antenna design is proposed to enhance the bandwidth via conversion of rectangular patch microstrip antenna into U-shaped patch. Then, a parasitic rectangular patch is added on top of the surface. The implementation of design consist the addition of square PBG (photonic band gap) structure on the ground plane. This method is applied to enhance the gain. This antenna will be design by using FR4 substrate with dielectric constant of $\varepsilon r = 4.4$, tangent loss of 0.019 and substrate height of 1.6mm. The coaxial feed will pass through substrate from patch to ground. There are two types of patch material been used; graphene and copper to identify and compare the performance. All the design and simulation will be using Computer Simulation Software (CST).

1.5 Brief Explanations on Methodology

To achieve the goal that has been set in the objectives of this project, there are so many works that need to be done. The first stage is learning the concept of microstrip patch antenna and electronics properties of graphene and how the implementations in antenna. The second stage will be designing and simulating the antennas model in CST software. Finally, compare and analyze the performance of the antennas. A detail explanation for the parts will be explained in Chapter 3.

1.6 Thesis Plan

In this report, there are 5 chapters which are introduction, literature review, methodology, result and conclusion and discussion. Not included in chapter is a

reference, abstract, table of content, table of picture and appendices. Chapter one shows the introduction of this project. It contains the background of the project and briefly explanation about the project methodology.

Chapter two consists of literature review of project. It covers the study of the project such as the basic information of antenna, microstrip patch antenna, basic information of graphene, and electronic properties of graphene that used in the project for the future plan. After that, it shows the choices can be made after all the study have been finished.

Chapter three shows about the methodology of the project. This chapter includes the flow chart and Gantt chart of the project that shows the process of this project from start till the end. By using the flow chat and Gantt chart, it can reduce an assumption that can be made when doing the analysis.

CHAPTER 2

LITERATURE REVIEW

This chapter discuss about reviews of existing project created to get an idea about the project design, conception and any information that related to improve the project. With different concept and design, there are other creations and innovations of projects done by other people. From the collected information, it can be a guideline in this project to improve the proposed project so that it works successfully.

2.1 Antenna Definition

Antenna is a transducer designed to transmit data and receive data in electromagnetic waves. It converts electric power into radio waves and vice versa in

order performing its operation. To transmit the waves or data, it will oscillate the frequency current to the antenna terminals and antenna will radiates the energy from transmission to electromagnetic waves. In reception, electromagnetic wave that has been transmitted will be intercepting by it then be amplified according to compatibility of the component or device that connected with the receiver. Most system or component that are connected wireless are using antenna such as radar, cell phones, walkie-talkie, broadcast radio or televisions, Bluetooth, satellite communications and many more that has same properties as those in in's operation.

Antennas are generally categorized in various techniques. One of the techniques is the frequency band of operation. The rest comprised of physical structure and electrical/electromagnetic design. The antennas that frequently used for LMR which both at base stations and mobile units represent only a minimal portion of all the antenna types[10][11].

Basically, non-directional antennas are simple dipoles or monopoles. Much more complex, directional antennas consist of arrays of elements, such as dipoles, or use one active and several passive elements, as in the Yagi antenna. Other than that, there are also many types of antenna included the wire antenna, aperture antenna, microstrip antenna and array antennas[10].

2.2 Antenna Concepts

An antenna gives the wireless system three fundamental properties: gain, direction and polarization. Gain is a measure of increase in power. Gain is the amount of increase in energy that an antenna adds to a radio frequency (RF) signal. Direction is the shape of the transmission pattern. As the gain of a directional antenna increases, the angle of radiation usually decreases. This provides a greater coverage distance, but with a reduced coverage angle. The coverage area or radiation pattern is measured in degrees. These angles are measured in degrees and are called bandwidths.

An antenna is a passive device which does not offer any added power to the signal. Instead, an antenna simply redirects the energy it receives from the transmitter. The redirection of this energy has the effect of providing more energy in one direction, and less energy in all other directions.

2.3 Basic Characteristics Microstrip Patch Antenna

Microstrip antennas received considerable attention starting in the 1970s. Microstrip antennas, as shown in Figure 2.1, consist of a very thin metallic strip (patch) placed a small fraction of a wavelength above a ground plane. The microstrip patch is designed so its pattern maximum is normal to the patch (broadside radiator). This is accomplished by properly choosing the mode (field configuration) of excitation beneath the patch. End-fire radiation can also be accomplished by judicious mode selection. For a rectangular patch, the length L of the element is usually $\lambda 0/3 < L < \lambda 0/2$.The strip (patch) and the ground plane are separated by a dielectric sheet (referred to as the substrate), as shown in figure below:

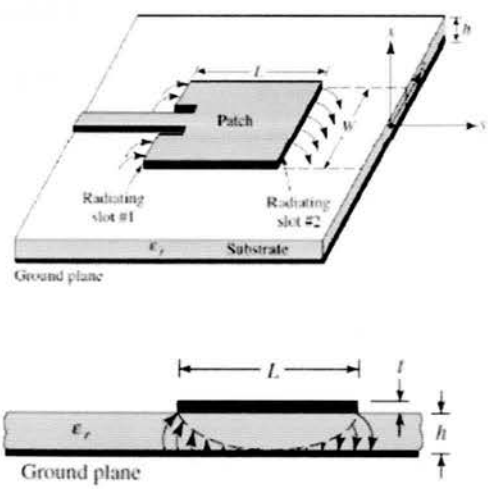

Figure 2.1 : Model of microstrip antenna [12]

There are numerous substrates that can be used for the design of microstrip antennas, and their dielectric constants are usually in the range of $2.2 \leq Ir \leq 12$. The ones that are most desirable for good antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size. Thin substrates with higher dielectric constants are desirable for microwave circuitry because they require tightly bound fields to minimize undesired radiation and coupling, and lead to smaller element sizes; however, because of their greater losses, they are less efficient and have relatively smaller bandwidths. Since microstrip antennas are often integrated with other microwave circuitry, a compromise has to be reached between good antenna performance and circuit design.

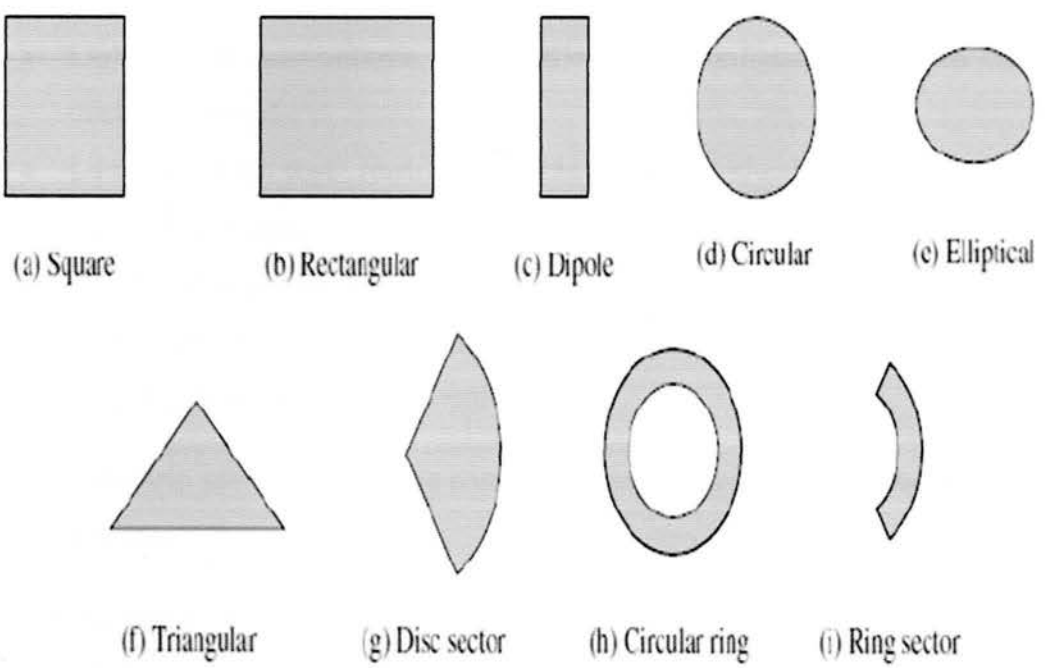

Figure 2.2: Representative shapes of microstrip patch elements