BEAM RECONFIGURABLE ARRAY ANTENNA WITH DUAL BAND FOR WLAN APPLICATION

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This thesis is dedicated to:

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My beloved mother, NOR AZIAH MANSOR, my father, MUHAMMAD NOR BIN ABDUL AMAN SHAH and all my siblings for your love and cares.

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ABSTRACT

Wireless communication technology is a fast developing technology which gives a huge impact on social life nowadays. This non wired technology urges a sturdy need for antenna development where antenna can be said as the core device for this technology. Researches on antenna are rapidly developing in the current research trend resulting in many antenna designs of various capabilities. Reconfigurable antenna is among popular designs in modern wireless technology because it allows single antenna to be employed in many systems. Originally, reconfigurable antenna can be categorised into three parts which is frequency, polarisation and beam pattern. This thesis is focusing on the beam pattern reconfigurable concept for antenna that operates at 2.45 GHz and 5.8 GHz band. This dual band reconfigurable is capable to steer the beam to three different directions by using only single design of planar array antenna. Three patch antennas are introduced in this thesis where these antennas are designed with the main beam facing three different directions. Partial ground plane and parabolic ground plane are used in developing the proposed reconfigurable antenna and finally, these patch antennas are combined with array configuration on single antenna design. This planar array reconfigurable antenna hence integrated with PIN diode as to make it a reconfigurable antenna. This proposed antenna can steer beams at -20°, -59°, and 61° at 2.45 GHz band while at 5.8 GHz band, proposed antenna can give steering angle of -9°, -20° and 23°. All the simulated and measured results are presented and compared in this thesis.

ABSTRAK

Teknologi komunikasi tanpa wayar adalah satu teknologi yang berkembang pesat yang memberi impak besar dalam kehidupan sosial masa kini. Keperluan pembangunan antena dalam teknologi tanpa wayar ini meningkat di mana antena boleh dikatakan sebagai alat utama dalam teknologi ini. Penyelidikan dalam bidang antena telah membangun dengan pantas dan menghasilkan pelbagai reka bentuk antena dengan pelbagai fungsi. Antena-boleh-konfigurasi adalah antara istilah popular di dalam teknologi moden tanpa wayar kerana ia membenarkan sesuatu antena itu bekerja dalam banyak sistem. Pada asalnya, antena-boleh-konfigurasi boleh dibahagikan kepada tiga bahagian iaitu yang boleh-konfigurasi frekuensi, boleh-konfigurasi polarisasi dan corak radiasi antena-boleh-konfigurasi. Dalam tesis ini, tumpuan adalah tentang konsep antena-boleh-konfigurasi corak radiasi beroperasi di 2.45 GHz dan 5.8 GHz. Antena-boleh-konfigurasi dua set frekuensi yang mampu menghalakan corak radiasinya ke tiga arah yang berbeza dengan menggunakan hanya satu reka bentuk antena. Dua jenis antena dwi jalur telah diperkenalkan dalam tesis ini di mana antena ini direka dengan rasuk utama antena diarahkan pada tiga arah yang berlainan. Lapisan belakang antena dengan bentuk parabola digunakan dalam membangunkan antena boleh konfigurasi yang dicadangkan dan akhirnya, antena ini akan berada di pelbagai konfigurasi dalam satah tunggal. Antena boleh konfigurasi ini akan digabungkan dengan diod PIN untuk membuat mereka antena boleh konfigurasi. Antena yang dicadangkan ini akan menghalakan corak radiasinya pada -20^0, -59^0 and -61^0 pada 2.45 GHz dan -9^0, -20^0 and 23^0 pada 5.8 GHz. Semua keputusan simulasi dan keputusan dibentangkan dan dibandingkan dalam tesis ini.

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LIST OF ABREVIATIONS

BW	-	Bandwidth
CST	-	Computer Simulation Technology
dB	-	Decibel
EM	-	Electromagnetic
FR4	-	Flame Resistant 4
ISM	-	Industrial Sciences Medical
ITS	-	Intelligent Transportation Systems
PCB	-	Printed Circuit Board
PEC	-	Perfect Electric Conductor
SMA	-	Sub Miniature version A
UV	-	Ultra Violet
VSWR	-	Voltage Standing Wave Ratio
EBG	-	Electromagnetic Band Gap

LIST OF SYMBOLS

c	-	Speed of light
D	-	Outer Probe feed diameter
d	-	Inner probe feed diameter
ε_r	-	permittivity
ε_e	-	Effective permitivity
e_0	-	Total efficiency
e_r	-	Reflection (mismatch)
e_c	-	Conduction efficiency
e_d	-	Dielectric efficiency
λ_0	-	Free Space wavelength
f_c	-	Center frequency
f_H	-	High frequency
f_L	-	Low frequency
h	-	Height of substrate
L	-	Length of patch
L_{eff}	-	Effective length
ΔL	-	Delta Length
Q	-	Material's quality factor
S	-	Area of patch
ΔS	-	Delta area of patch
Γ	-	Reflection coefficient
t	-	Thin Metallic Strip
V_o^-	-	Reflected voltage
V_o^+	-	Incident voltage
W	-	width of patch
W_{eff}	-	Effective width

Z_L	-	Load impedance
$\leq$	-	Less then
Z_O	-	Characteristic impedance
Ω	-	Ohm

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Printed antenna is one of the terms that have been widely used in the recent antenna technologies. This type of antenna has been rapidly developed over the past few decades. In this century, the needs of antenna with high performance and simple manufacturing process have become more interesting to be reviewed in research area. On top of that, the uses of printed antenna have become intensively popular among researchers because of its properties. This antenna can provide compact size, low profile, light weight, low cost and easiness in the fabrication process [1]. Although this antenna comes with low efficiency, low power and poor polarization [2], many researches had been conducted recently to overcome these matters [3-7]. In addition, printed antenna can be integrated with lump elements (resistor, capacitor and inductor), adaptive elements (PIN diode, Varactor Diode) and several active devices (amplifier). By adding these entire elements, several changes in resonance frequency, impedance, polarization, and pattern can be adopted into this antenna [8, 9]. This mechanism is called reconfigurable antenna.

Reconfigurable antenna is one of the upgraded technologies in wireless communication system, where this kind of antenna can operate multiple applications in

a single design. This antenna was developed by Brown in 1998 [10]. The beauty of reconfigurable antenna can be seen at its switches that are being used as the RF switch to change the antenna properties. The common switches used in research field are PIN diode, field effect transistor (FET), piezoelectric transducer and electromechanical system (MEMS) switches. Reconfigurable antennas are commonly grouped into three categories; frequency, polarization and radiation pattern reconfigurable antennas. There are some approaches that can be used to implement switches in reconfigurable antennas. The reconfigure mechanism can be controlled by controlling the *on* and *off*-states of the RF switches. Figure 1.1 illustrates a diagram representing the structure of a reconfigurable antenna.

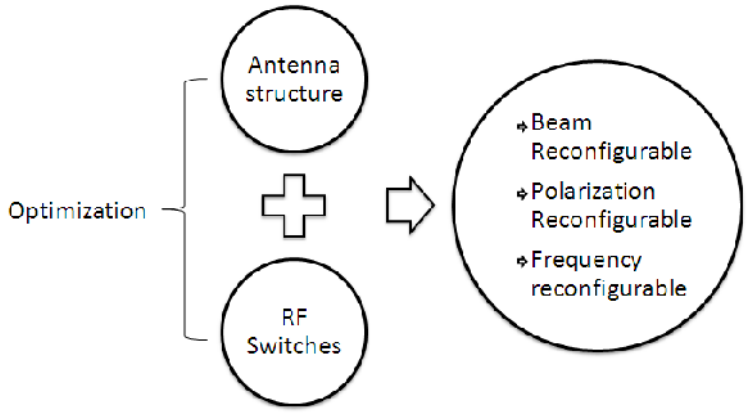

Figure 1.1: Flow Diagram of a Reconfigurable Antenna

A reconfigurable antenna enables a single antenna to perform multifunction activities. This is the reason why reconfigurable antenna can ensure the improvement of wireless communication systems. With the integration of switching mechanism, reconfigurable antenna can configure its properties in one dimension. For frequency reconfigurable antenna, it has the capability to select individual frequency as its operating frequency. The advantage of this antenna is it can reduce the adverse effect of co-site interference and jamming [11]. This antenna can also enhance the wireless system performance in terms of polarization diversity for reception and transmission activities. On the other hand, the polarization reconfigurable antenna enables square patch antenna to reconfigure the polarization from linear to circular. The disadvantage of circular polarization (CP) antenna is that it comes in large size and it cannot recover

none line of sight (NLOS) signal. As in terrestrial communication, some multipath signal is much needed to ensure NLOS reception can be done where in MIMO system, multipath signal were contributed to the information bit reception. This drawback has led the researchers to implement the advantages of CP into common linear polarization antenna and they found out that the solution to this problem is by using polarization reconfigurable antenna.

Lastly, the beam reconfigurable antenna can control the behavior of the main beam for one antenna. This includes beam shaping reconfigurable antenna and beam steering reconfigurable antenna. These radiation patterns of reconfigurable antenna have big potential in upgrading the performance of wireless communication systems. Beam shaping reconfigurable antenna enables an antenna to reconfigure its beam pattern by altering broad beam pattern to a narrow beam pattern antenna. This type of antenna has been rapidly developed in recent antenna research field where it gives several advantages compared to the normal array antenna [12]. This reconfigurable antenna can be applied to prevent environmental noise and electronic jamming, improves gain and security of a system, energy saving as it only steers signals to desired location, and increases the number of clients with the present of broad beam pattern in wireless system. The major advantage of this antenna is it can reduce the interferences and fading in multipath environments [13, 14]. These facts have motivated the author into creating a simple design of beam reconfigurable antenna.

1.2 Problem Statement

The reconfigurable antenna is a new development of antenna that is very useful in the recent wireless communication. Recent development in antenna technology requires us to create an antenna that gives high performances with simple design. A conventional array antenna is capable of producing a single directional beam pattern, therefore it limited to a fixed direction of main beam. This limitation can be overcome

by using beam reconfigurable antenna which is upgrading the single antenna into a multifunctional antenna. Therefore, beam reconfigurable which capable to steer the main beam at three different places in single antenna design was proposed in present research. There only one beam can be steered at one time by triggering the PIN diode configuration within the proposed design.

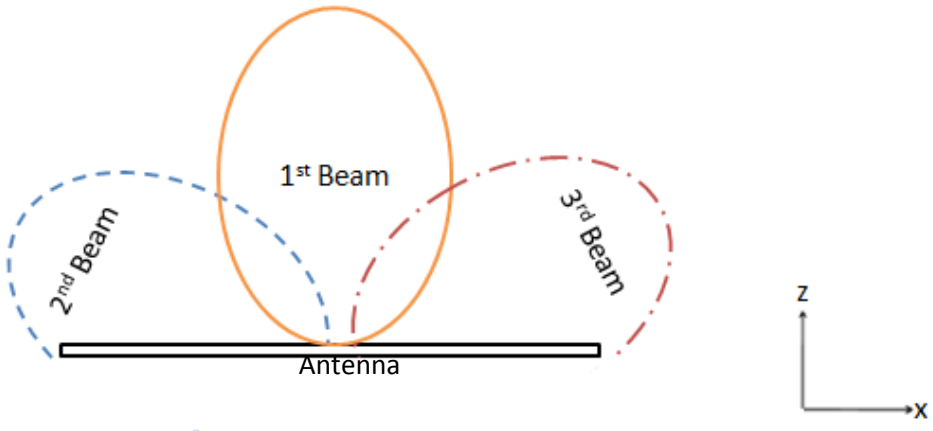

Figure 1.2: Antenna with Beam Steering Capability

The unique characteristics of printed antenna suit the recent development of the antenna technology, where nowadays the researchers are trying to implement low cost material with simple antenna structure in their design without neglecting the practicability of that antenna. Many researches have been conducted for beam reconfigurable antenna by using printed antenna technology and this has initiated a brief idea to the author to create a simple structure of it. Although printed antenna is a low efficiency antenna, the implementation of several techniques within the proposed design will be done in order to make it reliable in practical field. The evolvement in printed antenna technology has transformed reconfigurable antenna to a famous antenna technology in recent times. Reconfigurable antenna is a normal antenna which is integrated with number of RF switches and can perform several capabilities in a single design.

The integration of switches in conventional antenna design will alter the characteristics of an antenna. The number of switches used in the design will contribute to degradation of antenna performances. For every switch used in an antenna, a biasing network is needed to activate and deactivate it. When the number of switches increased, the biasing networks become more complicated and the antenna design will require more space. In addition, this problem will give out a huge coupling between the biasing networks and the elements in the antenna and it will degrade the performances of the antenna. To overcome this problem, a new reconfigurable antenna design with reduced number of switches will be constructed in this project.

1.3 Objectives of Research

This research will give a positive impact to the development of wireless communication technology. The project will introduce a new design of a simple antenna structure with an integration of RF switches to control the beam steering at desired direction. The objectives of this project are:

i. To design, simulate and fabricate a dual band reconfigurable antenna with beam steering capabilities which capable to steer the beam at three different directions (right-side, left-side and front-side) using corresponding software.
ii. To integrate the PIN diode with microstrip antenna so that reconfigurability in terms of radiation pattern can be performed.

1.4 Scope of Work

In order to achieve the objectives, several steps have been considered to accomplish the proposed reconfigurable antenna. This includes a comprehensive

literature review, which is required to obtain a reconfigurable antenna design. It is important to build a basic knowledge on designing the proposed antenna and to identify all the expected result in designing an antenna.

Proposed beam reconfigurable antenna was design at ISM and UNII band. For this reason, this antenna is suitable to be used in WLAN application where proposed antenna can generate three different radiation patterns with their main beam facing three different directions at both operating frequencies (2.45 GHz and 5.8 GHz). For simulation process, Computer Simulation Technology in Microwave Studio software was used as a simulation tools. All the antenna performances such as return loss, current distribution and radiation pattern were carefully discussed and compared to measurement result.

1.5 Layout of the Thesis

This thesis consists of 5 chapters which involve every step used to complete the proposed reconfigurable antenna. The thesis layout is organized as follows:

Chapter 2 presents the basic literature review of printed antenna technology. This chapter gives out an overview about the development of the printed antenna technology which is very popular in current research field. This will include the usage of printed antenna in smart antenna systems which incorporate the reconfigurable antenna. The reconfigurable antenna is a subchapter in the smart antenna systems as this antenna will allow the integration of RF switches within the antenna structures. This theoretical knowledge will help to proceed with next subchapter as this subchapter is mainly about the motivation of previous researches on the proposed reconfigurable antenna. As in this chapter, all the previous researches related to dual band antennas, directive antennas, and beam reconfigurable antennas are discussed. This reading will give basic knowledge on the development of the proposed antenna structure.

Chapter 3 discusses the steps taken to complete the design. This–chapter will focus on the design stage using appropriate software. Then, the fabrication stage had stretched out on which involves software part, printing and hardware part. The final stage of this chapter will include the measurement stage. This final stage can be used to determine either the fabricated antenna is working at proposed frequency band or not.

Chapter 4 analyzes the proposed reconfigurable antenna design. This chapter will discuss in details the proposed reconfigurable antenna, starting with dual band antenna with half ground plane and dual band antenna with defected ground plane technique. This chapter will continue on the integration of both antennas designed in single plane array antenna configuration. As a final step in completing proposed antenna design, there will be an introduction of PIN diode within the transmission line to produce the proposed antenna to become beam reconfigurable antenna. This discussion will discuss on the return loss data and radiation pattern data for each part. Finally, conclusion and suggestions for future work will be concluded in Chapter 5.

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