COMPACT MULTIBAND ANTENNA DESIGN

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Specially dedicated to,

My beloved and supportive parents,

My supervisor,

My family,

And to all my friends

For their Love, Encouragements and Best Wishes.

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ABSTRACT

In these recent years, a great advancement and evolution has been achieved in the wireless communication system. Besides that, the market also demands for mobile and multi-functional devices. Thus, an antenna which plays an important role in transmitting and receiving radio frequency signals in wireless system, also need to be compact as well as to be able to work in various applications. This project aims to design, simulate, and fabricate a compact multiband antenna which operates at two operating frequencies, 2.4 GHz and 5.2 GHz. All antenna designs involved are simulated by using CST software. FR4 board has been used for simulation and fabrication for all related designs. A compact multiband antenna is an antenna which has compact and multiband characteristic. Multiband refers to more than one frequency band or it can be also referred to more than one application. In compact multiband antenna design process, single band antenna must first be designed. Later, some techniques will be applied so as to achieve the desired compactness and multiband characteristic of an antenna. The compact multiband antenna is fed with signal pulses by using a waveguide port. Furthermore, the simulation result shows that the antenna has covered the frequency bands ranged from 2.4 GHz to 2.484 GHz and 5.15 GHz to 5.35 GHz with return loss less than -10 dB. Besides that, this antenna can also function with at least 2 dB gain, 4 dBi directivity, and 50% total efficiency. Therefore, the compact multiband antenna in this project can operate at IEEE Bluetooth/ WLAN/ISM and WLAN 5.2 GHz in an acceptable condition.

ABSTRAK

Dalam tahun kebelakangan ini, satu kemajuan besar dan evolusi telah dicapai dalam sistem komunikasi tanpa wayar. Selain itu, pasaran juga menuntut untuk peralatan mudah alih yang pelbagai fungsi. Oleh hal yang demikian, antena memainkan peranan penting dalam menghantar dan menerima isyarat frekuensi radio dalam sistem tanpa wayar serta antenna yang padat di mana boleh bekerja dalam pelbagai aplikasi. Projek ini bertujuan untuk mereka bentuk, simulasi, dan fabrikasikan antena padat yang beroperasi pada dua frekuensi operasi iaitu, 2.4 GHz dan 5.2 GHz. Semua reka bentuk antena yang terlibat adalah simulasi dengan menggunakan perisian CST. FR4 telah digunakan sebagai bahan untuk simulasi dan fabrikasi semua reka bentuk yang berkaitan. Sebuah antena pelbagai jalur padat antena yang mempunyai ciri-ciri padat dan pelbagai band. Pelbagai band merujuk kepada lebih daripada satu frekuensi band atau ini juga dirujuk sebagai lebih daripada satu aplikasi. Dalam proses reka bentuk antenna yang mempunyai pelbagai band, antena band tunggal yang pertama mesti direka dahulu. Kemudian, beberapa teknik yang akan digunakan untuk mencapai ciri-ciri antenna yang padat dan pelbagai band. Antena pelbagai band yang padat adalah disalurkan dengan isyarat dengan menggunakan port gelombang. Tambahan pula, keputusan simulasi menunjukkan bahawa antena telah melinkungi frekuensi band di antara 2.4 GHz, sehingga 2.484 GHz dan 5.15 GHz sehingga 5.35 GHz dengan return loss kurang daripada -10 dB. Selain itu, antena ini juga boleh berfungsi dengan gain yang sekurang-kurangannya 2dB, 4 dBi directivity, dan 50% jumlah kecekapan. Oleh itu, pelbagai band antena padat dalam projek ini berjaya untuk beroperasi pada IEEE/ Bluetooth/WLAN/WLAN/ISM dan WLAN 5.2GHz dengan keadaan yang boleh diterima.

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ABBREVIATION

AUT	-	Antenna Under Test
CPW	-	Co-Planar Waveguide
CST	-	Computer Simulation Technology
dB	-	Decibel
DGS	-	Defected Ground Structure
GHz	-	Gigahertz
GPA	-	Ground Plane Aperture
GPS	-	Global Positioning System
GSM	-	Global System for Mobile Communication
IEEE	-	Institute of Electrical and Electronics Engineering
ISM	-	Industrial, Scientific and Medical
RL	-	Return Loss
RX	-	Receiver
TX	-	Transmitter
UMTS	-	Universal Mobile Telecommunications System
WLAN	-	Wireless Local Area Network

LIST OF SYMBOL

λ	-	Wavelength
$\boldsymbol{a}$	-	Distance between the Center Point and the Edges
$\boldsymbol{c}$	-	Extended Slot Length
$\boldsymbol{D}$	-	Largest dimension of the antenna
$\boldsymbol{\varepsilon_r}$	-	Dielectric Constant
$\boldsymbol{\varepsilon_{reff}}$	-	Effective Dielectric Constant
f_r	-	Resonant Frequency
$\boldsymbol{g}$	-	Gap between Feed Line and Ground Plane
$\mathbf{G_R}$	-	Gain of AUT
$\boldsymbol{h}$	-	Thickness of Substrate
$\boldsymbol{\Delta L}$	-	Length Extension of Rectangular Patch
$\boldsymbol{L}$	-	Length of Rectangular Patch
$\boldsymbol{L_{eff}}$	-	Effective Length
$\boldsymbol{L_f}$	-	Length of Microstrip Feed
$\boldsymbol{L_{slot}}$	-	Length of Slot
$\boldsymbol{P_{CL}}$	-	Cable Loss
$\boldsymbol{R}$	-	Distance between Reference Antenna and AUT
$\boldsymbol{t_C}$	-	Thickness of Copper
$\boldsymbol{t_s}$	-	Thickness of Substrate
$\boldsymbol{W}$	-	Width of Rectangular Patch
$\boldsymbol{W_f}$	-	Width of Microstrip Feed
$\boldsymbol{W_s}$	-	Width of Substrate

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CHAPTER I

INTRODUCTION

1.1 Introduction

In a basic wireless communication system, it consists of a transmitter, receiver, and the transfer medium. Antenna is placed at the transmitter end and the receiver site. It is a metallic device which plays a vital role transmitting and receiving radio waves in air [1]. The captured waves will then be converted into electrical energy [2]. In the current advancement of the wireless communication system, peoples are no longer only wants but they need, request, and struggle for the compact, multi-functionality and low cost antenna. Thus, this demand on having different applications on a single device leads to the concept of different standards for different application. The developments in technologies also demand the integration of standards like 2.4 GHz (2.4-2.484 GHz) IEEE Bluetooth/WLAN/ISM and 5.2 GHz (5.15-5.35 GHz) WLAN [3-8]. Hence, an antenna which can operate at multi frequency bands is needed.

1.2 Problem Statement

With the advancement and evolution in the current communication system, wired communication system has slowly been replaced due to the high demand in wireless and mobile technologies. Thus, antenna, a metallic device to capture signals

in air, plays a vital role in this transition period. There are numerous wireless applications required by users worldwide. Besides that, devices nowadays are also more prefer to be mobile. Thus, the built-in antenna must also be compact so as to be able to fit into the mobile device.

Telecommunication devices are designed to be used in different country regions in the world. For example a mobile device which can operate using different standards such as GSM 850 (824 – 894 MHz), GSM 900 (880 – 960 MHz), GPS (1575 MHz), DCS (1710 – 1880 MHz), PCS (1850 – 1990MHz), UMTS (1920 – 2170 MHz) and wireless local area network (WLAN) (2400 -2484 MHz) [9]. Instead of having multiple single band antennas, a multiband antenna is more preferable to be used. Besides that, a multiband antenna can perform in different frequencies and thus, it may also reduce the product's compactness.

As a result, some techniques to achieve compact antenna with multiband characteristic had been proposed. In order to achieve multiband characteristic of a compact antenna, techniques such as fractal geometry technique [4][10-13], meandering technique [14-15], modifying ground plane, and also slot technique had been proposed.

1.3 Objective

This project has an objective which is to design a compact multiband antenna. An antenna is said to have multiband characteristic when it can operate at more than one frequency bands such as IEEE Bluetooth/ WLAN/ISM range from 2.4-2.484 GHz and also WLAN range from 5.15-5.35 GHz. The specification on the return loss has been set to be 10 dB which is also equal to 90% of antenna's matching efficiency.

1.4 Scope

The scope of this project is to design a compact multiband antenna with two resonant frequencies which are 2.4 GHz, and 5.2 GHz, covering IEEE Bluetooth/

WLAN/ ISM ranging from 2.4-2.484 GHz, and also WLAN ranging from 5.15-5.35 GHz. Along with this project, all antenna design works will be done by using CST software. The simulation of the antenna design includes finding on the basic parameters such as resonant frequency, return loss, gain, directivity and efficiency. The fabrication process is done by using chemical etching technique. This is because chemical etching technique is simple to be implemented and found in the faculty. The material used for designing the antenna is FR4 board which has the specification such as dielectric constant of substrate, ε_r of 4.4, tangent loss of substrate, tanδ of 0.019, thickness of substrate, t_S of 1.6 mm, and thickness of copper, t_C of 0.035 mm. The measurement will only be done after fabrication process. Antenna parameters such as resonant frequency, return loss, gain, and directivity will be measured by using UBP Synthesized Signal Generator (SG 2100), Spectrum Analyzer (PSA-3000), Combo Tester (ED-4770), Microstrip Trainer (ED-3300SP), Antenna Training Kit (TX and RX) and Antenna Trainer (ED-3200SP) which are all provided in the lab.

1.5 Methodology

This project was started with the literature review stage before entering the design stage. Techniques to achieve compact and multiband characteristic have been reviewed through the findings on books and journals. Later in the stage of designing a multiband antenna, a basic single band antenna will be first designed. The basic single band antenna design is drawn by using CST software and simulated to obtain the result. Next, parametric study had been done on the design by varying the shape of the patch and adding different shapes of slot to achieve the second operation bands.

The process will then proceed to fabrication stage if and only if the result is desirable. If it does not, then the process will back to the design stage. After fabrication, measurement and analysis on the antenna prototype will be done. The project can be only finalized if the result obtained is desirable. If it does not, the process will back to the fabrication process until a desirable result is obtained. The overall project's flow can be represented into a flowchart as in figure 1.1.

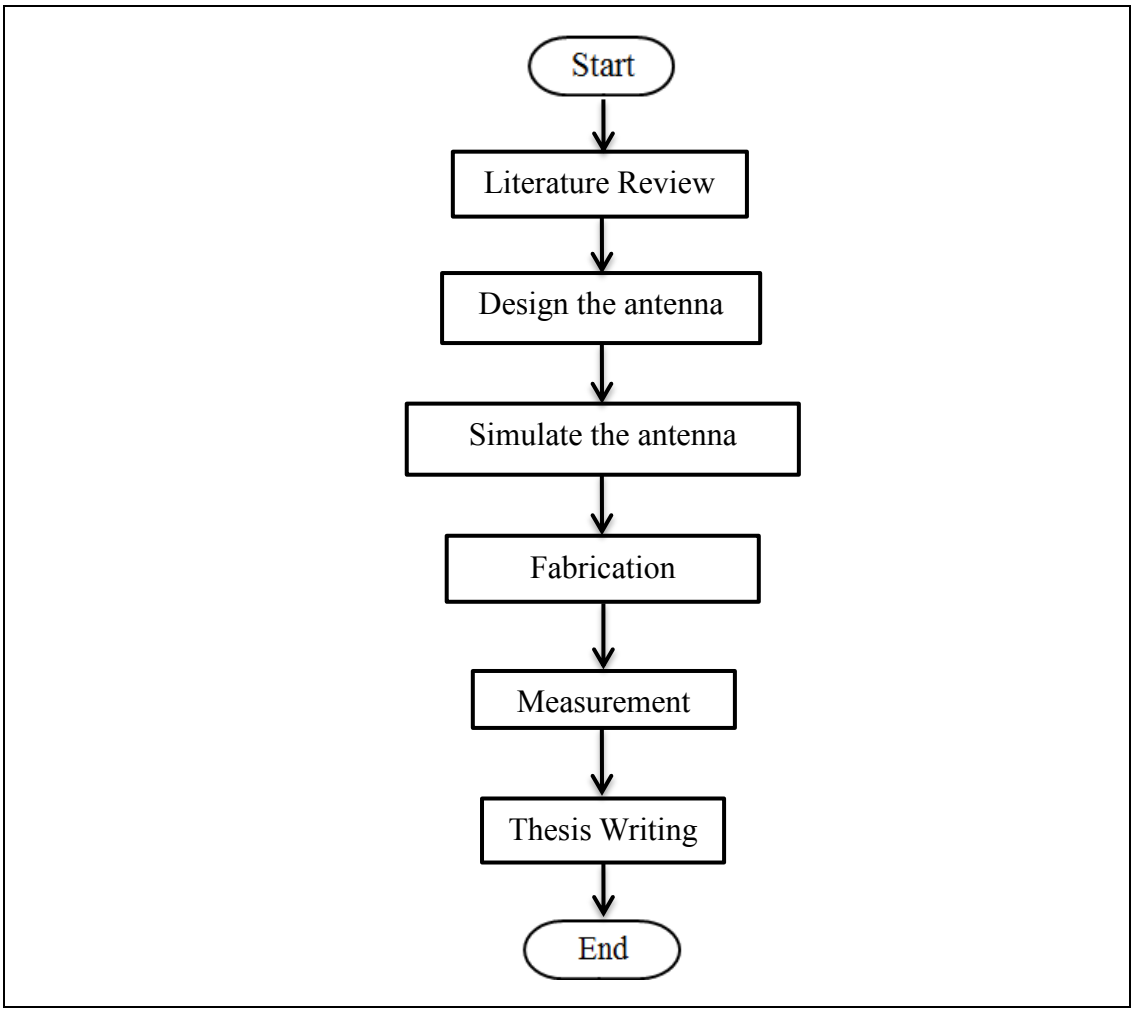

Figure 1.1 Flowchart of the Project

1.6 Report Structure

This report has been divided into five main chapters which are introduction, literature review, the design of compact multiband antenna, result and discussion as well as conclusion. The last chapter will end with a conclusion about this project and suggestion to further improve the project. In introduction chapter, objective, problem statement, scope and methodology of the project will first be review on. Literature review chapter will discuss about the general review on the project as well as techniques to design a compact multiband antenna. Furthermore, the design process will be stated stage by stage in design of compact multiband antenna's chapter. Then, the result obtained from the simulation and measurement will be discussed in the

result and discussion chapter. At the ending chapter, a conclusion about the project carried will be drawn and suggestion will be given to further improve the project.

CHAPTER II

LITERATURE REVIEW

This chapter discussed about the review on the design of a compact multiband antenna. At the beginning, a brief introduction will be given to show different types of antenna. Next, some of the basic antenna parameters will be discussed in the following sub-topic. Some techniques will also be reviewed to achieve multiband and compact characteristic.

2.1 Antennas

There are many types of antenna in this world. The layman might think that antennas are just something like dipole antenna, monopole antenna, loop antenna, horn antenna, parabolic antenna, helical antenna, and Yagi-Uda antenna. However, antennas family can be classified into few major groups. They are wire antennas, aperture antennas, lens antennas, array antennas, reflector antennas, and microstrip antennas [2].

Wire antennas seen from rooftop and automobiles are more familiar to the layman. Wire antennas such as straight line, loop, and helix wire antennas can be varied by different shapes and brings different functions and characteristics. The most common straight line wire antennas are dipole and monopole antennas. Moreover, loop antennas can be in circular, rectangular, square, elliptical or other configurations.

Aperture antennas are antennas which is more suitable to be used at higher frequency. They had been used for aircraft and spacecraft applications [2].

Lens antennas are grouped depending on the material used or shape of lenses. They can change different kinds of divergent energy into plane waves. Energy can also be converged by using lens so that it will not diverge to undesired directions [2].

Some radiation characteristics of antenna cannot be achieved by using just one single element. Thus, combinations of radiating elements (an array) in electrical and geometrical arrangement can obtain the desired radiation characteristic [2].

Parabolic reflector antenna is used for communication involving great distance. Corner reflector antenna has also been used although its popularity is not as common as parabolic reflector antenna [2]. Both of these antennas can be sometimes combined with another feeding mechanism to achieve higher performance such as to achieve higher gain.

Microstrip antenna consists of a metallic patch on a grounded substrate. The metallic patch can be in many kinds of configuration such as rectangular or circular patch. Microstrip antennas are popular for their low profile, suitable for planar and non-planar surfaces, simple and cheap to be fabricated. Thus, in this project, the antenna designed is a microstrip type antenna. Figure 2.1 shows some examples of antennas in different categories. They are wire antenna, aperture antenna, lens antenna, array antenna, parabolic antenna, and microstrip antenna.