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DESIGN OF MULTIBAND MICROSTRIP ANTENNA USING RECTANGULAR SLOT

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DESIGN OF MULTIBAND MICROSTRIP ANTENNA USING RECTANGULAR SLOT

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64781

A dissertation submitted in partial fulfilment
of the requirement for the degree of
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ABSTRACT

In wireless communication systems, the antenna is a critical component. A well-designed antenna efficiently reduces system requirements while increasing overall system performance. Many telecommunication providers need many frequencies to satisfy their needs. Hence a multiband antenna is preferred over a single-frequency antenna. Therefore, in this research antenna with multi band is chosen. In order to maintain the low cost, designated microstrip antenna with miniaturized design 30.23x21.81 mm^2 (W x L) which used FR-4 as a substrate is selected with the dielectric constant, εr = 4.3 mm and 1.6 mm of substrate thickness. The multi band antenna was designed and simulated by implementing three rectangular slots on the microstrip patch using CST software. The optimal parameters for this multi band antenna design were W_1 = 3 mm, L_1 = 8 mm, W_2 = 3 mm, L_2 = 8 mm, W_3 = 3 mm, and L_3 = 7 mm after optimisation using parameter sweep. By using rectangular slots on the microstrip patch, multi band operations were achieved at 2.56 GHz, 4.42 GHz and 5.82 GHz with a return loss of -17.91 dB, -23.18 dB and -51.04 dB, respectively.

ABSTRAK

Dalam sistem komunikasi tanpa wayar, antena adalah komponen kritikal. Antena yang direka bentuk dengan cekap mengurangkan keperluan sistem sambil meningkatkan prestasi keseluruhan sistem. Banyak penyedia telekomunikasi memerlukan banyak frekuensi untuk memenuhi keperluan mereka. Oleh itu antena berbilang jalur lebih disukai berbanding antena frekuensi tunggal. Oleh itu, dalam penyelidikan ini antena dengan pelbagai jalur dipilih. Untuk mengekalkan kos yang rendah, antena jalur mikro yang ditetapkan dengan reka bentuk kecil 30.23x21.81 mm^2 (*W x L*) yang menggunakan FR-4 sebagai substrat dipilih dengan pemalar dielektrik, εr = 4.3 mm dan 1.6 mm ketebalan substrat. Antena berbilang jalur telah direka bentuk dan disimulasikan dengan melaksanakan tiga slot segi empat tepat pada tampalan jalur mikro menggunakan perisian CST. Parameter optimum untuk reka bentuk antena berbilang jalur ini ialah W1 = 3 mm, L_1 = 8 mm, W_2 = 3 mm, L_2 = 8 mm, W_3 = 3 mm dan L_3 = 7 mm selepas pengoptimuman menggunakan sapuan parameter. Dengan menggunakan slot segi empat tepat pada tampalan jalur mikro, operasi berbilang jalur dicapai pada 2.56 GHz, 4.42 GHz dan 5.82 GHz dengan kehilangan pulangan masing-masing -17.91 dB, -23.18 dB dan -51.04 dB.

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LIST OF ABBREVIATIONS

ISM	-	Industrial, Scientific and Medical
RF	-	Radio Frequency
NFC	-	Near-Field Communication
RFID	-	Radio Frequency Identification
ITU	-	International Telecommunication Union
CST	-	Computer Simulation Technology
FR4	-	Flame Retardant Four
VSWR	-	Voltage Stand Wave Ratio
FCC	-	Federal Communications Commission
Wi-Fi	-	Wireless Fidelity
TV	-	Television
UHF	-	Ultra High Frequency
WW2	-	World War Two
EM	-	Electromagnetic
PCB	-	Printed Circuit Board
Wi-Max	-	Worldwide Interoperability for Microwave Access
S-parameter	-	Scattering parameter
BW	-	Bandwidth
TMM	-	Thermoset Microwave

Chapter 1

INTRODUCTION

1.1 Background Research

ISM band, known as the industrial, scientific, and medical radio group is one set of broadcast bands used in manufacturing, technological, and medicinal or a part of the radio frequency range that are globally allocated to use radio frequency (RF) wave for medical, scientific, and industrial aims rather than for telecommunications uses. ISM devices are devices which produce domestically radio frequency energy that is used for medical, scientific, industrial, domestic, and similar purposes, excepting in the telecommunication field [1]. Medical equipment, microwaves, industrial heating, and other forms of electrodeless lamps were among the first uses for this band. As a result, a variety of wireless communication protocols and devices have been created and produced throughout the years that can operate in these frequencies without interfering with the functioning of ISM devices. Nowadays, the ISM bands are the most often used for low-power and short-range telecommunications, which are among the most common instances of non-ISM devices such as Zigbee, near-field communication (NFC), Bluetooth, RFID wireless phones, and computer networks. In many parts of the world, various non-ISM device operations are subject to different regulations depending on whether the region is recognised by the International Telecommunication Union (ITU). Table 1.1 shows portion of the radio spectrum, ranging from 6765 kHz to 246 GHz, has been designated as ISM band used in Malaysia.

Table 1.1: ISM band frequencies [1]

Frequency range
6765 kHz – 6795 kHz
13.553 MHz – 13.567 MHz
26.957 MHz – 27.283 MHz
40.66 MHz – 40.70 MHz
2.400 GHz – 2.500 GHz
5.725 GHz – 5.875 GHz
24.00 GHz – 24.25 GHz
61.0 GHz – 61.5 GHz
122 GHz – 123 GHz
244 GHz – 246 GHz

In wireless technology, antennas are among the most advanced devices. Radio waves travel through the air in the form of electromagnetic radiation emitted by antennas. Then, the waveforms have been converted into electrical signals containing transferred information by the antenna. When it comes to an effective and efficient wireless network, antennas are critical components to consider. A decent antenna may be used for the household, workplace, and outdoor wireless networks to offer a high-quality connection that is not affected by interference. There is a large selection of antennas available, each with different specifications to choose from.

There are a variety of ways to transfer electromagnetic force from the sending source to the antenna or the antenna to the receiver, such as a hollow pipe or a coaxial line [2]. Antennas for transmitting and receiving are two different types of antennas. Figure 1.1 presents an overview of an antenna serves as a bridge between open space and a directing device. Based on Figure 1.1, standing waves in the transmission line can be seen as a result of both reflected waves from the interface and travelling waves from the source to an antenna.

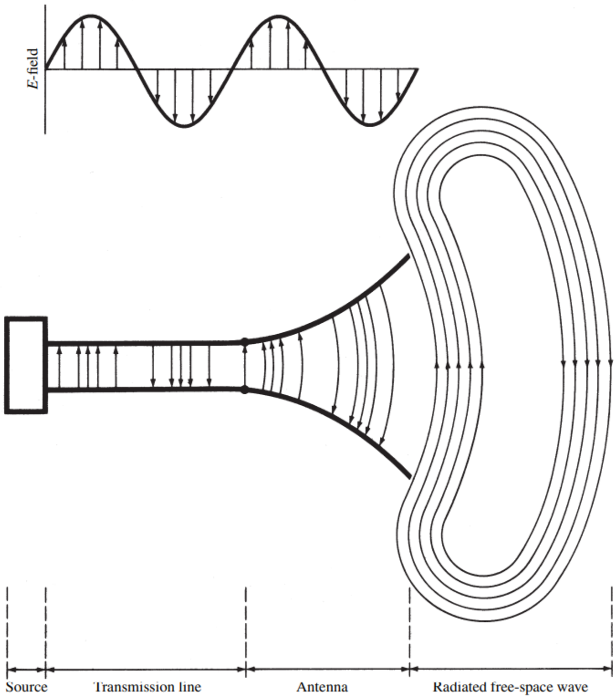

Figure 1.1: The use of an antenna as a transition device [2]

1.2 Problem Statement

Despite the name, ISM bands were designed to prohibit any radio frequency device for audio communications. A frequency licence is often required to operate in the ISM band, which has its own set of frequencies. Rather than depending on testing and certification, this assures that devices operating in the ISM bands do not interfere with communications equipment. In addition, the ISM bands are sometimes named as unlicensed bands since the approval procedure for devices operating in ISM bands is clarified [3].

The antenna has grown progressively difficult to work within recent years. This is due to the fact that various new wireless applications have increased the demands placed on them. Thus, it has increased the complexity of the wireless design. In current wireless environment, it is critical to developing dual band antennas that span the ISM frequency extents of 2.4–5.8 GHz to meet the rising need for ubiquitous communication, faster data speeds, and increased mobility [4].

The disadvantage of a single band antenna compared to a dual band antenna is oversized and the antennas size are costly to reduce. Due to the higher frequencies and smaller wavelengths of harmonic modes, a single band antenna with a fundamental mode is larger than a dual band antenna since the antenna cannot be decreased in size while operating in higher-order modes where the antenna may resonant. As a result, multi band antennas are used to reduce the antenna's overall size.

When other equipment is interfering with the frequency of a single band antenna, it will not be able to function on another frequency. Moreover, two single band antennas cannot compete with the efficiency of a multi band antenna, which can be built to the exact dimensions of a single band. The dual band antenna is designed to improve the antenna's performance in terms of antenna parameters such as size and structure of antenna, return loss, gain and bandwidth [5]. The performance of an antenna is a measure of the total quality of the antenna.

A high-quality multi band antenna can prevent any undesired frequency band from being resonantly reflected by the antenna. Many telecommunication providers need many frequencies to satisfy their needs. Hence a multiband antenna is preferred over a single-frequency antenna [6]. Some scholars have done their researches on different techniques used to design a dual band antenna. In 2015, a dual band textile antenna design for the ISM band was proposed using fractal geometry technique [7].

However, this technique was not suitable for microstrip antenna because it is hard to design and the gain of the antenna decreases [8]. Another technique was defected ground plane where instead of the radiating patch, the base plane is modified to suit the multiband requirements. The problem with this technique is that it achieves low gains while it produces wider bandwidth than the radiating patch modification technique. The gain of antenna needs to be improved to achieve enhanced dual band antenna. The higher the antenna gain, the more directional an antenna means the more range it can cover.

In this research, a multi band antenna is designed to overcome the addressed issues. The technique that will be used is modification of slots on the radiating patch. The technique has been used by previous papers and it is the easiest method to produce a multi band antenna. The modification of slots is a method to enhance antenna gain because it consists of a metallic surface, such as a flat plate, with a slot cut in it. The slot radiates electromagnetic waves when the plate is driven by frequency, creating additional slots resonance regions. This is also a good way to improve the bandwidth [9].

1.3 Objectives

These are the aims of this study:

i. To investigate the operation and design of antennas working at multi band.
ii. To design a multi band antenna by implementing modification of slots method using CST software.
iii. To analyse the performance of the designed multi band antenna in terms of gain, radiation pattern and return loss.

1.4 Scope of Research

This study aims to design a multiband band antenna for the ISM band using a modification of slots approach. Three frequency bands of 2.5 GHz, 4.4 GHz and 5.8 GHz are proposed. Microstrip patch antenna is used since it is low cost, small in size and comfortable to fabricate. Computer Simulation Technology program (CST) is applied to simulate and evaluate the performance of the multi band antenna design. Technique that will be used in this multi band antenna design is slots modification on radiating patch where three rectangular slots are attached on the rectangular patch of the antenna. The chosen substrate is FR4 for the antenna ground. The parameters such as return loss, voltage stand wave ratio, radiation pattern and gain are used to evaluate the performance of antenna. After the design development of the multi band antenna is perfectly simulated with optimized parameters, the analysis of the performance of the designed multi band antenna will be presented using graphs and diagrams.

1.5 Thesis Outline

This paper is split into five chapters: Introduction, Literature Review, Methodology, Results and Discussion and Conclusion. Chapter 1 will present about the background research, problem statement, objectives and scope of research.

Chapter 2 explains literature review of the research. The chapter begins with definition and background of ISM bands. It also includes basic concept of antenna, applications and types of antennas. Types of antennas such as dipole antenna, array antenna, waveguide antenna, horn antenna and microstrip antenna are presented together with their applications. The advantages, disadvantages and applications of microstrip are explained since the microstrip antenna is selected to design a dual band antenna in this thesis. Next, the parameters of antenna such as return loss, voltage stand wave ratio and the gain are discussed. Lastly, the techniques used by previous researchers are compared in a table and their limitations have been reviewed.

Chapter 3 elaborates the methodology of the thesis. The chapter includes flowchart, Gantt Chart and design modification. The computer program used to design the multi band antenna is CST simulation. The types of substrates are also mentioned in this chapter. The dimensions of geometry, structure and parameters of designated antenna are included in this section.

Chapter 4 describes interpret the simulation results of designated microstrip patch antenna with and without rectangular slot implementation on the microstrip patch. The results will be presented based on return loss, gain, directivity and shape of radiation pattern in polar plot of antenna which have been computed using Computer Simulation Technology (CST). Besides, the parameter analysis for rectangular slot varies will be analysed. The comparison between different designated microstrip antenna with and without slot rectangular implementation will be explained in detail.

Chapter 5 summarize all the findings of the research. The suggestion and recommendation for the future studies also stated.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter explains the definition, types and parameter of antennas used in this study. The fundamental concept of antenna is also discussed. Types of antennas such as dipole antenna, array antenna, waveguide antenna, horn antenna and microstrip antenna are presented together with their applications. Since microstrip antenna is selected in this antenna design, thus the features of microstrip antenna as well as its advantages and disadvantages are explained in this chapter. Next, antenna parameter which includes return loss, VSWR, gain, radiation pattern, bandwidth and efficiency that used to evaluate the performance of antenna are also explained. Lastly, the techniques used in previous researches will be compared and discussed.

2.2 Concept of Antenna

The antenna is a crucial element in wireless communication systems. It effectively minimises system requirements and increases overall system performance with a well-designed antenna. Broadcast TV, satellite communications, navigation and other wireless technologies are types of wireless telecommunication systems that use the antenna. As stated by Webster's Dictionary, antennas are "a usually metallic device (as a rod or wire) for radiating or receiving radio waves" [12].

Hertz developed the world's first wireless electromagnetic system in 1886 [13]. Later, Marconi achieved transmitting signals from England to Newfoundland in 901 across a large distance. Since Marconi's invention, antenna technology has been predominantly focused on wire-based radiation elements and their operating frequencies up to around Ultra High Frequency (UHF). Modern antenna technology did not emerge until World War Two (WW2) when researchers started developing novel components such as waveguide apertures, horns, reflectors, and lenses. Phased arrays were first used in 1937.

However, the most significant developments in the theory and implementation of phased array antennas happened during the 1960s [13].

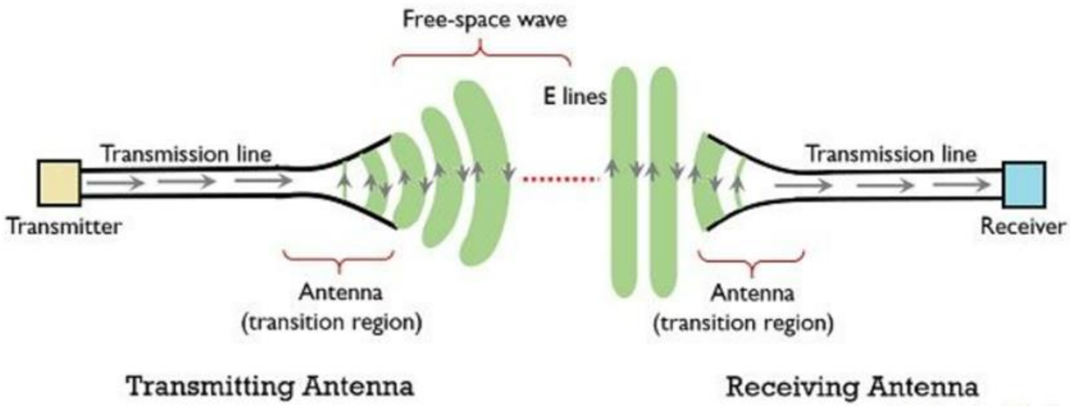

Figure 2.1: Basic principle of antennas [14]

Figure 2.1 demonstrates the transmission and delivery of EM waves in free space [14]. Basically, antennas are electromagnetic (EM) signal converting devices that operate in two modes that are transmitting mode and receiving mode. In sending mode, antennas convert driven EM waves to emitted free-space EM waves within transmission lines. Meanwhile, in receiving mode, antennas convert free-space EM waves to driven EM waves.

Antenna size is relatively referred to wavelength. Wavelength is the distance where an EM signal will travel during one complete cycle. The wavelength is reciprocally proportional to frequency [15]. The size of antenna through wavelength can be calculated by using equation shown below:

$$\lambda = \frac{c}{f} \tag{2.1}$$

Where:

λ : Wavelength (meter)

c : Light speed, 3.0×10^8 m/s

f : Frequency (Hz)

2.3 Types of Antennas

Antennas have a variety of types and each type may work in different ways. Two groups of antennas are omni-directional and directional where they deliver different radiation patterns. Omni-directional antenna obtains signals from all paths evenly meanwhile directional antennas receive signals from one direction [16]. Whip antennas are an example of omni-directional antennas covering a broad frequency spectrum although these antennas have no gain and become inefficient. Meanwhile, Yagi antennas are an example of directional antennas used for television reception. There are other types of antennas which are dipole, array, waveguide, horn and microstrip antenna will be discussed.

2.3.1 Dipole Antenna

The dipole antenna involves of two metal cords which trace on a PCB board. This type of omni-directional antenna is widely operated in ZigBee applications [17]. The size of each dipole antenna wire is roughly wavelength's quarter of the desired frequency of control. Physically, dipole antenna is restricted in power gain due to its widespread range and this antenna is in cylindrical form. It is also known as a half-wave dipole antenna because its total length is semi a wavelength. Figure 2.2 explains two poles of the antenna is equal to approximately quarter the radiator's operating wavelength. The side of the dipole has maximum voltage.

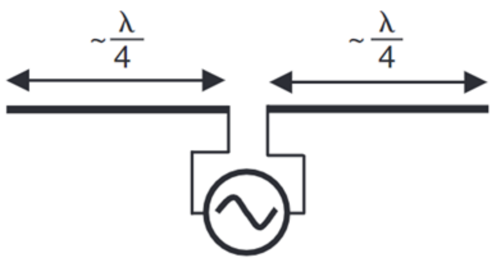

Figure 2.2: A half-wave dipole antenna [17]

2.3.2 Array Antenna

An array antenna or phased antenna is a series of multiple (two or more antennas) which connect each other as a combined antenna to achieve improved performance in transmitting and receiving radio waves over a single antenna. Individual elements and radiators make up the antenna's radiating structure. There is an induction field in each of