DESIGN A BOW-TIE PATCH ANTENNA WITH COMPLEMENTARY SPLIT RING RESONATOR

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"For my dad, mum and siblings"

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ABSTRACT

This project is focus on designing a bow-tie patch antenna with complementary split ring resonator to increase gain and reduce the size of the antenna compare to the existing patch antenna without complementary split ring resonator structure. Bow-tie microstrip antennas has become one of the most popular antennas used in the present day communication scenario due to their compact in nature compared to rectangular patches. Design of bow-tie patch antenna with complementary split ring resonator is based on a design of bi-triangular element microstrip antenna. The bow-tie patch actually is the combination of imaginary image of two triangular patches which are fabricated on a single substrate with complementary split ring resonator. The bow-tie patch antenna with complementary split ring resonator has been designed for wireless LAN communication, where the operating frequency is at 2.4 GHz. This project was divided into a few parts. Firstly is designing the antenna using CST Microwave Studio where it involves a matching network with the microstrip transmission feeding line. Then simulations were done to observe the return loss and radiation pattern of the antenna. Lastly project will proceed with hardware development by fabricating the antenna and compare between the simulation and measurement.

ABSTRAK

Projek ini adalah memberi tumpuan kepada bentuk antena bow-tie dengan tampalan cincin berpecah resonator untuk meningkatkan keuntungan dan mengurangkan saiz antena berbanding antena tampalan sedia ada tanpa struktur cincin berpecah resonator. Antena mikrojalur bow-tie adalah antara antena yang banyak digunakan dalam scenario komunikasi semasa disebabkan oleh sifatnya yang kecil berbanding dengan mikrojalur segi empat. Permintaan yang tinggi untuk peralatan komunikasi tanpa wayar jelas memerlukan penyelidikan untuk menghasilkan antena segi tiga. Antena bow-tie dengan tampalan cincin berpecah resonator adalah berasaskan reka bentuk dua antena segi tiga. Antenna mikrojalur bow-tie adalah gabungan dua segi tiga yang dipadankan dalam satu substrat dengan tampalan cincin berpecah resonator. Di dalam projek ini antena bow-tie dengan tampalan cincin berpecah resonator telah direka bentuk untuk aplikasi rangkaian kawasan setempat (LAN) di mana frekuensi pengendaliannya adalah pada frekuensi 2.4 GHz. Projek ini juga telah dibahagikan kepada beberapa bahagian. Pertama adalah reka bentuk antena menggunakan perisian gelombang mikro yang melibatkan pertimbangan penyepadanan galangan dengan mikrostrip. Kedua adalah simulasi bertujuan melihat perubahan kehilangan kembali dan bentuk sinaran antena berkenaan. Akhir sekali projek ini diteruskan dengan proses fabrikasi antena dan seterusnya perbandingan antara keputusan simulasi dan fabrikasi.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

WLAN	-Wireless Local Area Network
WiMAX	-Worldwide Interoperability for Microwave Access
RFID	- Radio Frequency Identification
FR4	-Flame Retardant 4
RF	-Radio Frequency
PDA	-Personal Digital Assistant
SMA	-Sub Miniature Version A
PCB	-Printed Circuit Board
CST	-Computer Simulation Technology
UV	-Ultra Violet
HPBW	-Half Power Beamwidth
FNBW	-First Null Beamwidth
CP	-Circular Polarization
SWR	- Standing Wave Ratio

CHAPTER I

INTRODUCTION

This chapter will give an overview concerning the project as project background, project objective, project scope, project methodology and summary of the project. This chapter will additionally clarify briefly the overall project progress from beginning until the project is complete.

1.1 Introduction

Due to the development of wireless technology very fast, the broadband antenna technology has devised small antenna and power are necessarily used in many applications of communication such as Wireless Local Area Network (WLAN) for 2400MHz, Worldwide Interoperability for Microwave Access (WiMAX) for 2500 MHz to 2800MHz, Radio Frequency Identification (RFID) for 2450 MHz frequency range and others [1]. On the other hand, consumption requirement of small antenna which is very high for mobile phone users, PDA, laptop and notebook are incorporated with WI-Fi technologies to connect.

Antenna as a device designed to transmit or receive electromagnetic energy, matching these sources of energy and the space as shows in Figure 1.1. However, an antenna is an important instrument in wireless communication systems used to transport electromagnetic energy from the transmitting source to the antenna or from

the antenna to the receiver, it also often called radiant systems. A good antenna design is an antenna that can fulfill system requirements and improve overall system performance [2]. The original information is changed, for example through some kind of modulation and treatment, and still conveyed or guided by a cable to the antenna.

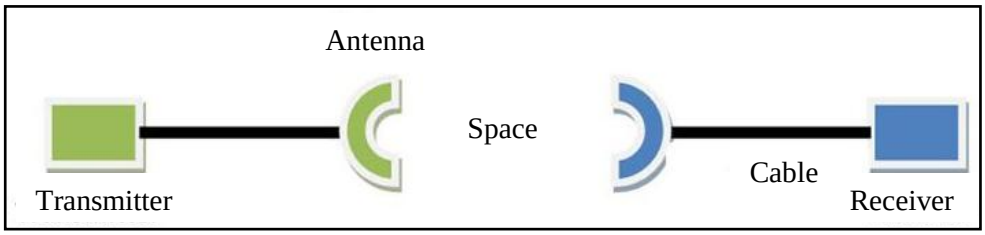

Figure 1.1: A simplified representation of a system for transmission and reception

In the future communication system, there will be a lot of demand to improve antenna performance due to increasing users, demand for higher speed in information transfer and the improvement in communication system technology. High bandwidth is one of the performance parameter because much wider bandwidth antenna will be needed when the frequency ranges is increasing than the originally required.

This project is focusing on designing a bow-tie patch antenna with complementary split ring resonator to increase gain and reduce the size of the antenna compare to the existing patch antenna without complementary split ring resonator structure [3]. A bow-tie antenna is based on a bi-triangular sheet of metal with the feed at its vertex as shows in Figure 1.2. This type of antenna is utilized extensively in many applications such as ground penetrating radar and mobile station. Bow-tie antennas have many advantages such as low profile, high radiation efficiency, ease of manufacturing and low fabrication cost [4]. Comparison between the bow-tie and fractal antenna shows that the bow-tie antenna has a wider bandwidth, higher gain, lower front-to-back ratio, lower cross-polarization level and smaller in size [5].

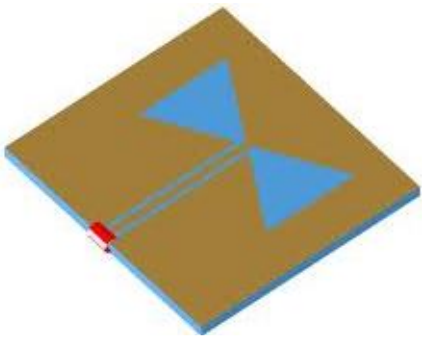

Figure 1.2: Bow-tie antenna

Split ring resonators (SRRs) structure is used to produce the negative permittivity or/and negative permeability as shows in Figure 1.3. This structure can be applied in many applications such as antenna, filter and microwave absorber. In 1999 by Pendry is the first man to develop a split ring resonator-base artificial negative magnetic permeability medium [1]. In the year of 2000, there was the first left hand medium (LHM) was developed with both negative permittivity and permeability by combining this structure with the array of strip wires (SW) [6].

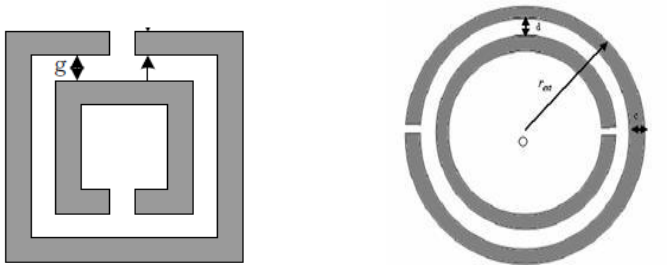

Figure 1.3: Split ring resonator structure of the antenna design

1.2 Objectives

The objectives of this project are to design bow–tie antenna with a new structure of split ring resonator at 2.4 GHz for wireless LAN application. Besides that, the other objective is to investigate the behavior of bow-tie antenna properties and to analyze the characteristic impedance, return loss and radiation pattern of the bow-tie antenna.

1.3 Problems Statement

This project is undertaken as a solution for how to increase gain and miniaturize the size of the bow-tie patch antenna design. In applications where size, weight, cost, performance, ease of installation, and aerodynamic profile are constrained, low profile antennas like a bow-tie patch antenna with split ring resonator are required. Bow-tie patch antenna inherently has narrow bandwidth (BW) and in general is half-wavelength structures.

Meanwhile, bow-tie patch antenna with split ring resonator have several advantages over microstrip patch antenna such as exhibit wider bandwidth, lower dispersion and radiation loss, higher gain, lower front-to-back ratio, lower cross-polarization level and smaller in size.

1.4 Project Scope

The scope of this project involves the design, implementation and testing of bowtie patch antenna with split ring resonator. It can be divided into 5 main phases, which are designed the bowtie patch antenna with a new structure of complementary split ring resonator at 2.4 GHz for wireless LAN application. The bow-tie patch actually is the combination of imaginary image of two triangular patches which are fabricated on a single substrate. The design of bow-tie microstrip antenna is based on the design of triangular microstrip antenna with complementary split ring resonator. Since the dimension of bow-tie microstrip antenna, calculation and formula will be applied to measure the right dimension of the bow-tie patch antenna design. A bow-tie patch antenna design with complementary split ring resonator will be designed, simulated, optimization in the CST Microwave Studio software.

Next, for the fabrication of the antenna, the layout of the antennas will be prepared. The fabrication was done by using the FR-4 substrate with dielectric constant, $\varepsilon r = 4.3$ at a frequency of 2.4 GHz for Wireless LAN and expected return loss better than - 10 dB. The fabrication antenna will be analyzed to verify the theory and model that has been made. The parameter involve in this stage is return loss, bandwidth, radiation pattern and the gain of the patch antenna.

1.5 Methodology

The first process in this project is the literature review. The review is to gather the information regarding bow-tie antenna via an IEEE journal, books, internet, journals, published work, reference books, magazine and study of the software implementation CST Microwave Studio.

The second process is a design of bowtie patch antenna with a new structure of complementary split ring resonator at 2.4 GHz for wireless LAN application. The designing and calculation processes are referring to the literature reviews that have been done in previous process. Then, the design was simulated with CST Microwave Studio to get the return loss, bandwidth, radiation pattern and the gain of the patch antenna. The normal bow-tie antenna is designed first then followed by a bow-tie patch antenna with complementary split ring resonator.

After that, the layout of the antennas is prepared before being fabricated. The simulated antenna was fabricated on FR4 board with dielectric constant, $\varepsilon r=4.3$, tangential loss, $\tan \delta=0.019$ and thickness, $h=1.6$mm. The fabrication process consists of three steps which is UV exposure, developing, and etching. After fabrication, the SMA port will be connected and soldered to the antenna for measurement purpose.

Next, is the measurement process. The fabricated antenna parameter that will be measured resonant frequency returns loss and bandwidth by using a network analyzer while gain and radiation pattern is measured using the RF analyzer and horn antenna as a transmitter. The result between simulation and measurement will be compared and analyzed. The last step is the report writing as shows in Figure 1.4.

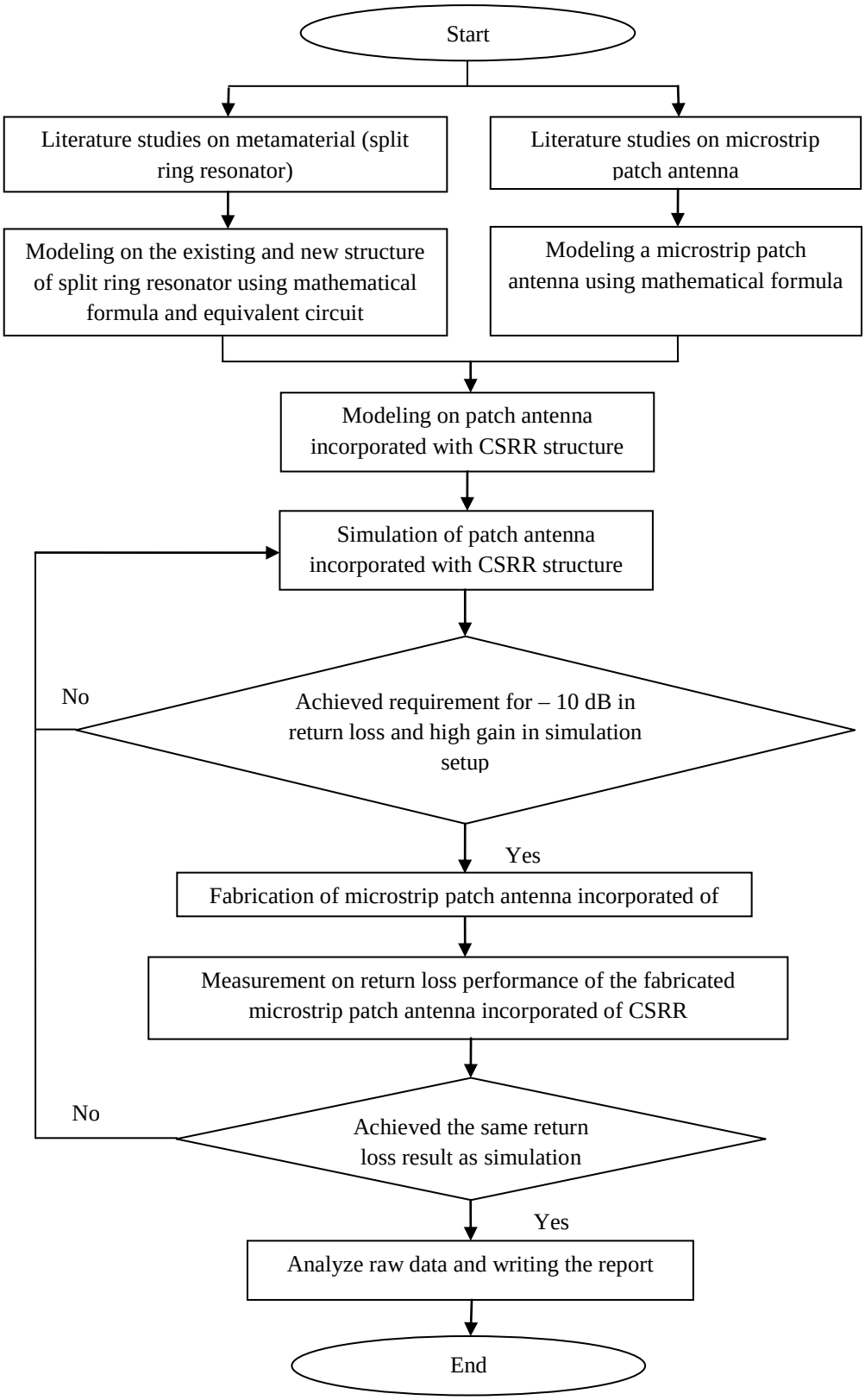

Figure 1.4: Flow Chart for the Antenna Project

CHAPTER II

LITERATURE REVIEW

This chapter will discuss about the fact and information about bow-tie antenna and development of the complementary split ring resonator.

2.1 Overview of Antenna

Around the 1830s, the early examination that encompassed the coupling of electricity and magnetism and displayed a definitive connection was that completed by Faraday. He skidded a magnetic concerning the coils of a wire attached to a galvanometer. In advancing the magnet, he was in result crafting a time-varying magnetic earth, that as a consequence (from Maxwell's Equations), have to have had a time-varying mechanical field. The coil replaced as a loop antenna and consented the electromagnetic radiation that was consented by the galvanometer - the work of an antenna. Interestingly, the believed of electromagnetic waves had not even been believed up at this point.

Antenna scrutiny and progress in the past hundred years as the epoch-making examination of Ben Franklin's kite, verifying the attendance of electromagnetic waves, has elevated in different surges. Ben Franklin's kite examination wasn't quite an antenna, as that seized lightning discharge, that is a manage present trail whereas the power is not transferred autonomous of the medium it travels. The human eye of sequence receives elevated frequency electromagnetic waves. Technically the eye

might be categorized as an antenna; though as it can't send waves, it is truly a sensor [7].

In the 1860s, when James Clerk Maxwell, fused electricity and magnetism into electromagnetism, he delineated light as and proved it to be an electromagnetic phenomenon. He forecasted the attendance of electromagnetic waves at wireless frequencies that is at far lower frequency than light. In 1886, Maxwell was proven right by Heinrich Rudolf Hertz who lacking comprehending it himself crafted the early ever wireless arrangement, encompassing of a transmitter and a receiver [8].

An antenna is the interface amid transmitter line and space. The frank believed to comprehend considering antennas is that they are passive devices. It's because, to work, they need no supply voltage. As well that, they do neither change nor procedure RF gesture exceptionally to amplify the power of RF signals. In the supplementary word, an antenna merely converts an electromagnetic gesture to an mechanical gesture at a receiver or mechanical gesture to an electromagnetic gesture at a transmitter [9].

If they are 100 % effectual, they exude no extra manipulation than is held to their input terminal. This is because all the power of the gesture is definitely absorbing. An antenna can be described as a conductor utilized for exuding electromagnetic power into space or for accumulating electromagnetic power from space. In broadband wireless, there are countless kinds of antennas obtainable to suit the necessities of the application. The main aspect of antenna selection is normally gain, but equally vital criteria contain such things as beamwidth, side and rear lobe rejection, cross-polarity isolation, and VSWR (voltage erect wave ratio).

2.2 Bow-tie Antenna

The bow-tie structure was first proposed by J. George in 1996. The bow-tie patch actually is the combination of imaginary image of two triangular patches which are fabricated on a single substrate [10]. A bowtie antenna was also made from a bi-triangular sheet of metal with the feed at its vertex [11]. Bow tie antennas, which basically are the limiting case of bi- triangular antennas, are attractive mainly due to their simplicity and wideband property. A bow-tie antenna is actually a flat version

of bi- triangular dipole antenna. These antennas have many advantages such as low fabrication cost, high radiation efficiency, ease of manufacturing & low profile [12].

Bow-tie microstrip antennas have come to be appealing candidates in the present day communication scenario due to their compact nature compared to rectangular patches. The ever rising demand for compact wireless communication equipment explicitly necessitates research on compact antenna options and which sparked interest of many researchers worldwide in the field of bow-tie patch antennas. Though in the literature, only very few attempts have been made towards the analysis of this kind antenna. The bow-tie patch antenna as a compact one and counselled an empirical formula for the resonant frequency of this new geodesy. This kind of antenna is utilized extensively in many applications such as ground penetrating radar, wireless communications and mobile station.

The bow-tie antenna has a narrow bandwidth because it is an example of a travelling wave structure; the analysis of a theoretical infinite antenna resembles that of a transmission line. For an infinite antenna, the characteristic impedance at the point of connection is a purpose of the cone angle only and is autonomous of the frequency. Useful antennas have finite length and a definite resonant frequency. Bow-tie antennas are often frequently utilized in electromagnetic interference (EMI) assessing whichever for immunity assessing or emissions testing [13]. The main advantages of bow-tie antennas are easy design and broadband impedance. Bow-tie antenna has been extensively learned in wireless system due to its advantages, such as broad impedance bandwidth, easy construction, light weight, easy to build and low cost. Moreover, effortlessly flexible to hybrid and monolithic microwave consolidated route fabrication method at RF and microwave frequencies. Meanwhile, alongside the quick progress of mobile communications, the enhance of second-generation mobile communications to third-generation mobile communications is becoming inevitable [14].

For instant, bow-tie antenna has a bigger bandwidth than rectangular antenna, or wide rectangular antenna has a bigger bandwidth than narrow one. The Bowtie patch antenna has bigger bandwidth [15], higher gain, lower front to back ratio, lower cross polarization level and is smaller in size compared to similar rectangular antenna. Disparate methods have been utilized to enhance the bandwidth, gain, return loss and directivity of the bow-tie antenna, such as impedance matching technique, imposing different resonator, reduction of radiation efficiency, slot and add the