COMPACT MICROSTRIP ARRAY ANTENNA USING ELECTROMAGNETIC BAND GAP (EBG)

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To my beloved mother, father
and my supervisor

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Thank you.

ABSTRACT

This project is to develop compact array antenna integrated with electromagnetic band gap or known as EBG to reduce mutual coupling between the arrays. The EBG structure has unique property such as the ability to suppress the propagation of surface wave. This structure frequently used as a part of antenna to improve the performance of the antenna especially to improve gain, efficiency, return loss and mutual coupling. In this project, microstrip patch antenna used because of the advantages such as cheap, easy to fabricate and easy to integrated with microwave circuit. It involves the investigation of microstrip patch array antenna performance when integrated with EBG. The research is to determined performance of the antenna whether there is an improvement in the antenna array element using EBG compared to the conventional antenna on mutual coupling, efficiency and gain. The simulation is using CST Microwave Studio. While, the fabrication will be use FR4 board as the substrate.

ABSTRAK

Projek ini adalah untuk menghasilkan barisan antena yang bersaiz kecil yang disepadukan dengan jurang jalur elektromagnetik atau dikenali sebagai EBG bagi mengurangkan gandingan bersama diantara barisan antena. Struktur EBG mempunyai sifat yang unik seperti keupayaanya untuk menekan penyebaran gelombang permukaan. Struktur ini sering digunakan sebagai sabahagian daripada antena untuk meningkatkan prestasi antena terutama untuk meningkatkan gandaan, kecekapan, *return loss* dan gandingan bersama sesuatu antena. Dalam projek ini, antena mikrostrip digunakan kerana kelebihannya seperti murah, mudah untuk membuat reka bentuk dan mudah untuk bersepadu dengan litar mikro. Ia melibatkan penyiasatan tampalan mikrostrip keatas prestasi barisan antena apabila disepadukan dengan EBG. Penyelidikan ini adalah untuk menentukan prestasi antena sama ada terdapat peningkatan dalam elemen tatasusunan antena menggunakan EBG berbanding tanpa menggunakan EBG pada gandingan bersama, kecekapan, dan gandaan. Simulasi antena menggunakan CST Studio Microwave dan fabrikasi akan menggunakan papan FR4 sebagai substrat.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The antenna is being developed due to the popularity in a wireless communication system and device. Antenna applied to the traditional radio, TV broadcast and wireless communication [1]. Microstrip patch antenna is a low profile radio antenna that is very popular in mobile and radio wireless communication. It can be mounted on a metal ground plane and consists of a flat rectangular of metal [2]. Microstrip patch antenna has more benefit compared to conventional antenna [3]. Patch antenna advantages such as easy to fabricate, lighter in weight, analysis, low cost and simple feeding structure [2, 4]. Moreover, this antenna can provide circular polarization, dual frequency operation and frequency agility [3]. However, it has narrow bandwidth, low efficiency, low gain and surface wave losses [4].

Electromagnetic band gap (EBG) known due to their proper electromagnetic properties which hardly to be observe in natural material and EBG structures are subsets of metamaterials [5]. In EBG periodic and aperiodic utilize stop and progress at the specific frequency of the electromagnetic waves propagation [1]. EBG has improved array antenna performance by integrating electromagnetic surface with an existing

antenna. The surface waves can be reduces if the directing electromagnetic wave propagates along ground plane and can increase back lobe which reduce signal to noise ratio. In addition, EBG structures reduce the mutual coupling and design low profile antennas with good radiation efficiency [1].

Previous project consist of 2 layers EBG substrates that implement with microstrip patch. The results produces higher gain with wider impedance bandwidth compared to conventional patch antenna [6]. Other than that, there are 4 elements array antenna using EBG that place on a ground plane. This structure can improve performance in antenna array elements, return loss and VSWR [7]. Mutual coupling of an antenna can be reduce by 2 layers EBG that provide lower resonant frequency [8].

This project will use two patch antennas and placed it above EBG. Mutual coupling is occurring when 2 antennas placed nearer. The array element is inserted with EBG to reduce mutual coupling [9]. In this paper, high impedance EBG is used on the ground plane and simulates and measured microstrip patch antenna with EBG. Simulation using CST to optimized the antenna parameters and fabricated using FR4 PCB. The frequency range of the antenna in this paper is 2.4Hz. The size of the antenna can affect the frequency range. The antenna range with EBG ground plane is designed to function both inside and outside the bandgap[10].

1.2 Problem Statement

Microstrip patch antenna had been used widely because of the advantages. However it has low efficiency and high Q factors. These disadvantages are a limitation in their application in various fields [3,4]. The major problem with microstrip patch antenna design is the substrate surface wave propagation. The antenna efficiency will reduce due to the surface wave propagation. This is because of the increasing of side and back lobe [11]. Meanwhile, the antenna array will cause the mutual coupling that defined as electromagnetic interaction between the antennas. It occurs when the

antennas are placed nearer and cannot be placed in a very compact arrangement [12]. Mutual coupling cause some losses in power and radiation pattern in the antenna [4]. The effect of mutual coupling can be reduces by added EBG. In addition, it can suppress the surface waves design low profile antenna with good radiation efficiency [5]. Hence improve the radiation pattern and gain [4]. The radiation pattern and return loss will be obtained by simulation and measurement.

1.3 Objectives

The main objective of this project is to design and develop compact microstrip array antenna with the implemented of Electromagnetic Band Gap (EBG). The EBG structure within the microstrip patch element will be investigate. The result is analysed by using the simulation in CST software. Next, the performance of the array antenna will be compared for the integration with and without electromagnetic band gap (EBG). The design antenna structure is fabricating using FR4 PCB. Lastly, the result for both simulation and measure is compare.

1.4 Scope of Project

This final year project is beginning with literature study regarding the topic. It focuses on the development of the antenna to meet the desired performance that can use in 2.4GHz.

The research is about microstrip patch antenna, array antenna and electromagnetic band gap (EBG). Antenna efficiency, radiation pattern, gain and mutual coupling need to be studied first for both single microstrip patch antenna and array antenna. There are several advantages when EBG is placed on the microstrip patch antenna. Therefore, EBG structure is the important element in this literature study.

CST software will be used for the simulation to design microstrip patch antenna and EBG. CST is most accurate an efficient computational to provide the variety tools for the antenna design. Before designing antenna, obtain the frequency for antenna and band gap. CST used to design single antenna and to optimize the result for achieving the centre frequency of 2.4GHz. The band gap of EBG will cover the frequency of array antenna which is 2.2GHz to 2.6GHz. From the single antenna, build array antenna. The distance between the array antennas is varied to analyse the mutual coupling, efficiency and gain. Moreover, CST is used to combine antenna array and EBG simulation. Place array antenna above EBG to analyse the performance on mutual coupling, gain, return loss and many more.

Fabrication is required after designed the antenna using CST in 2.4GHz resonant frequency. The substrate material of the antenna is FR4 board with dielectric constant 4.3 and thickness 1.6mm. There are several steps in fabrication. The steps are printed the layout design, expose the board to the ultra violet light, etching and lastly soldering.

The measurement process is last process in antenna designing. There are two parts measuring the antenna. The first part is to measure antenna return loss, mutual coupling and resonant frequency. The second part is identify radiation pattern of E polar, H polar, E cross polar and H cross polar. Figure 1.1, 1.2 and 1.3 shows the structures of compact microstrip array antenna using EBG for top view, front view and side view:

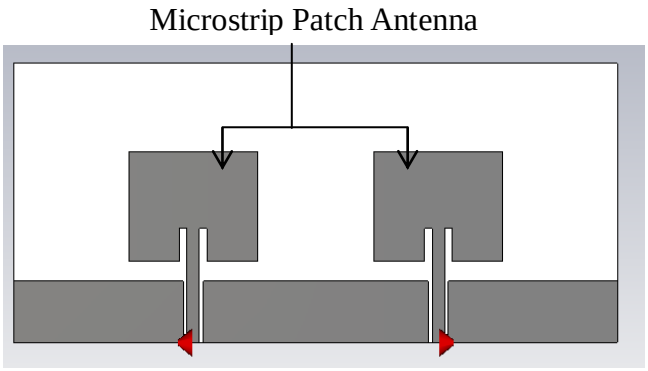

Figure 1.1: Top View.

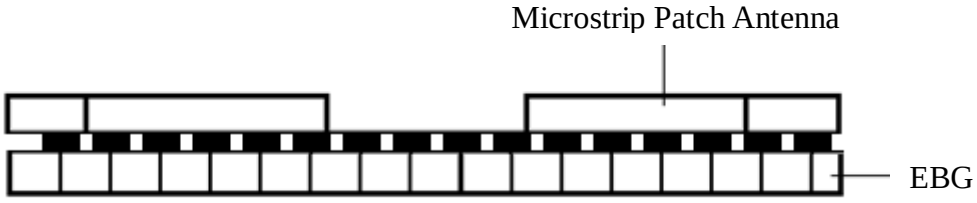

Figure 1.2: Front View.

Figure 1.3: Side View.

1.5 Project Planning

The project begins with literature study according to the topic that related. The research is about microstrip patch antenna, array antenna and electromagnetic band gap (EBG). Specification and calculation of the antenna was obtained from the research. After that, design single antenna, array antenna and EBG using CST software. Next, analyse the result of comparison between the array antenna performance with and without EBG. The fabrication process of the antenna can be done when all the specification meets the requirement. Next process is the measurement process of both array antenna with and without EBG. Lastly, the result between simulation and measurement of the antenna is compared. All the experimental results are included in this thesis report.

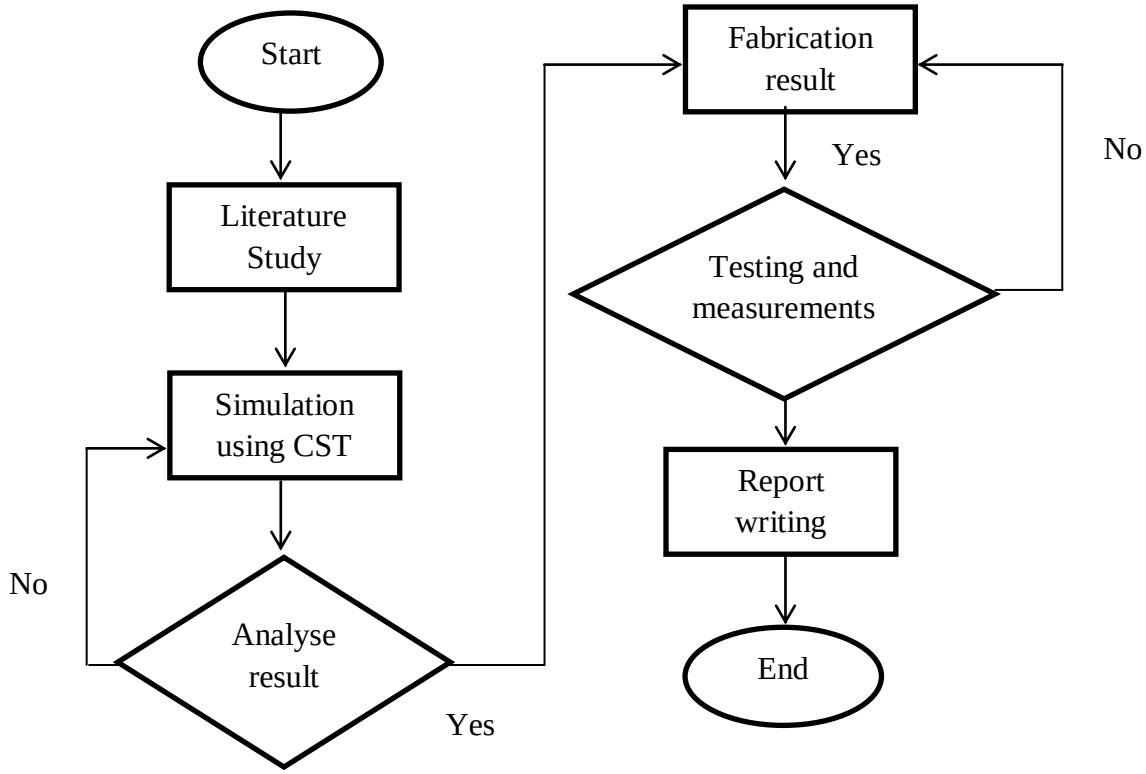

Figure 1.4: Flow chart of project

1.6 Organisation of Report

This report contain of five chapters which describe all the job process that has been done in PSM 1 and PSM 2. The chapter describes as follows.

Project introduction are describe in the first chapter. This chapter includes the objectives, problem statement, project planning and scope of projects. The work flow of this project is set up according to objective and scope of projects.

In chapter two, it consists of literature review. The theory is based on the microstrip patch antenna, array antenna and electromagnetic band gap (EBG).

The methodology is described in chapter 3. In this chapter it explains the steps to complete this project. It begins with the literature review, simulation using CST software and followed by fabrication and measurement. Design procedure of the antenna is included in this chapter. Steps of simulation, fabrication and measurement process are discussing in this chapter.

Chapter 4 is about result and discussion of the project. It includes the result of measurement and simulation of the antenna. This chapter discuss regarding simulation and measurement of single patch antenna, antenna array, electromagnetic band gap and antenna array using EBG.

The last chapter concludes the project with suggestion of future work to improve the antenna and EBG structure design.

CHAPTER 2

LITERATUE REVIEW

2.1 Antenna

Antenna defined as a device that used for receiving and radiating an electromagnetic wave in free space [13]. An antenna definition according to Webster's Dictionary is "a usually metallic device for receiving or radiating radio waves" [11]. Meanwhile, IEEE defines the antenna as "a means for radiating or receiving radio waves". In IEEE the standards used is IEEE Std 145-1983 [11]. In transmitter, an antenna as a conductor element converts electrical energy to electromagnetic energy in transmitter. However, in receiver it converts the electromagnetic energy to electrical energy. There are two types of antenna which are passive antenna and active antenna. The passive antenna is reciprocal device while, active antenna is not reciprocal devices. The passive antenna can use for both radiation and receiving the signal. The performance of the antenna is determined by the centre frequency, bandwidth (BW), polarization, gain, radiation pattern and impedance [14].

2.2 Antenna Properties

There are several properties to determine antenna performance. There are gain, radiation pattern, efficiency, surface wave and bandwidth.

The radiation pattern is defined as a "radiation properties of the antenna in graphical representation as a function of space coordinates" [11]. It describes of how the antenna radiates energy and it is present in the far field. The information is presented in the form of horizontal and vertical [11]. Radiation pattern parts are referred as lobes that consist of major and minor as show in figure 2.2. Back lobes and side lobes are consider as minor lobes. A radiation lobe is a part of radiation pattern that bounded by regions of relatively weak radiation intensity. Direction of maximum radiation is major lobe. Meanwhile, minor lobe is the undesired direction of antenna radiation [11].

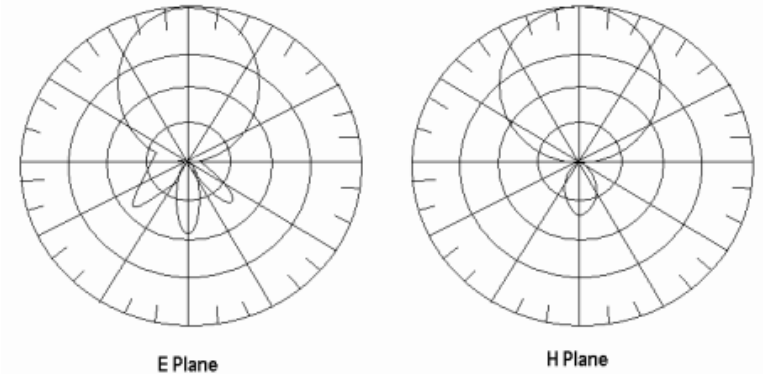

Figure 2.1: 2D radiation pattern [11].