DESIGN OF MULTIBAND ELECTROMAGNETIC BAND GAP (EBG) STRUCTURE

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This report submitted in partial fulfillment of the requirement for the award of Bachelor of Electronic Engineering (Telecommunication Electronics) With Honours.

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ABSTRACT

The research in the field of electromagnetic band gap or well known as EBG structure has becoming attractive in antenna community. This structure has a unique property such as the ability to suppress the propagation of surface wave in specific operating frequency defined by the EBG structure itself.

The aims of this project are to design, simulate and fabricate the new EBG structure operating at 2.4GHz and 5.5GHz frequency

The electromagnetic band gap structure always used as a part of antenna structure in order to improve the performance of the antenna especially for improves the gain and radiation pattern. In this project, microstrip antenna is used due to the advantages such as easy and cheap fabrication, light weight, low profile and can easily integrated with microwave circuit. This project involves the investigation of various EBG structure and the integration of the EBG structure with various antenna design through the simulation and fabrication process. The simulation is done by using microwave office software (MWO) and CST. The fabrication process involves the photo etching technique while the substrate used for antenna fabrication is FR4 board which has relative permittivity 4.7 and tangent loss 0.019.

The simulation result for Multiband Electromagnetic Band Gap (EBG) in this report.

ABSTRAK

Penyelidikan dalam bidang electromagnetic selar jalur atau lebih dikenali sebagai struktur EBG telah menjadi satu bidang yang cukup menarik dan mendapat perhatian dalam komuniti antena. Struktur ini memiliki sifat yang unik iaitu keupayaannya untuk menekan perambatan golombang permukaan untuk frekuensi kendalian tertentu yang dipengaruhi oleh struktur EBG itu sendiri.

Tujuan projek ini ialah untuk merekabentuk, simulasi and fibrikasi struktur EBG yang baru dan beroperasi pada frekuensi 2.4GHz dan 5.5GHz.

Struktur elektomagnetik selar jalur selalunya dijadikan sebahagian daripada struktur antena untuk membaiki prestasi antena terutamanya untuk meningkatkan gandaan antena dan juga membaiki corak pemancaran antena. Dalam projek ini, mikrostrip antenna digunakan kerana memiliki kelebihan berbanding antenna lain seperti mudah dan murah untuk membuat reka bentuk, ringan, strukturnya yang nipis, dan juga mudah untuk dipadukan dengan litar gelombang mikro. Projek ini melibatkan teknik mengikisan cahaya manakalan substrat yang digunakan ialah FR4 yang mempunyai kebertelusan relatif 4.7 dan kehilangan tangen 0.019.

Keputusan dari simulasi struktur Eletro Magnetik Selar Jalur (ebg) dalam pelbagai jalur telah ditunjukkan di dalam laporan ini.

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C	-	Speed of Light
E	-	Electric Field
H	-	Magnetic Field
Z	-	Impedence
ε	-	Permittivity
μ	-	Permeability
λ	-	Wavelength
β	-	Propagation Constant
σ	-	Conductivity of Metal
η	-	Normalized wave impedence
Γ	-	Reflection Coefficient

CHAPTER 1

INTRODUCTION

1.1 Introduction

Antenna is one of the important elements in the RF system for receiving or transmitting the radio wave signals from and into the air as the medium. Without proper design of the antenna, the signal generated by the RF system will not be transmitted and no signal can be detected at the receiver. Antenna engineering is a vibrant field which is bursting with activity and is likely to remain so in the foreseeable future. Many types of antenna have been designed to cater with variable application and suitable for their needs. One of the types of antenna is the microstrip antenna. The microstrip antenna has been said to be the most innovative area in the antenna engineering with its low material cost and easy to fabricate which the process can be made inside universities or research institutes.

Microstrip patch antennas have been an attractive choice in mobile and radio wireless communication. This is because they have advantages such as low profile, conformal, low cost and robust. However, at the same time they have disadvantages of low efficiency, narrow bandwidth and surface wave losses.

The birth of the electromagnetic band gap structure has triggered many novel antennas applications. Two commonly employed features are suppressing unwanted substrate modes and acting as an artificial magnetic ground plane. Today, many antennas are required to be small and broadband. Conventionally, in order to achieve small size and broadband operation patch antenna are fabricated on a thick piece of high permittivity substrate. There are two major disadvantages in this, firstly, the higher the relative permittivity of a material the more costly it would be. Second, unwanted substrate modes begin to form and propagate towards the edges of the substrate, which have a deleterious effect on the antenna radiation pattern. One can expect an increase in back radiation level, distortion of the main lobe and side lobes appearing.

In the 1990s, researches suggested the introduction of an electromagnetic band gap structure into the printed antenna substrate, which saw the capability of removing unwanted substrate modes. This EBG substrate has two commonly employed configurations namely the perforated and metallodielectric structures. The former consists of the periodic arrangement of air-columns. The effectiveness of the perforated structure relies on the high refractive index contrast between the air-columns and the relative permittivity of the dielectric material and the type of the lattice to use. For broadband and small volume mobile communication applications, the honeycomb-lattice was shown to be of good potential

1.2 Problem Statement

In the microstrip antenna design, the main problem to be faced is the propagation of surface wave on the substrate. The propagating of surface wave will reduce the efficiency of the antenna. This is due to the increasing of the side and back radiation. The front radiation is decreasing and the antenna gain is decreasing. In the array design, another problem occurred. Mutual coupling effect will occur when more than one element placed near each other. This problem occurs in the E-plane direction of the microstrip antenna. This project introduces an EBG structure to reduce the effect of surface wave and mutual coupling. The radiation pattern and the return loss of the antenna will be obtained by simulation. The antenna properties such as HPBW, co-polar, cross-polar and gain in both antennas with and without EBG structure will be investigated in both simulation and measurement.

1.3 Objectives

The main objective of this project is to design and develop Electromagnetic band gap for microstrip antenna application. Next, the behavior and properties of EBG structure will be investigated by simulation using CST or MWO Software.

1.4 Scope of Project

This project focuses on the development of the antenna to meet the satisfied performance that can be used in WLAN system. The first part of the project is to study the concept of electromagnetic band gap (EBG) structure. In the second part of the project, the performance of the EBG structure will be investigated by performing numerical simulation using microwave office Software (MWO) or CST. The antenna will be designed to operate at frequency of 2.4 GHz and 5.5GHz. The band gap characteristic of EBG structure must cover the bandwidth of the microstrip antenna to improve the performance.

1.5 Project Background

EBG structure recently is developed rapidly due to its unique properties to suppress the propagation of surface wave in microstrip antenna. EBG structure is also known as a high impedance surface due to its ability to suppress the propagation of surface wave at the certain operational frequency. This structure is also has ability to block the effect of mutual coupling effect in array application. Due to its unique properties defined by the structure itself, this project will be done to see the ability of the EBG structure to improve the performance of antenna especially in term of radiation pattern and gain.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Antenna is a device used for radiating and receiving an electromagnetic wave in free space. The antenna seems to be an interface between transmission lines and free space. Antenna is divided into two categories that are passive antenna and active antenna. Passive antenna is the reciprocal devices. It can be used whether for transmitting or receiving the information signal. Active antenna is not the reciprocal devices. The simple antenna is like the isotropic antenna where it can radiate signal for all direction but it is not practical built because the practical antenna is a half wave dipole antenna. Antennas can be categorized into 9 types which are:

i. Active integrated antennas
ii. Antenna arrays (including smart antennas)
iii. Dielectric antennas (such as dielectric resonant antennas)
iv. Microstrip antennas (such as patches)
v. Lens antennas (sphere)
vi. Wire antennas (such as dipoles and loops)

vii. Aperture antennas (such as pyramidal horns)
viii. Reflector antennas (such as parabolic dish antennas)
ix. Leaky wave antennas

2.2 Antenna properties

When dealing with RF antenna, some important concept should be learnt to design a good antenna performance. There are polarization, radiation pattern, half power beam width (HPBW), gain, voltage standing wave ratio (VSWR), efficiency and bandwidth.

Polarization is the physical orientation of the antenna in a horizontal or vertical position. Horizontal Polarization mean the electric field is parallel to the ground while vertical Polarization mean the electric field is perpendicular to the ground. Antenna is not being able to communicate effectively with each other if the polarized is not in the same way.

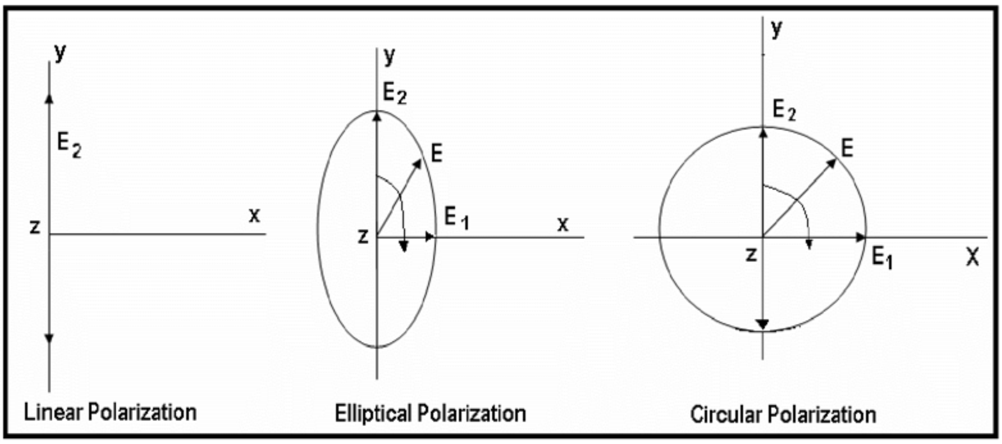

Figure 2.1: Orientation of the radiated wave's electrical field

Radiation pattern provides information which describes how an antenna directs the energy it radiates and it is determined in the far field region. The information is presented in the form of a polar plot for both horizontal (azimuth) and vertical (zenith or evaluation) sweeps. There are four quantitative aspects will be define in radiation pattern such as 3 dB beam width, directivity, side lobe levels and front to back ratio. The radiation pattern could be divided into main lobes, side lobes and back lobes.

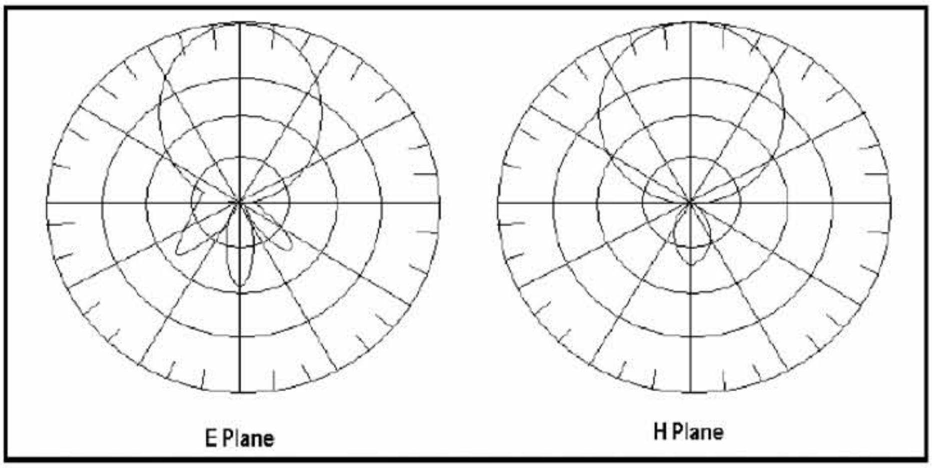

Figure 2.2: 2D radiation pattern

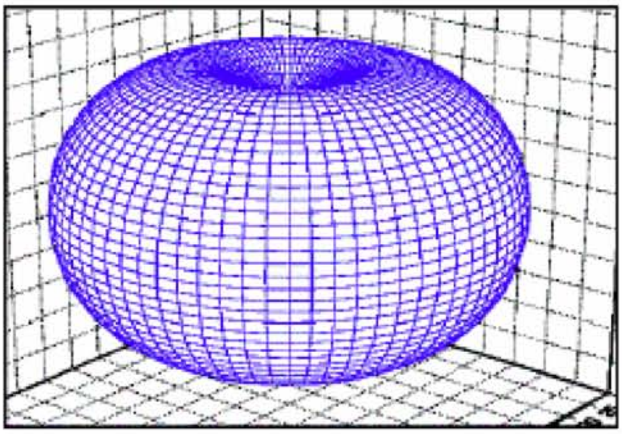

Figure 2.3: 3D radiation pattern

Beam width is a measure of the angular spread of the radiated energy or of the angular spread from which energy can readily be received the “width” of the RF signal beam that the antenna transmits. There are two type of beam width where both are measure in degrees. Firstly is the horizontal beam width which means it is perpendicular to the earth surface and another one is vertical beam width where it is parallel to earth surface. By controlling the width of the beam, the gain of antenna can be increased or decreased. By narrowing the beam width, the gain will increase and it is also creating sectors at the same time.

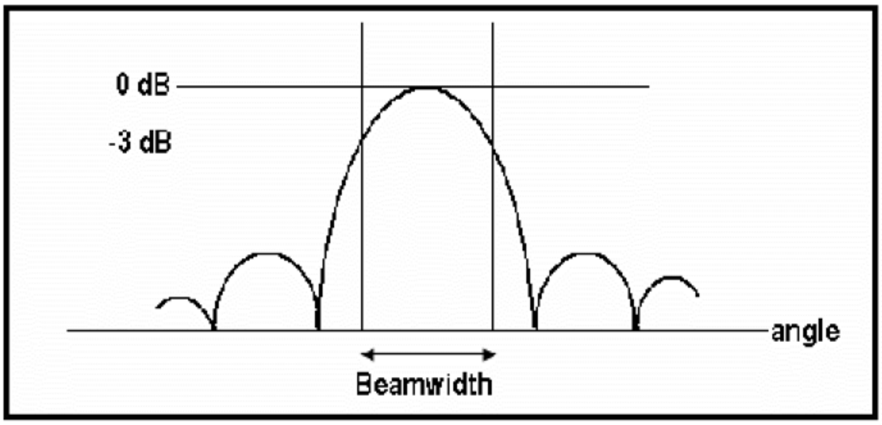

Figure 2.4: Beamwidth

The gain of the antenna can be described as how far the signal can travel through the distance. When the antenna has a higher gain it does not increase the power but the shape of the radiation field will lengthen the distance of the propagated wave. The higher the gain, the farther the wave will travel concentrating its output wave more tightly. The gain of an antenna must equal to its directivity if the antenna 100% in all efficient. Normally there are two types of reference antenna can be used to determine the antenna gain. Firstly is the isotropic antenna where the gain is given in dBi and secondly is the half wave dipole antenna where the gain is given in dBd. The relationship between dBi and dBd is given by;

$$dBi = dBd + 2.15 \text{ dB} \quad (2.1)$$

For all types of antenna, the gain can be determined by;

$$G = \frac{4\pi A_c}{\lambda^2} \tag{2.2}$$

Bandwidth refers to the range of frequency that the antenna will radiate efficiently where the antenna meets a certain set of specification performance criteria. When antenna power drop to half (3 dB), the upper and lower extremities of these frequency have been reached and the antenna no longer perform satisfactorily. The formula relates the bandwidth for the graph showed at figure 2.5 is given by;

$$BW = \frac{(f_2 - f_1)}{\sqrt{f_2 + f_1}} \times 100\% \tag{2.3}$$

The bandwidth is measured for return loss value below -10 dB

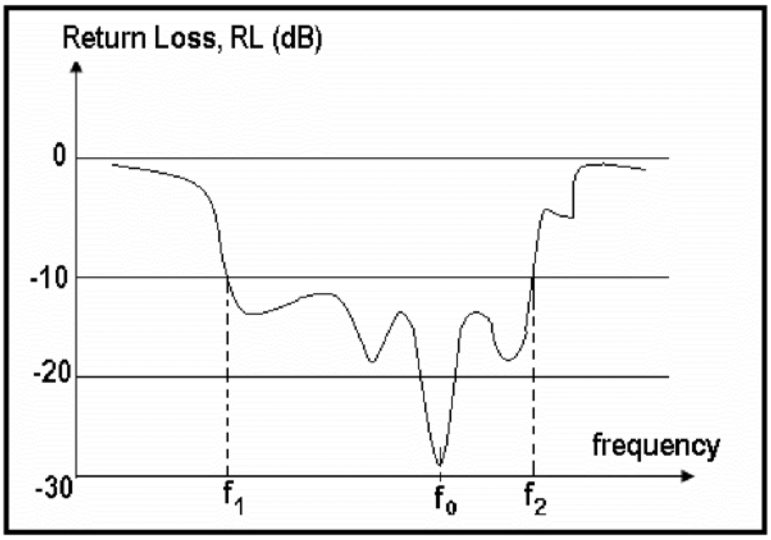

Figure 2.5: Graph of Return Loss vs frequency