ELECTROMAGNETIC BAND GAP (EBG) STRUCTURE

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This report is submitted in partial fulfillment of the requirements for the award of Bachelor of Electronic Engineering (Telecommunication Electronic) With Honours

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April 2009

"I hereby declare that this report is the result of my own work except for quotes as cited in the references."

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Date	:

Dedicated, in thankful appreciation for support, encouragement and understandings to my beloved mother, father, and friends for give me support to get through this journey in my project and further studies.

ACKNOWLEDGEMENT

Alhamdulillah, praise be to Allah, the Cherisher and Sustainer of world, most Gracious, most Merciful Lord. Praise be to Allah for enabling me to complete this analysis and research for Electromagnetic Band Gap (EBG) structure project and report for my final year project.

First and foremost, I would like to express my heartily gratitude to my supervisor, Mr. Mohamad Zoinol Abidin Bin Abd. Aziz for giving the guidance and enthusiasm throughout the progress of this project.

My appreciation also goes to my family who has been so tolerant and supports me all these years. Thanks for their encouragement, love and emotional supports that they had given to me.

Nevertheless, my great appreciation dedicated to my entire friend for supporting me steadfastly and their appreciated advice through my final year project completion.

ABSTRACT

In antenna design, there are surface waves that cannot propagate along the substrate. An increase amount of radiated power couples to space waves reducing antenna losses while increasing its gain and bandwidth. The Electromagnetic Band Gap (EBG) structures are periodic structures in which propagation of electromagnetic waves is not allowed in a specified frequency band. In this project, EBG structure had been designed in order to apply in antenna design to suppress surfaces waves and improve the radiation performance of the antenna. In designing EBG structure, the method had been used is finite difference time domain (FDTD). This EBG is designed by using microstrip. Then, the simulation process is done by using Computer Simulation Technology (CST). The purpose to simulate the design is to analyze antenna parameters, such as return loss, gain, radiation pattern and others. Various types and shapes of EBG structures had been designed such as circular, square and triangular EBG structures. Each shape is designed in two different conditions, such as EBG structures on same and different layer with microstrip patch antenna. From these designs, five EBG structures circuits were fabricated with different layer with microstrip patch antenna. Simulations and measurements show that EBG structure can achieve the lower return loss (<-10dB) compared to a microstrip without EBG structure.

ABSTRAK

Projek yang akan direka ialah struktur ‘*Electromagnetic Band Gap (EBG)*’. Struktur ‘*EBG*’ ialah struktur yang berkala di mana penyebaran gelombang elektromagnetik tidak dibenarkan dalam jalur frekuensi yang khusus. Jadi, untuk melaksanakan projek ini, struktur ‘*EBG*’ akan direka untuk diaplikasikan dalam reka bentuk antenna, di mana rekaan ini akan membantu menahan gelombang permukaan dan meningkatkan persembahan radiasi antena. Dalam projek ini, struktur *EBG* telah direka dalam perintah bagi memohon dalam reka bentuk antena untuk menumpas permukaan-permukaan gelombang-gelombang dan meningkatkan sinaran prestasi antena. Dalam mereka struktur EBG, kaedah yang telah digunakan adalah domain masa beza terhingga (FDTD). EBG ini telah direkabentuk menggunakan mikrostrip. Kemudian, untuk menjalankan projek ini, proses simulasi adalah dibuat dengan menggunakan *Computer Simulation Technology (CST)*. Tujuan untuk mensimulasi reka bentuk adalah bagi menganalisa antena parameter, seperti kehilangan balikan, pertambahan, pola sinaran dan lain-lain. Bermacam-macam jenis dan bentuk-bentuk bagi struktur-struktur EBG telah direka seperti bulat, empat segi dan segitiga. Tiap-tiap satu rupabentuk adalah direka dalam dua keadaan yang berbeza, seperti struktur-struktur EBG pada lapisan sama dan berbeza dengan mikrostrip antena. Daripada rekaan-rekaan ini, lima struktur-struktur EBG litar-litar direka dengan lapisan berbeza dengan mikrostrip antenna. Keputusan simulasi dan pengukuran struktur EBG boleh mencapai kehilangan balikan lebih rendah (<-10dB) disamakan ke satu mikrostrip tanpa struktur EBG.

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LIST OF ABBREVIATION

EBG	-	Electromagnetic Band Gap
CST	-	Computer Simulation Technology
FR4	-	Flame Retardant 4
FDTD	-	Finite Difference Time Domain
IEEE	-	Electrical and Electronics Engineers
EM	-	Electromagnetic
GPS	-	Global Positioning System
PEC	-	Potential Equalization Clamp
MTL	-	Multi Transmission Line
MoM	-	Method of Moments
FEM	-	Finite Element Method
L	-	Inductance
C	-	Capacitor
Z_p	-	Impedance for each periodic element
X_c	-	Coupling capacitor
Z_0	-	Initial impedance
a_1	-	Period of lattice
a_2	-	Period of lattice
L	-	Length
W	-	Width

c	-	Speed of light
f_0	-	Resonant frequency
ε_r	-	Dielectric substrate
ε_{eff}	-	Effective dielectric constant
L_{eff}	-	Effective length
ΔL	-	Length extension
h	-	Height
d	-	Thickness
ℓ	-	Length
r	-	Radius of lattice

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CHAPTER I

INTRODUCTION

1.1 Project Background

The Electromagnetic Band Gap (EBG) terminology has been suggested based on the photonic band-gap (PBG) phenomena in optics that are realized by periodical structures The EBG materials provide frequency bands or also can called bandgaps or stopbands inside which waves cannot propagate in the materials [1]. Electromagnetic Band Gap (EBG) structure is known as objects that prevent the propagation of the electromagnetic waves in a specified band of frequency for all angles and for all polarization state.

Surface wave is a mechanical wave that propagates along the interface between differing media, usually two fluids with different densities. A surface wave can also be an electromagnetic wave guided by a refractive index gradient.

1.2 Objective

The objectives of this project are to design an EBG structure that can suppress surface waves and improve the radiation performance of the antenna. The lower return loss (S_{11}) will be obtained by suitable lattices of EBG structure. Then the performance of the antenna will be measure based on its return loss, and radiation pattern.

1.3 Problem Statement

In antenna design, there are surface waves that cannot propagate along the substrate. An increase amount of radiated power couples to space waves reducing antenna losses while increasing its gain and bandwidth. The EBG structures are designed to suppress surface waves and improve the radiation performance of the antenna [2].

1.4 Scope of Work

The EBG structure is designed for different shapes, such as circular, square and triangular by using microstrip technique and method of finite difference time domain (FDTD) for antenna application [3]. Computer Simulation Technology (CST) is used to carry out the value of return loss, radiation pattern, gain, directivity and others parameters value of EBG structure. Then, the EBG structure circuit is fabricated on flame retardant 4 (FR4) board by using chemical etching technique. After that, network analyzer is used in order to measure the value of return loss at the resonant frequency. The value of gain and radiation pattern is also measured by using spectrum analyzer.

CHAPTER II

LITERATURE REVIEW

In this chapter, the literature reviews that had been researched are studied to understand more about Electromagnetic Band Gap (EBG) structure, and how to design it. The literature reviews that had been reviewed are closely related to the project.

2.1 Surface Wave

A surface wave is one that propagates along an interface between two different media without radiation, such radiation being construed to mean energy converted from the surface wave field to some other form [5].In surface waves, there have electric and magnetic field components, which is excited by different sources.

In order to suppress surface wave propagation, there were some techniques which can be use, such as special antenna designs, micromachining the substrate and employing electromagnetic band gap structure. The lack of availability of direct methods for investigating surface waves is becomes a problem in solving the suppression surface wave [6].

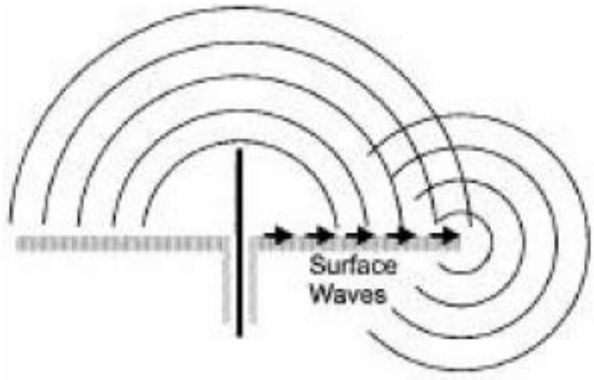

Figure 2.1 Surface waves lead to multipath [4]

2.2 Introduction EBG structure

In current years, there have many researches that have been done in growing interest on (EBG) structures. In solid state physics and related applied fields, a band gap, also called an energy gap or band gap, is an energy range in a solid where no electron states exist.

In electromagnetic band gap, the electromagnetic waves (EM) are transmitted. This transmission is occurred in a frequency range, which called forbidden frequency range or stop band [7]. According to the slow wave effect, EBG structures have their own property of reducing the phase velocity of EM modes, based on the frequencies near their band gap [8].

These structures have paying attention on a great deal of interest among researches due to their ability to influence the propagation of electromagnetic waves. The unique electromagnetic properties of EBG structures have led to a wide range of applications in antenna engineering. This section summarizes several typical EBG applications in antenna designs in the hope of stimulating discussions and new avenues of research in this area.

Surface waves are by-products in many antenna designs. Directing electromagnetic wave propagation along the ground plane instead of radiation into free space, the surface waves reduce the antenna efficiency and gain. The diffraction of surface waves increases the back lobe radiations, which may deteriorate the signal to noise ratio in wireless communication systems such as Global Positioning System (GPS) receivers. In addition, surface waves raise the mutual coupling levels in array designs, resulting in the blind scanning angles in phased array systems. The band gap feature of EBG structures has found useful applications in suppressing the surface waves in various antenna designs. For example, an EBG structure is used to surround a microstrip antenna to increase the antenna gain and reduce the back lobe. In addition, it is used to replace the quarter-wavelength choke rings in GPS antenna designs. Many array antennas also integrate EBG structures to reduce the mutual coupling level [9].

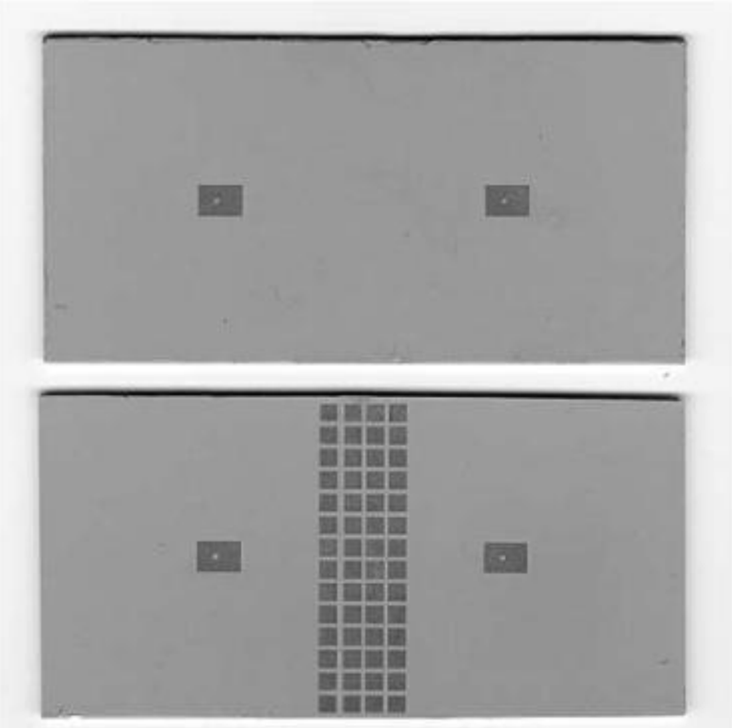

Figure 2.2 EBG substrate for surface wave suppressions: low mutual coupling microstrip array design [9].

Another favorable application of EBG is to design low profile wire antennas with good radiation efficiency, which is desired in modern wireless communication systems.

When an electric current is vertical to a Perfectly Electric Conducting (PEC) ground plane, the image current has the same direction and reinforces the radiation from the original current. Thus, this antenna has good radiation efficiency, but suffers from relative large antenna height due to the vertical placement of the current. To realize a low profile configuration, one may position a wire antenna horizontally close to the ground plane.

However, the problem is the poor radiation efficiency because the opposite image current cancels the radiation from the original current. In contrast, the EBG surface is capable of providing a constructive image current within a certain