Simulation and Analysis of Defected Ground Structure (DGS) as a Quarter Wavelength at 2.4 GHz band

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

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May 2011

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

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Dedicated to my beloved family especially my father and mother, lecturer, and also to all my friends

ACKNOWLEDGEMENT

First and foremost, I would like to praise God for His blessing. He gave me physical and mental strength to carry on my final year project up to completion.

I would like to express gratitude and thanks to my supervisor, Mr. Noor Azwan Shairi for his support and unfailing patience throughout the duration of the project. His encouragement and guidance are truly appreciated. Otherwise, this project has not been possible. I have learnt a lot under her guidance, be it practically or theoretically.

Other than that, I am also grateful to my all friends who help me and giving me opinion along implementation of this project.

I would like to thanks my parents on their moral support as I can count on them whenever I am upset or down.

Finally, I would like to offer thanks and deepest gratitude from the bottom of my heart for all the support, encouragement and inspirations I obtained throughout the duration of this project. The help rendered to me priceless, be it from the smallest of its kind to the largest.

ABSTRACT

DGS which is known as defected ground structure has been an increasing interest in studying microstrip lines with various etched defect on ground plane that prohibit wave propagation in certain frequency bands. The proposed DGS unit structure can provide the band gap characteristic in some frequency bands with only one or more unit lattice. By using a simple circuit analysis method, the equivalent circuit parameters are extracted. By employing the extracted parameters and circuit analysis method, the band gap effect for the provided defected ground structure can be explained. The low pass filters can be designed and implemented by using the derived and extracted equivalent circuit and parameter. Lastly, the overall results are an efficient and accurate means to produce the complete equivalent models of DGS circuit for the design of various RF, and microwave circuit which may require the high accurate design procedures.

ABSTRAK

DGS dikenali sebagai berpaling tadah struktur bawah telah menjadi satu faedah yang meningkatkan minat dalam belajar baris-baris mikrojalur dengan menjelma pelbagai jenis kecacatan bergores pada satah bumi yang melarang perambatan gelombang dalam kumpulan-kumpulan frekuensi tertentu. Struktur unit DGS yang telah dicadangkan boleh menyediakan jurang jalur biasa dalam beberapa jalur-jalur frekuensi dengan hanya satu atau lebih kekisi unit. Kaedah analisis litar mudah telah digunakan bagi mengenal pasti parameter litar adalah setara dan berpaling tadah struktur bawah dapat dijelaskan. Penapis lulus rendah boleh direka serta dilaksanakan dengan menggunakan terbitan dan mengambil litar setara serta parameter. Akhir sekali, keputusan secara keseluruhan adalah cekap dan tepat bagi menjanakan model-model setara lengkap litar DGS dengan memperkenalikan pelbagai jenis bentuk radio frequenksi , dan gelombang mikro litar yang memerlukan prosedur-prosedur reka bentuk tepat tinggi itu.

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LIST OF ABBREVIATION

DGS	Defected Ground Structure
PBG	Photonic band-gap
ADS	Advanced Design System
EM	Electromagnectic
RF	Radio Frequency
AC	Alternating Current
MW	Microwave
3D	Three Dimensions
TL	Transmission Line

CHAPTER I

INTRODUCTION

1.1 Background

In past few years, Defected Ground Structure (DGS) has played an important role in radio frequency/microwave circuits. The first defected ground structure was proposed in 1999 which based on the idea of photonic band-gap (PBG) structure and its application can be found in the design of planar circuits and low pass filter [1]. However, it is difficult to use a PBG structure for the design of microwave components due to the difficulties of the modeling. Another difficulty in using the PBG circuit is caused by the radiation from the periodic etched effects [5]. A DGS is where the ground plane metal is purposely modified with certain geometry to enhance performance. A variety of slot geometry is realized by etching a defective pattern in the ground plane which disturbs the shield current distribution in the ground plane. It can also be used in various circuits with antenna, filters, delay lines, phase shifters and so on [1].

The disturbance can change the characteristic of a transmission line, such as equivalent capacitance or inductance to obtain the slow wave effect and the band stop property [6]. In a word, any defect ground structure etched in the ground plane of the microstrip can give rise to increasing effective capacitance and inductance. In order to maintain the biasing line of DGS as a quarter wavelength, physical width has to be wider and length is shorter than that of the conventional bias line.

This project will further investigate the capability of DGS as a quarter wavelength at 2.4 GHz band. It involves software called Advanced Design System (ADS) to design and simulate the DGS.

1.2 Project Objective

The objective of this project is to do the parametric studies on the DGS as a quarter wavelength by analyzing at the DGS equivalent circuit and layout.

1.3 Problem Statement

1. No detail parametric study on the phase response of DGS at quarter wavelength [1,6,10,11].
2. Most of the technical papers focus on applications of DGS [5,7,9,17].

1.4 Scopes of Project

1. Design the DGS as quarter wavelength in ADS software as an equivalent circuit and layout.
2. Simulate and analyze the DGS in equivalent circuit and EM simulation in ADS software.

1.5 Methodology

This project consists of three stages. The literature review and background study are done for the first stage such as the basic conceptions and transmission characteristics of DGS. The equivalent circuit models of varieties of DGS units are also presented. After finished the study, second stage will be precede on the equivalent circuit and EM simulation by using Advanced Design System (ADS). Next, simulation results are compared by analysis the phase response of every change of parameters.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Recently, there has been an increasing interest in studying microstrip lines that prohibit wave propagation in certain frequency bands using defected ground structure (DGS) [1,2,3,4,5,6]. Therefore, DGS is an etched periodic or non-periodic cascaded configuration defect in ground of a planar transmission line such as microstrip, coplanar and conductor backed coplanar waveguide which disturbs the shield current distribution in the ground plane cause of the defect in the ground. This disturbance will change characteristic of a transmission line just like line capacitance and inductance [1].

. DGS can be realized by etching off a simple shape in the ground plane, depending on the shape and dimensions of the defect, the shielded current distribution in the ground plane is disturbed, resulting a controlled excitation and propagation of the electromagnetic waves through the substrate layer. The shape of the defect may be changed from the simple shape to the complicated shape for the better performance [5].

Different shapes of DGS have been studied such as concentric ring circle, spiral, dumbbells, elliptical and U- and V- slots. Every DGS shapes can be represented as a circuit consisting of inductance and capacitance, which can leads to a certain frequency band gap determined by the shape, dimension and position of the defect. DGS gives an extra degree of freedom in microwave circuit design and can be used for various types of applications [2].

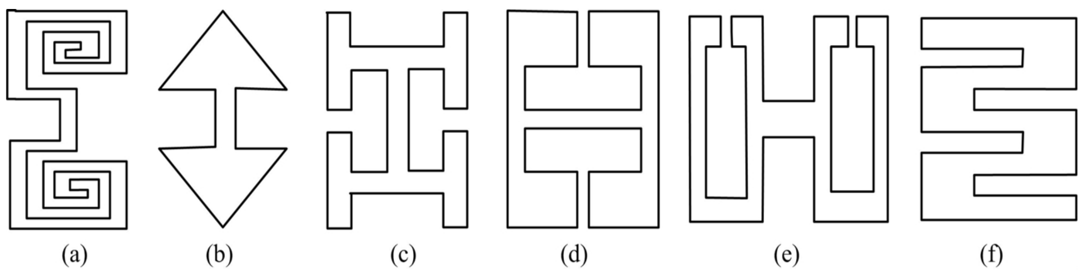

Figure 2.1: Different types of DGS: (a) spiral head (b) arrow-head slot (c) “H” shape slot (d) square open-loop with a slot in middle section (e) open loop dumbbell (f) inter-digital DGS [1]

In RF circuit, DGS provides a significant advantage by extending its applicability such in amplifiers, low pass filter, power dividers, couplers and RF switch**.** Researchers of DGSs are interested in the area of extensive capability in microwave circuit. The parameters of equivalent circuit model of DGSs were also researched and utilized to design. Many passive and active microwave and millimeter devices have been developed to suppress harmonics and realize the compact physical dimensions of circuits for the design flow of circuits with DGS comparatively simple [1].

2.2 DGS Unit Cell

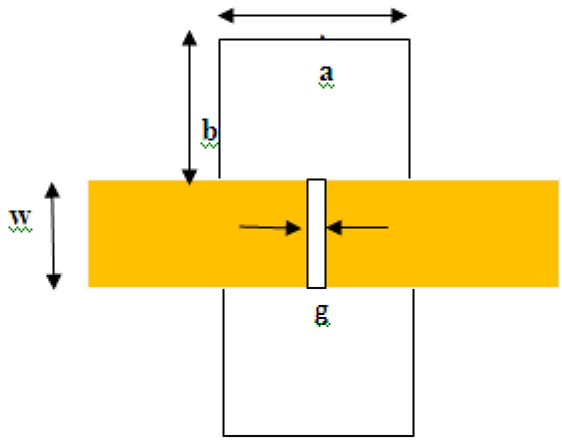

Figure 2.2 Dumbbell shapes of DGS [1].

A unit DGS (dumbbell) section is created in the ground plane as show in Figure 2.2 [5]. In many microwave circuits, the dumbbell shaped DGS pattern is commonly adopted because easy and simple to design. The dumbbell DGS are composed of two a x b rectangular defected areas, g x w gaps and narrow connecting slot wide etched area in backside metallic ground plane as shown in Figure 2.2 [1].

The DGS with the microstrip line employs and intentional defect on the ground and it provides band stop characteristic from the resonance property. The cut off frequency of the DGS is mainly dependent on the etched square area in ground plane. There is an attenuation pole location, which is due to the etched gap distance [1, 5].

An attenuation pole can be generated by combination of the inductance and capacitance elements. The frequency characteristic of the DGS section can be explained by varied the value of capacitor. The etched gap area, which is placed under a conductor line, provides the parallel capacitance with effective line inductance [1, 5, 7].

The proposed DGS section is fully describe by two parameters, they are the etched lattice dimension and the gap distance. Thus, different types of shape and slot geometries will affect the resonant frequency. Both of these will control the fundamental resonant frequency and higher order resonances [6]. To fulfill the different requirements, a variety of DGS shapes have evolved over time.

2.3 Equivalent circuit of DGS

Usually, design and analysis are two challenges for DGS. It is needed to remove the equivalent circuit parameters by applying the proposed DGS section to a practical circuit design example. In order to derive the equivalent circuit parameters of DGS unit at the reference plane, the S-parameter versus frequency should be calculated by full wave electromagnetic (EM) simulation to explain the cutoff and attenuation pole characteristic of the DGS section. At present, DGS can be equivalent by three types of equivalent circuits: (1) LC and RLC equivalent circuits, (2) π shaped equivalent circuit, (3) quasi-static equivalent circuit. For this project, the DGS will only use the LC and RLC equivalent circuit as shown in Figure 2.3 and Figure 2.4 [1].

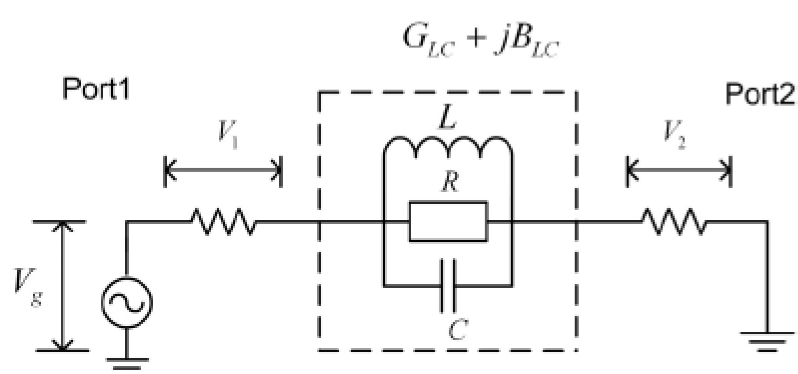

Figure 2.3: LC equivalent circuits of Dumbbell DGS [1].

The LC equivalent circuit of DGS with rectangular parts of dumbbell DGS increase route length of current and the effective inductance. The effective capacitor of the microstrip line can be increased by inserting a slot in the ground surface to accumulate the charge. Two rectangular defected areas and one connecting slot correspond to the equivalently added inductance (L) and capacitance (C) respectively. A resonance will only occur at a certain frequency because of the parallel LC circuit. As the etched area of the unit lattice increases, the effective series inductance increase and increasing the series inductance gives rise to a lower cut off frequency. When the etched gap distance increases, the effective capacitance decreases so that the attenuation pole location moves up to higher frequency [1].

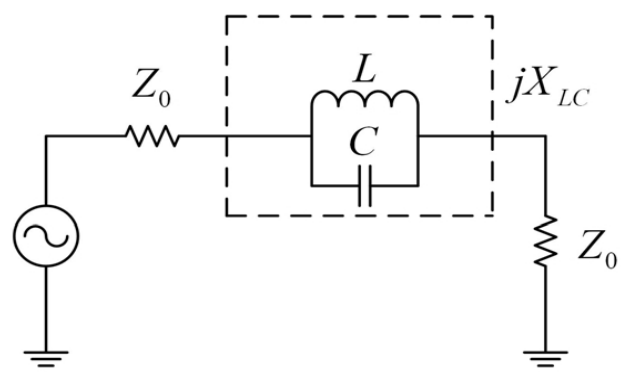

Figure 2.4: RLC equivalent circuits of Dumbbell DGS [1].

DGS can be modeled by a parallel R, L and C circuit connected to transmission lines at its both sides as shown in Figure 2.4 [1]. This resistance corresponds to the radiation, conductor and dielectric losses in the defect. The size of DGS is determined by accurate curve fitting results for equivalent circuit elements to correspond exactly to the required inductance [1].