

DESIGN OF RECONFIGURABLE DEFECTED GROUND STRUCTURE FOR MICROWAVE RESONATOR

RUSHILAWATY BINTI SULAIMAN

This report submitted in partial fulfilment of the requirements for the award of
Bachelor of Electronic Engineering (Wireless Communication) With Honours

Faculty of Electronics and Computer Engineering
Universiti Teknikal Malaysia Melaka

June 2012



UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

DESIGN OF RECONFIGURABLE DEFECTED GROUND STRUCTURE FOR
 MICROWAVE RESONATOR

Tajuk Projek :

Sesi Pengajian :

1	1	1	2	2
---	---	---	---	---

Saya RUSHILAWATY BINTI SULAIMAN

(HURUF BESAR)

mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (\checkmark) :

SULIT*

*(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

TERHAD**

** (Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD

Disahkan oleh:

 (TANDATANGAN PENULIS)

 (COP DAN TANDATANGAN PENYELIA)

Tarikh:

Tarikh:

DECLARATION

I hereby, declared this report entitled “DESIGN OF RECONFIGURABLE DEFECTED GROUND STRUCTURE FOR MICROWAVE RESONATOR” is the results of my own research except as cited in references.

Signature :
Author's Name : RUSHILAWATY BT SULAIMAN
Date :

APPROVAL

This report is submitted to the Faculty of Electronics and Computer Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electronics Engineering (Wireless Communication). The member of the supervisory committee is as follow:

.....
DR. ZHRILADHA B ZAKARIA
(Official Stamp of Supervisor)

DEDICATION

“In the Name of Allah, the most Beneficent, the Most Merciful”

Special dedication to my beloved parents,
Sulaiman B. Ishak & Hinum Bt. Lebai Hassan

My supporting brothers and sisters,

Darmadi B. Sulaiman

Dian Bt. Dominic

Mohd Husny B. Sulaiman

Mohd Hafis B. Sulaiman

Nur Farahana Bt. Ramli

Norsuhaida Bt. Sulaiman

Abu Hanifah B. Sulaiman

Muhammad Fadhil B. Abdul Rasit

*To my supervisor **Dr Zahriladha B. Zakaria,***

My friends and my fellow lecturers

Thank you for all your care, support and believe in me

ACKNOWLEDGMENT

First of all, all praise is to Allah, the Almighty, the Benevolent for His blessings and guidance had given me the inspiration to embark on this project and instilling in all of my strengths to complete this project with good health. Many obstacles were encountered during the implementation of the project but each of them has enhanced my knowledge in my field.

First and foremost, I would like to express my sincere appreciation to my supervisor, Dr Zahriladha bin Zakaria who has helped me a lot in giving ideas, opinions and positive criticism. I am grateful to have her as a supervisor and also my mentor. Her guidance and supervision will undoubtedly help me in my future undertakings.

Last but not least, I am also greatly indebted to Mr Noor Azwan bin Shairi for being such understanding and open minded for sharing and discussing knowledge until today. Thanks to those who have helped me indirectly or directly in completing this project.

ABSTRACT

Defected Ground Structure (DGS) has been used widely and they have shown increasing potential due to its drastic development for the several applications in this recent year. This project presents the reconfigurable DGS resonator fabricated on coplanar waveguide (CPW) technology. The objective of this project is to reconfigure the resonant frequencies operates at 3.5 GHz and 5.2 GHz by employing the Dumbbell-shaped DGS design on the ground plane. In order to implement, the capabilities of DGS to reconfigure at an arbitrary frequencies have been investigated. Four sets of DGS have been designed, simulated, measured and analysed. The first and second set is without PIN diode, while the rest two set is reconfigured with the PIN diode. The scope of work is divided into few parts which are research analysis, simulation, optimization, fabrication and measurement analysis of results. The DGS design is reconfigured by PIN diode operating at frequency of 3.45 and 5.54 GHz with return loss of -16.71 and -12.96 dB. The bandwidth is 1.53 and 2.28 GHz with corresponding loaded Q of 2.25 and 2.42. These indicate good return loss as the DGS transmits power above 90%. This DGS is operates from 2.39 GHz to 7.07 GHz frequency. This type of DGS is useful for applications when the undesired signal need to be removed such as radar and wideband systems. All simulated and measured frequency responses in very good agreement with each other.

ABSTRAK

Struktur Bumi Terdefek (DGS) telah digunakan dengan meluas dan mereka telah membuktikan penambahan potensi drastiknya dalam perkembangan untuk beberapa aplikasi dalam beberapa tahun terkini. Projek ini membentangkan kebolehubahan pengayun DGS yang difabrikasi ke atas teknologi sesatah pandu gelombang (CPW). Projek ini bertujuan untuk menyusun atur pengayun frekuensi pada frekuensi 3.5 GHz dan 5.2 GHz dengan menggunakan rekabentuk Dumbbell DGS pada satah bumi. Dalam tujuan untuk melaksanakannya, keupayaan DGS untuk menyusun atur pengayun frekuensi pada sembarang frekuensi telah disiasat. Empat set DGS telah direkabentuk, disimulasi, diukur dan dianalisis. Set pertama dan kedua adalah tanpa diod PIN, manakala dua set selebihnya disusun atur dengan diod PIN. Skop kerja dibahagikan kepada beberapa bahagian iaitu analisis kajian, simulasi, pengoptimuman, fabrikasi dan analisis keputusan pengukuran. Rekabentuk DGS disusun atur oleh diod PIN yang beroperasi pada frekuensi 3.45 dan 5.54 GHz dengan kehilangan kembali pada -16.10 dan -18.83 dB. Jalur lebar adalah 1.53 dan 2.28 GHz dengan kesamaan Q terbeban adalah 2.25 dan 2.42. Ini menunjukkan kehilangan kembali yang bagus dengan hantaran kuasa DGS di atas 90%. DGS ini beroperasi pada frekuensi 2.39 GHz sehingga 7.07. Jenis DGS ini boleh digunakan pada aplikasi apabila isyarat yang tidak diingini hendak dibuang seperti radar dan sistem jalur lebar. Kesemua sambutan frekuensi simulasi dan pengukuran berada dalam keadaan yang baik antara satu sama lain.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	TITLE PAGE	i
	DECLARATION	ii
	DEDICATION	iv
	ACKNOWLEDGEMENT	v
	ABSTRACT	vi
	ABSTRAK	vii
	TABLE OF CONTENTS	viii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF ABBREVIATIONS	xv
	LIST OF APPENDICES	xvii
1	INTRODUCTION	
	1.1 Project Background	1
	1.2 Problem Statement	2
	1.3 Objective of Project	2
	1.4 Scopes of Project	3
	1.5 Contribution	4
	1.6 Report Structure	4

2 LITERATURE REVIEW

2.1	Introduction	5
2.2	Defected Ground Structure (DGS) technology	5
2.3	Additional Applications of DGS	8
2.3.1	Antennas	8
2.3.2	Ultra-Wideband	8
2.4	Reconfigurable DGS	9
2.4.1	Slot Line	10
2.4.2	Lumped Element	11
2.5	Resonator	12
2.6	Equivalent Circuits of DGS	13
2.7	Types of DGS Equivalent Circuit	13
2.7.1	LC and RLC Equivalent Circuit	13
2.7.2	π Shaped Equivalent Circuit	15
2.7.3	Quasi-static Equivalent Circuit	16
2.8	Characteristics of Planar Transmission Lines	17
2.9	Coplanar Waveguide	19
2.10	Delay Line	20
2.11	Concluding Remark	20

3 METHODOLOGY

3.1	Introduction	21
3.2	Defected Ground Structure	21
3.3	Design Specification	22
3.4	Designing of Dumbbell-Shaped DGS Structure	23
3.5	Numerical Solution	24
3.6	Simulation and Analysis	24

3.7	Fabrication	24
3.8	Cutting and Drilling	25
3.9	Soldering	25
3.10	Measurement	26
3.11	Concluding Remark	27

4 DEVELOPMENT OF DGS

4.1	Introduction	28
4.2	Design of DGS1	29
4.2.1	Simulation Results	29
4.2.2	Measurement Results	30
4.2.3	Comparison between Simulated and Measured Results	32
4.3	Design of DGS2	33
4.3.1	Simulation Results	33
4.3.2	Measurement Results	34
4.3.3	Comparison between Simulated and Measured Results	36
4.4	Design of DGS3	37
4.4.1	Simulation Results (without PIN diode)	37
4.4.2	Measurement Results (without PIN diode)	38
4.4.3	Comparison between Simulated and Measured Results	39
4.4.4	Simulation Results (with PIN diode)	40
4.4.5	Measurement Results (with PIN diode)	42
4.4.6	Comparison between Simulated and Measured Results	43
4.5	Design of DGS4	44
4.5.1	Simulation Results (without PIN diode)	44

4.5.2	Measurement Results (without PIN diode)	46
4.5.3	Comparison between Simulated and Measured Results	47
4.5.4	Specification of DGS4 (with PIN diode)	48
4.5.5	Circuit Simulation Results (with PIN diode)	48
4.5.6	EM Simulation Results (with PIN diode)	50
4.5.7	Measurement Results (with PIN diode)	51
4.5.8	Comparison between Simulated and Measured Results	53
4.6	Summary of Simulated Results	54
4.7	Summary of Measured Results	55
4.8	Concluding Remark	57

5 CONCLUSION AND RECOMMENDATIONS

5.1	Conclusion	58
5.2	Recommendation	60

REFERENCES	61
-------------------	-----------

APPENDICES	64
-------------------	-----------

LIST OF TABLE

NO	TITLE	PAGE
2.1	Comparison between conventional DGS and reconfigurable DGS	9
2.2	Commonly Used Types of Planar Transmission Lines for MIC	18
4.1	Comparison of simulated and measured performances of DGS1	32
4.2	Comparison of simulated and measured performances of DGS2	36
4.3	Comparison of simulated and measured performances of DGS3 without PIN diode	40
4.4	Comparison of simulated and measured performances of DGS3 with PIN diode	44
4.5	Comparison of simulated and measured performances of DGS4 without PIN diode	47
4.6	Lumped element values for RLC circuits	50
4.7	Comparison of simulated and measured performances of DGS4 with PIN diode	53
4.8	Comparison of simulated performances of all DGS	55
4.9	Comparison of measured performances of all DGS	56

LIST OF FIGURES

NO	TITLE	PAGE
1.1	Layout of the proposed reconfigurable DGS resonator	3
2.1	Some common configurations for DGS resonant structures	6
2.2	Various types of DGS shapes	7
2.3	Lumped element parallel resonant circuit	11
2.4	Conventional design and analysis method of dumbbell DGS	14
2.5	LC equivalent circuit	14
2.6	RLC equivalent circuit for DGS unit	15
2.7	π shaped equivalent circuit for DGS unit	16
2.8	Quasi-static equivalent circuit for DGS unit	17
2.9	3D view of coplanar waveguide (CPW)	19
3.1	Project flow overview	22
3.2	Schematic diagram of proposed DGS resonator (half symmetrical view)	22
3.3	2D structure of Dumbbell-shaped DGS	23
3.4	Transformation of DGS layout into Coral Draw software	25
3.5	Fabricated DGS resonator completely soldered	26
3.6	Network analyzer and fabricated DGS under testing	27
4.1	Preliminary configuration DGS1	29
4.2	Simulated performances of DGS1	30
4.3	Fabricated DGS1	31
4.4	Measured response of DGS1	31
4.5	Simulated and measured response of DGS1	32

4.6	Layout of DGS2	33
4.7	Simulated performances of DGS2	34
4.8	Fabricated DGS2	35
4.9	Measured response of DGS2	35
4.10	Simulated and measured response of DGS2	36
4.11	Layout of DGS3 without PIN diode	37
4.12	Simulated performances of DGS3 without PIN diode	38
4.13	Fabricated DGS3 without PIN diode	39
4.14	Measured response of DGS3 without PIN diode	39
4.15	Simulated and measured response of DGS3 without PIN diode	40
4.16	Layout of DGS3 with PIN diode	41
4.17	Simulated performances of DGS3 with PIN diode	41
4.18	Fabricated DGS3 with PIN diode	42
4.19	Measured response of DGS3 with PIN diode	43
4.20	Simulated and measured response of DGS3 with PIN diode	43
4.21	Layout of DGS4 without PIN diode	45
4.22	Simulated performances of DGS4 without PIN diode	45
4.23	Fabricated DGS4 without PIN diode	46
4.24	Measured response of DGS4 without PIN diode	46
4.25	Simulated and measured response of DGS4 without PIN diode	47
4.26	Layout of DGS4	48
4.27	Equivalent circuit model	49
4.28	Circuit simulated performances	49
4.29	Simulated performances of DGS4 with PIN diode	51
4.30	Fabricated DGS4 with PIN diode	52
4.31	Measured response of DGS4 with PIN diode	52
4.32	Simulated and measured response of DGS4 with PIN diode	53
5.1	Layout of DGS4 with PIN diode	59
5.2	Simulated performances of DGS4 with PIN diode	60

LIST OF ABBREVIATIONS

DGS	-	Defected Ground Structure
CPW	-	Coplanar Waveguide
CPW-TL	-	Coplanar Waveguide Transmission Lines
PBG	-	Photonic Band Gap
LTCC	-	Low Temperature Co-fire Ceramic
LTCF	-	Low Temperature Co-fire Ferrite
SIW	-	Substrate Integrates Waveguide
UWB	-	Ultra-Wideband
WLAN	-	Wireless Local Area Network
WiMAX	-	Wireless Maximum
RF	-	Radio Frequency
UV	-	Ultraviolet
ADS	-	Advanced Design System
RLC	-	Resistance Inductance Capacitance
LC	-	Inductance Capacitance
LPF	-	Low Pass Filter
MIC	-	Microwave Integrated Circuit
RF	-	Radio Frequency
3D	-	Three Dimension
2D	-	Two Dimension
TEM	-	Transverse Electromagnetic
TE	-	Transverse Electric
EM	-	Electromagnetic

SMA - SubMiniature version A / Sub Multi Assembly

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Mathematical Modeling using Maple Software	64
B	INOTEK Exhibition 2012 Poster	65
C	INOTEK 2012 Award	66
D	Gantt Chart	67

CHAPTER 1

INTRODUCTION

1.1 Project Background

The increasing development of wireless applications introduces new requirements for transceiver architecture that feature excellent microwave performance and enhanced integration density. Since 1998, photonic band gap (PBG) structures and defected ground structures (DGS) have attracted the interest of many researchers [1]-[3].

The used of DGS technology into coplanar waveguide transmission lines (CPW-TL) compared to conventional transmission lines have many advantages such as to allow a simple reconfiguration and it is a very compact solution [4]. Furthermore, high performance, compact size and low cost often meet the stringent requirements of modern microwave communication systems. There have been some new technologies such as Low-temperature co-fire ceramic technology (LTCC), Low-temperature co-fire ferrite (LTCCF) and some new structures such as Photonic band gap (PBG), DGS, Substrate integrates wave-guide (SIW) and so on to enhance the whole quality of system [5].

In recent years, there have been several new concepts applied to distributed microwave circuits. One such technique is *defected ground structure* or DGS, where the ground plane metal of a microstrip, stripline, or coplanar waveguide circuit is intentionally modified to enhance performance.

The name for this technique simply means that a “defect” has been placed in the ground plane which is typically considered to be an approximation of an infinite, perfectly-conducting current sink. Furthermore, a ground plane at microwave frequencies is far removed from the idealized behavior of perfect ground. The additional perturbations of DGS not render as defective even though it is alter the uniformity of the ground plane [6].

1.2 Problem Statement

In fact, the conventional DGS produce the frequency response fixed at certain notch frequency. This way makes the DGS unable to act as reconfigurable for any microwave resonator. In order to overcome, this conventional DGS has been implementing with active diode as the reconfigurable component. Another problem statement is Ultra Wideband (UWB) face interferences of other signal such as WiMAX system and Wireless Local Area Network (WLAN) radio signal. In order to overcome, the DGS reconfigurable concept have been implement into the UWB system by obtaining the resonant frequency at 3.5 GHz which is for WiMAX system and 5.2 GHz for IEEE 802.11a lower band of WLAN system [8], [20], [21].

1.3 Objective of Project

The objective of this project is to design the DGS structure that can be reconfigured at any desired resonant frequencies. In order to implement, the capabilities of DGS to reconfigure at an arbitrary frequencies have been investigated. Thus, the

resonant frequency that reconfigured by PIN diode has been focuses [7]. This project have potential to be applied into the UWB application such to remove the undesired frequencies that interfere the UWB systems.

1.4 Scopes of Project

The scope of work is divided into few parts which are research analysis, simulation, optimization, fabrication, measurement analysis of results. The research processes are based on the review studies of DGS technology and it evolution in this recent year. Furthermore, the DGS development becomes popular year from year due to it renaissance implementation by the most researchers. Thus, the simulation process including the design of layout, simulation and optimize the frequency response. The simulation tools have been used is Advanced Design System 2011 (ADS) software and the DGS-shaped design that have been choose is Dumbbell-shaped design.

The fabrication part starts from printing the layout into transparent paper, UV exposure on substrate using the UV machine, etching, cutting, drilling, and soldering processes. Thus, the measurement processes have been done by measured the board using the Network Analyzer machine to obtain the frequency response.

The structure consists of a DGS resonator based on coplanar waveguide. The chosen shape of DGS design is Dumbbell-shaped which is the lattice shaped unit DGS shown in Figure 1.1.

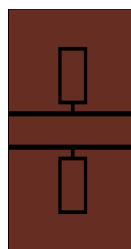


Figure 1.1: Layout of the proposed reconfigurable DGS resonator

1.5 Contribution

The contributions of this project are by applying the new discovery knowledge into the UWB system and for RF and microwave engineering fields. The expansion of this knowledge gives breakthrough to the society needs and country development. Besides, this project development may benefit to the institution and industries in Malaysia as well.

1.6 Report Structure

This report contains five chapters. Chapter 1 describes the background, problem statement, objectives and scope of the project.

Chapter 2 presents the brief theory of DGS and related literature review in designing the Dumbbell-shaped DGS structure.

Chapter 3 describes the methodology of the project which includes the design specification and procedure flow process.

Chapter 4 presents the simulation and measurement results. The results obtained are analysed and discussed.

The final chapter concludes the report and recommendations for further work are given.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to provide a review of past research effort relate to DGS technology, reconfigurable DGS, resonator, coplanar waveguide and the process used in this study. The chapter begins with the discussion of fundamentals of DGS. A review of other relevant research studies is also provided. The review is organized chronologically to offer sight to how past research efforts have laid the groundwork for subsequent studies, including the present research effort. The review is detailed so that the present research effort tailored to the present body of literature as well as to justify the scope and direction of the present research effort.

2.2 Defected Ground Structure (DGS) technology

DGS is an etched periodic or non-periodic cascaded configuration defect in ground of a planar transmission line (e.g., 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 characteristics of a transmission line such as line capacitance and inductance.

In a word, any defect etched in the ground plane of the microstrip can give rise to increasing effective capacitance and inductance [5]. DGS also attractive for band rejection which is remove the unwanted frequency and controllable center frequency through controlling one physical dimension of the DGS pattern [9].

The basic element of DGS is a resonant gap or slot in the ground metal, placed directly under a transmission line and aligned for efficient coupling to the line. Figure 2.1 shows several resonant structures that may be used. Each one differs in occupied area, equivalent RLC ratio, coupling coefficient, higher-order responses, and other electrical parameters. A user will select the structure that works best for the particular application [6].

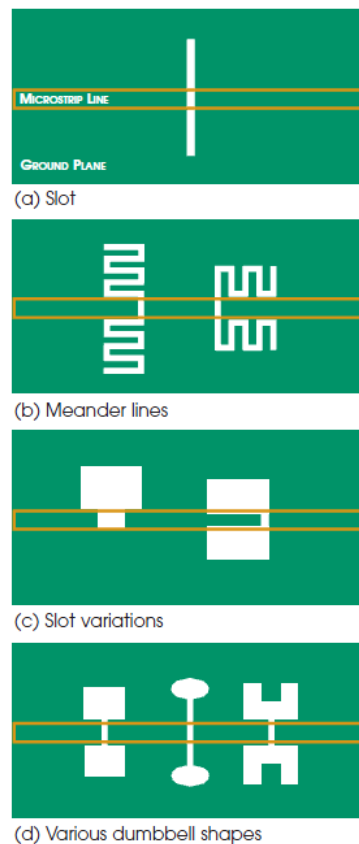


Figure 2.1: Some common configurations for DGS resonant structures [6]