Defected Ground Structure with Circle Dumbbell Shape as a Quarter Wavelength

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This report is submitted partial fulfillment of the requirement for the award of Bachelor of Electronic Engineering (Industrial Electronics/ Telecommunication Electronics/ Computer Engineering/ Wireless Communication) With Honours

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka (UTeM)

APRIL 2011

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : **DEFECTED GROUND STRUCTURE WITH CIRCLE DUMBBELL SHAPE AS A QUARTER WAVELENGTH**

Sesi Pengajian: **2010/ 2011**

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Especially for

My beloved mom and dad

My family

My supervisor

MR. NOOR AZWAN BIN SHAIRI

All beloved friends

Thanks for everything...

ABSTRAK

Projek ini merupakan sebuah projek yang melibatkan pengubahsuaian garis siaran bagi meningkatkan keboleh-upayaan siaran walaupun memiliki litar yang lebih kecil berbanding litar yang telah sedia ada. Pengubahsuaian ini dilakukan pada bahagian dasar sesebuah garis siaran jalur mikro di mana satu gangguan yang diberi nama Defected Ground Structure (DGS) atau gangguan struktur dasar akan diletakkan sejajar dengan garis siaran bagi membolehkan sifat gelombang terarah berubah. Peningkatan ini akan menyebabkan peningkatan pada kapasitan dan aruhan di mana peningkatan ini peningkatan ini akan menyebabkan peningkatan kesan gelombang perlahan (*slow-wave effect*). Hasil daripada perubahan ini akan dapat mengurangkan saiz litar untuk sesebuah aplikasi seperti antenna, penapis dan suis. Litar DGS ini akan direka untuk keupayaan sebagai gelombang suku pada jalur 2.4GHz. Setelah kesemua dasar-dasar ini dikaji dan difahami, litar untuk DGS akan dibentuk serta dilakukan simulasi ke atasnya sebelum ianya direalisasikan di atas papan litar bercetak FR4. Akhir sekali, ujian akan dilakukan ke atas prototaip DGS yang telah siap dicetak atas papan FR4 untuk memperolehi hasil sebelum dianalisa keupayaan sebagai gelombang suku pada 2.4 GHz.

ABSTRACT

The purpose of this project is to investigate the capability of Defected Ground Structure (DGS) with circle dumbbell shape as a quarter wavelength at 2.4 GHz band. This project involves with the studies of microstrip lines that prohibit wave propagation in certain frequency bands using defected ground structure (DGS). Theoretically, the ground plane structure of microstrip line can be modified to improve electrical performance and reduce the microstrip circuit size. Microstrip line with DGS has much higher impedance and increased slow-wave factor as compare to the conventional transmission lines. DGS is realized by etching a defective structure pattern in the ground plane which disturbs the shield current distribution. This disturbance can change the effective capacitance and inductance to obtain the slow-wave property. The circle dumbbell shaped DGS has been selected for this project as the transverse slot in the DGS. When the value of capacitance is increase the gap (g) will decrease. Increase the inductance will increase the radius (r) of the circle.

ACKNOWLEDGEMENT

I would like to gratitude and express my appreciation to all organizations and individuals who have kind heartedly contributed to my final year project in Universiti Teknikal Malaysia Melaka (UTeM). With the cooperation from all parties, the objectives of the project were achieved precisely to the expected outcome Additionally, I would like to give a honored thanks to Mr. NooR Azwan Bin Shairi for supervise me with the proper guidance and full cooperation in any phase of the project especially in solving the problems that occurs from first to last of my final year project. Furthermore, I would like to thanks to my parents and family who have support me for all this years with their love and caring in term of moral, financial and advice through this project. Lastly, my appreciation goes to my fellow links in UTEM, especially from FKEKK Computer Engineering department and all beloved friends. Their compliance in giving suggestions and technical support are valued while doing upon completion of my final year project. This project has achieved all the objectives and successfully done.

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CHAPTER 1

INTRODUCTION

1.1 Background

There have been increasing interests in studying microstrip lines that prohibit wave propagation in certain frequency bands using defected ground structure (DGS). DGS is implemented by modifying guided wave characteristics where it changes the propagation constant. DGS is realized by etching only a few areas on the ground plane under the microstrip line. Basically, the element of DGS is the resonant gap or slot in the ground metal, which placed directly under the transmission line and aligned for efficient coupling to the line. This project will further investigate the capability of DGS with circle dumbbell shape as a quarter wavelength at 2.4 GHz band. This project will use simulation tool to design and simulate the DGS. Then the prototype of DGS will be realized on FR4 board.

1.2 Project Objective

The objective of this project is to investigate the capability of DGS with circle dumbbell shape as a quarter wavelength at 2.4 GHz band. Then, this project will focus on the design and simulation of the DGS and finally realize the prototype on FR4 board.

1.3 Problem Statement

In literature review, there is a DGS with square dumbbell shape designed as a quarter wavelength. 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. DGS is realized by etching only a few defects on the ground plane which is used to reject a specific frequency band and reduce the circuit size of the high power switch [1]. This project will focus on using DGS with circle Dumbbell shape as a quarter wavelength which followed by realizing the prototype on FR4 board.

1.4 Project Scope

i. Studies the knowledge involved in this project such as Smith Chart and parameter in the DGS such as Scatting-Parameter, L-C Ratio and coupling coefficient.

ii. Design the DGS as quarter wavelength in ADS software as an equivalent circuit and layout.

iii. Simulate and analyze the DGS as a quarter wavelengths in the equivalent circuit and EM simulation in ADS software.

iv. Fabricate the selected DGS layout on FR4 board.

v. Test and measure the DGS performance using network analyzer for S-parameter performance.

CHAPTER 2

LITERATURE REVIEW

2.1 Defected Ground Structure (DGS)

There has been growing interest of research in the area of DGS, Defected Ground Structure in last few years and they have shown increasing potential for implementation in several applications. Applications of DGS in filtering circuits have several advantages such as circuit size reduction and suppression of spurious response. In order to achieve the requirement of high performance and compact filtering, various types of DSG resonators have been used earlier. DGS have been used for the implementation of the spurious response of the microstrip low pass filter and coupled band-pass filter. DGS can also be used as a building block of the filter; they are rather viewed to improve the response of filters, couplers and oscillators[1].

DGS is an etched periodic or non-periodic cascaded configuration defect in the ground of a planar transmission line such as microstrip, coplanar and conductor backed coplanar wave guided. DGS will disturb 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 [5]. In a word, any defect etched in the ground plane of the microstrip can give rise to increasing effective capacitance and inductance.

The isometric view of a conventional Defected Ground Structure is shown in Figure 2.1[2]; the surface current distribution on the ground plane resembles Figure 2.2. Taking this as the reference the ground plane of the DGS can be truncated as shown in Figure 2.3. The Frequency response of Figure 2.1 and Figure 2.3 being exactly the same, we would further the analysis of Fig. 3 in the light of different microstrip discontinuities.

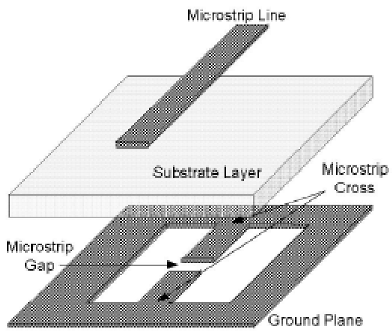

Figure 2.1: Isometric view of dumbbell shaped DGS

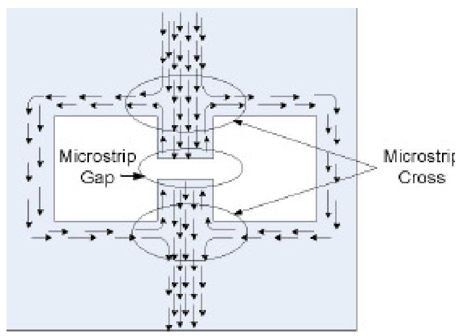

Figure 2.2: Distribution of surface current on the Ground Plane of a unit cell DGS

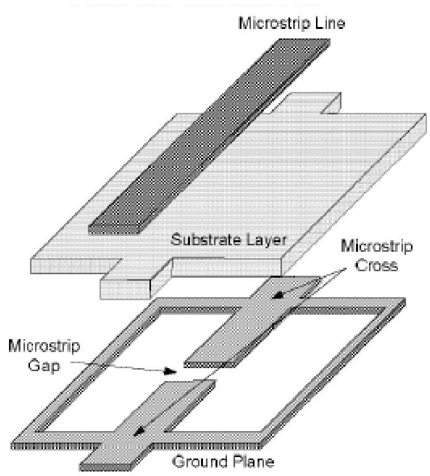

Figure 2.3: Truncated Structure according to distribution of current on surface of ground plane

The DGS with Circle Dumbbell Shape has two circular areas on both sides. The area of circle is depending to the radius *r, g x w* gaps and a narrow connecting slot wide etched areas in backside metallic ground plane.

Figure 2.4 shows several resonant structures that may be used [9]. The basic element of DGS is a resonant gap or slot in the ground surface (Figure 2.4a), placed directly under the transmission line and aligned for efficient coupling to the line. The dumbbell-shaped DGS (Figure 2.4b) includes two wide defected areas connected by a narrow slot. The conventional dumbbell-shaped DGS has been modified into an I-shaped DGS, as shown in Figure 2.4c. The frequency control of the I-shaped DGS is accomplished by adjusting the length of the transverse slot and the dimensions *a* and *b*. The stop-band characteristic of the DGS in Figure 2.4c depends on *l,* which is the distance between two rectangular lattices. In the *U*-shaped structure of Figure 2.4e, the loaded *Q*-factor increases as distance *s* decreases. Elliptic DGS cells are also obtained by etching a slot that connects two elliptic DGS shapes in a microstrip ground plane (Figure 2.4f). Figure 2.4g represents the DGS unit composed of two *U*-shaped slots connected by a transverse slot. This DGS section can provide cutoff frequency and attenuation pole without any periodicity, unlike other DGS [9,10].

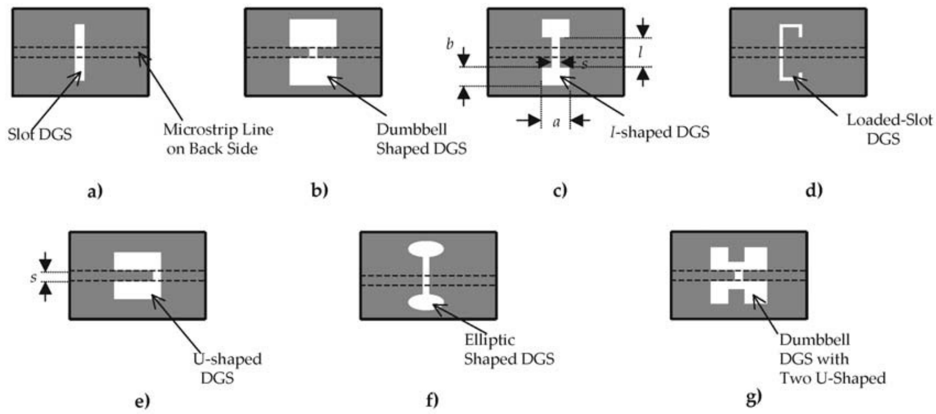

Figure 2.4: Some resonant structures used for defected ground structure (DGS) applications

2.2 DGS Equivalent Circuit

The equivalent circuit of the DGS can be represented by a parallel *LC* resonant circuit in series with the microstrip line. The transverse slot in the DGS increases the effective capacitance, while the *U*-shaped slots attached to the transverse slot increase the effective inductance of the microstrip line. This combination of DGS elements and microstrip lines yields sharp resonances at microwave frequencies which can be controlled by changing shape and size of the DGS circuitry. The shape and size of the DGS slot controls both the fundamental resonant frequency and higher order resonances. The size of the FR4 board area is also considered. To fulfill the different requirements, a variety of DGS shapes have evolved over time, including dumbbell, periodic, circular, spiral, *L*-, and *H*-shaped structures. There are three types of equivalent circuit, LC and RLC equivalent circuit, π shaped equivalent circuit, and quasi-static equivalent circuit. [8] For this project, the DGS will only use the LC equivalent circuit as shown in Figure 2.5. [7]

The parameters of equivalent circuit models of DGSs were also researched and utilized to design planar circuit easily [1].

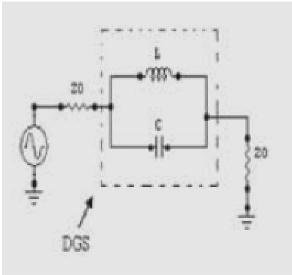

Figure 2.5: LC equivalent circuit

2.3 Application of DGS

There are widely applications in active and passive devices useful for compact design. Since each DGS provides its own distinctive characteristics depending on the geometries, such circuit functionalities as filtering unwanted signals and tuning high-order harmonics can easily be accomplished by means of placing required DGS pattern, which correspond to the desired circuit operations without increasing circuit complexity[9].

2.3.1 Delay lines

Placements of DGS resonators along a transmission line introduce changes in the propagation of the wave along the line. The DGS elements do not affect the odd mode transmission, but slows the even mode, which must propagate around the edges of the DGS “slot” [11].

2.3.2 Antennas

The filtering characteristics of DGS can be applied to antennas, reducing mutual coupling between antenna array elements, and reducing unwanted responses (similar to filters). This is the most common application of DGS for antennas, as it can reduce side lobes in phased array, improve the performance of couplers and power dividers, and reduce the response to out of band signals for both transmit and receive. An interesting application combines the slot antenna and phase shift behaviors of DGS. An array of DGS elements can be arranged on a flat surface and illuminated by a feed antenna, much like a parabolic reflector antenna. Each element re-radiates the exciting signal, but a phase shift can be built into the structure to correct for the distance of each element from the feed. The re-radiating elements introduce additional loss, but the convenience of a flat form factor is extremely attractive for transportable equipment or applications where a low-profile is essential.

2.3.3 Amplifier Design

Amplifier design also can benefit from DGS this due to a number of attractive features that DGS have that can help to improve the amplifier performance. First, the DGS structure is very simple and it is easily simulated or fabricated and this is suitable for periodic structure design. Second, its stop band characteristic could be used to suppress certain harmonics. Third, its insertion loss is much lower so extremely small