IMAGE REJECT FILTER DESIGN BY USING DEFECTED GROUND STURCTURE FOR SATELLITE APPLICATION

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DEDICATION

To my beloved father and mother

ACKNOWLEDGEMET

I want first to acknowledge with special thanks and appreciation to my supervisor Mr. Noor Azwan bin Shairi for his guidance and opinions along my project duration. His precious advice, contributions and comments has given great help for me in order to complete my project successfully.

Last but not least, I want to thank all the lecturers, friends and family for their undying support and help.

ABSTRAK

Tesis ini adalah berkaitan rekabentuk Penapis Tolakan Imej dengan menggunakan Defected Ground Structure (DGS). Rekabentuk ini diaplikasikan dalam Sistem Siaran Langsung Satelit yang menggunakan frekunsi jalur KU di antara 11.70GHz hingga 12.20GHz. Sistem Siaran Langsung Satelit mengunakan rekabentuk penerima superheterodyne sentiasa menghadapi masalah frekuensi imej. DGS adalah pendekatan baru untuk penapis jalur henti yang yang berpotensi menggantikan penapis konvensional yang saiznya agak besar dan harganya mahal. Penapis Tolakan Imej dengan menggunakan DGS telah direkabentuk dan dianalisa menggunakan perisan Advanced Design System (ADS). Hasilnya, DGS ini berjaya direka menggunakan Alumina sebagai substratum untuk Penapis Tolakan Imej bagi aplikasi Sistem Siaran Langsung Satelit pada frekuensi imej xx GHz. Lebar jalur penapis DGS ini adalah 9.30GHz. Pembaikan dan cara-cara alternatif untuk perekaan penapis jalur henti telah dibincangkan untuk kerja-kerja akan datang.

ABSTRACT

The purpose of this project is to design an Image Reject Filter by using Defected Ground Sturture (DGS). The platform that used for this project is the Direct Broadcast Satellite (DBS) system which employs the Ku-band as its operating band at 11.70GHz until 12.20GHz. Direct Broadcast Satellite system uses superheterodyne receiver architecture which suffers from the problem of image frequencies. Defected Ground Stucture (DGS) is the new approach to the bulky and expensive bandstop filter that conventionally used. The integrated bandstop filter which is introduced as image rejection filter at 9.30GHz in the receiver system of Direct Broadcast Satellite is design by using Advanced Design System (ADS). At the end of the project, the improvements and alternative ways to design the bandstop filter has been discussed.

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CHAPTER I

INTRODUCTION

1.1 Background

Nowadays, high performances, compact size and low cost are the stringent requirements that have to be fulfilled in modern microwave communication system. Defected Ground Structure (DGS) is one of the new structures to enhance the quality of the system. It 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 wave guide). The disturbance of the shield current distribution in the ground plane will changes the characteristics of transmission line. In brief, any defect etched in the ground plane of microstrip will consequence in increasing effective capacitance and inductance.

Applications of DGS in radio frequency/microwave (RF/MW) circuits find numerous advantages like circuitry size reduction and spurious response suppression. Its importance in filter applications has intentionally increased due to its steep and broad rejection bandwidth properties. The focus of the project is on the design and simulation of Image Reject Filter by using Defected Ground Structure for satellite application. The Image Reject Filter is implemented in the Superheterodyne Receiver System of Direct Broadcasting Satellite at Ku-Band.

1.2 Problem Statement

In most cases, the Bandpass Filter is used to sort out the unwanted image frequencies that received by the receiver system. There is less or no details study on the use of Bandstop Filter as Image Reject Filter in Superheterodyne Receiver System. Due to the bulky size and impedance matching issues for conventional filters, the Defected Ground Structure is applied in the Image Reject Filter. In this project, the application of Direct Broadcasting Satellite at Ku-band is chosen as a platform for Defected Ground Structure at high frequency.

1.3 Research Objective

The objective of this project is to design the Image Reject Filter by using Defected Ground Structure for Satellite application at Ku-Band.

1.4 Scopes of Study

The research project will focus on:

(a) Circuit modeling of Image Reject Filter by using Defected Ground Structure.
(b) Layout design of of Image Reject Filter by using Defected Ground Structure.
(c) Simulation and analysis of circuit modeling and layout design of Defected Ground Structure.

The simulations and analysis of the project are carried out by using two different substrates – FR4 and Alumina 99.6%.

1.5 Organization of Study

This study will be categorized into five chapters which are the Introduction, Literature Review, Methodology, Results, Discussion and Conclusion.

Chapter 1 contains the background of the problem statement, the objectives and the scopes of the study. In this chapter, it summarizes the progress of study and describes the plan to accomplish the study.

In Chapter 2, the information and theory of which is related to the research is studied and summarized. The source of the information is from journals, books, internet, articles and etc.

Chapter 3 describes overview of the research methods and how to conduct the research methods. The steps to perform the simulation and analysis will be included in this chapter.

Chapter 4 presented the result of simulation in table and graph form and the discussion of the result that obtained in details. The discussion will include the problems that encountered during the simulation of results. Alternative solutions will be proposed to improve the performance of Defected Ground Structure.

Chapter 5 summarizes the main findings and how the scope is covered fully and recommendation for further studies.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Recent years, there are new technologies in modern communication systems to boost up the whole quality of system. Most of passive and active microwave and millimeter devices are design to suppress the harmonics and realize the compact dimensions of circuits. The existent new technologies such as Low-temperature co-fire ceramic technology (LTCC), Low-temperature co-fire ferrite (LTCF) and some new structures such as Photonic band gap (PBG), Defected ground Structure (DGS), Substrate integrate wave-guide (SIW) are those which meet the rigid requirements of microwave communication system. As some of the listed technologies are facing the difficulties of modeling and radiation for the design of the microwave or millimeter-wave components, DGS is proposed to alleviate these problems [1].

DGS provides numerous advantages and it has wide application in microstrip circuits where the frequency notch can reduce complexity and enhance performance [2]. A designer of microstrip circuits focuses on the analysis, synthesis and calculation of microstrip circuit (conductor trace), including configuration, dimensions and structure of microstrip conductor. The design of passive and active microwave and millimeter devices by using DGS is simpler if compared with other new technologies e.g. photonic band gap (PBG) which uses numbers of design parameters.

The design of DGS is where the ground plane metal of a microstrip (or stripline, or coplanar waveguide) circuit been modified on purpose to improve its performance. It is an etched periodic or non-periodic cascaded configuration which is defect in ground of a planar transmission line which disturbs the shield current distribution in the ground plane cause the defect in the ground [3]. The disturbance gives effect on the characteristic of transmission line. It increases the effective capacitance and inductance.

2.2 Characteristics of Defected Ground Structure (DGS)

The basic element of DGS is a resonant gap or slot in ground metal, placed directly under a transmission line and aligned for efficient coupling to the line. Figure 2.1 shows some resonant structures used for defected ground structure applications. Each differs in the occupied area, equivalent L-C ratio, coupling coefficient, higher-order responses, and other electrical parameters [2]. To fulfill different requirements for bandwidth (Q) and center frequency, a variety of DGS shapes have introduced (e.g. dumbbell, periodic, fractal, circular, spiral, L-, and H- shapped structures where the shape does not overlap other portions of the circuit.

Microstrip lines with DGS have stop band, higher impedance and increased slow-wave factor than the conventional transmission lines. The application of DGS on microstrip line yields sharp resonances at microwave frequency. The resonant frequency is controlled by the shape and size of the slot. Figure 2.2 shows the conventional dumbbell-shapped DGS which is composed of two $a \times b$ rectangular defected area, $g \times w$ gaps and a narrow connecting slot wide etched areas in the backside of metallic ground plane [3].

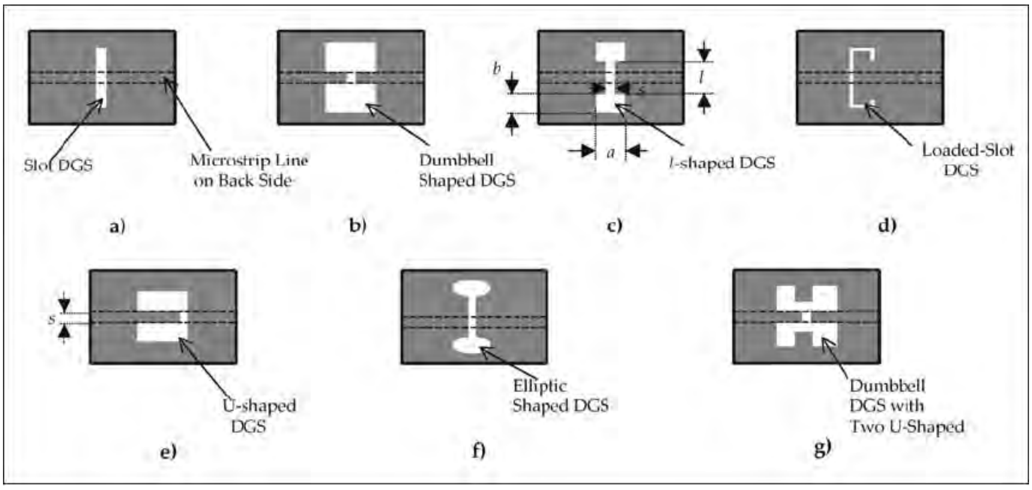

Figure 2.1: Some resonant structures used for Defected Ground Structure (DGS) applications [2].

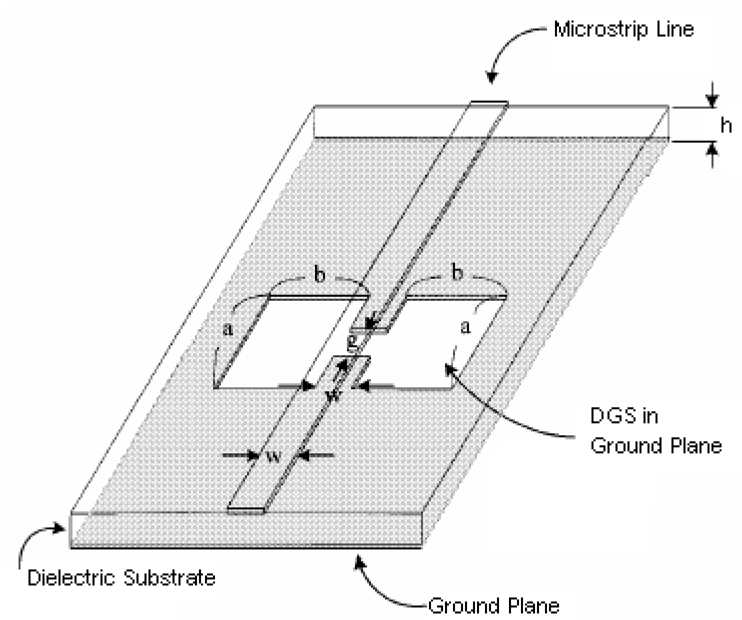

Figure 2.2: Three-dimensional (3D) view of a dumbbell DGS unit [3].

2.3 Equivalent Circuit of Defected Ground Structure (DGS)

To apply the proposed DGS section to a practical circuit design, it is necessary to extract the equivalent circuit parameters. To derive the equivalent circuit parameters of DGS unit at the reference plane, the S-parameter versus Frequency has to be calculated by full-wave electromagnetic (EM)-simulation in order to explain the cutoff and attenuation pole characteristics of the DGS section [1]. However, there is no correlation between the physical dimensions of DGS and the equivalent LC parameters. Parametric study is used to correlate between the layout design and equivalent circuit of the DGS. Hence, conventional methods are time consuming and the result is not predictable [1, 4-5].

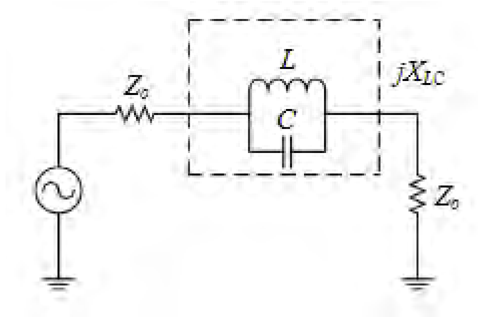

Figure 2.3: Equivalent circuit of the dumbbell circuit of DGS unit**.**

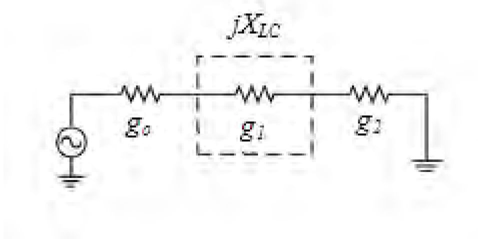

Figure 2.4 – Butterworth-type one pole prototype low-pass filter circuit.

The equivalent circuit of a DGS unit of the low pass filter (LPF) is shown in Figure 2.3. The rectangular defected area increases the length of the route for current and effective inductance while the slot part gathers the charge and increases the effective capacitance of the microstrip line. Resonance that occurs at certain frequency is due to the parallel L-C circuit. As the rectangular defected area increases, the effective inductance increases and gives rise to a lower cut off frequency [6-8]. The increasing of gap distance decreases the effective capacitance. It will results in the movement of the attenuation pole location to higher frequency.

To match the DGS with the Butterworth low pass filter as shown in Figure 2.4, the reactance value of both circuit are equal at cutoff frequency. The radiation effects are neglected as there is less radiation by the DGS unit if compared with the periodic Photonic Bandgap structure [4]. In this project, a single DGS unit is used. Hence, the *L* and *C* are derived as follows [8]:

$$X_{LC} = \frac{1}{w_o C}\left(\frac{w_o}{w} - \frac{w}{w_o} \right) \qquad (2.1)$$

where w_o is the resonance frequency of parallel LC resonator.

$$C = \frac{w_o}{Z_o g_1}\left(\frac{1}{w_o^2 - w_c^2} \right) \qquad (2.2)$$

$$L = 1/4\pi^2 f_o^2 C \qquad (2.3)$$

where the f_o = resonance (attenuation pole), f_c is the cutoff frequency.

2.4 S-parameters

Scattering parameters (the elements of scattering matrix or S-matrix) define the electrical behaviors of linear electrical networks when stimulated by electrical signals. It is widely used in radio frequency (RF) and microwave circuit design to describe both active and passive devices' electrical behaviors as shown in Figure 2.5 The electrical properties of networks of components (inductors, capacitors and resistors) can be expressed as gain, return loss, voltage standing ratio (VSWR), reflection coefficient and amplifier stability by S-parameters.

Figure 2.5: Two port network

The designed circuit will be analyzed in two port network. The relationship between the reflected, incident power wave and S-parameter can be expressed in matrix below [13]:

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} \quad (2.4)$$

by expanding the matrices into equations:

$$b_1 = S_{11}a_1 + S_{12}a_2 \qquad b_2 = S_{21}a_1 + S_{22}a_2 \quad (2.5)$$

Each 2-port S-parameter has the following descriptions:

- S_{11} is the input port voltage reflection coefficient.
- S_{12} is the reverse voltage gain.
- S_{21} is the forward voltage gain.
- S_{22} is the output port voltage reflection coefficient.

In this paper, S_{21} and S_{11} are the main concerns as S_{21} shows the insertion lost of the filter which is in dB expression of the transmission coefficient where as S_{11} shows the input return loss of the system.

2.5 Advantages of DGS

DGS has numerous of advantages which allow it to have wide applications in active and passive devices for compact design. The desired circuit operations can be done by varying the geometric parameters of DGS without increasing the circuit complexity. For DGS, there are only a few elements having the similar typical properties as the periodic structure like the stop-band characteristic. Thus, the circuit area becomes relatively small without periodic structures [1-3]. DGS can be designed and implemented easily. It has higher precision with basic defect structures. Its pattern is easily fabricated and the extraction of equivalent circuit is simpler.