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DESIGN AND ANALYSIS OF SIW BANDSTOP FILTER FOR INTERFERENCE SUPPRESSION IN X BAND COMMUNICATION SYSTEM

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DESIGN AND ANALYSIS OF SIW BANDSTOP FILTER FOR INTERFERENCE SUPPRESSION IN X BAND COMMUNICATION SYSTEM

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Special dedication to my beloved family, my kind hearted supervisor PM. Dr. Badrul Hisham Ahmad and to all my dearest friends.

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ABSTRACT

Radio Detection And Ranging (RADAR) are widely used in many applications such as in military, aviation, and weather-sensing. Basically radar is an object-detection system that uses radio waves to determine the range, altitude, direction, or speed of objects by transmitting pulse and receiving reflected signal. Signal interference and harmonics is a common problem that exist in radar system. The need of bandstop filters to eliminate unwanted frequency is crucial. So the filter response need to be of a high Q-factor for high selectivity and high level of frequency suppression for filtering. Bandstop filter is placed after the receiver part to eliminate the unwanted signal received contained with the actual echo signal reflected by the object. Theoretically, a high notch depth and selectivity of matched bandstop filters can be produced by using only two lossy resonators. New developments in the design of band reject filters are essential to meet the ever increasing demands on suppression of unwanted signals and miniaturization of microwave communications systems. Substrate Integrated Waveguide (SIW) is a waveguide that synthesize inside a substrate and the propagating wave is delimit by arrays of via holes. The field distribution in SIW is similar with a conventional rectangular waveguide. Hence, it takes the advantages of low cost, high level suppression, high Q-factor and can easily be integrated into microwave and millimeter wave integrated circuits.

ABSTRAK

Radio Detection and Ranging (RADAR) banyak digunakan dalam aplikasi seperti dalam tentera, penerbangan, dan ramalan kaji cuaca. Pada asasnya radar adalah sistem pengesanan objek yang menggunakan gelombang radio untuk menentukan julat, ketinggian, arah, atau kelajuan objek dengan menghantar gelombang dan menerima pantulan isyarat. Inteferens isyarat dan harmonik adalah masalah biasa yang wujud dalam sistem radar. Keperluan penapis bandstop untuk menghapuskan frekuensi yang tidak diingini adalah amat penting. Jadi respon penapis perlu mempunyai faktor Q yang tinggi untuk pemilihan dan tahap frekuensi penindasan bagi proses penapisan. Penapis Bandstop diletakkan selepas bahagian penerima untuk menghapuskan isyarat tidak diingini yang diterima di mana ia mempunyai gema isyarat sebenar yang dipantulkan daripada objek. Secara teorinya, kedalaman kedudukan tinggi dan pemilihan padanan penapis bandstop boleh dihasilkan dengan hanya menggunakan dua resonator ‘lossy’. Perkembangan baru dalam reka bentuk penapis bandstop adalah penting untuk memenuhi permintaan yang semakin meningkat pada penindasan isyarat yang tidak diingini dan pengecilan sistem komunikasi gelombang mikro. Substrate Integrated Waveguide (SIW) adalah waveguide yang mensintesis dalam substrat dan gelombang yang merambat membatasi oleh tatasusunan melalui lubang. Pengagihan lapangan di SIW adalah sama dengan waveguide segi empat tepat konvensional. Oleh itu, ia dapat memberi kelebihan dari segi kos rendah, penindasan yang tinggi, faktor Q-tinggi dan boleh disepadukan ke dalam gelombang bersepadu litar.

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LIST OF ABBREVIATIONS

SIW	Substrate Integrated Waveguide
ADS	Advanced Design System
EM	Electromagnetic
PCB	Printed Circuit Board

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Microwave filters can be found in most of microwave subsystems, from entertainment via satellite television, civil and military radar systems. Enhancement of the development of microwave communications systems and millimeter wave has encouraged the need for the suppression of multiple unwanted signal bandwidth for military applications. Bandstop and bandpass filters play an important role in the microwave and millimeter wave systems, which are used to distinguish the desired and undesired signal. Several bandstop filter is primarily designed for single-band rejection application.

This project is about designing and analyzing of a bandstop filter by using substrate integrated waveguide (SIW) which operates at X-band frequency in radar applications. This project studies and analyze on the implementation of the band suppression or rejection which can be applied to reject pulse signals or bandwidth signals in radar application.

This filter will operates in the X-Band frequency since this type of frequency band mostly used in the operation of communication that is related to the military, such as satellite communication, radar, space communication, amateur radio and terrestrial communications and networking. SIW will be used in this filter because it has been proven that it is significant in microwave and millimeter-wave communication systems for its' attractive advantages of high Q, low insertion, reduced size, low costs, and easily to be integrated with planar circuits that of a rectangular waveguide.

1.2 PROJECT OBJECTIVE

The objective of this project is to design and analyze the X-band bandstop filter by using Substrate Integrated Waveguide (SIW). The increasing development of microwave and millimeter-wave communication systems has promoted the need for suppression of multiple unwanted signals for military broadband applications. Bandstop and bandpass filters play an important role in microwave and millimeter-wave systems, which are applied to discriminate the desired and unwanted signals.

The objectives of this project includes:

- To be able to understand the basic fundamental of microwave filters.
- To be able to understand the concept of waveguide in order to design a bandstop filter.
- To be able to understand the SIW concept to apply to the X-band bandstop filter where the SIW replaces the waveguide walls with a series of metallic via holes through the substrate to achieve the same effect of metallic walls.
- To be able to design and simulate the bandstop filter using Advanced Design System (ADS)

- To be able to analyze the results from the simulation
- To be able to optimize and tune the results

1.3 PROJECT SCOPE

The scope of work for this project is to study and analyze the data or information about two major areas of interest. Firstly is to understand the concept and principal of the bandstop filter and secondly to understand the SIW design in order to achieve the objective of this project. The main scope of this project is to fully understand the principles of filters by studying the characteristics of the bandstop filter and collect the data and information on this topic.

Suitable time allocation has been set in order to study, analyze and understand about the rectangular waveguide, SIW cavity and basic concept of the SIW design. Another area that needed careful attention was on the simulation process in order to achieve the correct simulation outcome and theoretically comparable output. The understanding and familiarization of the ADS software is most significant to enable a simulation output. Furthermore, the knowledge on the properties of the substrate board is important in the design process. The use microwave range where the signal involved and the bandwidth can be best recommended for the X- Band and military applications.

The project scope for this project include:

- Integrating rectangular waveguide inside a FR-4 substrate.
- Focusing on the concept and principal of the Bandstop filter and the SIW technology
- design and simulation using ADS software
- Frequency operation of this project is in the range of X-band frequency (8.0-12.0 GHz) with 450MHz bandwidth.
- The insertion loss is less than 0.5 dB and return loss more than 15 dB

- The proposed filter is a design bandstop filter utilizing substrate integrated waveguide cavity resonators to provide the required resonance.

1.4 PROBLEM STATEMENT

Microwave communication systems control a large division of the world and other long haul voice, data and multimedia transmission. Many developing wireless communication systems, such as direct broadcast satellite (DBS) television, personal communication systems (PCSs), wireless local area networks (WLANs), cellular radio (CVs) system and global positioning satellite (GPS) systems, operate in the frequency range of 1.5 GHz to 94 GHz, and it depends on microwave technology. All of this require filter to operate for high quality assurance and performance.

The development of technology has change in some aspect, one of the most critical aspect is the miniature size of the SIW. The SIW technology can produce a small sized filter besides having additional advantages such as high Q, low cost and lower loss compared to other filter technology. This filter will give high performance and support the device well.

Radio Detection and Ranging (RADAR) is an object-detection system that uses radio waves to determine the range, altitude, direction, or speed of objects by transmitting pulse and receiving reflected signal. Signal interference and harmonics is common problems that exist in RADAR system. Bandstop filter is crucial to eliminate unwanted frequency. So the filter responses need to be high Q-factor for selectivity and high level of frequency suppression for filtering. Bandstop filter is placed after the receiver part to eliminate the unwanted signal received contained with the actual echo signal reflected by the object. Theoretically, a high notch depth and selectivity of matched bandstop filters can be produced by using only two lossy resonators. New developments in the design of band reject filters are essential to meet the ever increasing demands on suppression of unwanted signals and miniaturization of microwave communications systems. Substrate

Integrated Waveguide (SIW) is a waveguide that synthesize inside a substrate and the propagating wave is delimit by arrays of via holes. The field distribution in SIW is similar with a conventional rectangular waveguide. It have the advantages of being low cost, having high level of suppression, high Q-factor and can easily be integrated into microwave and millimeter wave integrated circuits.

1.5 PROJECT METHODOLOGY

Since this is final year project, it needs more concentration on research and design of the X-band bandstop filter using SIW. The project methodology will cover the complete flow of the progress of this project. The flow chart and the planning of this project are enclosed in Chapter 3.

The various method and resources that are used in this project include:

1) Literature reviews
    - Reference books, references from the World Wide Web, journals and work paper for conferences.

2) Discussions with supervisor and lecturers.
    - Get more information about the project and examined the project from time to time

3) Discussions with classmates and course mate
    - Discuss with friends who propose a similar design concept.

4) Simulation

- It will be done by varying parameters using Advanced Design System (ADS) in order to get the required results which are approximately accurate to the theoretical results.

5) Analysis

- The last stage of the project to analyze the results of the designed filter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Rectangular waveguides is one type of the transmission lines. Many application use this waveguide. There are some components such as detectors, isolators, couplers, attenuators and slotted lines are available for variety of standard waveguide bands between 1GHz to above 220GHz. Microwave and millimeter-wave systems that brought the evolution of the waveguide make the utilities of this technology in many more applications.

The propagation of an electromagnetic wave directed by a waveguide that cooping the wave energy. The waveguide usually consists of hollow metallic pipes with uniform cross sections. To obtain much higher Q factors, the waveguide resonators are very important elements in filter design compared to coaxial or other TEM transmission lines. Waveguides and TEM transmission lines have significant differences. TEM propagation is supported by a transmission line that has minimum of two conductors and has a zero cut-off frequency. There is no minimum size of the cross section of TEM line in order for signal propagation to occur other than that determined by dissipation losses. The boundary of the pipe is consisted in the waveguide.

Electromagnetic energy will propagate and its cross section dimensions as the waveguide has a distinct cut-off frequency above. Besides, propagation in waveguide occurs with field pattern, or modes. An infinite number of modes each of which has their own cut-off frequency is supported by any waveguide. Function of frequency are the characteristic impedance and the propagation constant of a waveguide. TEM modes cannot exist inside waveguides because they need minimum of two conductors to propagate, and simplest modes are those with purely transverse E fields (TE and H modes) or purely transverse H fields (TM or E modes). In order to understand how it propagates inside the waveguide, these modes needs to analyze.

2.2 APPLICATION OF RF AND MICROWAVE FILTER

Microwave systems have a huge effect in a fast changing society. Applications are variety, from entertainment via satellite television, to civil and military radar systems. Radar systems are used for detecting and locating air, ground or sea going targets, and for air traffic control systems, missile tracking radars, automotive collision avoidance systems, weather forecast, motion detectors and a wide variety of remote sensing systems.

Filter design is extraordinary in that it uses a synthetic network, with which it is possible to apply a systematic procedure to work forward from specification to final design theory. The used of design based on analysis is the converse of most engineering disciplines. However, in order to design the filters, knowledge of network synthesis is not