DESIGN AND FABRICATION OF SUBSTRATE INTEGRATED WAVEGUIDE BANDSTOP FILTER

SITI SABARIAH BT SABRI

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Specially dedicate to my beloved parent, Sabri Bin Mat Ali and Siti Khodijah Bt Hashim and also to my siblings who give the encouragement and support for me to completed this thesis. Not forgotten to my supervisor Dr.Badrul Hisham Bin Ahmad who gave me lot of guidance and advice throughout this project until successful. Thanks you very much to all of you.

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ABSTRACT

This paper presents the designs of Substrate Integrated Waveguide (SIW) bandstop filter. In order to give the bandstop response, this network comprises a Substrate Integrated Waveguide (SIW) cavity resonator which is coupled to a strip line. SIW are high performance broadband interconnects with excellent immunity to electromagnetic interference and suitable for use in microwave and millimeter-wave electronics, as well as wideband systems. They are very low-cost in comparison to the classic milled metallic waveguides as they may be developed using inexpensive printed circuit board (PCB) fabrication techniques. With the advent of SIW technology in microwave area, many circuits are designed based on these structures. SIW is synthesized by placing two rows of metallic via-holes in a substrate. The field distribution in an SIW is similar to that in a conventional rectangular waveguide. Hence, it takes the advantages of low cost, high Q-factor and can easily be integrated into microwave and millimeter wave integrated circuits. The transmission loss of the on substrate transitions may be much lower than that of the transitions or coupling sections made between the conventional waveguide and planar circuits. Whilst many researches using this technology are being carried out, this project proposes that instead of designing bandstop filter based on a SIW rectangular or square resonator. In order to develop a bandstop filter base on the SIW rectangular resonator, cavity resonator coupled to a strip line to give bandstop response. The microstrip probe was positioned in the middle of SIW resonator to ensure only the TE_{10} mode was excited. The size of the resonators, diameters of the metal posts and spacing of adjacent posts are consider based from with the length of the resonators approximate to a half guide wavelength long at the center frequency.

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ABSTRAK

Projek ini menerangkan mengenai reka bentuk *Substrate Integrated Waveguide* (SIW) bandstop filter. Untuk memberikan respon bandstop, rangkaian ini terdiri daripada *Substrate Integrated Waveguide* (SIW) resonator rongga yang digabungkan dengan garis jalur . Mereka sangat murah berbanding dengan pandu klasik logam giling kerana mungkin akan dibangunkan dengan menggunakan papan litar murah bercetak (PCB) teknik fabrikasi. Dengan munculnya teknologi gelombang mikro SIW, banyak litar direka berdasarkan struktur ini. SIW disintesis dengan meletakkan dua baris logam melalui-lubang di substrat. Edaran lapangan di sebuah SIW adalah serupa dengan yang di pandu gelombang persegi panjang konvensional. Oleh kerana itu, mengambil keuntungan dari kos rendah, tinggi Q-faktor dan dengan mudah dapat diintegrasikan ke dalam rangkaian gelombang mikro dan milimeter bersepadu. Hilangnya penularan pada peralihan substrat mungkin jauh lebih rendah berbanding dengan peralihan atau bahagian gandingan dibuat antara pandu gelombang konvensional dan litar planar. Sementara banyak kajian menggunakan teknologi ini sedang dilaksanakan, projek ini mencadangkan bahawa merancang penapis *bandstop* berdasarkan resonator SIW persegi panjang atau bujur sangkar. Dalam rangka mengembangkan asas penapis bandstop pada resonator SIW persegi panjang, resonator rongga digabungkan ke saluran jalur untuk untuk memberikan respon *bandstop*. Jalur mikro probe diposisikan di tengah resonator SIW untuk memastikan hanya mod TE_{10} sangat senang. Saiz resonator, diameter posting logam dan jarak yang berdekatan posting mempertimbangkan berdasarkan dari dengan panjang resonator anggaran dengan panjang gelombang panduan setengah panjang di frekuensi tengah.

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LIST OF SYMBOLS

λ_g	Guide wavelength
λ_o	Center frequency wavelength
f_o	Center frequency
ω_c	Cut off frequency for waveguide
a	Width of a waveguide
c	Speed of light
l	Waveguide length
b	Height of a waveguide
ε_r	Dielectric constant

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CHAPTER I

INTRODUCTION

1.1 PROJECT BACKGROUND

Many research have been carried out in order to develop high-performance microwave and millimeter-wave waveguides components that are fabricated using low-cost technologies. Substrate Integrated Waveguide (SIW) was introduced as laminated [1, 2] waveguides that can be easily implemented using common printed circuit board (PCB) fabrication methods. There are various SIW-based components, interconnects and circuits have been developed and their advantages are justified in comparison to their milled waveguide or transmission line based counterparts.

The components such as power divider, resonator cavities and filters that have been developed using microstrip, stripline and milled-waveguide technologies are now redesign using SIW platform. SIW-based components like waveguide cavities have also been integrated directly into a PCB platform, allowing significant cost reduction in development and mass production of resonator based microwave oscillator and filters. The high quality factor of waveguide cavities provides excellent frequency selectivity for cavity coupled filters and resonators [3 – 5].

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The frequency selectivity of coupled SIW cavities is exploited in numerous microwave filter topologies [6-8]. Recently, it is possible to develop fully integrated multichip modules (MCM) system incorporating SIW filters and high-gain antennas. Slot array SIW antennas and SIW cavity backed antennas provide microwave system designers with ability to incorporate low-cost, high-performance antenna on the same substrate as monolithic microwave integrated circuits (MMIC).

This project was conducted to study in details about the architecture of Substrate Integrated Waveguide (SIW) and on how to design SIW bandstop filters. The network comprises the SIW, cavity resonator coupled to a strip line in order to obtain bandstop response by using Advance Design Systems (ADS) momentum.

1.2 Problems Statement

Rectangular waveguide often used for signal transmission between system modules for low loss and high power applications. However, systems with rectangular waveguides are often large and heavy [5]. Transitions between rectangular waveguides and planar circuits cannot be held without extra supporting structure.

SIW was introduced because it can be easily integrated into substrates for planar circuits, such as printed circuit board (PCB) and low-temperature co-fired ceramics (LTTC). Compared with conventional rectangular waveguides, SIW has the advantage of low-cost, compact and easy-integrated with planar circuits. Besides, SIW have better quality factor than conventional printed circuit board (PCB).

In the rectangular SIW resonator design, rectangular and circular cavities are cascaded one by one in our designed filter to separate second resonances and coupling between similar cavities can be achieved through the different cavity between them. To reject the spurious frequencies thoroughly, radiating slots are inserted at positions to cut the currents of the second resonant modes without disturbing the first resonant currents.

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The evolution of technology have brought the changes of this things in many aspect, one of it is size. The SIW technology can produced the smallest size filter that include some additional advantages such as high Q, low cost and lower loss compared to other technology of filter. This filter will give high performance.

1.3 PROJECT OBJECTIVES

The objective of this project is to analyze and design a Substrate Integrated Waveguide bandstop filter. This filter design can be achieves by understanding the basic concepts of bandstop filter designs. SIW is a new technology that consist more advantages. To apply this technology to the multiple-band bandstop filter, the concept of SIW has to be understood first. The SIW replacing the waveguide walls with a series of metallic via holes through the substrate to achieve the same effect of metallic walls.

Besides, to produce high performance of the SIW bandstop filter, manufacturing process of this filter is so important. The fabrication process needs to be done carefully in order to minimize the difference between simulation and measurement results. A part from it, types of board have been chosen is the one of factor that affected the results.

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1.4 SCOPE

The scopes of this project were divided into several parts. First parts are the literature study on the details about the architecture of SIW. The calculation of SIW component such as dimension for waveguide, size of the via hole and microstrip line will be calculated. After that, the bandstop filter was designed based on the specification and later simulation will take place.

After an extensive simulation and obtained the best frequency response for SIW bandstop filter, fabrication process was carried out by using FR4 board. This filter then was measured by using network analyzer.

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1.5 METHODOLOGY

This project start with literature study and research of the functions of SIW and others topic that related to this project. This literature study is done by find out all the journal, articles and books that related to this project either in website or any other materials. Next, all the process to setup ADS momentum, and the flow on how to run the simulation were learned. From the simulation, the bandstop response for SIW banstop filter is observed. Lastly, the design filter was fabricated and tested.

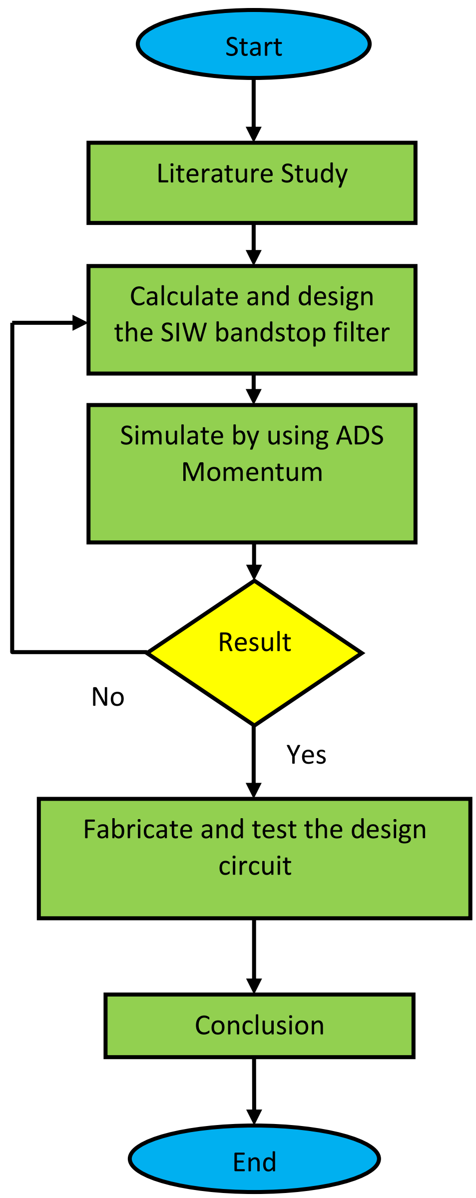

Figure 1.1: Flow chart for the whole process of the project

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1.6 REPORT STRUCTURE

This report consists of chapters that will explain and discuss more details about this project. This report was divided into 5 chapters. The first chapter gives a brief explaination about Substrate Integrated Waveguide (SIW). It also gives an introduction about the overall process of project.

Second chapter is about the literature review of the project. Background knowledge of SIW and its components. The literature review helps to understand the basic fundamental of this project.

Third chapter will explain about the project methodology. It gives details about the methods used and all the process involved in this project.

Fourth chapter is about the result and discussion of this project, finding the analysis throughout the research and project development. All the data and results that obtained during this project will be documented in this chapter.

Lastly, fifth chapter is about the conclusion of this project. This chapter rounds up the attained achievement of the whole project and reserves suggestions for possible future research.

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CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

Microwave filters are vital components in a huge variety of electronic system, including cellular radio, satellite communications and radar. The specifications on these devices are usually severe, often approaching the limit of what is theoretically achievable in terms of frequency selectivity and phase linearity. However, knowledge of network synthesis is not the only tool needed in order to design filters. Synthesis provides the designer with a prototype network which can then be transformed into a variety of microwave networks including TEM transmission lines, waveguides and dielectric resonator realizations [13].

2.2 RF AND MICROWAVE FILTER

Microwave systems have an enormous impact on modern society. Applications are diverse, 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

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avoidance systems, weather forecast, motion detectors and a wide variety of remote sensing systems. Microwave and RF filters are widely used in all these systems in order to discriminate between wanted and unwanted signal frequencies. Cellular radio provides particularly stringent filter requirements both in the base stations and in mobile handset. A typical filtering application is shown in Figure 2.1. [13]

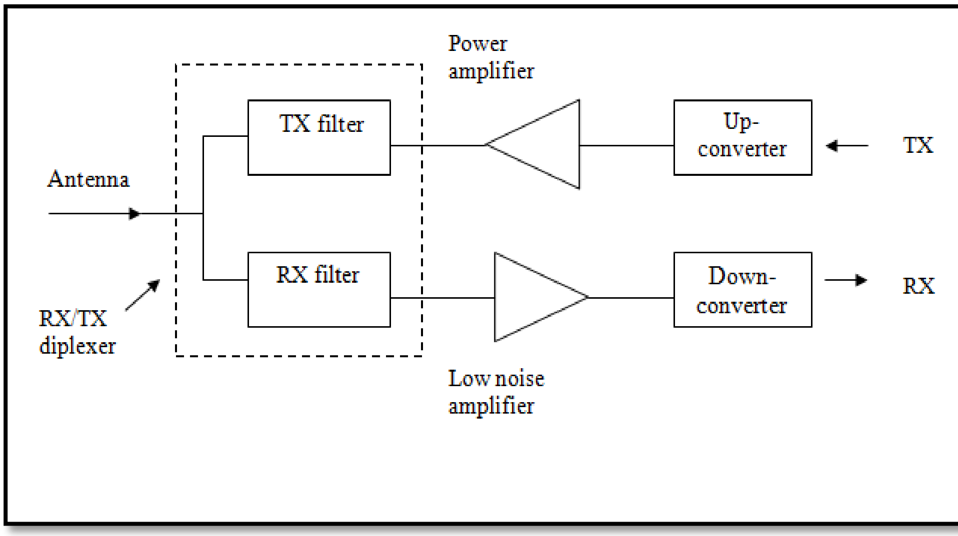

Figure 2.1: RF front end of a cellular base station [13]

2.3 INTRODUCTION OF SUBSTRATE INTEGRATED WAVEDUIDE (SIW)

Nowadays, the quick development of the high-performance of microwave and millimeter-wave communication systems influences the high-demand of this technology. SIW which is based on planar dielectric substrates with top and bottom metal layers perforated with metalized holes. It provides a compact size, low-cost, sharp selectivity and low insertion loss for integrating active circuits, passive components and radiating elements on the same substrate. Among these are the substrate integrated waveguides (SIWs), initially introduced as laminated waveguides [1, 2], that can be easily implemented using common printed circuit board (PCB) fabrication methods. Since the introduction of SIWs, or laminated waveguides, various SIW-based components,

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interconnects, and circuits have been developed and their advantages are justified in comparison to their milled waveguide or transmission line based counterparts.

As interconnects, it is seen that the substrate integrated waveguide (SIW) interconnects provide a broadband bandpass signaling medium with excellent isolation of electromagnetic interference (EMI) [18], while planar conventional transmission lines are known as the performance bottleneck in ultra wideband systems due to their limited bandwidth and high-frequency losses. In an SIW, the electric field distribution fills the volume inside the waveguide interconnect and surface currents propagate on the larger total cross-sectional area of the waveguide walls, resulting in lower conductor losses [19]. As clock frequencies and circuit densities continue to increase, closely spaced microstrip and stripline interconnects will no longer be viable options for interconnection of system modules due to their open structure and increased susceptibility to crosstalk and EMI.

SIWs, as a new means of signal transmission, have been the basis for the design of many circuit components. Components such as power dividers, resonator cavities, and filters that have been developed using microstrip, stripline or milled-waveguide technologies are now redesigned using the SIW platform. The criticism that has been raised about these new interconnects and components are that they possess a relatively large footprint. Research works published in [7], [20] have in particular focused on the development of waveguide miniaturization methods.

Various types of SIW power dividers, couplers, and diplexers have been designed and optimized for operation at microwave and mm-wave frequency bands using PCB substrates [21]. Other SIW-based components like waveguide cavities have also been integrated directly into a PCB platform, allowing significant cost reduction in the development and mass production of resonator based microwave oscillators and filters. The high quality factor of the waveguide cavities provides excellent frequency selectivity for cavity coupled filters and resonators [22]. The frequency selectivity of coupled SIW cavities is exploited in numerous microwave filter topologies [23]. It is

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