ANALYSIS AND DEVELOPMENT OF MULTIPLE-BAND BANDSTOP FILTER USING SUBSTRATE INTEGRATED WAVEGUIDE (SIW) TECHNOLOGY

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Special dedication to my family, my kind hearted supervisor PM. Tan Kim See and to all my dearest friends.

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ABSTRACT

This project is about the analysis and development of a multiple-band bandstop filter using Substrate Integrated Waveguide (SIW) technology. Bandstop and bandpass filters play an important role in microwave and millimeter-wave systems, which are applied to discriminate the desired and unwanted signals. A new transversal coupling network is used to design a multiple-band bandstop filter. By carefully placing resonators in the coupling network will result in the generation of a number of centre frequencies. Some of these frequencies may have similar resonating frequency to realize a number of frequency band rejections or suppressions which can be applied to reject pulse signals or bandwidth signals in broadband application. This filter will be use in X-band which is for military broadband microwave application. This project will study and analyze on the feasibility of the number of the band suppressions or rejections and develop a prototype for best application. Whilst many researches using Substrate Integrated Waveguide (SIW) technology are being carried out because of it has proven its significance 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.

ABSTRAK

Projek ini adalah berkenaan dengan analisis dan menghasilkan multi-band bandstop filter menggunakan teknologi Substrat Integrated Waveguide (SIW). Bandstop dan bandpass filter memainkan peranan penting untuk membezakan isyarat yang diingini dan tidak diingini dalam microwave dan sistem milimeter-wave. Konsep new transversal coupling network telah digunakan untuk menghasilkan multi-band bandstop filter. Dengan memasukkan resonator ke dalam coupling network akan menghasilkan beberapa jumlah generasi frequecy centre. Beberapa frekuensi mungkin mempunyai frekuensi resonansinya sama untuk mewujudkan sejumlah frequency band yang tidak diingini atau hendak di hentikan yang boleh dilaksanakan untuk menolak isyarat pulse atau isyarat bandwidth dalam aplikasi broadband. Filter ini akan digunakan di X-band sebagai aplikasi tentera dalam microwave broadband. Projek ini akan mengkaji dan menganalisis mengenai seberapa banyak jumlah suppresion band atau rejection band yang boleh dimasukkan ke dalam satu filter dan menghasilkan prototaip untuk aplikasi terbaik. Sementara itu, banyak kajian telah dibuat dengan menggunakan teknologi Substrat Integrated Waveguide (SIW) sedang dilakukan kerana mempunyai banyak kebaikan yang telah terbukti signifikan dalam komunikasi microwave dan sistem milimeter-wave seperti berkualiti tinggi, penyisipan rendah, mengurangkan saiz, kos rendah, dan mudah untuk diintegrasikan dengan litar planar yang dari waveguide persegi panjang.

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LIST OF ABBREVIATION

3D	3 Dimension
DBS	Direct Broadcast Satellite
EBG	Electromagnetic Band Gap
GHz	Giga Hertz
GPS	Global Positioning Satellite
HFSS	High Frequency Structures Simulation
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunications Union
MHz	Mega Hertz
mm	Millimeter
PCB	Printed Circuit Board
PCS	Personal Communication Systems
RF	Radio Frequency
SIW	Substrate Integrated Waveguide
SMA	Sub-Miniature version A
TE	Transverse Electric
TEM	Transverse Electric and Magnetic
TM	Transverse Magnetic
TV LNB	Television Low Noise Block-downconverter
WLAN	Wireless Local Area Networks

CHAPTER I

INTRODUCTION

1.1 INTRODUCTION

Microwave filter can be found in most of microwave subsystems, from entertainment via satellite television, to civil and military radar systems. The increasing development of microwave and millimeter-wave communication systems has promoted the need for suppression of multiple unwanted signals for military broadband applications [1]. Bandstop and bandpass filters play an important role in microwave and millimeter-wave systems, which are applied to discriminate the desired and unwanted signals. Many bandstop filters are mainly designed for single-band rejection applications.

This project is about the development of a multiple-band bandstop filter which is the single filter that consists of more than two stop band frequencies. In order to achieve this project, a new transversal network is used in the rectangular waveguide to design a multiple-band bandstop filter by combining several resonators to the transmission line. This project will study and analyze on the feasibility of the number of the band suppressions or rejections which can be applied to reject pulse signals or bandwidth signals in broadband application.

This filter will operate in the X-band network because this network consist of the operation of communication that related to the military, such as satellite communication, radar, space communication, amateur radio and terrestrial communications and networking. SIW technology will be used in this filter because of it has proven its significance 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 analyze and develop a multiple-band bandstop filter by using Substrate Integrated Waveguide (SIW) technology. This objective can be achieved by understanding the concepts of new transversal network in rectangular waveguide in order to design multiple-band of bandstop filter. 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.

Many bandstop filters are mainly designed for single-band rejection applications. The new transversal network which uses a resonator concept can combine the single-band rejection to be two or multiple-band rejection. Besides, the technology of filter is also very important on this project. There are a lot of types of rectangular waveguide that can be used but this project will use SIW technology. SIW is new technology of the filter that promise many 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.

Furthermore, the type of board is also an important consideration in this project. The board will give different result from fabricated and simulated results. To minimize the difference between the simulation and fabrication, suitable board has to be chosen. An in-depth understanding and familiarization on the simulation software is required before the prototype can be considered. This SIW technology is a new technology, so ADS software will come handy for the simulation process. This project will used HFSS as simulation software of this technology.

1.3 PROJECT SCOPE

The scope of work of this project is to study and analyze the data or information about two major areas of interest. The first one is to understand the concept and principal of the multiple-bandstop filter and the second is the SIW technology 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. For the multiple-band bandstop filter, it will be focused on the understanding and analysis of the concept and properties of the new transversal network and the feasibility of the number of the band suppressions or rejections. Then outcome is to develop a prototype for best application as published in numerous papers and books.

With the SIW technology, time was set aside to study, analyze and understand about rectangular waveguide, SIW cavity and basic concept of the SIW technology. Another area that needed attention was on the simulating process. With a sound outcome from the simulation process, having a comparable output theoretically, then only will the prototype be developed. In this aspect, the understanding and familiarization of the HFSS software is most significant to enable a simulation output. Apart from that, the knowledge on the properties of the substrate board is necessary to decide which one is the best board to be selected for the fabrication process. Finally, the study about the frequency spectrum and the microwave channel application has to be considered for the main application. The use of which microwave range, the signal involved and the bandwidth can be best recommended for the X- Band and military applications.

The other scope of work includes:

- Application of theoretical engineering principles on the proposed project.
- Design and production of the required circuit board for the project.
- Prepare the necessary documents.
- Project presentation.
- Publishing final report.

1.4 PROBLEM STATEMENT

Microwave filter can be found in most of microwave subsystems, from entertainment via satellite television, to civil and military radar systems. 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. Many bandstop filters are mainly designed for single-band rejection applications. The multiple-band bandstop filter can increase the capability of the used filter.

Microwave communication systems handle a large fraction of the world and other long haul voice, data and multimedia transmission. Most of the currently 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 thus rely heavily on microwave technology. All these need filter to operate for high quality assurance and performance.

The evolution of technology have brought about changes in many aspect, one of the most critical aspect is the miniature size of the SIW. The SIW technology can produce the small size filter besides additional advantages such as high Q, low cost and lower loss compared to other technology of filter. This filter will give high performance and support the device well.

1.5 PROJECT METHODOLOGY

As the final year project, this project needs more concentration on research and construction of the multiple-band bandstop filter using SIW technology. The project methodology will cover the complete flow of this project progress. The flow chart and K-chart of the program are enclosed in Chapter 3.

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

1) References books, references from the web link, journals and work paper conferences.
2) Discussion with lecturers and supervisor.
3) Discussion with classmate and course mate.
4) Simulation and fabrication.
5) Troubleshooting of project.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

Rectangular waveguides are one of the earliest type of the transmission lines. They are used in many applications. A lot of components such as isolators, detectors, attenuators, couplers and slotted lines are available for various standard waveguide bands between 1GHz to above 220GHz. The microwave circuitry recently uses the planar transmission line such as microstrips line and strips lines. The need of waveguides in many applications such as microwave and millimeter-wave systems brought the evolution of this technology [1].

A waveguide is a structure which directs the propagation of an electromagnetic wave by confining the wave energy. It normally consists of hollow metallic pipes with uniform cross sections. Waveguide resonators are useful elements in filter design as they generally have much higher Q factors than coaxial or other TEM resonators. There are distinct differences between waveguides and TEM transmission lines. A transmission line has a minimum of two conductors and support TEM propagation, which 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. On the other hand, a waveguide has only one consisting of the boundary of the pipe.

The waveguide has a distinct cut-off frequency above which electromagnetic energy will propagate and its cross section dimensions. Furthermore, propagation in waveguide occurs with field pattern, or modes. Any waveguide can support an infinite number of modes each of which has their own cut-off frequency. Both the characteristic impedance and the propagation constant of a waveguide are function of frequency. 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). It is necessary to analyze these modes in order to understand how it propagates inside the waveguide.

2.2 APPLICATION OF 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-avoidance systems, weather forecast, motion detectors and a wide variety of remote sensing systems.

The design of filters is unusual in that it uses network synthesis, with which it is possible to apply systematic procedures to work forward from a specification to a final theoretical design. This is the converse of most engineering disciplines which tend to use design rules based on analysis. A prerequisite to skills in network synthesis is a thorough grounding in the circuit theory of passive networks, a subject often treated superficially in modern electrical engineering degree courses. 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 realization. Thus the designer also has to have a reasonable knowledge of the properties of the electromagnetic of these devices.

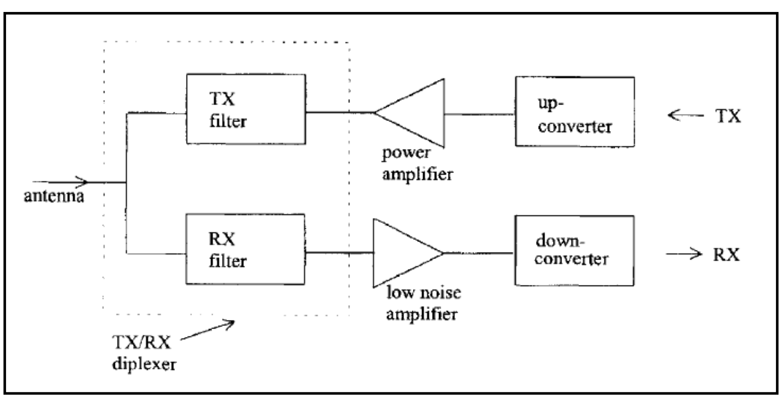

Figure 2.1: RF front end of a cellular base station.