GENERALIZED CHEBYSHEV MICROWAVE FILTER FOR WIDEBAND APPLICATIONS

LIM FENG SHENG

This report is submitted partial fulfillment of requirements for the award of Bachelor of Electronic Engineering (Telecommunication Electronics) With Honours

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

June 2012

UNIVERSTI TEKNIKAL MALAYSIA MELAKA

FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN

PROJEK SARJANA MUDA II

TajukProjek : **GENERALIZED CHEBYSHEV MICROWAVE FILTER FOR WIDEBAND APPLICATIONS**

SesiPengajian :

1	**1**	**/**	**1**	**2**

Saya **LIM FENG SHENG**

mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (√) :

☐	**SULIT***	*(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	**TERHAD****	**(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
√	**TIDAK TERHAD**	

Disahkan oleh:

_________________________ __________________________________

(TANDATANGAN PENULIS) (COP DAN TANDATANGAN PENYELIA)

Tarikh: Tarikh: …………………………….

"I hereby declare that this report is the result of my own work except for quotes as cited in the references."

Signature : ……………………………………….
Author : Lim Feng Sheng
Date : June 2012.

"I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering (Telecommunication Electronics) With Honours."

Signature	: ……………………………………….
Supervisor‟s Name	: Dr. Zahriladha bin Zakaria
Date	: ……………………………………….

Dedicated to my beloved family

ACKNOWLEDGEMENT

I would like to thank my project supervisor, Dr. Zahriladha bin Zakaria for his guidance throughout the project. Besides, I appreciated the idea of the project and helps given by my project supervisor.

In addition, I would like to thank my family for supporting me morally throughout my completion of the project. Last but not least, I would like to thank the faculty for giving a chance to take part on a project which is a requirement to fulfilling the bachelor degree where I had gained great experiences and knowledge.

ABSTRACT

This project proposes a 7th order generalized Chebyshev filter with cut-off frequency at 10.6GHz to achieve wideband requirements such as in ultra wideband (UWB) by using Advance Design System (ADS) software. Normally, the conventional Chebyshev will produce amplitude variation in the passband and the transmission zeroes cannot be placed independently hence the selectivity of the filter is limited. Hence, this project intend to design a generalized Chebyshev filter prototype where the transmissions zeros can be placed independently hence offer better selectivity than the conventional Chebyshev characteristic. This project will be design based insertion loss method and is expected to achieve return loss with better than -20dB and insertion loss of -60dB at cutoff frequency of 10.6GHz. This proposed work represent the a 7th generalized Chebyshev lowpass filter using suspended stripline substrate for UWB applications such as wireless personal area network (WPAN), high-speed wireless universal serial bus (WUSB), satellite communication and next-generation Bluetooth technology.

ABSTRAK

Projek ini membentangkan satu penapis "generalized" Chebyshev dengan tujuh turutan dengan frekuensi potong pada 10.6GHz untuk mencapai syarat-syarat jalur lebar contohnya seperti jalur lebar ultra (UWB) dengan menggunakan perisian Advanced Design System (ADS). Biasanya, penapis Chebyshev konvensional akan mengeluarkankan variasi amplitude dalam laluan dan sifar penghantaran tidak boleh diletakkan secara bebas justeru pemilihan turas adalah terbatas. Oleh sebab itu, penapis "generalized" Chebyshev dipilih kerana penghantaran sifar boleh diletak secara bebas maka ia menawarkan prestasi yang lebih tinggi daripada ciri-ciri Chebyshev konvensional. Projek ini akan direka berdasarkan kaedah "insertion loss" dan dijangka mencapai "return loss" yang lebih rendah daripada -20dB dan "insertion loss" di -60dB di mana "cutoff frequency" berada di 10.6GHz. Penapis ini akan direalisasikan dengan teknologi garis jalur bergantung dan digunakan dalam aplikasi UWB seperti WPAN, WUSB, komunikasi antara satelit dan teknologi Bluetooth generasi akan datang.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

NOMENCLATURE

ADS	Advanced Design System
GHz	Giga Hertz
MHz	Mega Hertz
IEEE	Institution of Electrical and Electronic Engineer
IL	Insertion Loss
P_{LR}	Power Loss Ratio
RL	Return Loss
RF	Radio Frequency
TEM	Transverse Electromagnetic Wave
UWB	Ultra Wideband

SYMBOLS

%	Percentage
π	Pi
λ	Wavelength
Ω	Ohm
β	Propagation Constant
C	Capacitance
dB	Decibel
f_c	Cut-off frequency
k	Constant
l	Length of stub
L	Inductance
m	M-derived Constant
N	Number of order
n	Number of order
S_{11}	Return Loss
S_{21}	Insertion Loss
Z_o	Characteristic impedance

CHAPTER 1

INTRODUCTION

1.0 Introduction

Radio frequency (RF) filter or microwave filter is a type of passive device with two ports network because it passes the desired signal and blocks the unwanted signal. Filters are commonly employed in microwave and millimeter-wave transceivers as channel separators. Basically, it have four types of frequency responses which are low pass, high pass, band pass and band stop characteristics.

In several industries such as satellite and airborne communication, there are continuous demands for smaller size, lighter weight, and lower manufacturing cost devices [1]. Therefore, size reduction has becoming a major design consideration for practical applications in broadband wireless access communication system. As the size of the RF filter decrease, the application system will become smaller in size.

Current generation of miniature surface-mount RF and microwave filters based on variety of technologies to achieve small size while maintaining low pass band insertion loss with high out-of-band rejection. Nevertheless, the performances of the filter must not be influenced by the size and the design of compact filter should achieve fine system performances such as good bandwidth, low return loss and exact center frequency.

1.1 Objective

The objective of this project is to design a generalized Chebyshev lowpass filter for wideband applications and to realize the filter using suspended stripline substrate.

1.2 Problem Statement

Even though the conventional Chebyshev microwave filter is designed with better rate of attenuation compared to other microwave filter, there are still improvement needs to be done in order to increase the performance of Chebyshev filter. For example, the conventional Chebyshev will produce amplitude variation in the passband and the transmission zeroes cannot be placed independently hence the selectivity of the filter is limited. The objective of the project is to design a generalized Chebyshev microwave filter for wideband applications and to minimize the cost of production of the generalized filter. The generalized Chebyshev will achieve higher selectivity and lower losses compared to conventional Chebyshev filter due to the transmissions zeros can be placed independently. Besides that, by reducing the number of the circuit order, the size of the generalized Chebyshev filter will be reduced.

1.3 Scope of Work

In order to design the generalized Chebyshev microwave filter, the basic of filter design and character of filter need to be studied. Then the next step will proceed to circuit designing. The circuit will be design based on prototype of low pass filter. After that, the physical layout of the filter will be constructed by using Advanced Design System (ADS) software. Then, the filter will be fabricated according to the physical layout. Simulation and measurement results are compared in order to verify the objective in this research work.

1.4 Methodology

This project is categorized to three major stages. The literature review and background study on the particular topics are done for the first stage to ease understanding in the filter techniques, characteristics and design concepts of the lowpass filter. The second stage will proceed on the construction and simulation of generalized Chebyshev protoptype using Advanced Design System (ADS) software. Next, the generalized 7th order Chebyshev lowpass filter are then physical transformed and em simulated. The last stage is the hardware fabrication on the generalized 7th order Chebyshev lowpass filter. This stage also involved measurement of the fabricated hardware and the measurement result is compared to the simulated result.

1.5 Organization of Report

This thesis consists of five chapters which are categorized as below to discuss on the project of generalized Chebyshev lowpass filter design.

Chapter 2 is the literature survey of the RF filter designs, which covers the background study on the miniaturized lowpass filter design and literature review on filter design theory. These will influence the selection of the filter design method and the techniques in the project.

Chapter 3 discusses the methodology of the project. The methods and procedures to design generalized Chebyshev lowpass filter is covered in this chapter.

Chapter 4 illustrates the simulations and measurement results of the band pass filter. Result analysis and discussion are covered in this chapter.

Chapter 5 describes the conclusion and it also includes recommendations of this project.

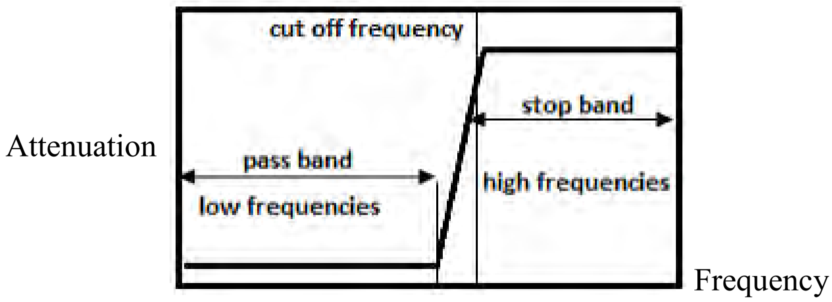
CHAPTER 2

LITERATURE REVIEW

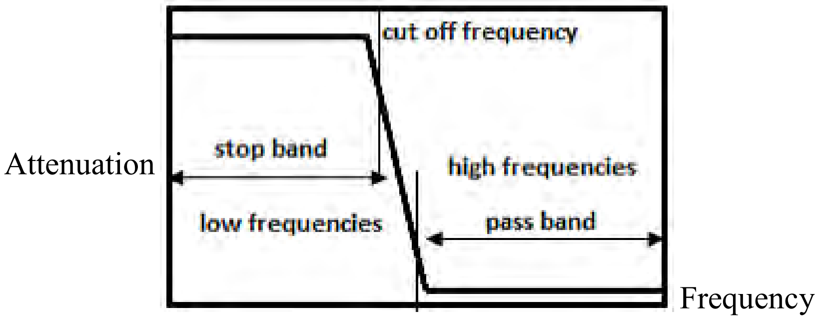
2.0 Introduction

This chapter discusses the literature review of microwave filter design principles, microstrip technology, and the literature survey of miniaturized low-pass filter. The literature review in this chapter influences the selection of design methods and the characteristic polynomial function of the RF filter design.

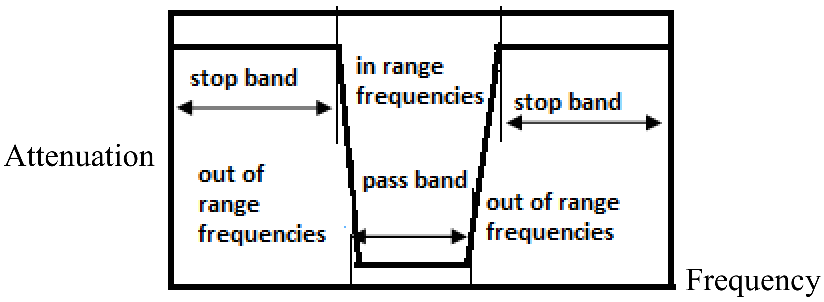
Filter can be classified by its frequency response characteristic such as low-pass, high-pass, band-pass, and band-stop as described earlier. The four types of frequency response are shown in Figure 2.1.



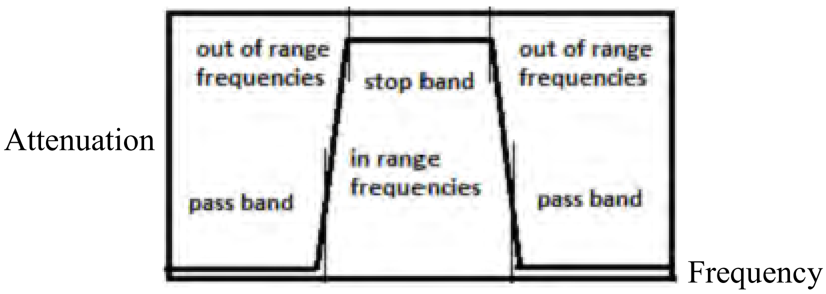
(a) High-pass Filter



(b) Low-pass Filter



(c) Band-pass Filter



(d) Band-stop Filter

Figure 2.1: Examples of frequency response of (a) High-pass Filter (b) Low-pass Filter (c) Band-pass Filter (d) Band-stop Filter [10]

Figure 2.1 represents the frequency response with attenuation versus frequencies. For ideal filter, the pass-band indicates that there is no attenuation of signals whereas high attenuation discards signals in the stop band. Low pass filter passes low frequencies signals and rejects frequencies signals higher than the cut-off frequency. However, high pass filter passes high frequencies signals and attenuates frequencies signals lower than the cut-off frequency. Band pass filter, on the other hand, allows only a range of frequencies to pass through while attenuating frequencies signals outside the range. Vice versa, band stop filter rejects a range of frequencies while allowing frequencies outside band to pass through.

The RF filter design techniques or the characteristic polynomial functions that are commonly design are Butterworth, Chebyshev, Elliptic Function, Bessel, Linear Phase, and etc. Each of the characteristic polynomial function has different characteristic responses. Filter can be fabricated either on lumped element, distributed elements or both the combination. The parameters of interest of the filter are frequency range, bandwidth, stop band attenuation, transient response, and group delay. An ideal filter shows zero insertion loss, constant group delay over the required pass band, and infinite rejection elsewhere [11].

In our time, wideband filters with extreme selectivity are required in certain applications. For example cellular radio base stations often use low loss dielectric resonator filters, and the spurious modes of these devices often occur at frequencies only 25 per cent above the passband. In another example, radar warning receivers broadband multiplexers require octave plus bandwidths with at least 60dB stopband insertion loss within 10 per cent of the band-edge frequency. Therefore „clean-up" lowpass filters must have high selectivity combined with low loss and small size. Such severe specifications are not easily achievable using all-pole transfer functions and more selective generalized Chebyshev characteristics are often required [12].

2.1 Literature Survey of Generalized Chebyshev Filter

In the research of Zlatoljub D. Milosavljevic [13], a class of generalized prototype filters with asymmetrically located transmission zeros was designed. The frequencies of extreme values of magnitude characteristic in the stopband are obtained by solving a set of non-linear equations. In this research, an exact, efficient and simple procedure was presented for the calculation of transmission zeros, for a class of generalized Chebyshev low-pass prototype filters with a maximum of two asymmetrically located transmission zeros of a multiplicity. The transmission zeros can be of arbitrarymultiplicity, and their maximum number is four. The frequencies of magnitude characteristic extreme values in the stopband have been obtained in closed form. Transmission zeros have been calculated by solving nonlinear equations and new equations for zero orders of maximally selective filters with equiripple stopband characteristic have been presented. The generalized Chebyshev prototype is one of themost useful because it combines the equiripple amplitude characteristic with the arbitrary position of transmission zeros in the complex plane. These filters are suitable for realization in different technologies, e.g., ceramic technology, cavity, and waveguide filters, etc., and can be used in handsets, base-station, and satellite applications, etc. Three examples have been given. One of them has verified transmission zeros calculation procedure, another has presented the synthesis procedure for the prototype, and the third has shown a realized ceramic filter for handset applications.

The research made by Hisham L. Swady [9], a generalized Chebyshev-like approximation for low-pass filter was designed. This research presents a novel general approach for analog filter designing for Chebyshev-like approximation with odd order. Chebyshev-like filters differs from classical Chebyshev ones in the ripple factor, Ɛ, which is not equal amplitudes with classical one. In an example for n=2, N=5, with utilizing numerical techniques to evaluate w_i"s, w_i=0.5 and w_2=0.9 are obtained. Then, the pole locations of the new filter are: -0.5143, -0.1449±j1.0056 and -0.407±j0.6076 for δ_p=0.894. In this paper, we have addressed a generalized Chebyshev-like approximation for low-pass filter design. The approach for one approximation method is compared with those of the classical Chebyshev filter. The obtained results show that the proposed designed filter gives lower Q values of complex poles with a considerable value of flatness of the filter passband response.

In another research done by Jian-Yu Li, Chun-Hsiang Chi, and Chi-Yang Chang [14], a systematic and analytical method for the exact synthesis of generalized Chebyshev wideband hybrid ring based bandpass filters with a controllable transmission zero pair is developed. The basic configuration of the proposed filters consists of a hybrid ring, a multi-section short-circuited stub and a multi-section open-circuited stub. In this configuration, the position of the controllable transmission zero pair can be easily designed by setting the impedances of the multi-section short-circuited stub and the multi-section open-circuited stub. According to the position of the controllable transmission zero pair, two kinds of filters are proposed. The filter has controllable transmission zero pair on the real axis (imaginary frequency) that they can be arranged to improve the group delay flatness. On the other hand, the filter has a controllable transmission zero pair on the imaginary axis (real frequency) and the desired stopband suppression can be obtained by adjusting the optimal position of them. This synthesis method is developed to obtain the impedance value of each line section and ripple factors of the filters with respect to given specifications (center frequency, passband bandwidth and transmission zeros).

According to Christopher Ian Mobbs and John David Rhodes [7], a design method for narrow-band suspended substrate stripline filters having a true bandpass structure is presented. A generalized Chebyshev lowpass prototype is used, resulting in a convenient form of realization in suspended substrate stripline. A prototype device, designed with the aid of a computer program, is given as an example. Results from this device show that the method of realizing such a filter is viable for many applications and may be suitable to replace more conventional types of microwave filter realized using TEM-mode resonator. In this research, with the aid of a computer program to carry out the design procedure outlined, a fifth-degree filter, based on a 20-dB return loss prototype having a passband from 5 to 5.5GHz, was constructed. A ground spacing of 0.070in was used and the widths of the series section were chosen to be 0.030in, which is as small as a convenient for these