MICROWAVE FILTER – STEPPED IMPEDANCE LOWPASS FILTER AT 2.4GHz

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To my beloved parents:

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ABSTRACT

This project presents the design of microwave lowpass filter for wireless local area network application operating at 2.4GHz frequency. The designed filter is Chebyshev response type two stepped impedance structure with pass bandwidth of 0.0835GHz. It has been observed that the minimum attenuation is less than -23dB at 3GHz frequency, insertion loss of 6.042dB, passband ripple of 4.326dB and stopband ripple is 15dB. Simulation and optimisation uses Microwave Office software and the filter design is implemented using standard fabrication process on FR-4 substrate.

ABSTRAK

Projek ini menerangkan tentang reka bentuk penapis gelombang mikro untuk kegunaan jaringan tempatan tanpa wayar yang beroperasi pada lingkaran 2.4GHz. Jenis penapis yang telah direka adalah penapis galangan-tangga Chebyshev jenis dua yang mempunyai lebar-jalur 0.0835GHz. Pemerhatian yang dilakukan mendapati susutan minimum adalah lebih rendah dari -23dB pada 3GHz frekuensi, kehilangan sisipan pada 6.042dB, riak gelombang pada lulus-jalur adalah 4.326dB dan riak gelombang pada henti-jalur adalah 15dB. Simulasi dan pengoptimum telah dilakukan menggunakan perisian Microwave Office dan perlaksanaan fabrikasi dibuat pada substrak FR-4.

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ABBREVIATIONS

EBG		Electromagnetic Band Gap
IEEE	-	Institute of Electrical and Electronics Engineers
EM	-	ElectroMagnetic
FR-4	-	Flame Retardant 4
ISM	-	Industrial, Scientific and Medical
LTCC	-	Low Temperature Co-fired Ceramics
LPF	-	Low Pass Filter
LPP	-	Low Pass Prototype
MLIN	-	Microstrip Line (Closed Form)
MSTEP	-	Microstrip Step in Width (Closed Form)
MSUB	-	Microstrip Substrate Definition
PCB	-	Printed Board Circuit
PDA	-	Personal Digital Asassistant
SMA	-	Sub-Miniature version A
TEM	-	Transverse ElectroMagnetic
TLM	-	Transmission Line Method
UV	-	Ultra-Violet
VSWR	-	Voltage Standing Wave Ratio
WLAN	-	Wireless Local Area Network
	-	Modulated Frequency
		Relative Dielectric Constant
ε_{eff}		Effective Permeability
h		Substrate Height
		Substrate Thickness
		Length
		Width

CHAPTER I

INTRODUCTION

1.1 Introduction

Microwave filter are two-port network, reciprocal, passive, linear device which attenuate heavily the unwanted signal frequencies while permitting transmission of wanted frequencies [1]. The type of construction of this filter is a reflective filter which is consists of capacitive and inductive elements producing ideally zero reflection loss in the pass band region and very high attenuation in the stop band region. The practical filters have small non-zero attenuation in the pass band a small signal output in the attenuation or stop band due to the presence of resistive losses in reactive elements of propagating medium [1]. The proposed Microstrip Stepped-Impedance lowpass filter is designed for 2.4 GHz operating frequency which is suitable for ISM band (Industry, Scientific and Medical) with attenuation at 3GHz stop bandwidth [2].

The stepped impedance distribution element filter is one of the most popular microstrip filter configurations used in the lower microwave frequencies. It is easy to manufacture because it has open-circuited ends and it is easy to design. Microstrip filters play an important role in many RF applications. As technologies advances, more stringent requirements for filters are required. One of the requirements is compactness of filters.

1.2 Objective

The objective of this project is to design a micostrip lowpass filter (LPF) using microstrip technology. This filter designed for wireless local area network (WLAN) application.

1.3 Literature Review

In modern wireless telecommunication system, compact size and high performance filter are commonly required to reduce the cost and enhance system performance. The use of microwave filters can be found in many applications in microwave circuits and telecommunication systems, implemented in a number of topologies. One of the conventional filters is the stepped impedance filter mainly due to the ease of implementation in either microstrip or coplanar technology [8], [12], [13].

Earlier filter designs have mostly been focused on using a modified silicon substrate where the variation in substrate height and effective permittivity is accomplished by etching [14]. Different concepts and materials have been suggested for achieving a high dielectric constant and also the advantage of being tunable by varying the composition. Several ideas of how to perform this with different technologies have been presented [19]. Also commercially available low temperature co-fired ceramics (LTCC) tapes exist with dielectric values of about 4 to 10. These tapes, together with high dielectric constant ceramics (bi-pyrochlore), could also be combined and used for achieving a variation in dielectric constant [19].

The stepped impedance filter is normally design by alternating low and high impedance regions where the change in impedance is controlled by the line width of the strip. For achieving a high degree of attenuation in the stop band, it is necessary to obtain a 'high to low impedance ratio' (Z_H=Z_L) or increase the order of the filter. If a dielectric homogeneous substrate is used the limitations are directly related to the achievable line widths. In addition, to arrive at narrow line widths could also be difficult due to process limitations (minimum possible feature size). By using a non-homogeneous dielectric substrate instead where a change in dielectric constant, ε_r, is introduced, it would be possible to create a stepped impedance filter with a continuous microstrip width.

Other designs have also utilised the method of etching the ground plane to producing a variation in the effective permittivity [15], [16], [17]. However, using etching ground plane will locally change the effective permittivity. The technology of etching the ground plane will also introduce unwanted radiation in microwave applications and therefore require necessary shielding. Therefore other designs utilising materials with different dielectric constants could offer a new possibility to produce filters and other devices [18].

Recently, the new stepped impedance geometry with different working principle, design procedure, performance, and physical size, mediate, and high working frequency have been introduced. It is called electromagnetic bandgap structure (EBG structure) [17], [20], [21]. The comparison between these two techniques and analysis is explained on [22]. This EBG structure has the advantage working in higher frequency and high attenuated in the stopband. Less size that conventional stepped impedance geometry. However, the ripples level of in the passband of this EBG structure higher that conventional stepped impedance technique.

In combination with progress in finding new high dielectric constant materials this could be an interesting technology for improving some of the filter performances. The size reduction of the filter could also become an important factor where large line widths could be replaced by smaller line widths by introducing a higher dielectric constant.

For the conclusion, I choose to design a conventional geometry of microstrip lowpass filter using high and low impedance technique. Various numerical method have been developed by a number of researchers to ease simulation effort when designing microstrip lowpass filters [2], [12], [13] which includes transmission line method (TLM). TLM is a technique for solving Maxwell's equation in the presence of complex environment [24]. TLM is regarded as the most practical for its analysis and design. TLM has been popular in the construction of an equivalent circuit model due to its accuracy and numerical efficiency.

1.4 Scope of Project.

Several important parameters generally considered are pass bandwidth, stopband attenuation and frequencies, insertion loss and return loss. This filter operates in the ISM frequency band covering 2.4 GHz to 2.4835 GHz. The filters discussed in this project are design to have pass bandwidth of 0.0835GHz with minimum stop band attenuation of -23dB at 3GHz and insertion loss below 10dB and also designed to operate between terminated impedance 50ohm which is typical used for WLAN system. The filters are designed using Microwave Office design software and implemented on flame redundant (FR-4) substrate with dielectric constant of 4.7, loss tangent of 0.019 and substrate height of 1.6mm.

Several scopes of work have been determined are:-

1 Doing literature review by referring to related books and IEEE journal.

2 To calculate the stepped impedance lowpass filter, design and simulate the filter using Microwave Office to met WLAN specification.

3 To obtain the physically dimension filter values, dielectric material characteristic and obtain frequency response of the filter.

4 To fabricate filter on the microstrip board

5 Analysis will be carried out to compare the simulation and the measurement result.

1.5 Project's Methodology

Figure 1.1 shows the flow chart of this project. It used as general plan to get this project done. This project involves 4 major phases:

1st phase: Literature Review

- o Gathering the project's information via texts book, Internet, journals, magazines, published work and reference books.

- Doing research to know the detail about designing dual-plane microstip low pass filter.
- Study of the software implementation (Microwave Office)
- Have meeting with supervisor and lecturers.

2nd phase: Calculation and analysis

- Analyzed and calculated all the parameters that related to design the Step impedance filter and.
- Using Matlab software to calculate physical dimension and all parameters needed.

3rd phase: Software Implementation development

- Used software (Microwave Office) to design and measurement of filter.
- To obtain the precise value using this software.

4th phase: Hardware Development

- Then proceed to design microstrip filter using etching technique and do the measurement using spectrum analyzer. Finally, comparison between simulation and measurement data.

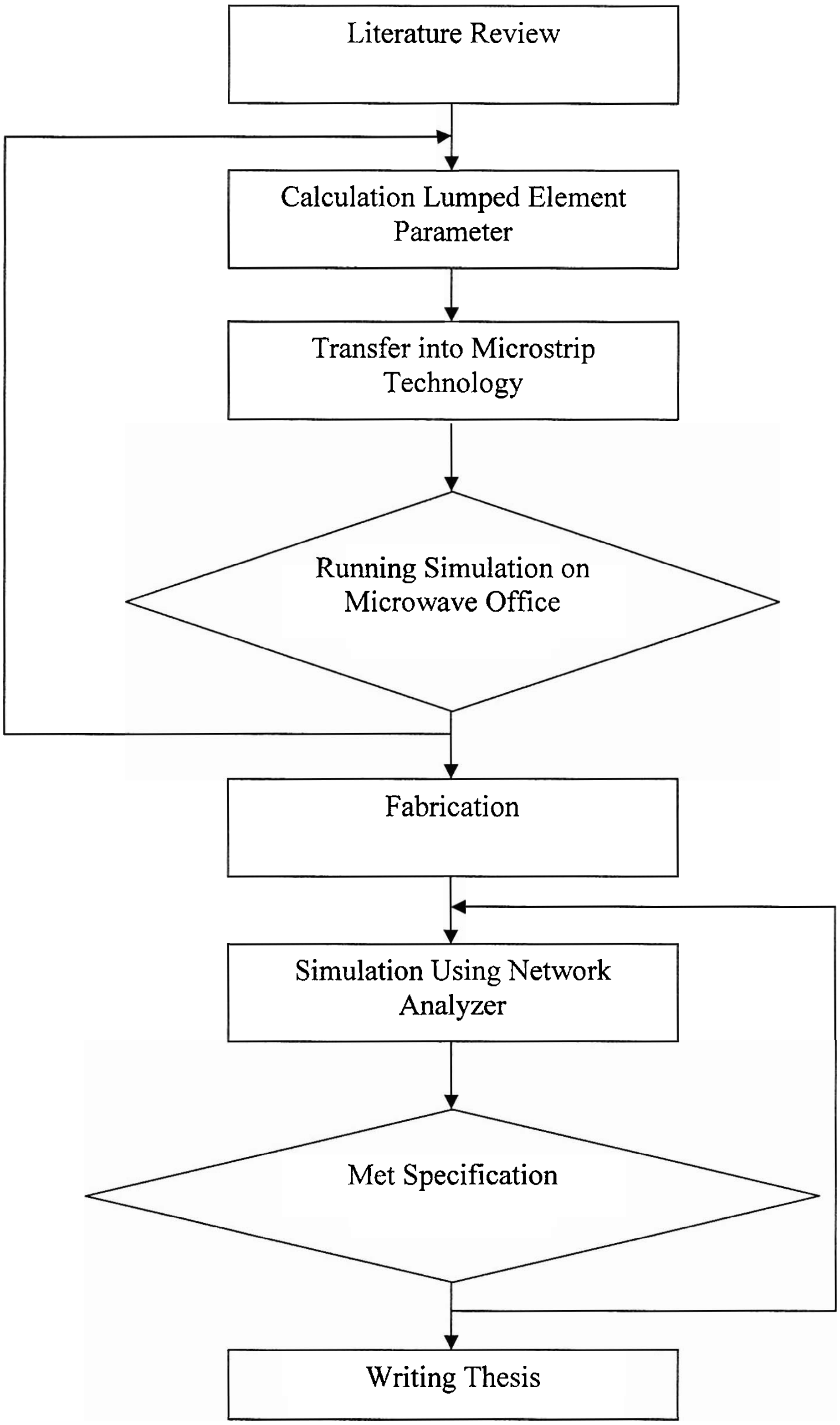

Figure 1.1: Flow Chart of Methodology.

1.6 Expected Result

From [27], [28], we identified the filter specifications that have specific value in order to meet the WLAN filter specifications requirement. The filter will be developed using FR-4 substrate with the following specifications. Table 1.1 shows the expected result of the WLAN filter.

Table 1.1: Expected result of the filter.

Filter's Parameter	**Value.**
Cut-off frequency (-3dB)	2.49GHz
Bandwidth Cover	2.4GHz – 2.4835GHz
Bandwidth	0.0835GHz (3.42%)
Passband Ripple	0.5dB
Minimum Attenuation	-23dB
Insertion loss	< 10dB

CHAPTER II

LITERITURE REVIEW

2.1 Lowpass Filter in WLAN application.

Microstrip filters play various roles in wireless or mobile communication systems. Microwave and RF filters are widely used in this system in order to discriminate between wanted and unwanted signal frequencies [3]. The concept of a low-pass filter exists in many different forms, including electronic circuits (like a *hiss filter* used in audio), digital algorithms for smoothing sets of data, acoustic barriers, blurring of images, and so on. Implementations of lowpass filter in WLAN application shown in Figure 2.1. The input baseband signal which is included voice, data, and video is assumed to be at a frequency f_m. A lowpass filter serves to remove frequency beyond the passband of the channel [2]. Lowpass filter is designed for use in harmonic rejection applications for cellular handsets, wireless PDA's, and IEEE 802.11b WLAN which might cause interference with other communications [30]. It's provided high harmonic attenuation respectively at a maximum insertion loss of 0.5dB. Lowpass filter also determine the voice performance in the data signal.

Basically, communication is the process of transmission information from transmitter to receiver. The microstrip filter is either of suitable component that are using on the receiver and transmitter of microwave communication system [9]. Lowpass filter is located at the part of ending in transmitter device.