DESIGN AND DEVELOPMENT OF BANDPASS FILTER BASED ON HIGH Q

CAVITY FILTER STRUCTURES FOR MICROWAVE IMAGING

TECHNOLOGY

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For my beloved mother who never failed to support me through this journey, Puan Hajjah Zaini binti Ahmad

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ABSTRACT

Microwave system is the new emerging technology that had shown a vast impact towards the modern generations due to the development and advanced microwave technology. The microwave technology is like the open door to the future where there are a massive potential regarding the radio frequencies applications. In order to accomplished this advanced technology, the design of high performance bandpass filter is very important. Filters are one of the most important component in microwave application that are used to discriminate between desired and undesired frequencies in devices. They have played the main key to distinguish the devices in term of devices' performance and cost especially in the congested spectrum. Therefore, this thesis presents the design and development of bandpass filter based on high Q cavity filter structures for microwave imaging technology. The filter will provide high frequency selectivity and low insertion loss that will be the main criteria for high Q filter design which results in high performance. The design process is designed by the lossless Chebyshev lowpass prototype and followed by the transformation of the lowpass prototype to rectangular waveguide cavity bandpass filter. The simulation with the aid of EM Simulator will be tuned in order to obtain the desired design specification. Besides, the filter is designed with smaller size despite the high number of resonators. This will lead a design of bandpass filter with high performance. Since the design provides a high performance bandpass filter, it is great in for the use of microwave imaging technology.

ABSTRAK

Sistem pengambaran gelombang mikro adalah satu teknologi yang sedang berkembang pesat dan telah memberi satu impak besar kepada generasi moden masa kini. Sistem pengambaran gelombang mikro juga menjadi satu pintu yang baru kepada masa hadapan dimana potensi sistem ini telah melangkau menjadi satu aplikasi yang hebat. Namun, untuk mencapai tahap kecanggihan teknologi sebegitu, rekabentuk penapis lulus jalur merupakan satu komponen penting dalam aplikasi gelombang mikro dimana ia adalah satu sistem yang hanya membenarkan frekuensi dalam julat tertentu sahaja untuk melepasinya dan menyingkirkan frekuensi yang berada di luar julat tersebut. Penapis lulus jalur ini menjadi satu kunci utama dalam menyediakan keupayaan dan kos yang bersesuaian dengan sesuatu gadjet terutama dalam satu frekuensi yang padat. Oleh itu, tesis ini mengemukakan satu rekabentuk dan pembangunan penapis lepas jalur mengunakan Chebyshev berturas rendah ke penapis lulus jalur pemandu berongga berbentuk segi empat tempat. Simulasi yang dibuat dengan menggunakan satu bantuan daripada satu program simulasi elektromagnetik akan ditala untuk mendapatkan satu rekabentuk yang diidamkan. Selain itu, penapis lulus jalur ini juga direkabentuk dengan bentuk yang kecil meskipun bilangan penyalun yang banyak. Maka, rekabentuk penapis jalur ini akan beroperasi dengan keupayaan yang tinggi. Disebabkan rekabentuk ini menyediakan penapis lulus jalur yang berkeupayaan tinggi, maka ia amat sesuai untuk digunakan dalam sistem pengambaran gelombang mikro.

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ω	Angular frequency of passband frequency
ω_C	Angular frequency of cut-off frequency
λ_{g1}	Guide wavelength at lower frequency
λ_{g2}	Guide wavelength at upper frequency
λ_{g0}	Center guide wavelength
f_0	Center frequency
f_c	Cut-off frequency
c	Speed of light
a	Waveguide width
b	Waveguide height
l	Waveguide length
L_A	Stopband insertion loss
L_R	Passband return loss
N	Degree of Chebyshev / Number of stages
S	Ratio of stopband to passband frequencies
ε	Ripple level
α	Attenuation constant
K	Characteristic impedance of impedance inverter
Z	Impedance
B	Susceptance
ψ	Electrical length
C	Capacitor
L	Inductor
r	Element number

CHAPTER 1

INTRODUCTION

This chapter will explain about the overview project of design and development of bandpass filter based on high Q cavity filter structures for microwave imaging technology. This chapter will cover the summary of the project, objectives, and problem statements. Project scope and project methodology that will be implemented throughout the project until it successfully done.

1.1 Summary of the project

Microwave imaging technology has been receiving many researchers attention since decades because of its versatility and suitability for various range of applications. This technology has received its attention due to its attractive features as a diagnosis application. Since then, many researchers has been improving and building a new improved performance technology of microwave to fit the market demand. From the microwave imaging structures, a microwave bandpass filter is a structure that are allowing a certain frequencies to pass through them and discriminates all others. Waveguide cavity filter is one of the most common microwave filter to be designed and developed since it is very likely to achieve the most efficient performance compared to other type of microwave filters. This waveguide cavity filter is said to have a very high Q factor, high power capability and have low loss compared to others.

This project will propose a 3D waveguide cavity bandpass filter from the High Frequency Electromagnetic Simulation (EM Simulator) software and in spectrum analyzer. The proposed microwave filter will operate at 5.0 GHz frequency with 200 MHz bandwidth. In order to design an efficient and high performance bandpass filter for microwave imaging application, a very selective bandpass response and a very low insertion loss at the passband must be achieved. From the studies of the literature review, the rectangular waveguide filter will provide both high frequency selectivity and low insertion loss where the bandpass filter will allow specific frequencies and reject unwanted frequencies. Having high selectivity frequencies and very low insertion are the main criteria for high Q cavity structure. For this various reasons, we proposed the rectangular waveguide filter for microwave imaging based on high Q cavity structures.

Nevertheless, high performance specification of bandpass filter by using conventional lumped element or planar technologies are very high to produce. Therefore, a 3D waveguide filter is proposed. This will design with the help of EM Simulator software and the simulation result will be analyzed and presented in order to get the most efficient design for the waveguide filter.

1.2 Problem Statement

Waveguide filters, microstrip filters and strip-line filters are widely used in the microwave technologies for many years. Thus, with this increasing usage of these technology, the demand from the market for an efficient and high performance bandpass filter especially in microwave imaging technology has been rising. Therefore, the bandpass filter should have the design of filter that has high frequencies selectivity and low insertion loss.

For the world where we created compact and small devices, planar technologies as such microstrips and strip-line filters are preferred compared to waveguide filters due to their small and compact design. Nevertheless, planar technologies are tough to meet high performance specifications of bandpass filter applications. Bandpass filter needs to have a high Q factor in order to achieve high performance. Therefore, among all the filter designs, waveguide filter is the most likely to achieve all the high performance specifications for the modern market. However, despites all the advantages, a waveguide filter has one disadvantage which is its size is larger than any other filter design.

Since it is very difficult for the market to achieve a high performance bandpass filter design, a bandpass filter based on high Q cavity filter structure is proposed to overcome the problem by having high selectivity frequencies and low insertion loss. This specifications will be result in high Q factor.

1.3 Objectives

The objectives for the design and development of Bandpass filter based on High Q Cavity structures for Microwave Imaging are:

1) To design and development Bandpass Filter based on high Q cavity filter structure through simulation using EM simulator software.

1.4 Scope of Project

In this project, we include the study of the background, techniques, calculation, parametric study and the designing procedure of the design and development of bandpass filter based on high Q cavity structure for microwave imaging. The design and simulation of the bandpass filter based on high Q cavity structure will be done with the EM Simulator software. The filter design will be design according to standard rectangular waveguide data provided by the microwave engineering book written by David M Pozar which are stated from the table below

Table 1.1 Design specification

Band	H (G)
Recommended frequency range (GHz)	3.95 – 5.85
TE_{10} cutoff frequency (GHz)	3.152
EIA designation WR-XX	WR-187
Inside dimensions (cm)	4.755 x 2.215
Outside dimension (cm)	5.080 x 2.540

From the table above, the final design of the bandpass filter based on the high Q cavity filter needs to meet all the design specification in order to achieve an efficient and high performance bandpass filter.

1.5 Project Methodology

This project starts with reviewing the characteristic of the bandpass filter at 5 GHz before calculation works are made. Then, it will proceed to EM simulator simulation before a conclusion to the performance of the bandpass filter is made.

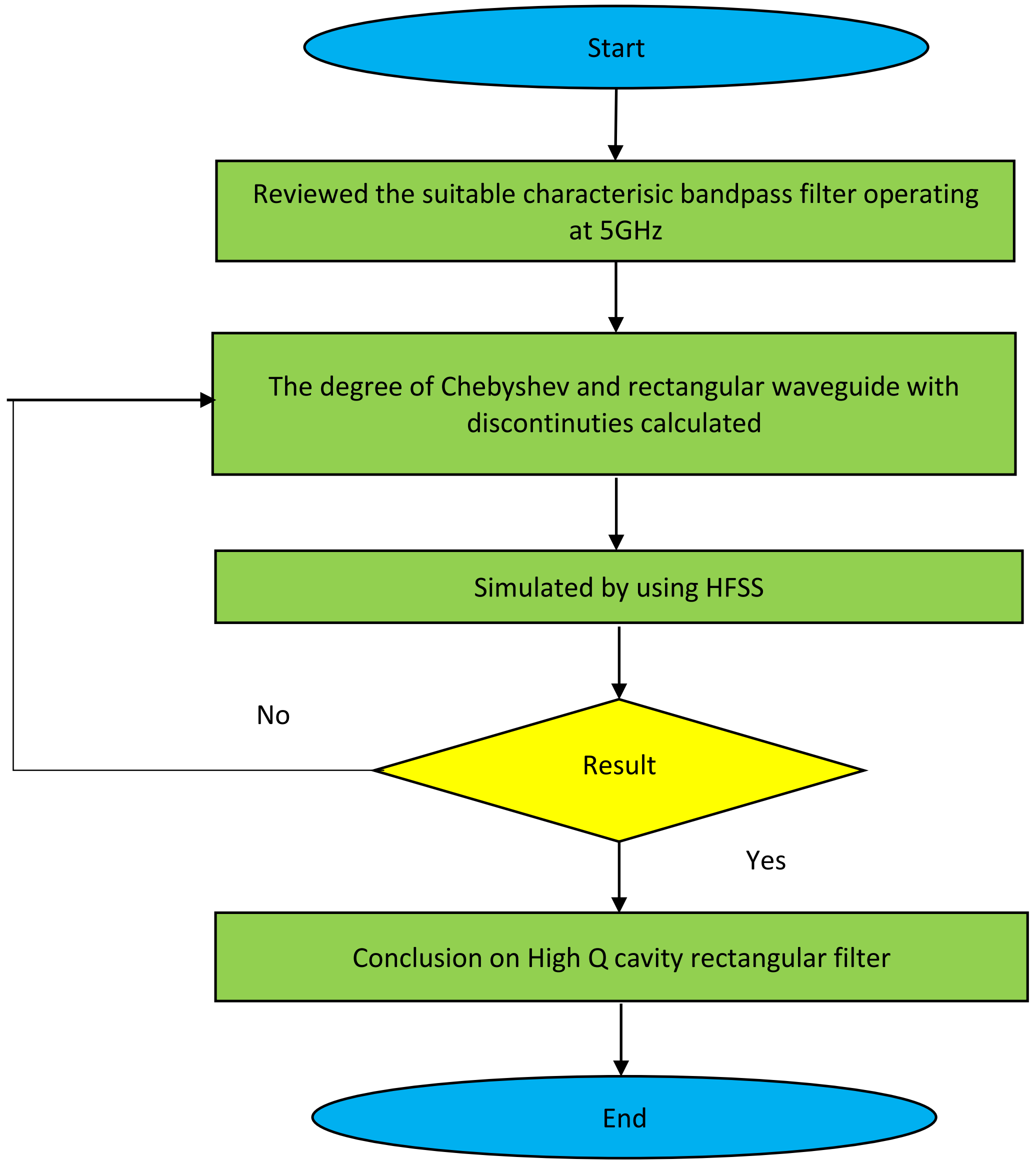


Figure 1.1 Project methodology flow chart

1.5.1 Literature Outline

Beginning of this project, we will do a whole literature study on the title; design and development of the bandpass filter based on high Q cavity filter for Microwave Imaging and understand thoroughly on the project. This literature study involves on the findings and understanding of the background knowledge, project concept, and all related calculations for the waveguide cavity filter to be designed in the EM Simulator software. All the literature studies are retrieved from various information that can be obtained from books, journals, websites and calculations.

1.5.2 Calculation and Design of the Bandpass Filter

The calculation for the bandpass filter is obtain from the book study and implement into the design to achieve the specification for an efficient and high performance bandpass filter. The best approximation calculation to the specification is chose. Early design is sketched on the paper and all the parameters will be obtained before proceeding the design to EM Simulator software to obtain the simulation.

1.5.3 Simulation

The designs are then simulated by using the EM Simulator software until the most efficient and the highest performance bandpass filter is achieved. The bandpass filter will be simulated into three different parts which are the

1.5.4 Fabrication of the Final Design

After the final design has achieved the design specification, the design will be fabricated after the EM Simulator design is converted to Autocad design. Then, a measurement test will be made at the lab to compare the measurement result with the simulation result.

1.6 Thesis Outlines

This thesis will consists of five chapters which are Chapter 1 is the introduction, Chapter 2 is the Literature Review, Chapter 3 is the Methodology, Chapter 4 is the Result and Discussion and last but not least, Chapter 5, Conclusion and Future Work.

Chapter 1 which is the introduction n will include the overview of the project, problem statement, objectives of the project, scope of project and project methodology. As for Chapter 2, the chapter will explain in detail regarding to the project title in term of theories and concepts. For Chapter 3, the chapter will explain the design method used in the project based on the best method and theoretical formulas founds from the literature review. Besides, Chapter 4 will consists of the discussion of the results as well as detailed results from simulation and also measurement. Lastly, chapter 5 will consists of conclusion of the project as well as future work that can be done in order to improve the project.

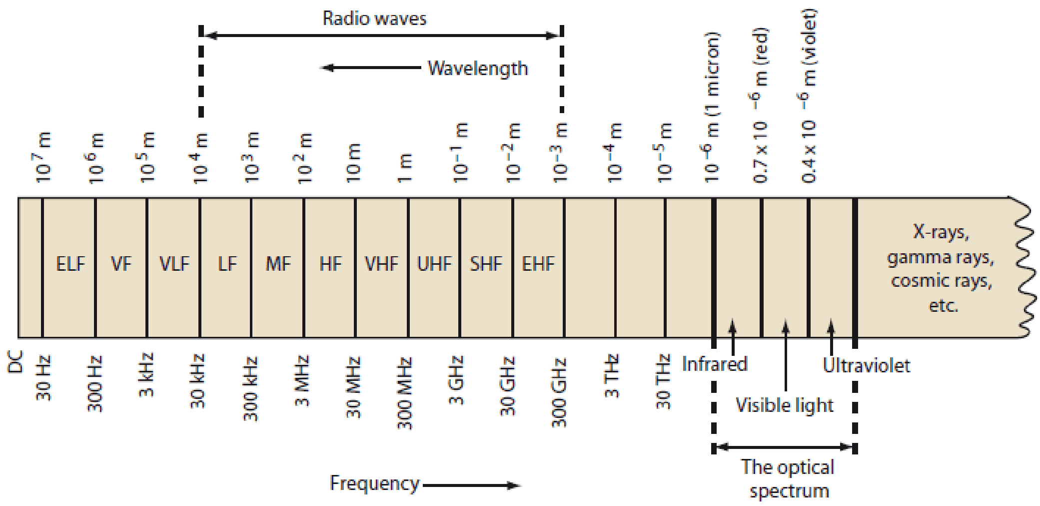
CHAPTER 2

LITERATURE REVIEW

This chapter will cover all the theoretical and concept of that related to the bandpass filter based on high Q cavity structures for microwave imaging. This includes the microwave imaging concept, filter response, high pass filter, low pass filter, bandpass filter, high Q factor, fundamental of waveguide, propagation mode in waveguide, discontinuities concept in waveguide filter and the design method of waveguide cavity using the Chebshey method.

2.0 Microwave Spectrum

Microwave is a form of electromagnetic wave that covers the behavior of alternating current ranging from 100MHz to 1000GHz frequencies. This frequencies are then categorized into different level of frequencies, from high frequency to ultra-high frequency. However, in term of microwave, the preferable frequencies ranging from 30 to 300 GHz, and this correspond with electrical wavelength between $\lambda = c/f$ = 1o cm and λ = 1 mm, respectively [1]. A standard circuit theory often cannot be used directly to solve microwave network problems due to the fact that, generally the lumped circuit element approximation of circuit is not valid at high radio frequency (RF) and microwave frequencies.



1. The electromagnetic frequency spectrum ranges from dc to light. The lower radio frequencies are designated mainly by frequency. The optical ranges are referred to by wavelength.

Figure 2.1 Microwave spectrum

As for microwave components, it is often act as distributed elements. This is caused of the phase of current or voltage changes drastically over the physical extent of the device due to device dimensions are on the order of the electrical wavelength. In other word, lower frequencies of microwave, the wavelength become large enough that there is insignificant phase variation across the device dimensions.

Figure 2.2 One of the application of microwave; microwave oven