

# **THE BUTTERWORTH MICROSTRIP HAIRPIN FILTER**

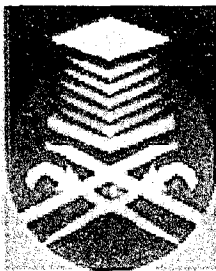
Presented in partial fulfillment for the award of

*Bachelor of Engineering (Hons.) (Electrical)*

**Universiti Teknologi Mara**

**40450 Shah Alam**

**Selangor Darul Ehsan**



**HARTINI BINTI MOHD ISA**  
**Faculty of Electrical Engineering**  
**Universiti Teknologi Mara**  
**40450 Shah Alam**  
**Malaysia**  
**APRIL 2005**

## ACKNOWLEDGEMENT

In the name of Allah S.W.T, The most beneficial and the most merciful. It is with deepest serve gratitude of the A-Mighty that gives strength and ability to complete this project.

I would like to take this opportunity to express special thanks to my project supervisor, Assoc. Prof. Dr. Zaiki bin Awang for his guidance, advice, kindness and also being helpful to guide me throughout the development of this project. My appreciation also goes to the laboratory technician, En Hisham for his assistance in measurement and fabrication.

Finally, I would like to express my special thanks to my beloved parents for their support and unending prayers and also to all my friends who had help me directly or indirectly in successful completion of my project.

## ABSTRACT

The purpose of this project is to design a microstrip band-pass filter operating at microwave frequencies using computer-aided design (*CAD*) package. A maximally flat bandpass-filter with centre frequency of 8 GHz was designed to have an insertion loss not exceeding 0.5 dB in the passband and a return loss of more than 40 dB in the stopband. To compare the performance of the hairpin filter design with its real-world counterpart, a test filter was fabricated on microstrip with a 0.5 mm substrate thickness and relative permittivity ( $\epsilon_r$ ) of 2.33. The filter was designed, simulated and optimized with the aid of a *CAD* package *HP-Eesof Libra*.

## TABLE OF CONTENTS

|                       | PAGE |
|-----------------------|------|
| DECLARATION           | i    |
| DEDICATION            | ii   |
| ACKNOWLEDGEMENT       | iii  |
| ABSTRACT              | iv   |
| LIST OF FIGURES       | v    |
| LIST OF TABLES        | viii |
| LIST OF ABBREVIATIONS | x    |

### CHAPTER 1 INTRODUCTION

|     |   |    |
|-----|---|----|
| 1.1 | Objective and introduction to project                 | 1  |
| 1.2 | Introduction to microwave engineering                 | 2  |
| 1.3 | Literature survey                                     | 6  |
| 1.2 | Microstrip circuits                                   | 8  |
| 1.3 | Filters   | 9  |
| 1.4 | Computer aided design (CAD)                           | 11 |
|     | 1.4.1 The need for CAD practice                       | 9  |
|     | 1.4.2 Flowchart of CAD procedure for microwave design | 11 |
| 1.5 | CAD package for microwave design                      | 12 |
|     | 1.5.1 <i>Eesof Libra TouchStone</i>                   |    |

## **CHAPTER 2                    THEORY OF MICROWAVE FILTERS**

|       |   |    |
|-------|---|----|
| 2.1   | Introduction to microwave engineering         | 15 |
| 2.2   | Introduction to microwave filters             | 16 |
| 2.2.1 | Ideal microwave filters                       | 17 |
| 2.2.2 | Band-pass filters                             | 20 |
| 2.2.3 | Butterworth (maximally flat) band-pass filter | 22 |
| 2.3   | Theory of hairpin filter                      | 24 |

## **CHAPTER 3                    DESIGN AND SIMULATION**

|       |  |    |
|-------|--|----|
| 3.1   | Butterworth low-pass characteristic                | 37 |
| 3.1.1 | The normalized Butterworth low-pass characteristic |    |
| 3.2   | Transformation from lumped to distributed elements | 46 |
| 3.3   | Parallel coupled line construction                 | 52 |
| 3.4   | Hairpin filter structure                           | 57 |
| 3.5   | Simulation results                                 | 65 |
| 3.5.1 | Lumped element simulation                          | 66 |
| 3.5.2 | Distributed element simulation                     | 67 |
| 3.5.3 | Butterworth hairpin filter before optimization     | 68 |
| 3.5.4 | Butterworth hairpin filter after optimization      | 68 |

## **CHAPTER 4                    FABRICATION TECHNIQUES**

|       |                                     |    |
|-------|-------------------------------------|----|
| 4.1   | Introduction                        | 69 |
| 4.1.1 | Mask preparing                      | 70 |
| 4.1.2 | Photoresist process                 | 73 |
| 4.1.3 | Exposing the microstrip to UV light | 74 |
| 4.1.4 | Developing the image                | 75 |