

# **WIDE BAND MICROSTRIP BANDPASS FILTER**

**THANALETCHUMI MOHAN**

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

**Faculty of Electronic and Computer Engineering**

**Universiti Teknikal Malaysia Melaka**

**May 2008**



UNIVERSITI TEKNIKAL MALAYSIA MELAKA  
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN  
PROJEK SARJANA MUDA II

Tajuk Projek : WIDE BAND MICROSTRIP BANDPASS FILTER  
Sesi Pengajian : 2007/2008

Saya THANALETCHUMI MOHAN 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)

Alamat Tetap: N0: 85, Taman Sri Jaya, Batu 5 ½, Jalan

Meru, 41050 Klang, Selangor.

  
(COP DAN TANDATANGAN PENYELIA)

**CHAIRULSYAH WASLI**

Lecturer

Faculty Electronics and Computer Engineering (FKEKK)  
Universiti Teknikal Malaysia Melaka (UTeM),  
Locked Bag 1200,  
Ayer Keroh, 75450 Melaka

Tarikh: 9 / 5 / 2008

Tarikh: 9 / 5 / 2008

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

Signature : .....  .....

Name : THANALETCHUMI MOHAN

Date : 9 MAY 2008

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

Signature

: .....

Supervisor's Name

: MR. CHAIRULSYAH BIN WASLI

Date

: 9 MAY 2008

This project and research work is dedicated to my beloved parents for their loving caring throughout my life, my loving brother and sisters and my friends for their encouragement and love.

## ACKNOWLEDGEMENT

First and foremost, I am externally grateful to Mr. Chairulsyah Bin Wasli, my project supervisor, for providing outstanding feedback and encouragement, and offered many practical suggestion and ideas to accomplish this project. His thoughtful and constructive review is especially helpful to me in the planning of my project development. It has been invaluable learning experience.

I would like to thank my beloved family for their encouragement and never ending support. Their support and lovely companionship is another important source of strength for me. Without their devoted love and sacrifices, none of this would have been possible. My deepest appreciation goes to all my fellow friends for the companionship, fruitful suggestion, proof reading and wishes.

Lastly, I would like to acknowledgement every individual who give me a helping hand in order to achieve this accomplishment.

## ABSTRAK

Tesis ini membincangkan secara terperinci mengenai analisis, reka bentuk, simulasi, proses fabrikasi and pengujian penapis lulus jalur gelombang mikro. Penapis lulus jalur digunakan sebagai alat frekuensi pemilihan di kebanyakan aplikasi gelombang mikro. Terdapat beberapa aplikasi untuk penapis lulus jalur. Sebagai contoh ia digunakan di bahagian keluaran pengayun elektronik untuk megambil keluar frekuensi ataupun di bahagian masukkan pengayun elektronik dan penguat untuk membenarkan frekuensi tertentu. Untuk tesis ini, pilihan selari pasangan topologi dipilih. Perisian MATLAB dan Advanced Design System digunakan untuk pengiraan manakala Microwave Office Software digunakan untuk simulasi. Projek ini akan digunakan untuk mencari lebar jalur yang maksima yang boleh dicapai oleh turas dan selain itu ia digunakan untuk membandingkan pretasi lebar jalur yang berlainan, sebagai contoh pada 10%, 20% dan pada lebar jalur maksima. Turas ini direka pada pusat frekuensi 2.4GHz dengan 12% lebar jalur. Turas ini menggunakan FR4 sebagai substrat. Penapis lulus jalur ini merupakan calon terbaik untuk aplikasi perhubungan mikro.

## ABSTRACT

This thesis report discusses analysis, design, simulation, fabrication and testing of a band pass filter by using microstrip technology. Bandpass filters are used as frequency selective devices in many RF and microwave applications. There is several application of a bandpass filter. For example it is used at the output of the oscillator to take out the required frequency or at the input of the receiver and the amplifier to pass the required frequency. In this report, the choice of parallel coupled line filter topology is discussed. MATLAB and Advanced Design System Software is use for calculation while Microwave office software is use for simulation. The project will be use to find the maximum bandwidth that be can achieve by the filter and beside that it also use to compare the performances of a different bandwidth for example bandwidth at 10%, 20% and at maximum bandwidth. The filter is designed at a center frequency of 2.4GHz with 12% bandwidth and using FR4 as a substrate. This filter can be good candidate for applications in the microwave communication.



## TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	PROJECT TITLE	i
	REPORT VERIFICATION STATUS FORM	ii
	DECLARATION	iii
	SUPERVISOR DECLARATION	iv
	DEDICATION	v
	ACKNOWLEDGEMENT	vi
	ABSTRAK	vii
	ABSTRACT	viii
	TABLE OF CONTENTS	ix
	LIST OF TABLES	xii
	LIST OF FIGURES	xiv
	LIST OF TERMS	xvii
	LIST OF APPENDICES	xix
<b>I</b>	<b>INTRODUCTION</b>	
1.1	INTRODUCTION	1
1.2	OBJECTIVES	2
1.3	PROBLEM STATEMENT	2
1.4	SCOPE OF WORKS	2
1.5	PROJECT METHODOLOGY	3

## II LITERATURE REVIEW

2.1	MICROSTRIP	4
2.1.1	Microstrip Lines	5
2.1.2	Effective Dielectric Constant	5
2.1.3	Charateristics Impedance and Guide Wavelength	6
2.1.4	Losses in Microstrip Lines	6
2.1.5	Advantages and Disadvantages of Microstrip Lines	8
2.1.6	Parallel Coupled Line Filter	8
2.2	FILTER	10
2.2.1	Types of Filters	10
2.3	FREQUENCY RESPONSE OF FILTERS	11
2.3.1	Maximally Flat or Butterworth Prototype	12
2.3.2	Chebyshev Response	12
2.3.3	Bessel	13
2.3.4	Elliptic Filter	14
2.4	SCATTERING PARAMETERS	14
2.4.1	Scattering Parameters for a Two Port Network	15
2.4.2	Definitions of Two Port S-Parameters	17

## III RESEARCH METHODOLOGY

3.1	PROJECT METHODOLOGY	19
3.1.1	Literature review	19
3.1.2	Calculation and Analysis	19
3.1.3	Software Implementation Development	20
3.1.4	Hardware Development	20

<b>IV</b>	<b>RESULT</b>	
4.1	CALCULATION RESULT	21
4.1.1	First Step - Filter Specifications	22
4.1.2	Second Step - Determination of Filter Order	24
4.1.3	Third Step - Determination of Lowpass Prototype Elements	25
4.1.4	Fourth Step - Lowpass to Bandpass Transformation	27
4.1.5	Fifth Step - Determination of Width, Space and Length	29
4.2	SIMULATION RESULT	36
4.2.1	Simulation for Bandwidth 10%	37
4.2.2	Simulation for Bandwidth 12%	41
4.2.3	Simulation for Bandwidth 20%	45
4.3	EFFECT OF CHANGING THE DIMENSION OF COUPLED LINE	49
4.4	FABRICATION	50
4.4.1	Process of Fabrication	51
4.4.2	Fabricated Filter	53
4.5	MEASUREMENT RESULTS	53
4.5.1	Measurement Result for Bandwidth 10%	54
4.5.2	Measurement Result for Bandwidth 12%	62
<b>V</b>	<b>DISCUSSION AND CONCLUSION</b>	
5.1	DISCUSSION	70
5.2	CONCLUSION	72
5.3	FUTURE WORKS	73
	<b>REFERENCES</b>	<b>74</b>

## LIST OF TABLES

NO	TITLE	PAGE
4.1	Space as Function of Bandwidth	21
4.2	Specifications of Filter for Bandwidth 10%	22
4.3	Specifications of Filter for Bandwidth 12%	23
4.4	Specifications of Filter for Bandwidth 20%	23
4.5	FR4 Substrate Properties	23
4.6	Filter Order	25
4.7	Lowpass Prototype Elements Result for Bandwidth 10% and 12%	27
4.8	Lowpass Prototype Elements Result for Bandwidth 20%	27
4.9	Lowpass to Bandpass Transformation Result for Bandwidth 10%	28
4.10	Lowpass to Bandpass Transformation Result for Bandwidth 12%	29
4.11	Lowpass to Bandpass Transformation Result for Bandwidth 20%	29
4.12	Width, Space and Length Result for Bandwidth 10%	31
4.13	Width, Space and Length Result for Bandwidth 12%	33
4.14	Width, Space and Length Result for Bandwidth 20%	36
4.15	Optimized Dimension of Coupled Line	39
4.16	Optimized Dimension of Coupled Line	43
4.17	Optimized Dimension of Coupled Line	47
4.18	Measurement for Bandwidth 10% - Sample 1	54
4.19	Measurement for Bandwidth 10% - Sample 2	56
4.20	Measurement for Bandwidth 10% - Sample 3	58
4.21	Comparisons of Sample 1,2 and 3	60
4.22	Measurement for Bandwidth 12% - Sample 1	62
4.23	Measurement for Bandwidth 12% - Sample 2	64

4.24	Measurement for Bandwidth 12% - Sample 3	66
4.25	Comparisons of Sample 1, 2 and 3	68
4.26	Comparisons between Calculation, Simulation and Measurement (Bandwidth 10%)	71
4.27	Comparisons between Calculation, Simulation and Measurement (Bandwidth 12%)	72

## LIST OF FIGURES

NO	TITLE	PAGE
1.1	Flow Chart of Project Methodology	3
2.1	Microstrip Layout	4
2.2	Cross Section of Microstrip Lines	5
2.3	Equivalent Circuit of a Parallel Coupled Line Filter	9
2.4	General Layout of Parallel Coupled Filter	9
2.5	Basic Filter Responses	11
2.6	Frequency Responses of Various Filters	12
2.7	Chebyshev Lowpass Filter	13
2.8	Elliptic Function Response	14
2.9	Two Port Network	15
2.10	Two port Network with Root Power Variables	16
2.11	Two Port Network Parameters	18
4.1	Steps for Calculation	22
4.2	Attenuation Response	25
4.3	Physical Dimension of Line Description at $50\Omega$	30
4.4	Physical Dimension of Line Description at 1 and 4	30
4.5	Physical Dimension of Line Description at 2 and 3	31
4.6	Physical Dimension of Line Description at $50\Omega$	32
4.7	Physical Dimension of Line Description at 1 and 4	32
4.8	Physical Dimension of Line Description at 2 and 3	33
4.9	Physical Dimension of Line Description at $50\Omega$	34
4.10	Physical Dimension of Line Description at 1 and 5	34
4.11	Physical Dimension of Line Description at 2 and 4	35

4.12	Physical Dimension of Line Description at 3	35
4.13	Layout of Microstrip Filter	36
4.14	Circuit Schematic	37
4.15	Simulation Graph	37
4.16	Optimized Simulation Graph	38
4.17	EM Structure	39
4.18	EM Structure Simulation Graph	40
4.19	Actual Layout in CoreDraw	40
4.20	Circuit Schematic	41
4.21	Simulation Graph	41
4.22	Optimized Simulation Graph	42
4.23	EM Structure Layout	43
4.24	EM Structure Simulation Graph	44
4.25	Actual Layout in CoreDraw	44
4.26	Circuit Schematic	45
4.27	Simulation Graph	45
4.28	Optimized Simulation Graph	46
4.29	EM Structure Layout	47
4.30	EM Structure Simulation Graph	48
4.31	Actual Layout in CoreDraw	48
4.32	Effect of Changing Coupled Line Width	49
4.33	Effect of Changing Coupled Line Space	50
4.34	Process of Fabrication	52
4.35	Fabricated Parallel Coupled Filter (10%)	53
4.36	Fabricated Parallel Coupled Filter (12%)	53
4.37	Network Analyzer	53
4.38	Return Loss ( $S_{11}$ )	55
4.39	Insertion Loss ( $S_{21}$ )	55
4.40	Return Loss ( $S_{11}$ )	57
4.41	Insertion Loss ( $S_{21}$ )	57
4.42	Return Loss ( $S_{11}$ )	59
4.43	Insertion Loss ( $S_{21}$ )	59
4.44	Return Loss Graph for Three Samples	60

4.45	Insertion Loss Graph for Three Samples	61
4.46	Return Loss ( $S_{11}$ )	63
4.47	Insertion Loss ( $S_{21}$ )	63
4.48	Return Loss ( $S_{11}$ )	65
4.49	Insertion Loss ( $S_{21}$ )	65
4.50	Return Loss ( $S_{11}$ )	67
4.51	Insertion Loss ( $S_{21}$ )	67
4.52	Return Loss Graph for Three Samples	68
4.53	Insertion Loss Graph for Three Samples	69



## LIST OF TERMS

FR4	-	Flame Resistant 4
ADS	-	Advanced Design System
BW	-	Bandwidth
L	-	Length
S	-	Space
W	-	Width
$\epsilon_r$	-	Relative Dielectric Constant
t	-	Thickness
$\epsilon_{ff}$	-	Effective Dielectric Constant
$Z_0$	-	Characteristics Impedance
$\lambda_g$	-	Guide Wavelength
$\alpha$	-	Attenuation Constant
$\alpha_d$	-	Dielectric Attenuation Constant
$\alpha_c$	-	Ohmic Attenuation Constant
$\tan \delta$	-	Dielectric Loss Tangent
$Z_{oe}$	-	Even Mode
$Z_{oo}$	-	Odd Mode
LAN	-	Local Area Network
GPS	-	Global Positioning System
RF	-	Radio Frequency
$Z_L$	-	Load Impedance
$Z_s$	-	Source Impedance
$V_{in}$	-	Incident Voltage
$V_m$	-	Reflected Voltage

$S_{11}$	-	Return Loss
$S_{21}$	-	Insertion Loss
$a_m^2$	-	Ripple Height
$a$	-	Attenuation Height

**LIST OF APPENDICES**

<b>NO</b>	<b>TITLE</b>	<b>PAGE</b>
A	Calculation in Matlab to Determine the Order of Filter for Bandwidth 10%	75
B	Calculation in Matlab to Determine the Order of Filter for Bandwidth 11%	83
C	Calculation in Matlab to Determine the Order of Filter for Bandwidth 12%	91
D	Calculation in Matlab to Determine the Order of Filter for Bandwidth 13%	99
E	Calculation in Matlab to Determine the Order of Filter for Bandwidth 20%	107
F	Calculation in Matlab to Determine the Order of Filter for Bandwidth 30%	117

## CHAPTER I

### INTRODUCTION

#### 1.1 INTRODUCTION

Bandpass filters are used as frequency selective devices in many RF and microwave applications. Filters are realized using lumped or distributed circuit elements. However with the advent of advanced materials and new fabrication techniques, microstrip filters have become very attractive for microwave applications because of their small size, low cost and good performance. There are various topologies to implement microstrip bandpass filters such as end-coupled, parallel coupled, hairpin, interdigital and combline filters.

This paper presents the design of a wide band microstrip bandpass filter with 12 % bandwidth centered at 2.4GHz. The filter design is concentrated on the parallel coupled microstrip filter using Flame Resistant 4 (FR4) as substrate. The FR4 board was chosen for this project because it is cheap and efficient. Parallel-coupled microstrip filters have been widely used in the RF front end of microwave and wireless communication systems for decades. Major advantages of this type of filter include an easy synthesis procedure, good repetition, and a wide range of filter fractional bandwidth.

The approaches used to achieve this project are through analysis, design, simulation, fabrication and testing. Computer simulation Microwave Office 2004 is

used for designing the filter. Beside that, Matlab and Advanced Design System (ADS) software is used for calculation where it is used to determine width, space and length.

## **1.2 OBJECTIVES**

The objectives of this project are:-

1. To design wide band microstrip bandpass filter with 2.4GHz operating frequency.
2. To achieve the maximum bandwidth of the filter.
3. To compare the performance of the filter by using different value of bandwidth and explain its trade off.

## **1.3 PROBLEM STATEMENT**

The problem nowadays are most of the microstrip bandpass filters in the market has a limited bandwidth. To overcome this problem, wide band microstrip bandpass filter is designed. These wide bands are not easily obtainable with conventional filter implementations. The second problem is most of the filter with wide bandwidths is expensive. This project will develop a wide band filter with lower cost and higher performances.

## **1.4 SCOPE OF WORKS**

The scopes of works in this project are:

1. To determine width, spacing and length of the bandpass filter.
2. Design the filter using Microwave Office software and simulate the designed filter to get the properties or specification of the filter.
3. To fabricate the wide band microstrip bandpass filter on the Microstrip Board.
4. To compare the simulation and the measurement value.

## 1.5 PROJECT METHODOLOGY

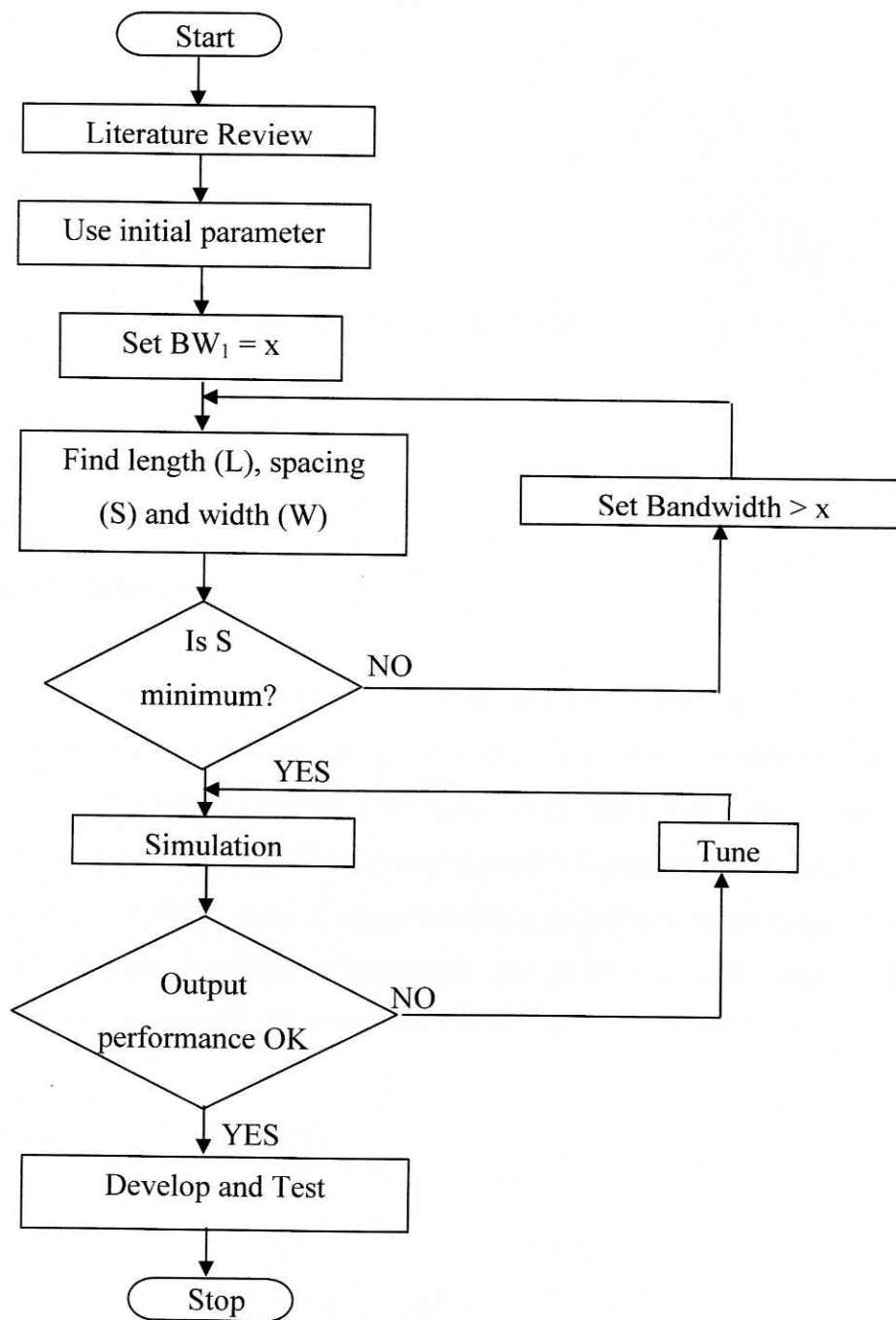


Figure 1.1: Flow Chart of Project Methodology

## CHAPTER II

### LITERATURE REVIEW

#### 2.1 MICROSTRIP

Microstrip line is one of the most popular types of planar transmission lines. A microstrip transmission line is shown in Figure 2.1. It is a single conducting microstrip line with a width ( $w$ ) and a thickness ( $t$ ) on the top of a sheet dielectric substrate that has a relative dielectric constant ( $\epsilon_r$ ) and a thickness ( $h$ ), and the bottom of the substrate is a ground plane. Compared with a stripline, a microstrip line uses only a single dielectric substrate. A microstrip line is dispersive in nature and its characteristics impedance and effective dielectric constant vary with frequency [1].

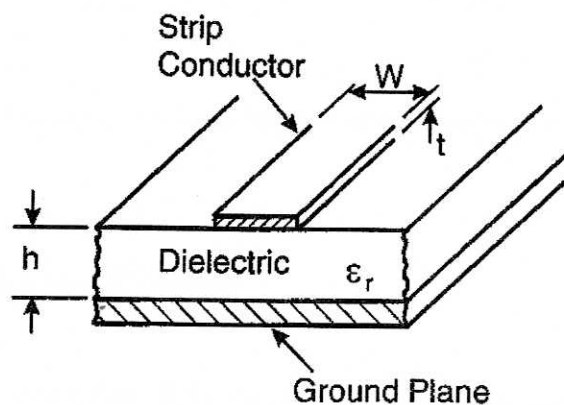


Figure 2.1: Microstrip Layout

### 2.1.1 Microstrip Lines

A microstrip lines consists of a single ground plane and thin strip conductor on a low loss dielectric substrate above the ground plane. Since the size of the microwave solid-state devices is very small (of the order  $0.008\text{-}0.08\text{mm}^3$ ), the technique of signal input to these devices and extracting output power from them uses microstrip lines on the surfaces on which they can be easily mounted. Figure 2.2 shows a typical cross-section of a microstrip lines. Due to absence of top ground plate and the dielectric substrate above the strip, the electric field remains partially in the air and partially in the lower dielectric substrate. Due to open structure and any presence of discontinuity, the microstrip line radiates electromagnetic energy. The radiation loss is proportional to the square of the frequency. The use of thin and high dielectric materials reduces the radiation loss to the open structure where the fields are mostly confined inside the dielectric [2].

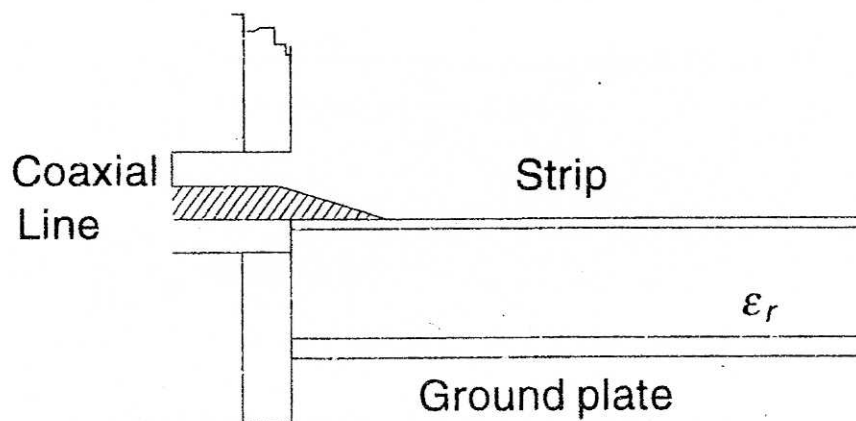


Figure 2.2: Cross Section of Microstrip Lines

### 2.1.2 Effective Dielectric Constant

Since the propagation field lines in a microstrip lies partially in air and partially inside the homogeneous dielectric substrate, the propagation delay time for a quasi-TEM mode is related to an effective dielectric constant  $\epsilon_{\text{eff}}$  given by: