BANDPASS FILTER DESIGN USING PLANAR COUPLE MICROSTRIP LINES

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Specially dedicated to my beloved parents
Ismail bin Taib and Siti Hasnah binti Ahmad,
brother, sisters and all my fellow friends
who have encouraged, guided and inspired me throughout my journey of education

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ABSTRACT

Filter is highly desirable in communication system. It functions to pass through the desired frequencies within the range and block unwanted frequencies. In addition, filters are also needed to remove out harmonics that are present in the communication system. The objective of this project is to design, construct and fabricate microstrip suitable with centered at 9GHz. The filter must operate within the unlicensed 9GHz band. This application is in the X band range (8-12GHz) currently being used for industrial, medical and scientific applications. A planar couple microstrip lines prototype filter was produced with the bandwidth is 1GHz. The filter covers the 9GHz band and the bandwidth from 8.5GHz to 9.5 GHz. The filter was fabricated on FR4 board, that had a relative dielectric constant, $\varepsilon r = 4.7$, a loss tangent $\tan \delta = 0.019$ and thickness, h of 1.6 mm.

ABSTRAK

Peranti penapis sangat diperlukan dalam sistem komunikasi. Ia berfungsi membenarkan satu julat frekuensi yang dikehendaki dan menghalang satu julat frekuensi yang tidak dikehendaki. Di samping itu, penapis juga diperlukan untuk membuang harmonik yang tidak dikehendaki dalam sistem komunikasi. Projek in bertujuan untuk merekabentuk dan membina penapis jalurmikro yang boleh beroperasi dalam frekuensi 9GHz. Aplikasi in didalam ukuran X band (8-12GHz), yg selalunya digunakan untuk industri, perubatan dan saintifik. Pasangan mikrostrip garis planar ini menghasilkan lebarjalur 1GHz iaitu dari frekuensi 8.5GHz sehingga 9.5GHz. Antenna tersebut dibina pada FR4 yang mempunyai $\varepsilon r = 4.7$, tan $\delta = 0.019$ dan ketebalan, h of 1.6 mm.

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LIST OF ABBREVIATIONS

LPF	-	Lowpass filter
BPF	-	Bandpass filter
BSF	-	Bandstop filter
IL	-	Insertion loss
RT	-	Return loss
BW	-	Bandwidth
PCB	-	Printed circuit board
I/O	-	Input/output
Zo	-	High impedence
Zoo	-	Z odd
Zoe	-	Z even
ADS	-	Advance design system
dB	-	Decibel
εr	-	Dielectric constant
h	-	Dielectric substrate
SIW	-	Substrate integrated waveguide
TEM	-	Transverse electromagnetic
NEMA	-	Nasional Electrical Manufacturers Association
FR	-	Fire resistant
HFSS	-	High Frequency Structure Simulator
N	-	Number of element

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CHAPTER I

INTRODUCTION

1.1 Project Overview

This project will develop a bandpass filter using planar couple microstrip lines. Using Advance Design System (ADS) the planar couple will be design and then determine the best specs refer to simplicity in fabricating. The planar couple will be simulate, fabricate and tested.

Filters are essential in the RF front end of microwave wireless communication system. In planar microstrip and stripline realization, one of the most common implementation methods for bandpass and bandstop filters with required bandwidths up to a 40% of central frequency is to use a cascade of parallel coupled sections.

The synthesis procedure which consists of the design equation for the coupled line physical parameters (space-gap between parallel lines, line widths and lengths) is easy and can be found in any classical microwave books. Based on this, a well defined systematic procedure, for the required parallel coupled microstrip filter physical parameters can be easily derived for both Butterworth and Chebyshev response of any order. The filter can be fabricated easily and it exhibits reasonably good performance compared with other planar circuit filters.

Although parallel coupled bandpass microstrip filter is very popular and simple, the traditional design does suffer from a fundamental limitation, namely, the presence of spurious response at twice the basic passbands at the design frequency.

1.2 Problem Statement

Microstrip is a cheaper, reliable and easy to connect with the other planar device. Compare to waveguide, microstrip is thus much less expensive than traditional waveguide technology, as well as being far lighter, Q high and more compact.

1.3 Objectives

The objectives of this project are:

i. To design, develop and test a bandpass filter using microstrip planar couple lines.
ii. To compare the result of couple line filter with rectangular waveguide bandpass filter and SIW

1.4 Scope

The scope of this project is to design microstrip parallel coupled bandpass filter using Advanced Design System (ADS) 2008 software, matching to 50 Ω microstrip line parallel coupled and analysis of insertion loss and return loss using Chebyshev response characteristic with passband ripple of 0.5dB between the passband frequencies of

8.5GHz and 9.5GHz. The frequency is operate in X band range between 8GHz to 12GHz. This project will involve simulation and fabrication of microstrip bandpass filter. The design will be fabricate on FR4 board with dielectric constant is 4.7. After that it will be compare with regtangular waveguide bandpass and SIW bandpass filter.

1.5 Project Outline

This thesis comprises of six chapters. The first chapter briefly discusses the overviews about the project such as introduction, objectives, problem statements and scope of this project.

Chapter 2 describes about the research and information about the project. Every facts and information, which found through by any references had been selected. This literature review has been explained about the planar couple microstrip lines.

Chapter 3 will discuss about the project methodology used in this project such as calculation, simulation, fabrication and testing. All these methodology should be followed for a better performance.

Chapter 4, describe about the discussion and project finding such as the result and analysis. The result is presented by calculation. All the initial simulation results of planar couple microstrip line and collected data are documented using the table and discussed it. This is including the graphs that have obtained during the simulation.

Chapter five describe about expected result and the comparison results between simulation and measurement.

Finally the conclusion has been made and recommendation for the future works. The recommendation is added to give an opinion and also an improvement on how the future works should have done.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter gives a literature review and information relating to the microstrip design with the basic information related to this project and the design formulas for calculating.

2.2 Microstrip Line

2.2.1 Basic Microstrip Line

The microstrip line is most commonly used as microwave integrated circuit transmission medium. Microstrip transmission line is a kind of "high grade" printed circuit construction, consisting of a track of copper or other conductor on an insulating substrate. There is a "backplane" on the other side of the insulating substrate, formed from a similar conductor. Basically, it comprised of a metal strip supported above a larger dielectric material and a ground plane. Looking at the cross-section of the microstrip transmission line, the track on top of the substrate will serve as a "hot" conductor, whereas the backplane on the bottom serves as a "return" conductor. Microstrip can therefore be considered a variant of a two wire transmission line [1].

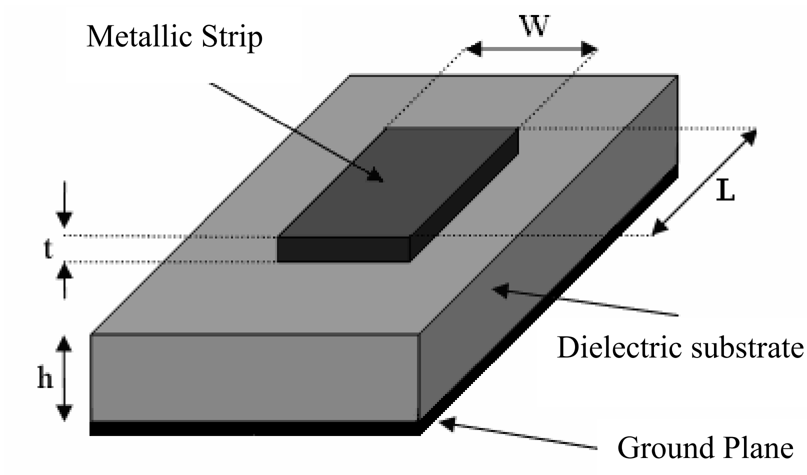

Figure 2.2.1: Structure of Microstrip Configuration [1]

The general geometry of microstrip is shown in figure 2.2.1 as above. The most important dimensional parameters in microstrip circuit design are the width *w* and height *h* (equivalent to the thickness of the substrate). Another important parameter is the relative permittivity of the substrate (εr). The thickness of the metallic, top conducting strip *t* and conductivity *s* are generally of much lesser importance and may be often neglected. The metallic strip is usually printed on a microwave substrate material.

2.2.2 Microstrip Field Radiation

If one solves the electromagnetic equations to find the field distributions, one will tend to find very nearly a completely TEM (transverse electromagnetic) pattern. This means that there are only a few regions in which there is a component of electric or magnetic field in the direction of wave propagation. The field pattern is commonly referred to as a Quasi-TEM pattern. Shown in figure 2.2.2 is the electromagnetic field pattern of the basic microstrip transmission line.

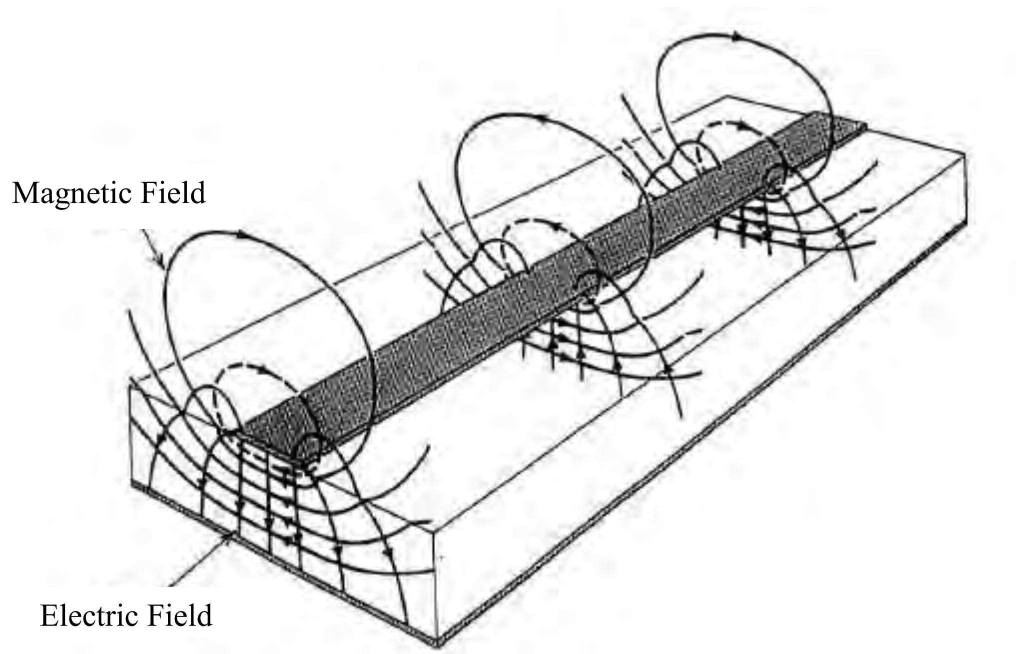

Figure 2.2.2: Electromagnetic Field Pattern of a Microstrip[1]

Under some conditions, one has to take into account of the effects due to longitudinal fields. An example is geometrical dispersion, where different wave frequencies travel at different phase velocities, and the group and phase velocities are different. The difference between microstrip transmission line and stripline is that the microstrip is a homogenous transmission line. This means that the electromagnetic fields are not entirely contained in the substrate. Hence, microstrip line cannot support pure TEM mode of transmission, as phase velocities would be different in the air and the substrate. Instead, a quasi-TEM mode is established. The quasi-TEM pattern arises because of the interface between the dielectric substrate and the surrounding air. The electric field lines have a discontinuity in direction at the interface. The boundary conditions for electric field are that the normal component (i.e. the component at right angles to the surface) of the electric field times the dielectric constant is continuous across the boundary; thus in the dielectric which may have dielectric constant 10, the electric field suddenly drops to 1/10 of its value in air. On the other hand, the tangential component (parallel to the interface) of the electric field is continuous across the boundary. In general, a sudden change of direction of electric field lines at the interface is observed, which gives rise to a longitudinal magnetic field component from the second Maxwell's equation, curl E = - dB/dt. Since some of the electric energy is stored in the air and some in the dielectric, the effective dielectric constant for the waves on the transmission line will lie somewhere between that of the air and that of the dielectric. Typically the effective dielectric constant will be 50-85% of the substrate dielectric constant. Since the microstrip structure is not uniform, it will support the quasi-TEM mode [2].

2.2.3 Substrate Materials

The choice of substrate used is an important factor in the design of a microstrip filter. Important qualities of the dielectric substrate include [3]:

i. The microwave dielectric constant
ii. The frequency dependence of this dielectric constant which gives rise to "material dispersion" in which the wave velocity is frequency-dependent
iii. The surface finish and flatness
iv. The dielectric loss tangent, or imaginary part of the dielectric constant, which sets the dielectric loss
v. The cost
vi. The thermal expansion and conductivity
vii. The dimensional stability with time
viii. The surface adhesion properties for the conductor coatings
ix. The manufacturability (ease of cutting, shaping, and drilling)
x. The porosity (for high vacuum applications)

Since the substrate dimensions and dielectric constant are functions of substrate temperature, the operating temperature range becomes an important property in the design of any microstrip filter. In addition, the dielectric constant and loss tangent are also functions of frequency. As for a physical property which is important in fabrication of the filter, they are resistance to chemicals, tensile and structural strengths, flexibility, machinability, impact resistance, strain relief, formability, bondability and substrate characteristic s when clad. Generally, there are two types of substrates used: soft and hard substrates [2]. Soft substrates are flexible, cheap and can be fabricated easily. However, it possesses higher thermal expansion coefficients. Typical examples of soft substrates are RT Duriod 5870 (εr = 2.3), RT Duriod 5880 (εr = 2.2) and RT Duriod 6010.5 (εr = 10.5). As for hard substrates, it has better reliability and lower thermal expansion coefficients. On the other hand, it is more expensive and non-flexible. Typical examples of hard substrates are quartz (εr = 3.8), alumina (εr = 9.7), sapphire (εr = 11.7) and Gallium Arsenide GaAs (εr = 12.3).

Normally, thick substrates with low dielectric constants are often used as it provides better efficiency, larger bandwidth and loosely bound fields for radiation into space. However, it would also result in a larger filter size. On the other hand, using thin substrates with higher dielectric constants would result in smaller filter size. The drawbacks are that it is less efficient and has relatively smaller bandwidths. Therefore, there must be a design trade-off between the filter size and good filter performance.

2.2.4 Applications

Due to the fact that most present-day systems demand for small size, lightweight and low cost the employment of microstrip technology arises extensively over the years. Microstrip are particularly suited to those applications where low profile because it can conform to a given shape easily. Shown below are some typical system applications which employ microstrip technology [8]:

i. Satellite communications
ii. Doppler and other radars
iii. Radio altimeter
iv. Command and control