DESIGN OF MICROSTRIP S-BAND BANDPASS FILTER FOR S-BAND APPLICATION

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Specially dedicated to

My beloved father, mother and aunt,

To my family and friends,

Thanks for all the encouragement and support

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ABSTRACT

S-Band is range of frequency from 2GHz to 4GHz which is a part of microwave system and a partly combination between Ultra High Frequency (UHF) and Super High Frequency (SHF). There are many applications uses part of S-Band frequencies as their frequency spectrum for a specified application like the most extensive use in wireless telecommunication nowadays, Wireless Local Area network Access (WLAN) which operates at 2.4GHz, HSDPA, HSUPA, Bluetooth, WiMAX, LTE and other applications which uses part of the S-Band frequency. To satisfy the needs for many applications to be used at once, S-band microstrip bandpass filter is proposed as it functions to filter out other frequencies from the passband region using planar microstip transmission topologies. The objective of this project is to design, simulate, fabricate and analyze the bandpass filter at S-Band application. To design the prototype, certain constraints had to be identified, like lumped element works well in low frequencies but at high frequencies, problem arises. Such, the inductor and capacitors are only available for a limited range of values, and the distance between the filter components at microwave frequency is not negligible. Hence, microstrip transmission line is used to the design as it capabilities of handling wideband of fabricated. The BPF will be designed using parallel coupled line method and hairpin line method which will be simulated using ADS Simulation, fabricated using FR-4 substrate, and analyzed using network analyzer. The design is compared between the ideal case design, parallel-coupled line design, and hairpin line design for its S_{11} and S_{21} values. The result gives out a good agreement between the simulation and measured values. The best technique for the BPF design in this project is by using parallel coupled line method which gives out -14.591dB, -4.8903dB for S_{11} and S_{21} respectively. In terms of size and compact structures, hairpin design is preferable.

ABSTRAK

Jalur-S, merupakan sebuah rangkaian frekuensi dari 2GHz hingga 4GHz, yang di mana menggunakan sedikit frekuensi daripada gelombang mikro dan adalah gabungan antara UHF dan SHF. Pelbagai aplikasi pada masa kini yang menggunakan Jalur-S sebagai spektrum pilihan. Antaranya, WLAN yang beroperasi di frekuensi 2.4 GHz, HSDPA, HSUPA. Bluetooth, WiMAX, LTE dan aplikasi yang lain yang menggunakan rangkaian jalur-S. Untuk memenuhi kehendak dan permintaan bagi meliputi segala aplikasi ini. Penapis jalurlulus bagi jalur-S menggunakan teknologi lapisan mikro telah dicadangkan bagi menapis keluar segala frekuensi yang tidak berada di dalam laluan jalurlulus. Objektif bagi projek ini adalah untuk mereka bentuk, simulasi, fabrikasi dan menganalisis penapis laluan jalur-S. Bagi mencipta proto-taip tersebut, beberapa kekangan telah perlu dikenal pasti, antaranya elemen tergumpal berfungsi dengan baik pada kadar frekuensi yang rendah, dan masalah datang apabila frekuensi menjadi tinggi. Antaranya, kapasitor dan pengaruh hanya mempunyai nilai yang terhad dan jarak antara komponen pada frequensi gelombang mikro adalah sangat tidak boleh diabaikan. Justeru, transmisi lapisan mikro digunakan untuk mereka bentuk kerana ianya berupaya mengendalikan frekuensi yang tinggi dan luas juga mudah untuk fabrikasi. Penapis laluan jalurlulus ini akan direka menggunakan kaedah pasangan sejajar dan pasangan penyalun rambut, kemudian kedua-dua reka bentuk akan disimulasikan menggunakan simulasi ADS, fabrikasi menggunakan FR-4 dan dianalisis menggunakan mesin penganalisis rangkaian. Reka bentuk akan dibandingkan antara pasangan sejajar, penyalun rambut dan elemen tergumpal, pada S_{11} dan S_{21}. Pasangan sejajar mendapat keputusan yang terbaik iaitu -14.591dB, -4.8903dB for S_{11} and S_{21}, dan reka bentuk penyalun rambut adalah lebih baik dari segi saiz dan struktur kompak.

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LIST OF ABBREVIATION

BPF	-	Bandpass Filter
CDMA	-	Code Division Multiple Access
EM	-	Electro Magnetic
HSDPA	-	High Speed Downlink Packet Access
HSUPA	-	High Speed Uplink Packet Access
HD	-	High Definition
LTE	-	Long Term Evolution
Q-TEM	-	Quasi Transverse Electro Magnetic
S-BAND	-	Frequency range from 2GHz - 4GHz
TEM	-	Transverse Electro Magnetic
UMTS	-	Universal Mobile Telecommunication Systems
UWB	-	Ultra Wideband
VSWR	-	Voltage Standing Wave Ratio
WiMAX	-	Wireless interporable Microwave Access
WLAN	-	Wireless Local Area Network
WMAN	-	Wireless Metropolitan Area Network
WCDMA	-	Wideband Code Division Multiple Access
UHF	-	Ultra High Frequency
SHF	-	Super High Frequency
DC	-	Direct Current

LIST OF SYMBOLS

C	-	Capacitor
dB	-	Decibel
f	-	Frequency
g	-	Element Values
G	-	Giga
h	-	Height
Hz	-	Hertz
I	-	Current
L	-	Inductance
M	-	Mega
m	-	Meter
mA	-	Miliampere
mm	-	Milimeter
mW	-	Miliwatt
nm	-	Nanometer
π	-	Pi
P	-	Power
R	-	Resistance
S	-	Scattering
V	-	Voltage

ω	-	Angular Frequency
Y	-	Admittance
Z	-	Impedance
Γ	-	Reflection Coefficient
δ	-	Fractional Bandwidth
ε_r	-	Relative Dielectric Constant
η	-	Efficiency
λ	-	Wavelength
Ω	-	Ohm

CHAPTER I

INTRODUCTION

This chapter will explain on the project background, objective of project, problem statement, scope of project, methodology and report structure.

1.1 Project Background

Bandpass filter is an electronic device that are used in both transmitted and received signals which have to be filtered first at certain center frequency between two specific frequency (bandwidth) [1]. Bandpass filter is an important component which must be found in transmitter and receiver. A transmitter or receiver without a filter will not be able to filter in or out specified wanted frequencies. In the rapid advancement and developments in wireless telecommunications technology nowadays, with a major increase in the market demand which intended the government sector to seek for invention and developments of new applications in wireless communications.

As what we have discovered in communication these days in, the development of Worldwide interoperability Microwave Access (WiMAX) and Long Term Evolution (LTE) in telecommunication services in many countries. They offer certain features such as the coverage in which customer are supported with minimal signal of EM waves, high capacity for faster data rate transfer, and the quality of services (QoS) with no error [2]. These are the new applications or systems which had to be opened to a certain frequency regions in order to provide additional transmission capacity. But this is not all; there are many more applications like mobile television which are now widely used in High Definition Television (HDTV) nowadays, Wireless Local Area Network (WLANs), Bluetooth, and also home based consumer electronics like cordless phone and microwave oven. With a brief research, most of this applications uses certain part of frequency region which is located S-Band frequency region which is frequency ranging from 2GHz to 4GHz to operate.

In realization to this system, a new transmitter and receiver are indeed to be completed. To design the system, the choice of transmission line technology is important to provide a good parameters measure for the efficiency of the design. Microstrip is preferable since the technology of microstrip transmission line is most extensive used planar transmission line in Radio Frequency (RF) application [1]. Compared to conventional circuit and coaxial lines, printed planar transmission lines are widely used, having a broadband in frequency, provide compact circuit and light in weight, and generally economical to produce since they are readily adaptable to hybrid and monolithic integrated-circuit(IC) fabrication technologies at RF and microwave frequencies [3].

Apart from that, the primary objective of this project is to design, simulate, fabricate and analyze the microstrip bandpass filter at S-Band application. The scope criteria of this project are to study and designing the Microstrip Bandpass Filter at S-Band application. The filter characterization will be identified and the design will be test first by simulating it with ADS Simulation Software, then it will be fabricated using FR-4 as the microstripline substrate material on the printed circuit board (PCB) and the network design will be tested using network analyser. Lastly the design must be analyzed and the result must obtained and presented for the insertion loss and return loss using S-Parameter [2].

The methodology of this project is convenient to be conducted as following the path to achieve the objective of the project. Literature reviews from journals are the core method of this project. Later on is the identification of the specification for the filter as well as to design the filter. After the filter has been designed, it has to be simulated using ADS simulation software and the result will be analyzed using S-Parameter. Lastly, we will go to the fabrication of the filter and the product would be tested. The result is expected that the design should be able to obtain insertion loss and return loss at the most minimum value guided with S-Parameter.

1.2 Problem Statements

The choice of transmission technology is the most prior in this project in order to provide a perfect parameters result and efficiency towards the bandpass filter design for a minimal insertion and return loss. In choosing the transmission systems, one should achieve the following properties which are single mode operation for S-Band frequency (2-4GHz), and providing low insertion loss and low return loss. There are many type of transmission line like waveguide which has the advantages of high power-handling capability and low loss but is bulky and expensive. The other one is coaxial line which has very high bandwidth and is convenient for test applications, but is a difficult medium in which to fabricate complex microwave components [4].

Next one, conventional circuit or lumped circuit which is conceptually helpful starting point to see how various designs can be realized. But in synthesizing the circuit in this manner, the implicit symmetries of a lumped circuit element only has a single mode of propagation and length scales characterizing the element are small compared to a wavelength which must be respected over the required design band. Also, the circuit can only be characterized by a single parameter.

In this case, transmission line is realized since it is characterized by two or more parameters. Such differences in dimensionality between idealized and physically achievable components in lumped circuit can lead to a breakdown in applicability of simple circuit based synthesis approaches [5]. In this limit, planar transmission line models are realized and full wave analysis approaches are required to simulate the response. Planar transmission lines are divided into four topologies; Co-Planar Waveguide, Stripline, Slotted line and Microstripline. With a brief study, microstripline is chosen as it fulfills the requirements of the wideband bandpass filter design which is operating at S-Band (2-4GHz) frequency.

Microstrip is well confined for large line width over substrate height ratios and is well suited for realizing elements with low characteristic impedance and radiation loss. Slotline on the other hand has poor field confinement and can be susceptible to radiative loss. Microstrip filter is preferable since the technology of microstrip transmission line is most used planar transmission line in Radio Frequency (RF) application [1]. It is based on printed circuit board (PCB) and offers easy and cheap in production compared to conventional circuit and coaxial lines [3].

In designing and obtaining the specification of the bandpass filter, a very few first step have to be carried out to obtain the approximate calculation based on basic conventional components such as inductors and capacitors. Some problems need to be identified during the design like what is the maximal loss inside the pass region and how the filter characteristics should be in transition region. Some strategies are indeed to be applied in such the choice of waveguide technology which is preferable in order to obtain the minimal insertion loss [3].

Bandpass filter plays a major significant role in these wireless communication systems, since the transmitted and received signals need to be filtered as center frequency with a specific bandwidth. In the realization of widely application uses part of the frequency at S-Band which brings so much benefit to the mankind. Hence, this has brought me to design a bandpass filter operating S-Band application using microstrip.

1.3 Project Objectives

The objective of this project is to design, simulate, fabricate and analyze the microstrip bandpass filter at S-Band (2GHz-4GHz) application.

1.4 Scope of Work

The working scope for this project will cover entirely on bandpass filter operating at S-Band frequency with the bandwidth of 2 to 4 GHz.

i) Study and designing the Microstrip Bandpass Filter at S-Band application
ii) Identification of the type of microstrip bandpass filter.
iii) Comparing between ideal case design, parallel-coupled line design and hairpin line design.
iv) Simulating the design using ADS Simulation software .
v) Fabricating the microstripline design using FR-4 as substrate on printed circuit board (PCB) and test the network of the design using network analyser.
vi) Analyzing comparing the design result for the insertion and return loss with S-Parameter towards S_{11} and $S_{21.}$

1.5 Thesis Outline

Generally, this report consists of 5 chapters which non included with references and appendices. In chapter 1, the introduction about the project is presented. The chapter includes brief explanation about the background of the project, problem statement, objective of the project and the scope of work that is conducted through out the project.

For the second chapter which is chapter 2, is basically more about literature review of the paperworks, books and journals that are related to the project. Apart from that, an explanation about the S-band frequency is stated into this chapter. Also, a deeper look and review about the theory of microstrip technology is presented in this chapter.

As in the third chapter, chapter 3 describes about the methodologies that are applied in this project which are the key step in designing the microstrip bandpass