DESIGN OF MULTI-BAND BANDPASS FILTER FOR NEXT GENERATION WIRELESS SYSTEM

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

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DECLARATION

I declared that this thesis entitled "DESIGN OF MULTI-BAND BANDPASS FILTER FOR NEXT GENERATION WIRELESS SYSTEM" is the result of my own research except as cited in the reference.

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APPROVAL

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

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DEDICATION

Special dedication to my beloved parents,

Lee Wing Fook & Kong Lai Peng

My supporting siblings:

Lee Poh Yoke

Lee Kah Meng

To my supervisor

PM Dr Zahriladha Bin Zakaria

My friends and my fellow lecturers

Thank you for all your care, support and believe in me

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ABSTRACT

This project presents the design of multi-band bandpass filter using microstrip with Defected Microstrip Structure (DMS) to produce bandpass and band reject characteristics simultaneously. This class of filter is designed based upon $\lambda_{g0}/4$ short-circuited stubs structure of 7th degree. The integrated multi-band BPF and DMS produce 3 wideband bandpass and 2 band reject response simultaneously in order to remove any undesired signals in the passband of the bandpass response with S11, better than -20dB and insertion loss, S21, of around -1dB respectively. The DMS exhibits two band-reject responses better than -20dB and forms first band 2.3GHz-2.7GHz, second band 3.1GHz-4.8GHz and third band 5.15GHz-5.85GHz. This design is simulated on a Roger Duroid RO4350 with a dielectric constant, ε_r of 3.48 and a thickness of 0.508 mm while the loss tangent is 0.0019. The theoretical, simulated and measured results were obtained and demonstrated in this thesis. This type of filter is useful in any RF/ microwave communication systems such as Worldwide Interoperability for Microwave Access (WiMAX) and wireless UWB tracking system.

ABSTRAK

Projek ini membentangkan reka bentuk penapis jalur laluan yang pelbagai jalur menggunakan penapis laluanlulus menggunakan kecacatan struktur mikro-strip untuk menghasilkan laluan jalur dan jalur menolak yang bercirikan serentak didalam respon penapis. Kelas penapis direka berdasarkan λ_{g0} / 4 struktur pendek litar pintas dengan 7 perintah. penapis jalur laluan yang pelbagai jalur bersepadu dengan kecacatan struktur mikro-strip menghasilkan 3 jalur lebar laluan jalur dan 2 respon jalur menolak pada masa yang sama untuk mengeluarkan apa-apa isyarat yang tidak diingini dalam kehilangan pulangan S11, lebih baik daripada -20dB dan kehilangan masukkan S21, kira-kira -1dB masing-masing. DMS mempamerkan dua respon jalur menolak yang lebih baik daripada -20dB dan membentuk jalur pertama 2.3GHz-2.7GHz, jalur kedua 3.1GHz-4.8GHz dan jalur ketiga 5.15GHz-5.85GHz. Reka bentuk ini adalah disimulasikan menggunakan Roger Duroid RO4350 dengan pemalar dielektrik, ε_r 3.48 dan ketebalan 0.508mm manakala kehilangan tangen adalah 0,0019. Teori, simulasi dan keputusan diukur diperolehi telah ditunjukkan di dalam tesis ini. Jenis penapis ini adalah berguna dalam mana-mana sistem komunikasi gelombang mikro seperti Akses Gelombang Mikro (WiMAX) dan wayarles sistem pengesanan UWB.

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CHAPTER I

INTRODUCTION

1.1 Introduction

Wireless communication has been rapidly developing in recent years. The evolution has started with Global System for Mobile Communications (GSM) and has proceeded to Wireless Local Area Network (WLAN), Worldwide Interoperability for Microwave Access (WiMAX), Code Division Multiple Access (CDMA), and the latest, Long Term Evolution (LTE) and Fifth Generation (5G). Microwave filters are required in microwave systems to separate wanted and unwanted signals. Recently, multi-band microwave filters developed by various researchers to satisfy the current demands of wireless communication systems. Before, single-band filters can only operate in single-frequency bands are used. After researching and demanding, dual-band and tri-band or multi-band microwave which can be supported in a single device are needed. A single device has the ability to work in multiple frequencies and support various wireless communications such as GSM, WLAN, WiMAX and LTE is one of the requirements for global devices [1].

Defected Microstrip Structure (DMS) is made by etching a little slot over the microstrip, generating a stop band as a function of the slot length. With DMS, there is no etching in the ground plane as avoiding any increment of leakage through the ground plane. In the case of the DMS structure, there was no frequency shift for different microstrip lengths. As a result, the design of a specific DMS structure is independent of the microstrip length which can be very useful in the design of microstrip filters, among other different applications. In this proposed project, a new design of triple-band band pass filter integrated with DMS [2].

1.2 Problem statement

Development in wireless communication has created more potential in IEEE 802 family local area networks and metropolitan area networks. They able to support high speed wireless broadband applications with rather long reach, mobility, and roaming. The most latest wireless communication network LTE or Long Term Evolution UMTS networks have made strong inroads into the commercial arena worldwide. So, a single microwave filter which can support multiple wireless applications is strongly demanded. The challenges to circuit designers designing a multi-band band pass filter are to achieve compact size and low insertion loss simultaneously. The previous works are usually too many components inside and cause large circuit size. Besides of the ability to support various wireless communication applications, also need to satisfy the specifications of band pass filter which are size reduction, high stability, high selectivity simultaneously [3].

1.3 Objective

The objectives of this project is to design and develop a multi-band band pass filter for wireless communication system at frequency 2.3-2.7GHz, 3.1-4.8GHz, 5.15-5.85GHz by using the planar microstrip line. In order to introduce a multi - band, design the Defected Microstrip Structure (DMS) to remove the unwanted frequency band. The capabilities of DMS to introduce notched responses have been investigated. Lastly, fabricate and validate the design of multi-band band pass filter through experimental works in laboratory and compare the results with the simulation result in software.

1.4 Scope of project

The design of this proposed project is multi-band band pass filter. The topology of the band pass filter is quarter wavelength short-circuited stubs with Defected Microstrip Structure (DMS). The pass band bandwidth of the filter is 2.3-2.7GHz, 3.1-4.8GHz and 5.15-5.85GHz at -3dB. The pass band return loss is better than -20dB whereas the pass band insertion loss is between 0dB till -1dB. Besides, the stop band insertion loss is better than 40dB. Before fabrication, design and simulate the filter and DMS in Advanced Designed System (ADS) software. The material used to fabricate this filter is Roger 4350B with dielectric constant of 3.48 and loss tangent of 0.0019. This filter is done with equation of short circuited stubs and the introduced notched responses. The DMS technology is carried out using a parametric study to provide the shape and better performance in term of selectivity.

1.5 Chapter review

Chapter I mainly describes the general overview of this project. Chapter 1 explains the introduction, problem statement, objective and scope of this project. Besides, this chapter also reviews all chapters of this project.

Chapter II mainly describes findings on a literature review of the project. It covers related research from band pass filter, dual-band band pass filter, tri-band band pass filter, multi-band band pass filter and DMS. The chapter starts with the basic theory and fundamental of the filter. The basic understanding of the parameters and the basics of microwave filter must be clearly made before continuing on understanding the project. The most important part of this chapter is emphasizing literature on different technique designing band-pass filter.

Chapter III will explain in detail the implementation of the project. Design multi-band band pass filter and DMS will be illustrated in detail. Besides, process for designing this project will be constructed. To design multi-band band pass filter, there are a few important processes must undergo such as calculation, simulation, fabrication and measurement.

Chapter IV will illustrate, explain, discuss and present the simulation result and measurement result of multi-band bandpass filter. For the implementation of this project, design start from ideal transmission line structure, then microstrip line structure, next momentum layout structure and last physical structure of multi-band bandpass filter.

Chapter V will discuss about the conclusion, sustainable development, commercialization and the future work for this project.

CHAPTER II

LITERATURE REVIEW

In this chapter, it describes findings on a literature review of the project. Overall, it covers related research from band pass filter, dual-band band pass filter, tri-band band pass filter, multi-band band pass filter and DMS. The chapter starts with the basic theory and fundamental of the filter. The basic understanding of the parameters and the basics of microwave filter must be clearly made before continuing on understanding the project. The most important part of this chapter is emphasizing literature on different technique designing band-pass filter.

2.1 Band pass filter

Band pass filters play a significant role in wireless communication systems. Transmitted and received signals have to be filtered at a certain center frequency with a specific bandwidth. Figure 2.1 illustrates the basic bandpass filter frequency response. A band pass filter is an important component must be found in the transmitter and receiver. Band pass filter is a passive component which is able to select signals inside a specific bandwidth at a certain center frequency and reject signals in another frequency region, especially in frequency regions, which have the potential to interfere the information signals [4].

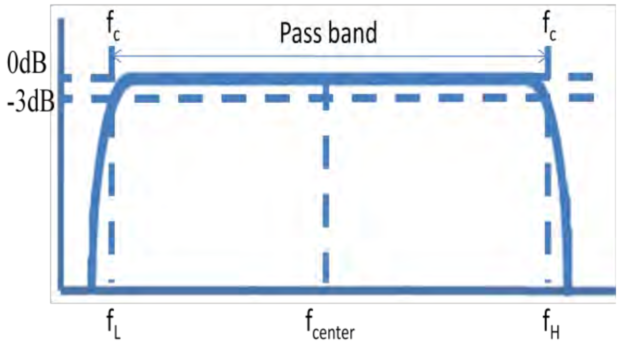

Figure 2.1: Frequency response of band pass filter.

2.2 Planar microstrip band pass filter

Microstrip line is one of the most popular types of planar transmission lines primarily because it can be fabricated by photolithography processes and is easily miniaturized and integrated with both passive and active microwave devices. Figure 2.2 shows the example of planar microstrip band pass filter. The planar transmission line is a transmission line with conducting metal strips that lie entirely in parallel planes. The most common structure has one or more parallel metal strips placed on a dielectric substrate over a conducting ground plane. All the active devices and all the interconnecting lines, impedance-matching elements, capacitors, inductors and resistors are fabricated on the planes [5].

Figure 2.2: Example of planar microstrip band pass filter.

2.3 Multi-band band pass filter

Multi-band band pass filter is the filter which has three desired frequency bands by introducing notched responses as illustrated in Figure 2.3. The notched responses will remove the unwanted frequency bands and introduce the desired frequency bands for multiple wireless communication applications.

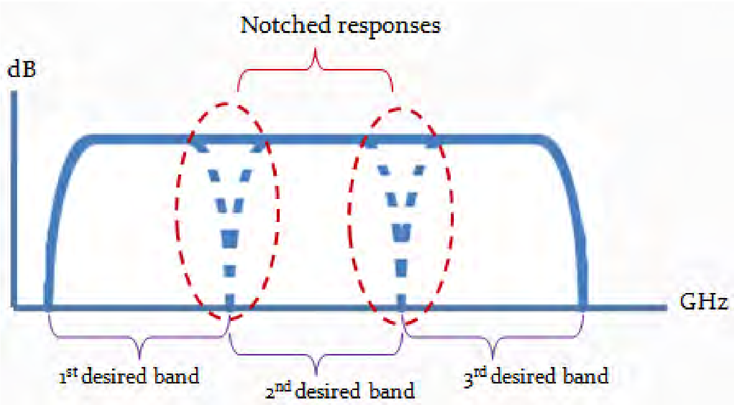

Figure 2.3: Notched responses introduced to remove unwanted frequency range.

2.4 Notched responses

Design Defected Microstrip Structure (DMS) is one of the ways to introduce notched responses. DMS structure is made by etching a little slot over the microstrip as shown in Figure 2.4. It is based on the changed in impedance (inductance and capacitance) in microstrip with slotted planes. DMS will produce a narrow bandwidth and sharp rejection at a specific frequency. It can also be represented by the single parallel RLC [2].

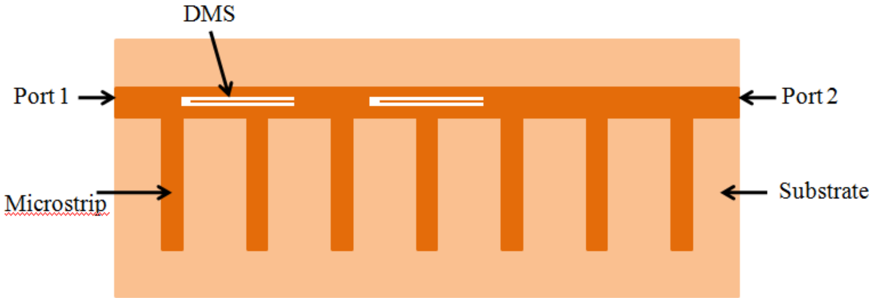

Figure 2.4: DMS structure on the microstrip.

2.5 Related research

In order to implement this project, findings and researches about the bandpass filter have been done and tabulated as shown in Table 2.1.

Table 2.1: The information on related research papers.

[No]	Filter /Year	Researcher(s)	Freq (GHz)	Insertion loss, S_{21}(dB)	Return loss, S_{11}(dB)	Substrate/dielectric constant	Method
[6]	Dual band/ 2011	J. Lee and Y. Lim	2.4, 5.2	1.4, 1.3	14.1, 22.3	Taconic RF-35A/3.5	Interdigital capacitor loop step impedance resonator and short circuit stub loaded resonator
[7]	Dual band/ 2010	H.W. Liu, Z.C. Zhang, S.Wang,	1.57, 2.4	1.55-1.63	>15	-/4.5	F-shaped spurline embedded

		L.Zhu,X.H.Guan,J.S.Lim and D. Ahn					into uniform impedance resonator
[8]	Dual band/ 2012	M.T. Doan, W.Q. Che and W.J. Feng	2.4, 5.2	Minimum 0.85	>20	-/4.4	Short-stub loaded half wavelength resonator
[9]	Tri band/ 2012	A.M. Elelimy, A.M. El-Tager, A.G. Sobih and M.H. Abdel-Azeem	0.9, 2.45, 3.5	0.85, 1.12, 1.16	10.8, 18.14, 16.25	Roger RT/Duroid 6010 Teflon/ 10.5	Cross coupled resonators to produce tri-section step impedance resonator
[10]	Triple band/ 2011	C.Y.Lin, W.T.Li, C.P.Liang and S.J.Chung	2.4, 3.5, 5.2	-	>10	-	Cascade grounded active inductor circuit topology
[11]	Tri-band/ 2011	Z.B.Wang, F.Nasri, C.W.Park	6.42, 10.7, 14.98	15.7, 31.7, 30.1	-	Duroid 5880/2.2	Interdigital hairpin finger structure
[12]	Triple band/ 2014	J.P.Wang, J.D.Zhao, J.L. Li	5.2, 5.8, 8.0	>15	<15	Duroid 5880/3.38	Parallel U-shaped defected microstrip structure
[13]	Triple-band/ 2012	M.M.Prabhakar and M.G.Madhan	0.925, 1.575,	3.88, 3.78, 4.8	6.79, 7.19, 6.49	FR4/4.4	Trisection SIR