DESIGN OF NONLINEAR FREQUENCY SELECTIVE LIMITER

NOOR AZAMIAH BINTI MD FAUZI

This Report Is Submitted In Partial Fulfillment Of Requirement For The Bachelor Degree of Electronic Engineering (Telecommunication)

Fakulti Kejuruteraan Electronik dan Kejuruteraan Komputer
Universiti Teknikal Malaysia Melaka

June 2013

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : DESIGN OF NONLINEAR FREQUENCY SELECTIVE LIMITER

Sesi Pengajian : 1 2 / 1 3

Saya .....NOOR AZAMIAH BINTI MD FAUZI..... 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)

(COP DAN TANDATANGAN PENYELIA)

Dr. Zahriladha Bin Zakaria
Timbalan Dekan (Akademik)
Fakulti Kejuruteraan Elektronik Dan Kejuruteraan Komputer
Universiti Teknikal Malaysia Melaka (UTeM)
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

Tarikh: 12/6/2013

Tarikh: 12/6/2013

DECLARATION

"It is hereby declared that all materials in this report are the effort of my own work and materials which are not the effort of my own work have been clearly acknowledged."

Signature : .....

Name : NOOR AZAMIAH BINTI MD FAUZI

Date : 12/6/2013

DECLARATION

"I / we acknowledge that I have read this paper in my / our this paper is sufficient in scope and quality for the award of Bachelor of Electronic Engineering (Telecommunication). "

Signature : .....

Supervisor Name : DR. ZAHRILADHA BIN ZAKARIA

Date : 12/6/2013

DEDICATION

To To Allah

I devoted my life and death to You, Allah. May my life is within Your guidance.

To My Mother

Midah Binti Idris

Thank you for your sacrifice and love. No such compensate except from Allah.

To My Supervisor and Lecturer's

Thank you for all the knowledge and support. Your support, patience, and encouragement give me strength throughout the whole course. May Allah bless us.

To all friends

Thank you for your support, advice and motivation

ACKNOWLEDGEMENT

In the Name of Allah, Most Gracious, Most Merciful

Assalamualaikum…..

First and foremost, I would like to thank ALLAH for giving me strength to complete the final year project from September 2012 until June 2013. Who gave me an opportunity, courage and patience to carry out this work. I feel privileged to glory His name in the sincerest way through this small accomplishment. I seek His mercy, favor and forgiveness.

I would like to express my deepest gratitude to my Supervisor, Dr.Zahriladha bin Zakaria for his constant patience, support and constructive guidance for this project. Special thanks also to Dean and Deputy Dean of FKEKK, all the Lecturers who taught me throughout my course, the Postgraduate Study Centre, and friends. I would also like to thank the technician at LAB for his cooperation and support.

Last but not least, Thanks to my beloved mother Midah Bt Idris and my family for supporting me throughout my final year project. Without your support, I will never get to complete my final year project.

Noor Azamiah Binti Md Fauzi. June, 2013

ABSTRACT

This thesis presents the design of a nonlinear frequency selective limiter based upon bandstop response in order to improve receiver sensitivity for radar application. A frequency selective limiter is used to limit signals at each individual frequency independently in order to improve the receiver sensitivity. If compared to the tracking bandstop filter, FSL has a better performance due to the automatic suppression when the threshold is exceeded and, therefore, no extra control circuit is required. The FSL also plays its role as a limiter for signal equalization when accepting a large required signal. Other than that, the frequency selective limiter restricts the excess of signals whilst maintaining the power of low level signal. The three main elements involved in FSL were 90 degree hybrid coupler, quarterwave transformer and first order subnetwork. Simulation using the Advanced Design System, firstly it was done using schematic simulation, a circuit-oriented computation, followed by Momentum, which is an Electromagnetic simulation. Lastly, the prototype was fabricated using FR4 substrate and being measured using a network analyzer to obtain bandstop attenuation. In order to measure performance of the frequency selective limiter circuit, three different types of pin diode have been used as a comparison of circuit performance.

ABSTRAK

Tesis ini membentangkan tentang rekabentuk litar penghad frequensi bersempadan terpilih berdasarkan respons ‘bandstop’ untuk tujuan meningkatkan sensitivity penerima pada aplikasi radar.Frequency Selective Limiter (FSL) digunakan untuk menghadkan isyarat pada setiap frekuensi individu bebas untuk meningkatkan sensitiviti penerima. Jika dibandingkan dengan pengesanan penapis ‘bandstop’, FSL mempunyai prestasi yang lebih baik disebabkan oleh penindasan automatik apabila ambang dilampaui dan dengan itu tiada litar kawalan tambahan diperlukan. FSL juga memainkan peranannya sebagai penghad bagi persamaan isyarat apabila menerima isyarat yang diperlukan adalah besar. Selain daripada itu, FSL akan menyekat lebihan isyarat sambil mengekalkan kuasa pada isyarat tahap rendah. Tiga elemen utama yang terlibat dalam FSL adalah ’90 degree hybrid coupler’, ‘quarterwave transformer’ dan ‘ first order subnetwork’. Di dalam simulasi menggunakan ADS, langkah pertama yang dilakukan adalah simulasi skematik, satu pengiraan yang berorientasikan litar, diikuti oleh Momentum yang merupakan simulasi elektromagmet. Akhir sekali, prototaip telah dibina menggunakan substrat FR4 dan pengukuran dilakukan dengan mengunakan ‘Network Analyzer’ untuk mendapatkan atenuasi ‘bandstop’.Dalam usaha untuk mengukur prestasi FSL, tiga jenis pin diod yang berbeza telah digunakan sebagai perbandingan prestasi litar.

CONTENT

LIST OF TABLES

LIST OF FIGURE

LIST OF ABBREVIATIONS

ADS	Advanced Design System
ECCM	Electronic Counter countermeasure
ECM	Electronic Counter Measure
ELINT	Electronic Intelligence Receivers
EMI	Electromagnetic Interference
EM	Electronis Warface
FSL	Frequency Selective Limiter
IFM	Instantaneous Frequency Measurement
POI	Probability of Interception
RF	Radio Frequency
RWR	Radar Warning Receiver

CHAPTER I

INTRODUCTION

1.1 Introduction of Project

Wireless communication has become a part of our life today. Wireless technology owes its rapid growth to the fundamental component in the development of microwave circuits and systems, which are the fundamental components of applications [1-2].

Because of the advanced in wireless technology, has increased the demand of the existence of a frequency spectrum. Due to the frequency management synchronized, the overall frequency range is isolated into a small division that have been allocated for a certain applications. The existing application has filled up the frequency spectrum starting from the section of kilohertz to a small amount of hundred megahertz. Thus, the increasing of new applications required the application to be operated at higher frequencies in the range of microwave frequency bands because

microwave frequencies provide many benefits such as miniaturization, elevated capacity and high level of integration.

As a solution to removing the interfering signals in application, a new solution is proposed in this project. In order to limit the signal at each individual frequency separately, a frequency selective limiter is used. If compared to the tracking bandstop filter, FSL has a better performance due to the automatic suppression when the threshold is exceeded and, therefore, no extra control circuit is required. Secondly, the FSL also plays its role as a limiter for signal equalization when accepting a large required signal. Lastly, whilst maintaining the power of low level signal the frequency selective limiter circuit will restricts the excess of the signals. The vibrant range of the signal is in this way dense which leads to the enhancement in signal recognition.

1.2 Objective of Project

The objective of this project is to design a nonlinear frequency selective limiter based upon bandstop response for receiver sensitivity improvement for radar application. This frequency selective limiter function is to limit signals at each individual frequency independently to improve the receiver sensitivity.

1.3 Problem Statement of Project

In order to achieve frequency agility, without complex tuning techniques,the wideband receiver front end has used a low-noise transistor or travelling wave tube. But, in wideband front ends, they are very susceptible to interference from transmitting at nearby locations. In wide-open radar warning receiver's application, there is a problem where usually one of detecting a large number of signals across a wide dynamic range [e.g. 60dB]. The frequency of large unwanted signals is unknown, thus making them impossible to filter out all of unwanted signals via conventional filtering techniques. In order to improve the receiver sensitivity, a Frequency Selective Limiter is used to limit

signals at each individual frequency independently. The FSL is designed to provide attenuation of the signals above a set of signals.

1.4 Scope of Project

The purpose of this project is to design frequency selective limiter using a hybrid coupler with band stop resonator. This project will be release using micro strip technology. At high power level, FSL generates a band stop response and a near all-pass response at low signal powers. For single channel limiting, a device with one resonator or being called first order FSL, produced a band stop response centered at 2.4 GHz. The three main elements involved in FSL were 90 degree hybrid coupler, quarter wave transformer and first order sub network. This FSL circuit will be designed by using Advance Design [ADS] System software. In ADS simulation, a design process will be done by using schematic simulation, a circuit-oriented computation, followed by Momentum, which is an Electromagnetic simulation. Lastly, the prototype will be fabricated using FR4 substrate and being measured using a network analyzer to obtain band stop attenuation. Other than that, the performance of the FSL circuit will be compared by using three different pin diodes.

1.5 Methodology of Project

This project is beginning by doing literature reviews on selected topics. In the literature review section has been learned about the fundamentals of frequency selective limiter, type of limiter and basic of 90 degree hybrid coupler. Next, the circuit design is done by calculating all the parameters involved and then the physical layout of the design frequency selective limiter will be constructed. Then the simulation will be carried out by using the ADS software. When all the specification meets the requirement, the fabrication process of the frequency selective limiter circuit will be carried out. Next the testing and measurement of the fabricated frequency selective

limiter will be carried out again, hence it will compare with all the calculated and simulated results. All experimental results will be included in the final report.

1.6 Chapter Review

This thesis will focus on the realization of new, compact configurations for "frequency selective limiter" circuit. Unlike the conventional filter configurations, these new filter configurations have convenient physical dimensions for a practical realization. The principle of the FSL operation was described. Then, a design based on nonlinear bandstop filters was proposed.

Chapter 2 provides a brief description of the fundamental frequency selective limiter and the types of limiter theory. The fundamental frequency selective limiter included the concept of FSL, characteristic of FSL and application of FSL. Various types of limiter circuit will be discussed. The criteria involved in the selection of the limiting circuits used in microwave receivers are addressed. The relevance of parameters used in any limiter design such as the cutoff /center frequency and 3-dB bandwidth.

In Chapter 3, a design of first-order nonlinear bandstop filter included a design process, design parameter and material is presented. Analysis of the circuit and related issues are described. The design of a prototype and measured results are reported.

Chapter 4 discussed the result obtained throughout the process. It involved result in the simulation part using ADS and also the experimental result. The comparison between simulation and measurement result will be presented.

Finally, Chapter 5 will conclude the whole aspect this project, along with suggestions for future research ideas.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

In this part, will be discussing about fundamental of frequency selective limiter and the type of limiter. The fundamental frequency selective limiter will be discussed about the concept of frequency selective limiter, characteristic frequency selective limiter and application of frequency selective limiter. Lastly, the type of limiter included conventional limiter, integrated limiting circuit and frequency selective limiter will be discussed in this part.

2.2 Fundamental of Frequency Selective Limiter

2.2.1 Concept of Frequency Selective Limiter

The limiter is located at the front-end of microwave receivers at the microwave application. The function of the limiter is protecting the sensitive circuit from the large interfering signals. The shunt PIN diode is used in conversational limiters where it placed in front the receivers. The weakness of PIN limiters are cannot distinguish at the frequency of the received signals. According to [3-4], PIN limiter will respond with the total RF power, the accumulative power was exceeding the limiting threshold will be attenuated at all signals. Therefore, PIN limiter can limit the magnitude of large signals, with a resultant decrease in sensitivity and the interfering signal is removed.

The function of the frequency selective limiter (FSL) is to limit signals at each individual frequency independently. In general, the technique FSL is can reduce if the threshold is exceeded, give the equalization and limit the load signals while maintaining signal strength is low. In figure 1.2 shown the performance of an ideal frequency selective limiter where a wide band receiver interrupts numerous signals with wide dynamic range. Therefore, these signals will be entered into the frequency selective limiting system. Furthermore, FSL also uses a series bandstop resonator loaded with diode limiter in which it is placed in front of the circuit configuration of a shunt with receivers.

Frequency selective limiter produced a bandstop response throughout the frequency of the high power signal. The reduction of stop band is different with the input power level. The shrinking of stop band will be increased if the input power also increases. The frequency selective limiter allows the signal through with nominal reduction for low input power. At the highest amplitude signal on the circuit will be cut under a threshold, while the signal power small to be maintained.

For that reason is the sensitivity of wide band receiver is particularly enhanced. In addition, the decrease in signal dynamic range helps gesture recognition, by the growing possibility of interception (POI). The perfect frequency selective limiters will operate in a linear, thus no inter-modulation products can be produced. But, as usual, limiters are

always considered as non-linear devices [5]. Thus, the modulation occurs as two or more signals received simultaneously.

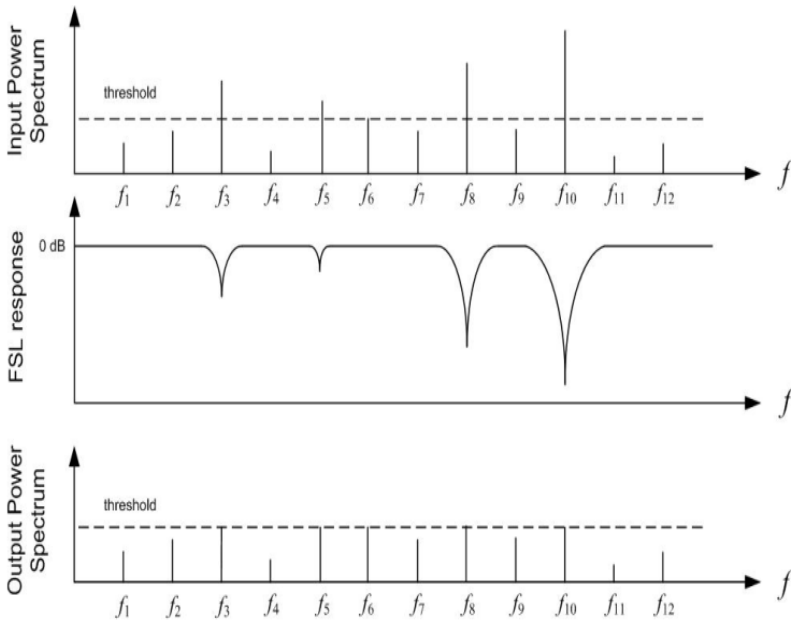

Figure 2.1: Performance of a frequency selective limiter [1-4]

2.2.2 Characterization of Frequency Selective Limiter

The characteristic of frequency selective limiter can be illustrated by considering a certain parameters. They are frequency selectivity, limiting threshold, spike leakage, and power handling.

In the case of frequency selection, it is an important indicator to prove the selected frequency limiter operating in multiple signal environments. In general, it is the sum of the two lowest frequency signal received at the same time but still operate alone. This indicator is directly linked to the new parameter called the bandwidth limit. The limiting bandwidth is the bandwidth of the response that occurs when a high input power block. The limit level at each frequency level depends on the level of the input signal. In this

thesis, the limiting bandwidth is defined as a bandwidth of the bandstop response in which the maximum attenuation is obtained.

The limiting threshold of control that is authorized to go by the circuit. Any excess power is limited so that the output maintains almost stable at the threshold, regardless of the additional increase in input power [5]. The limiting threshold is important parameters for limiting circuit because it confirms the level of protection for the front circuit for high power signal. Based on diode limiters, the threshold level is determined by the built-in voltage of the semiconductor materials used.

Ideally, the frequency selective limiters will suppress large input signals and mechanical immediately. Furthermore, they have a time delay before the achievement of limiting force. This delay time depends on the type of limiters. For example, Ferrite-based limiters have a tendency to have a longer delay time of the semiconductor light-based limiters. The main advantage of high-power pulse signal can leak over time delay circuit current limiting. This is known as spike leakage. Typically, the front-end devices such as light detector are able to comply with these peak powers. For this reason, the conversion speed limiters must be fast enough to avoid a large increase in leakage, which can cause harm to the device front-end.

Frequency selective limiters basically dealing with a high power signal. It is required that they are able to endure with a certain level of power. The power handling capability is an important feature for each type of frequency selective limiter. Basically, ferrite-based limiters are able to comply with the higher RF power than diode-based limiter [5].

2.2.3 Application of Frequency Selective Limiter

There are two examples of the application of frequency-selective limiters to particular electromagnetic interference (EMI) applications are given in this section.

First, the FSL is considered can be used in a satellite to provide channel equalization when the satellite is used as a multiple access repeater. Consider the usual case of a wideband amplifier in a satellite for multiple channel transmission, but suppose

that the channels are individually assigned to separately locate ground-based transmitter sites. Therefore, the signal level at the satellite receiving antenna terminals could vary widely between channels. A desire to have all channels at an equal signal level when entering the final stage can use of an FSL to increased the satellite efficiency [1].

The second example is the usage of radar in electronic warfare (EW) systems. These subjects are widely discussed in many textbooks such as [6-9]. The electromagnetic spectrum for the Allied Forces are used in EW system where it systems can also encrypt signals to be delivered which made it difficult to be intercepted or understood by the enemy. At the same time, EW systems must be able to bypass the RF signal, analyze the signal and then take appropriate action. Figure 1.1 below shows the examples of EW applications.

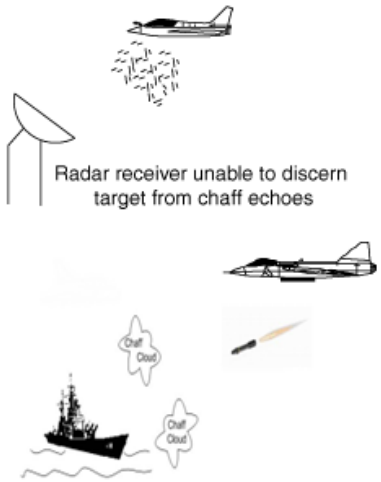

Figure 2.2: Electronic warfare applications [5]

The figure 2.2 showed the ground radar to detect an enemy aircraft. Radar receiver provides information such as position, track and angle of arrival and data processing are combined to surface-to-air missile to be launched consequences. A radar warning receiver (RWR) detects the involvement of weapons and electronic activate response (ECM) such as jamming or bait on the beleaguered aircraft. Otherwise, the