ANALYSIS AND MEASUREMENT OF BFU520W LNA DESIGN FOR VHF APPLICATION

By

SARAVANAN MANOGARAN

A dissertation submitted for partial fulfilment of the requirement for the degree of Master of Science

June 2014

ACKNOWLEDGEMENT

The road leading to degree was told to be long journey of perseverance and indeed it was. I was fortunate in obtaining divine grace in enduring the path full of trial and tribulations in the labour of studies while working for the past 1 year. Many individuals deserve warm gratitude for making this thesis a reality.

First and foremost, I would like to thank my supervisor, Dr. Nor Muzlifah Mahyuddin for his monumental guidance throughout this postgraduate program. His vocabulary of knowledge and vast experience have assisted me in identifying the problem arises throughout the project and the maturity to overcome the obstacles. I look up to her as an excellent research advisor and would like express my utmost gratitude. Thank you again Dr. Nor Muzlifah Mahyuddin

I am indebted to all senior technical staff design engineers of Motorola Technologies. To name a few, Trukesh Nadarajan, Aldrin Raj and also not forgetting Ragavan Krishnamoorthy. Their professionalism and great technical advice as well as enthusiastic technical inputs have inspired me to continuously challenge myself to reach new levels.

Last but not least, my acknowledgements would not be complete without expressing my gratitude to fellow working colleagues for their unconditional love, support and care throughout my studies. Their love and overwhelming support in the face of any obstacles or adversity I faced was not only instrumental but essential in the completion of this thesis. I would not be where I am today without their contributions and foundations that they have provided throughout the years.

Dedications to my beloved parents

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND NOMENCLATURE

LNA	Low Noise Amplifier
IIP3	Third-order Intercept Point Input
OIP3	Third-order Intercept Point Output
SNR	Signal to Noise Ratio
ADS	Advanced Design System
VHF	Very High Frequency
UHF	Ultra High Frequency
PTT	Push To Talk
ECAD	Electronic Computer Aided Design
TRL	Through, Reflect and Line
DC	Direct Current
W-CDMA	Wide Band Code Division Multiple Access
RF	Radio Frequency
P	Phase Constant
MN	Matching Network
NF	Noise Figure
RL	Return Loss
FET	Field Effect Transistor
PCB	Printed Circuit Board
TV	Television
GSM	Global System for Mobile

IC	Integrated Circuit
AGC	Automatic Gain Control
AMP	Amplifier
IMN	Input Matching Network
DUT	Device under Test
PSA	Precision Spectrum Analyzer
VLIF	Very Low Intermediate Frequency
IF	Intermediate Frequency
ATE	Automated Test Equipment
SINAD	Signal to Noise and Distortion Ratio
IM	Inter Modulation
CPK	Process Capability

ANALYSIS AND MEASUREMENT OF BFU520W LNA DESIGN FOR VHF APPLICATION

ABSTRACT

The Low Noise Amplifier (LNA) is one of the critical blocks in a receiver chain lineup of a two way portable radio. The main function of a LNA is to amplify weak signals without adding excessive noise. LNA design optimization in the conventional way often involves tedious and iterative process that takes various parameters trade-off into considerations such as gain versus Third-order Intercept Point (IIP3), Noise Figure (NF), 1dB compression point and F2 Blocking. Choosing the best possible LNA design has always been a daunting task for designers across the globe. This research identifies the BFU520W as one of the LNA which meets the important criteria in the portable two way radio communication world. This validation proves that this LNA selection is a robust, efficient and yet comparable or better compared to legacy LNA topology. This LNA which is wideband capable needs to provide constant gain, low noise and unconditionally stable to ensure the whole receiver lineup, from the Front End till Back End meets the standard specification. In order to achieve this, BFU520W was validated to replace the legacy LNA as due cost constraints which will eventually reduce to 70% of its operating cost.The BFU520W was highlighted due to this reason and the performance are validated to be or as comparable as the legacy LNA,The susbsection results will be discussed at the end of this research and BFU520W is definitely the best ironic replacement for the Legacy LNA.

ANALISIS DAN PENGUKURAN BFU520W PENGUAT HINGAR RENDAH DALAM MEREKA BENTUK APLIKAS VHF

ABSTRAK

Penguat Hingar Rendah (LNA) merupakan salah satu blok yang kritikal di dalam aturcara penerima isyarat radio mudahalih dua hala. Fungsi utama LNA ini adalah bagi memperkuatkan isyarat lemah tanpa menambah hingar yang berlebihan. Pengoptimuman rekabentuk LNA tradisional seringkali melibatkan proses yang amat membosankan dan lelaran yang mengambil kira kompromi antara pelbagai parameter seperti gandaan lawan Poin Pintas Atur-ketiga (IIP3), Rajah Hingar, Poin kompresor 1dB dan Penghalang F2. Memilih rekabentuk LNA yang terbaik dengan kos yang paling efektif selalu merupakan satu tugas yang amat sukar bagi perekabentuk di seluruh glob. Kajian ini memilih BFU520W sebagai satu LNA yang memenuhi kriteria penting di dalam dunia komunikasi radio mudahalih dua hala. Pengoptimuman ini membuktikan bahawa pilihan LNA ini mantap, efektif dan setanding atau lebih baik berbanding topologi LNA legasi. LNA ini yang mana berkebolehan untuk berfungsi pada jalurlebar perlu menghasilkan peguat yang konsisten, hingar rendah dan sentiasa stabil bagi memastikan keseluruhan aturcara penerima, dari depan hingga ke belakang mematuhi piawaian yang ditetapkan.

CHAPTER 1

INTRODUCTION

1.1 Overview

Low Noise Amplifier (LNA) is an electronic amplifier usually used in the front end of a receiver circuitry in a radio. In a portable two way radio device it is used as an amplifier to attenuate the very weak signal that being picked up by the device through antenna before channeling the amplified signal to the receiver circuitry. Despite its wide usage in the communications world, it has always been a tough challenge even for the top notch engineers to design a LNA which is both robust and efficient.

In today's two way portable radio communication system, LNA offers a first level of amplification of the signal being picked up or received by the system's antenna. Therefore the LNA plays an important role in the receiver chain. A good design are measured by its ability to amplify extremely low signal level without adding additional noise to the original signal thus preserving the required Signal to Noise Ratio (SNR) of the system at extremely low power levels. The performance of a LNA can be gauged by considering the various parameters such as noise level, gain, power level, impedance matching, stability and linearity. (J.S. Goo et al., 2003)

A high performance LNA with inductive source degeneration is introduced to generate the real part of input impedance without using a noisy resistor. The source inductance is typically adjusted at such so that the real input impedance meets the ideal 50 ohm matching condition. Also an additional inductor is placed at the gate node to resonate out the gate-source capacitance, which in turn reduces the output noise power level. (B.H. Jung, A. Gopinath, et al., 2003)

A few big challenges was encountered during the optimization to design an architecture of a good LNA with optimum gain, Third-order Intercept Point from the Input (IIP3), noise figure, 1dB compression point and stability. The optimization was carried out with the aid of Advance Design System (ADS) simulation tool.

1.2 Objective and Purpose

The main objective and purpose of this research is to be able to shed more light on the LNA topology that is used in a two way portable radios and the proposal of a more robust, efficient and cost effective design. This thesis discusses the optimization of BFU520W LNA with the current topology designs. This LNA topology is required to operate and cater the Very High Frequency (VHF) band, which ranges from 136MHz to 174MHz, and Ultra High Frequency (UHF) band, which ranges from 403MHz to 470MHz. Despite this wideband capability of the LNA, able to accommodate both VHF and UHF and frequencies, this thesis content is focused only on the VHF band. The purpose of this research is to design and validate a more robust, efficient and cost effective LNA design to be used in the receiver chain of a VHF band two way portable radio device or more commonly known as VHF band walkie-talkie.

In a nutshell, below are the objectives of this optimization .

- To optimize the current topology with a new LNA, BFU520W
- To design and validate a more robust, efficient and cost effective LNA design to be used in the receiver chain of a VHF band two way portable radio
- To validate Subsection Performance in Extreme Temperature

1.3 Problem Statement

The problem is designing a robust LNA which can cater for all frequency range.BFU520W is wide band an its proposed that this LNA will be covered on other wide band LNA's.The problem or hurdle that may arise is that applying this BFU520W LNA in the current topology.As it's a not plug and play device and it needs matching elements to be improvised.Beside's all the subsection evaluation under the EIA and ETS should meet the requirements

1.4 Research Problem

During the preliminary study, choosing the essential LNA for the project was like finding a needle in a haystack. The criteria was the importance of the cost and as well the performance should not degrade from the legacy product.After hours of selection, the BFU520W was selected.Below are the comparison with other LNA's

Table 1 : Comparison of BFU520W with other LNA's in the market

LNA Types	SKY65047	BFU520W	SST12LN01	ZFL-500LN
Manufacturer	Skyworks	NXP	SST	Mini Circuits
Noise Figure Specification	1.5 dB	0.8 dB	1.55dB	2.9dB
Operating Current	7.2mA	3.5mA	10-12mA	8.2mA
3rd Order Input Intercept point	-6dBm	+11dBm	>1dBM	+14dBm
Input Return Loss	14dB	18dB	13dB	10dB
Output Return Loss	15dB	17dB	16dB	15dB

1.5 Thesis Outline

This thesis is organized in a total of 6 chapters. Each chapter is carefully written to provide more details and clarification of the total research for all readers. Chapter 1 is the introduction part of the research covering the objective and purpose of the research. In order to provide more clarification a brief research methodology is also included in this chapter.

Literature review is being presented in Chapter 2. The current available and used topology in the industry world with its advantages and disadvantages are being discussed in this chapter. This is to enlighten the understanding of the best topology and also the learning on the standard method being used in both designing and validating the topology in current times.

Chapter 3 describes the methodologies that are used in both designing and implementation of the LNA topology that is proposed in detail. The methodologies also covers all the setup of the measurement and methods of measurement used in order to obtain the all the data and results pertaining to the design being discussed.

Chapter 4 presents a detailed results and all the discussion pertaining to the results obtained from all testing and experiments that have been conducted on the proposed LNA topology.

Last but not least, the final chapter, Chapter 5, provides the conclusions derived from the research together with suggestion for future work that can be realized for this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Regardless Portable or Mobile two way communication radio, widely known as walkie talkie, are the two way communication devices. Its fundamental are ironically pre historic as it its been used since World War II. Its development has to been given credit to Donald L Hings and radio Engineer Alfred J.Gross the fore founders at the Engineering Teams at Motorola or formerly known as Galvin Manufacturing Company of Chicago (Leonard, 2005). The group includes Dan Noble who architects the design using FM technology, Henry Magnuski who was the principal RF Engineer back then, Marion Bond, Lloyd Morris and Bill Vogel (Wolinsky, 2003). Despite it was initially planned for the military, eventually after the war it was spread across the globe for public safety usage and become commercially hit .In the world of today, portable devices are also the main communication devices used in most of the mission critical operations along with military worldwide as a police force, medical agencies and fire service due to its main advantages compared to other communication devices such as:

- Real Time Communications – Two way radio provides real time communication where the user has to only press the PTT on in another word ‘Push -To-Talk’ button and within a fraction of a second , the user is able talk and convey the message in real time. On a day to day of fire fighting and tactical and operational communication, this is one of the key factors in many organizations to rely on

- Group Communication – Another Unique feature is the in a portable two way radio area capable and equipped with one call to multi user. This means that capability allows single user to convey their messages to multiple listeners at the same time without any delay or lagging

- Ease of Mobility- Due to the design of two way radio's whereby it incorporates both receiving and transmitting capability without any assistance from external applications or devices, it is very mobile. Users with a set of two way radio's are able mobilize to almost any part of terrain nor location and still able convey and receive messages.

2.2 Low Noise Amplifier (LNA)

Low Noise Amplifier (LNA) is one critical stage in the receiver chain lineup. The main function of a LNA is to amplify weak signal without adding excessive noise. This is critical as LNA is normally the first stage in the receiver chain lineup. LNA design in the conventional way often involves tedious and iterative optimization process that takes various parameters trade-off into consideration, such as gain versus IP3, Noise figure versus input matching, stability versus gain, etc. As such, LNA designer tends to find it time consuming without the aid of a proper simulation tool and significant correlation results between simulation and actual design measurement. Agilent design system

(ECAD) and TRL calibration tool were used to reduce the design cycle time and provide better correlation between simulation and actual measurement. This paper gives the LNA designer a design guide through using ADS.

LNA design be it a modular LNA or a discrete transistor LNA, requires a good start up to yield a lean design process which could fulfill the design requirements. This research provides engineers a design guideline of LNA DC biasing, input and output matching circuit; checking of maximum gain available, wide-span stability, IIP3 and plotting of noise cycle and gain cycle for optimum impedance matching point selection with ADS simulation. The paper also outlines the auto optimization done using ADS.

According to (Noh & Tun Zainal Azni, 2006), 2.14GHz Low Noise amplifier (LNA) for the use in a Wide Band Code Division Multiple Access (W-CDMA).The amplifier has a forward gain or in another word the Output return Loss (S21) of 11dB which is meeting the standard. The Noise Figure of only 1.4dB which is lesser then 1.8dB.The input power which denotes to the 1 dB compression point of the LNA is -11dBm and the IIP3 is 6.6dBm.However the current drain consumed by the LNA circuit is 12.7mA.This is a drawback as low current drain approximate less the 5mA will enable a better high IIP3(>8dBm).

In order to meet the demand of High Volume of MBC13916 LNA production, a low cost automated RF set up has been established. A production DC machine was then modified with the aid of network analyzer to measure the S parameters at 1.9 GHz (Kaufman & Baker, 2003).

Across the globe, the LNA design has been adapted in many research and applications. The design of two stages LNA in micro strip technology using the active bias networks for K Band applications. The technology conveyed was and with Noise Figure of 1.78dB, a power gain of 15.37dB and with 17.34 dB and 22.33 dB input and output return loss. The LNA topology used was a 2 stage cascaded design as shown below. The first amplifier function to excel the noise figure and the second amplifier is to achieve the required gain at the desired Noise Figure as in the Table 2-1 and Figure 2-1 (M. Challal, 2011).

Table 2-1: Specification for the LNA

Parameters	**Specifications**
Operating Frequency{Ghz}	24.125
Bias Point	Vds=2V & Ids =10mA
Technology	Microstrip
Gain{dB}	> 15
Noise Figure {dB}	< 2
Return Loss {dB)	>10

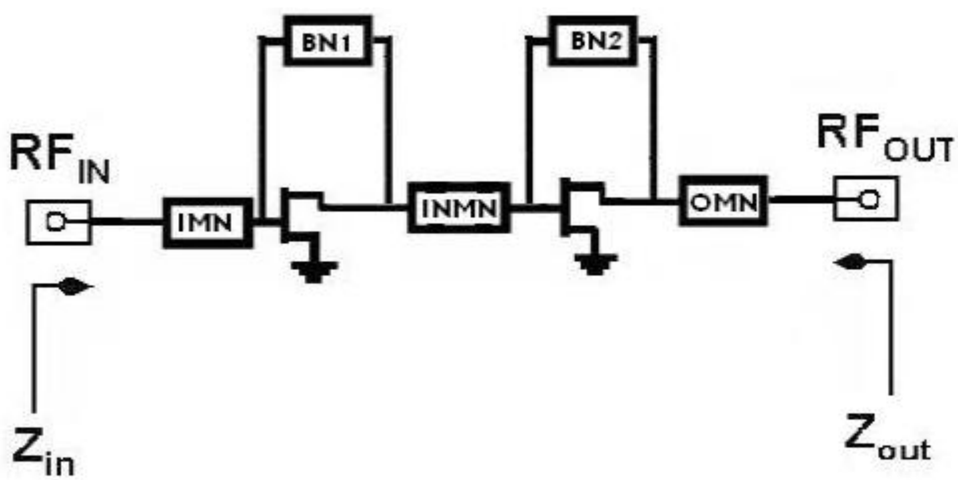

Figure 2-1: Two Stages Amplifier Topology

The 2 stage's LNA are based on input, inter –stage and output matching networks. For any LNA, matching networks are the most important elements. The Matching have been designed on a smith chart by using a single open tub matching technique .When the stub's length and position are matched, the input impedance Zin, which is at the junction of the micro strip stub and the line matches exactly the characteristics impedance, Zo of the system. The input impedance. Zin of an ideal terminated transmission line is:

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan \beta l}{Z_0 + jZ_L \tan \beta l} \tag{2.1}$$

Where the ZL is the terminating impedance, I is the physical distance along the line from a particular load and P is the phase constant. However once choosing a DC bias point for the desired gain and noise figure (NF) stability of transistor should be analyzed. Since NE3514S02 LNA is unstable, shunt resistor with 200 ohms is added in the output port. After checking the stability, matching networks (MN) have been considered.

Case Study of LNA design at 30GHz was discussed recently in an international conference .It uses two single stage LNA topologies which includes a magnetic feedback LNA and a cascade LNA. Post layout Simulations with the Gain of (S21) at only 5.9dB and the Input (S11) and Output Return (S22) loss at -11.8dB and -11.4dB respectively. The Noise Figure is estimated at 3.9dB which is extremely high and improper for the industry. The case study emphasizes the need of proper LNA design with low NF (Antonopoulos, Papathanasiou, & Bucher, 2012).

A journal paper describes that for a 800/900 band portable two way communication, the LNA of Maxim 2373 IC was selected. Though this LNA does not support wideband operations, it still provides desired gain, Noise Figure and IIP3 that covers in frequency range. ADS momentum simulation used for the simulation purposes. A comparison between simulated and measured data for the Maxim 2373 IC has been tabulated in the Table 2-2 below.

Table 2-2: Maxim 2373 IC Simulation and Measurement Comparison

850MHz			
Parameter	Simulated	Measured	Goal
Gain	18.21dB	18.70dB	> 16dB
Input RL	-12.81dB	-12.14dB	< -10dB
Output RL	-10.97dB	-10.82dB	< -10dB
941MHz			
Parameter	Simulated	Measured	Goal
Gain	17.06dB	17.76dB	> 16dB
Input RL	-15.34dB	-15.14dB	< -10dB
Output RL	-10.37dB	-11.27dB	< -10dB

Although the goal of the gain is more the 16 dB and its achievable, the Output return loss is marginally above on the desired goal. This is comparable for both the 800 and 900MHz **(**LNA Design guide with Agilent Design System, 2009, Maxim Integrated Product, LNA Life2372/71 datasheet, 2002)

Voltaire LS is ideal for designing low-noise amplifiers (LNAs). In this application note, a technique called *negative-image modeling* was used to design and optimize input and output circuits for an 8-12 GHz LNA, and how the tune mode and genetic optimizer simplifies the design process. The RF transistor (LNA) choosed is the NE32400 chip FET. This is a low-noise device, rated at 0.6dB noise figure (NF) at 12GHz gain. Like all low-noise FETs, the optimum NF is achieved at the current drain 10mA (Mass, 1999). .

In the development of wideband low noise amplifier (LNA), it is important to choose the ideal topology. One of the researches done was on the balanced amplifier topology, which was using the hybrid coupler and advanced E-PHEMPT transistor technology in order to produce good wideband performance on the important parameters. The LNA was fabricated in PCB Board and with the desired goal of Noise Figure of 1 dB, S parameters of Input and Output return losses greater then -10dB for a wideband frequency range from 136-941MHz. However the it requires a dual supply of 5V each and total current consumptions of 120mA.Across the globe, balanced amplifier is widely adopted in the LNA design because of it excellent performance in input and output return losses, low noise figure and better stability compared to the single ended amplifier, However the drawback between other topology such as the negative feedback design and a balanced amplifier is the balanced amplifier design topology requires bigger PCB because they need longer transmission lines for the coupler (Osman & Noh, 2012).

There are many configurations to LNA design. In such , a low noise cascaded LNA using a T- Matching network applicable for wireless applications has been studied. The amplifier uses the FHX76LP Low Noise FET. The LNA designed using the T- Matching network which consists of lump reactive element at the output and input terminal. The cascode LNA produces gain of 18.5dB and NF of 1.3dB.The (S11) and (S22), input and output return loss are respectively at -11.5dB and -12.3dB. This design on the front end low noise amplifier is one of the challenges and constraints in the world of RF. The LNA needs to provide good input impedance match, adequate power gain and certainly the Low NF. Despite much high gain amplifier topologies have been proposed in the past, the cascode technique induces results in a higher bandwidth and gain. Figure 2-2 shows typical cascode LNA circuit (Othman, Ibrahim, Husain, Ahmad, & Senon, 2012).

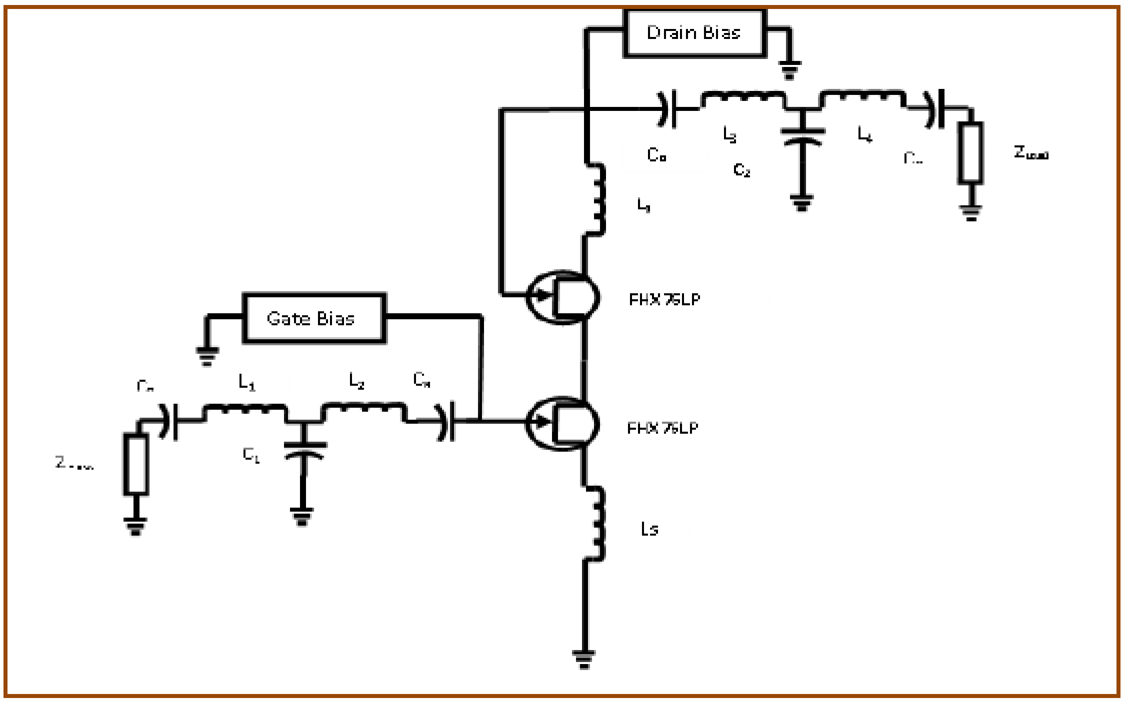

Figure 2-2: Cascode LNA Circuit

Wide band RF is not only used in the normal two way portable communication but also in the architecture of mobile TV applications which covers from the VHF Tri Band (174-248MHz) to the UHF Band (470-746MHz). In the architecture, the RF front end consists of a single to differential LNA with low amplitude /phase mismatch and also an active notch filter as shown in Figure 2-3. The Notch filter behave as such it accepts linear active inductors and rejects unwanted modulations in the 850/900 GSM noise by approximate 37dB.The RF front end has gain around 15dB and NF of 5dB.

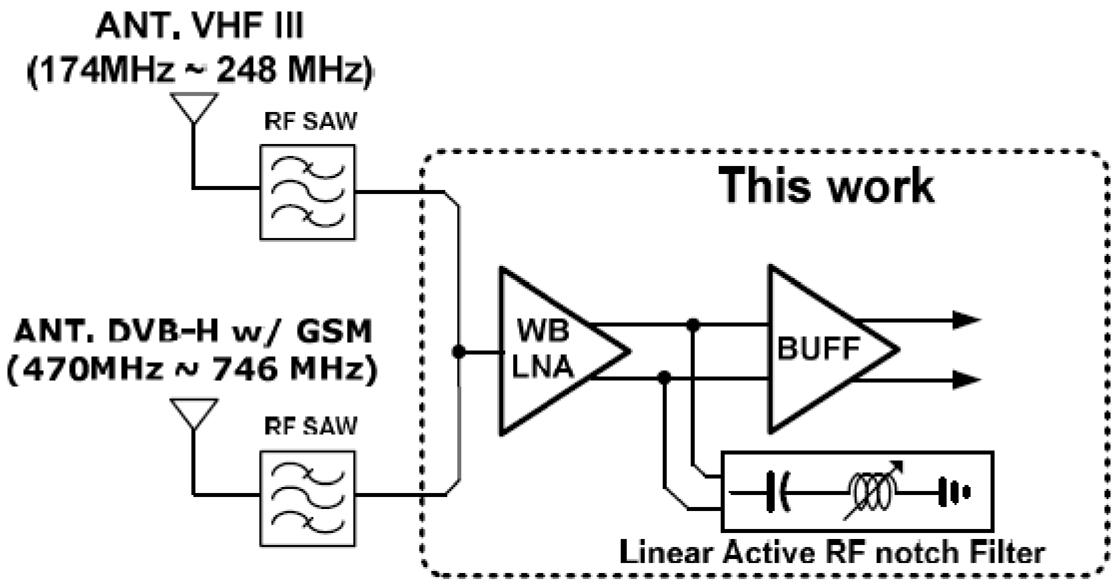

Figure 2-3: Block Diagram of RF Front End

This wide –band single to differential LNA has it’s own pro n cons. In order to reduce common mode noise rejection and also the even order harmonics, the circuit is being compensated with a balun to convert the single ended signal to a differential one. In this process, since the balun is located at the front of the LNA, it degrades the NF of the receiver and optimistic increase the cost of the receiver system (Sang Gyun, Seung Hwan, & Yun Seong, 2013).

LNA circuit with possible combination of matching circuit has been researched. The combination of ‘T” and “L” type matching circuits. Using the ADS simulation, the circuit is simulated .The circuit is constructed with two possibilities, which is with and without stabilizing circuit and feedback circuit .The RCL series circuit is constructed as a feedback circuit to improve the stability of the LNA circuit. There is couple of try and errors matching circuit simulation done. Example are L-L matching, L-T matching, T-T matching and T- L matching. Of all this the T-L matching provides the best results for the stability as shown in Table 2-3. NF for T-L matching is around 1.81dB which is about 0.35dB better the nearest matching of L-L. (Design and Comparison of Different Matching Techniques for Low Noise Amplifier Circuit, D. Senthilkumar1, Dr.Uday Pandit khot2, Prof. Santosh Jagtap3, Feb2013)

Table 2-3: Comparative Results of LNA Circuit W.SC and WO.SC

	L-L		L-T		T-L		T-T	
	WO.SC	W.SC	WO.SC	W.SC	WO.SC	W.SC	WO.SC	W.SC
S_{21}	16.280	10.390	13.539	5.237	16.296	14.140	13.588	6.468
S_{12}	-14.170	-27.300	-16.910	-32.500	-14.150	-23.500	-16.864	-29.400
S_{22}	-4.370	-16.100	-1.790	-1.240	-5.537	-6.290	-2.120	-11.800
S_{11}	-2.922	-1.820	-11.250	-3.810	-2.937	-17.200	-11.923	-10.100
K	0.409	1.14	0.409	1.133	0.409	1.304	0.409	1.254
NF	0.906	2.150	0.906	2.478	0.906	1.816	0.906	3.974

As a conclusion from Table 2-3, with all the possible simulation, it is proven the “L” output matching and “T” type input matching combination provides the better results without much degradation in the Gain, NF and in the perspective of stability design strategy of a LNA is determined by series of cascaded devices. Additional stage will add to noise. Hence it’s critical for the Noise and Gain characteristics.

$$F_{total} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2} + \ldots + \frac{F_n - 1}{G_1 G_2 \ldots G_{n-1}} \qquad (2.2)$$

By using the Friis formula, a cascaded system with total noise factor is being calculated. F1 and G1 which represents the Noise factor and gain of the first stage, dominates the overall Noise Factor. Hence the function of the LNA is to support sufficient signal gain to overcome the noise of the surrounding stages (Edwall, 2008).

Basic Selectivity of an LNA plays a vital role in the characteristics of its important parameters. There are two types of LNA, one is the single band and another is the multiband LNA’s. Multi band LNA’s are suitable for the wideband applications and tunable amplifier needed for this methodology. This however creates tradeoffs between linearity and gain. For the single band, it operates in a specific operating frequency. The implementation can be done with multiband antenna feeding to a single wide band LNA as in Figure 2-4 or multiple antennas with a dedicated narrowband LNA as shown in Figure 2-5.(Dinesh Cherukumudi, 2011)

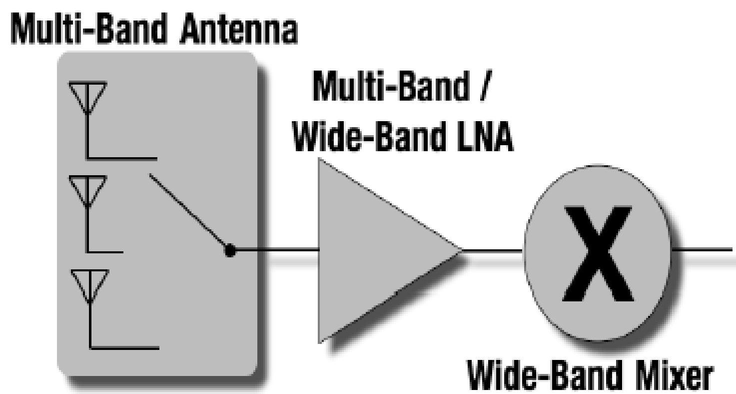

Figure 2-4: Multiband Antenna with Single Wideband LNA

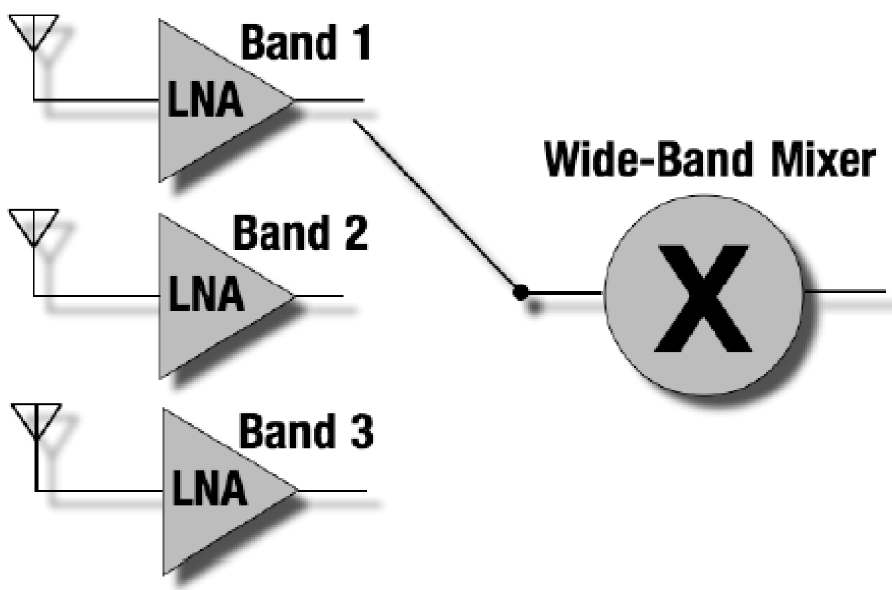

Figure 2-5: Multiband Receiver with Couple of Narrowband LNA

As reported by Anwar Faizd Osman and Prakash Chacko (Technical Paper,2011) , wider band LNA provides a tougher challenge to the radio designer. It requires a LNA at it receiver front end as it needs to provide constant gain, high linearity and Low Noise for it to meet the specifications as tabulated in Table 2-4. LNA–LIFE which utilizes from the MAXIM2371 IC consists of single channel, single ended, small signal low noise amplifier with AGC incorporated.

Table 2-4: Portable 8/900MHz LNA Specification Using LNA-LIFE IC

Parameter	**Specs**
Gain (dB)	> 12
Noise Figure (dB)	< 1.9
IIP3 (dBm)	> 0
Stability Factor (K)	> 1
Stability Factor (B1)	> 0
Operating Freq (MHz)	850-941

The LNA-LIFE with construction as shown in Figure 2-6 provides constant gain at the frequency at 850-941MHz. The Noise Figure however higher than the normal class A, LNA which is around 1.5 or lesser. Higher NF means the Signal to Noise Ratio will be deteriorated.

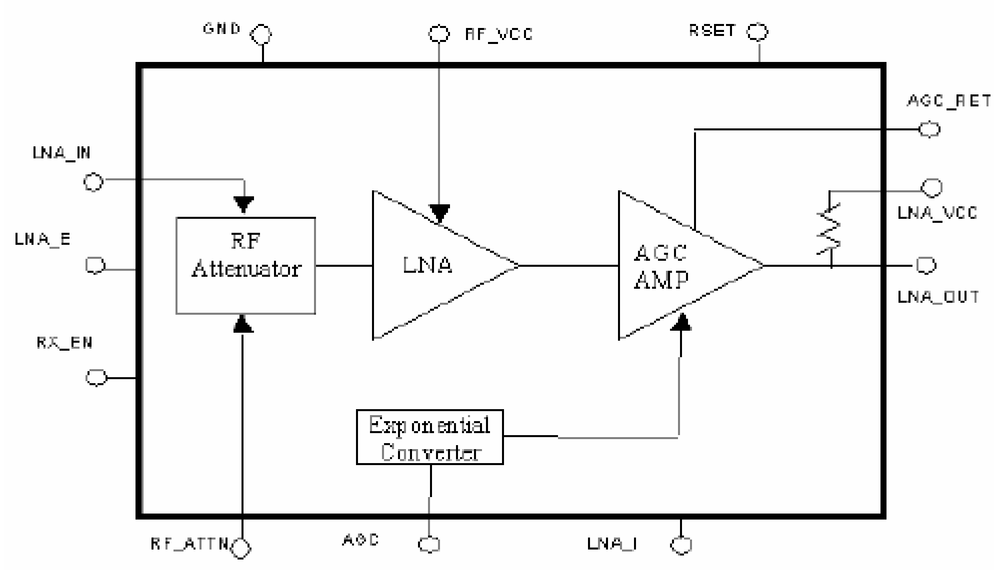

Figure 2-6: LNA-LIFE Block Diagram

Low Cost and small size constraint of the LNA was always been a huge criteria in a LNA design. In such for the narrowband LNA for the UHF band using the micro strip technology always synthesize a particular optimization. The well known topology of the LNA is shown in the Figure 2-7. The LNA transistor which is specified by the S-Scattering Matrix is consists gain element, biasing stage, input matching network (IMN) and an output matching network. In this proposed methodology is redefined by using a case study which the design of LNA amplifier. The transistor for this feasibility study is the NE68033 which has gain between 19dB to 20dB which is greater than the desired gain needed .The K factor is between 0.73 and 0.85 at the desired operating frequency and the problem arises when the RF transistor is no longer conditionally stable at the UHF band. (Rodríguez, Sebastián, 2011)

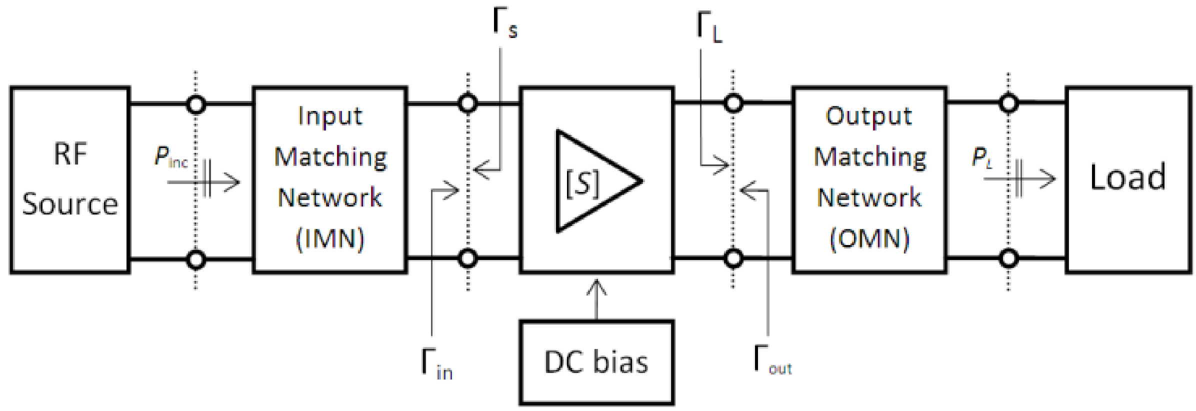

Figure 2-7: General Diagram of A RF Amplifier

As summary of the literature review, the approach selected was the balanced amplifier topology for this LNA with the matching components .This is because the NF is less then 1 dB which is one of the requirement of the project. Besides that, the current drain of this LNA is less then 5 mA which is important as the lesser the current drain the better the battery life performance. The test results and measurements will be discussed in later chapters

CHAPTER 3

THEORY, DESIGN AND IMPLEMENTATION

3.1 Introduction

In a typical LNA design, there are few considerations to be taken consider off. Cost of the RF transistor, size of the transistor itself. As discussed on Chapter 2, since there is many architecture and topology which attributes to the LNA in radio. For the scope of this thesis, the RF transistor of BFU520W is chosen due to its high speed and low noise application in a plastic. The Minimum Noise Figure is = 0.6dB at 900Mhz and Maximum stable gain of 18.5dB.This RF transistor is used in the LNA for VHF Band which operates in the region of 136-174Mhz.In the next subtopics, design methodology for LNA measurement using the BFU520W is discussed. The novelty here is by using the same topology as the previous Legacy LNA and the subsection results should be comparable with the current BFU520W.Then it is followed by the measurement set ups to measure the LNA gain and Input and output return loss, Noise Figure, 1dB Compression Point and F2 Blocking. Figure 3-1 illustrates the summary of the design steps in the LNA implementation.

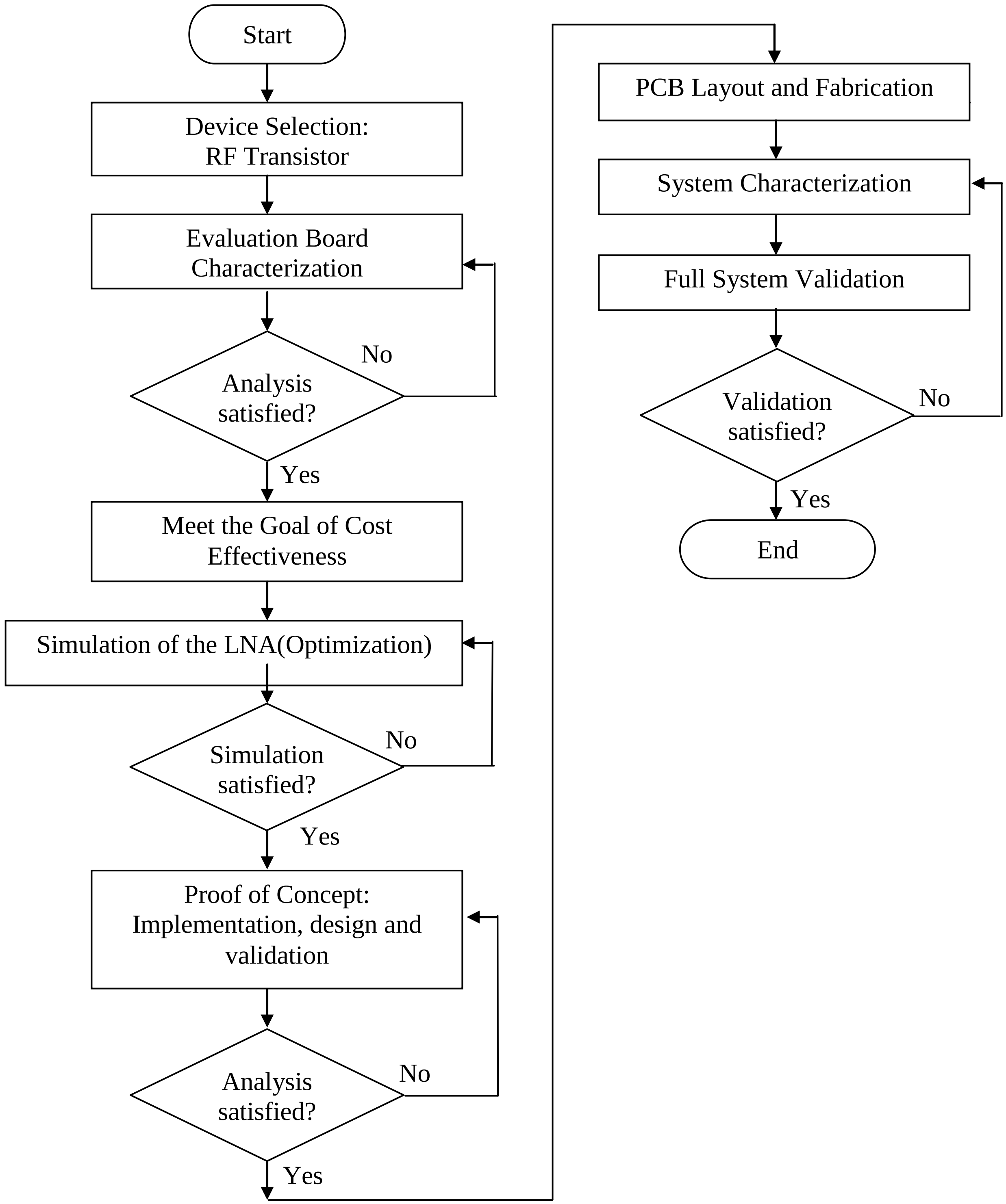

Figure 3-1: Research Methodology Flow Chart

3.1.2 The Design Goal of the BFU520W is as table below.Despite it wide band capability, its only tested for the content of VHF only.The gain needed for this LNA methodology is around 10 dB.Reason being, high gain induces the overall IIP3 system performance.One of the main criteria is the current drain for the LNA.A low consumption of current drain is needed .Input and Output return loss is targeted to be less the <-10dBm

Parameter	**Goal**
Frequency	136-174(VHF) but supports wideband till 1 Ghz
Gain	Approx 10 dB
Current Drain	<5mA
IIP3	>-5 dBm
Input Return Loss	<-10dBm
Output Input Return Loss	<-10dBm
K Factor (Until 5 Ghz)	> 1
B1 Factor (Until 8 Ghz)	> 0

Table 3-1: VHF LNA Design Goal

3.2 Measurement Setup

In following sections below, test setup and configurations for each measurement will be shown separately and in precise. In order to ensure the accuracy of the measurement, equipment ensured been calibrated and measurement has been repeated three times to verify the repeatability

3.2.1 LNA Measurement with Test Fixture

For evaluation purposes, the LNA BFU520W as shown in Figure 3-2 was tested in a fixture. This is to correlate the LNA performance according to the data sheet.

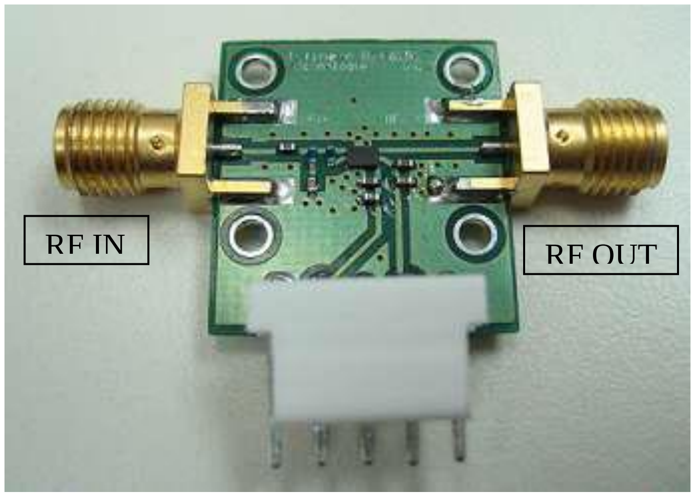

Figure 3-2: LNA Application Test Fixture

3.2.2 Noise Figure Calculation

Noise Figure offset is measured during the calibration stage. In an ideal case, for the NF measurement, the LNA is being measured in a shield room. In this case, the NF offset obtained is 0dB. The Noise Figure captured by the 8595E Spectrum Analyzer as shown in Figure 3-3 is at 0.9 dB. Noise figure equation is given by:

$$\text{NoiseFigure (shown by 8595E)} + \text{NoiseFigure Offset} = \text{NoiseFigure} \quad (3.1)$$

By using the equation above, the Noise Figure for the BFU520W is calculated as below: