DESIGN FABRICATION AND CHARACTERIZATION OF FRONT-END RECEIVER FOR 5 GHZ WLAN APPLICATIONS

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ABSTRACT

Design Fabrication and Characterization of Front-End Receiver for 5 GHz WLAN Applications

The aim of this work is to present a design of a radio front end receiver working at 5 GHz using Agilent Advanced Design System (ADS) and to simulate it.

The design method for the radio frequency front-end receiver consists of 2 stages. The components are designed and simulated in the first stage, and then all the components are merged into a PCB in the second stage. This PCB is then manufactured and assembled. A network analyzer is used to made all measurements on the radio front-end receiver and the examination components, to calculate the S-parameters.

The result of our work is a useful design and prototype, which has proved that it is possible to design systems for 5 GHz on a laminate substrate.

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CERTIFICATE OF CORRECTNESS AND APPROVAL

It is hereby certified that information in this thesis "**Design Fabrication and Characterization of Front-End Receiver for 5 GHz WLAN Applications**" carried out by 1) Capt. Arsal Bilal 2) Capt. Waleed Ullah 3) Capt. Nadeem Hamayun 4) Capt. Imran Haider under the direction of Assoc. Prof. Dr. Farooq Ahmed Bhatti in partial fulfillment of our degree of Bachelor of Telecommunication Engineering is correct and approved. The plagiarism of this document is …….. %.

Approved By

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Project Supervisor

Military College of Signals, NUST

DECLARATION

We hereby declare that no content and form of work presented in this thesis has been submitted in support of another award of qualification or degree either in this institution or anywhere else.

DEDICATION

This proposition is devoted in thanks to ALLAH ALMIGHTY our Creator who has blessed us with wisdom, knowledge and understanding then to our parents for their direction and their endless support. Then to our Faculty for their guidance and supervision. Without their help and supervision this project would not have been made possible.

ACKNOWLEDGEMENT

The accomplishment of this project would not have been possible without the contribution of different people the names of which cannot be reckoned with. Their assistances are sincerely respected and thankfully recognized. We would like to thank following:

To Allah Almighty who is the most Powerful and Merciful and everything is in His obedience.

Assoc. Prof. Dr. Farooq Ahmed Bhatti for his support and guidance during the entire project.

To all relatives, friends.

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ABBREVIATIONS

ADS	Advanced Design System
BPF	Band Pass Filter
EM	Electromagnetic
LNA	Low Noise Amplifier
LPF	Low Pass Filter
NF	Noise Figure
O/P	Output Power
PA	Power Amplifier
PCB	Printed Circuit Board
RF	Radio Frequency
RX	Receiver
SMD	Surfaced Mounted Device
TX	Transmitter
WLAN	Wireless Local Area Network

CHAPTER 1

1. INTRODUCTION

Due to the prompt progress in wireless communication, certain applications are being developed such as cellular, paging, cordless, data over voice and the wireless local networking. Because of the need of multimedia service as wireless and the swift expansion of communication signal processing procedure, the high data rate i-e 6~54Mbps wireless Local Area Network standard developed in July 1999.

In our project, we are presenting the 5GHz band RF Front End Receiver prototype which will be designed and tested in the wireless channel. We need to implement the receiver on the printed circuit board (PCB) but before that the characteristics of receiver are simulated using commercial software ADS.

1.1 PROJECT OVERVIEW

We have selected **"Front-End Receiver for 5 GHz WLAN Applications"** as our project. Project envisages on the design, fabrication and characterization of receiver front-end for 5 GHz WLAN applications. This front-end receiver forms a necessary part of the receiving systems.

1.2 PROBLEM STATEMENT

With the modern swift advance in wireless communication, innumerable applications are being appeared such as cellular, cordless, data over voice, paging and the wireless local networking. Because of the need of multimedia service which is wireless and the prompt expansion of communication signal processing technique, the high data rate i-e 6~54Mbps wireless Local Area Network standard was developed in July 1999. So, we need to have systems that can sustenance the requisite data rate.

1.3 APPROACH

1. Design a simple receiver front-end
2. Characterize the receiver front-end
3. Reducing the noise and Increasing the gain by using appropriate ICs
4. Design fabrication and testing the hardware

1.4 OBJECTIVES

In our project, we are going to simulate process for making 5GHz band RF Front End receiver using ADS software and results are optimized by using optimizations techniques in ADS.

1.5 ORGANIZATION

Manuscript starts with the abstract which defines the main details of our project **Design Fabrication and Characterization of Front-End Receiver for 5 GHz WLAN Applications**, and then the introduction section that states the problem statement, approach, scope, objectives and limitations. The literature review segment defines the several means read online and in different books before the initiation of the project. The design and development part has the diagrams which define the comprehensive design of the project, its components, and the simulated results. The analysis and evaluation part deals with the testing the actual results against expected results. The forthcoming work gives states the improvements which can be applied to the application.

CHAPTER 2

RADIO FREQUENCY THEORY

In this chapter there will be the basic concepts of RF theory and design.

2.1 GENERAL THEORY

We have low frequency circuits and high frequency circuits. When we work on low frequency circuits Kirchhoff's voltage and current laws can be used as testing or analysis tool. When we go to the higher frequency these laws will not give the accurate results. The cause is that the wavelength becomes small to such an extent that voltage and current will transmits changed waves pattern, magnitude and phase in the conductor.

2.1.1 TRANSMISSION LINES

In typically solid ground circuit vogue, at high frequency the road has higher performance. Xmn-lines are conductors are always compard with ground reference voltages. Samples of Xmn-lines are 2-Wire lines, concentric and small strip lines. Within these conductors voltage and current propagate in the shape of waves and therefore magnitude and phase vary over the entire conductor. Since Kirchoff's lawas of current and voltage laws do not take those variations of over transmission lines into thought and there straight away use is not possible.

2.1.2 S-PARAMETERS

Scattering parameter or a great deal of commonality referred as 'S'-parameters illustration plays a really vital role in RF-systems with reference to measure and technical documentation. This importance is since ancient system characterizations like opener short-circuit measurements won't be accomplished as a result of it's completed throughout an occasional frequency application. Measure ways that for low-frequency systems generally commit to live the complete V or I as a perform of frequency. At higher frequency band using these steps result will never be better. Insted the developed S-parameters, that unit of measurement made public as a result of the relation of normalized power waves and unit of measurement are comparatively easy.

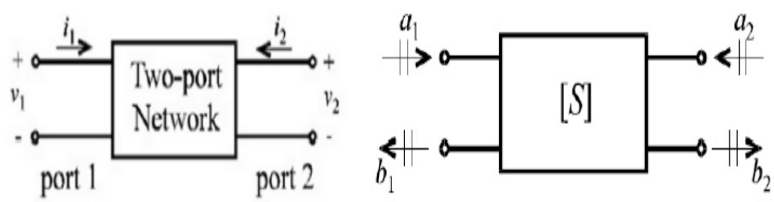

Fig 2.1: 2-port network

Fig 2.3 gives two completely completely different 2-port representations, the one to the left show definition for V and I and additionally proper one show normalized incidented power-wave and normalized reflected one.

Reckoning on that port that is terminated completely completely different ‘S’-parameters for a 2-port network are going to be found. . S21 and S12 shows what strength of incident-wave that propagate through device from port-1 to port-2 and from port-2 to port-1. S21 and S12 specify what proportion of the incident wave that link up with device from port one to port a combine of and from port a combine of to port one.

2.2 LOW NOISE AND POWER AMPLIFIERS

Designing RF circuit's exploitation amplifiers differs significantly from the quality low frequency vogue methodology. At high frequencies heaps of thought ought to be taken into thought, like V and I to matching networks to chop back the V undulation quantitative relation VSWR and undesirable frequencies. Therefore, one in each of foremost very vital tasks of turning out with Associate in Nursing RF equipment circuit is to substantiate stability of circuit. Once the specific equipment is stable, noise and gain circle areas typically pinched at intervals the Smitth Chart to visualize the properties of circuit. Turning out with Radio Frequency amplifiers is sometimes a trade-off between gain, noise and stability.

CHAPTER 3

DESIGN PROCESS

3.1 DESIGN OVERVIEW

An Interface between a receiver and antennas is the radio front-end receiver. After receiving a signal, we will filter it and then amplify. Before down conversion we will balance the signal.

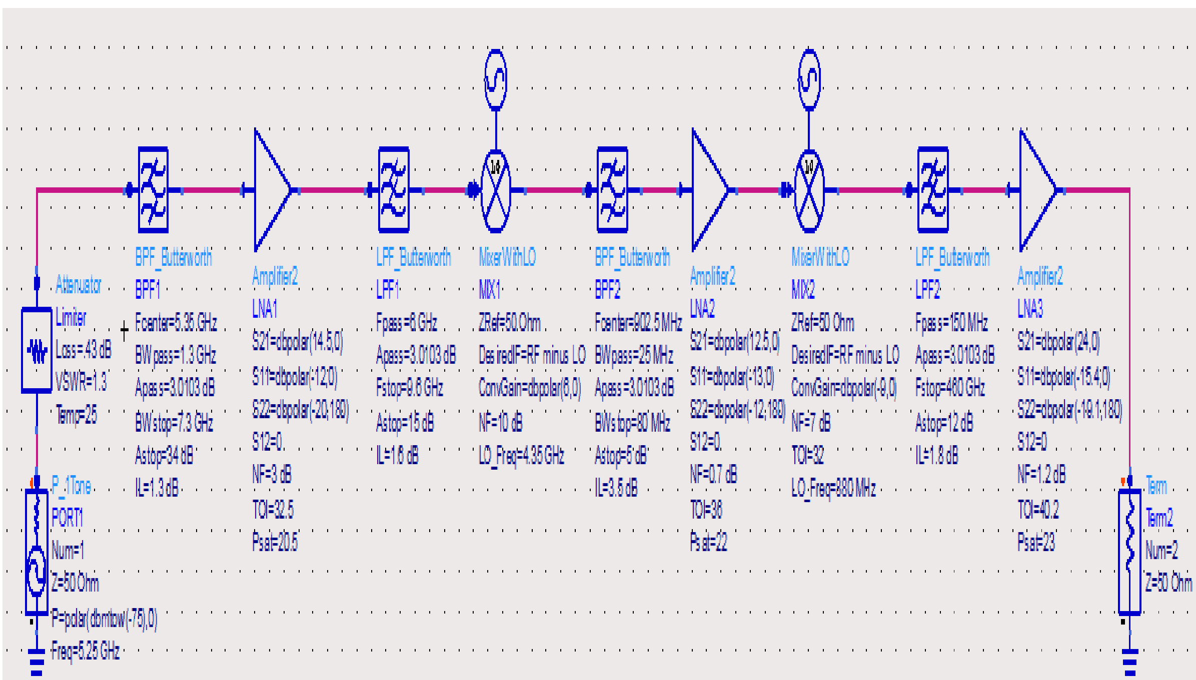

Figure 3.1: Design of the Receiver

3.2 DESIGN SPECIFICATIONS

Table 3.1: Design Specifications

PARAMETER	REQUIREMENT
FREQUENCY	5.15 – 5.35 GHz
Noise Figure	less than10 dB
Gain (receiver)	16 dB
Minimum sensitivity	-74 dBm
SNR	19.1 dB
Operating Voltage	5V

Table 3.1 shows the design specifications for the designing of RF front end receiver at 5 GHz .

3.3 COMPONENTS

3.3.1 SIGNAL GENERATOR

Signal Generator is a Function Generator. As per our requirement, Frequency and power will be provided through a signal. So that it behaves like an antenna, whose frequency is 5.25GHz and received power of -74 dBm.

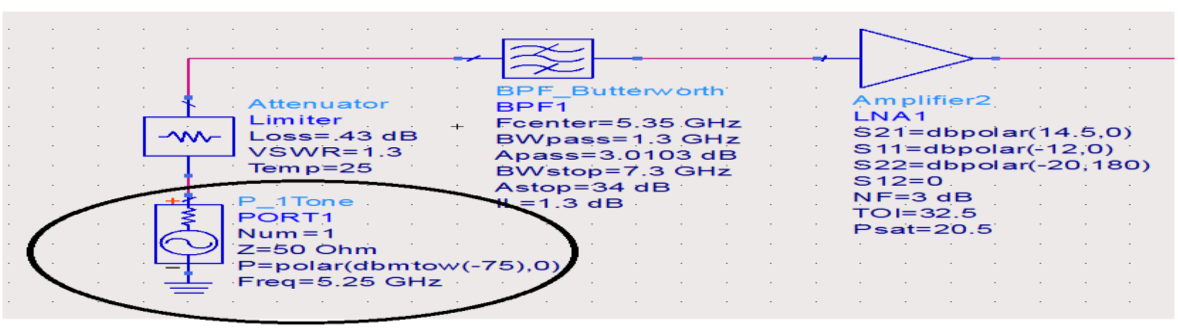

Figure 3.2 Signal Generator

3.3.2 LIMITER

In this system, the IC of the Limiter used here is RLM-63-2W+ of Minicircuits with a frequency of 30 MHz to 6 GHz. Data sheet of the IC RLM-63-2W+ can be found on website as shown in reference no [6]. Figure 3.4 shows the Limiter that is placed in a Receiver, we assume the power received at the antenna is -74 dBm. It takes maximum power upto +3dbm , here in our case we are receiving -74 dBm. If the power received is more than +12dBm , then this limiter will attenuate that power and then pass it on.

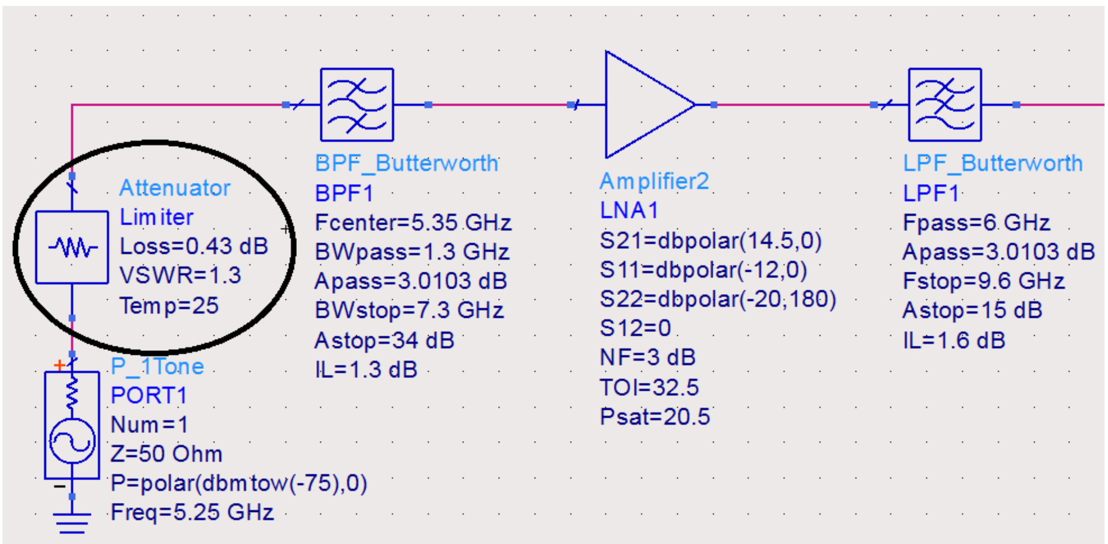

Figure 3.4 Limiter in RF Front End Receiver

Figure 3.5, 3.6, 3.7 shows the Noise Figure, Gain and Output power of the limiter respectively.

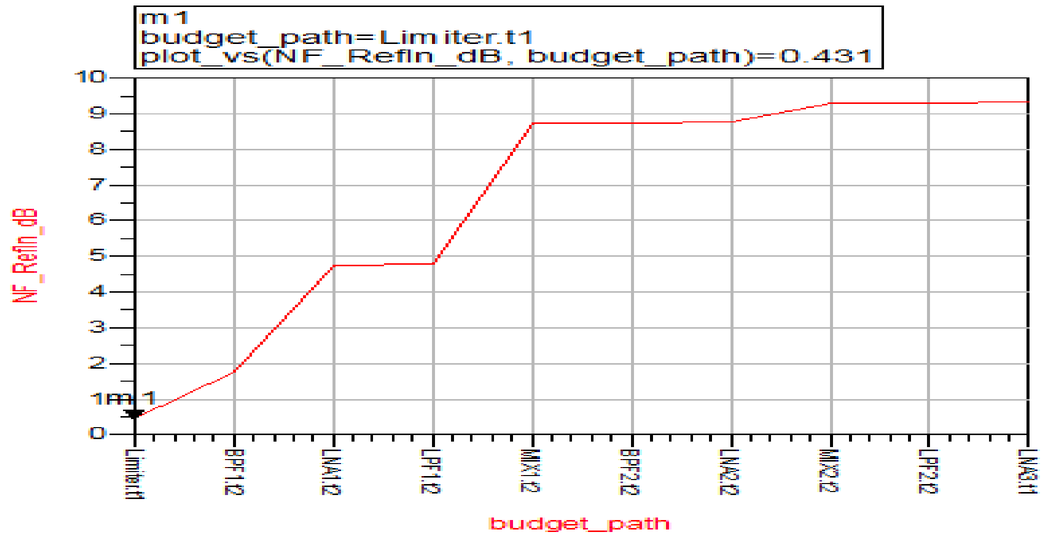

Figure 3.5 Noise Figure of a Limiter

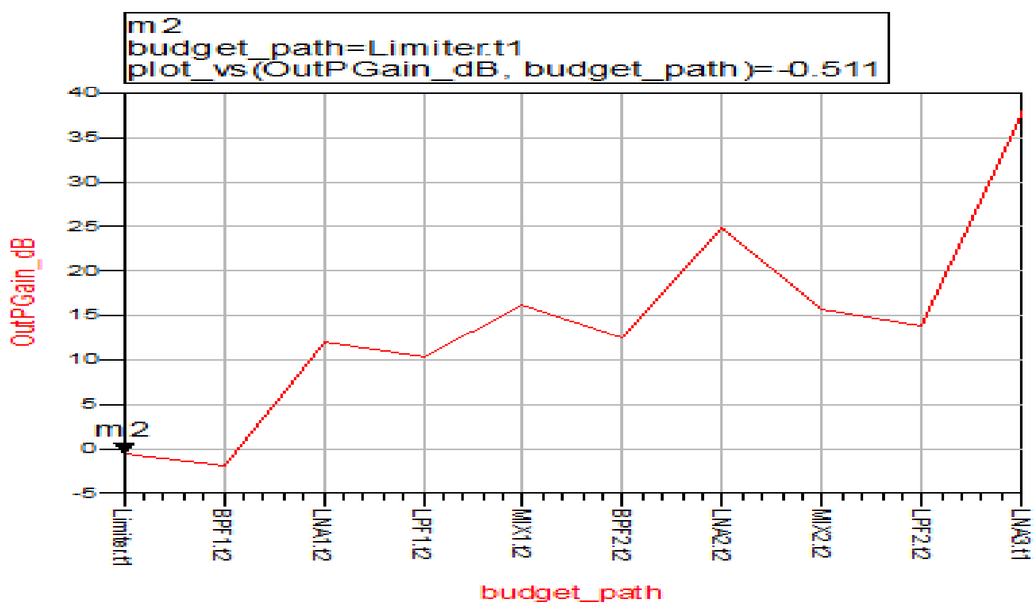

Figure 3.6 Output Gain of a Limiter

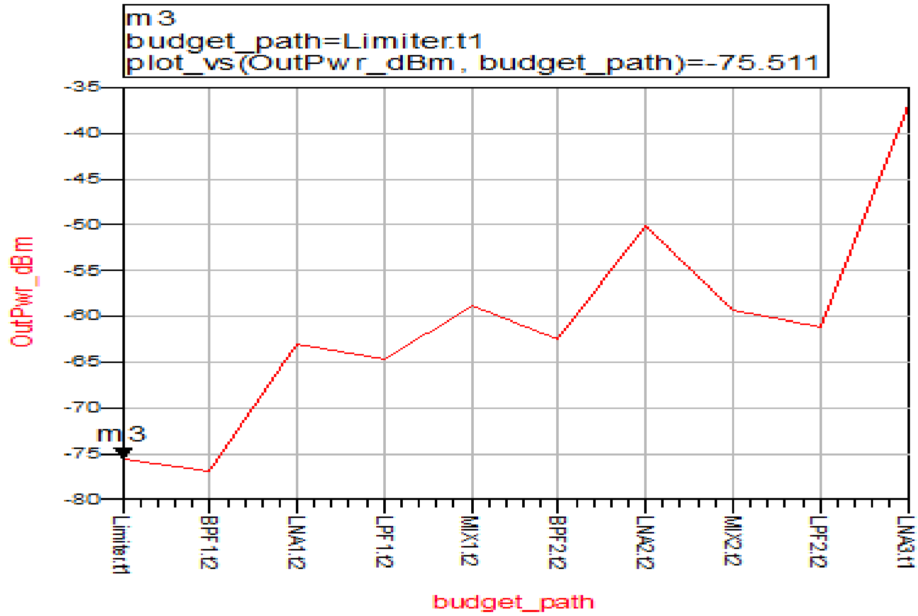

Figure 3.7 Output Power of a Limiter

Table 3.2: Result of Limiter

Component	Noise Figure (dB)	Output Gain (dB)	Output Power (dBm)
Limiter	**0.43**	**-0.51**	**-75.51**

Table 3.2 shows the Noise Figure , Output Gain and Output power of the Limiter used at the start to limit the signal power.

3.3.3 BAND PASS FILTER

In this system, the IC of the Band Pass Filter used here is BFCW-542+ of Minicircuits with a frequency of 4.7 GHz to 6 GHz. Data sheet of the BFCW-542+ can be found on website as shown in reference no [7]. A BPF is a component that allow frequencies in a specific interval and attenuates frequencies other than that interval.

In our front end Rx, a BPF 1 is used to permits signals at intervals of specific range of frequency to be detected, whereas stopping signals at undesirable frequencies that are added to the signal through the air in the shape of noise. A BPF is to improve the quantitative relation and sensitivity of a Rx.

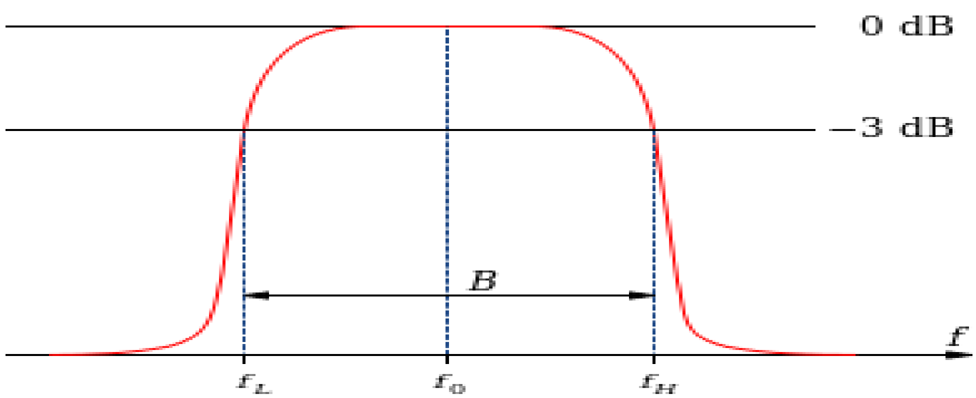

Figure 3.8 Graph of Band pass Filter

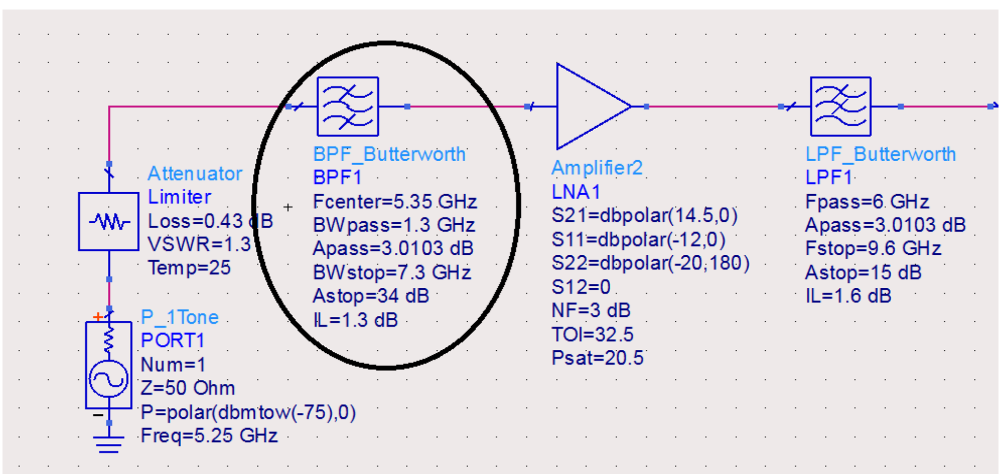

Figure 3.9 Band Pass Filters 1 in RF Front End Receiver

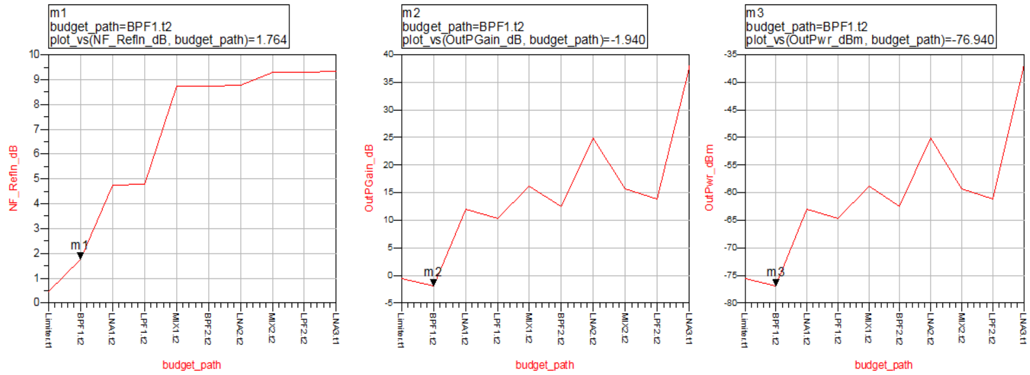

Figure 3.10 Noise Figure, Output Gain and Output Power of Band Pass Filter1

Table 3.3: Result of BPF 1

Component	Noise Figure (dB)	Output Gain (dB)	Output Power (dBm)
Band Pass Filter 1	**1.764**	**-1.940**	**-76.94**

Table 3.3 shows the Noise Figure , Output Gain and Output power of the Band Pass Filter used to stop the undesired frequencies in the received signal.

3.3.4 LOW NOISE AMPLIFIER

In this system, the IC of the Low Noise Amplifier used here is hmc717a of Analog Devices with a frequency of 4.8 GHz to 6 GHz. Data sheet of the hmc717a can be found on website as shown in reference no [8]. A low-noise amplifier 1 that is used here is to amplifies a low-power signal that is received from Band Pass Filter whereas not considerably degrading its signal/noise ratio. In wireless applications, a low-noise amplifier is a device that will increase the amplitude of weak RF signals of a receiver without adding noise into it.

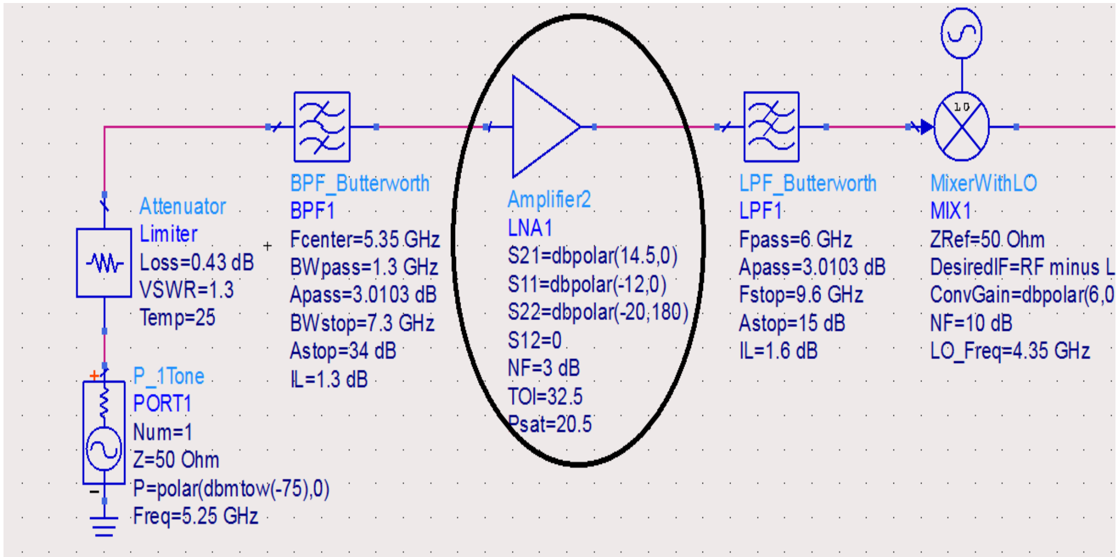

Figure 3.11 Low Noise Amplifier 1 in RF Front End Receiver

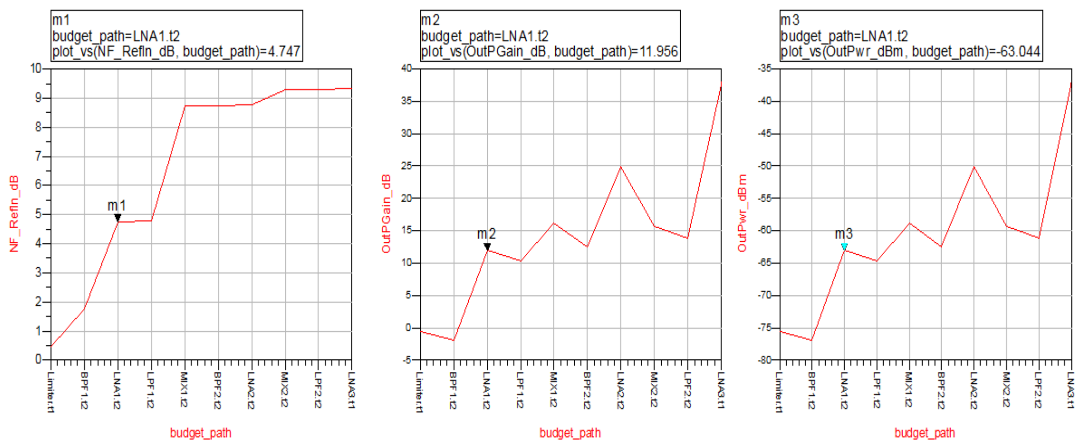

Figure 3.12 Noise Figure, Output Gain and Output Power of Low Noise Amplifier 1

Table 3.4: Result of LNA 1

Component	Noise Figure (dB)	Output Gain (dB)	Output Power (dBm)
Low Noise Amplifier 1	4.747	11.956	-63.04

Table 3.4 shows the Noise Figure , Output Gain and Output power of the Low Noise Amplifier 1 used to improve the SNR of the received signal.

3.3.5 LOW PASS FILTER

In this system, the IC of the Low Pass Filter used here is XLF-63+ of Minicircuits with a frequency of DC to 65 GHz. Data sheet of the XLF-63+ can be found on website as shown in reference no [9]. Low Pass Filter 1 is used here to allow the signal of frequencies below certain frequency and attenuates those which are above the desired frequency

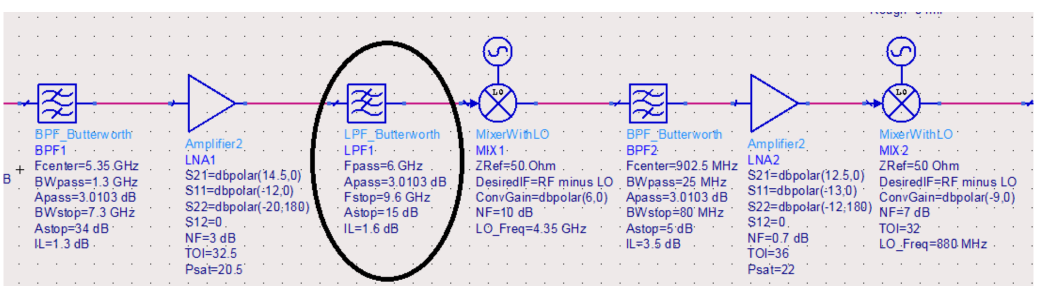

Figure 3.13 Low Pass Filter 1 in RF Front End Receiver

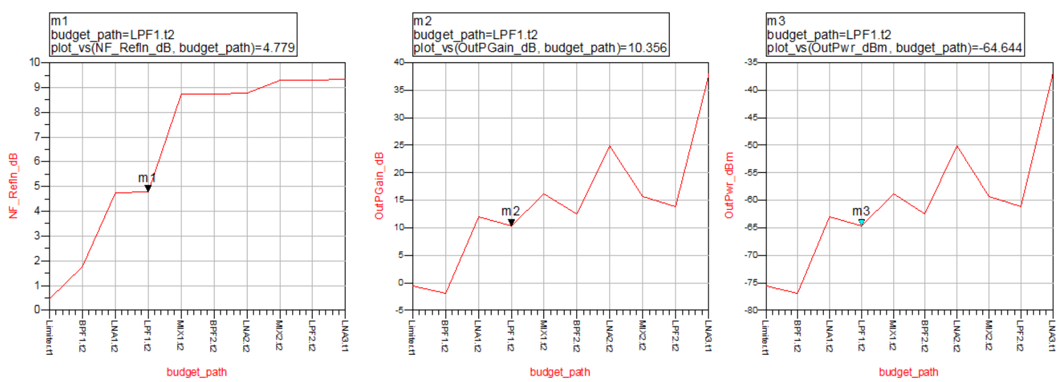

Figure 3.14 Noise Figure, Output Gain and Output Power of Low Pass Filter 1

Table 3.5: Result of LPF 1

Component	Noise Figure (dB)	Output Gain (dB)	Output Power (dBm)
Low Pass Filter 1	**4.779**	**10.356**	**-64.64**

Table 3.5 shows the Noise Figure , Output Gain and Output power of the Low Pass Filter 1 used to allow the signal below certain frequency of the received signal.

3.3.6 MIXER

In this system, the IC of the Mixer used here is MDA4-752H+ of Minicircuits with a frequency of DC to 65 GHz. Data sheet of the MDA4-752H+ can be found on website as shown in reference no [10]. We are doing the two step heterodyning in our design. In the first step, the mixer is used with Local Oscillator (LO) of 4.35 GHz , RF Input 5.25 GHz and giving out the IF output of 990 MHz, so the mixer at first stage is down converting the signal to IF . Mixer is a device that receives RF/ IF signal and down converts / up converts it into IF/ RF signal.

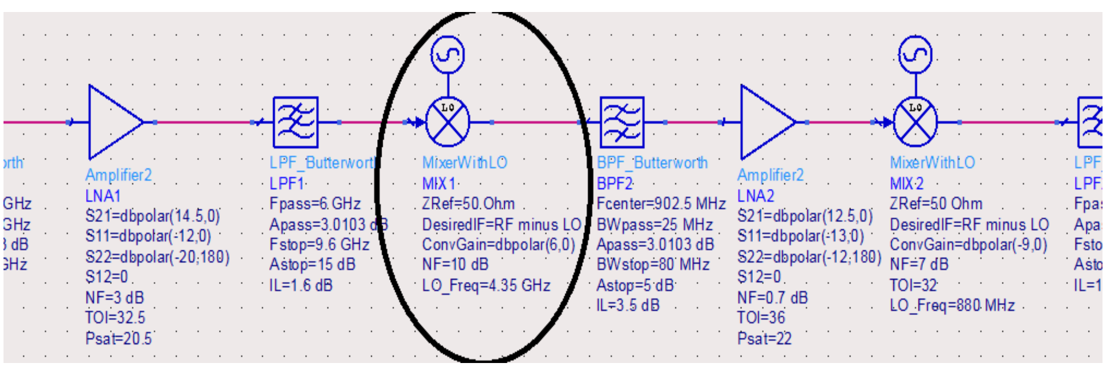

Figure 3.15 Mixer 1 in RF Front End Receiver

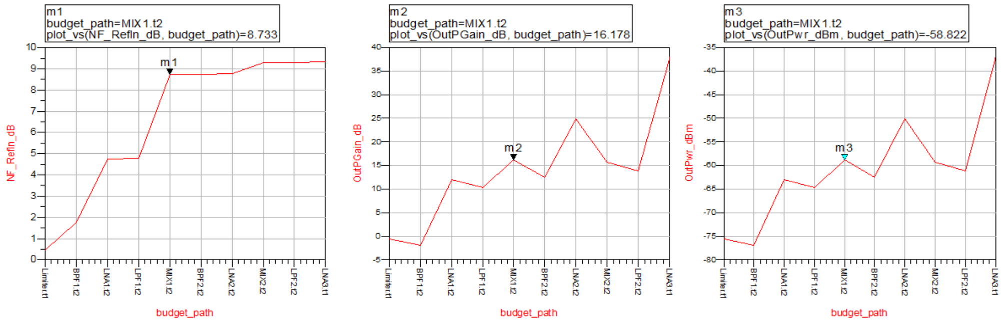

Figure 3.16 Noise Figure, Output Gain and Output Power of Mixer 1

Table 3.6: Result of Mixer 1

Component	Noise Figure (dB)	Output Gain (dB)	Output Power (dBm)
Mixer 1	**8.733**	**16.11**	**-58.82**

Table 3.6 shows the Noise Figure , Output Gain and Output power of the Mixer 1 used to down convert the RF signal to IF Signal.

3.3.7 BAND PASS FILTER

In this system, the IC of the Band Pass Filter used here is TFS902 of Vectron International with a frequency of DC to 2 GHz. Data sheet of the TFS902 can be found on website as shown in reference no [11]. Band Pass Filter used here is to attenuate undesired frequency signals / harmonics generated by the Mixer 1, as mixer is a active device and it generates harmonics. After attenuating the undesired signal, the desired signal is allowed to pass through it .

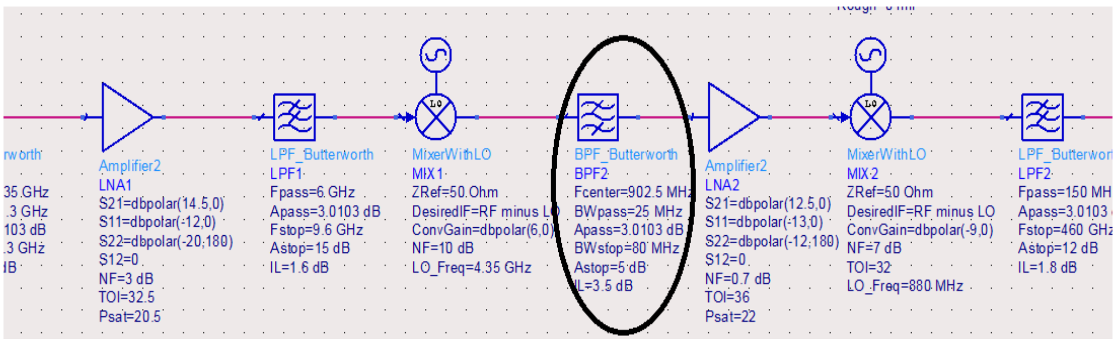

Figure 3.17 Band Pass Filter 2 in RF Front End Receiver

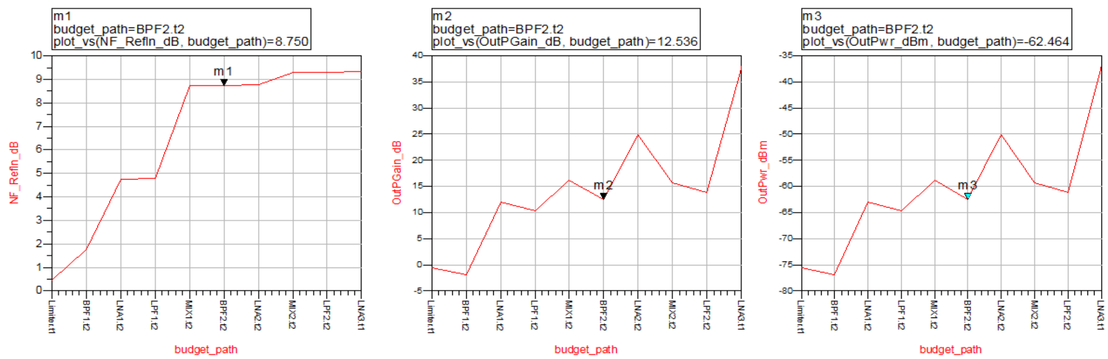

Figure 3.18 Noise Figure, Output Gain and Output Power of Band Pass Filter 2

Table 3.7: Result of BPF 2

Component	Noise Figure (dB)	Output Gain (dB)	Output Power (dBm)
Band Pass Filter 2	**8.750**	**12.53**	**-62.46**

Table 3.7 shows the Noise Figure , Output Gain and Output power of the Band Pass Filter 2 used to attenuates the undesired frequency signals

3.3.8 LOW NOISE AMPLIFIER

In this system, the IC of the Low Noise Amplifier used here is hmc376 of Analog Devices with a frequency of 700 MHz to 1 GHz. Data sheet of the hmc376 can be found on website as shown in reference no [12]. After passing through the band pass filter the Signal strength decreases, so LNA 2 used here is to improve the SNR of the received signal without increasing noise.

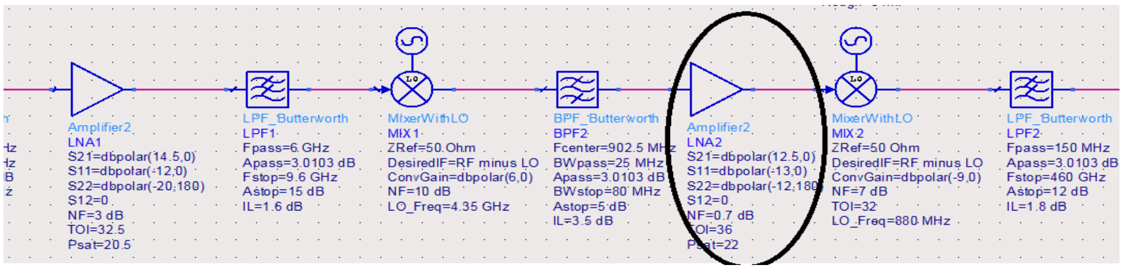

Figure 3.19 Low Noise Amplifier 2 RF Front End Receiver

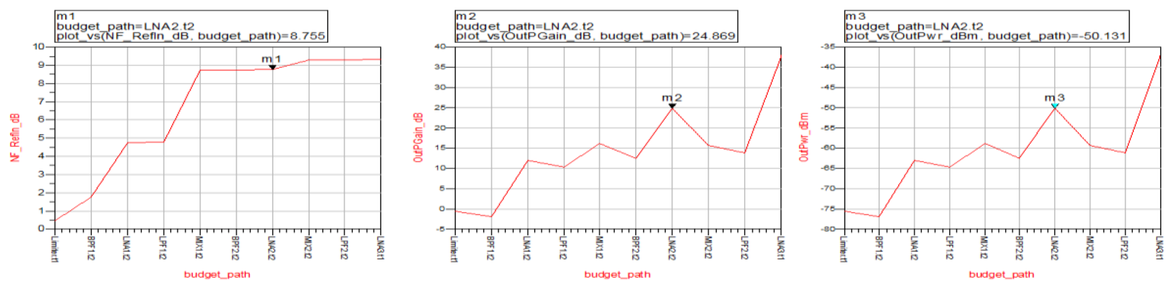

Figure 3.20 Noise Figure, Output Gain and Output Power of Low Noise Amplifier2

Table 3.8: Result of LNA 2

Component	Noise Figure (dB)	Output Gain (dB)	Output Power (dBm)
Low Noise Amplifier 2	**8.755**	**24.869**	**-50.13**

Table 3.8 shows the Noise Figure , Output Gain and Output power of the Low Noise Amplifier 2 used to improve the SNR of the received signal.

3.3.9 MIXER

In this system, the IC of the Mixer used here is hmc684 of Analog Devices with a frequency of 700 MHz to 1 GHz. Data sheet of the hmc684 can be found on website as shown in reference no [13]. The Mixer 2 used here is the 2nd step to heterodyning, in which it down converts the RF Signal (990 MHz) to IF Signal (20 MHz) signal.

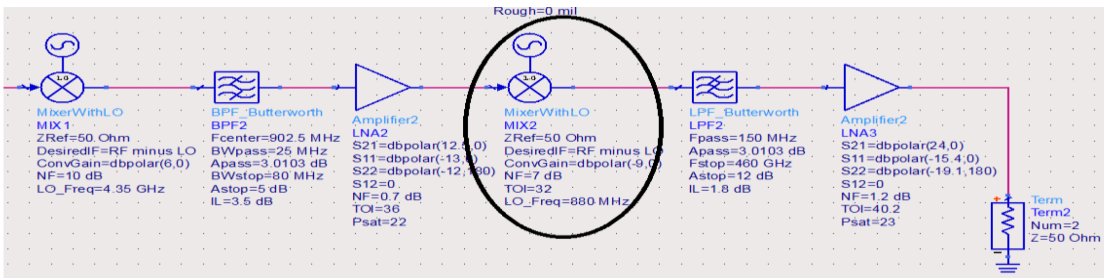

Figure 3.21 Mixer 2 RF Front End Receiver

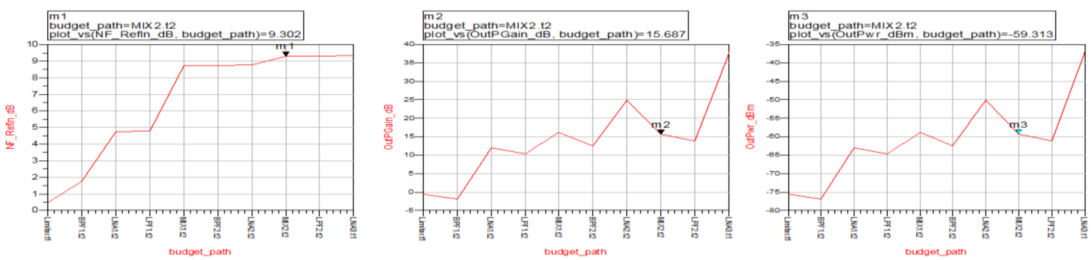

Figure 3.22 Noise Figure, Output Gain and Output Power of Mixer 2

Table 3.9: Result of Mixer 2

Component	Noise Figure (dB)	Output Gain (dB)	Output Power (dBm)
Mixer 2	9.302	15.687	-59.313

Table 3.9 shows the Noise Figure , Output Gain and Output power of the Mixer 2 used to down convert the signal from 990 MHz to 20 MHz.

3.3.10 Low Pass Filter

In this system, the IC of the Low Pass Filter used here is XLF-151+ of Miniciruits with a frequency of DC to 21 GHz. Data sheet of the XLF-151+ can be found on website as shown in reference no [14]. Low Pass Filter 1 is used here to allow the signal of frequencies below certain frequency and attenuates those which are above the desired frequency

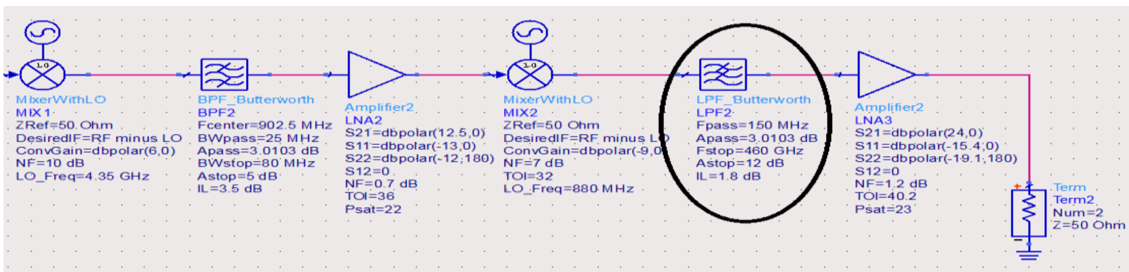

Figure 3.23 Low Pass Filter 2 RF Front End Receiver

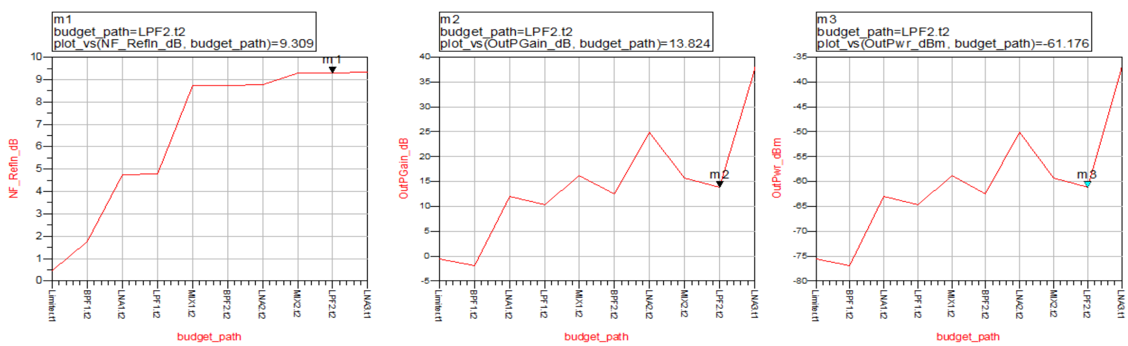

Figure 3.24 Noise Figure, Output Gain and Output Power of Low Pass Filter2

Table 3.10: Result of LPF 2

Component	Noise Figure (dB)	Output Gain (dB)	Output Power (dBm)
Low Pass Filter 2	9.302	13.824	--61.176

Table 3.10 shows the Noise Figure , Output Gain and Output power of the Low Pass Filter 2 that allows to pass the frequencies below certain specific frequency

3.3.11 LOW NOISE AMPLIFIER

In this system, the IC of the Low Noise Amplifier used here is PHA-13LN+of Miniciruits with a frequency of 1 MHz to 1 GHz. Data sheet of the PHA-13LN+can be found on website as shown in reference no [15]. After passing through the Low pass filter the Signal strength decreases, so LNA 3 used here is to improve the SNR of the received signal without increasing noise.

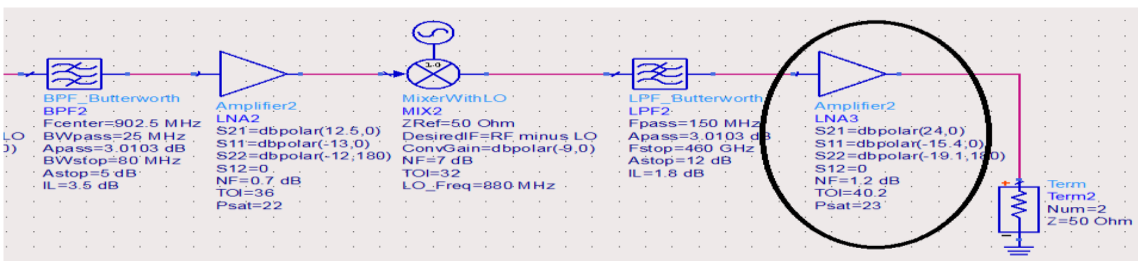

Figure 3.25 Low Noise Amplifier 3 RF Front End Receiver

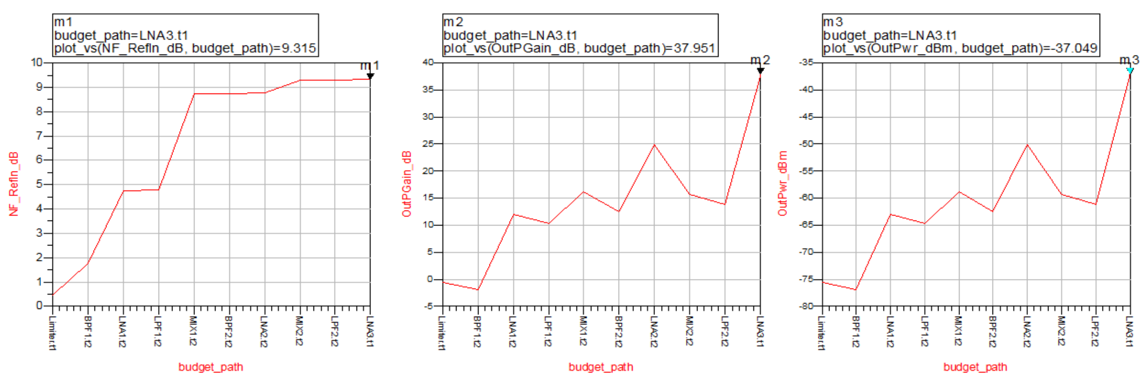

Figure 3.26 Noise Figure, Gain and Output Power of Low Noise Amplifier 3

CHAPTER 4

SIMULATED RESULTS

The complete circuit of RF Front End Receiver is shown in Figure 3.1 whose simulated results of the total Output Power, Gain and Noise Figure is shown in Figure 4.1 , 4.2, 4.3 respectively

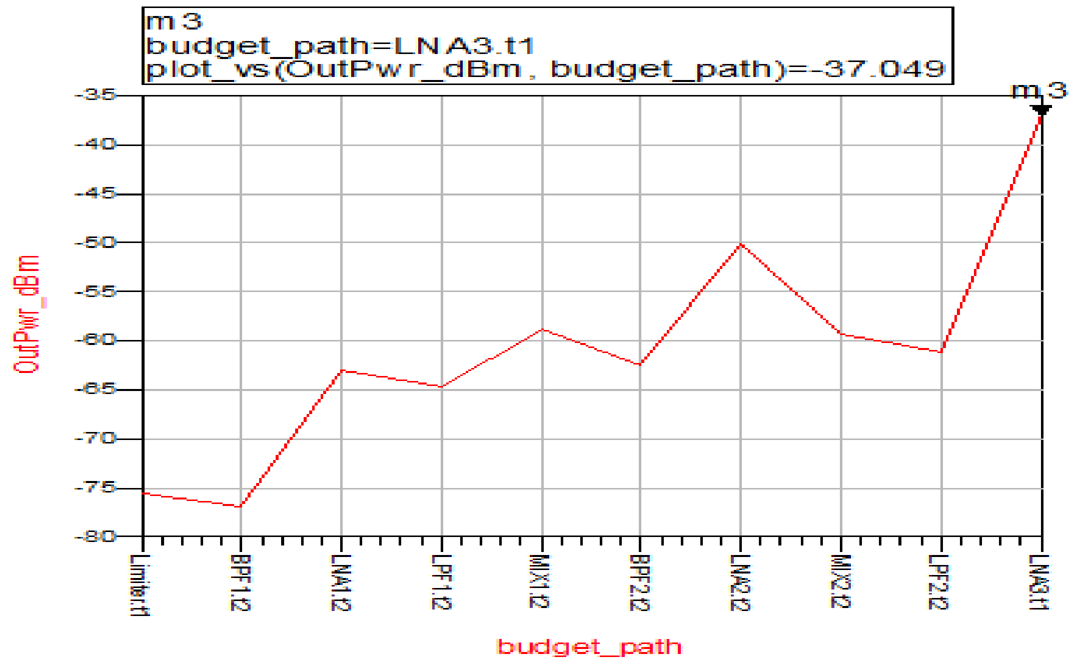

Figure 4.1: Graph of Total Output Power Vs Budget Path

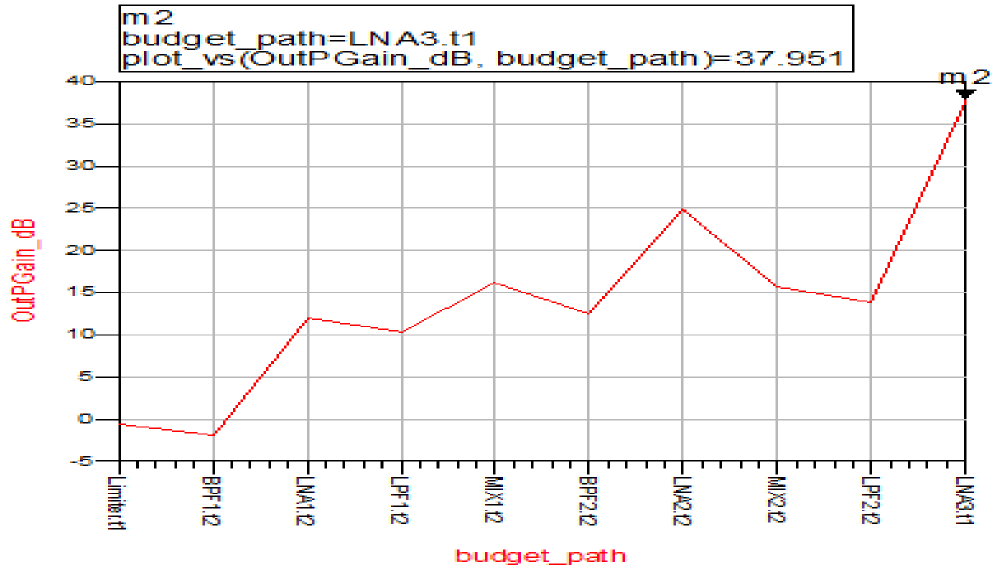

Figure 4.2: Graph of Total Output Gain Vs Budget Path

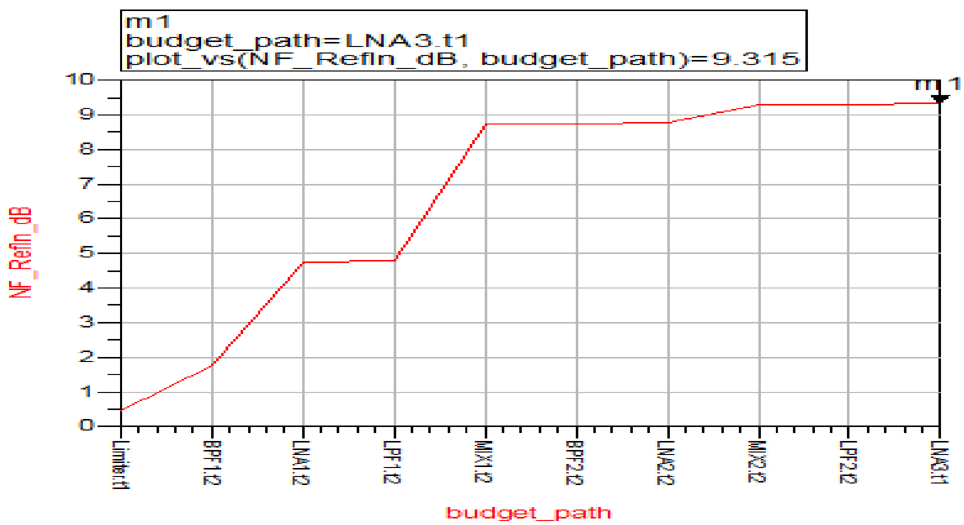

Figure 4.3: Graph of Total Noise Reflection Vs Budget Path

Table 4.1: Stepwise Noise Figure, Output Gain And Output Power

Component	Noise Figure (dB)	Output Gain (dB)	Output Power (dBm)
Limiter	0.431	-0.511	-74.511
Band Pass Filter 1	1.764	-1.940	-75.94
Low Noise Amplifier 1	4.747	11.956	-62.04
Low Pass Filter 1	4.779	10.356	-63.64
Mixer 1	8.733	16.118	-57.82
Band Pass Filter 2	8.750	12.536	-61.46
Low Noise Amplifier 2	8.755	24.869	-49.13
Mixer 2	9.302	15.687	-58.31
Low Pass Filter 2	9.302	13.824	-60.17
Low Noise Amplifier 3	9.315	37.951	-37.049

Table 4.1 Shows the step wise Output Gain, Output Power and Noise Figure in our design of RF Front End Receiver for 5 GHz Wireless LAN applications. The total gain at the end of the front end receiver which we are achieveing is 37.951 dB which is much better than the desired gain of 16 dB and the achieved Noise Figure is 9.315 dB which is better then the desired 10 dB Noise Figure.

CHAPTER 5

5.1 CONCLUSION

The objective of this project was to make a design of a 5 GHz RF front-end Rx with the help of ADS and simulate the results of the design. The design is ready with the simulation of results but due to high cost of ICs used in the design we did not go to develop its hardware. This project was a difficult task for implementation as a whole so for the ease and completion of the project, it has been divided into two distinct portion of simulations and fabrication of hardware. First step of simulation has been done in detail by our group and the second step of fabrication is left for the group who will continue it .

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