PALESTINE POLYTECHNIC UNIVERSITY

FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

DESIGN OF BAND-SELECTIVE REPEATER

İntroduction to graduation Project's report

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Abstract

The intended project is a design, simulation and hardware implementation of a cellular repeater .This cellular repeater can be operated in GSM900 band to rectify the problems of poor signal service inside buildings. We design and simulate the circuitry of duplex reception, amplification and transmission with automatic gain control system by using MultiSim software. We show that the assembling and verification process of the repeater's building is broadly consistent with the modern, legal and registered model to come up with low-power brand repeater with maximum gain 75dB and output power 15 dBm.

Key Words: GSM Cellular Repeater, Band-Selective Repeater, wireless RF booster, GSM Repeater.

ملخص المشروع

هذا المشروع يهدف الى تصميم,محاكاة وبناء مقوي الاشارات الخلوية,بحيث يمكن تشغيله في نطاق الجيل الثاني(900 ميجاهيرتز) للتغلب على مشكلة ضعف الاشارة داخل الابنية.المرحلة الاولى تهدف الى تصميم ومحاكاة نظام يستقبل,يقوي,ويرسل بالاتجاهين من خلال برنامج ملتي سم.

المرحلة الثانية تناقش خطوات البناء و التحقق من أداء المقوي للخروج ب مقوي اشارة يعد ذو طاقة منخفضة ب قيمة تكبير أقصاها 75dB وطاقة صادرة تساوي 15dBm

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CHAPTER ONE

INTRODUCTION

1.1 Overview
1.2 Motivation
1.3 State of Problem
1.4 Objectives
1.5 Historical Background
1.6 Related Work
1.7 Method of Approach
1.8 Expected Challenges

1.1 Overview

With all the wireless systems in use today, getting a strong connection to a network has become a prevalent issue. Many times, frustrated users sit at their buildings, unable to get a cellular connection due to the building construction materials, obstacles and the remoteness of the base station. To rectify such problem, network equipment will be installed between the user and the network towers! Some signals are propagated through wireless repeaters. If a mobile station (MS) is too far away from its base station (BS), a cellular repeater can be placed in between the MS and the BS. The repeater will receive the signal from the BS through yagi antenna and retransmit it at a higher power. This will extend the range of the cellular network, giving the MS access. Repeaters are stationary hardware; they are put in one place and left there to perform their duty. The environment they are in, though, is not stationary.

A cellular repeater is a system of duplex reception, amplification, and transmission used to enhance uplink (UL) and downlink (DL) signals in areas of low radio coverage. This enhancement expands the coverage of cellular network base transceiver stations (BTS) at low cost. This cellular repeater is economical as all the components used are of low cost and hence total cost has been integrated. It is user-friendly and eco-friendly. These are similar to the cellular broadcast towers used by the network providers for broadcasting, but are much smaller and are recommended to use for a particular building only. Modern cellular repeater amplifiers rebroadcast cellular signals inside the building. The systems usually use an external directional antenna to collect the best cellular signal, which is then transmitted to an amplifier unit which amplifies the signal, and retransmits it locally, providing significantly improved signal strength. The more advanced models often also allow multiple cell phones to use the same repeater at the same time, so are suitable for commercial as well as home use [8].

1.2 Motivation

Throughout our period of study, the feeling of the importance to graduate with a distinguished project has always been on mind. We have become more motivated after we attended Jawwal training course; Jawwal has provided us with the opportunity to hone our skills and enhance our knowledge in the field of telecommunications. The idea of our project has been specifically sparked by one of the conversations held with Jawwal staff. The latter mentioned that the local student could actually produce and control tools that are so much needed by the company and that are only internationally available. The staff also urged students to spare them the high costs, time and hassle of checkpoints and the shipment of such tools that might take. Knowing that the needed tools are not structurally complicated nor sophisticated, we have come to believe that we can make them ourselves that means less money and efforts on the part of Jawwal and a boost of the local market and tools on the part of students.

We studied the Palestinian market and we found that the country miss the local made of any type of repeaters although its internal structure is consist of basic, available –to some extend-elements like (low-noise, high power) amplifier, lumped filter and duplexer, but in its basic design, i.e. (RLC elements), so we end up with the decision to take this opportunity to design and build our own product. At the beginning we start with GSM 900 MHz repeater as it is much needed and the pre-decided time is really a major item to take in consideration, but the work will continue to be updated with the cellular technology in use as a future work.

The market for cellular repeaters is expected to grow rapidly over the coming years; this is due to the combination of the poor network coverage in some areas due to natural topography and/or lack of urban development and the large scale departure from the land-line system. Usually each large buildings like malls, hospitals, churches, hotels,…, etc. may use lead in their roofing material, will very effectively block any signal as well as the trend of building these days has a significant thickness of concrete, or a large amount of metal used in its construction, will attenuate the signal rapidly. So it is very worthy to get in deep in the structure of the repeater and implement its internal component to serve our starting point – inside comity - and then outside.

1.3 Statement of Problem

In some poorly covered areas, either outdoor such as outback, streets, tunnels, mountain valleys, etc., or indoor as large building especially underground floors, the connection between base station and mobile station is not strong enough to handle a call or even connect to the cellular network provided by the operator due to the remoteness of the base station that service

As long as the capacity provided by the cell is not the matter of the problem, our project can receive, amplify and re-transmit signals in both the uplink direction (from the MS to the BTS) and the downlink direction (from the BTS to the MS). The repeater may provide communication service to the coverage hole, which was previously not serviced by the BTS. Repeaters may also augment the coverage area of a sector by shifting the location of the coverage area or altering the shape of the coverage area. Conventional repeaters may utilize fixed gains which may not be optimal as the MS changes location and/or as the channel conditions vary.

1.4 Objectives

We aim for designing a repeater box that branded as a low/medium power where its output power reach up to 17dBm and gain up to 75 dB by taking all specifications and requirements of the proposing cellular operator. We further aim to design the software that contains all commands that remotely control the parameters of the repeater box. The system should eventually:

- Provide GSM cellular signal coverage to places, particularly in multi floor buildings.
- Improve the quality of the GSM signal in case of obstructions.
- Save on very high costs of new base station installations.
- Qualifying the product to serve local operator's needs and as a true alternative to imported ones.

1.5 Historical Background

Repeater amplifiers have acquired great prominence in the radio communication industry in the last few years, due to a rapidly growing demand for extended communications services inside all types of urban structures. However, they made their first appearances several decades ago, as a part of "leaky feeder" or "leaky coax" radio communication systems in underground mines, vehicular and railroad tunnels. One-way repeater amplifiers were used in various configurations for simplex and semi-duplex radio communication in underground tunnels. Two-way repeater amplifiers appeared more recently, and TX RX Systems Inc. has played a significant role in their development. TX RX Systems Inc. was the first manufacturer of fully integrated, two-way repeater amplifier systems in the U.S. The first UHF two-way repeater amplifiers were manufactured in 1978, in response to a requirement by Motorola Communications. They were subsequently installed in an Inland Steel Corporation coal mine in Illinois, where they continue to provide reliable underground radio communication to this day. Since then, thousands of TX RX Systems' repeater amplifiers have been sold for private, commercial, government and military applications that include paging, radiotelephone, trunking and two-way radio systems in the frequency range from 66 to beyond 960 MHz [10].

1.6 Related work

Over the last decade, the deployment of wireless communication systems around the world has been phenomenal. Wireless communication technology has improved along a logical path, from simple first-generation analog systems designed for business use to second-generation digital wireless communication systems for business and personal applications.

There are a number of technologies that perform similar functions to repeaters, such as smart repeaters, mobile phone boosters and external antennas. These are discussed in more detail below.

- **Smart repeaters**

A smart repeater is a new technology that is able to actively monitor mobile network signals and adjust its transmit power in real time to avoid interference with the mobile network. By contrast, most existing repeaters require a technician to physically install the device and configure it to the mobile network. This may require regular physical monitoring or adjustments by a mobile operator's technician. A smart repeater removes the need for this by actively monitoring the signal and self-adjusting its output.

This new category of modern boosters utilizes powerful all-digital baseband processors to clean the signal before it is rebroadcast (hence the "Smart" in the name Smart Signal Booster). Most of the Smart Signal Boosters have gains of 100 dB (compared to analog booster's gain of 63 to 70 dB) and are carrier-specific (hence they can have higher gain in the US according to new FCC regulations).

- **Mobile phone boosters**

A mobile phone booster also improves signal reception for a mobile phone user. Unlike a repeater, a mobile phone booster is normally physically connected to a user's mobile phone and amplifies the signal for the benefit of that phone. The mobile phone booster has two ports, one for connecting the mobile device and the other for connecting an external antenna.

Connecting a mobile device to the booster is done using a patch lead. With each device usually has its own unique external antenna port, you must find one that fits your device model. This action can cause interference to other users on the same network, since increased power levels nearby base stations to the point where they become 'blinded' to other calls. The coverage is reduced to a small percentage of the original area, and as more boosters are used, the coverage becomes worse.

The sale and supply of mobile phone boosters is already prohibited under the Telecommunications (Prohibition of Mobile Phone Boosters) Declaration 2011. This is due to the level of destructive interference generated by boosters.

- **Mobile phone external antennas**

There are a number of other devices currently on the Australian market that can be legally used to improve a user's mobile phone reception. These include external antennas that plug into a handset or are fixed to a vehicle; these devices do not amplify the received signal, but simply improve the signal reception. These devices generally do not interfere with the mobile network and they are not proposed to be subject to the new regulations.

1.7 Method of Approach

Generally cellular mobile repeater means a radio communications device that draws power from a power source and that, operating as a single radio communications device or as part of a system of radio communications devices, is able to:

- (a) Receive a radio emission from a base station and retransmit the radio emission (or transmit a replica of the radio emission) to:
  - (i) Another base station; or
  - (ii) A mobile station; or
- (b) Receive a radio emission from a mobile station and retransmit the radio emission (or transmit a replica of the radio emission) to:
  - (i) Another mobile station; or
  - (ii) A base station.

Where the base station is the radio communications transmitter that is part of a telecommunications network by means of which a public mobile telecommunications service is supplied.

Mobile station means a transmitter that is:

- (a) Established for use:
  - (i) In motion on land, on water or in the air; or
  - (ii) In a stationary position at unspecified points on land, on water or in the air; and
- (b) Used to access a public mobile telecommunications service.

Example 1: A wireless modem operating in a laptop computer.

Example 2: A hand-held cellular telephone with a radiating antenna in the telephone.

To implement the internal structure of a repeater achieves the previously missions; the internal physical path will be divided into two paths; one for the down-link and the other for the up-link

path, each path consists of the same block diagram, but with differences in the frequency range which the component tuned based on that range.
Because of we are dealing with ultra high frequency (UHF) band, mismatching between circuits become a very critical issue, it needs highly care and accuracy to reduce the insertion loss as much as possible. So we are going to work separately on each stage and after validation and testing, stages will be gathered and further processing will be provided to ensure that a stable statement is achieved.

1.8 Expected Challenges

Repeater is not a noiseless device and may contribute additional noise into the receiver at the BTS. While one repeater may not appreciably increase the noise floor at the BTS, the cumulative effect of many repeaters may noticeably raise the noise floor of the BTS, thereby reducing the effectiveness of the communication links in the coverage area. While the amount of signal and noise broadcast back to the BTS can be manipulated by adjusting the repeater gain and the repeater to donor antenna gains, it may be challenging to simply set the total link gain to a desired value in conventional repeaters.

To reach the adequate statement for the standards and specification internationally known, the component must have adequate linearity, this is very important to have a stable system and avoid non-linear forms of noise which may result.

Conventional approaches to avoid these types of non-linear distortion typically involve automatic gain controllers (AGCs) to limit the dynamic range of the analog signal so that it “fits” into the component. However, for interference cancellation repeaters, the AGC prevents accurately the oscillations which occur when interference is happened by attenuating the incoming signal through attenuator, a call may drop at this session.

CHAPTER TWO

BACKGROUND

2.1 Repeater Amplifier Basics

2.2Repeater Amplifier Applications

2.3Reasons for Weak Signal

2.4 Legal Issue

2.1 REPEATER AMPLIFIER BASICS

Definition of Non-Heterodyne (Broadband) Repeater Amplifier

Non-heterodyne (broadband) repeater amplifiers utilize linear amplifiers with input and output filters that restrict pass bandwidth to a specified frequency range. No frequency conversion processes are involved in their operation. Filter pass bandwidth may range from 25 KHz at VHF to 25 MHz at GSM cellular frequencies. Non-heterodyne amplifiers are generally less complex and expensive than heterodyne (channelized) repeater amplifiers. They therefore provide a cost-effective solution to a wide variety of communication problems [2.1].

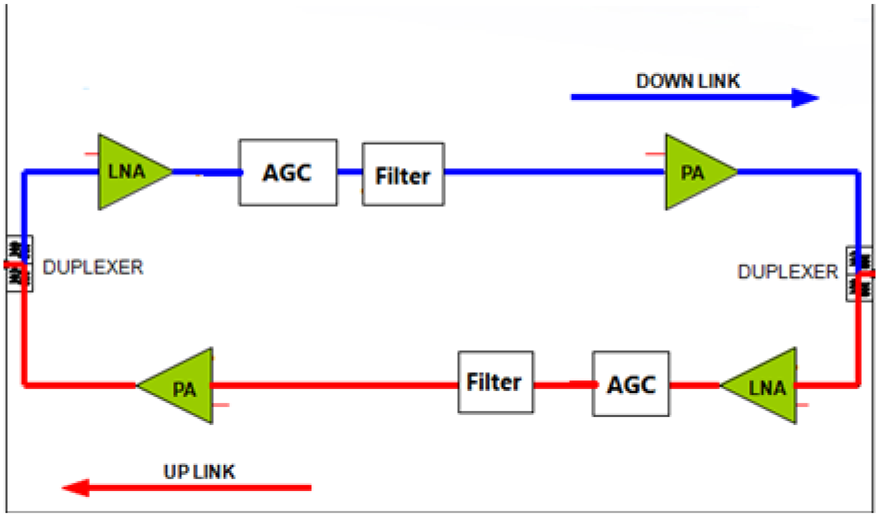


Figure 2.1: Generalized Non-Heterodyne, Two-Way Repeater Amplifier System.

As figure 2.1 shows, Non-heterodyne repeater amplifiers typically consist of the following basic elements:

- Linear amplifiers that provide the required RF gain and output power
- Input and output filters
- Gain control circuitry
- Power supply
- Optional power backup
- A cabinet or enclosure

2.1.1 Linear Amplifiers

Amplifier linearity, i.e. the ability to amplify signals without creating output distortion products, is a primary consideration in non-heterodyne repeater amplifier systems, especially because of the frequent need to amplify multiple signals on different frequencies. Class-A linear amplifier is a natural choice for this kind of service, because of their excellent linearity and predictable behavior.

2.1.2 Filters

Filters perform important functions in repeater amplifier systems. In one-way systems, input filters reject undesired signals to minimize the potential for interference, and output filters attenuate out-of-band amplifier noise and saurian. In two-way systems, the input and output filters on adjacent amplifier branches also provide selectivity well in excess of total amplifier gain at all frequencies, in order to assure unconditional amplifier stability. In repeater amplifiers with more than two amplifier branches, stable operation can only be achieved with filter designs that provide sufficient isolation between all possible branch pairs (uplink and downlink paths).

2.1.3 Gain Control

Amplifier gain requirements vary widely from one application to another or even from one location to another within the same system. Maximum repeater amplifier gain is set at the factory, in accordance with system design requirements. The maximum gain listed in the repeater amplifier system specification is the sum of individual stage gains in each branch, minus filter and other losses. In our design, the gain can be reduced by variable attenuators. The gain can be further reduced, if necessary, by bypassing low-level stages. Automatic gain control is required in applications where input levels vary over a wide range but output power per carrier must be kept below a specified maximum.

2.1.4JFET Transistor

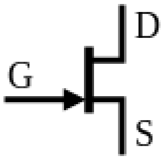


Figure 2.2: JEFT Transistor

JFET transistor is the simplest type of field-effect transistor. They are three-terminal semiconductor devices that can be used as electronically-controlled switches, amplifiers, or a variable resistor when operated in the holmic region by varying the value of Vgs voltage-controlled resistors.

Unlike bipolar transistors, JFETs are exclusively voltage-controlled in that they do not need a biasing current. Electric charge flows through a semiconducting channel between *source* and *drain* terminals. By applying a reverse bias voltage to a *gate* terminal, the channel is "pinched", so that the electric current is impeded or switched off completely. A JFET is usually on when there is no potential difference between its gate and source terminals. If a potential difference of the proper polarity is applied between its gate and source terminals, the JFET will be more resistive to current flow, which means less current would flow in the channel between the source and drain terminals. Thus, JFETs are sometimes referred to as depletion-mode devices.

JFETs can have an n-type or p-type channel. In the n-type, if the voltage applied to the gate is less than that applied to the source, the current will be reduced (similarly in the p-type, if the voltage applied to the gate is greater than that applied to the source). A JFET has large input impedance, which means that it has a negligible effect on external components or circuits connected to its gate [2.2].

2.2 Repeater Amplifier Applications

Repeater amplifier system applications can be grouped into three different categories: Type I: Tunnels.

Type II: Buildings or enclosed structures.

Type III: Shadowed areas behind high terrain or structures.

The above categories cover a wide variety of specific applications ranging from high-rise office buildings to aircraft carriers. The difference lies in the type of signal distribution system utilized to provide radio coverage inside the enclosed or blocked area.

Type I Applications: Tunnels

Tunnels are long, narrow underground or interior spaces, bounded by lossy materials such as reinforced concrete, soil, rock or others. Radio Signals in Tunnels Radio signals do not propagate well in narrow tunnels bounded by lossy walls. Attempts at coupling 30 to 960 MHz radio signals into tunnels by means of antennas have typically resulted in longitudinal propagation ranging from poor to very bad. For this reason, "leaky feeder" systems, consisting of transmission lines that are deliberately made to radiate along their length, have been developed to generate relatively uniform RF fields inside tunnels.

Type II Applications: Buildings

Buildings require three-dimensional signal distribution systems to provide coverage in relatively open spaces, narrow corridors, staircases and ventilation or elevator shafts. A high-gain, head-end repeater amplifier usually provides an interface between an external radio system and the interior of the building. In large building complexes with many users (hospitals or large factories, for example), it may be preferable to use an internal, dedicated base station to provide communication service to users in the facility. Two-way line amplifiers may then be required to overcome signal distribution losses within the complex cable, directional and Omni-directional antennas to achieve optimum coverage of elevator shafts, corridors and open areas. Propagation loss inside buildings may be significantly higher than free-space propagation loss. Diffraction, attenuation by structural elements and complex multipath effects cause anomalies which make it difficult to accurately predict signal levels.

Type III Applications: Shadowed Areas

Shadowed areas behind high terrain or man-made structures can be covered with a repeater amplifier with two antennas. One antenna links the system base station or repeater with the repeater amplifier. The other antenna is aimed at and provides coverage in the shadowed area [2.3].

2.3 Reasons for weak signal

- Rural areas

  in many rural areas the housing density is too low to make construction of a new base station commercially viable. In these cases, it is unlikely that the service provider will do anything to improve reception, due to the high cost of erecting a new tower. As a result, the only way to obtain strong cell phone signal in these areas is usually to install a home cellular repeater [2.4].

- Building size

  large buildings, such as warehouses, hospitals, and factories, often have no cellular reception further than a few meters from the outside wall. Low signal strength is also often the case in underground areas, such as basements, and in shops and restaurants located towards the center of shopping malls. This is caused by both the fact that the signal is attenuated heavily as it enters the building and the interference as the signal is reflected by the objects inside the building. For this reason, in these cases, an external antenna is usually desirable.

- Multipath interference

  Even in urban areas, which usually have strong cellular signals throughout, there are often dead zones caused by destructive interference of waves which have taken different paths (caused by the signal bouncing off buildings etc.). These usually have an area of a few blocks and will usually only affect one of the two frequency ranges used by cell phones. This is because the different wavelengths of the different frequencies interfere destructively at different points. Directional antennas are very helpful at overcoming this since they can be placed at points of constructive interference and aligned so as not to receive the destructive signal.

- Building construction material

  Some construction materials rapidly attenuate cell phone signal strength. Older buildings, such as churches, which may use lead in their roofing material, will very effectively block any signal. Any building which has a significant thickness of concrete, or a large amount of metal used in its construction, will attenuate the signal. Concrete floors are often poured onto a metal pan, which completely blocks most radio signals. Some solid foam insulation and some fiberglass insulation used in roofs or exterior walls have foil backing, which can reduce transmittance. Energy efficient windows and metal window screens are also very effective at blocking radio signals.

2.4 Legal Issue

A repeater operates within apparatus or spectrum licensed radiofrequency bands. Therefore, the licensee (in practice, the relevant mobile carrier) can authorize the use of a repeater. The unlicensed operation of a repeater is subject to the offence provisions in sections 46 and 47 of the Radio Communications Act.

The interference management provisions in Part 4.2 of the Radio Communications Act may also apply where a person is operating a repeater and causing interference to a mobile carrier's service.

Repeaters may be deployed by mobile carriers as part of their ordinary network management practices. When used in this manner, repeaters are considered network equipment. Because the repeater is installed and configured by the licensee (the relevant mobile carrier), the risk of interference to the telecommunications network is minimized and is entirely manageable by the carrier.

However, repeaters can also be used by end-users without the carrier's authorization. This type of use mainly occurs where an individual purchases a repeater to improve their personal mobile coverage. This typically occurs in rural or remote locations, or to address particular in-building coverage issues. However, when installed and used without the mobile carrier's authorization, the repeater may benefit the end-user's coverage, but also has the capacity to disrupt or prevent other end-users' access to the cellular network, including preventing access to the emergency call service [2.5].

2.4.1 Scale of the problem

While the use of unauthorized repeaters commonly introduces interference into mobile networks and degrades performance, it is only practical to track down a subset of the devices that are causing a serious impact (for example, those that substantially block coverage and access to customers). Carriers believe that for every device that it discovers causing a serious impact there are many others that either cannot be located or are causing a low level of interference which is not sufficient to justify the expense involved in identifying and disabling those devices. Carriers believe that several thousand such devices could currently be active; however, it is not possible to provide an accurate estimate of the number of unauthorized mobile repeaters that are currently being used nationally on mobile networks.

2.4.2 Network Impact

In serious cases the unauthorized repeater devices can effectively shut-down or block an entire mobile network cell, meaning that no-one can make calls, including emergency calls, to or from the affected area.

Less serious, but more common and difficult to track down, are cases where the interference generated causes reduced cell coverage, call dropouts and significantly lower broadband speeds in the affected areas. The remainder (majority) of these unauthorized repeater deployments cause a marginal degradation in network performance. Carriers have advised that it is virtually impossible to find individual devices in this latter category and it would not be cost effective to attempt to find those devices, even though their cumulative impact can be significant.

CHAPTER THREE

System Design

3.1 Overall System Design Aspects

3.2 Low Noise Amplifier Design

3.3 Filter Design

3.4 Automatic Gain Control Design

3.5 Power Amplifier Design

3.1 Overall System Design Aspects:

We are going to divide the total required gain (75 dB) into three stages; low noise amplifier (LNA) with13 dB gain, automatic gain control (AGC) with maximum 60 dB gain and power amplifier (PA) with 13 dB gain.

Repeater's mission is to amplify the incoming signal which vary in its power to a fixed amount of output power, so we designed the AGC circuit to overcome the wide band variety of the input signal, where we got a fixed output power 2 dBm from the output of AGC circuit and after adding the PA gain, which is 13 dB, we are going to come up with 15 dBm as the overall system fixed power, that is suites its application where there is a poor coverage inside buildings.

At the beginning, the incoming range of entire received power from the donor antenna is (-60 to -80) dBm, the donor antenna gives a gain of 5dB, so the range before the repeater system is (-55 to -75) dBm.

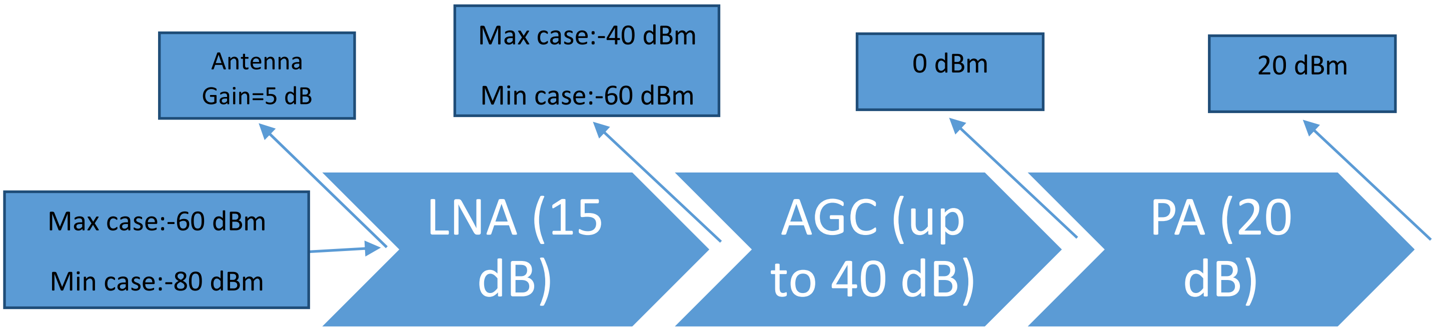


Figure 3.1: gain division of the system.

3.2 Low Noise Amplifier (LNA) Design:

To employ the linearity performance of the amplifier, it should be class-A. The Class A amplifier is the most common and simplest form of power amplifier that uses the switching transistor in the standard common emitter circuit configuration as seen in figure 3.1. We use Silicon VDMOS/LDMOStransistor (P123) as it is designed for RF applications and provide high linearity and low noise, it is always biased “ON” so that it conducts during one complete cycle of the input signal waveform producing minimum distortion and maximum amplitude to the output. The following is the description of the design procedures and calculation.

3.2.1) Power Transfer

The LNA circuit should provide 13 dB gain, it convert that gain to the input signal ,which have a power range from -55 dBm to -75 dBm. Assuming the best case, i.e. -55dBm input signal, we shall get an output power equal to **-55(dBm) + 13 (dB) = -42 dBm** (1e-7 Watt) .This means that the power transferred to the load must be 1e-7 W.4

$Pmax = \frac{Vdd^2}{2*R}$ [3.1] $R_{max} = \frac{Vdd^2}{2*P} = \frac{5^2}{2*10^{-7}} = 125M\ \Omega$

So we must guarantee a maximum value of output impedance of 125 MΩ. Let’s say we use 9520K Ω (Rs).

3.2.2) Output Matching Network

We use a LC “parallel filter” with $Q = \frac{Fc}{BW}$ [3.2] $= \frac{947.5*10^6}{25*10^6} = 38.$

Where Fc: Resonance Frequency.

BW: Bandwidth.

For parallel circuits:

$Q = P_{stored}/P_{dissipated} = I^2X/I^2R^{[3.1]}$

$Q_{//} = |X/R| = |38|$

$Q = |Xc + Xl| \Rightarrow Xc = 19\Omega\ , Xl = 19\Omega$

Where: X = Capacitive or Inductive reactance at resonance

R = Series resistance.

From here, L and C value can be evaluated as:

$L_{//}=\frac{Xl}{2*pi*f}$ [3.2]= $\frac{19}{2*3.14*947.5*10^{6}}=2.95\,nH$

$C_{//}=\frac{1}{2*pi*f*Xc}=\frac{1}{2*3.14*947.5*10^{6}*19}=8.8\,pH$

3.2.3) Large Inductor (BFL)

BFL inductor works as a RFchoke,because it“chokes off” the flow of RF current through it and must be “large enough”. Large enough means at least 10 times theoutput impedance (Rs).

$X_{\text{BFL}} \geq 10*Rs \Rightarrow BFL=\frac{10*9520K}{2*pi*f}=\frac{9520\,K}{2*3.14*947.5*10^{6}}=1.6\,mH$

3.2.4) DC Blocking Capacitor

We must provide a DC blocking capacitor andan impedance-transforming network. Thisfunction may be combined in a LC series circuit with Q=20.

Since $Q_{\text{series}}=\left|\frac{R}{X}\right|$, evaluate L and C value as

$L_{1s}=\frac{\text{R}\,load}{2*pi*f*Q}=\frac{50}{2*3.14*947.5*10^{6}*20}$= 420.1 nH

We can combinethe 2 parallelinductors to have amore compact schematic.

$L_{1}=\frac{L1s*L//}{L1s+\text{L}//}=\frac{420.1*10^{-9}*2.95*10^{-9}}{420.1*10^{-9}+(2.95*10^{-9})}=1.5\,nH$

$C_{out}=\frac{1}{2*pi*f*Q*Rs}=\frac{1}{2*3.14*947.5*10^{6}*20*9520*10^{3}}$ =8.83 pF

3.2.5) Bias Point

Class A amplifier bias point must be chosenin order to have a conduction angle of 360°.

$V_{gs} \leq V_{Bias} \leq$ Vdd

We use R1=3k and R2=10k. This will give usa bias voltage of

$$V_{bias} = \frac{R2}{R2+R1} * Vdd = \frac{10k}{13k} * 5 = 3.85\ V$$

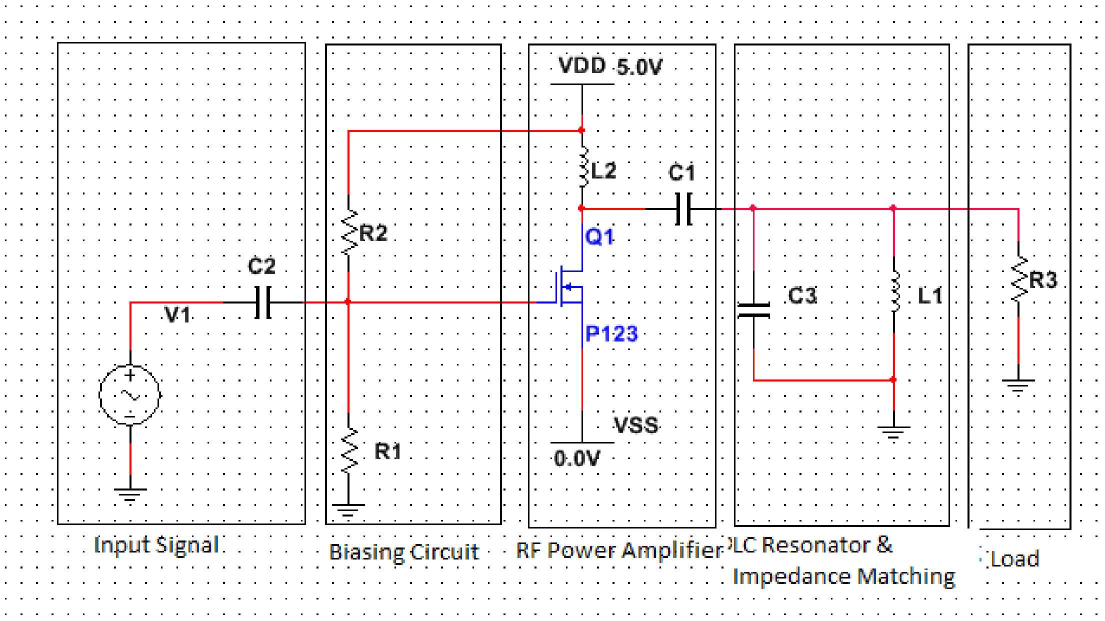


Figure 3.2: LNA Circuitry Stages.

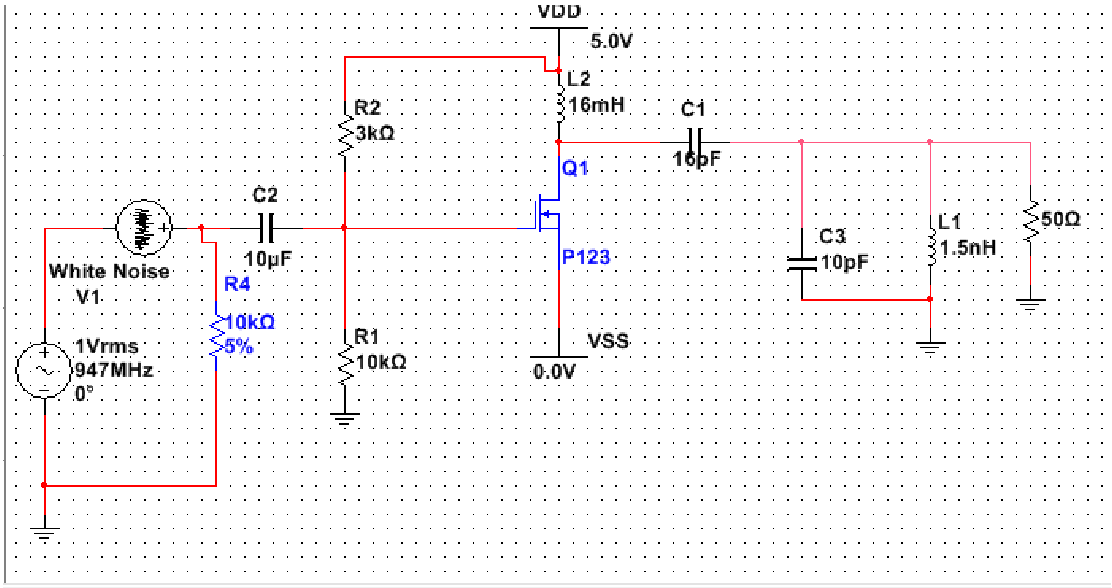
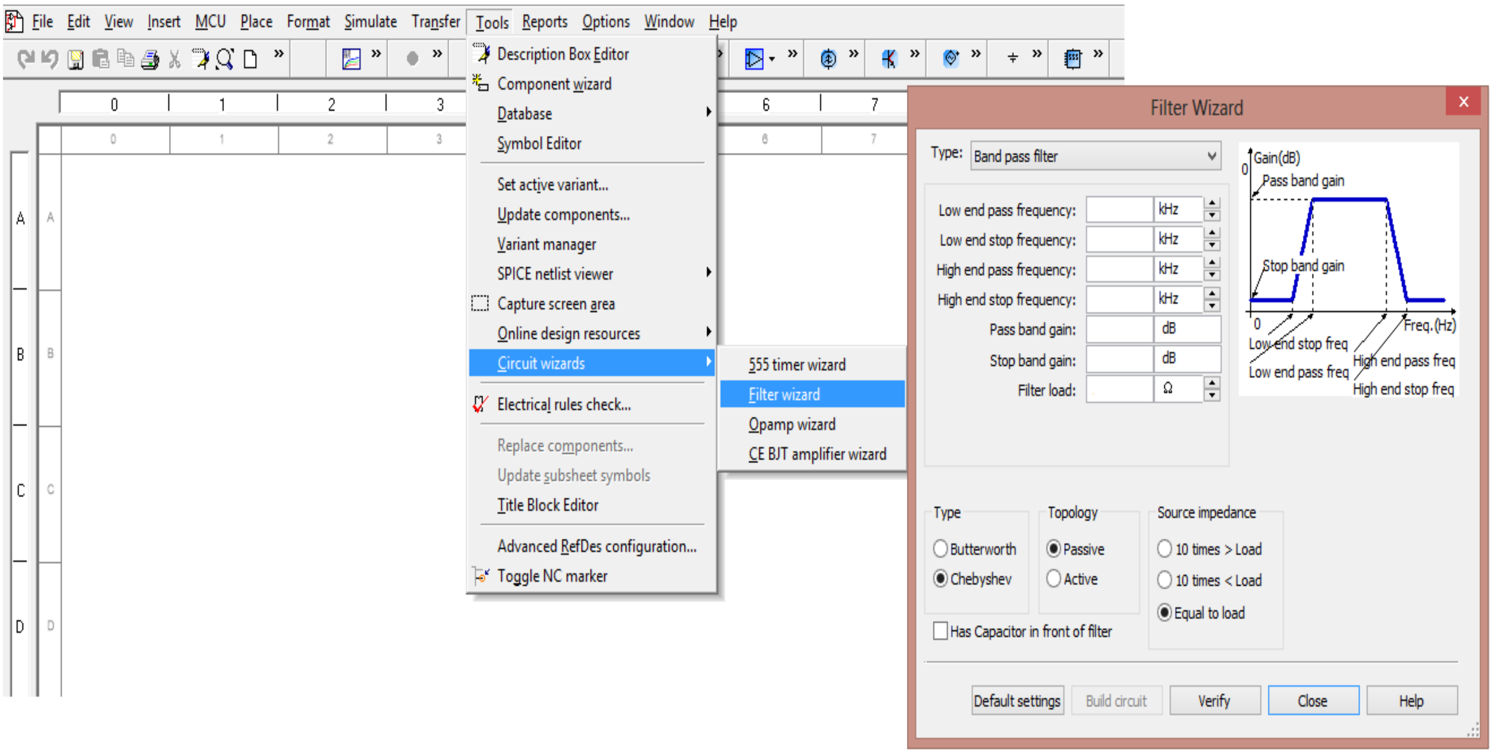


Figure 3.3: Valued LNA Circuitry.

3.3 Filter Design

Filter stage designed by using passive component, because it difficult to design active filter for high frequency. This stage designed by using Multisim tools.



Type: Band pass filter

Type: ● Chebyshev

Topology: ● Passive

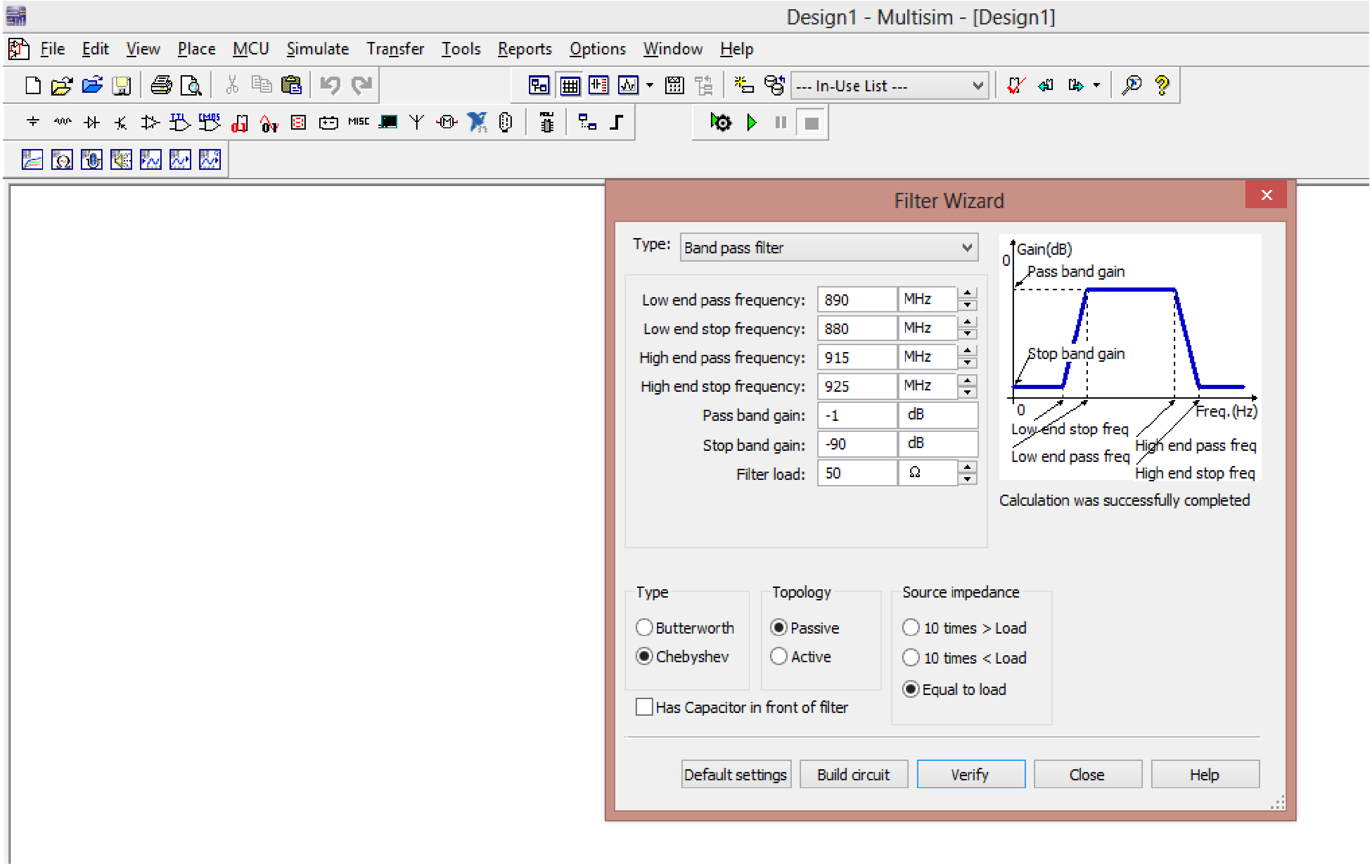
Source impedance: ● Equal to load

Figure 3.4:Filter Design Tools in Multisim.

Chebyshev filter ischosen to design this stage because they are used where the frequency content of a signal is more important than having constantamplitude. The Chebyshev response is a mathematical strategy for achieving a faster roll-off by allowing ripple in the frequency response.

3.3.1) Up Link Filter

Up Link filter designed to pass Up Link band [890M – 915M] and reject other frequencies.



Type: Band pass filter

Low end pass frequency: 890 MHz
Low end stop frequency: 880 MHz
High end pass frequency: 915 MHz
High end stop frequency: 925 MHz
Pass band gain: -1 dB
Stop band gain: -90 dB
Filter load: 50 Ω

Calculation was successfully completed

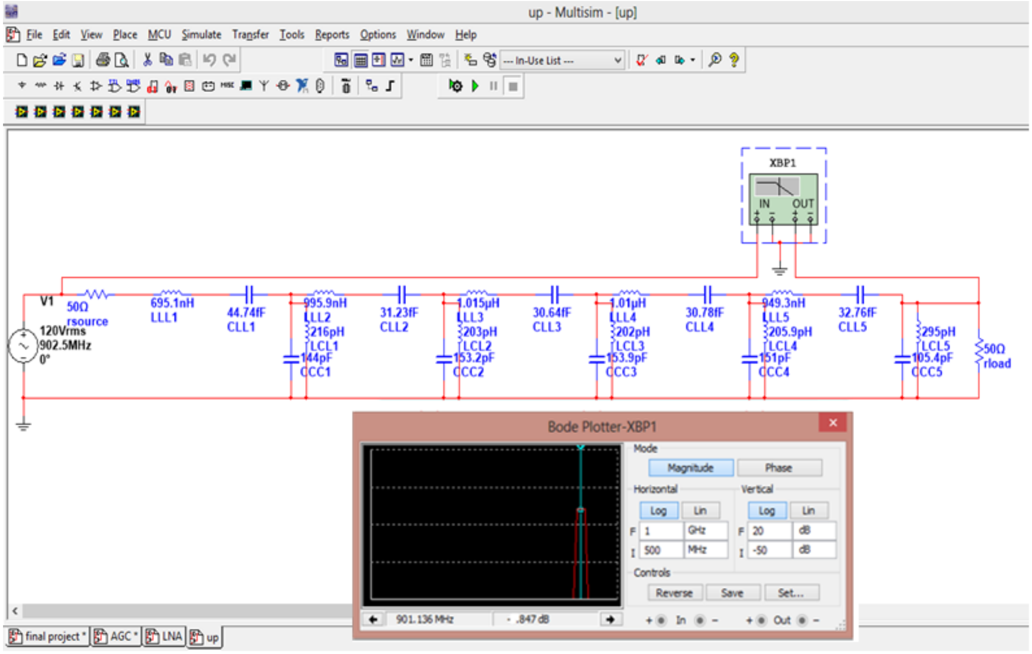
Type
○ Butterworth
● Chebyshev

Topology
● Passive
○ Active

Source impedance
○ 10 times > Load
○ 10 times < Load
● Equal to load

☐ Has Capacitor in front of filter

Figure 3.5:Up Link Filter Design.



Horizontal: Log
F 1 GHz
I 500 MHz

Vertical: Log
F 20 dB
I -50 dB

901.136 MHz   - .847 dB

Figure 3.6: Up-Link Filter Circuitry and Response.

The filter is 5th order.

Transfer function for Chebyshev 5th order $|H(\Omega)|^2 = \frac{1}{1+ \text{€}^2 CN^2(\Omega)}$

CN (Ω) = $\cos(5\cos^{-1}(\Omega))$ $|\Omega| \leq 1$

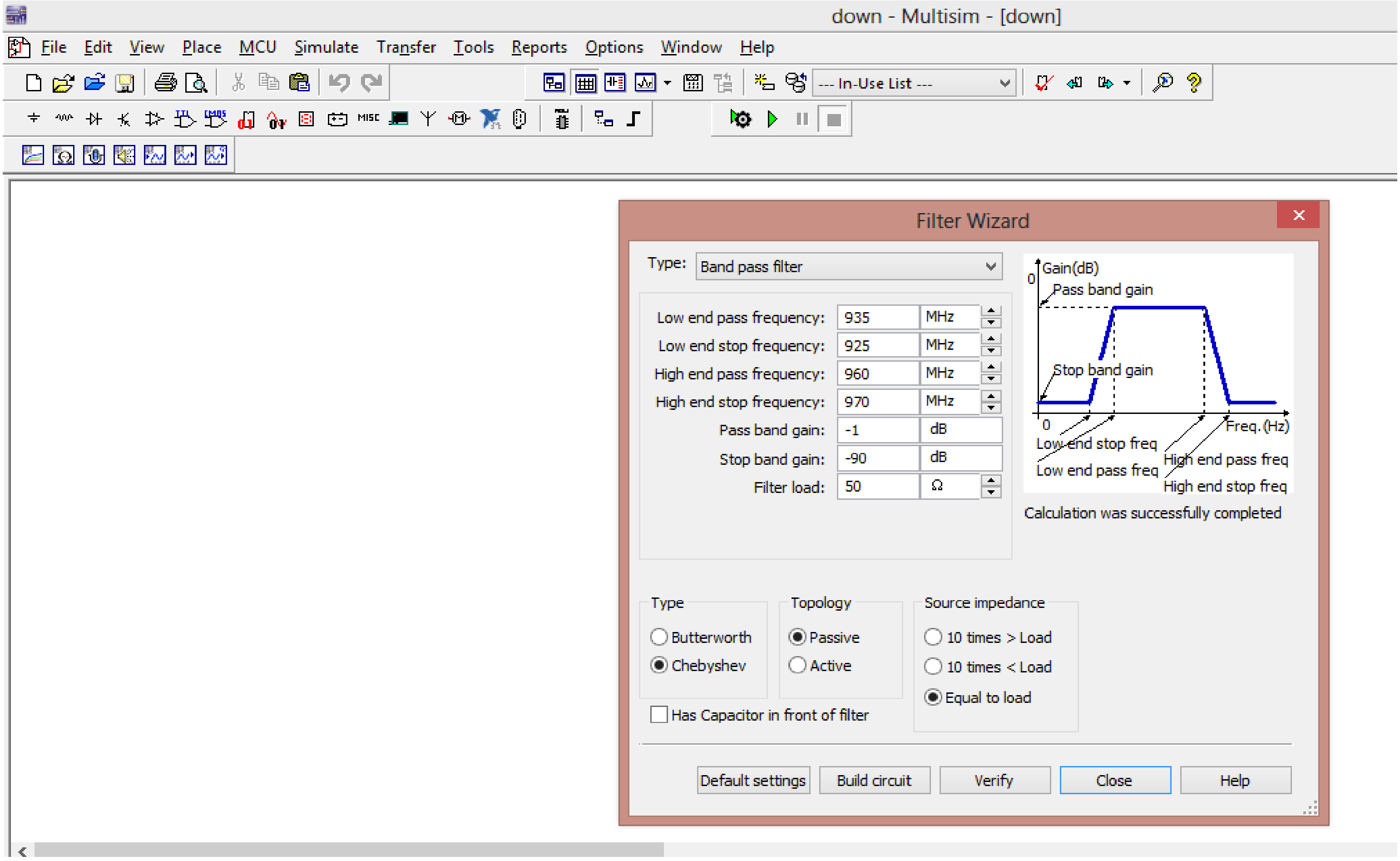
$\cos(5\cosh^{-1}(\Omega))$ $|\Omega| > 1$

€ = $\sqrt{-1 + 10^{R}}$

R = RdB/10RdB: pass band ripple in dB

3.3.2) Down-Link Filter

Down Link fifth order filter is designed to pass Down Link band [890M – 915M] and reject other frequencies.



Type: Band pass filter

Low end pass frequency: 935 MHz

Low end stop frequency: 925 MHz

High end pass frequency: 960 MHz

High end stop frequency: 970 MHz

Pass band gain: -1 dB

Stop band gain: -90 dB

Filter load: 50 Ω

Calculation was successfully completed

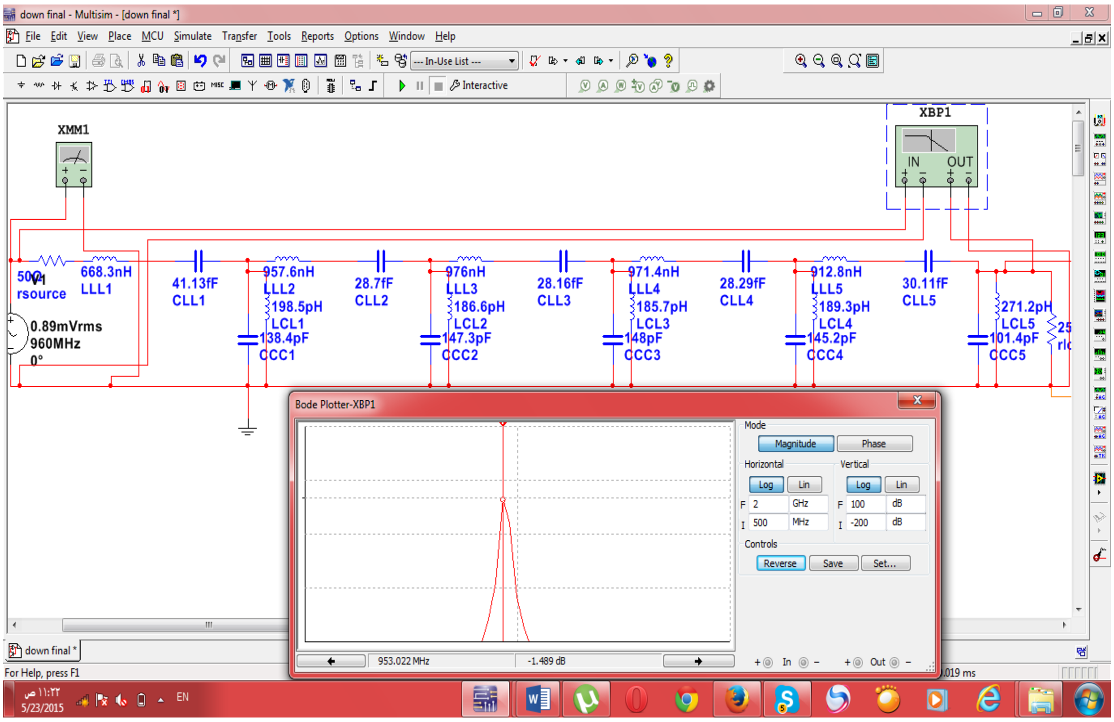
Type
○ Butterworth
● Chebyshev

Topology
● Passive
○ Active

Source impedance
○ 10 times > Load
○ 10 times < Load
● Equal to load

☐ Has Capacitor in front of filter

Figure 3.7: Down- Link Filter Design.



Mode: Magnitude

Horizontal: Log; F 2 GHz; I 500 MHz

Vertical: Log; F 100 dB; I -200 dB

953.022 MHz   -1.489 dB

Figure 3.8: Down- Link Filter Circuitry and Response.

3.4 Automatic Gain control Design:

AGC stage designed to provide controlled signal amplitude at its output, due to the variation of the amplitude in the input signal.

This stage designed by usinga single gate gallium arsenide field effect transistor (GA As FET) as the RF preamplifier in the design, to obtain the reduction in noise figure and providing an AGC control signal to vary the gain of the RF preamplifier so that the subsequent circuits are not overloaded when high RF signal levels appear at the input.

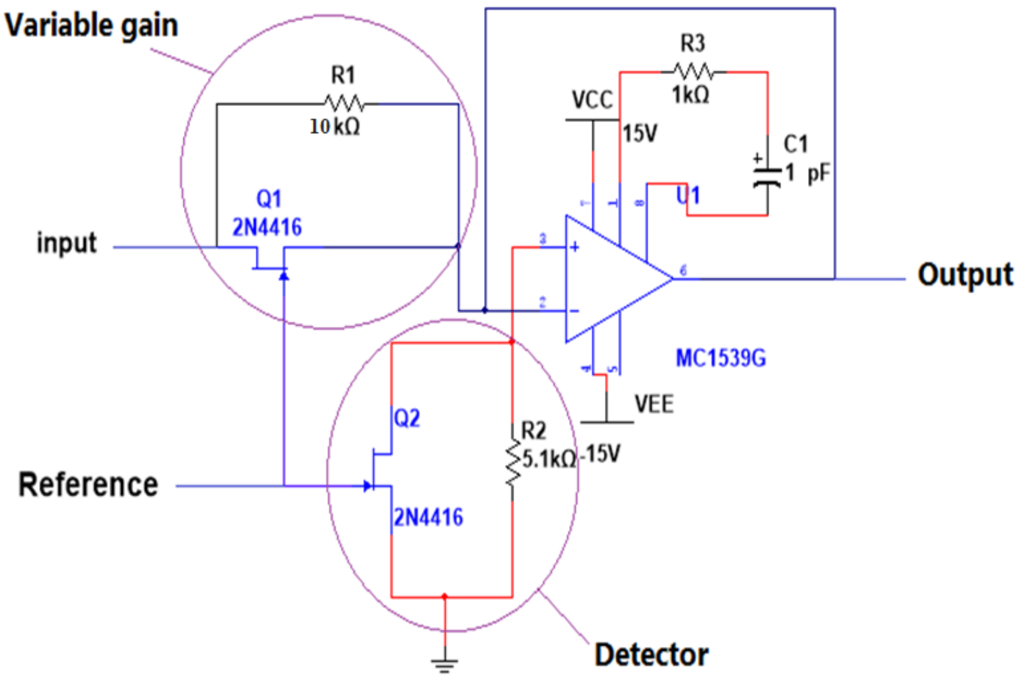


Figure 3.9: AGC circuitry.

Note: This circuit used for Up Link and Down Link.The values of the components are taken from the reference. [3.3]

3.5 Power Amplifier Design:

The PA circuit should provide 13 dB gain, it convert that gain to the input signal thatcomes from the output of the AG, which has 2 dBm Power value.So, the output power that will be transferred to the load is 2(dBm) + 13 (dB) = 15 dBm(0.03162W).

$Pmax = \frac{Vdd^2}{2*R}$ [3.1] $R_{max} = \frac{Vdd^2}{2*P} = \frac{5^2}{2*10^{-7}} = 125M\,\Omega$

3.2.2) Output Matching Network

We use a LC "parallel filter" with $Q = \frac{Fc}{BW}$ [3.2] $= \frac{947.5*10^6}{25*10^6} = 38.$

Where Fc: Resonance Frequency.

BW: Bandwidth.

For parallel circuits:

$Q = P_{stored}/P_{dissipated} = I^2X/I^2R$[3.1]

$Q_{//} = |X/R| = |38|$

$Q = |Xc + Xl| \Rightarrow Xc = 19\Omega\,, Xl = 19\Omega$

Where: X = Capacitive or Inductive reactance at resonance

R = Series resistance.

From here, L and C value can be evaluated as:

$L_{//} = \frac{Xl}{2*pi*f}$ [3.2] $= \frac{19}{2*3.14*947.5*10^6} = 2.95\,nH$

$C_{//} = \frac{1}{2*pi*f*Xc} = \frac{1}{2*3.14*947.5*10^6*19} = 8.8\,pH$

3.2.3) Large Inductor (BFL)

BFL inductor works as a RFchoke,because it"chokes off" the flow of RF current through it and must be "large enough". Large enough means at least 10 times theoutput impedance (Rs).

$$X_{BFL} \geq 10 * Rs \Rightarrow BFL = \frac{10*9520K}{2*pi*f} = \frac{9520\ K}{2*3.14*947.5*10^{6}} = 1.6\ mH$$

3.2.4) DC Blocking Capacitor

We must provide a DC blocking capacitor andan impedance-transforming network. Thisfunction may be combined in a LC series circuit with Q=20.

Since $Q_{series} = \left|\frac{R}{X}\right|$, evaluate L and C value as

$$L_{1s} = \frac{R\ load}{2*pi*f*Q} = \frac{50}{2*3.14*947.5*10^{6}*20} = 420.1\ nH$$

We can combinethe 2 parallelinductors to have amore compact schematic.

$$L_1 = \frac{L1s * L//}{L1s + L//} = \frac{420.1*10^{-9}*2.95*10^{-9}}{420.1*10^{-9}+(2.95*10^{-9})} = 1.5\ nH$$

$$C_{out} = \frac{1}{2*pi*f*Q*Rs} = \frac{1}{2*3.14*947.5*10^{6}*20*9520*10^{3}} = 8.83\ pF$$

3.2.5) Bias Point

Class A amplifier bias point must be chosenin order to have a conduction angle of 360°.

$V_{gs} \leq V_{Bias} \leq Vdd$

We use R1=3k and R2=10k. This will give usa bias voltage of

$$V_{bias} = \frac{R2}{R2+R1} * Vdd = \frac{10k}{13k} * 5 = 3.85\ V$$

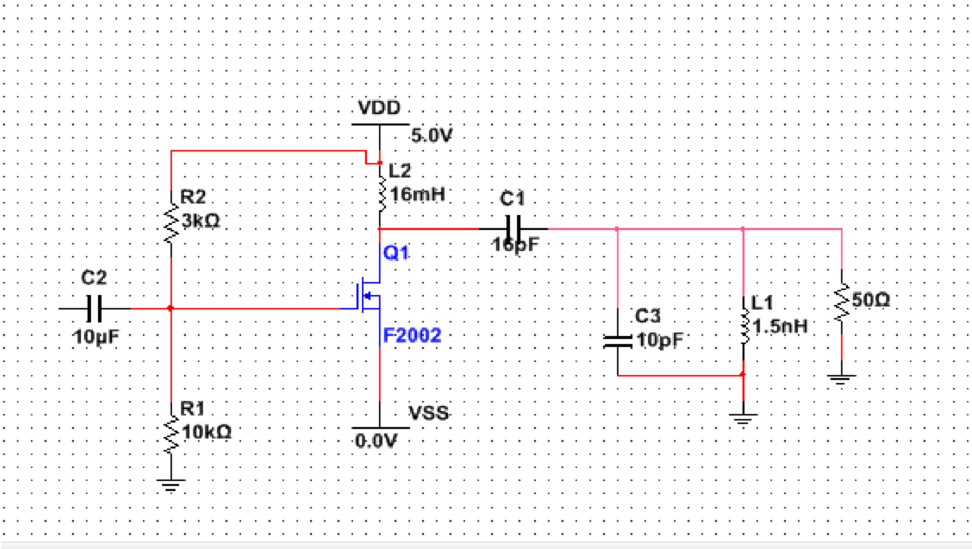


Figure 3.10: PA circuitry.

CHAPTER FOUR

Simulation Result

4.1 Low Noise Amplifier Result

4.2 Filter Result

4.3 Automatic Gain Control Result

4.4 Power Amplifier Result

4.5 Over All system Result

4.1 Low Noise Amplifier Result

To test the LNA response white noise added at the input of the LNA stage.

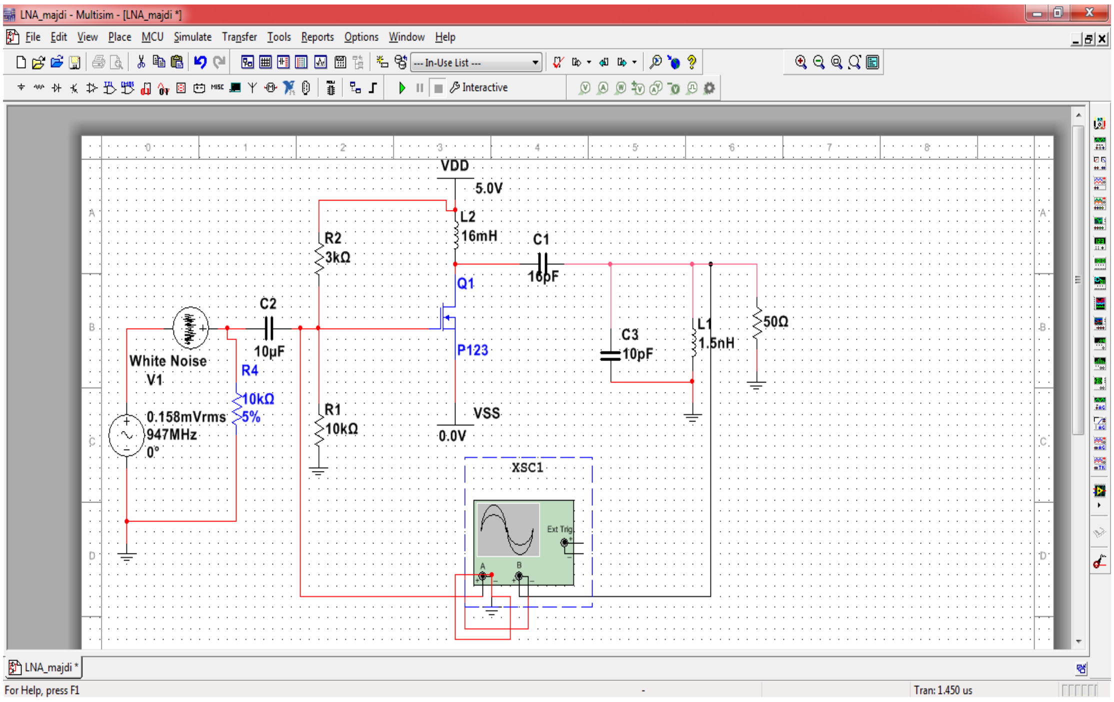


Figure 4.1:LNA Circuit

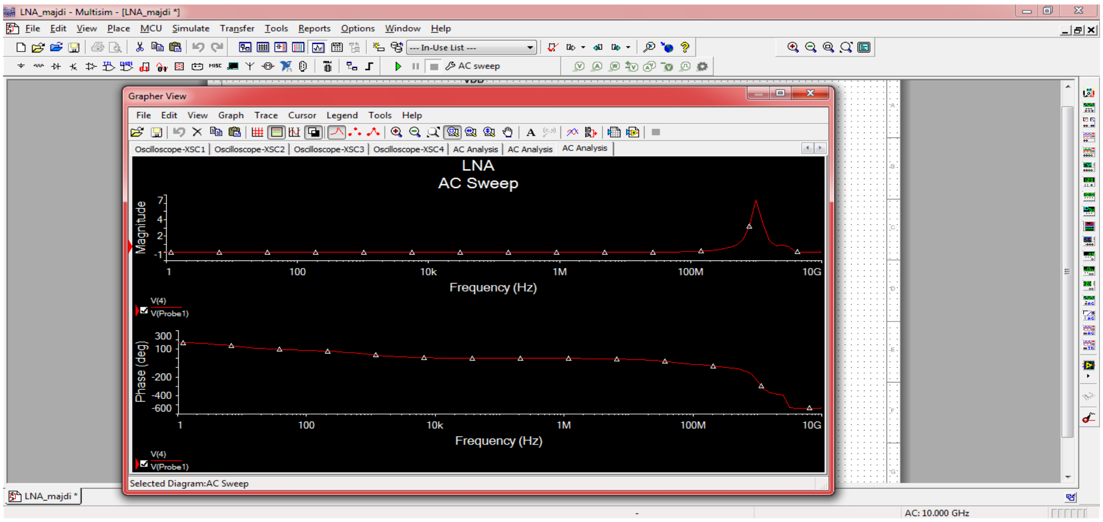
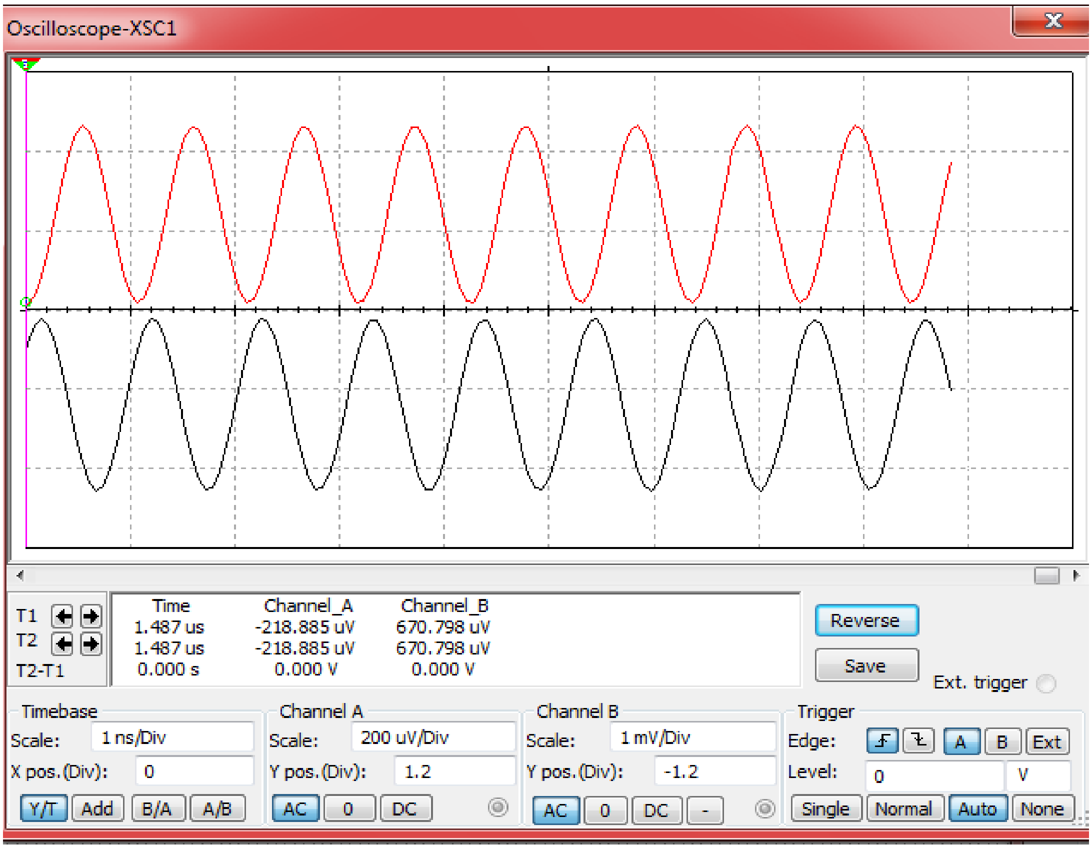


Figure 4.2: LNA AC Analysis



	Time	Channel_A	Channel_B
T1	1.487 us	-218.885 uV	670.798 uV
T2	1.487 us	-218.885 uV	670.798 uV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase Scale: 1 ns/Div
X pos.(Div): 0
Channel A Scale: 200 uV/Div
Y pos.(Div): 1.2
Channel B Scale: 1 mV/Div
Y pos.(Div): -1.2
Trigger Edge: A
Level: 0 V

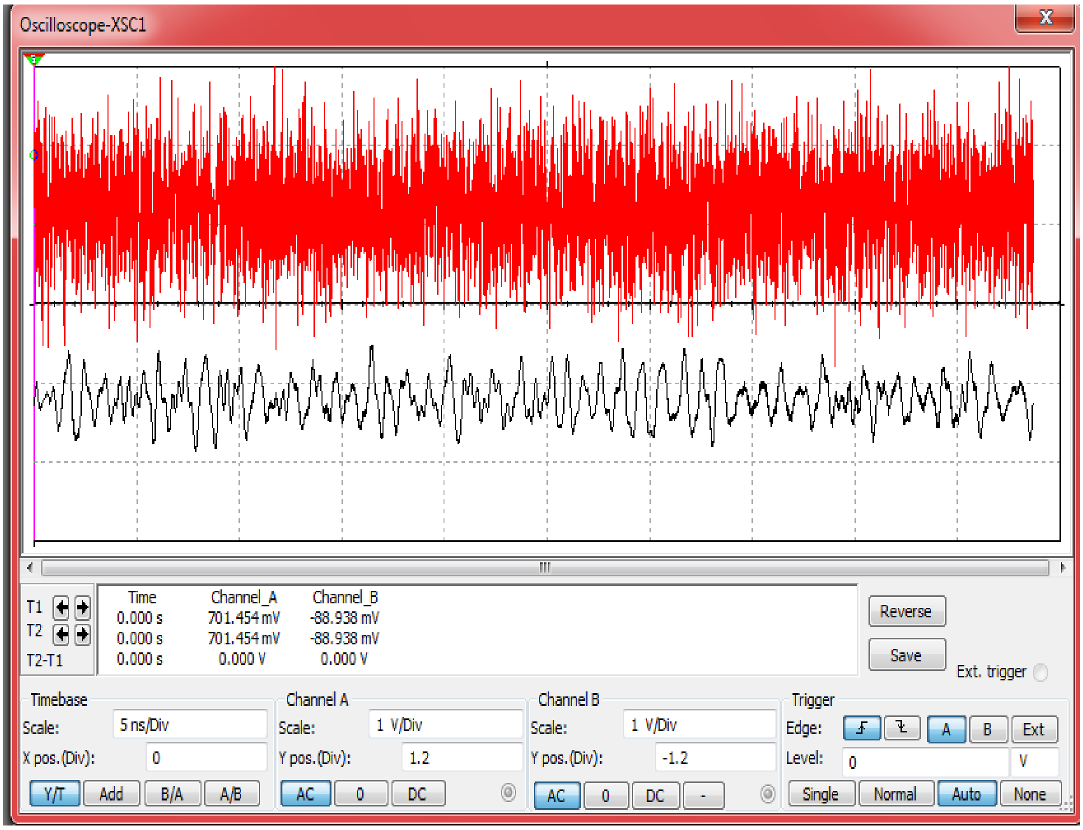
Figure4.3:LNAWithout Noise

*From oscilloscope input voltage = 0.2mv & output voltage =1 mv

Gain= 20 log (output voltage / input voltage)

Gain = 20 log (1/0.2) = 13.9 dB

After adding, the white noise to the input sine signal and input the noised signal to the LNA stage.



	Time	Channel_A	Channel_B
T1	0.000 s	701.454 mV	-88.938 mV
T2	0.000 s	701.454 mV	-88.938 mV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase
Scale: 5 ns/Div
X pos.(Div): 0

Channel A
Scale: 1 V/Div
Y pos.(Div): 1.2

Channel B
Scale: 1 V/Div
Y pos.(Div): -1.2

Trigger
Edge: A
Level: 0 V

Figure 4.4:LNA with Noise

The Oscilloscope result show the effect of the LNA stage on the noised signal, noise was attenuated and the original signal (sine signal) amplified.

4.2 Filter Result

4.2.1Down Link Filter:

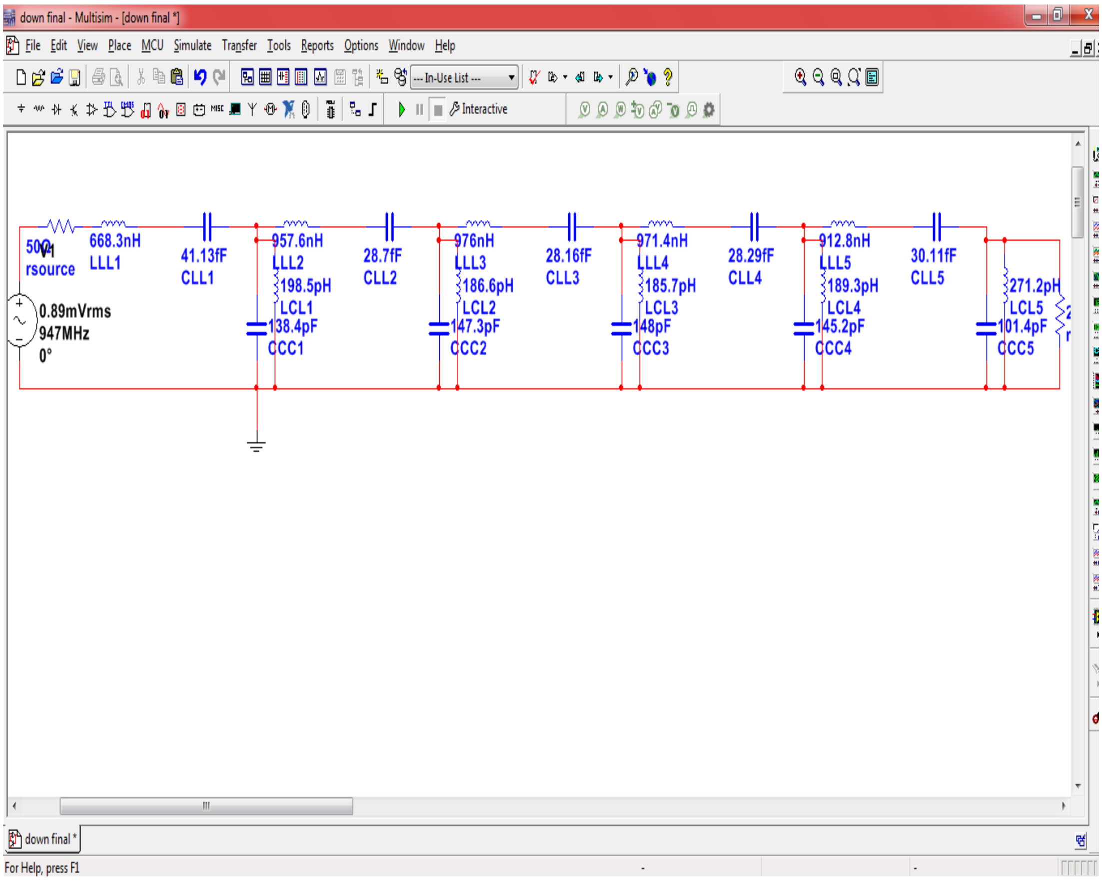
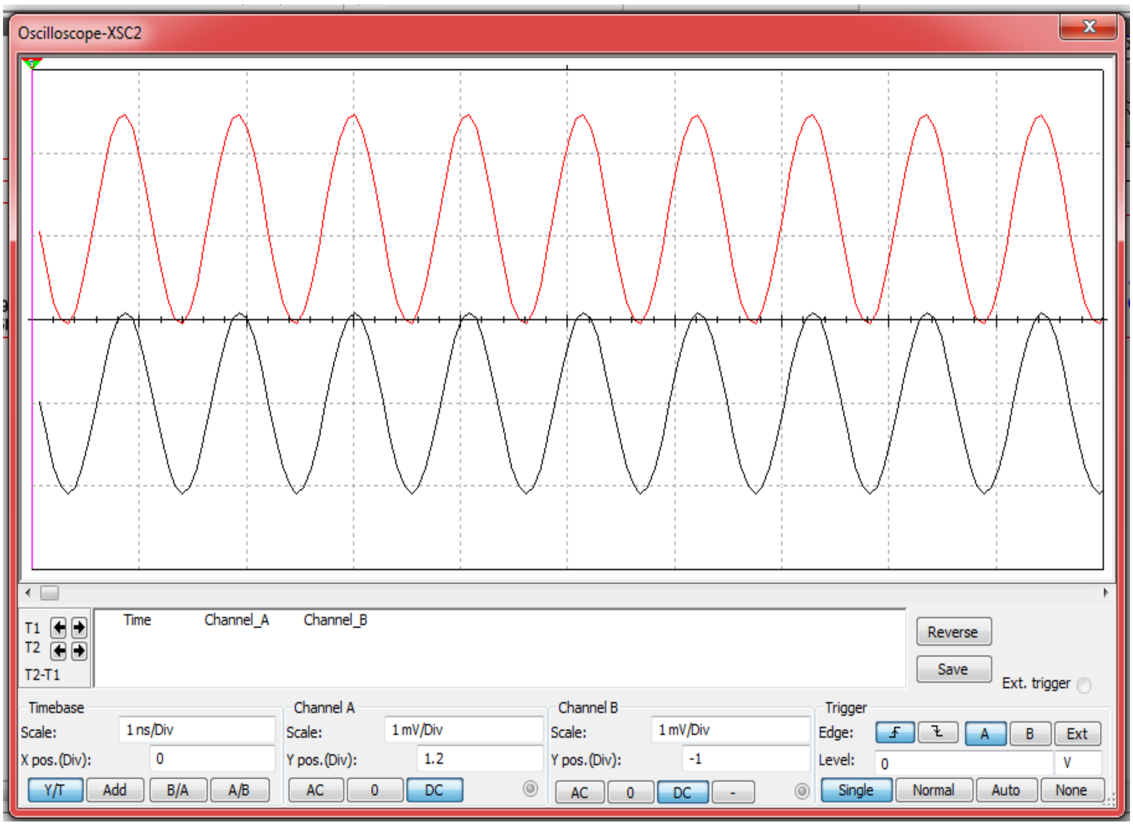


Figure 4.5: Uplink Filter (935MHz-960MHz)



Timebase
Scale: 1 ns/Div
X pos.(Div): 0

Channel A
Scale: 1 mV/Div
Y pos.(Div): 1.2

Channel B
Scale: 1 mV/Div
Y pos.(Div): -1

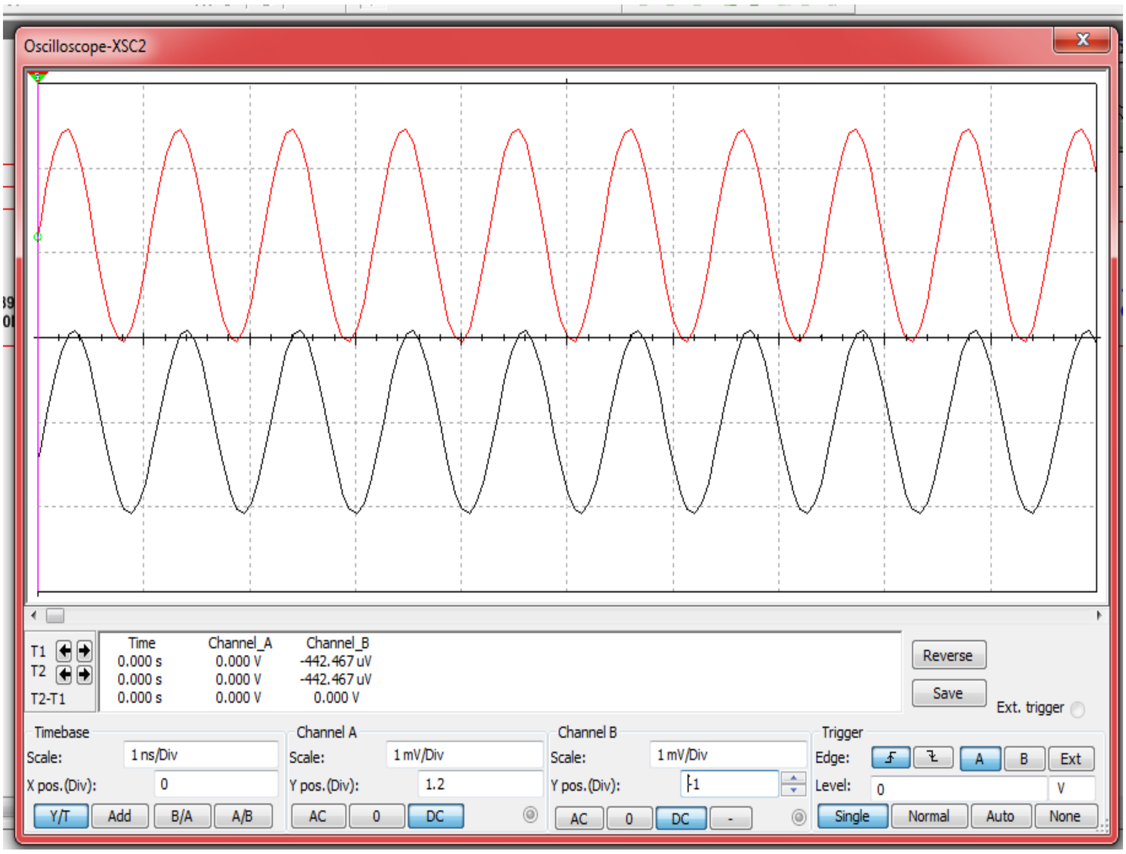
Trigger
Edge: A
Level: 0 V

Figure 4.6: Filter Output at 935MHz

Assuming input voltage 2.5mV, from Oscilloscope output voltage 2.15mV.

$$\text{Gain} = \frac{Output\ voltage}{Input\ Voltage} = \frac{2.15}{2.5} = 0.86$$

Gain (dB) = 20Log (0.86) = -1.3dB



	Time	Channel_A	Channel_B
T1	0.000 s	0.000 V	-442.467 uV
T2	0.000 s	0.000 V	-442.467 uV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase
Scale: 1 ns/Div
X pos.(Div): 0

Channel A
Scale: 1 mV/Div
Y pos.(Div): 1.2

Channel B
Scale: 1 mV/Div
Y pos.(Div): -1

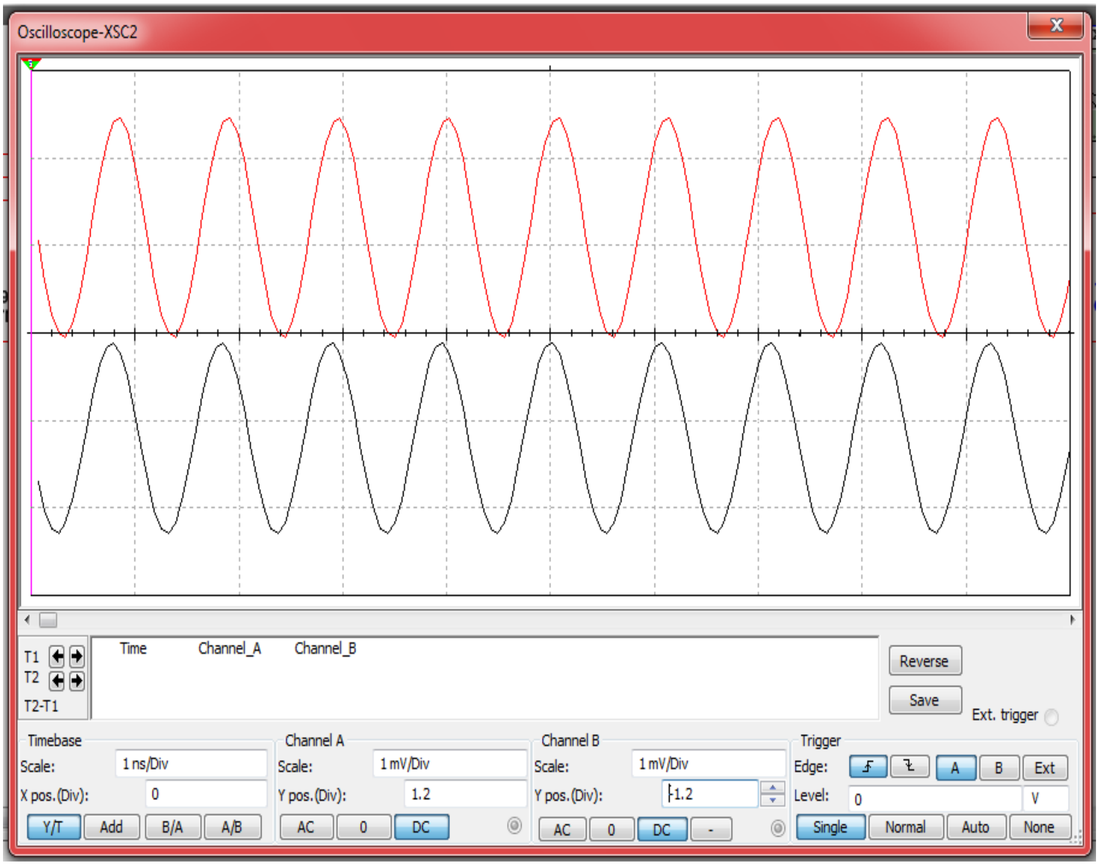
Trigger
Edge: A
Level: 0 V

Figure 4.7: Filter Output at 940MHz

Assuming input voltage 2.5mV, from Oscilloscope output voltage 2.17mV.

Gain = $\frac{Output\ voltage}{Input\ Voltage}$ $= \frac{2.17}{2.5} = 0.86$

Gain (dB) = 20Log (0.868) = -1.22dB



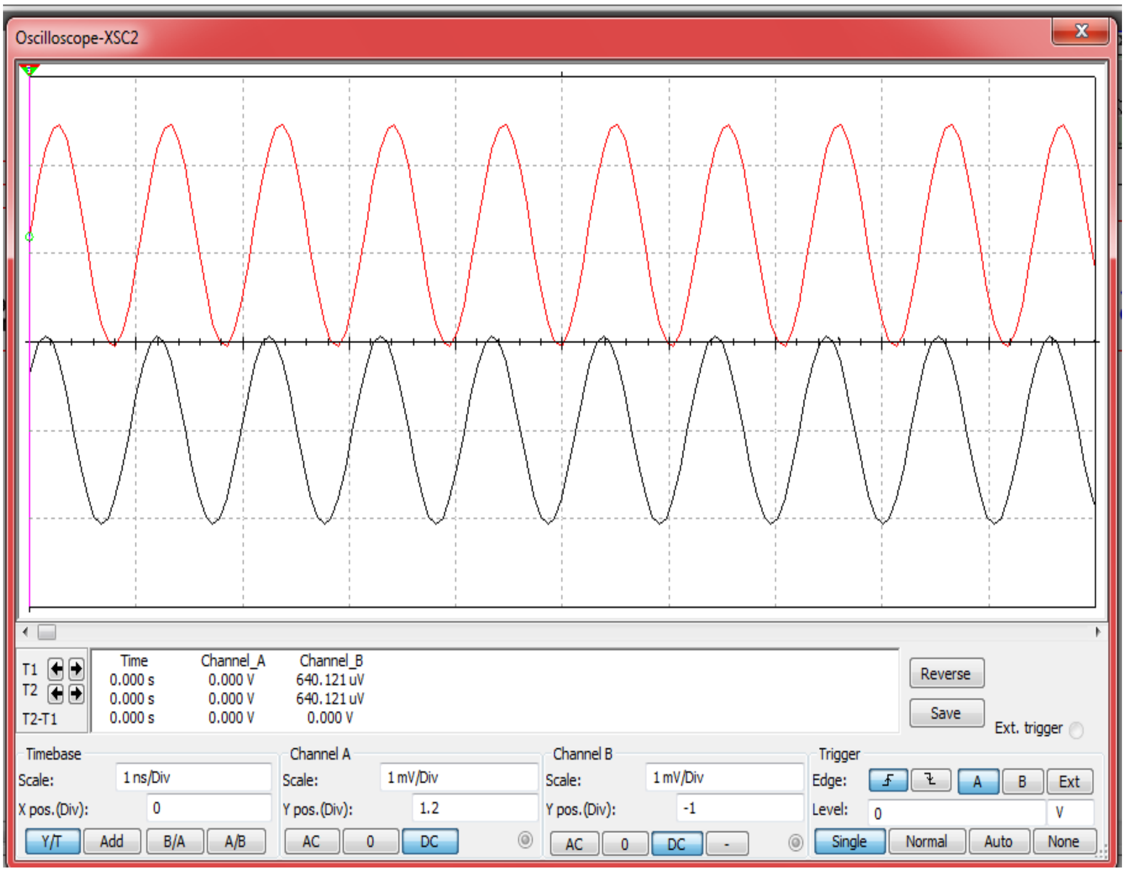
Timebase Scale: 1 ns/Div
X pos.(Div): 0
Channel A Scale: 1 mV/Div
Y pos.(Div): 1.2
Channel B Scale: 1 mV/Div
Y pos.(Div): 1.2
Level: 0 V

Figure 4.8: Filter Output at 947MHz

Assuming input voltage 2.5mV, from Oscilloscope output voltage 2.19mV.

Gain = $\frac{Output\ voltage}{Input\ Voltage}$ = $\frac{2.19}{2.5}$ = 0.87

Gain (dB) = 20Log (0.875) = -1.15dB



	Time	Channel_A	Channel_B
T1	0.000 s	0.000 V	640.121 uV
T2	0.000 s	0.000 V	640.121 uV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase
Scale: 1 ns/Div
X pos.(Div): 0

Channel A
Scale: 1 mV/Div
Y pos.(Div): 1.2

Channel B
Scale: 1 mV/Div
Y pos.(Div): -1

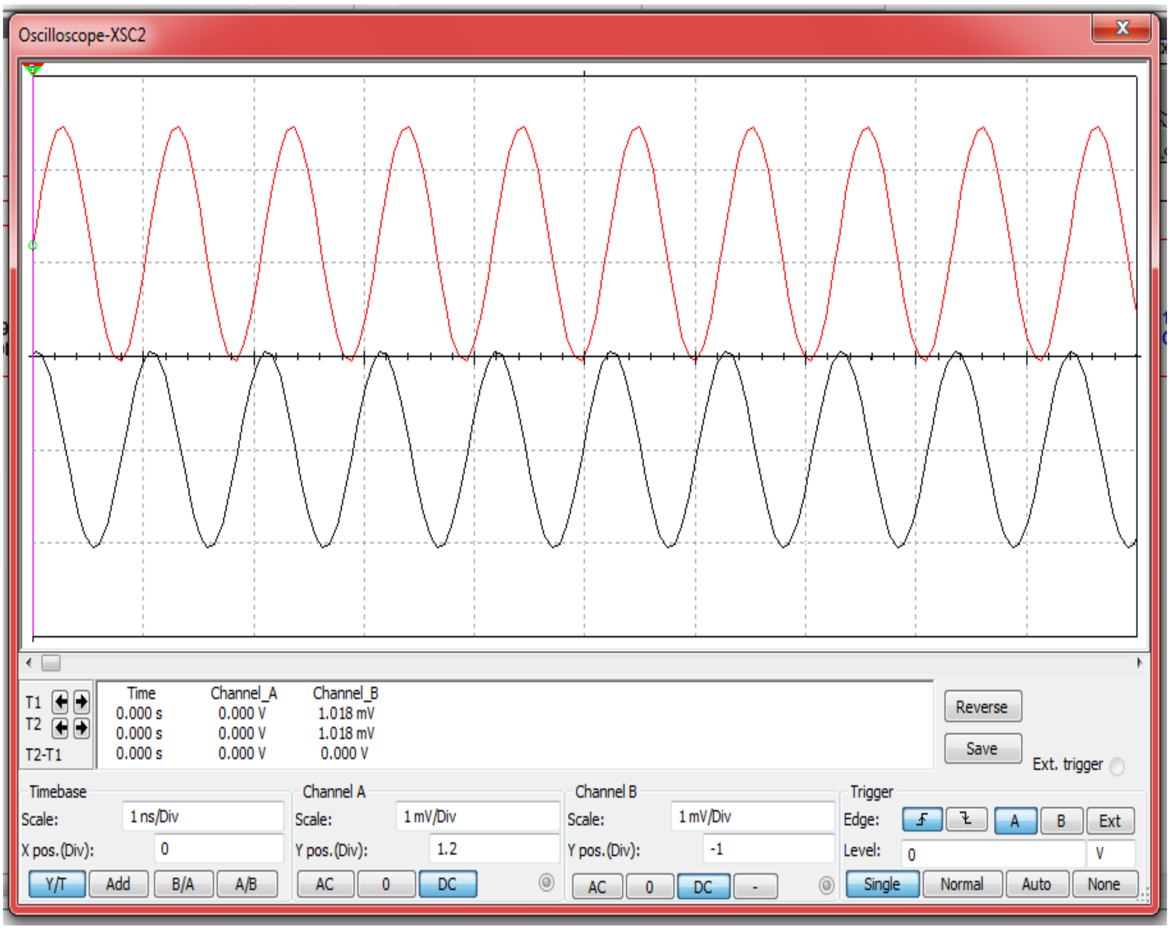
Trigger
Edge:
Level: 0 V

Figure 4.9: Filter Output at 955MHz

Assuming input voltage 2.5mV, from Oscilloscope output voltage 2.12mV.

$$\text{Gain} = \frac{Output\ voltage}{Input\ Voltage} = \frac{2.12}{2.5} = 0.85$$

Gain (dB) = 20Log (0.85) = -1.4dB



	Time	Channel_A	Channel_B
T1	0.000 s	0.000 V	1.018 mV
T2	0.000 s	0.000 V	1.018 mV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase
Scale: 1 ns/Div
X pos.(Div): 0

Channel A
Scale: 1 mV/Div
Y pos.(Div): 1.2

Channel B
Scale: 1 mV/Div
Y pos.(Div): -1

Trigger
Edge:
Level: 0 V

Figure 4.10: Filter Output at 960MHz

Assuming input voltage 2.5mV, from Oscilloscope output voltage 2.1mV.

$$\text{Gain} = \frac{Output\ voltage}{Input\ Voltage} = \frac{2.1}{2.5} = 0.84$$

Gain (dB) = 20Log (0.84) = -1.5dB

Table 4

Frequency (MHz)	Gain (dB)
915 The edge of the uplink band	-129 acceptable attenuation to prevent uplink and downlink interference
920	-113
925	-92
926	-87
930	-63
931	-56
932	-47
933	-36
935	-1.3
940	-1.22
947	-1.15
955	-1.4
960	-1.5
965	-59

4.2.2Up Link Filter

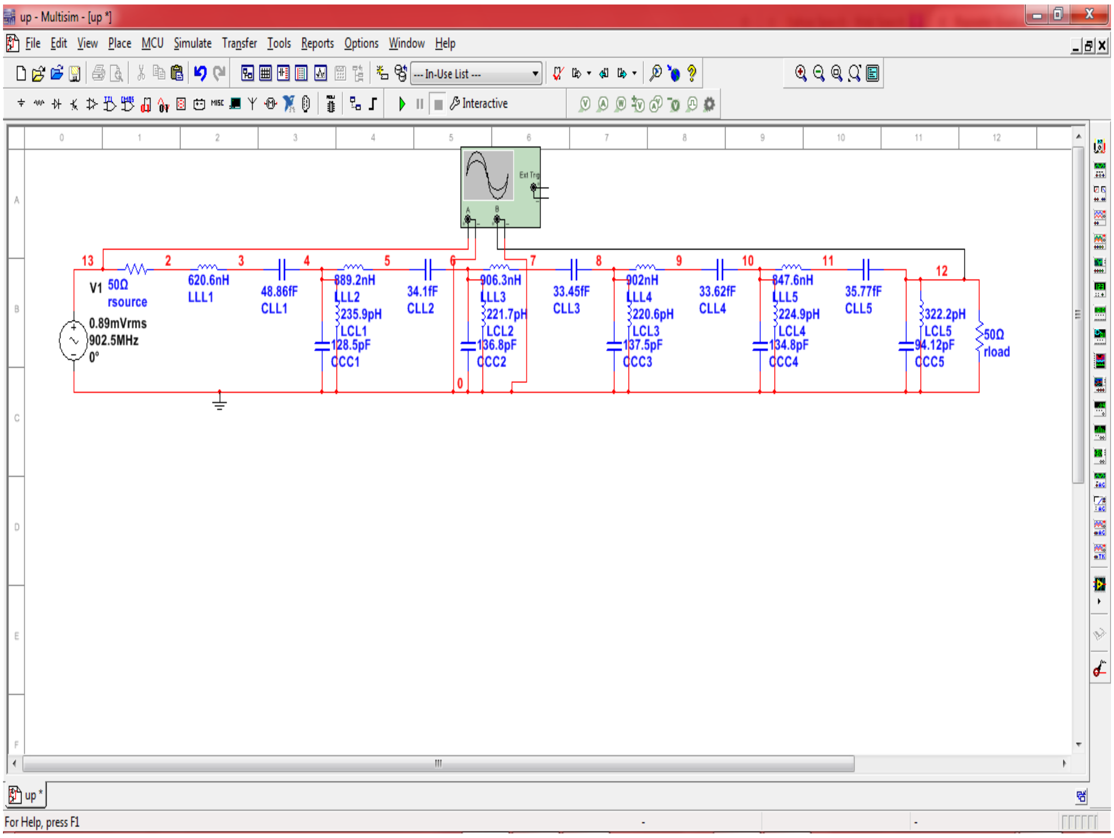
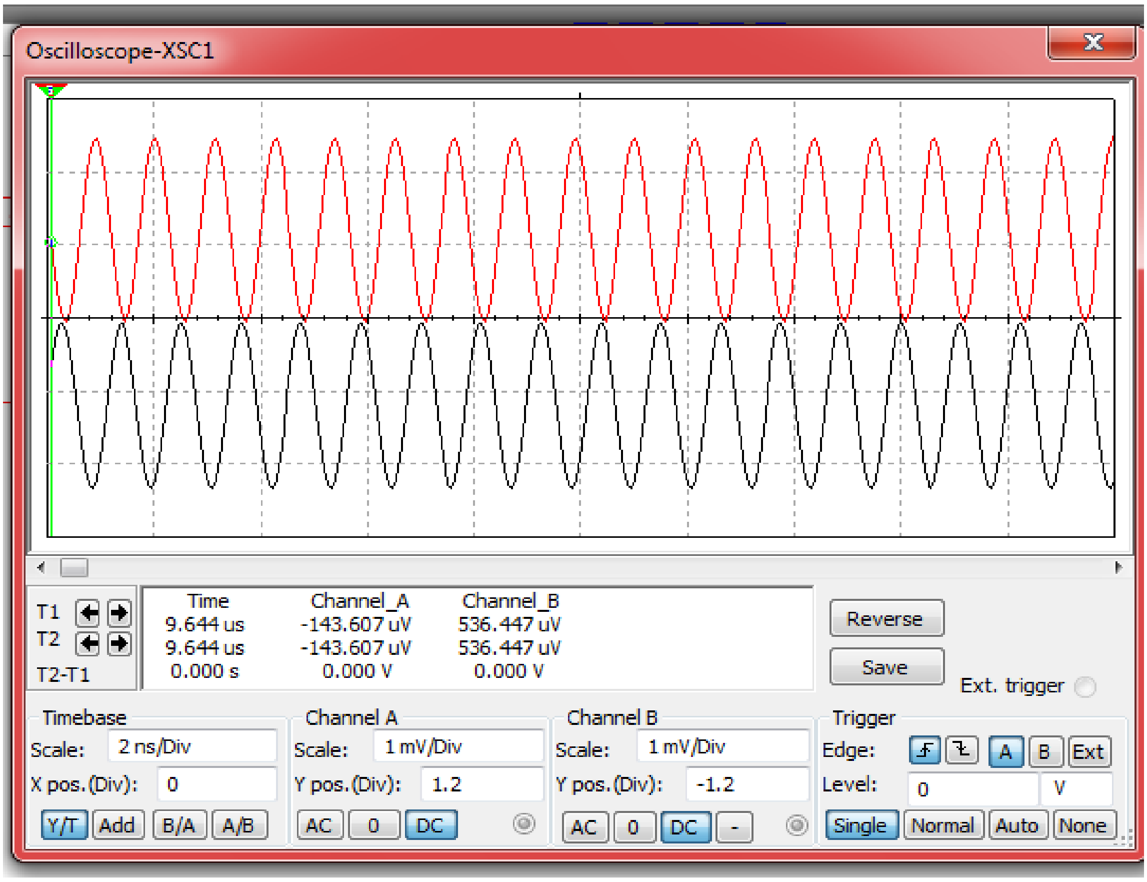


Figure 4.11: Uplink Filter (890MHz-915MHz)



	Time	Channel_A	Channel_B
T1	9.644 us	-143.607 uV	536.447 uV
T2	9.644 us	-143.607 uV	536.447 uV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase
Scale: 2 ns/Div
X pos.(Div): 0

Channel A
Scale: 1 mV/Div
Y pos.(Div): 1.2

Channel B
Scale: 1 mV/Div
Y pos.(Div): -1.2

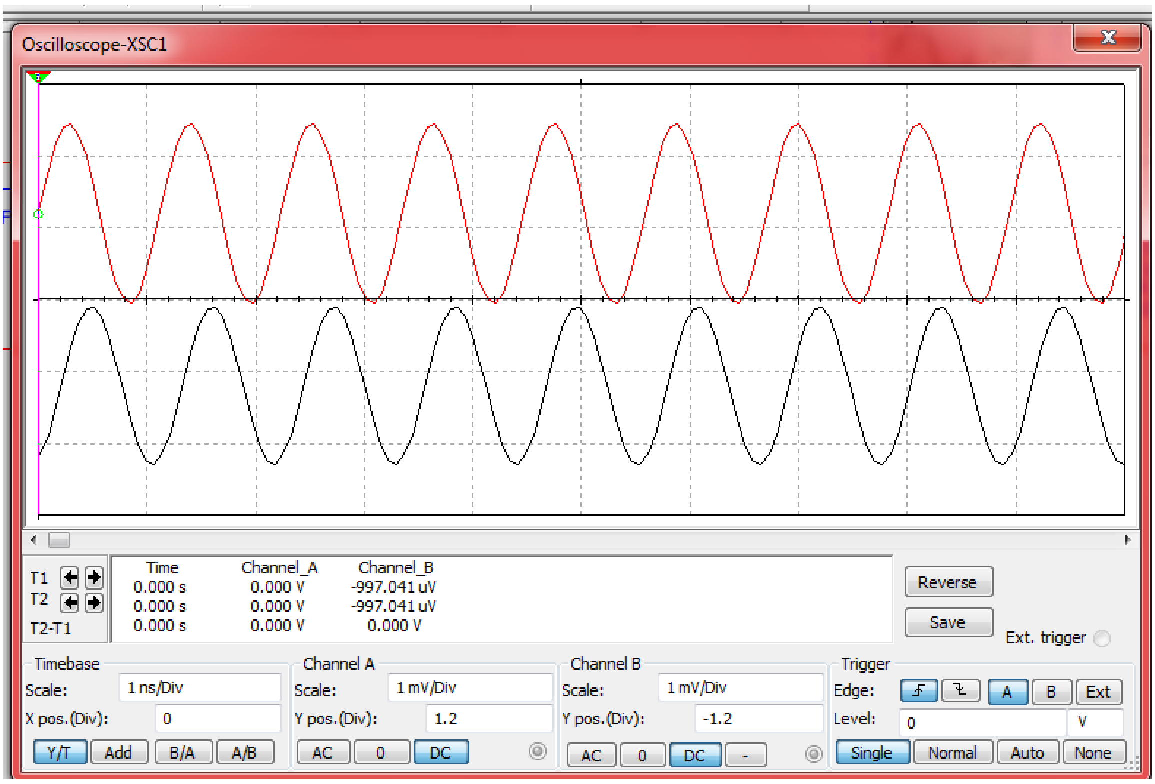
Trigger
Edge: A
Level: 0 V

Figure 4.12: Filter Output at 890MHz

Assuming input voltage 2.5mV, from Oscilloscope output voltage 2.21mV.

$$\text{Gain} = \frac{Output\ voltage}{Input\ Voltage} = \frac{2.21}{2.5} = 0.88$$

Gain (dB) = 20Log (0.884) = -1.07dB



	Time	Channel_A	Channel_B
T1	0.000 s	0.000 V	-997.041 uV
T2	0.000 s	0.000 V	-997.041 uV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase
Scale: 1 ns/Div
X pos.(Div): 0

Channel A
Scale: 1 mV/Div
Y pos.(Div): 1.2

Channel B
Scale: 1 mV/Div
Y pos.(Div): -1.2

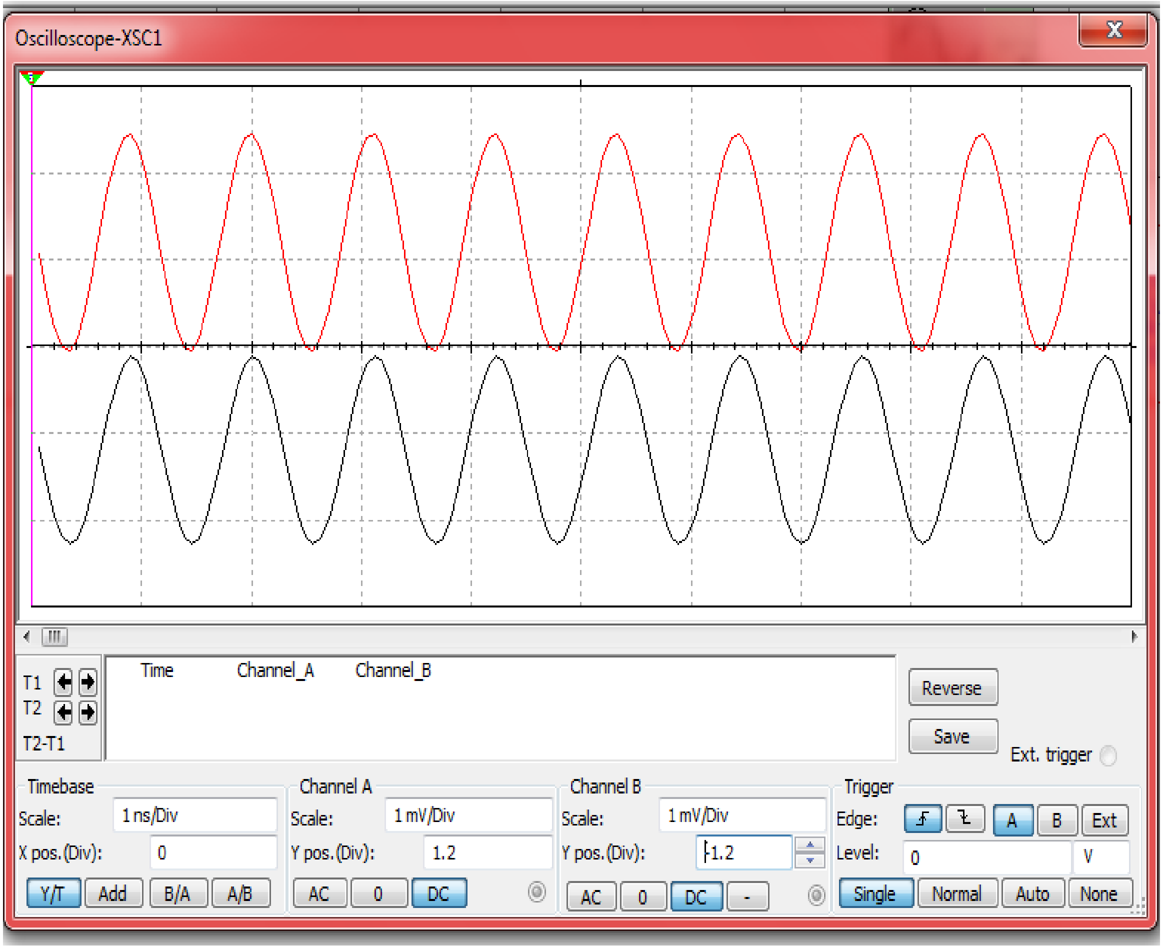
Trigger
Edge: A
Level: 0 V

Figure 4.13: Filter Output at 895 MHz

Assuming input voltage 2.5mV, from Oscilloscope output voltage 2.18mV.

$$\text{Gain} = \frac{Output\ voltage}{Input\ Voltage} \qquad = \frac{2.18}{2.5} = 0.87$$

Gain (dB) = 20Log (0.864) = -1.18dB



Timebase Scale: 1 ns/Div
X pos.(Div): 0

Channel A Scale: 1 mV/Div
Y pos.(Div): 1.2

Channel B Scale: 1 mV/Div
Y pos.(Div): 1.2

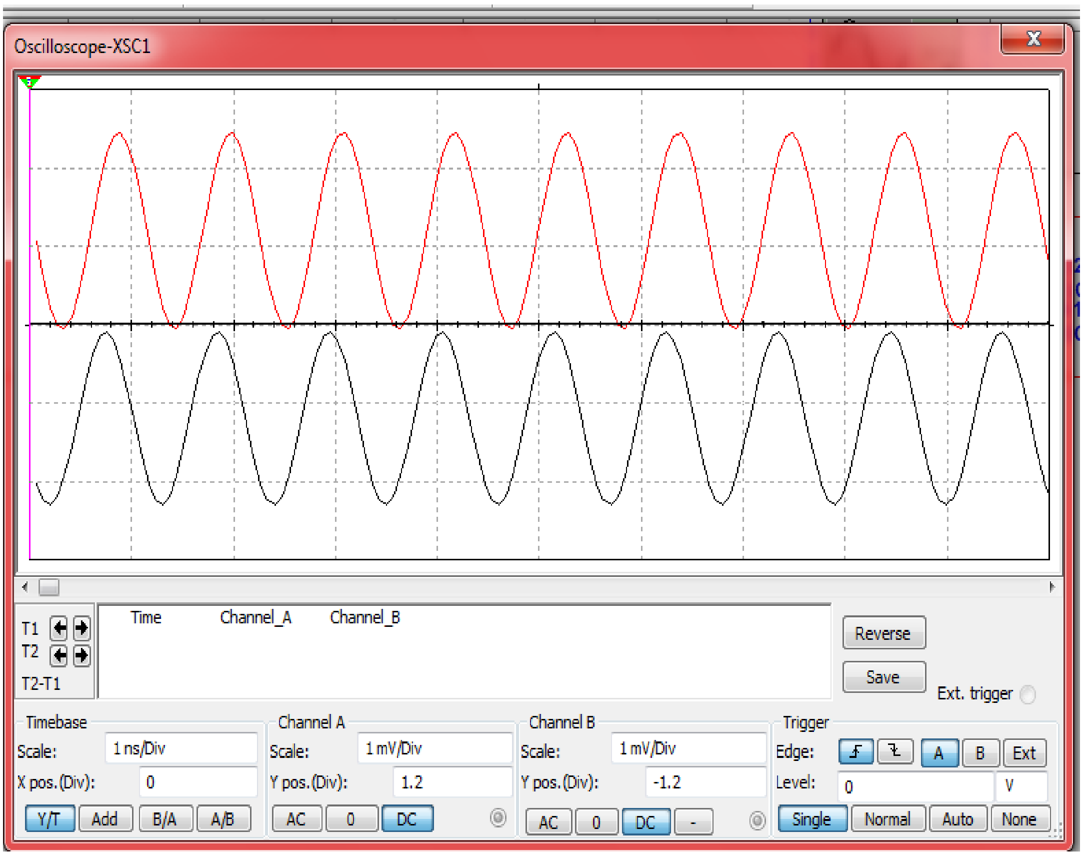
Trigger Level: 0 V

Figure 4.14: Filter Output at 902.5MHz

Assuming input voltage 2.5mV, from Oscilloscope output voltage 2.16mV.

$$\text{Gain} = \frac{Output\ voltage}{Input\ Voltage} \qquad = \frac{2.16}{2.5} = 0.86$$

Gain (dB) = 20Log (0.864) = -1.26dB



Timebase
Scale: 1 ns/Div
X pos.(Div): 0

Channel A
Scale: 1 mV/Div
Y pos.(Div): 1.2

Channel B
Scale: 1 mV/Div
Y pos.(Div): -1.2

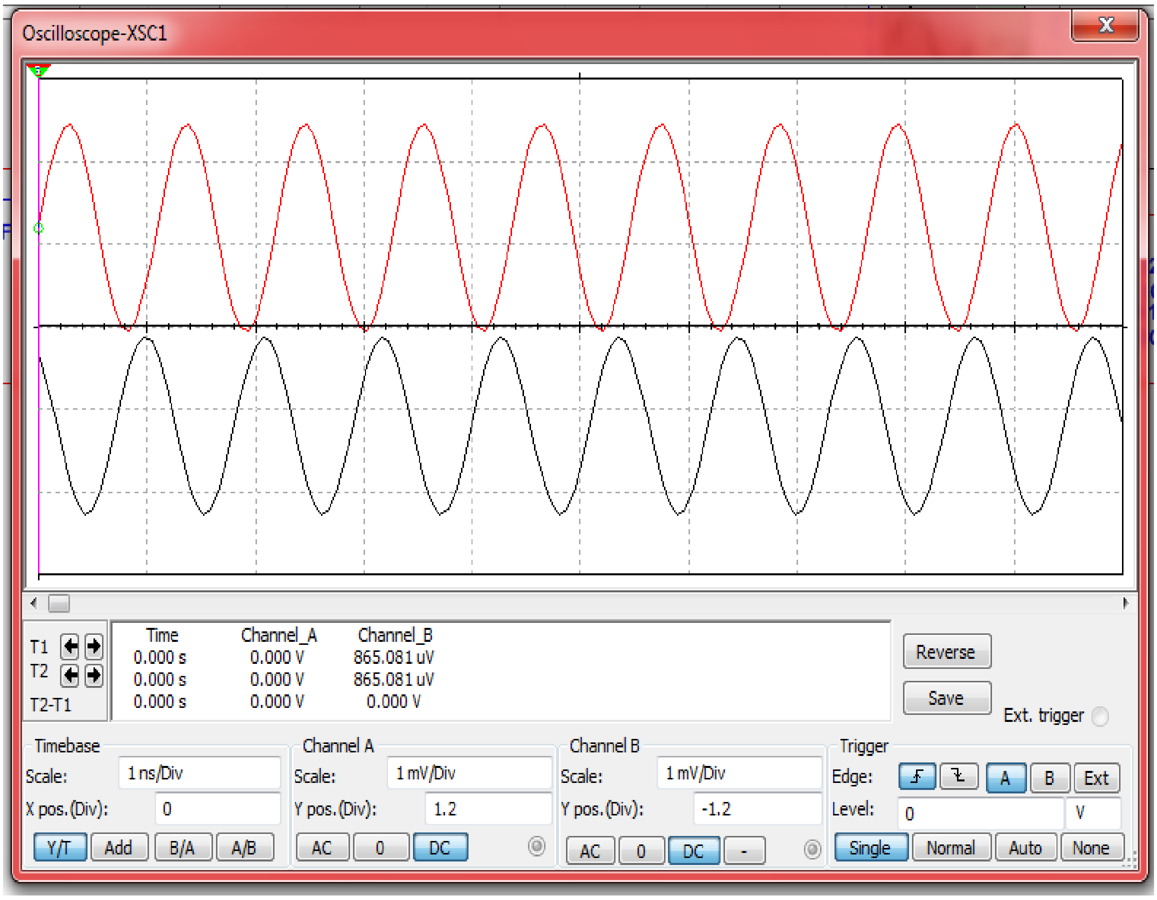
Trigger
Level: 0 V

Figure 4.15: Filter Output at 910MHz

Assuming input voltage 2.5mV, from Oscilloscope output voltage 2.2mV.

$$\text{Gain} = \frac{Output\ voltage}{Input\ Voltage} \qquad = \frac{2.2}{2.5} = 0.88$$

Gain (dB) = 20Log (0.88) = -1.1dB



Oscilloscope-XSC1

	Time	Channel_A	Channel_B
T1	0.000 s	0.000 V	865.081 uV
T2	0.000 s	0.000 V	865.081 uV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase
Scale: 1 ns/Div
X pos.(Div): 0

Channel A
Scale: 1 mV/Div
Y pos.(Div): 1.2

Channel B
Scale: 1 mV/Div
Y pos.(Div): -1.2

Trigger
Edge:
Level: 0 V

Figure 4.16: Filter Output at 915MHz

Assuming input voltage 2.5mV, from Oscilloscope output voltage 2.14mV.

$$\text{Gain} = \frac{Output\ voltage}{Input\ Voltage} \qquad = \frac{2.14}{2.5} = 0.85$$

Gain (dB) = 20Log (0.856) = -1.35dB

Table 2

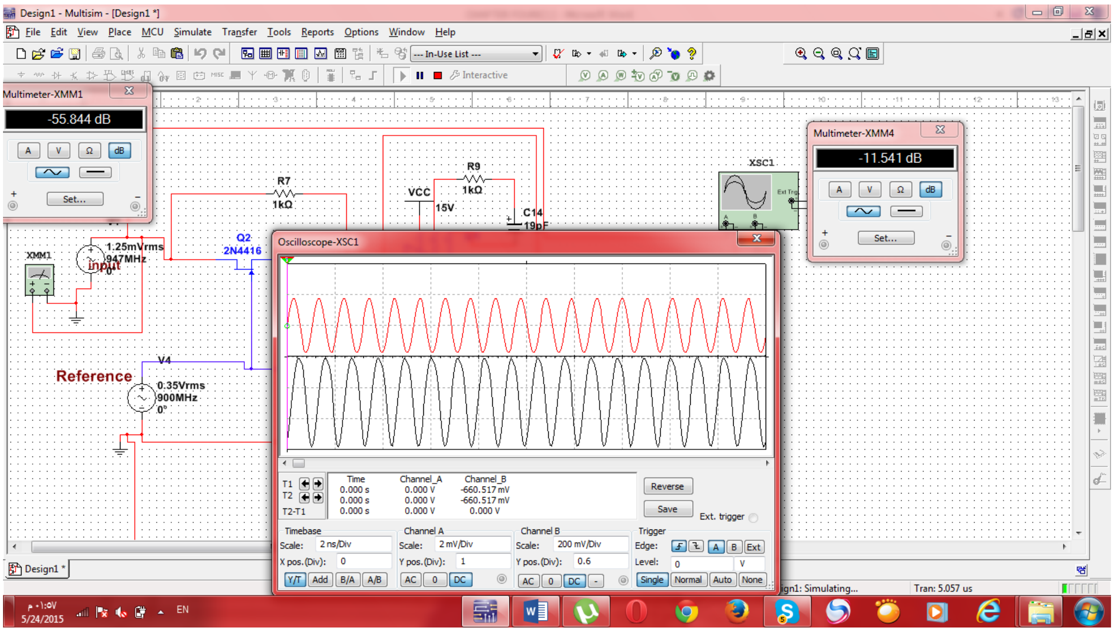
Frequency (MHz)	Gain (dB)
880	-82
885	-52
887	-30
890	-1.07
895	-1.18
902.5	-1.26
910	-1.1
915	-1.35
918	-33
920	-52
935 The edge of the downlink band	-118 acceptable attenuation to prevent uplink and downlink interference

4.3 Automatic Gain Control Result

The power input signal range of the repeater [-60dBm - -80dBm], we test the circuit at the best case -60dBm, and at the worst case -80dBm.

After the LNA stage the input power range of the AGC stage [-42dBm - - 62dBm].

1) At the best case the input power of the AGC stage -42dBm.



```
      Time      Channel_A   Channel_B
T1    0.000 s   0.000 V     -660.517 mV
T2    0.000 s   0.000 V     -660.517 mV
T2-T1 0.000 s   0.000 V     0.000 V
```

Timebase Scale: 2 ns/Div; X pos.(Div): 0

Channel A Scale: 2 mV/Div; Y pos.(Div): 1

Channel B Scale: 200 mV/Div; Y pos.(Div): 0.6

Trigger Edge: A; Level: 0 V

Figure 4.17: Automatic Gain Controller

*Input power = -42dBm

Power (dBm) = voltage (dBm) – 47   (At 50 ohm impedance)

V(dB$_m$)=(-42)+47=5 V(dB$_m$)

V(dB$_m$)=20log (mV)

5=20log(Vm)→Vm=1.77mV

Vrms=Vm/√**2**→Vrms=1.25mV

Voltage (dB) = voltage (dBm) – 60

Input voltage = 5dBm = -55dB

Assuming power reference 2 dBm

Power (dBm) = voltage (dBm) – 47   (At 50 ohm impedance)

V (dB$_m$) = (2) +47=49V (dB$_m$)

V (dB)=(-11) V (dB)

From the figure output power -23VdB

V (dB$_m$) = (-11) +60=49V (dB$_m$)

Power (dBm) =49-47=-2dBm

Gain (dB) =output power (dBm) – input power (dBm)

Gain = 2dBm + 42dBm = 44dB.

2) At the average case the input power of the AGC stage -52dBm.

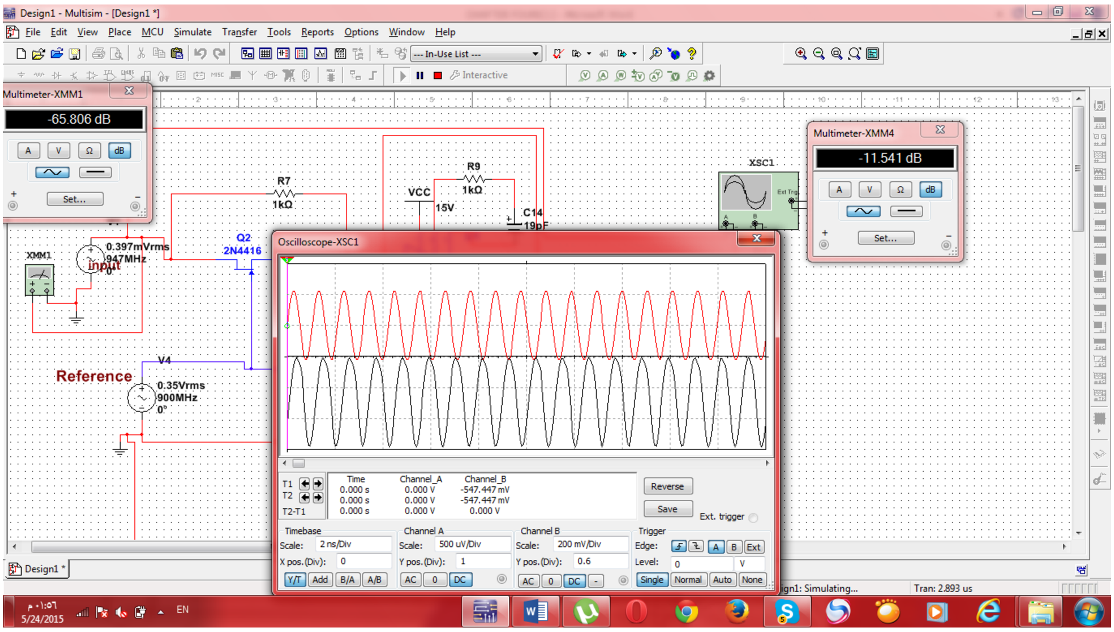


Figure 4.18: Automatic Gain Controller

*Input power = -52dBm

Power (dBm) = voltage (dBm) – 47   (At 50 ohm impedance)

V (dB_m) = (-52) +47= (-5) V (dB_m)

V (dB_m) =20log (mV)

-5=20log (Vm) →Vm=0.562mV

Vrms=Vm/√**2**→Vrms=0.397mV

Voltage (dB) = voltage (dBm) – 60

Input voltage = -5dBm = -65dB

Assuming power reference 2 dBm

Power (dBm) = voltage (dBm) – 47   (At 50 ohm impedance)

V (dB$_m$) = (2) +47=49V (dB$_m$)

V (dB) =-(-11)V (dB)

From the figure output power -11VdB

V (dB$_m$) = (-11)+60=49 V(dB$_m$)

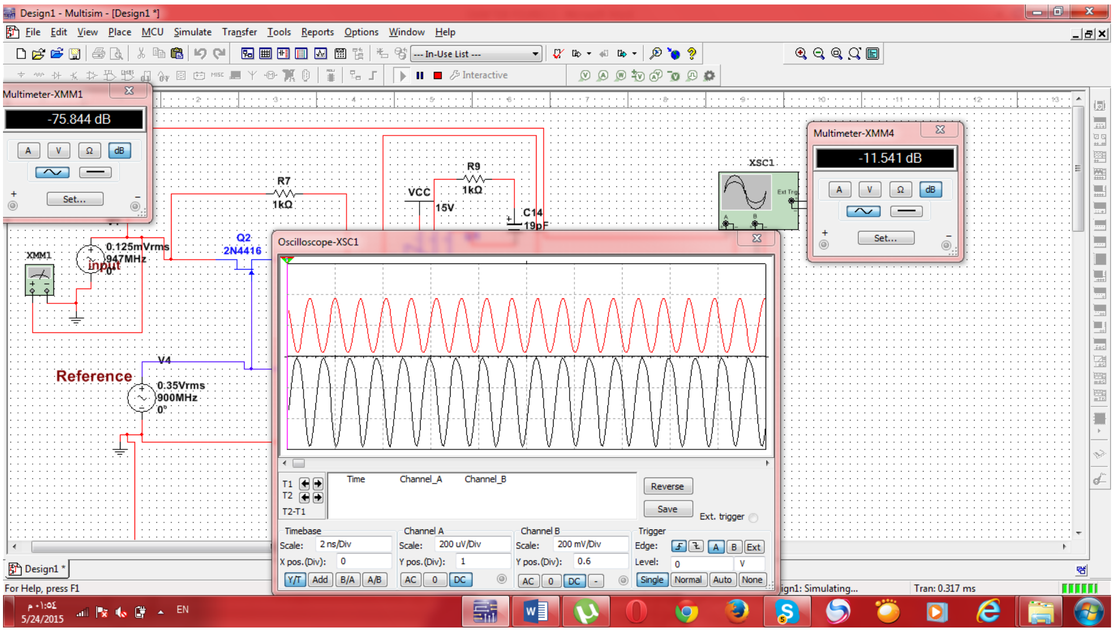
Power (dBm) =49-47=-2dBm

Gain (dB) =output power (dBm) – input power (dBm)

Gain = 2dBm + 52 dBm = 54dB.

The range of the AGC stage gain [10dB – 65dB].

3) At the worst case the input power of the AGC stage -62dBm.



Multimeter-XMM1: -75.844 dB

Multimeter-XMM4: -11.541 dB

Timebase — Scale: 2 ns/Div; X pos.(Div): 0

Channel A — Scale: 200 uV/Div; Y pos.(Div): 1

Channel B — Scale: 200 mV/Div; Y pos.(Div): 0.6

Trigger — Edge: A; Level: 0 V

Figure 4.19:Automatic Gain Controller

*Input power = -62dBm

Power (dBm) = voltage (dBm) – 47   (At 50 ohm impedance)

V (dB_m) = (-62) +47= (-15) V (dB_m)

V (dB_m) =20log (mV)

-15=20log (Vm) →Vm=0.177mV

Vrms=Vm/√**2**→Vrms=0.125mV

Voltage (dB) = voltage (dBm) – 60

Input voltage = -15dBm = -75dB

Assuming power reference 2 dBm

Power (dBm) = voltage (dBm) – 47   (At 50 ohm impedance)

V (dB$_m$) = (2) +47=49 V (dB$_m$)

V (dB) =-(-11)V (dB)

From the figure output power -11VdB

V (dB$_m$) = (-11)+60=49 V(dB$_m$)

Power (dBm) =49-47=-2dBm

Gain (dB) =output power (dBm) – input power (dBm)

Gain = 2dBm + 62 dBm = 64dB.

The range of the AGC stage gain [10dB – 65dB].

4.4 Power Amplifier Result

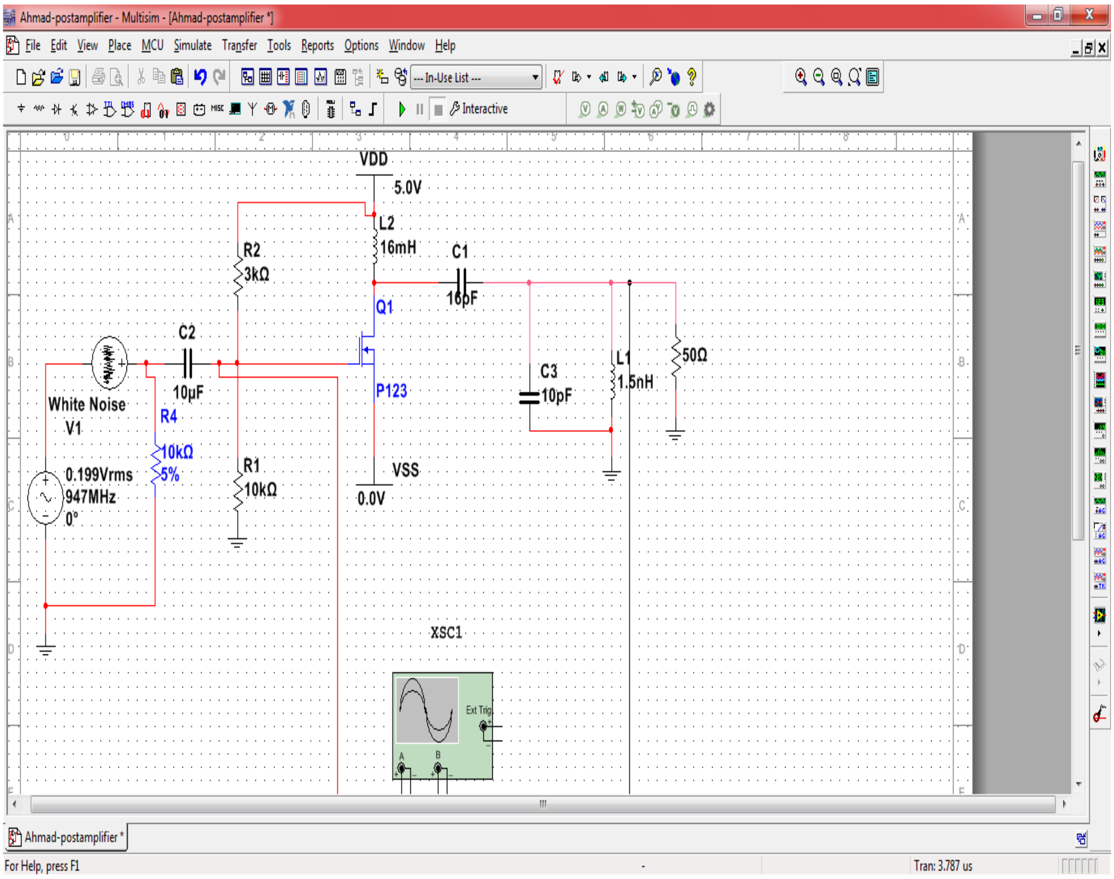
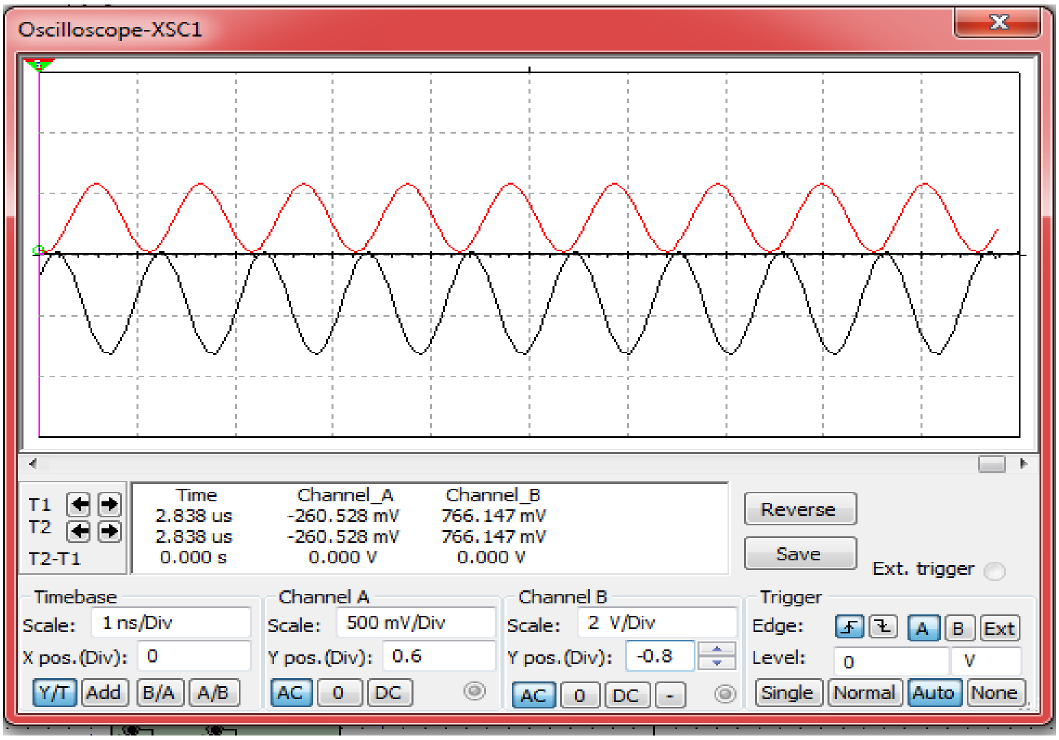


Figure 4.20: Power Amplifier Circuit



	Time	Channel_A	Channel_B
T1	2.838 us	-260.528 mV	766.147 mV
T2	2.838 us	-260.528 mV	766.147 mV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase
Scale: 1 ns/Div
X pos.(Div): 0

Channel A
Scale: 500 mV/Div
Y pos.(Div): 0.6

Channel B
Scale: 2 V/Div
Y pos.(Div): -0.8

Trigger
Level: 0 V

Figure 4.21: Power Amplifier Output

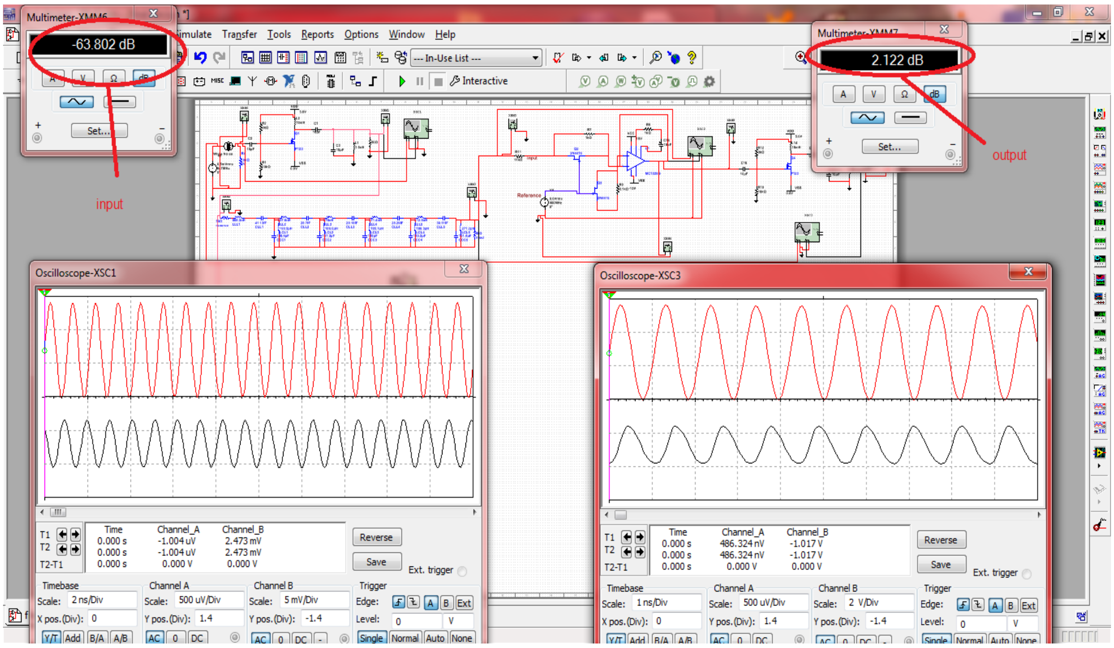
*From oscilloscope input voltage = 550 mv & output voltage = 2.8v

Gain= 20 log (output voltage / input voltage)

Gain = 20 log (2.8/550m) = 14 dB

4.5 Over All system Result

1) System without noise


Multimeter-XMM6: -63.802 dB

Multimeter-XMM7: 2.122 dB

Oscilloscope-XSC1

```
        Time      Channel_A   Channel_B
T1      0.000 s   -1.004 uV   2.473 mV
T2      0.000 s   -1.004 uV   2.473 mV
T2-T1   0.000 s   0.000 V     0.000 V
```

Timebase Scale: 2 ns/Div; X pos.(Div): 0

Channel A Scale: 500 uV/Div; Y pos.(Div): 1.4

Channel B Scale: 5 mV/Div; Y pos.(Div): -1.4

Trigger Level: 0 V

Oscilloscope-XSC3

```
        Time      Channel_A    Channel_B
T1      0.000 s   486.324 nV   -1.017 V
T2      0.000 s   486.324 nV   -1.017 V
T2-T1   0.000 s   0.000 V      0.000 V
```

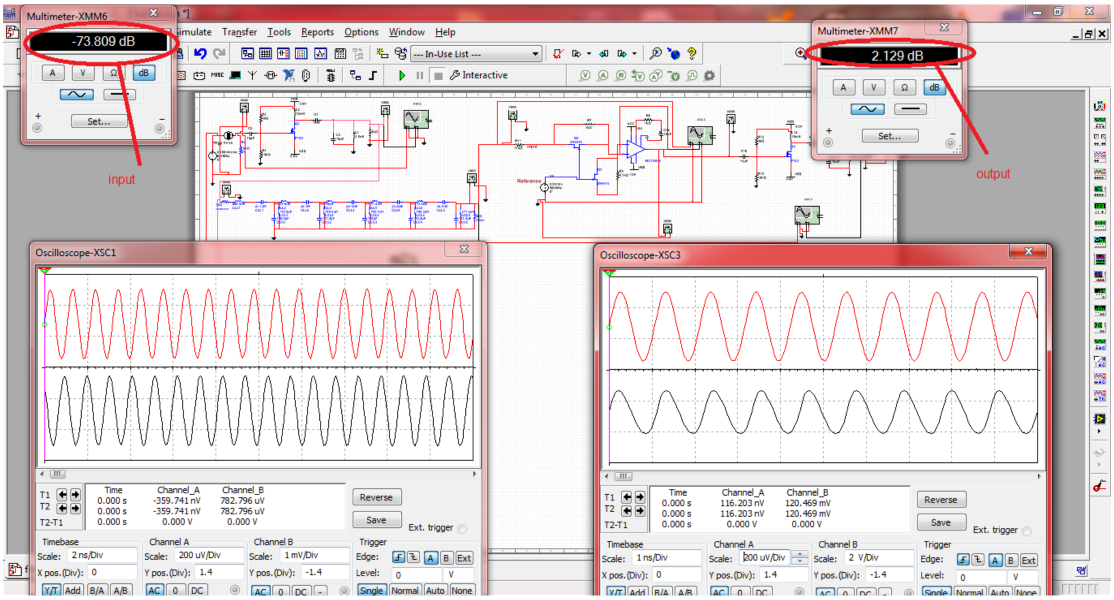
Timebase Scale: 1 ns/Div; X pos.(Div): 0

Channel A Scale: 500 uV/Div; Y pos.(Div): 1.4

Channel B Scale: 2 V/Div; Y pos.(Div): -1.4

Trigger Level: 0 V

Figure 4.22: Output System at -50dBm


Multimeter-XMM6: -73.809 dB

Multimeter-XMM7: 2.129 dB

Oscilloscope-XSC1

```
        Time      Channel_A     Channel_B
T1      0.000 s   -359.741 nV   782.796 uV
T2      0.000 s   -359.741 nV   782.796 uV
T2-T1   0.000 s   0.000 V       0.000 V
```

Timebase Scale: 2 ns/Div; X pos.(Div): 0

Channel A Scale: 200 uV/Div; Y pos.(Div): 1.4

Channel B Scale: 1 mV/Div; Y pos.(Div): -1.4

Trigger Level: 0 V

Oscilloscope-XSC3

```
        Time      Channel_A    Channel_B
T1      0.000 s   116.203 nV   120.469 mV
T2      0.000 s   116.203 nV   120.469 mV
T2-T1   0.000 s   0.000 V      0.000 V
```

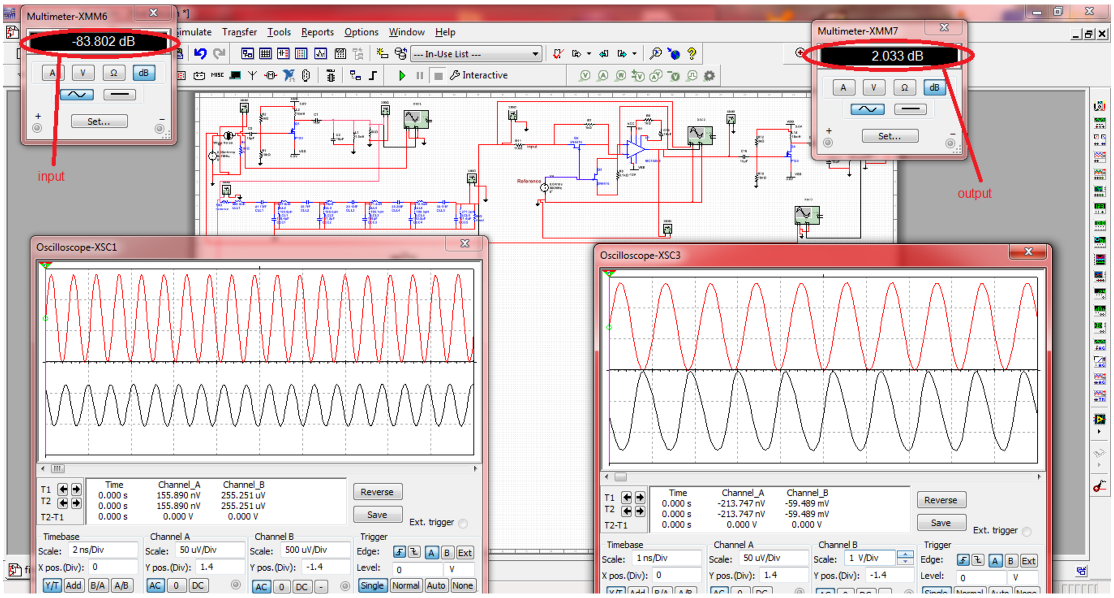
Timebase Scale: 1 ns/Div; X pos.(Div): 0

Channel A Scale: 200 uV/Div; Y pos.(Div): 1.4

Channel B Scale: 2 V/Div; Y pos.(Div): -1.4

Trigger Level: 0 V

Figure 4.23: Output System at -60dBm



Multimeter-XMM6: -83.802 dB

Multimeter-XMM7: 2.033 dB

Oscilloscope-XSC1:

```
      Time      Channel_A    Channel_B
T1    0.000 s   155.890 nV   255.251 uV
T2    0.000 s   155.890 nV   255.251 uV
T2-T1 0.000 s   0.000 V      0.000 V
```

Timebase Scale: 2 ns/Div; X pos.(Div): 0

Channel A Scale: 50 uV/Div; Y pos.(Div): 1.4

Channel B Scale: 500 uV/Div; Y pos.(Div): -1.4

Trigger Level: 0 V

Oscilloscope-XSC3:

```
      Time      Channel_A     Channel_B
T1    0.000 s   -213.747 nV   -59.489 mV
T2    0.000 s   -213.747 nV   -59.489 mV
T2-T1 0.000 s   0.000 V       0.000 V
```

Timebase Scale: 1 ns/Div; X pos.(Div): 0

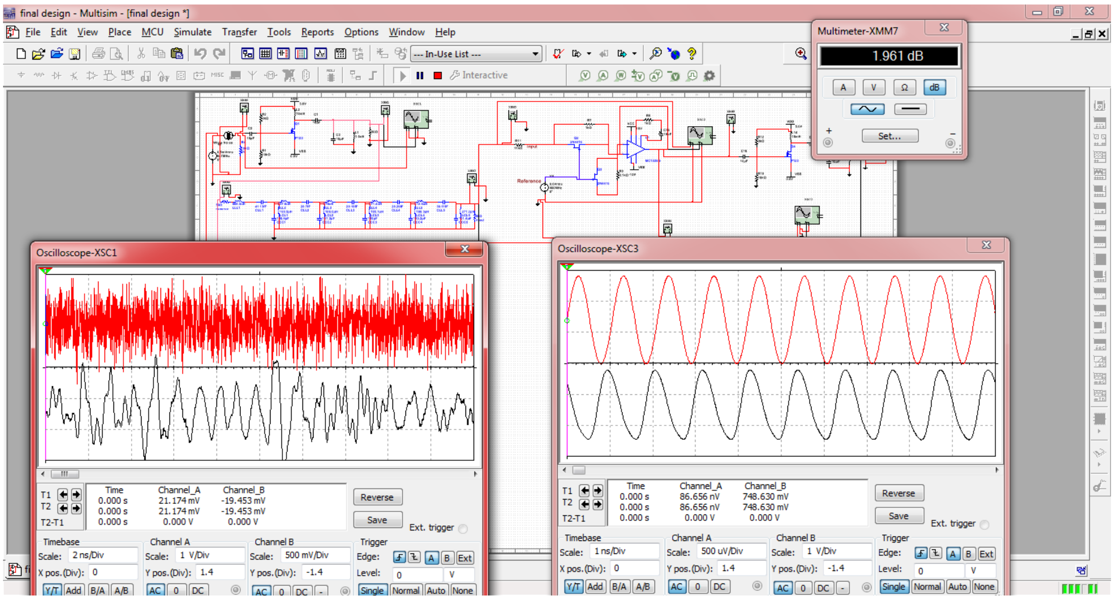
Channel A Scale: 50 uV/Div; Y pos.(Div): 1.4

Channel B Scale: 1 V/Div; Y pos.(Div): -1.4

Trigger Level: 0 V

Figure 4.24: Output System at -70dBm

2) System with noise



Multimeter-XMM7: 1.961 dB

Oscilloscope-XSC1:

```
      Time      Channel_A    Channel_B
T1    0.000 s   21.174 mV    -19.453 mV
T2    0.000 s   21.174 mV    -19.453 mV
T2-T1 0.000 s   0.000 V      0.000 V
```

Timebase Scale: 2 ns/Div; X pos.(Div): 0

Channel A Scale: 1 V/Div; Y pos.(Div): 1.4

Channel B Scale: 500 mV/Div; Y pos.(Div): -1.4

Trigger Level: 0 V

Oscilloscope-XSC3:

```
      Time      Channel_A    Channel_B
T1    0.000 s   86.656 nV    748.630 mV
T2    0.000 s   86.656 nV    748.630 mV
T2-T1 0.000 s   0.000 V      0.000 V
```

Timebase Scale: 1 ns/Div; X pos.(Div): 0

Channel A Scale: 500 uV/Div; Y pos.(Div): 1.4

Channel B Scale: 1 V/Div; Y pos.(Div): -1.4

Trigger Level: 0 V

Figure 4.25: Output System at -50dBm

Multimeter-XMM7: 1.901 dB

Oscilloscope-XSC1

	Time	Channel_A	Channel_B
T1	0.000 s	-4.364 mV	63.427 mV
T2	0.000 s	-4.364 mV	63.427 mV
T2-T1	0.000 s	0.000 V	0.000 V

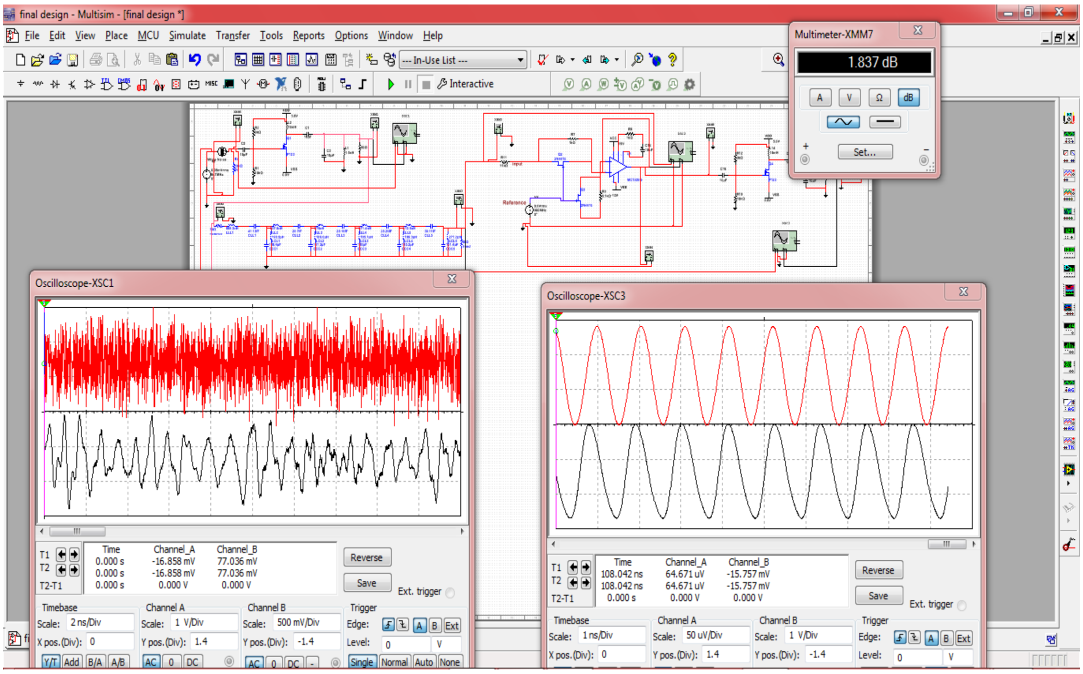
Timebase Scale: 2 ns/Div X pos.(Div): 0
Channel A Scale: 1 V/Div Y pos.(Div): 1.4
Channel B Scale: 500 mV/Div Y pos.(Div): -1.4
Trigger Level: 0 V

Oscilloscope-XSC3

	Time	Channel_A	Channel_B
T1	0.000 s	-54.544 nV	154.791 mV
T2	0.000 s	-54.544 nV	154.791 mV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase Scale: 1 ns/Div X pos.(Div): 0
Channel A Scale: 200 uV/Div Y pos.(Div): 1.4
Channel B Scale: 1 V/Div Y pos.(Div): -1.4
Trigger Level: 0 V

Figure 4.26: Output System at -60dBm



Multimeter-XMM7: 1.837 dB

Oscilloscope-XSC1

	Time	Channel_A	Channel_B
T1	0.000 s	-16.858 mV	77.036 mV
T2	0.000 s	-16.858 mV	77.036 mV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase Scale: 2 ns/Div X pos.(Div): 0
Channel A Scale: 1 V/Div Y pos.(Div): 1.4
Channel B Scale: 500 mV/Div Y pos.(Div): -1.4
Trigger Level: 0 V

Oscilloscope-XSC3

	Time	Channel_A	Channel_B
T1	108.042 ns	64.671 uV	-15.757 mV
T2	108.042 ns	64.671 uV	-15.757 mV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase Scale: 1 ns/Div X pos.(Div): 0
Channel A Scale: 50 uV/Div Y pos.(Div): 1.4
Channel B Scale: 1 V/Div Y pos.(Div): -1.4
Trigger Level: 0 V

Figure 4.27: Output System at -70dBm

Input (dB$_m$)	Output LNA (dB$_m$)	Output filter (dB$_m$)	Output AGC (dB$_m$)	Output power amp (dB$_m$)
-50	-37	-38	2 (40dB)	15
60-	-47	-48	2 (50dB)	15
-70	-57	-58	2 (60dB)	15

Chapter Five

Fabrication of the System

5.1 Box Design

5.2 PCB Board

5.3 ICs

5.1 Box Design

Natural-finish aluminum enclosure case has been designed and printed using CNC printer machine to contain two single layer printed circuit board (PCB) vertically. With built-in grooves for holding circuit board, the box can provide excellent electromagnetic shielding performance as well as to the middle sliding panel which make it easier to use and insert the grounded PCB as shown in figure 5.1.2. Heat sinks are used to enhance heat dissipation from hot surfaces. A heat sink does this by increasing the surface area that is in contact with the air.

The box design has been saved in two file format; .SLDASM & X_T format, so it can be opened using many programs like Solidworks, 3D Cad, Solid view and Auto Cad programs and others. The design has been done individually for each part and then integrated by screws as follow:

- Base part, which defines the box shape as it is the container of the PCB.
- Middle part, which is the sliding panel that separates between the two layers.
- Right cover, which contains the entrance of the antenna and charger.
- Upper cover, which is the closing panel of the base.

This enclosure is to take a 120mm wide board with board lengths 80mm or 160mm. It is also available in non-standard lengths. The circuit board can have components 31mm high for the floor plate and 18mm high for the top plate. Exterior dimensions of the aluminum electronic enclosure are 197mm x 138.8mm x 56mm and the interior are 195mm x 122.5mm x 45.3mm. There is 16 screw ports with a diameter 3 m.

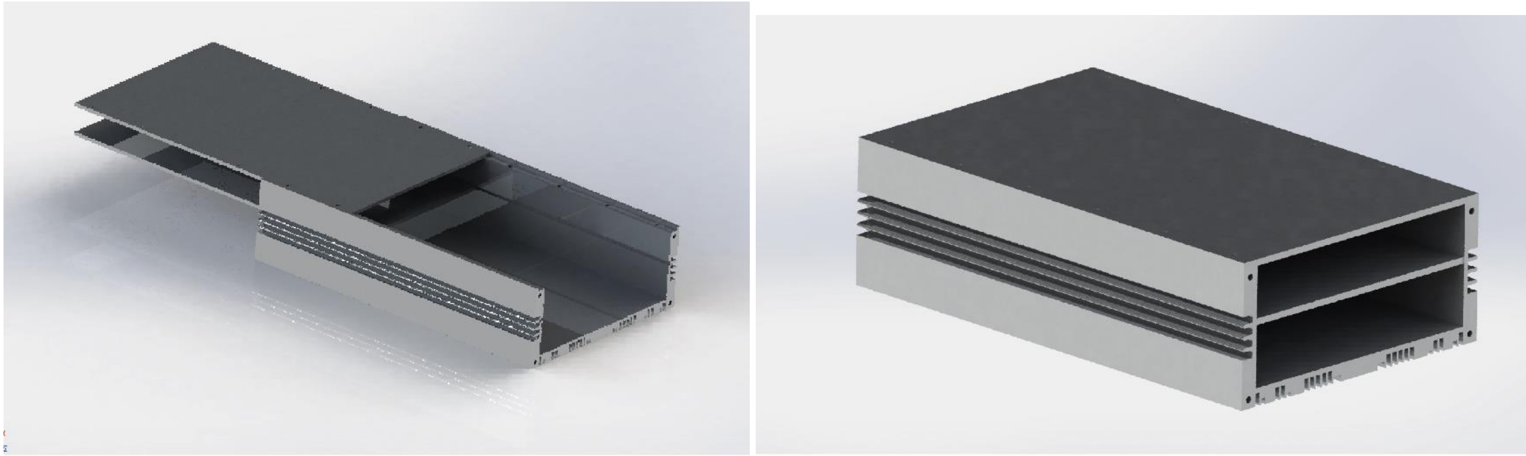


Fig 5.1.1: 3D block diagram of the box

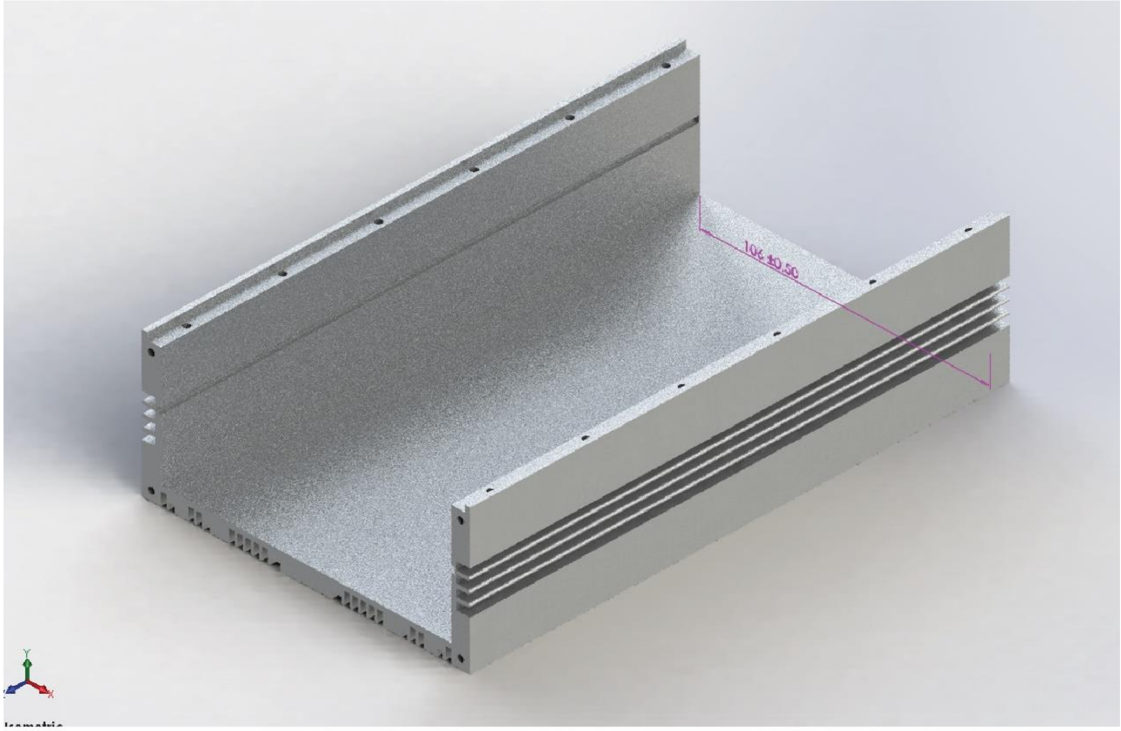


Fig 5.1.2: External 3D View of the Box

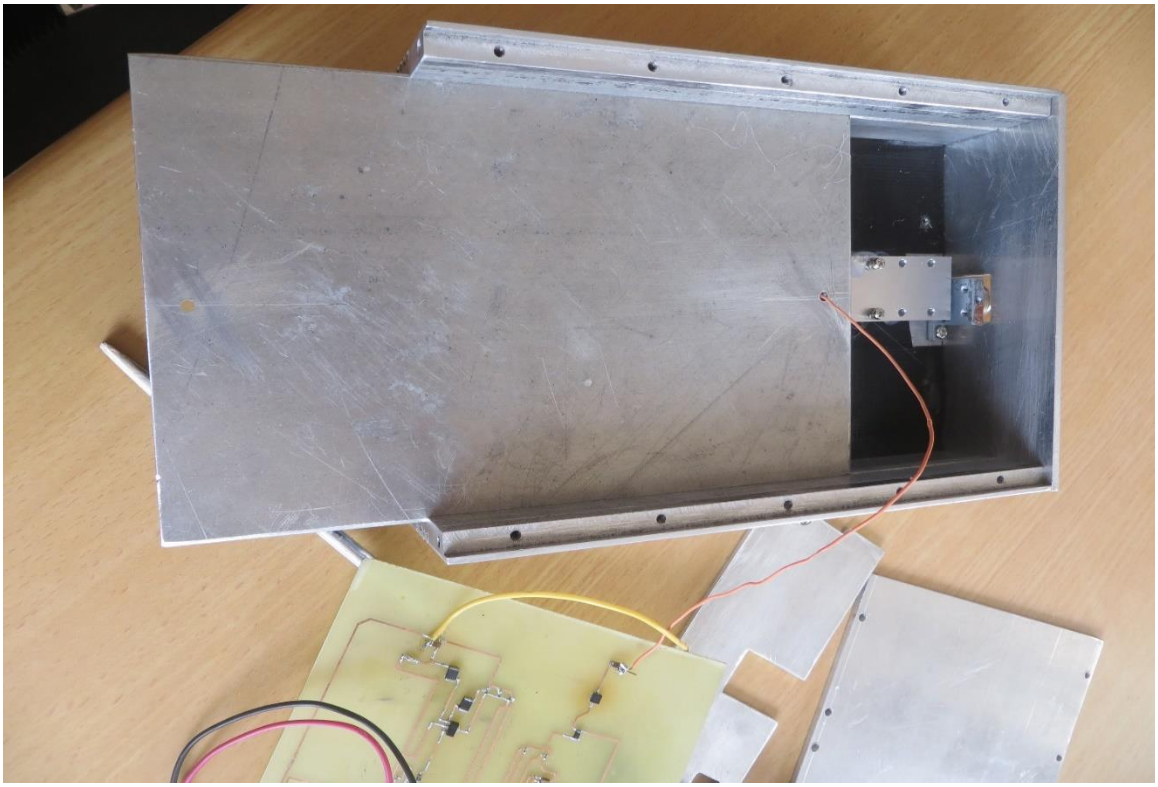


Fig 5.1.3: Upper Real View of the Box

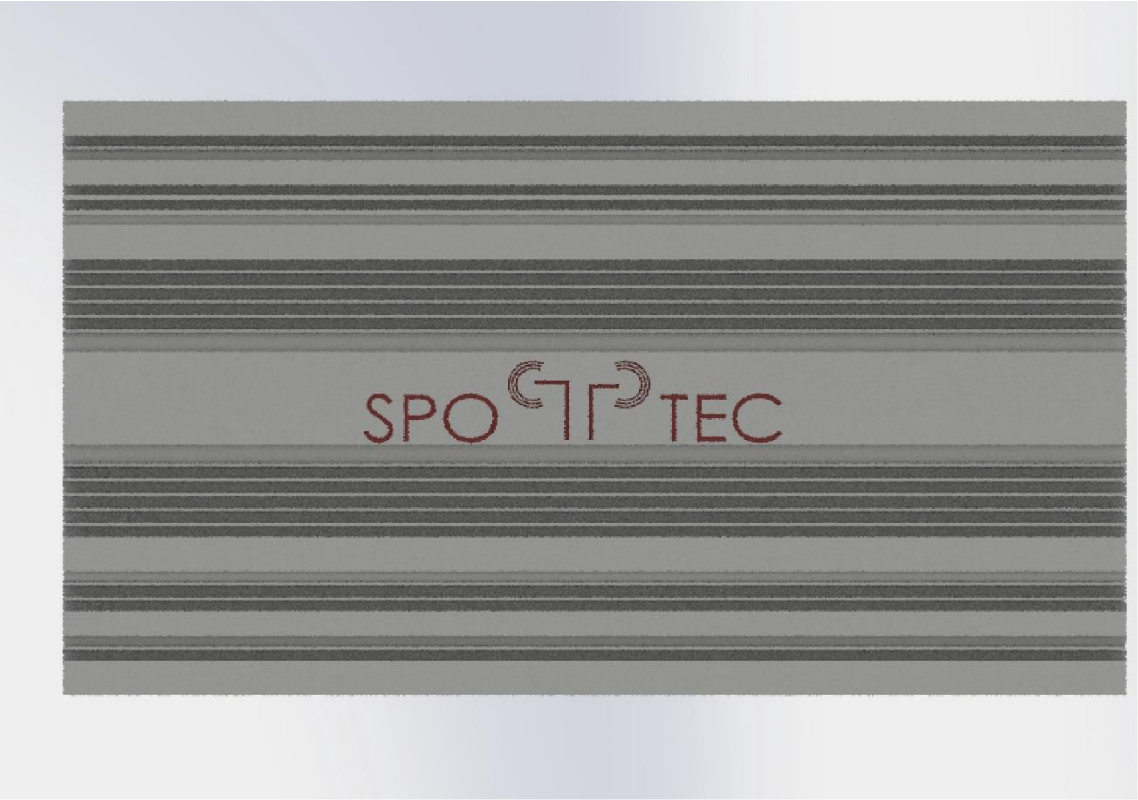


Fig 5.1.4: Top 3D View of the Box

Fig 5.1.5: Top Real View of the Box

5.2 PCB Board

A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. We used a single layer PCB to hold the ICs of flat no-leads packages such as quad-flat no-leads (QFN) and dual-flat no-leads (DFN) physically and electrically connect integrated circuits to printed circuit boards. Flat no-leads, is a surface-mount technology, one of several package technologies that connect ICs to the surfaces of PCBs without through-holes [5.1].

Our board has only copper connections and no embedded components, it has many traces, each trace consists of a flat, narrow part of the copper foil that remains after etching. The resistance determined by width and thickness of the traces must be sufficiently low for the current the conductor will carry [5.2]. Power and ground traces is wider than signal traces as shown in fig 5.2.1

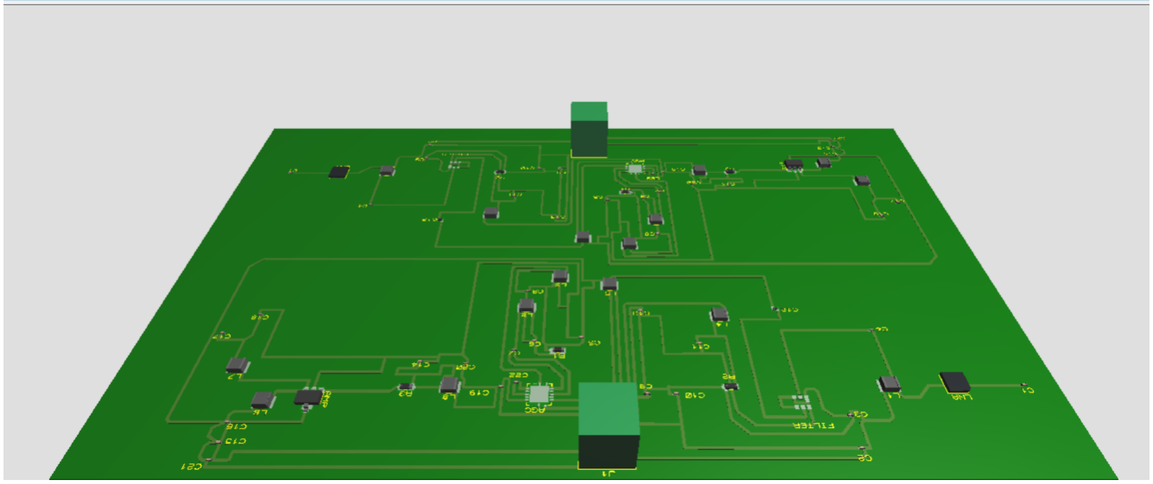


Fig 5.2.1: PCB Board Layout

The printed circuit board has a size 195mm x 120mm x 0.25mm

To accomplish soldering of the surface mounted ICs on the board we used the following tools and materials:

- Hot air rework SMD station, with temperature 110 degree Celsius
- Solder wire roll 100 gm with diameter 0.6 mm, with 2% Flux
- Magnifying Glass-Small
- Specimen Mount Mini-Tongs
- Multimeter

5.3 ICs

5.3.1 Variable Gain Amplifier (TQM8M9079)

The TQM8M9079 is an analog controlled variable gain amplifier (VGA) which operates from 500 to 2700 MHz. The VGA is able to provide broadband performance with +29 dBm third-order intercept point (OIP3) over a wide frequency range while only consuming 95 mA current. The TQM8M9079 integrates two broadband gain blocks with a voltage variable attenuator. The three stages are individually accessible via package I/O contacts. This permits full flexibility to insert other components or filters between the stages [5.2].

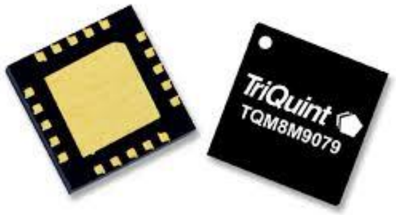


Fig 5.3.1: leadless packages of VGA

The TQM8M9079 is packaged in a RoHS-compliant, compact 5x5 mm surface-mount leadless package and it is targeted for use in wireless infrastructure, IF gain control in point-to-point applications and for general purpose wireless.

5.3.2 High Linearity LNA (TQP3M9005)

The TQP3M9005 is a high linearity low noise gain block amplifier in a low-cost surface-mount package. At 1.9 GHz, the amplifier typically provides 15.3 dB gain, +34 dBm OIP3, and 0.8 dB Noise Figure while only drawing 50 mA current. The device is housed in a leadfree/green/RoHS-compliant industry-standard 16-pin 3x3 mm QFN package.

The TQP3M9005 has the benefit of having high linearity while also providing very low noise across a broad range of frequencies. This allows the device to be used in both receive and transmit chains for high performance systems. The amplifier is internally matched using a high performance E-pHEMT process and only requires an external RF choke and blocking/bypass capacitors for operation from a single supply. The internal active bias circuit also enables stable operation over bias and temperature variations [5.3].

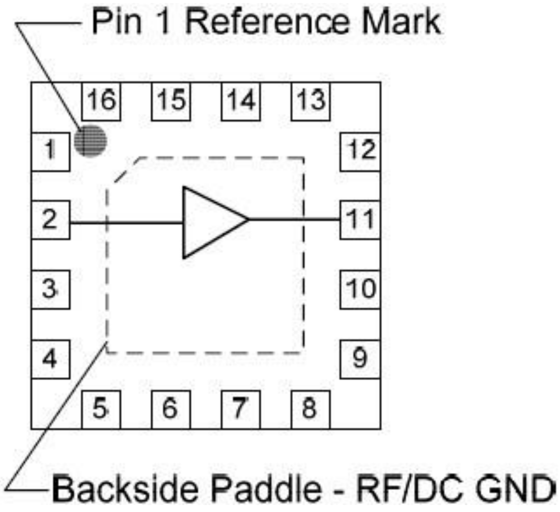


Fig 5.3.2: Functional Block Diagram of LNA

5.3.3 High Linearity Amplifier (TQP7M9102)

The TQP7M9102 is a high linearity driver amplifier in a low-cost, RoHS compliant, surface mount package. This InGaP/GaAs HBT delivers high performance across a broad range of frequencies with +44 dBm OIP3 and +27.5 dBm P1dB while only consuming 135 mA quiescent current.

Fig 5.3.3: SOT-89 Package of HLA

The TQP7M9102 incorporates on-chip features that differentiate it from other products in the market. The amplifier integrates an on-chip DC over-voltage and RF over-drive protection. This protects the amplifier from electrical DC voltage surges and high input RF input power levels that may occur in a system. On-chip ESD protection allows the amplifier to have a very robust Class 2 HBM ESD rating [5.4].

5.3.4 Surface Acoustic Wave(SAW) Filter- 897.5 MHz (856671)

The TriQuint 856671 is a low loss RF filter with a center frequency of 897.5 MHz and a bandwidth of 35 MHz. The insertion loss is 1.9 dB and the filter is provided in a small surface mount hermetic package. It is used in the path of uplink SAW filter [5.5].

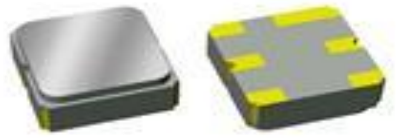


Fig 5.3.4: SMP of 897.5 MHz

5.3.5 Surface Acoustic Wave(SAW) Filter- 942.5 MHz (856528)

The TriQuint 856528 is a low loss RF filter with a center frequency of 942.5 MHz and a bandwidth of 35 MHz. The insertion loss is 2.5 dB and the filter is provided in a small surface mount hermetic package, it is used in the downlink path [5.6].

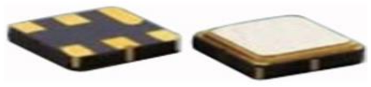


Fig 5.3.5: SMP of 942.5 MHz SAW filter

CHAPTER SIX

Measurement and System Verification

1. Overview
2. Measurement Tools
3. Measurement Procedure
4. Measurement Result

6.1 Overview

In this chapter measurement tools, procedure and results are reported. The system was measured at Alwaha building in central Hebron (2nd floor) where the GSM 900 MHz received signal was already detected as weak.

6.2Measurement Tools

We used a panel antenna with 10dB gain as donor antenna and directional antenna with 10dB gain as service antenna. A feeder coaxial line with loss 0.7dB/10m was used to connect the donor antenna with the repeater hardware and connect the repeater hardware with the service antenna.

Figure 6.2.1: Donor antenna

Figure 6.2.2: Feeder

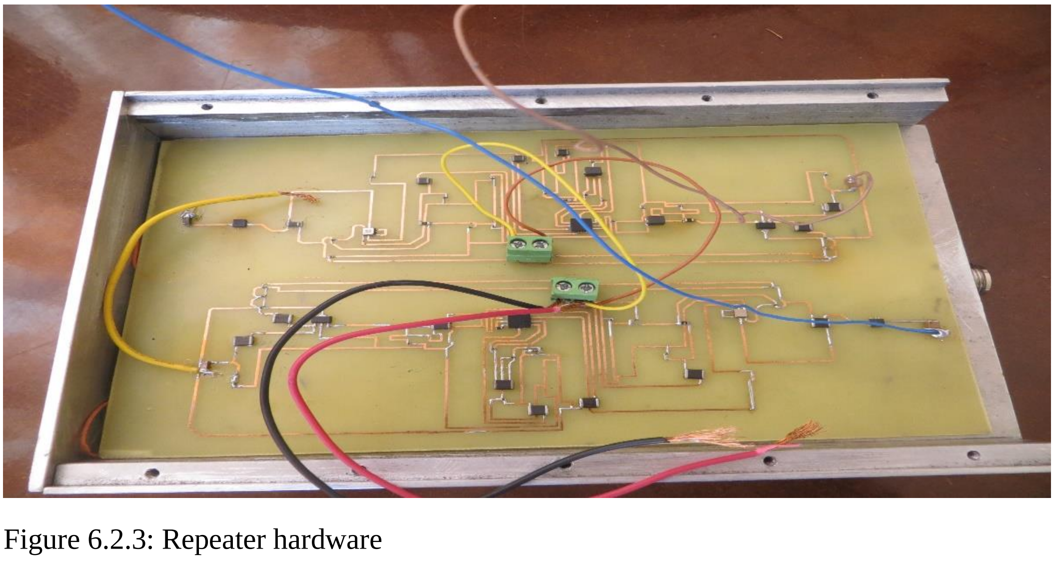


Figure 6.2.3: Repeater hardware

Figure 6.2.4: Service antenna

6.3 Measurement Procedure

The donor antenna was installed outdoor at a 10m distance for the repeater system. The service antenna was installed indoor at a 10m distance for the repeater as well.

We measured the signal power outdoor (using a Galaxy mobile) with an Android operating system. It represented the received power of the donor antenna. The signal power indoor was then measured to represent the output power of the service antenna.

6.4 Measurement Result

Input Power (Pin)	Average output Power (Pout)
-66dBm	-35dBm

To calculate the repeater gain:

Pout = Pin + Gain (repeater) + Gd + Gs – FL – PL – FAF

Gain= Pout – Pin –Gd –Gs+ FL + PL + FAF

Gd: the gain of the donor antenna (10dB)

Gs: the gain of the service antenna (10dB)

FL: feeder loss (0.7dB)

PL: path loss

FAF: floor attenuation factor (12.9dB) [1]

$PL = PL(d0) + 10 * n * \log\left(\frac{d}{d0}\right)$ [1]

d0: reference distance (1m)

PL(d0) = 31.7 [1]

n: mean path loss exponent (2.76 for the same floor) [1]

d: the distance between the service antenna and the measurement place(2m)

PL = 31.7 + 10 * 2.76 *log (2/1)

= 40dB

G = - 45 - -66 – 10 – 10 + 0.7*2 + 45

= 65.3dB

Pout	Pin	Gd	Gs	FL	PL	FAF	G
-35dBm	-66dBm	10dB	10dB	1.4dB	40dB	12.9dB	65.3dB

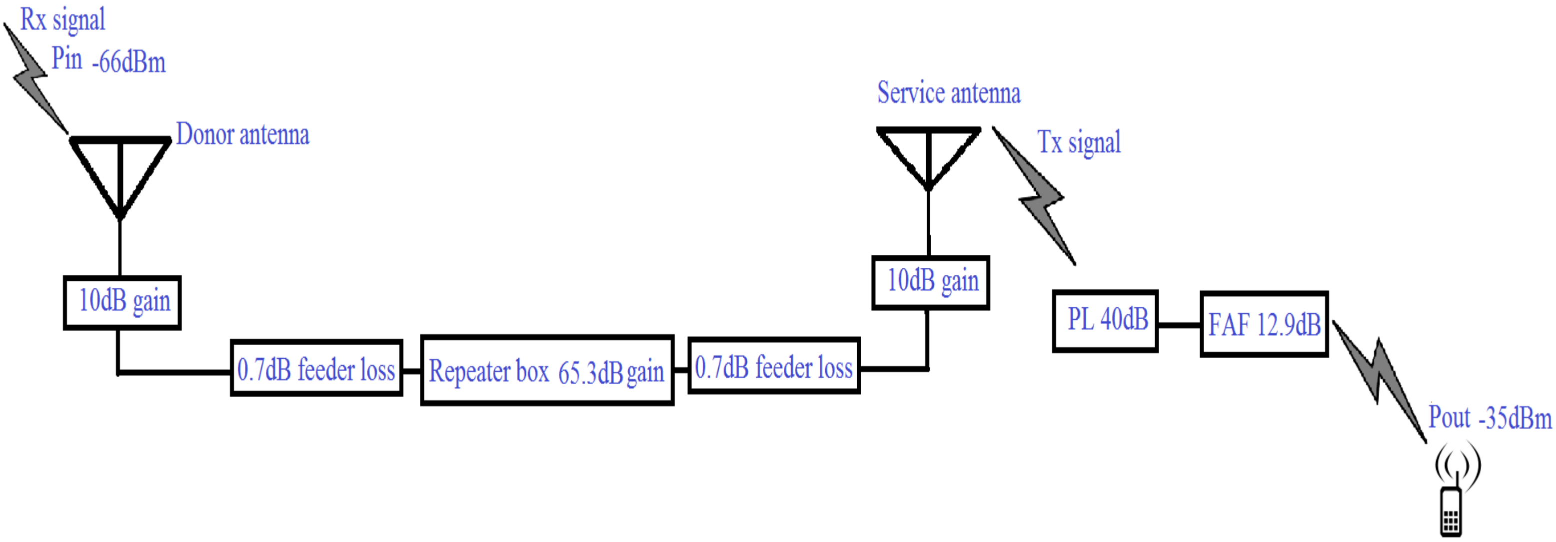


Figure 6.4.1: Gain Block Diagram

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[1.2] ETSI GSM 11.26/ETS 300 609-4.

[1.3] J. L. JIMÉNEZ-MARTÍN 1, V. GONZÁLEZ-POSADAS 1, F. J. ARQUÉS 1, DECEMBER 2009, Dual Band High Efficiency Power Amplifier Based on CRLH Lines, RADIOENGINEERING, VOL. 18, NO. 4, P.567-578

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