Design and Development of Active Antenna for Wireless Communications System

By

GC Qasim Nawaz

GC Muhammad Moaz Raja

GC Hafiz Bilal Zubair Janjua

GC Mian Uzair Ahmed

Supervisor

Asst Prof Dr Maryam Rasool

Submitted to the Faculty of Electrical Engineering, Military College of Signals National University of Sciences and Technology, Rawalpindi in partial fulfillment forth

Requirements of a B.E Degree in Telecommunication Engineering

June 2023

CERTIFICATE OF CORRECTIONS & APPROVAL

Certified that work contained in this thesis titled **"Active antenna for wireless communications System"**, carried out by GC Qasim Nawaz, GC M. Moaz Raja, GC Hafiz Bilal Janjua and GC Mian Uzair under the supervision of Asst Prof Dr Maryam Rasool for partial fulfillment of Degree of Bachelor of Electrical Engineering, in Military College of Signals, National University of Sciences and Technology, Islamabad during the academic year 2022-2023 is correct and approved. The material that has been used from other sources it has been properly acknowledged / referred.

Approved by Supervisor

Asst Prof Dr Maryam Rasool

Dated:____Jun 2023

DECLARATION

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

Plagiarism Certificate (Turn it in Report)

This thesis has ____ similarity index. Turnit in report endorsed by Supervisor is attached

Qasim Nawaz
NUST serial no 00000325603

Hafiz Bilal Janjua
NUST serial no 00000325592

M. Moaz Raja
NUST serial no 00000325054

Mian Uzair
NUST serial no 00000325062

Signature of
Supervisor

Asst Prof Dr Maryam Rasool

Acknowledgements

We must say that the work we have done would be nothing without the will of Allah Almighty Who created us from a clot of congealed blood. This is indeed a great blessing of Allah Almighty who taught us the use of pen and taught us which we knew not. We are highly Thankful to the creator of mankind who helped us on every step and guided us through the right path and made things easy for us to complete this whole project. This is indeed a great blessing of Allah Almighty. Especially, we are thankful to the instructors who guided us throughout this task. It’s the result of their efforts and guidelines that we are standing on this place. And also we cannot forget the day and night prayers of our parents.

We would also like to express special thanks to my supervisor Asst Prof Dr Maryam Rasool for her help throughout this Project. We can safely say that we haven't learned any other engineering subject in such depth than the ones which she has taught.

Finally, we would like to express my gratitude to all the individuals who have rendered valuable assistance to my study.

Dedicated to Allah Almighty (The most compassionate and the Merciful), instructors for their guidance and our parents whose tremendous support and prayers let us to this wonderful accomplishment.

Abstract

Research on multiple antenna systems has been a hot topic in recent years due to demand for higher transmission rate and more reliable link in rich scattering environment in wireless communications.

Our project "Active Antenna for wireless communications system" is an antenna structured for 5G communication. This frequency range involves S-Band (02-04 GHZ) spectrum which have applications in Satellite communication and for high-speed transmission. Also, the S-Band offers greater bandwidth, relieving network congestion. It is less susceptible to atmospheric attenuation. This merit of S-Band radar prevents considerable impairments to electromagnetic signals due to rain, ice, snow. S- Band radar is capable of seeing beyond severe weather conditions, making it useful for civilian and military aircraft navigation. The Antenna provides high speed, lower latency and greater capacity of remote execution. Its simple structure and compact design make it ideal to use in any portable indoor or outdoor applications, which require higher bandwidth to improve itsoverall communication efficiency.

This project is an industry project which is sponsored by NESCOM. The design parameters were optimized, by using the specifications provided by NESCOM.

TABLE OF CONTENTS

Chapter1: INTRODUCTION……………………………………………….……..14

Chapter 2: LITERATURE REVIEW…………………………………………..32

Chapter 3: Antenna Design and Development……………………………......40

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

1G	1st Generation
2G	2nd Generation
3G	3rd Generation
4G	4th Generation
5G	5th Generation

CHAPTER 1

Introduction

1.1 Overview

Active antennas with low noise amplifiers (LNAs) improve signal reception in wireless communication systems. A small active antenna receives the signal and an LNA amplifies it to increase signal-to-noise ratio. This project aims to design and implement a low-noise active antenna for wireless communication systems. This entails designing a compact active antenna, choosing a low-noise amplifier, and integrating them into a system.

Simulation and practical implementation will demonstrate the active antenna with LNA's ability to improve wireless communication signal reception. This project will help design and optimize active antenna with LNA systems for satellite, cellphone, and radar communication [1].

1.2 Objectives

- To design an active antenna with a low noise amplifier for 2.4GHz wireless communication.
- To optimize the design of the active antenna and low noise amplifier system to obtain the highest possible gain and the lowest possible noise figure.
- Simulating the active antenna and low noise amplifier system with the proper simulation software in order to evaluate its performance characteristics.
- To fabricate and test the active antenna and low noise amplifier system in the lab to validate the simulation results.
- To analyze and interpret the simulation and testing results for the active antenna and low noise amplifier system.
- Comparing the performance of the active antenna and low noise amplifier system to that of existing systems and assessing its benefits and limitations.
- To provide recommendations for future research and development.

These objectives will guide your research and assist you in achieving the desired project outcomes. It is essential to explicitly define the project's objectives in order to remain focused and on track throughout its duration.

1.3 Scope

Depending on the specific application of the active antenna with low noise amplifier system, the scope of wireless communication in our project will vary. For a wireless sensor network or Internet of Things application, the scope includes system design, performance evaluation, protocol research, power management, and comparison to other antenna systems [2]. For a Wi-Fi or Bluetooth application, the scope encompasses system design, performance evaluation, modulation scheme research, and comparison to other antenna systems [3].

1.4 Deliverables

The deliverables for our project will include

- A comprehensive design report for the active antenna with low noise amplifier system, including design parameters, optimization procedure, and simulation outcomes.
- A prototype of the active antenna with low noise amplifier system that has been fabricated and tested, along with a test report validating the simulation results.
- A performance analysis report evaluating the gain, directivity, and noise figure of the active antenna with low noise amplifier system.
- A report that compares the efficacy of the active antenna with low noise amplifier system to that of existing antenna systems used for similar applications.
- A report on a wireless communication system that includes, if applicable, a detailed design and performance evaluation of the wireless communication system.
- Presentation of the project's outcomes to a technical audience, emphasizing the project's significant contributions and repercussions.
- Recommendations for additional enhancements and future research that identify prospective enhancement and development areas**.**

1.5 Relevant Sustainable Development Goals

Several Sustainable Development Goals (SDGs) are pertinent to our project on designing an active antenna with low noise amplifier for wireless communication. The SDGs are a set of 17 objectives adopted by the General Assembly of the United Nations in 2015 to end poverty, protect the planet, and ensure peace and prosperity for all.

Among the SDGs pertinent to our endeavor are:

- SDG 9 **-** Industry, Innovation, and Infrastructure: The objective of your project is to design and develop a novel technology solution for wireless communication, thereby advancing infrastructure and innovation [4].

- SDG 7 **-** Affordable and Clean Energy: The optimization of the active antenna with low noise amplifier and the implementation of a power management scheme could result in energy-efficient wireless communication system solutions [5].

- SDG 12 **-** Responsible Consumption and Production: The optimization of the active antenna with low noise amplifier system could result in the development of more sustainable wireless communication systems by reducing power consumption and enhancing data transfer efficiency [6].

- Your initiative could contribute to mitigating climate change and reducing carbon emissions by designing an energy-efficient and sustainable wireless communication system.

- SDG 17 **-** Partnerships for the Goals: Collaboration with industry partners, academic institutions, and other stakeholders could result in the creation of more innovative and sustainable wireless communication solutions [7].

Our initiative contributes to a number of Sustainable Development Goals, particularly in the areas of innovation, sustainable infrastructure, energy, and climate action.

1.6 Structure

Table 1.1 Structure of Thesis

Chapter	**Description**
Introduction	Provides an overview of the project, objectives, scope, and research questions
Literature Review	Reviews the relevant literature on active antennas, low noise amplifiers, and wireless communication systems
Methodology	Describes the methodology used to design, optimize, simulate, fabricate, and test the active antenna with low noise amplifier system
Results and Discussion	Presents the results of the project, including the simulation, testing, and performance evaluation of the active antenna with low noise amplifier system, and discusses their implications
Wireless Communication System	Describes the design and performance evaluation of the wireless communication system, if applicable
Conclusion	Summarizes the project's objectives, methodology, results, and conclusions, and suggests future research directions
References	Lists all the sources cited in the thesis following a standard citation style
Appendices	Includes any additional material relevant to the project but not included in the main text

1.7: Types of Antennas:

Antenna is a device that communicates through Radiowaves. It acts both as receiver and as a transmitter.

1.7.1: Patch Antenna:

- Patch antennas, often called microstrip antennas, are commonly used in wireless communication systems, satellite communication, radar systems, and other applications because of their high performance at microwave frequencies. It is a type of planar antenna where the radiating element (usually a metallic patch) is positioned on top of a grounded substrate [8].

- There are three primary parts that make up a patch antenna's framework:

- **The radiating element:** A thin sheet of metal, usually copper or aluminum that emits electromagnetic radiation. It can be square, rectangular, or round in shape and send out and receive electromagnetic waves.

- The electrical features of an antenna, such as impedance matching and radiation pattern, are determined by the substrate, which is a dielectric material (often fiberglass, ceramic, or other non-conductive materials) that mechanically supports the radiating element. In order to reduce the overall size of the antenna, the substrate is often thinner than the wavelength at which it operates.

- **The ground plane:** A conducting plane used to improve the antenna's radiation pattern and overall efficiency by reflecting electromagnetic waves from the antenna's substrate. As a reference point for the antenna's operation, it is often connected to the ground or a ground plane in the system.

- **Microstrip transmission lines**: Thin strips of metal on the substrate, typically supply power to the patch antenna by linking the radiating element to the feed point. The feed point is where the RF signal is applied or removed, and it can be found either on the patch's edge or in the patch's middle [9].

- Depending on the size, shape, and substrate qualities, patch antennas can be built to function in a wide range of frequency bands. The size and shape of the patch in relation to the ground plane determines the radiation pattern, which can be omnidirectional, directed, or even contoured. For wireless communication applications where weight and size are limits, patch antennas are a great choice due to their compact size, low profile, and ease of manufacture. However, their performance can be hindered by their limited bandwidth and their sensitivity to nearby objects or structures

1.7.2: Dipole Antenna:

- Dipole antennas are commonly used for radio transmission and reception. It has a feed point at the center of a conducting wire or rod half the wavelength of the radio frequency. The word "dipole" comes from its two poles, with the feed point in the middle.

- Depending on the radiation pattern and application, dipole antennas can be horizontal or vertical. When aligned horizontally, it is called a "horizontal dipole," and when vertically, a "vertical dipole"[10].

- Dipole antennas have these parts:

- **Radiating element:** A dipole antenna's radiating element is usually a straight copper or aluminum wire. A "half-wave dipole" is a radiating element that is half the wavelength of the radio frequency. Radiating elements send and receive electromagnetic waves [11].

- **Feed point:** The radiating element's feed point applies or extracts radio frequency signals. The transmission line or receiver connects the two halves of the radiating element at the dipole's center.

- **Balun (optional):** A dipole antenna may use a balun (short for "balanced-unbalanced"). Baluns match the dipole antenna's balanced impedance to the transmission line or receiver's unbalanced impedance, boosting performance and minimizing signal loss [12].

- Dipole antennas are simple, installable, and have a large bandwidth. Radio and television broadcasting, wireless communication, amateur radio, and other wireless communication technologies utilize them. The most common radiation patterns for dipole antennas are omnidirectional in the horizontal plane for horizontally oriented dipoles and doughnut-shaped or bi-directional in the vertical plane for vertically oriented dipoles.

- Dipole antennas are utilized as reference antennas because of their efficiency and adaptability. They are also used to make arrays and Yagi-Uda antennas.

1.7.3 Loop Antenna:

- The most common forms of loop antennas are circles, squares, and rectangles, however other geometric shapes can also be used. It can be used to send or receive radio waves at a wide range of frequencies and for a wide range of purposes, from longwave to microwave.

- The principle of electromagnetic induction is at the heart of how loop antennas function. If an alternating current (AC) is passed through the loop, a magnetic field will be produced and spread outward. The electric field produced by this magnetic field radiates outward from the loop, where it can be picked up by additional antennas for reception or used to send electromagnetic waves into space [13].

- The term "loop antenna" really refers to numerous distinct designs.

- Magnetic loop antennas, or "magnetic loops," are a type of small loop antenna that are often much smaller than the wavelength of the frequency being used. Their small size and great efficiency have made them a popular choice for receiving communications in the HF (high frequency) and VHF (very high frequency) bands [14].

- The LF (low frequency) and MF (medium frequency) bands require larger antennas, hence large loop antennas are frequently employed for transmission and reception in these ranges. They are common in broadcasting and communication systems due to their long range communication capabilities [15].

- The term "loop array" refers to a collection of loop antennas configured in a specific way to produce a certain radiation pattern or level of performance. Multiple loop elements are employed to control the radiation pattern in sophisticated antenna systems like phased arrays.

- The advantages of loop antennas include their compact size, low profile, and reliable performance even in confined areas. Because of their directional radiation pattern, they can also mitigate or even remove interference from specific directions. Loop antennas have a restricted bandwidth, are very sensitive to adjacent objects, and are less efficient than other antenna types.

- Loop antennas find widespread use in a variety of fields, from broadcasting and telecommunications to amateur radio and radio astronomy. When space is at a premium, or when strict performance standards must be met, they are frequently employed.

Classification of Loop Antenna

Generally, loop antennas are classified as follows:

- **Electrically small loop antenna**: The type of loop antenna having a length of wire or circumference of loop less than one-tenth of wavelength is known as a small loop antenna.

Thus, here **$C < \lambda / 10$**

These types of antennas offer small radiation resistance having value even smaller than their loss resistances. So, it offers, poor radiating ability, thus is not considered as good radiators.

Due to this reason these are not used in transmitting applications. Therefore, find uses at the receiving sections, where having a good signal to noise ratio is more important than the efficiency of the antenna.

Irrespective of the shape of the loop, the field pattern of all the small loops is the same as that of infinitesimal dipole having maximum along the plane and null perpendicular to the plane of the loop.

- **Electrically large loop antenna**: When the circumference of the loop is approximately equivalent to free space wavelength then it is referred as an electrically large loop antenna. This means

$C \sim \lambda$

In the case of large loop antennas, the field pattern is such that the null is in the direction of the antenna axis.

The increase in the perimeter or the number of turns in the loop electrically enhance the radiation resistance of the loop. This is so because, with the increase in the length, the circumference approximately reaches wavelength and in that case, the field pattern will vary and the maximum will shift from plane to the axis of the loop.

Applications of Loop Antenna

As we have already discussed that, loop antennas are majorly used for the purpose of receiving the signal. Thus these are mainly used in:

1. Aircraft direction finders.
2. In radio receivers for receiving high-frequency waves.
3. Loop antennas are also used as ultra-high frequency transmitters.
4. In RFID devices, to detect the position of the transmitter.
   So, we can say, that loop antennas along with ease of construction provide the simplicity of operation, thus are widely used.

1.7.4 Array Antenna:

- An array antenna is a special kind of antenna made up of many separate antenna elements configured in a certain configuration. In most cases, these components are similar and work in phase, meaning they receive the same signal and emit a unified pattern.

- Array antennas have several uses, some of which include radio astronomy, radar, satellite communications, and wireless communication systems. Higher gain, enhanced directivity, and the ability to bend and steer the radiation pattern to achieve desired coverage and beamforming capabilities are just a few of the benefits they provide over single-element antennas [16].

- Linear arrays, planar arrays, and conformal arrays are only a few of the array antenna configurations that exist. Antenna elements in a conformal array are placed to follow the contours of a curved surface, like an airplane or a car, while those in a linear array are aligned in a straight line.

- In passive arrays, each element receives its own feed, whereas in active arrays, each element is equipped with its own phase shifters and amplifiers for fine-grained beamforming control. The radiation pattern of an active array can be actively adjusted in real time to account for shifting external circumstances, and the array itself offers more refined beamforming capabilities.

- Array antennas have become an essential part of current wireless communication systems and radar applications due to their increased efficiency, scalability, and adaptability in these areas of operation. They have many practical applications and remain a hotspot for electromagnetics and wireless communications researchers.

1.7.5 Monopole Antenna:

- A monopole antenna is a radio antenna with a single radiating or receiving element, often a vertical conductor. The term "monopole" is used to distinguish this type of antenna from its dipole cousin, which has two poles (a positive and a negative) and hence needs a balanced feed. In addition to their employment in wireless communication and broadcasting infrastructures, broadcast stations, mobile devices, and Radio Frequency Identification (RFID) systems, monopole antennas find utility in a wide variety of other applications [17].

- Different varieties of monopole antennas exist, each with their own unique design and set of desirable features. The following are examples of typical monopole antennas:

- With a quarter-wave monopole antenna, the ground plane acts as a virtual "mirror" to reflect the radio waves up the vertical conductor. It's a typical and straightforward layout for monopole antennas, making it suitable for applications as diverse as automobile antennas and hand-held radios.

- Forgoing the need for a ground plane is the half-wave monopole, which consists of a vertical conductor that is half a wavelength in length. It's often seen in portable electronics like walkie-talkies, radios, and mobile phones, where it goes by the name "whip" antenna.

- This top-loaded monopole antenna is physically shorter than a standard monopole but is "top-loaded" with capacitance to boost its performance and produce resonance. It is commonly employed in indoor antennas and antennas for embedded devices, two types of antennas that have minimal space requirements.

- It is possible to send or receive electromagnetic waves in a uniform spherical pattern with an omnidirectional monopole antenna, as the name implies. Wi-Fi routers and base stations use it frequently because of the need for widespread coverage in wireless communication networks.

- Monopole antennas are widely used because of their many practical benefits, including their straightforward construction, straightforward installation, and omnidirectional emission pattern. However, there are constraints that must be taken into account while designing and deploying these systems, including low bandwidth and low efficiency.

1.7.6 Microstrip Antenna:

- Microstrip antennas, a form of printed antenna popular in today's communication systems, excel at transmitting signals in the microwave and millimeter-wave ranges. Small and unobtrusive, this antenna features a ground plane opposite a conducting patch on a dielectric substrate. Microstrip antennas can be called patch or planar antennas as well.

- A microstrip antenna consists of a conducting patch that can be either rectangular, circular, or another shape, and is fed by a coaxial cable or other feedlines at a predetermined place on the patch. The radiation pattern, impedance matching, and bandwidth of an antenna are all set by its dielectric substrate, which is often a low-loss material like FR-4 (a type of printed circuit board material).

- The many benefits of microstrip antennas include:

- Since microstrip antennas are flat and thin, they can be easily integrated into compact devices like smartphones, tablets, and wireless sensors. They are easily printable on a printed circuit board, which streamlines production.

- Because of its flat, planar construction, microstrip antennas are ideal for uses where every ounce counts, including in aerospace and satellite systems.

- Microstrip antennas can easily be designed for multiband operation by using different resonant modes of the patch or by adding additional patches on the same substrate, allowing them to operate over a broad frequency range, from microwave to millimeter-wave bands.

- Microstrip antennas, depending on the form and feeding processes employed in the patch design, can have either omnidirectional or directed radiation patterns. That's why you can use them for things like satellite communication, radar, and wireless networks.

- Microstrip antennas can be tailored to the needs of a given application through a variety of design parameters, including patch shape and size, substrate material and thickness, feeding method, and ground plane configuration.

- Microstrip antennas have a number of advantages over other antenna types, but they are also susceptible to surface wave losses and have a low radiation efficiency in comparison to other antenna types. These restrictions can be overcome with the help of good design and optimization practices.

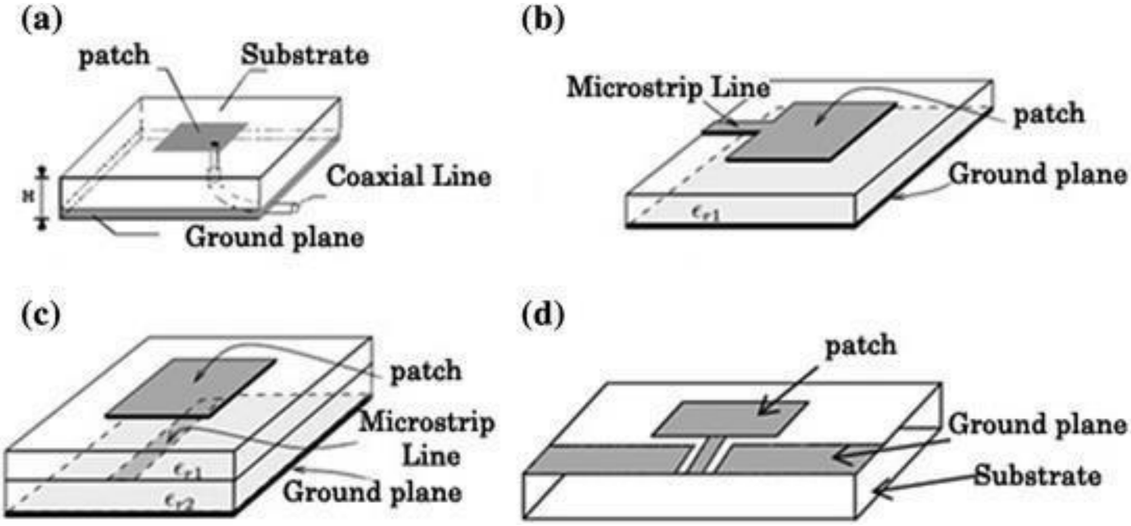


Fig 1.1 Different elements of micro strip antenna

Micro strip antennas can be bent and shaped to fit any surface, flat or curved, and they weigh very little. When installed, it requires relatively little space in the framework. With today's printed circuit technology, they may be made with ease and at little cost. Patch antennas, however, have several drawbacks. Low efficiency, narrow bandwidth of less than 5%, and low RF power due to the small gap between the radiation patch and the ground plane are the main drawbacks of the micro strip antennas, making them unsuitable for high-power applications.

There are many methods of feeding a micro strip antenna. The most popular methods are:
1. Micro strip Line.
2. Coaxial Probe (coplanar feed).
3. Proximity Coupling.
4. Aperture Coupling.

1.8: Type of Antenna due to direction:

There are numerous varieties of antennas, each of which can be classified according to the radiation pattern or directionality that they exhibit. According to their degree of directional sensitivity, the following are some typical types of antennas.

1.8.1: Omni- Directional Antenna:

The electromagnetic radiation from and received by an Omni-directional antenna is uniformly distributed in all directions, giving the antenna a spherical radiation pattern. It's made to send and receive signals in all directions without favoring any one over the others.

When the transmitter or receiver needs to communicate with devices in different directions without having to adjust the antenna's orientation, an omni-directional antenna is typically used. This includes a wide variety of wireless communication systems, radio and television broadcasting, cellular networks, Wi-Fi networks, and other wireless communication systems. They are typically utilized when a large coverage area is sought or when the transmitter's or receiver's location is unpredictable.

Many different types of vertical antennas (e.g., quarter-wave and half-wave vertical antennas), dipole antennas, collinear antennas, and helical antennas, are all examples of Omni-directional antennas. Depending on the needs of the application, they can operate in a variety of frequency ranges, from very low frequencies (VLF) to very high frequencies (EHF).

Omni-directional antennas are advantageous because of their 360-degree coverage, making them ideal for situations requiring simultaneous signal reception or transmission in several directions. However, their range and signal strength may be constrained in comparison to that of directional antennas, which are built to concentrate the signal in a single location. Coverage area, range, interference, and other factors all play a role in deciding whether an omnidirectional or directional antenna is the better fit for a given application.

1.8.2: Directional Antenna:

A directional antenna, often called a directional aerial or simply a "beam antenna," is an antenna that sends and receives radio waves in a predetermined direction and pattern. In contrast to omnidirectional antennas, which send and receive signals in all directions with equal strength, directional antennas boost the signal in one direction while weakening it in others.

A few of the many uses for directional antennas are:

In wireless communication systems including Wi-Fi networks, cellular networks, and point-to-point microwave communications, directional antennas are frequently utilized. They can be used to improve signal quality in a certain direction, extend the range of a wireless network, or create long-distance connections between two places.

Broadcasting uses directional antennas to direct a signal from a transmitter to a designated coverage area or target area for television and radio transmissions. The goal of their design is to increase signal strength and decrease interference by focusing the transmitted signal in a single direction.

The use of directional antennas is crucial to the operation of radar and satellite communication systems. Air traffic control, weather observation, and military surveillance are just few of the many uses for radar antennas. Television broadcasting, internet access, and remote sensing are just few of the many uses for satellite communication antennas.

In the world of amateur radio, directional antennas are frequently utilized for long-distance communication. Yagi-Uda antennas, log-periodic antennas, and dish antennas are all common forms of directional antennas used in amateur radio.

Directional antennas can be found in a wide variety of forms, including the Yagi-Uda, patch, parabolic, and horn antennas. The coverage pattern, operating frequency, and environmental circumstances at the installation site are all important considerations when settling on a directional antenna. An perfectly pointed directional antenna can provide the coverage and signal strength you require, but only if it is installed and aligned correctly.

1.9 Micro strip Patch Antenna:

1.9.1 History

- Due to its small size, low profile, and simple integration with other electrical components, the micro strip patch antenna is widely utilized in today's wireless communication systems. The advent of printed circuit boards (PCBs) and microwave integrated circuits (MICs) in the early 1950s marks the beginning of the era of the micro strip patch antenna.

- Researchers and engineers in the electronics sector in the 1950s and 1960s looked into new methods of designing antennas that could be combined with PCBs. An important development in this area was the introduction of planar antennas, which may be mounted flat on a PCB. Because of this, micro strip transmission lines, a special kind of transmission line that may be printed as a trace on a PCB, were created.

- The micro strip transmission line is made up of a ground plane and a small strip of conductor on top of a dielectric substrate. Micro strip patch antennas are basic, compact planar antennas made by adding a radiating element, such as a patch of conductor, to the top surface of the micro strip transmission line.

- Due to their compact size and simple integration into electronic systems, the earliest microstrip patch antennas found their primary use in military applications like radar systems. The development of microwave technology and the increasing need for wireless communication systems in the civilian sector led to the widespread adoption of micro strip patch antennas for use in a wide variety of commercial applications, including cellular telephones, satellite communications, wireless routers, and radio frequency identification (RFID) systems.

- Improvements in bandwidth, gain, efficiency, polarization, and radiation pattern are just some of the ways that microstrip patch antenna design has evolved over the years thanks to the hard work of academics and engineers. Microstrip patch antennas' performance can be improved by experimenting with different patch shapes and sizes, such as rectangular, circular, triangular, and elliptical.

- Microstrip patch antennas are already commonplace in everything from consumer electronics to aerospace and defense systems that rely on wireless communication. They remain a hotspot for innovation in the realm of wireless communication, with researchers always seeking to boost their capabilities and broaden their use cases.

1.9.2 Introduction to Patch Antenna:

Patch antennas are an important topic of study and development in the fields of antennas and RF engineering, despite their widespread usage in a variety of wireless communication systems due to its adaptability and performance qualities.

- Typically, a patch antenna will have a metallic radiating element printed on a dielectric substrate in the shape of a square or rectangle. Supporting the radiating element mechanically and separating it from the ground plane, a conducting surface positioned below the substrate, is the substrate, which is typically a thin, flat, and insulating material like fiberglass or ceramic [18].

- A feed mechanism, often a coaxial wire or a microstrip transmission line, linked to the edge or corner of the patch excites the radiating element of a patch antenna. An antenna's ability to send and receive radio waves is made possible by the electromagnetic field produced when an RF signal is delivered to the feed and causes an oscillating current on the patch.

- Patch antennas are planar antennas because they can be easily integrated with other electronic components since they sit flat on a surface like a printed circuit board (PCB) or a ground plane. Because of the common practice of printing the metallic patch and the feed structure on a PCB as a trace, these antennas are sometimes referred to as microstrip antennas.

- Depending on the size and shape of the patch, as well as the qualities of the dielectric substrate, patch antennas can be built to function at a wide range of frequencies, from very low frequencies (VLF) to very high frequencies (EHF). Mobile communication, satellite communication, radio frequency identification (RFID) systems, wireless local area networks (WLANs), and a plethora of other wireless communication applications all benefit from their utilization.

- The benefits of patch antennas are their compact design, low profile, quick integration, and straightforward production. There are, however, drawbacks to these antennas that make them less desirable than other options. Despite this, patch antennas continue to be a hotspot for innovation in the antenna and RF engineering communities, and they find widespread application in a variety of wireless communication systems thanks to their adaptability and strong performance.

1.9.3 Main Constituents:

A patch antenna typically consists of several key constituents, which work together to enable its operation. These constituents include:

Radiating element: The metallic patch that is in charge of sending or receiving radio frequency (RF) waves is known as the radiating element. It is often printed on a substrate made of dielectric material and can take on a variety of shapes, including square, rectangular, circular, or elliptical, depending on the radiation properties and frequency of operation that are needed.

Dielectric substrate: The dielectric substrate is an insulating material that is flat, thin, and offers mechanical support to the radiating element. Additionally, the dielectric substrate contributes to the determination of the electrical properties of the antenna. To attain the appropriate level of electrical performance from the antenna, the substrate is often constituted of high-dielectric-constant materials like fiberglass, ceramic, or polymer, and its thickness is purposefully tailored to meet these requirements**.**

The ground plane: It is a conducting surface that is positioned below the dielectric substrate. It acts as a reference point for the radiating element and is known as the ground plane. It does double duty as a reflector in addition to assisting in the antenna's overall radiation pattern shaping. In an antenna system, the ground plane is often bigger than the radiating element and is frequently connected to the system ground or the common reference point.

Feed Mechanism: The term "feed mechanism" refers to the component of the antenna that is in charge of feeding RF signals to the antenna as well as stimulating the radiating element. It is typically attached to the edge or the corner of the patch and can take on a variety of forms, such as a waveguide, a microstrip transmission line, or a coaxial cable. In some cases, it is also connected to the center of the patch. The performance of the patch antenna is susceptible to being significantly influenced by the design of the feed mechanism as well as its placement.

1.10. Types of Amplifier:

Amplifiers are electronic devices that are used to raise the amplitude or strength of a signal, most commonly an electrical voltage or current. Amplifiers can also be used to increase the frequency of the signal. There is a wide variety of this component, each of which can be utilized in a variety of contexts and displaying its own set of features. The following are examples of some of the most common kinds of amplifiers:

1.10.1. Low Noise Amplifier:

- A low noise amplifier (LNA) is a type of amplifier that is intended to amplify weak signals with a relatively low amount of additional noise. LNAs are most commonly utilized in communication systems like radio receivers, satellite communication systems, and wireless communication systems. This is because the incoming signals are frequently weak and require amplification prior to any further processing. The fundamental purpose of a low noise amplifier, or LNA, is to give high gain while maintaining a low noise figure. The noise figure is a measurement of the additional noise that is produced by the amplifier.

The following are some of the most important qualities of a low noise amplifier:

- A low noise figure is a measurement of the additional noise that is produced by an amplifier, and it is given in decibels (dB). LNAs are developed to have low noise figures, often below 3 dB, in order to decrease the signal-to-noise ratio (SNR) degradation that can occur as a result of the weak signals that are brought into the system.

- High Gain: Low-noise amplifiers (LNAs) are engineered to deliver a high voltage or current gain, often in the range of 10 to 30 dB, to amplify weak signals to a level that can be efficiently processed by following stages in the system. This enables the weak signals to be transmitted over longer distances.

- High Input Impedance: Low Noise amplifiers (LNAs) often have high input impedance, which assists in minimizing the loading impact on the input signal source and enables effective signal transfer without loss of signal intensity. LNAs are also known as low noise amplifiers.

- Operation in Either Wideband or Narrowband LNAs can be built for either wideband or narrowband operation, depending on the requirements of the particular application being used. Narrowband LNAs are tuned for a certain frequency band, but wideband LNAs are meant to work across a broad frequency range. Wideband LNAs are more versatile. Low Power Consumption Because LNAs are frequently used in portable or battery-powered devices, having a low power consumption is an essential feature to look for in these types of devices. LNAs are often developed with an emphasis on conserving energy and reducing overall power consumption, all while preserving the appropriate level of performance.

- High Linearity: LNAs may also be required to provide high linearity, particularly in communication systems where the signals may be prone to interference or distortion. This is especially true in situations where the signals may be distorted. Signal distortion can be avoided, and the quality of the received signals can be preserved, by using LNAs with a high linearity.

- Stability and Reliability: LNAs are normally designed to be stable and reliable over a wide range of working circumstances, including temperature, humidity, and voltage changes. This is a design goal that is typically pursued while the LNAs are being developed.

- Integrated circuits (ICs), bipolar junction transistors (BJTs), and field-effect transistors (FETs) are some examples of the different types of circuit topologies and technologies that can be utilized to build low-noise amplifiers (LNAs). The individual application requirements, such as frequency range, noise figure, gain, power consumption, and cost, should guide the selection of an LNA design.

1.10.2 Power Amplifiers:

Antennas, speakers, motors, and other high-power loads can be driven with the help of power amplifiers, which are electronic devices that increase the input signal's power level. Audio amplification, RF (Radio Frequency) amplification, wireless communication systems, radar systems, and many more applications all rely on power amplifiers to boost weak signals to usable levels.

A power amplifier's primary purpose is to boost the intensity of a weak input signal while keeping the waveform and other features of that signal unchanged. Gain, efficiency, linearity, bandwidth, and output power are the typical metrics used to classify power amplifiers. A few examples of power amplifiers are:

- Amplifiers based on bipolar junction transistors (BJTs) are able to switch between common emitter (CE), common base (CB), and common collector (CC) modes, all of which are semiconductor devices. BJT amplifiers are widely utilized in audio amplifiers and RF amplifiers due to their great linearity.

- Amplifiers based on field-effect transistors (FETs) require a voltage to be applied to the transistor's gate terminal in order for the device to function. RF amplifiers, particularly low noise amplifiers (LNAs) for communication systems, frequently employ FET amplifiers due to their high input impedance, low noise, and excellent stability.

- Electron devices (triodes, tetrodes, and pentodes) that operate in a vacuum to amplify signals are at the heart of vacuum tube amplifiers. Vacuum tube amplifiers are widely employed in high-fidelity audio amplifiers and some RF amplifiers due to their high output power capability.

- Audio amplifiers and some RF amplifiers benefit greatly from Class D amplifiers because of their high efficiency and the switching mechanisms they employ. Class D amplifiers are widely employed in battery-operated gadgets and other contexts where minimizing power consumption is crucial.

- Integrated circuit (IC) amplifiers are constructed utilizing semiconductor chips that combine a number of functional elements into a single package. Audio amplification, radio frequency amplification, and other uses requiring powerful signal amplification at high frequencies all make extensive use of integrated circuit amplifiers.

- Depending on the biasing and efficiency of the amplifier, power amplification can be classified as Class A, Class B, Class AB, or Class C. Power amplifier output power, efficiency, linearity, distortion, and cost are all factors to consider while deciding on a model and class. A power amplifier's ability to boost a signal to a level where may be used to drive a load reliably and efficiently is essential to the proper functioning of many electronic systems.

1.10.3 Current Amplifiers:

A current amplifier is an electronic circuit that takes in an electrical signal and outputs a version of that signal with its current amplified by some predetermined factor. Current amplification of an input signal describes the phenomenon. A continuous signal or a time-varying waveform can be input. The voltage component of the input signal should remain unaltered by the current amplifier during this procedure. The schematic for a common current amplifier is shown below.
Current magnitude as a function of time is represented by the waveforms at the input and output terminals. Take note of how a constant multiplier is applied to the stretched waveform at the output.

Ideal current amplifier properties:

- An amplifier's theoretical behavior must be specified by a set of rules/characteristics before it can be designed. These desirable qualities are as follows:
- Current gain (Ai) of an amplifier must be consistent across its entire input signal range.
- Temperature and humidity shouldn't affect the gain of the modern amplifiers.
- The current amplifier's input impedance (the effective resistance between the terminals) should be set to zero.
- The current amplifier's output impedance (the effective resistance between the terminals) must be infinite.
- Current amplifiers cannot achieve the ideal impedance stated above under realistic conditions. However, they serve only as guidelines for creating current amplifier circuits that come close to ideal. Both the theoretical model of a current amplifier and its practical counterpart are shown in the diagram below.

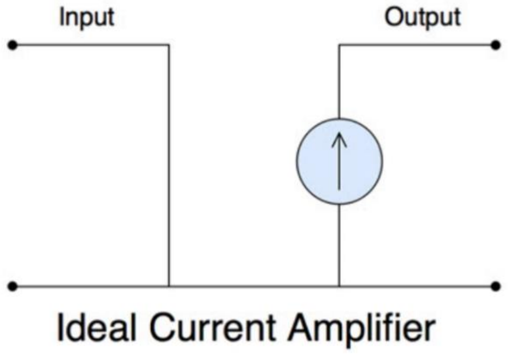


Figure 1.2 Ideal Current Amplifier

Uses for Currently Available Amplifiers:

Here are a few examples of how modern amplifiers are put to use:

- To improve the bass output of amplifier systems, current amplifiers are often employed to increase the power with which the speakers are pushed.
- Many modern industrial manufacturing systems, such as laser and water jet cutting machines, use current amplifiers with variable gain to regulate the intensity of the fabrication process.

Current amplifiers are used to boost weak input signals in sensor systems so that they can be used in succeeding circuits [19].

1.11: Low Noise Amplifier

1.11.1: History:

Lee De Forest improved upon his 1906 Audion, a two-element vacuum tube amplifier, and patented a new design with three elements in 1907 [US Patent 879532]. The Audion was effective as an amplifier. However, the principle of the genuine vacuum tube was not discovered until around 1912, when other researchers were striving to extend the audion's lifespan. The need to differentiate it from other generic types of vacuum tubes led to the later adoption of the name triode. The term "triode" is reserved for completely devoid-of-air vacuum tubes. The triode was also independently invented by an Austrian named Robert von Lieben. Electronic innovations including radio, television, radar, high-fidelity sound reproduction, the telephone, analog and digital computers, and industrial process management would not have been possible without vacuum tubes.

In 1925, Canadian physicist Julius Edgar Lilienfeld patented the first FET [US patent1745175], then in 1926 and 1928, he patented the FET in the United States [US patents 1900018 and 1877140]. Patent GB 439457 was issued to German inventor Oskar Heil in 1934 for a device with similar functionality. However, no experimental devices were created because the technology was not available at the time. In 1947, physicists John Bardeen, Walter Brattain, and William Shockley led a team to design the bipolar junction transistor (BJT) at Bell Telephone Laboratories. Germanium (Ge) was used in the creation of the gadget. The first transistor pocket radio, the TR-1, was released in 1954, and it used a 22.5-volt battery to power 4 Ge transistors for a playback time of nearly 20 hours. In the twenty years that followed, transistors replaced tubes in practically all applications save those requiring extremely high power [20].

Parametric amplifiers are another type of low-noise amplifier (LNA) that finds widespread application in fields such as radio astronomy, long-distance space and satellite communication, and radar. In order to create a negative resistance amplifier, this circuit employs a varactor diode pushed by a high frequency source. Due to the FET's improved low noise figure and its ability to operate at extremely low temperatures with ultra-low noise temperatures, it has largely supplanted the parametric amplifier in recent years.

After the discovery of the bipolar transistor effect, it took some time for a semi-conducting FET device (the junction gate field-effect transistor) to be manufactured commercially. The MOSFET (metal-oxide-semiconductor field-effect transistor), first suggested by Dawon Kahng in 1960, will ultimately replace the JFET and have a more far-reaching influence on electronic development. Long anticipated by Lilienfeld, Heil, Shockley, and others, the first successful insulated-gate field-effect transistor (FET) was created in 1959 by M. M. (John) Atalla and Dawon Kahng at Bell Labs by overcoming the "surface states" that prevented electric fields from penetrating the semiconductor material.

Elements in the III, IV, and V groups of the periodic table are semiconductors utilized in transistors. The manufacture of the field-effect transistor (FET) in GaAs, InP, and GaN has been made possible by developments in semiconductor processing, and these materials have also been used to create heterostructures that have resulted in the HEMT, PHEMT, and MHEMT [21].

1.11.2: Introduction:

Low noise amplifiers, often known as LNAs, are electronic components that are able to amplify signals that are extremely weak and supply voltage levels that are appropriate for analog-to-digital conversion or additional analog processing.
They are utilized in applications that need the use of low amplitude sources such as a wide variety of transducers and antennae. The performance of the measuring system is dominated by the gain and noise that are introduced by the first stage when dealing with weak sources. As a result, the selection of an appropriate LNA is absolutely necessary to ensure the successful operation of the experimental setup.
The gain of an LNA is defined as the ratio of the power of the output signal to the power of the input signal. The gain of an LNA needs to be fine-tuned so that the signal is amplified just enough without adding too much noise. The noise figure quantifies the amount of noise introduced into the signal by the amplifier; a smaller noise figure indicates less noise introduction by the amplifier.

To ensure that the amplified signal is in good shape for transmission to the next step of the system, LNAs may also have filtering and impedance matching components. Filters can be employed to get rid of extraneous frequencies, and impedance matching components make sure the LNA's input and output impedances are compatible with the source and load [22].

Bipolar junction transistors (BJTs), field-effect transistors (FETs), and other amplifier types can all be used to create LNAs. The gain, noise figure, and power consumption requirements of the amplifier will inform the decision of which technology to use.

The LNA is essential to communication systems because it boosts weak signals while cutting down on noise, allowing for clear communication even at great distances.

1.11.3: Specifications:

The specifications of low noise amplifier are shown below

The weak signal received by the receiver component from the antenna in a communication system requires amplification. Low Noise Amplifiers (LNAs) are the key component for achieving this amplification. A number of metrics, including gain, noise figure, chip area, linearity, power consumption, and bandwidth, can be used to characterize this amplifier.
The following block diagram depicts the low noise amplifier. Using a common gate amplifier, active inductor, and common drain stage, a low noise amplifier can be designed. In order to achieve the optimum input and output matching, common gate amplifiers are typically utilized at the input stage and common drain amplifiers are typically used at the output stage. [23]Gain and noise figure are two of the features that the low noise amplifier must have, but other factors such as power supply, bandwidth, chip area, and linearity are more important in making a final decision.

Gain:

In order for the receiver to be able to process the amplified signal, the gain of the LNA must be high enough. Typically, the gain of an LNA will be between between 10 and 30 dB (decibels).

Noise Level:

The noise figure is the ratio between the total noise power from the output and the noise power from the input. The noise figure is a measure of an amplifier's performance. Typical signal generators or noise generators are typically used to measure the noise figure, which describes the noise performance of an RF system. When the noise figure is small, the RF system operates more efficiently.

The incoming signal and any background noise are both amplified by a low noise amplifier. In addition, the low noise amplifier contributes noise to the final product. The S/N ratio drops as a result. The noise floor of a high-quality LNA is typically below 1.5 dB

Linearity:

A low noise amplifier's linearity is the degree to which it can boost a signal without distorting it. Assuming a linear output stage, the dB of power output is equal to the product of the input signal and the gain.

An LNA's linear operation is attained when its input signal is -60 dBm in amplitude. Once the LNA's input signal reaches 0 dBm, however, the LNA becomes nonlinear, the output signal becomes distorted, the gain drops to 10 dB, and the amplitude of the output signal is merely +5 dBm.

1.12 Problem Statement

Wireless communication systems that rely on passive antennas have limited gain, restricted bandwidth, and high levels of background noise. Our goal is to design and implement a low noise amplifier(LNA) for use in wireless communication that not only overcomes these restrictions but also meets other design requirements like size, cost, and power consumption by virtue of its high gain, low noise figure, and wide bandwidth.

1.13 Proposed Solution

An active antenna coupled with a low noise amplifier (LNA) is presented as the answer for this project. The active antenna will have a low noise and high gain, and it will be designed to work at a frequency of X GHz. An active antenna’s performance will be modeled and optimized using stimulation tools before a hardware prototype is built and tested. Gain, noise figure, bandwidth, and radiation pattern are just a few of the metrics we’ll use to access the active antenna’s effectiveness. The success of this endeavor will establish that wireless communication systems can effectively employ active antennas in conjunction with LNAs, opening the door for further development of active antenna design and implementation.

CHAPTER 2

Literature Review

2.1: ACTIVE INTEGRATED ANTENNA WITH LOW NOISE AMPLIFIER DESIGN AT 5 GHz

For use in wireless communication, a 5 GHz Active Integrated Antenna with Low Noise Amplifier (ALNA) has been designed and built. The low noise figure was accomplished by combining a dual-layered micro strip near proximity coupled patch antenna operating at 5 GHz with a low noise amplifier. The measured results show that the active device has a bandwidth of around 10%, a noise figure (NF) of 1.22 dB, an excellent return loss of larger than 12 dB, and good impedance matching. This paper details the approach, simulations, and experimental operations that were undertaken to reach the aforementioned goal. The best possible layout and outcomes were simulated with LINC2 and Microwave Office software.

Thinking about the design

Antenna design heavily relies on picking the right substrate. To maximise efficiency, bandwidth, and radiation from the antenna, a thick (t1) substrate with a low permittivity is required, whereas a thin (t2) substrate with a high dielectric is required to reduce unwanted radiation and coupling [24]. The patch is made from FR4 substrate (6r1 = 2.33, tl= 125 mils) and the feedline, which is part of the LNA circuitry, is made from FR4 substrate (6r2 = 4.7, t2= 63 mils) from the Rogers Corporation.

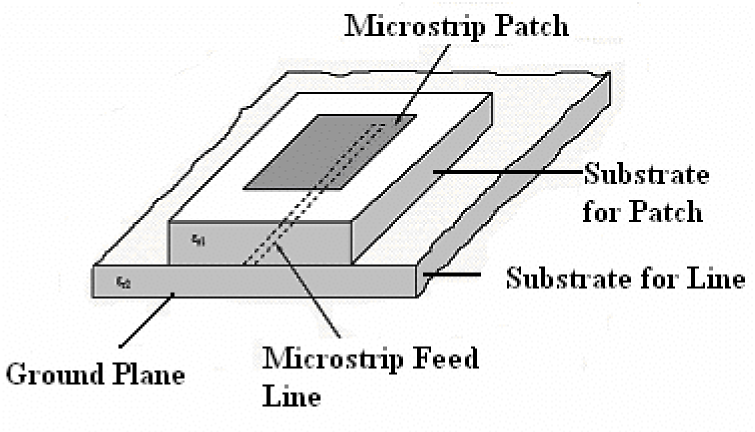


Fig 2.1 Proximity coupled Antenna

2.2: Rectangular Microstrip Patch Antenna Array for RFID Application Using 2.45 GHz Frequency Range

For an RFID reader in the microwave frequency range, this research discusses the design and execution of a 22-element microstrip phased antenna array. The fundamental goal of this work is to optimise the dimensions of patch antennas to achieve a resonance frequency of 2.45 GHz. The microstrip patch antenna, different feeding strategies, and the phased array antenna are only some of the examples of state-of-the-art microwave antenna designs that we analyse and contrast [25]. Compared to a conventional microstrip patch antenna, which has a greater beamwidth, investigations have demonstrated that a phased antenna array, which is the reception antenna of a commercial reader system, delivers higher RFID system coverage. The radiation pattern, return loss, and VSWR of the antenna are simulated with MATLAB code, and then plotted with SONNET software. The observed and modelled antenna performance also correlates well with real-world performance.

By exciting a single square patch with a new asymmetrical slot and two separate truncated corners, the authors of this study offer a compact design of a circularly-polarized (CP) micro strip antenna that accomplishes dual band for WiMAX applications. The antenna can be easily and cheaply manufactured, and its impedance bandwidth of 7.2% over both bands is more than adequate.

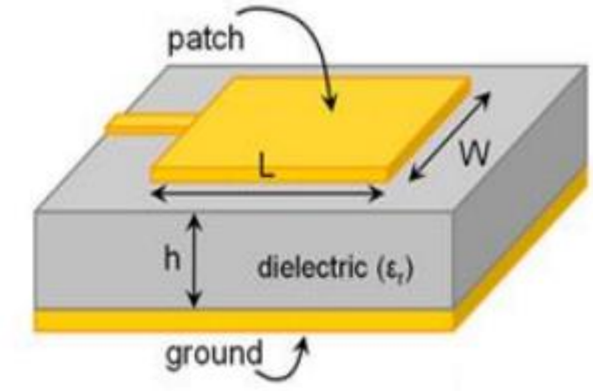


Fig. 2.2 Antenna Design

2.3: PERFORMANCES ANALYSIS OF LNA-ANTENNA CO-DESIGN FOR UWB SYSTEM

Here, we discuss ultra-wideband (3.1-5.1 GHz) co-design of an antenna and Low Noise Amplifier (LNA). In order to maximise performance within a fixed power budget, the key principle of co-design is to eliminate the need for a perfect 50 Q impedance match between the LNA and the antenna. On the LNA side, the co-design is advantageous since it allows for the elimination of many of the expensive integrated passive parts in the matching circuit. The co-designed LNA is more efficient in terms of size, cost, and noise figure. There is now no requirement for a constant and realistic input impedance at the antenna's input across the whole frequency spectrum. This is the moment where the dimensions are scaled down. The strategy used to quantify the performance boost is a comparison between a traditional 50 Q antenna design and a co-designed active antenna design using the same LNA architecture, power usage, and antenna type.

Strategic Co-Design The central concept is to optimise the entire system by "simultaneously" designing the LNA and the antenna. First, it will be necessary to connect the two separate groups of designers and the resources they use. The impedances predicted by the EM simulator (CST MWSR) for the antenna and the impedances estimated by the circuit design tool (ADSR) for the LNA are practically interfaced by a joint simulation platform (ADSR). The complex impedance profile vs frequency was then carefully tailored by adjusting a handful of carefully chosen parameters for each parts. Parametric co-simulations are run by an algorithm [26].

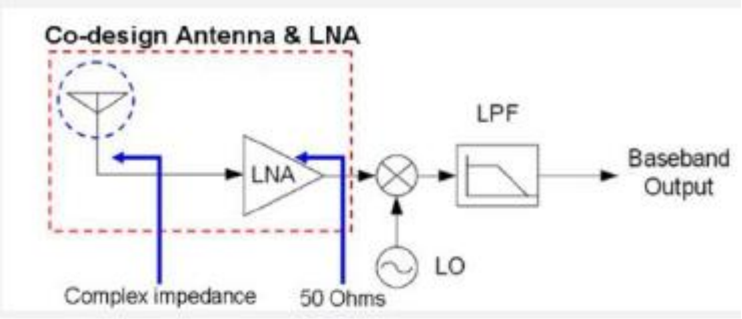


Fig 2.3 Co-design of Antenna LNA

2.4: A New Design of Dual-Port Active Integrated Antenna for 2.4/5.2 GHz WLAN Applications

In this paper, we introduce and describe a novel design for a microstrip active integrated antenna (AIA) that takes the form of a dual-port monopole-slot antenna. Due to its dual-port design, the primary designed passive antenna is compatible with both the 2.4-2.84 GHz and 5.15-5.35 GHz WLAN bands. Filtering structures at appropriate frequencies are implemented in the form of a coupling sleeve-arm and an inverted T-shaped slot on the ground plane of the antenna, respectively, to minimise the transmission coefficient between the two ports of the antenna. With the addition of a power amplifier (PA) and a low noise amplifier, the suggested passive two-port antenna becomes a dual port microstrip AIA that can function as a full-duplex transceiver in the WLAN frequency bands in which it operates. Both passive and active antennas have been measured, and the findings confirm that the designed antennas emit in the expected ways at the operating frequencies.

DESIGN AND SETUP OF A PASSIVE DUAL-PORT ANTENNA

We report the improved design parameters for the suggested dual-port monopole-slot-like micro strip passive antenna arrangement. Ansoft Simulation Software's High Frequency Structure [27] is used to generate the simulation results.

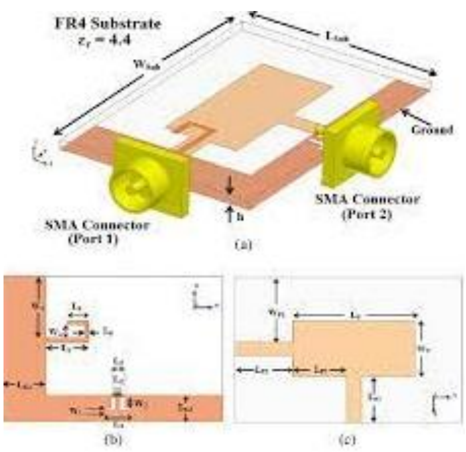


Fig 2.4 The Geometry of the proposed passive dual-port antenna: (a) side view, (b) bottom view, (c) top view

2.5: Reconfiguring UWB Monopole Antenna for Cognitive Radio Applications Using GaAs FET Switches

Here we introduce a revolutionary ultra-wide band (UWB) tiny strip monopole antenna with a switchable multiband capability. To provide reconfigurability, numerous stubs of varying lengths are connected to the monopole's main feed line through GaAs field effect transistor (FET) switches. The antenna is small and versatile in that a variety of reconfiguration bands are available, and most importantly, the performance of the antenna is unaffected by the straightforward biassing of the GaAs FET switches. Since GaAs FET switches have low insertion loss and low ON resistance, they do not degrade antenna gain or efficiency, and the simple biassing approach and small number of external biassing components required [28]. The total peak gain of the antenna increased by 20% compared to the UWB instance when it was altered to operate in several frequency bands.

The Antenna Concept

Fig. 2.5 [29] depicts the proposed reconfigurable UWB monopole antenna. On one side of the dielectric substrate (in this study, the FR4 substrate employed has a thickness of 1.52 mm), a 12.5 mm wide disc, a 50 microstrip feed line, and four 0.75 mm thick stubs are printed. The dielectric substrate is 50 mm in length and breadth. In order to reach 50 impedance [30], the width of the microstrip feed line is set at mm.

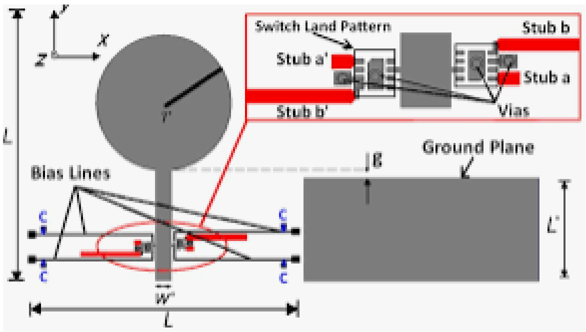


Fig 2.5 Geometry of the proposed reconfigurable UWB antenna design

2.6: Investigation on Performance of Microstrip Patch Antenna for a Practical Wireless Local Area Network (WLAN) Application

This study explores the efficiency of a microstrip patch antenna in a realistic wireless LAN setting. The idea of a transmission line serves as the foundation for this layout. The ground and patch materials in the antenna design are annealed copper, whereas the substrate is FR4 (lossy) with a dielectric constant (Er) of 4.3. The substrate has a width of 71.62mm and a length of 55.47mm. Dielectric material is standard FR4 size, with a height of 1.6mm. For a resonance frequency of 2.573 GHz, the dimensions of the conducting patch element are 35.81mm in width and 27.73mm in length. The antenna layout was fine-tuned using a CST studio suite simulation for optimal performance.

Design

Annealed copper is used for the ground and patch, and FR4 (a lossy dielectric with an Er of 4.3) is used as the antenna design substrate. The dimensions of the substrate are 71.62mm in width and 55.47mm in length. The dielectric material is sized at the usual FR4 height of 1.6mm. The dimensions of the conducting patch element, which allow it to resonate at 2.573 GHz, are 35.81 mm in width and 27.73 mm in length.

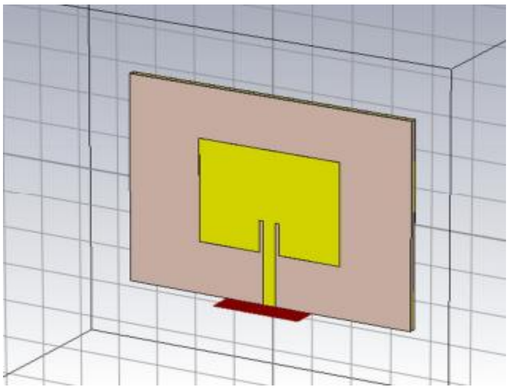


Fig 2.6 Design Geometry (a)

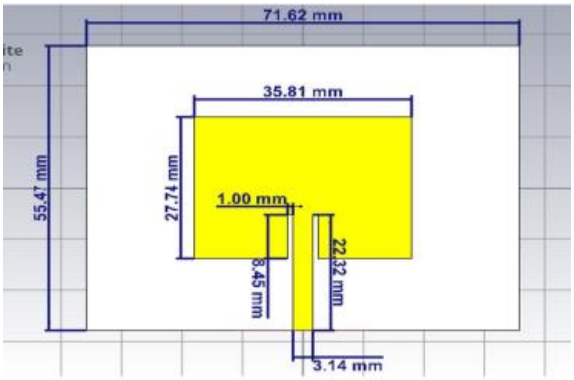


Fig 2.6(b) Design Geometry (b)

Microstrip patch antennas require careful measurements of both width and length to determine the input impedance. The bandwidth is proportional to the square of the width, so a larger width will have a greater bandwidth than a smaller one. Increasing the width decreases the impedance, however a very broad patch antenna, which requires more room and controls the radiation pattern, may be required to decrease the input impedance.

2.7: A Review of LNA Topologies for Wireless Applications

In this study, we will discuss several literature reviews on the topic of low noise amplifier (LNA) design. Several new LNA architectures will be discussed, but this study will zero in on four specific topologies: the forward body bias, self-biased inverter, common source cascade, and cascade. These designs reduce the amount of energy needed to run a conventional CMOS wireless sensor network. In addition, we discuss input and output matching, as well as high gain and low noise. After that, we go into how each topology performs so as to deliver ultra-low power consumption while simultaneously optimising all attributes. These comparisons among the four topologies will serve as the basis for future study as we work to develop a new, effective LNA architecture.

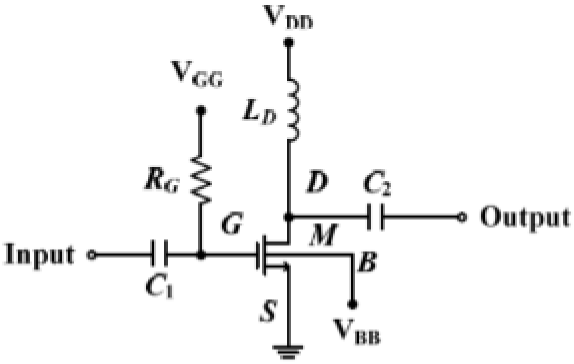


Fig 2.7 Schematic of LNA

Due to the rapid advancement of wireless communication technologies, RF receiver performance is increasingly demanded. Since the LNA is the starting point of the receiver circuit, it's important that it meet a number of criteria that ensure optimal system performance. Low power consumption, high gain, and low noise figure are examples of such criteria.

2.8: Comparison Table

Table 2.1 Comparison Table

Paper no#	Design	Operating Frequency	Gain	Applications
01	Active integrated Antenna with Low noise Amplifier	05GHz	4.56dBi	for GNSS, 5G and WIFI-6E Applications
02	A Rectangular Microstrip Patch Antenna	2.4GHz	8dB	For Ultra-Wide Band Applications.
03	A Dual-Band Circularly-Polarized Patch Antenna with a Novel	2.53GHz	5dBi	WiMAX Application

	Asymmetric Slot			
04	A Dual port active integrated Antenna	2.4/5.2GHz	5dBi	WLAN Applications
05	Reconfiguring UWB monopole Antenna	2.55 - 3.2 GHz		For switching from narrow to wide band.
06	Investigation on Performance of Microstrip Patch Antenna	2.573GHz		WLAN Applications
07	A Review of LNA Topologies for Wireless Applications	2.4GHz	10.1dB	Wireless transceiver system

2.9: Specifications Table

This project is an industry based project which is sponsored by NESCOM. The design parameters were optimized, by using the specifications provided by NESCOM shown below in Table 2.2

Table 2.2 NESCOM Specifications Table

Sr.#	Parameters	Specification
1	Frequency Band	S-Band
2	Impedance Bandwidth	>100 MHz
3	Antenna Passive Gain	>3dBi
4	Beam Width	>60 x 60
5	Antenna Polarization	Circular (Preferable)
6	Antenna Axial ratio (AR)	< 3 dB
7	S11@fo	< -15dB
8	LNA Gain	>18dB

9	Noise Figure	< 2dB
10	Size	< 5000mm^2

CHAPTER 3

Antenna Design and Development

Implementing design on HFFS and came across different parameters that are discussedbelow.

3.1. Substrate Selection:

Substrate is an insulator that is used to give electrical and mechanical strength stability. They are used to decrease the size of antenna and help to produce displacement currents when in response produces time varying magnetic field.

The thickness of substrate is directly proportional to the bandwidth of antenna [31].The substrate selection depends on two things.

3.1.1 Loss tangent (tan ((δ)) :

Loss tangent (tan (δ)**)** or Dielectric loss is measure of signal loss due to dissipation of electromagnetic energy.

Loss tangent is for high frequencies, for low frequency dissipation factor is used instead of loss tangent.

A low loss tangent means low losses at certain frequency, loss tangent changes little bit with frequency change.

3.1.2. Dielectric constant (ϵr):

It is the ratio of permittivity of material withrespect to the permittivity of vacuum.

$k=E/E0$

K= dielectric constant

E= permittivity of the substance

$E0$= permittivity of a vacuum

Keeping the parameters of substrate in mind, the substrate chosen is FR 4 Substrate.

This material is highly desirable for high Frequencies to have a better gain anddirectivity with respect to aperture efficiency.

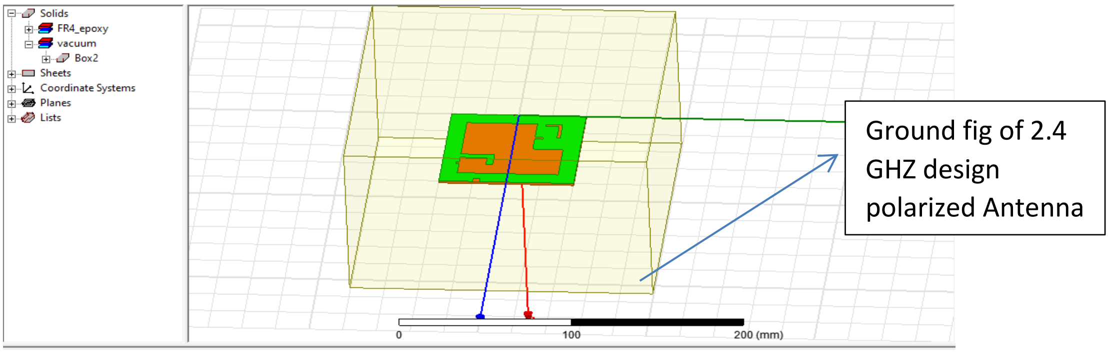
Data Sheet (FR4):

Table 3.1: Data sheet of FR4

Property	FR4
Dielectric Constant, K Process	3.3-4.8 (depends upon material composition)
Substrate Thickness	H=1.58mm
Loss Tangent	0.019
Conductor Thickness	0.035
Dissipation Factor	0.0.17
Thermal Expansion	1.4 x10 -1
Specific Density	1.850 Gram per cm3
Relative Permittivity	4.4
Thermal Conductivity	0.29
Flammability	V-0
Lead-Free Process Compatible	Yes

3.2. HFSS design:

The antenna was designed on HFFS software using following parameters:



Ground fig of 2.4 GHZ design polarized Antenna

Fig. 3.1 Initial HFSS Design (1)

All simulations are performed using HFFS. Here we have designed the model on HFFS which had given the good results [32]. The substrate used in it is FR4

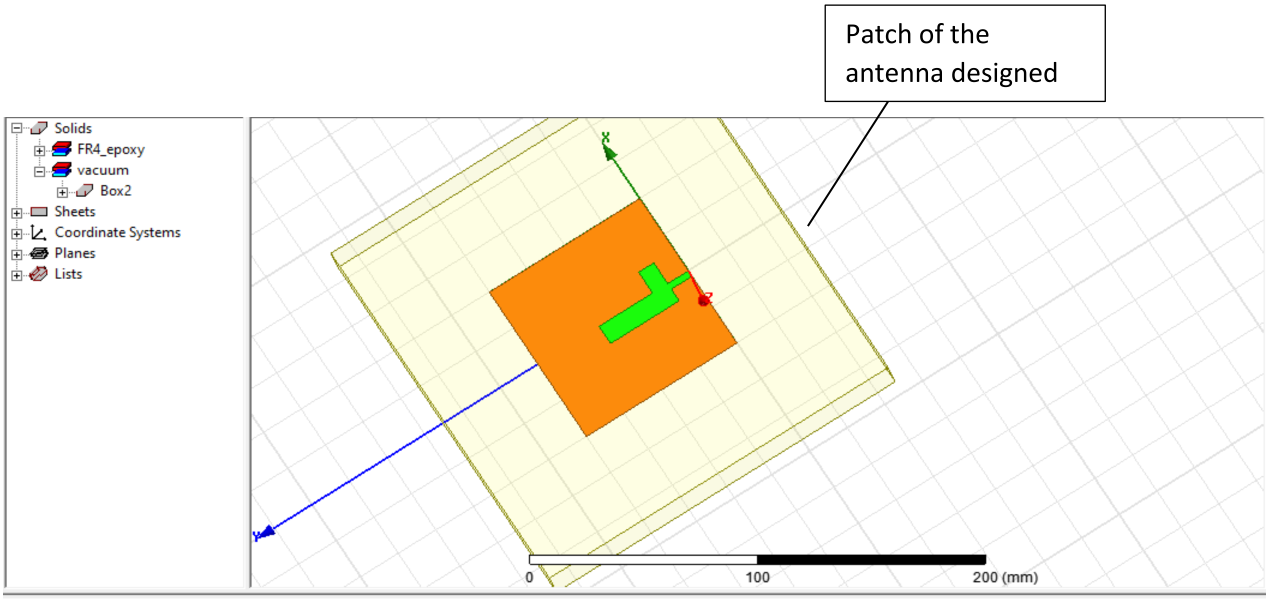
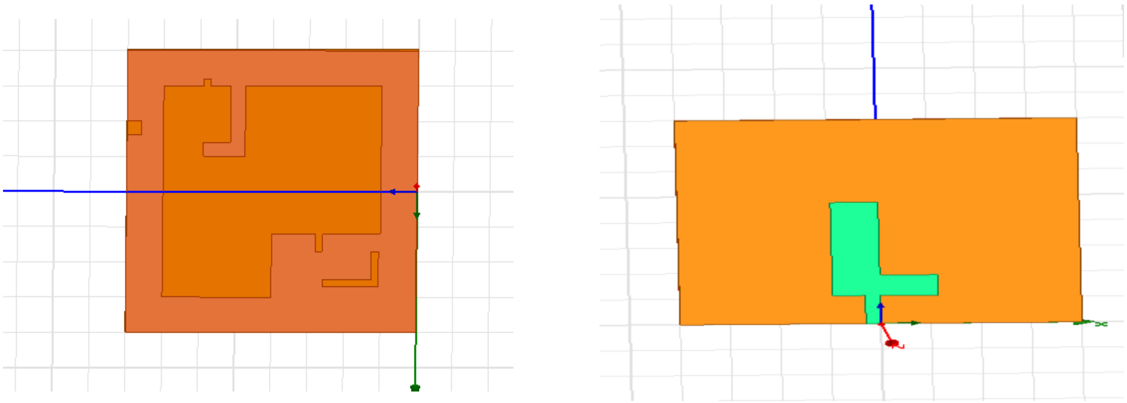

Patch of the antenna designed

Fig. 3.2 Initial HFSS Design (2)

Dimensions:

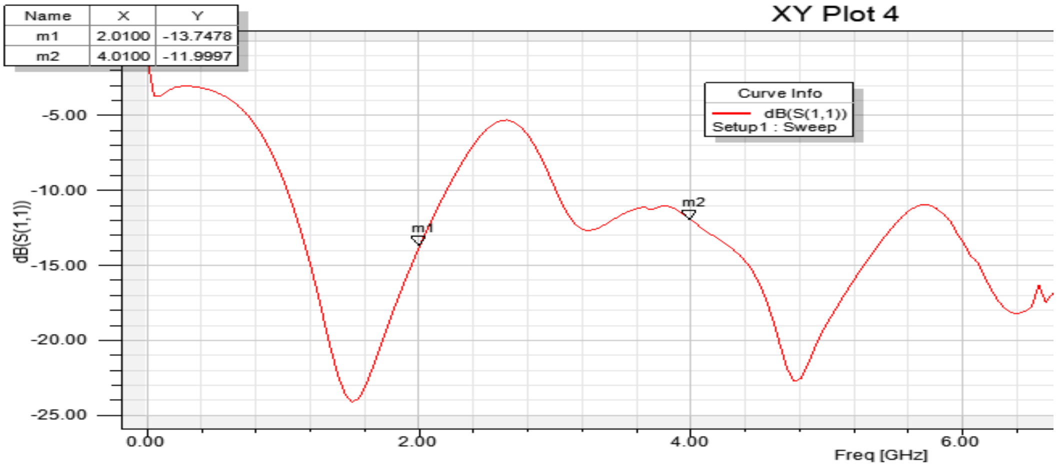

Ground surface of the Antenna

Patch of the Antenna

Fig. 3.3 Dimensions of Antenna

RESULTS

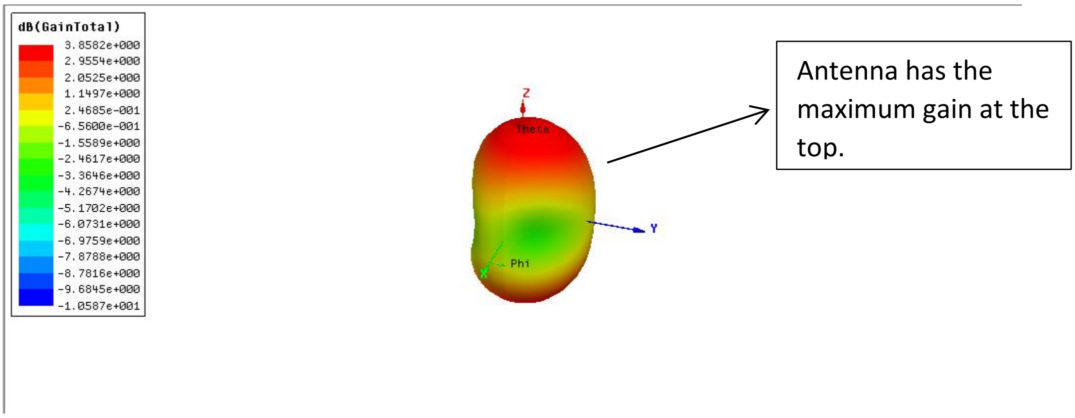
S(1,1) Plot:



These results show that antenna is working in S-Band, but it is slightly mismatched

Fig. 3.4 This first graph shows the S (1,1) results of the upper design

3.4 3D Polar Plot:



Antenna has the maximum gain at the top.

The above figure shows the results of 3D polar plot which represents the gain of antenna. Now this is the 3D polar plot of the antenna, and it shows the gain of the design.

Fig 3.5 Gain plot

3.5. Engraving Slots in Patch Antenna:

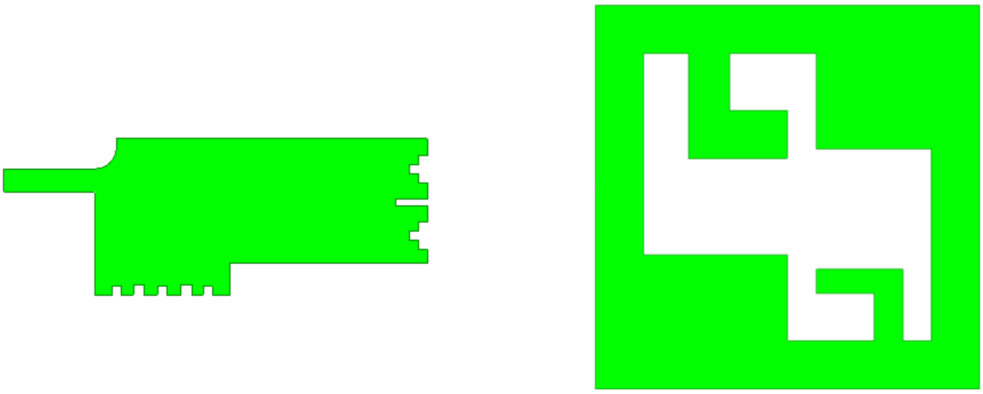
3.5.1Slot Engraving:

Slots are holes that are usually made in patch structure forseveral different reasons. Few of them are defined below.

1) To have a new resonance frequency.
2) To increase/decrease the gain of antenna structure.
3) To adjust antenna impedance with cable impedance.
4) For mechanical structure in order to fold or bent the antenna.[33]

3.5.2Design after Slotting:

So to have a new band we put these 6 slots in the patch due to which we got differentresults. The design with slots is shown below.



Patch of Antenna

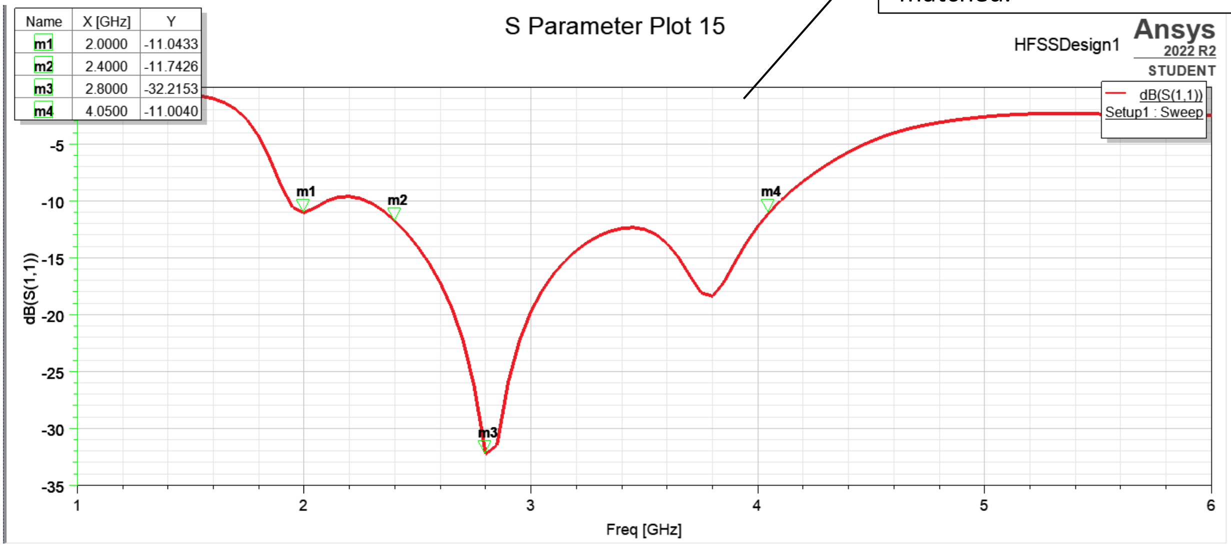
Ground of Antenna

Fig 3.6 Antenna Slot Design

RESULTS

S(1,1) Plot:

These results shows the optimization of Antenna. These S(1,1) plots shows the antenna is completely matched.



Name	X [GHz]	Y
m1	2.0000	-11.0433
m2	2.4000	-11.7426
m3	2.8000	-32.2153
m4	4.0500	-11.0040

Fig 3.7 S(1,1) Plot

The above S(1,1) plot shows that the antenna is working from 2.4 GHz to 4.05 GHz

Radiation Plot:

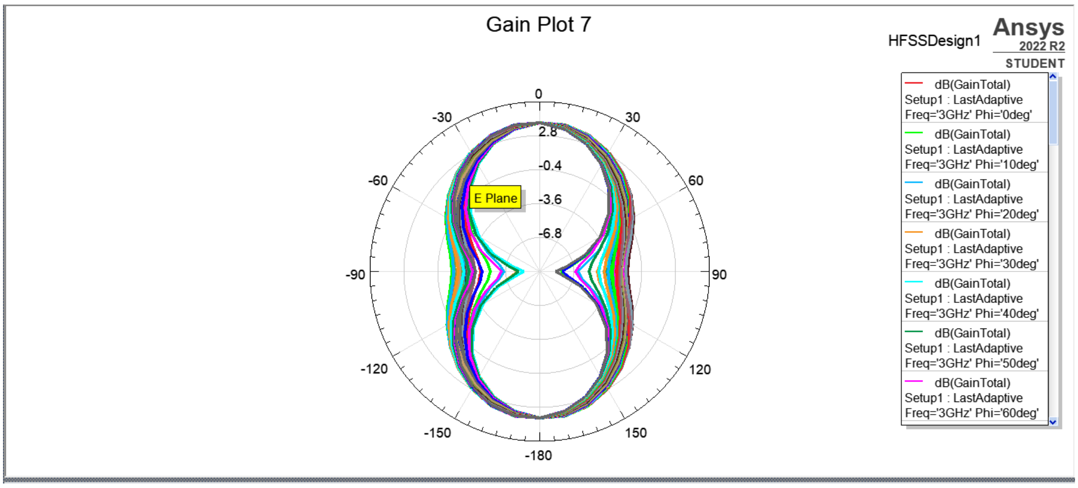
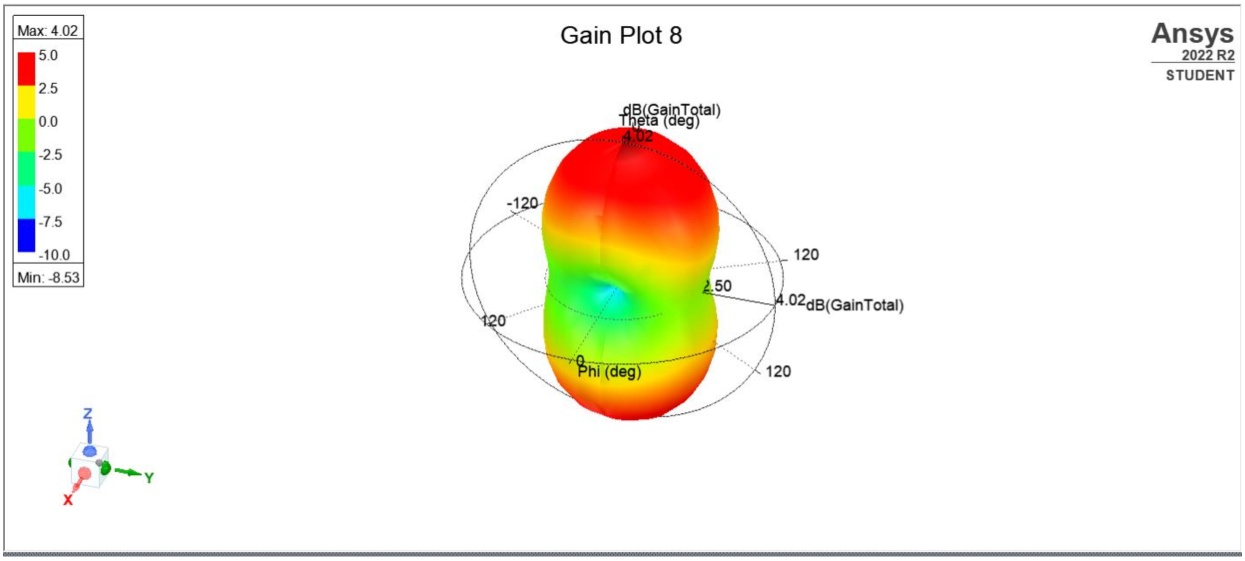


Fig 3.8 Radiation Plot

3D polar Plot:



These plots shows the Gain of the Antenna and the Gain is maximum at the top.

Fig 3.9 3D Plot

3.6 Antenna Fabrication and Testing

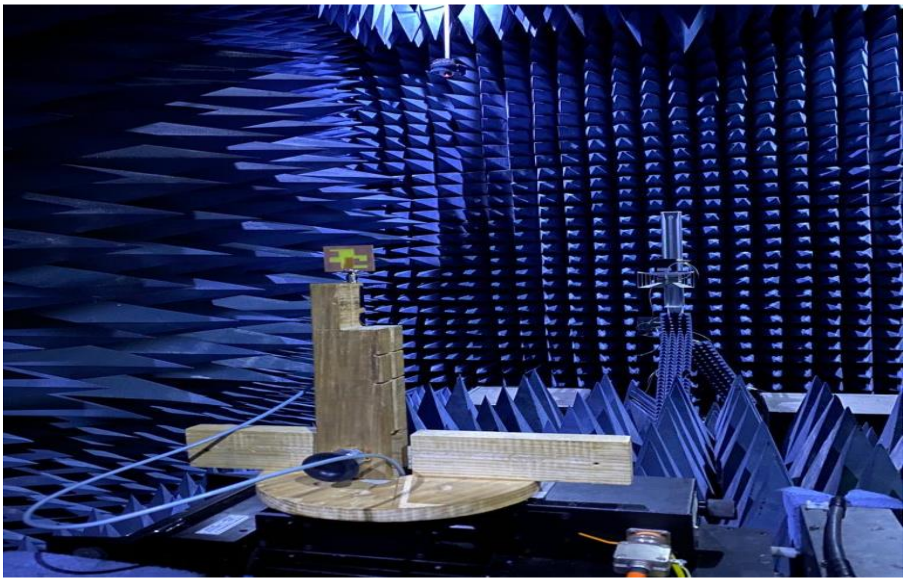


Fig 3.10 Anechoic Chamber Testing

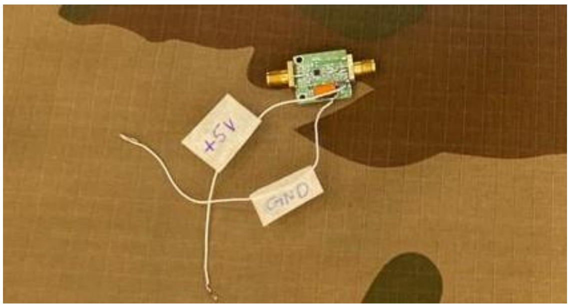


Fig 3.11 LNA

Fig 3.12 Active Antenna

3.7 Final Antenna Design

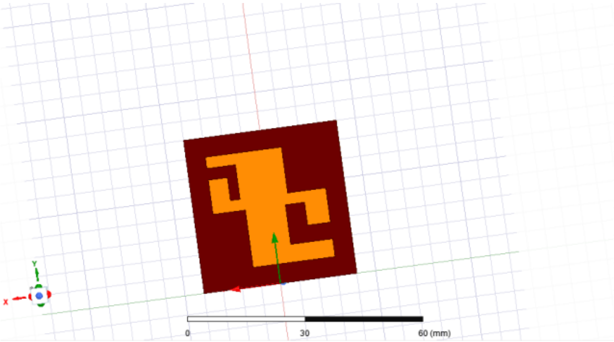


Fig 3.13 Ground

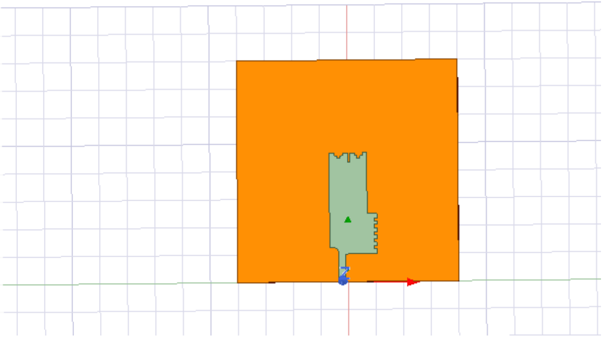


Fig 3.14 Patch

CHAPTER 4

Low-Noise Amplifier

4.1 LNA specifications

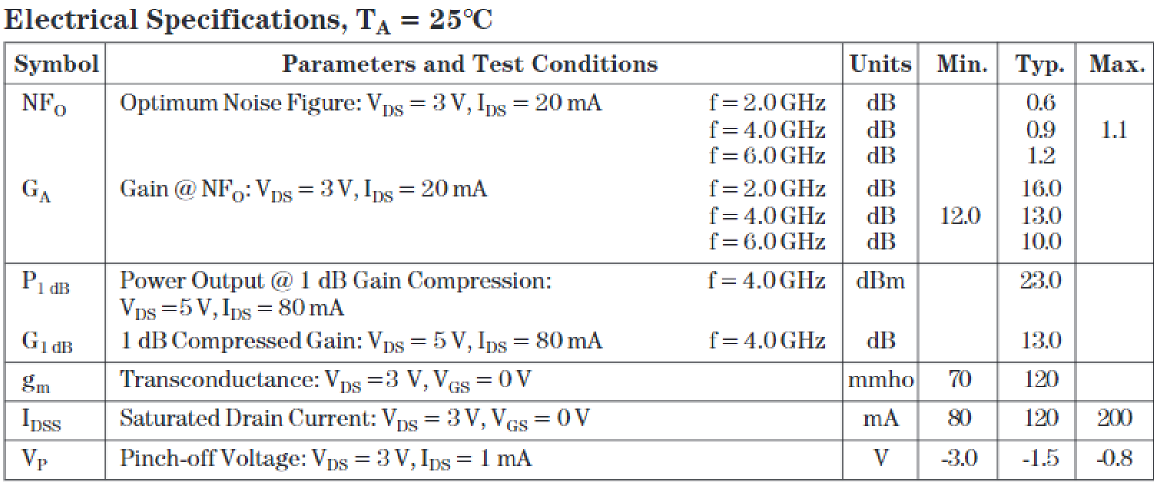
Gain, linearity, gain flatness, and stability are all prioritised throughout the LNA's design process. The following details also apply to the co-designed antenna-LNA combination. The LNA described in [34] is detailed in the following table.

Table 4.1 LNA Specifications

Design Frequency	2.4 GHz
Gain	>14dB
Input Return Loss	<-14dB
Output Return Loss	<-14dB
Noise Figure	<=1.4dB
P1dB	>10dBm
OIP3	>20dBm

4.2 Selection of Active Device

The active device is selected based on the specifications. ATF 21170 microwave transistor datasheet provides the following specifications at 2.4 GHz



Electrical Specifications, $T_A = 25°C$

Symbol	Parameters and Test Conditions		Units	Min.	Typ.	Max.
NF_O	Optimum Noise Figure: $V_{DS} = 3\,V$, $I_{DS} = 20\,mA$	f = 2.0 GHz	dB		0.6	
		f = 4.0 GHz	dB		0.9	1.1
		f = 6.0 GHz	dB		1.2	
G_A	Gain @ NF_O: $V_{DS} = 3\,V$, $I_{DS} = 20\,mA$	f = 2.0 GHz	dB		16.0	
		f = 4.0 GHz	dB	12.0	13.0	
		f = 6.0 GHz	dB		10.0	
$P_{1\,dB}$	Power Output @ 1 dB Gain Compression: $V_{DS} = 5\,V$, $I_{DS} = 80\,mA$	f = 4.0 GHz	dBm		23.0	
$G_{1\,dB}$	1 dB Compressed Gain: $V_{DS} = 5\,V$, $I_{DS} = 80\,mA$	f = 4.0 GHz	dB		13.0	
g_m	Transconductance: $V_{DS} = 3\,V$, $V_{GS} = 0\,V$		mmho	70	120	
I_{DSS}	Saturated Drain Current: $V_{DS} = 3\,V$, $V_{GS} = 0\,V$		mA	80	120	200
V_P	Pinch-off Voltage: $V_{DS} = 3\,V$, $I_{DS} = 1\,mA$		V	-3.0	-1.5	-0.8

Fig 4.1 Electrical Specifications

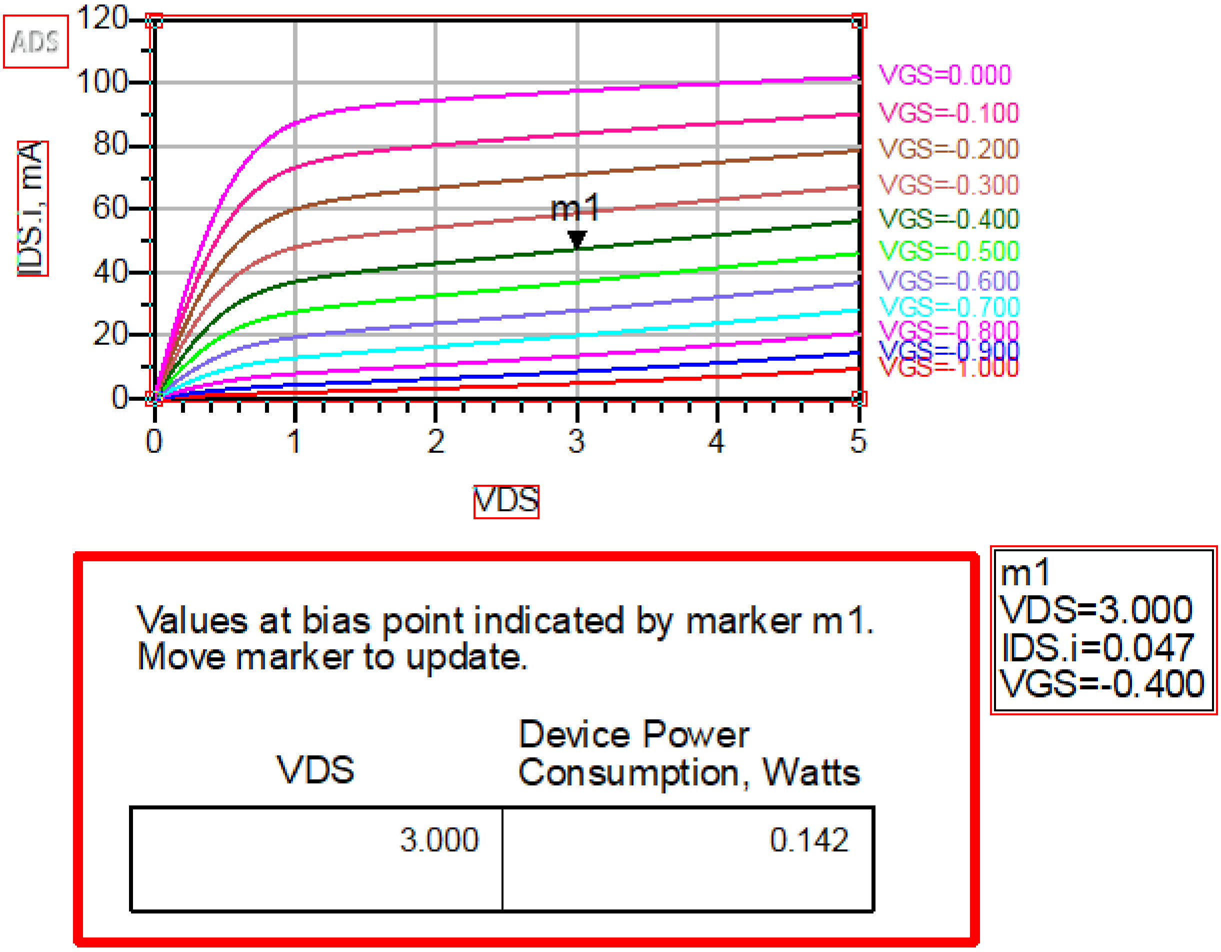
The ATF-21170 is a high performance gallium arsenide Schottky barrier-gate field effect transistor housed in a hermetic, high reliability package. This device is designed for use in low noise or medium power amplifier applications in the 0.5-6 GHz frequency range. This GaAs FET device has a nominal 0.3 micron gate length with a total gate periphery of 750 microns. Proven gold based metallization systems and nitride passivation assure a rugged, reliable device [35].

Features

- Low Noise Figure: 0.9 dB Typical at 4 GHz
- High Associated Gain: 13.0 dB Typical at 4 GHz
- High Output Power: 23.0 dBm Typical P 1 dB at 4 GHz
- Hermetic Gold-Ceramic Microstrip Package

4.3 Bias point Selection

To maintain a drain current of I_{DS} = 47 mA with a drain to source voltage of V_{DS} = 3V, the appropriate gate voltage V_{GS} has to be determined.



Values at bias point indicated by marker m1.
Move marker to update.

VDS	Device Power Consumption, Watts
3.000	0.142

m1
VDS=3.000
IDS.i=0.047
VGS=-0.400

Fig 4.2 Simulation Results of DC Biasing

By performing a DC simulation of the transistor with sweeping V_{DS} for different V_{GS} values, the bias points curves as shown in Figure are obtained and it is seen that V_{GS} = 400mV will hold the transistor in the desired bias point specified for optimum gain and noise figure [36].

4.4 Stability Network Design:

A resistive passive bias network is designed to maintain the bias point VDS = 3V, IDS = 47mA and VGS = 400mV

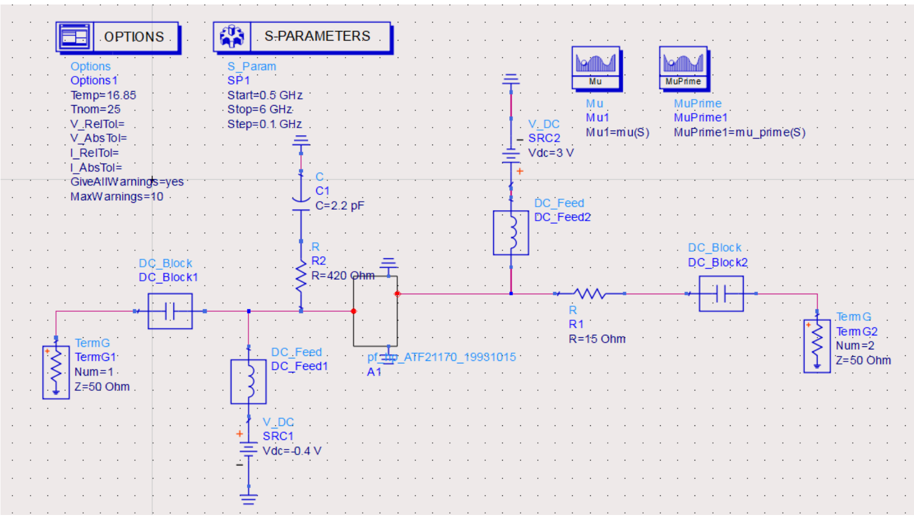


Fig 4.3 Schematic Design of Stability Network

4.5 Biasing Network Design:

The Bias network will feed the DC to the device to make it operational. In the previous step, ideal DC feed was used to analyze the stability of the device. We have designed that bias network on a substrate to make it work on our desired Operational Frequency for practical design. There are two options for bias network design:

- RF Choke
- High Impedance Quarter Wavelength Line.

Substrate:

The substrate to be used is FR4.

Resonant frequency = 2.4GHz
Substrate thickness h = 1.58mm
Effective dielectric constant = 3.91
Patch width = 38.01mm
Patch length = 28.77mm
Width of 50Ω transmission line = 5.93mm
Length of inset feed = 15.80mm
Inset depth = 9.23mm

Notch width g =1.51mm.

An integral part of a microstrip patch (metallic sheet) antenna is its substrate, which is the base or container in which the antenna is manufactured. Microstrip antennas need the substrate primarily for mechanical support. The electrical performance of the antenna, circuits, and transmission line may be impacted by the substrate, which must be made of a dielectric substance to give this support.

It might be challenging to find a substrate that can suit both the electrical and mechanical criteria.It is crucial to choose the appropriate substrate in terms of price, efficiency, and footprint. To create a patch antenna, an insulating dielectric substrate is connected to a continuous metal layer, which serves as a ground plane, and the antenna element pattern is etched into the metal trace.

Dielectric substrates are utilised to increase mechanical and electrical reliability. They aid to generate displacement current, which, according to Ampere's Law, results in a time-varying magnetic field, and so minimise the antenna's overall size. This, in turn, may generate a time-varying electric field (per Faraday's equation), giving rise to an electromagnetic field that can then spread. Therefore, a substrate may improve an antenna's capacity to radiate.

Antenna designers should begin by choosing the substrate material and thickness for their microstrip patch antennas. Therefore, it is simpler to build an antenna if the designer has a firm grasp on how the substrate material and thickness affect the antenna's performance. When building a microstrip patch antenna, it is crucial to choose the right dielectric material and thickness.

- The simulation results show perfect match because we have designed biasing network to avoid any impedance mismatch to account for any reflection [37].

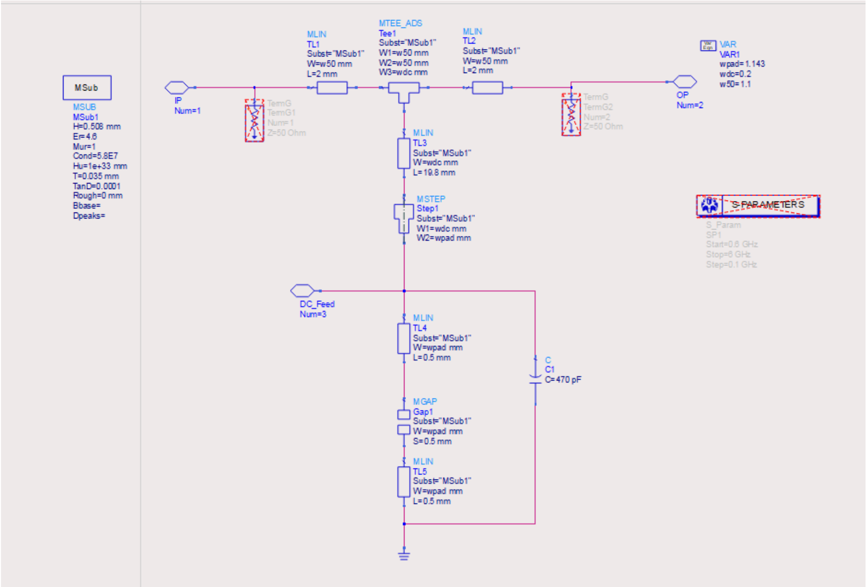
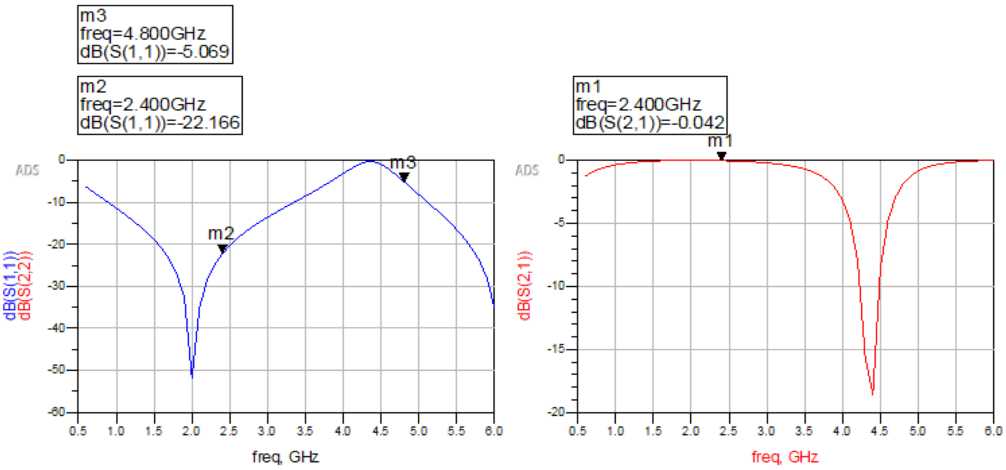


Fig 4.4 Bias Network



Biasing network simulation result.

4.6 Impedance Matching Network:

The ZOPT, Zsource and Zload values for 50 terminations can be derived using a straightforward transistor S-parameter simulation. The Smith chart tool in ADS is used to create the matching networks that transform these impedances to 50, with the L and C components lumped together. The matching networks are designed with a series capacitor element near the transistor in mind since they also need to serve the purpose of a DC block. In contrast to a regular RF power amplifier, an LNA has its matching optimized for a smaller NF.[38]

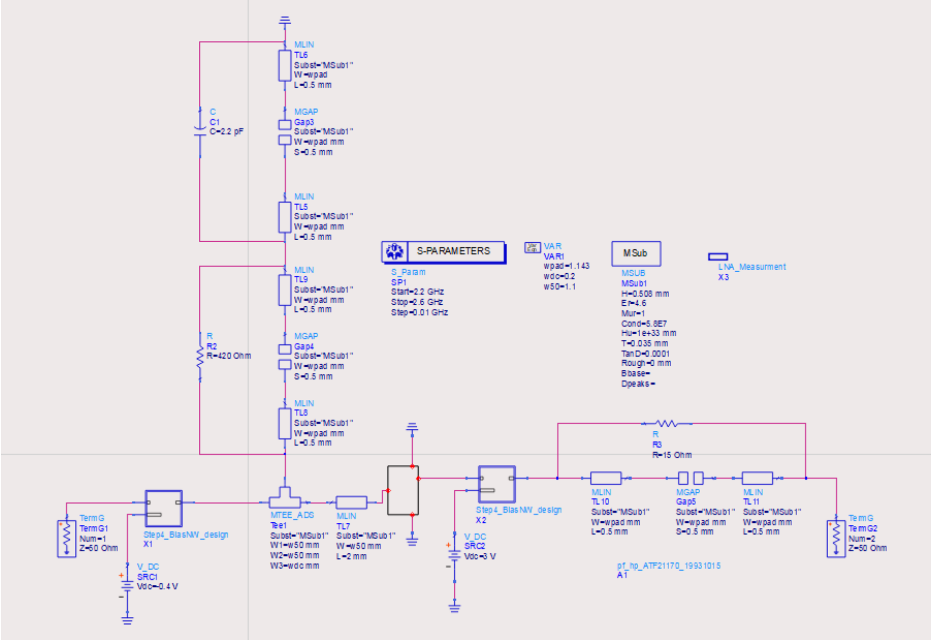


Fig 4.5 Schematic diagram of Impedance matching network

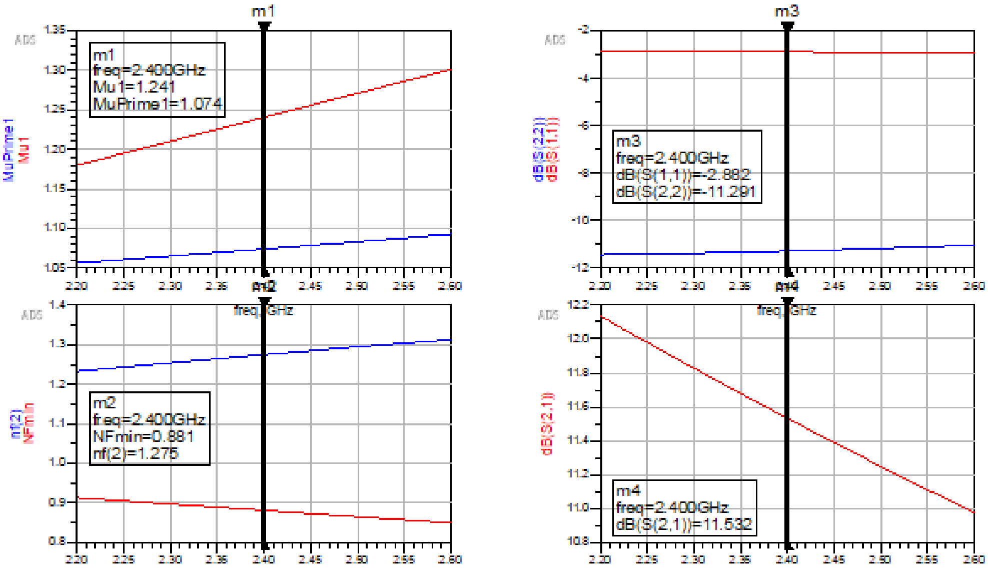
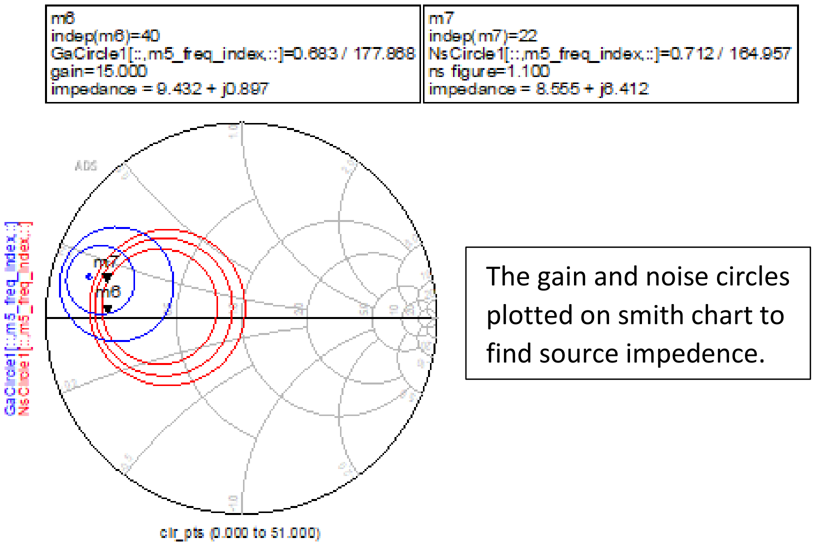


Fig 4.6 Simulation results of IM network

- The simulation results shown below
- The transistor is still stable
- Low Noise figure at design frequency
- Moderate Gain
- But poor input Return loss (|S11|=2.882dB)

Computation of ΓS and ΓL

- For LNA design, source impedance should be selected by intersection of Noise figure and constant gain circles



```
m6
indep(m6)=40
GaCircle1[::,m5_freq_index,::]=0.683 / 177.868
gain=15.000
impedance = 9.432 + j0.897
```

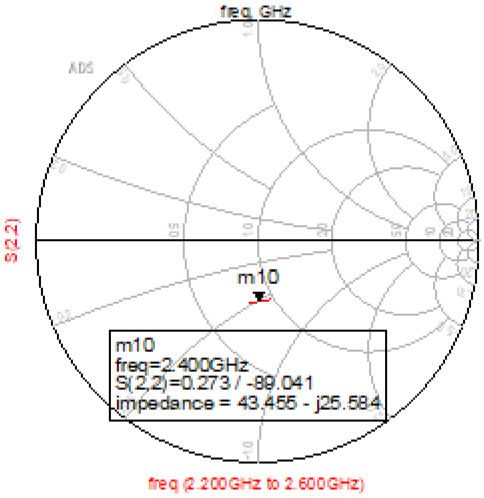
```
m7
indep(m7)=22
NsCircle1[::,m5_freq_index,::]=0.712 / 164.957
ns figure=1.100
impedance = 8.555 + j6.412
```

The gain and noise circles plotted on smith chart to find source impedence.

Fig 4.7 Schematic Plot of Gain and Noise circles

- This intersection point is our desired source impedance

o $\Gamma S = 0.683 < 177.868$



```
m10
freq=2.400GHz
S(2,2)=0.273 / -89.041
impedance = 43.455 - j25.584
```

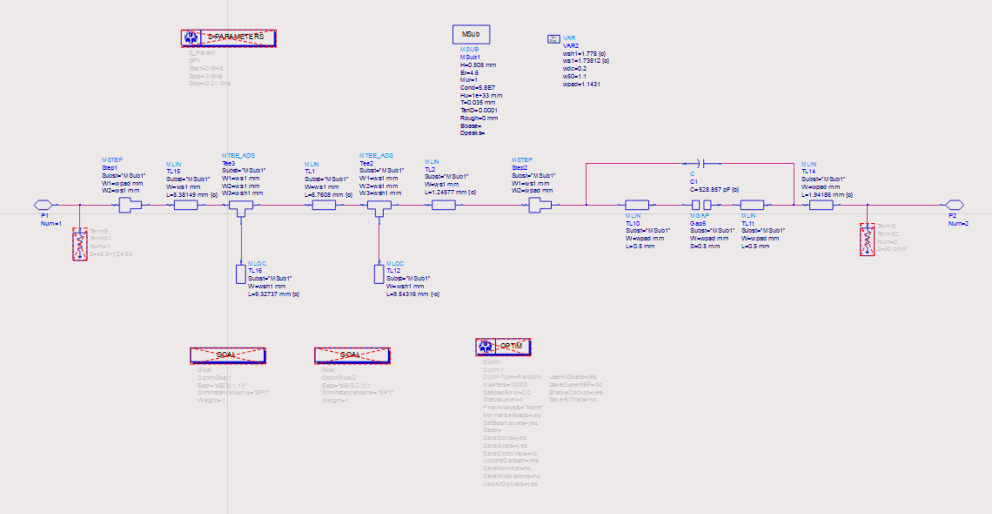
S22 plotted on smith chart for computation of load impedence.

Fig 4.8 Schematic Plot of S(2,2)

- $\Gamma L = 0.273 < -89.041$

4.7 Optimization:

- To achieve the desired matching (i.e., $|\boldsymbol{S11}| < -\boldsymbol{14dB}$ and $|\boldsymbol{S22}| < -\boldsymbol{14dB}$) we have performed optimization
  - After optimization, the LNA circuit is looking like



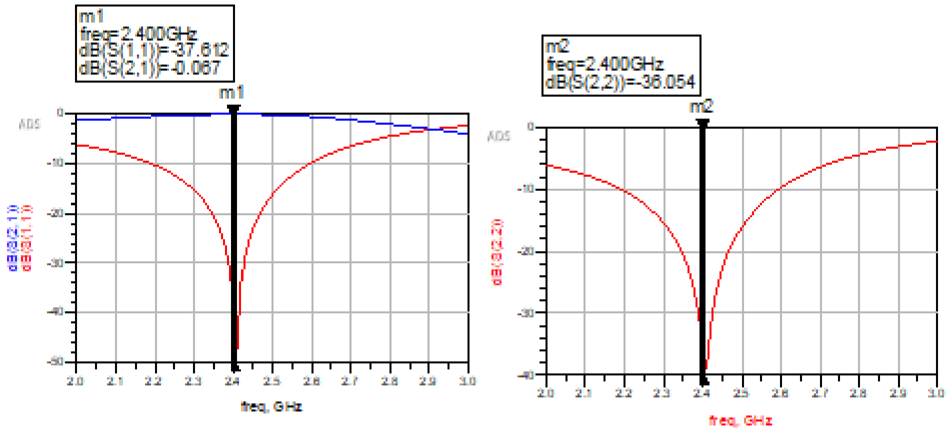


Fig 4.9 Optimized results

After performing line calc tools and optimization, fine tunning we get our desired results at 2.4 GHz

After the converting the input matching network into physical microstrip lines the result will be as shown;

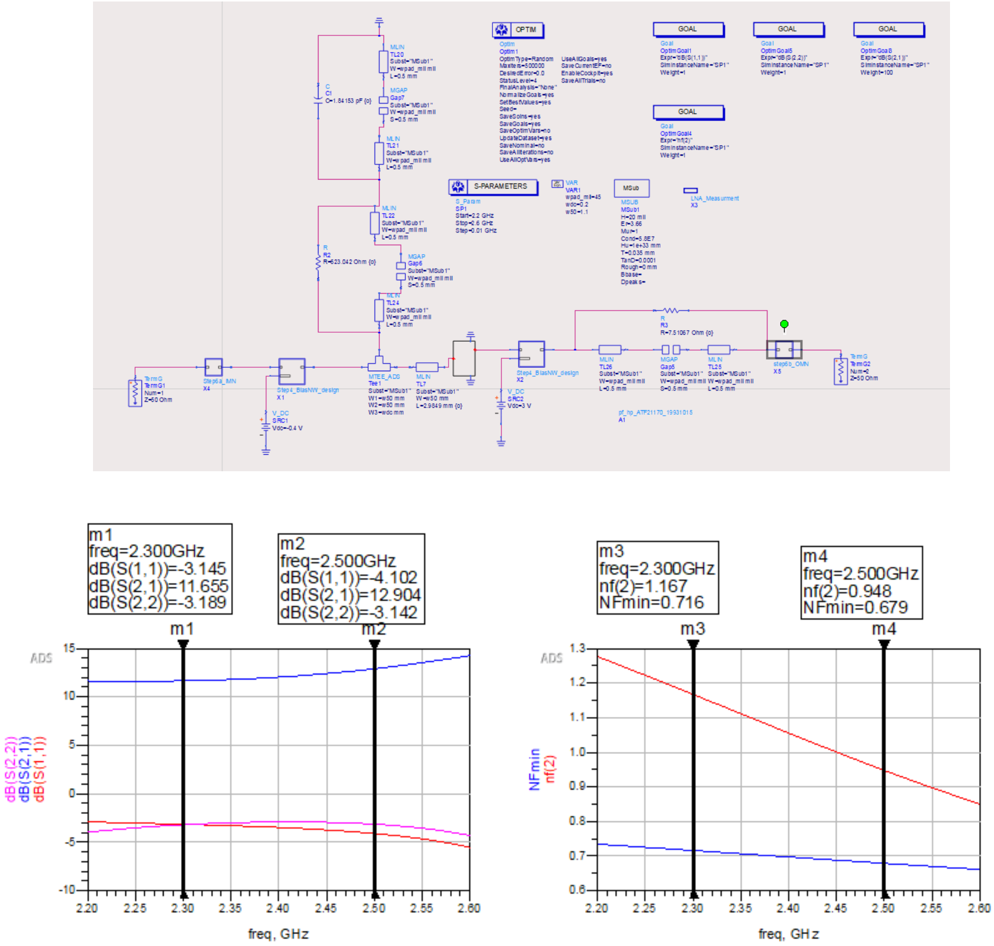
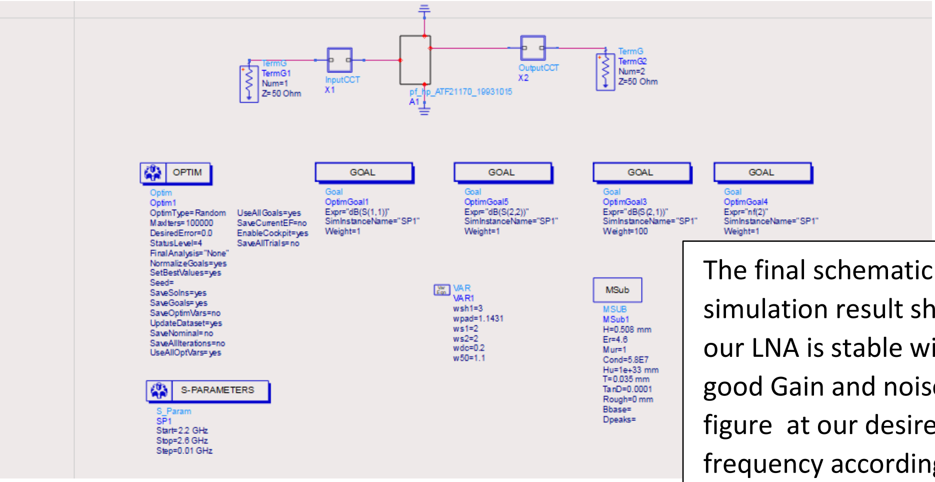


Fig 4.10 Simulation Results after Optimization

Simulation results shows our desired results on our desired specifications.

4.8 Layout Design:

Input and output design after generating into the hierarchy is shown below



Optim
Optim1
OptimType=Random
MaxIters=100000
DesiredError=0.0
StatusLevel=4
FinalAnalysis="None"
NormalizeGoals=yes
SetBestValues=yes
Seed=
SaveSolns=yes
SaveGoals=yes
SaveOptimVars=no
UpdateDataset=yes
SaveNominal=no
SaveAllIterations=no
UseAllOptVars=yes
UseAllGoals=yes
SaveCurrentEF=no
EnableCockpit=yes
SaveAllTrials=no

Goal
OptimGoal1
Expr="dB(S(1,1))"
SimInstanceName="SP1"
Weight=1

Goal
OptimGoal5
Expr="dB(S(2,2))"
SimInstanceName="SP1"
Weight=1

Goal
OptimGoal3
Expr="dB(S(2,1))"
SimInstanceName="SP1"
Weight=100

Goal
OptimGoal4
Expr="nf(2)"
SimInstanceName="SP1"
Weight=1

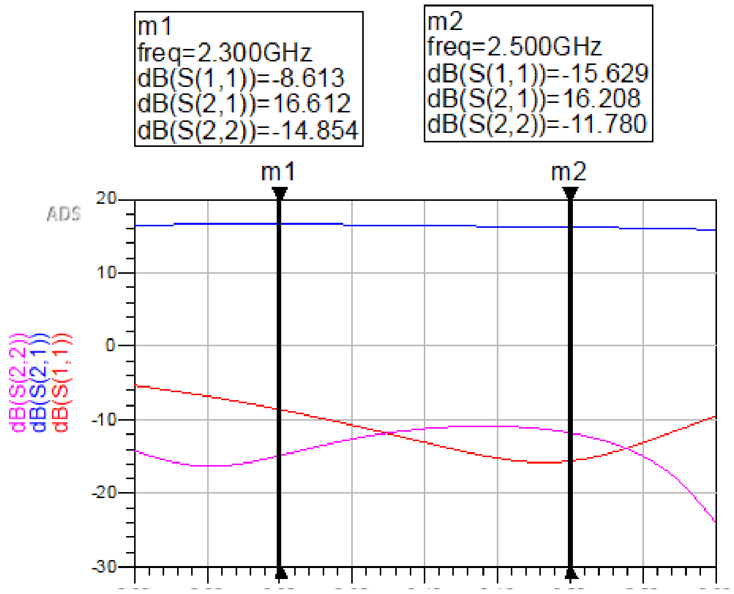
VAR
VAR1
wsh1=3
wpad=1.1431
ws1=2
ws2=2
wdc=0.2
w50=1.1

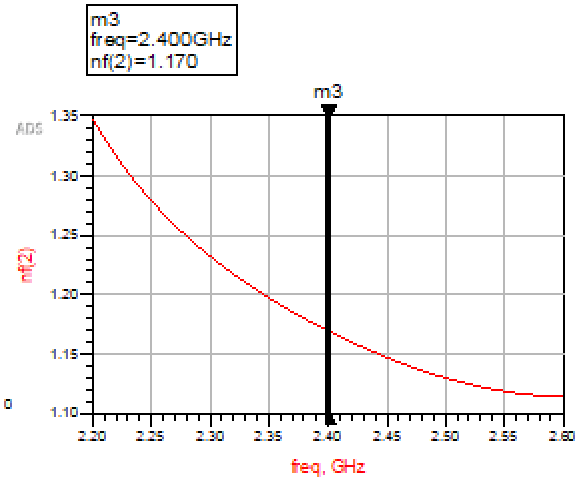
MSUB
MSub1
H=0.508 mm
Er=4.6
Mur=1
Cond=5.8E7
Hu=1e+33 mm
T=0.035 mm
TanD=0.0001
Rough=0 mm
Bbase=
Dpeaks=

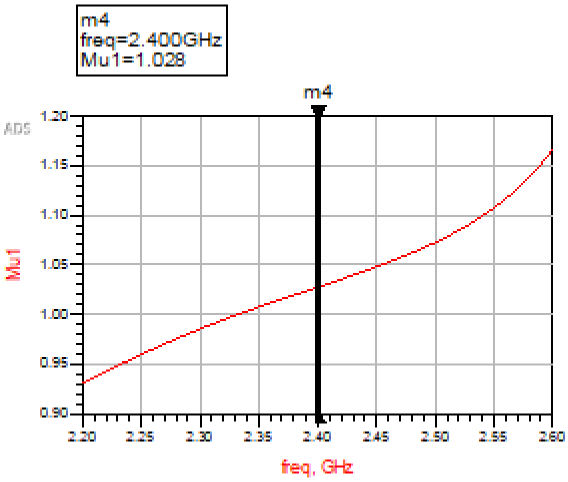
S_Param
SP1
Start=2.2 GHz
Stop=2.6 GHz
Step=0.01 GHz

Fig 4.11 Final Schematic Design

The final schematic and simulation result shows our LNA is stable with good Gain and noise figure at our desired frequency according to the desired







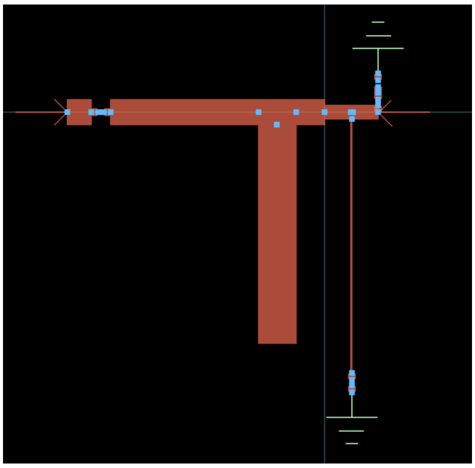
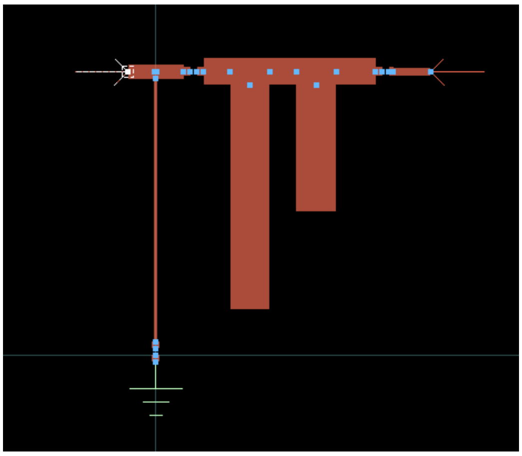
Input Layout Design	Output Layout Design
	

Fig 4.12 Layout Design

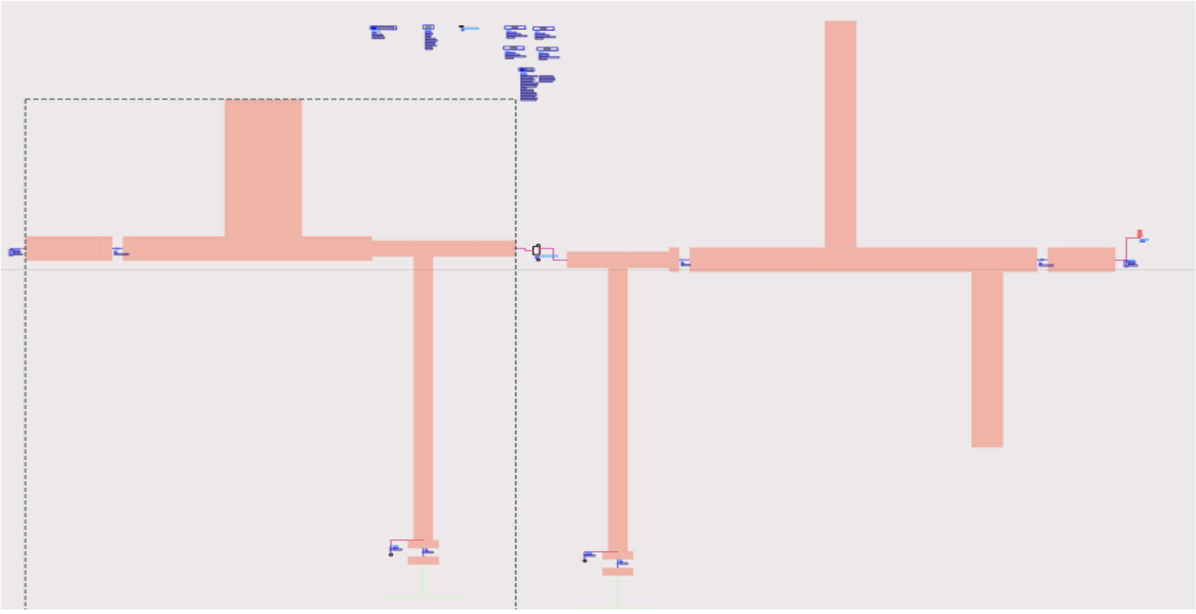


Fig 4.13 EM Co-simulation

4.9 LNA Specifications Comparison:

The specifications comparison of LNA with required parameters are listed below:

Parameters	Required	Achieved
Gain	> 14 dB	16.1dB
Input Return Loss (S11)	< -14 dB	-16.2dB
Output Return Loss (S22)	< -14 dB	-16.06dB
Noise Figure	<= 1.4 dB	0.945dB

4.10 Complete LNA on layout level:

The layout of LNA is designed with ADS momentum with substrate definitions for FR4 substrate as its specification has been discussed earlier.

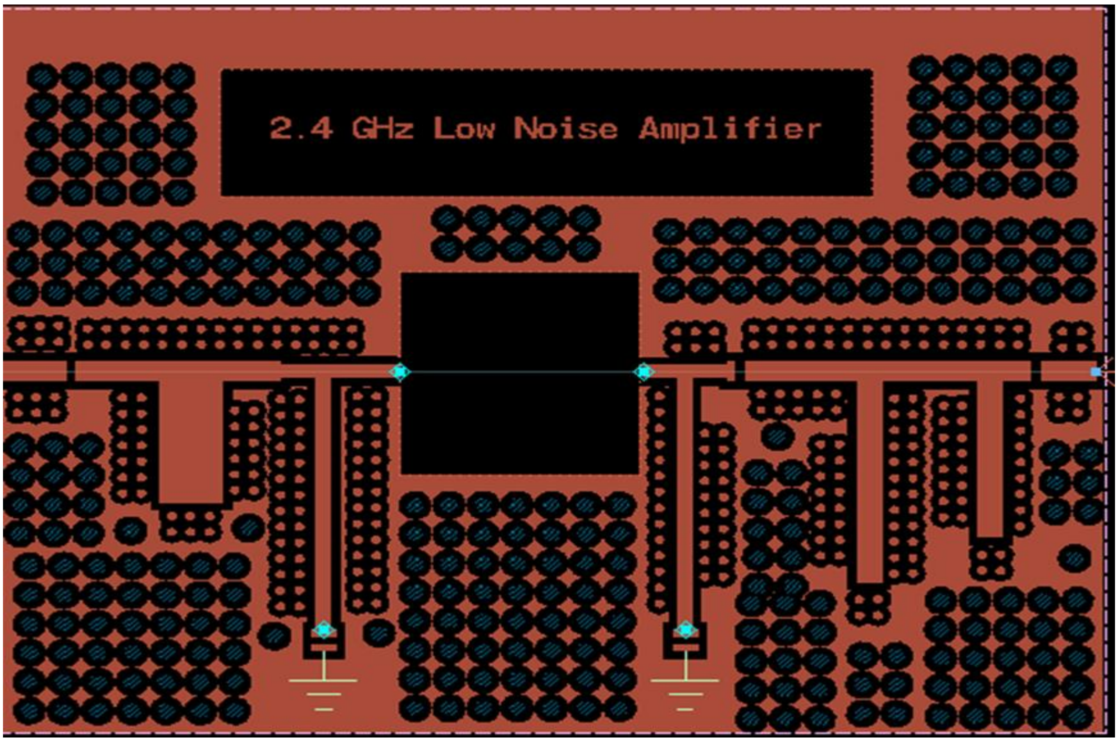


Fig. 4.14 LNA Layout

Conclusion:

- The overall performance of LNA is not degraded because we take care of discontinuities and other factors in our initial designs that not only helped us to generate the layout very easily. After fabrication there will be minimum deviation in the results w.r.t to our specifications.

4.11. Co-Design and layout Preparation

In common RF engineering, LNA designer and antenna designers work independently. The link between antenna and LNA is the conventional characteristic impedance in RF system,50Ω in communication applications and 75 ohms in TV signal system.

To perform the co-design of the antenna and LNA, the input matching network of the LNA is removed and only the DC blocking capacitor is left. The resulting LNA layout is shown in figure.

It is observed that a fair matching between all plotted S-parameters is possible with a suitably designed microstrip line at the input of the LNA. The proper length and width of the microstrip line is found out by sweeping these dimensions and observing the plots

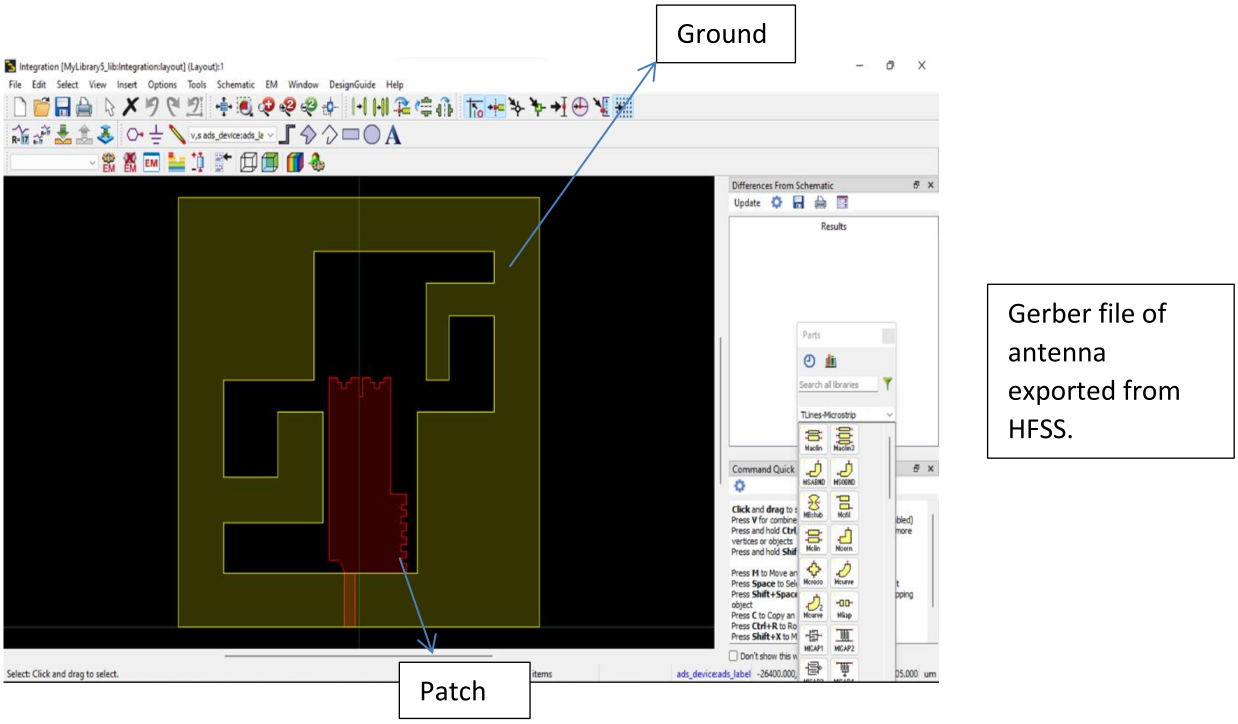
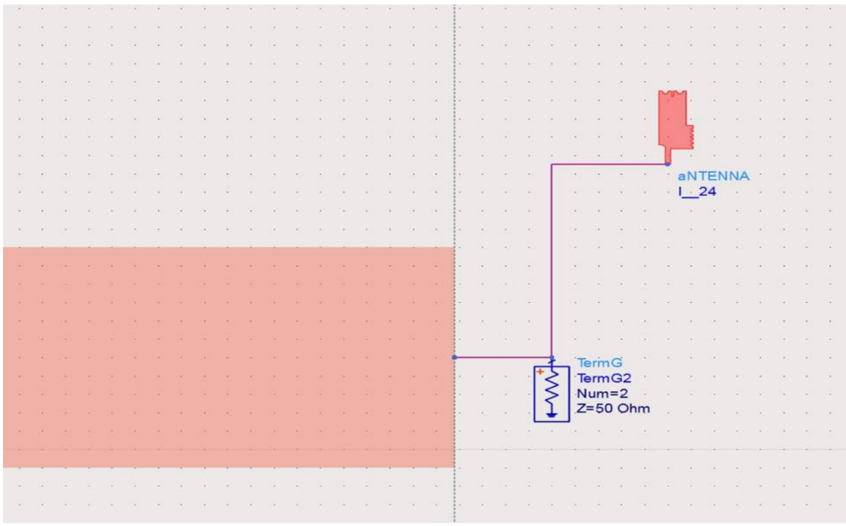


Fig 4.15 Gerber Layout



The figure shows the co design of antenna and LNA, where antenna was imported from HFSS and was integrated wih LNA in ADS.

Fig 4.16 Integrated Schematic of LNA and Antenna

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion:

We have effectively designed and implemented an active antenna with a low noise amplifier (LNA) for 2.4GHz wireless communication. Our work intended to increase signal strength and decrease noise in wireless communication, and our findings demonstrated that the integrated system achieved these goals. We optimized the matching network between the LNA and the antenna, determined the optimal location for the LNA, and constructed the system using the proper materials and components. A variety of tests, including radiation pattern measurement, gain, noise figure, and frequency response, were used to evaluate the device's performance. The results demonstrated that the system met project objectives and performed well. Our contribution to the field of wireless communication is a dependable and robust system for increasing signal strength and decreasing disturbance. Additional study could investigate the use of various materials and components to enhance the efficacy of the active antenna with LNA system

5.2 Future Work:

Future project tasks include integrating the low noise amplifier (LNA) with the antenna, constructing the system, and assessing its performance. The integration process entails designing and optimizing the matching network between the LNA and antenna, determining the optimal placement of the LNA in relation to the antenna, and testing the integrated system to ensure that it fulfills the project's objectives. The antenna and LNA components will be created using fabrication techniques, such as printed circuit board (PCB) fabrication, and then assembled. Performance evaluation will consist of conducting a variety of tests to evaluate the system's performance, contrasting the results with the project's objectives and requirements, and evaluating the system's performance in a variety of environments and conditions to ensure its reliability and robustness. By completing these tasks, the project will be designed, manufactured, and evaluated in accordance with its objectives and specific at.

CHAPTER 6

REFERENCES

[1] "Antenna Theory and Design" by Warren L. Stutzman and Gary A. Thiele.

[2] "Wireless Sensor Networks: Principles, Design, and Applications" by Shuang-Hua Yang.

[3] "Wi-Fi Handbook: Building 802.11b Wireless Networks" by Frank Ohrtman.

[4] The official website of the United Nations dedicated to the Sustainable Development Goals provides comprehensive information on each goal, including SDG 9. You can find relevant reports, publications, and resources on this platform.

[5] Title: "Energy-Efficient Wireless Communication Systems for Sustainable Development" Authors: Yansha Deng, Houbing Song, and Mohamed-Slim Alouini

[6] Title: "Green Communications: Theoretical Fundamentals, Algorithms, and Applications" Authors: Z. Han, M. V. Simic, T. S. Rappaport, and C. Rowell

[7] Title: "Partnerships for Sustainable Development: Perspectives, Practices, and Prospects" Authors: David Satterthwaite and Diana Mitlin

[8] Title: "Microstrip Patch Antennas: A Designer's Guide" Author: Rod Waterhouse

[9] "Microstrip Antenna Design Handbook" by Ramesh Garg, Prakash Bhartia, Inder Bahl, and Apisak Ittipiboon

[10] Title: "Antenna Theory: Analysis and Design" Authors: Constantine A. Balanis

[11] Pozar, D. M. (2011). Microwave engineering (4th ed.). Wiley.

[12] Balanis, C. A. (2016). Antenna Theory: Analysis and Design (4th ed.). John Wiley & Sons.

[13] Volakis, J. L. (2011). Antenna engineering handbook (4th ed.). McGraw-Hill.

[14] Orr, W. I., Cowan, S. G., & Cowan, S. G. (2001). Loop antenna handbook. American Radio Relay League

[15] "Loop Antennas," Radio-Electronics.com

[16] Mailloux, R. (Ed.). (2005). Phased Array Antenna Handbook (2nd ed.). Artech House.

[17] Balanis, C. A. (2016). Antenna theory: analysis and design (4th ed.). Wiley.

[18] S. M. Ali, A. A. Dahman and A. R. Sebak, "Microstrip Patch Antennas

[19] L. V. Blake, Antennas, New York: John Wliey & Sons, 1966. QUALCOMM, “What can we do with 5G NR Spectrum Sharing that isn't possible today?,” 13 December 2017. [Online]. Available: https://www.qualcomm.com/media/documents/files/new-3gpp-effort-on-nr-inunlicensed-spectrum-expands-5g-to-new-areas.pdf

[20] NIVIUK, "NR frequency band," [Online]. Available: http://niviuk.free.fr/nr_band.php

[21] P. M. Paul, K. Kandasamy and M. Sharawi, "SRR loaded slot antenna for multiband applications," 2017 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, 2017, pp. 2529-2530, doi: 10.1109/APUSNCURSINRSM.2017.8073307

[22] C. Huang, Y. Jiao, Z. Weng and X. Li, "A planar multiband antenna based on CRLH-TL ZOR for 4G compact mobile terminal applications," 2018 International Workshop on Antenna Technology (iWAT), 2018, pp. 1-3, doi: 10.1109/IWAT.2018.8379200

[23] N. I. M. Elamin and T. A. Rahman, "2-Element slot meander patch antenna system for LTE-WLAN customer premise equipment," 2015 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC), 2015, pp. 993-996, doi: 10.1109/APWC.2015.7300191

[24] T. Cai, G. Wang and J. Liang, "Analysis and Design of Novel 2-D Transmission-Line Metamaterial and Its Application to Compact Dual-Band Antenna," in IEEE Antennas and Wireless Propagation Letters, vol. 13, pp. 555-558, 2014, doi: 10.1109/LAWP.2014.2312313

[25] B. Zong, G. Wang, C. Zhou and Y. Wang, "Compact Low-Profile Dual-Band Patch Antenna Using Novel TL-MTM Structures," in IEEE Antennas and Wireless Propagation Letters, vol. 14, pp. 567-570, 2015, doi: 10.1109/LAWP.2014.2372093. 104

[26] A. Boukarkar, X. Q. Lin, Y. Jiang and Y. Q. Yu, "Miniaturized Single-Feed Multiband Patch Antennas," in IEEE Transactions on Antennas and Propagation, vol. 65, no. 2, pp. 850-854, Feb. 2017, doi: 10.1109/TAP.2016.2632620

[27] Huawei Technologies Co. Ltd., "5G Spectrum Public Policy Position," Huawei Technologies, Shenzen, China, 2017

[28] L. Tao, J. Xu, H. Li, Y. Hao, S. Huang, M. Lei and K. Bi, "Bandwidth Enhancement of Microstrip Patch Antenna Using Complementary Rhombus Resonator," Wireless Communications and Mobile Computing, vol. 2018, 2018, doi: 10.1155/2018/6352181

[29] B. K. Kumar, P. V. V. Kishore and K. K. Naik, "Design of Rectangular Patch Antenna with X-slots for Wireless Communications," 2018 Second International Conference on Inventive Communication and Computational Technologies (ICICCT), 2018, pp. 1448- 1451, doi: 10.1109/ICICCT.2018.8473111

[30] L. Sun, G. Zhang, B. Sun, W. Tang and J. Yuan, "A Single Patch Antenna With Broadside and Conical Radiation Patterns for 3G/4G Pattern Diversity," in IEEE Antennas and Wireless Propagation Letters, vol. 15, pp. 433-436, 2016, doi: 10.1109/LAWP.2015.2451132.

[31] K. M. Mak, H. W. Lai and K. M. Luk, "A 5G Wideband Patch Antenna With Antisymmetric L-shaped Probe Feeds," in IEEE Transactions on Antennas and Propagation, vol. 66, no. 2, pp. 957-961, Feb. 2018, doi: 10.1109/TAP.2017.2776973

[32] W. Shi, Z. Qian and W. Ni, "Dual-Band Stacked Annular Slot/Patch Antenna for Omnidirectional Radiation," in IEEE Antennas and Wireless Propagation Letters, vol. 15, pp. 390-393, 2016, doi: 10.1109/LAWP.2015.2447280.

[33] X. -Q. Zhu, Y. -X. Guo and W. Wu, "A Novel Dual-Band Antenna for Wireless Communication Applications," in IEEE Antennas and Wireless Propagation Letters, vol. 15, pp. 516-519, 2016, doi: 10.1109/LAWP.2015.2456039. 105

[34] Y. He, K. Ma, N. Yan and H. Zhang, "Dual-Band Monopole Antenna Using SubstrateIntegrated Suspended Line Technology for WLAN Application," in IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 2776-2779, 2017, doi: 10.1109/LAWP.2017.2745503

[35] S. Liu, W. Wu and D. -G. Fang, "Single-Feed Dual-Layer Dual-Band E-Shaped and USlot Patch Antenna for Wireless Communication Application," in IEEE Antennas and Wireless Propagation Letters, vol. 15, pp. 468-471, 2016, doi: 10.1109/LAWP.2015.2453329

[36] Y. L. Elo, F. Y. Zulkifli and E. T. Rahardjo, "Design of wideband microstrip antenna with parasitic element for 4G/LTE application," 2017 15th International Conference on Quality in Research (QiR) : International Symposium on Electrical and Computer Engineering, 2017, pp. 110-113, doi: 10.1109/QIR.2017.8168463

[37] A. A. Salih and M. S. Sharawi, "A Dual-Band Highly Miniaturized Patch Antenna," in IEEE Antennas and Wireless Propagation Letters, vol. 15, pp. 1783-1786, 2016, doi: 10.1109/LAWP.2016.2536678

[38] R. Goncalves, P. Pinho and N. B. Carvalho, "Compact, Frequency Reconfigurable, Printed Monopole Antenna," International Journal of Antennas and Propagation, vol. 2012, 2012, doi: 10.1155/2012/602780

UG Thesis Qasim

ORIGINALITY REPORT

18 %	12%	10%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.diva-portal.org Internet Source	2 %
2	"Handbook of Antenna Technologies", Springer Science and Business Media LLC,2016 Publication	2 %
3	vdocuments.mx Internet Source	1 %
4	www.alldatasheet.com Internet Source	1 %
5	www.ijraset.com Internet Source	1 %

6	www.researchgate.net Internet Source	1%
7	resmilitaris.net Internet Source	1%
8	www.jpier.org Internet Source	1%

9 Linjie Chen, Amin Aminaei, Leonid I. Gurvits, Marc Klein Wolt, Hamid Reza Pourshaghaghi,Yihua Yan, Heino Falcke. "Antenna design andimplementation for the future space Ultra- Long wavelength radio telescope", Experimental Astronomy, 2018 <1%
Publication

10 Submitted to HCUC <1%
Student Paper

11 www.ijert.org <1%
Internet Source

12 S Poonguzhali, A. Sivasangari, S. Lalithakumari, D. Sathish Kumar. "A Novel Reconfigurable Antenna Architecture for Wireless Applications", 2022 International Conference on Smart Technologies and Systems for Next Generation Computing (ICSTSN), 2022 <1%
Publication

13 www.utmel.com <1%
Internet Source

14 Bories, S., M. Pelissier, C. Delaveaud, and R. Bourtoutian. "Performances analysis of LNA-antenna co-design for UWB system", IET Seminar Digests, 2007. <1%
Publication

15	Tamer Aboufoul. "Reconfigurable printed UWB circular disc monopole antenna", 2011Loughborough Antennas & Propagation Conference, 11/2011 Publication	<1%
16	datospdf.com Internet Source	<1%
17	dspace.ewubd.edu:8080 Internet Source	<1%
18	eprints.utm.my Internet Source	<1%
19	www.electronicshub.org Internet Source	<1%
20	barnsleygymnastics.org Internet Source	<1%
21	yix.fourcornersdailypost.com Internet Source	<1%
22	Edward C. Niehenke.. "The evolution of low noise devices and amplifiers", 2012 IEEE/MTT-S International Microwave Symposium Digest,2012 Publication	<1%
23	Arash Valizade, Pejman Rezaei, Ali A. Orouji."A NEW DESIGN OF DUAL-PORT ACTIVE INTEGRATED ANTENNA FOR 2.4/5.2 GHZ	

WLAN APPLICATIONS", Progress In Electromagnetics Research B, 2014
Publication

<1%

24

Aboufoul, Tamer, Akram Alomainy, and Clive Parini. "Reconfiguring UWB Monopole Antenna for Cognitive Radio Applications Using GaAs FET Switches", IEEE Antennas andWireless Propagation Letters, 2012.
Publication

<1%

25

ir.kluniversity.in
Internet Source

<1%

26

Adina Jubangaliyeva, Edisa Shoshi, Paula Elisabeth Pinto, Nada Aroob Bealallo, Abdullah Masuk, Istvan Balajti. "Circular Loop,E-patch, Blade, and Spiral Array Antennas for Cyber-Physical System Applications", 2022 23rd International Radar Symposium (IRS), 2022
Publication

<1%

27

Submitted to Orissa University of Agriculture& Technology
Student Paper

<1%

28

R.H. Witvers. "Integrated Active AntennaNoise Figure Characterization Using a Cryogenic Anechoic Noise Source", 31stEuropean Microwave Conference 2001, 10/2001
Publication

29	Submitted to The University of Manchester Student Paper	<1%
30	www.freepatentsonline.com Internet Source	<1%
31	www.semanticscholar.org Internet Source	<1%
32	Toh, . "Brief Review of Maxwell's Theory", Electromagnetic Theory for ElectromagneticCompatibility Engineers, 2013. Publication	<1%
33	onlinewww.jpier.org Internet Source	<1%
34	digital.library.adelaide.edu.au Internet Source	<1%
35	Abdullah Eroglu. "RF/Microwave Engineeringand Applications in Energy Systems", Wiley, 2022 Publication	<1%
36	Gunjan Mittal Roy, Binod Kumar Kanuajia, Santanu Dwari, Sandeep Kumar, Hanjung Song. "2–18GHz wide band co-design integrated LNA with active antenna for mobilecommunication technologies", Analog Integrated Circuits and Signal Processing, 2018 Publication	<1%

37

Xiang Guan, H. Hashemi, A. Hajimiri. "A fully integrated 24-GHz eight-element phased- array receiver in silicon", IEEE Journal of Solid- State Circuits, 2004

Publication

<1%

38

vdoc.pub

Internet Source

<1%

39

Submitted to Durban University ofTechnology

Student Paper

<1%

40

Peter, T., M.K.A. Rahim, J. Din, and T. Masri."Active integrated antenna with low noise amplifier design at 5 GHz", IET Seminar Digests, 2007.

Publication

<1%

41

Niehenke, Edward C.. "The evolution of transistors for power amplifiers: 1947 totoday", 2015 IEEE MTT-S International Microwave Symposium, 2015.

Publication

<1%

42

Peter C. L. Yip. "High-Frequency Circuit Designand Measurements", Springer Science and Business Media LLC, 1990

Publication

<1%

43

Submitted to Yonsei University

Student Paper

<1%

malrep.uum.edu.my

<1%

44 Internet Source <1%

45 T NOERGAARD. "Know Your Standards",Embedded Systems Architecture, 2005
Publication <1%

46 Submitted to University of Sunderland
Student Paper <1%

47 Submitted to Higher Education CommissionPakistan
Student Paper <1%

48 Mahmoud Abdipour, Gholamreza Moradi, Reza Sarraf Shirazi. "Ultra-low noise active microstrip antenna", International Journal of Microwave and Wireless Technologies, 2013
Publication <1%

49 Submitted to Nottingham Trent University
Student Paper <1%

50 Submitted to University College Birmingham
Student Paper <1%

51 download.atlantis-press.com
Internet Source <1%

52 Min Gao, Bowei Wang, Yan Li, Buning Tian. "ANew Pattern Reconfigurable Loop Antenna with Wide Beam Width", 2018 Cross Strait Quad-Regional Radio Science and Wireless Technology Conference (CSQRWC), 2018 <1%

Publication

53 archive.org
Internet Source
<1%

54 fenix.tecnico.ulisboa.pt
Internet Source
<1%

55 Lloyd E. Matthews. "The Optimum Source Impedance and Noise Figures of TelevisionInput Tubes With Various Circuits", IRE Transactions on Broadcast and Television Receivers, 1/1959
Publication
<1%

56 Remy Cellier. "Analysis and design of an analog control loop for digital input class Damplifiers", 2011 18th IEEE International Conference on Electronics Circuits and Systems, 12/2011
Publication
<1%

57 etheses.bham.ac.uk
Internet Source
<1%

58 fccid.io
Internet Source
<1%

59 Mohammad S. Sharawi, Sagar K. Dhar, OualidHammi, Fadhel M. Ghannouchi. "Miniaturised active integrated antennas: a co−design approach", IET Microwaves, Antennas & Propagation, 2016
Publication
<1%

60	Submitted to University of Hertfordshire Student Paper	<1%
61	catalog.montgomerycollege.edu Internet Source	<1%
62	core.ac.uk Internet Source	<1%
63	docplayer.net Internet Source	<1%
64	pdfcoffee.com Internet Source	<1%
65	scholarbank.nus.edu.sg Internet Source	<1%
66	www.ijariit.com Internet Source	<1%
67	www.thesatelliteshop.net Internet Source	<1%
68	"SM381 book 1 Unifying electricity and magnetism ISBN9781473032422 itm5124952",Open University Publication	<1%