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Abstract:

In modern wireless communication systems, enhancing signal quality and reception efficiency is a critical goal. Smart antennas offer a promising solution by enabling directional signal reception and dynamic adjustment according to the signal source. This research presents the development of a smart antenna system controlled using an Arduino Uno, integrating a Yagi antenna, NRF wireless module, LCD I2C display, and servo motors. The key challenge addressed in this study is how to dynamically orient the antenna in real time toward the desired signal source to optimize reception strength. To achieve this, we designed a control system where the servo motors adjust the antenna's direction based on signal strength data collected via the NRF module. The results demonstrate that the antenna can be dynamically oriented to maximize the signal-to-noise ratio, confirming the feasibility of real-time control and selection of optimal signal sources. This system shows potential applications in both communication and signal-tracking fields, particularly in environments where signal sources are mobile or obstructed.

Keywords: Yagi Antenna, Arduino Uno, NRF Module, LCD I2C, Servo Motors, Smart Antenna, Wireless Signal Tracking.

Résumé:

Dans les systèmes de communication sans fil modernes, l'amélioration de la qualité du signal et de l'efficacité de la réception est un objectif essentiel. Les antennes intelligentes offrent une solution prometteuse en permettant une réception directionnelle et un ajustement dynamique selon la source du signal. Cette recherche présente le développement d'un système d'antenne intelligente contrôlé par un Arduino Uno, intégrant une antenne Yagi, un module NRF, un écran LCD I2C et des servomoteurs. Le problème principal abordé est la manière d'orienter dynamiquement l'antenne en temps réel vers la source de signal désirée afin d'optimiser la réception. Pour ce faire, nous avons conçu un système de commande où les servomoteurs ajustent la direction de l'antenne en fonction de la puissance du signal détectée par le module NRF. Les résultats montrent que l'antenne peut être orientée dynamiquement pour maximiser le rapport signal/bruit, ce qui confirme la faisabilité d'un contrôle en temps réel et d'une sélection efficace de la source. Ce système présente un fort potentiel dans les domaines de la communication et du suivi de signaux, notamment dans des environnements où les sources sont mobiles ou obstruées.

Mots-clés : Antenne Yagi, Arduino Uno, Module NRF, Écran LCD I2C, Servomoteurs, Antenne intelligente, Suivi de signal sans fil.

الملخص

في أنظمة الاتصالات اللاسلكية الحديثة، يُعد تحسين جودة الإشارة وكفاءة الاستقبال هدفًا أساسيًا. وتُعتبر الهوائيات الذكية حلاً واعدًا، حيث تتيح استقبالًا اتجاهيًا وقدرة على التعديل الديناميكي حسب مصدر الإشارة. يعرض هذا البحث تطوير نظام هوائي ، ومحركات سيرفو. LCD I2C ، وشاشةNRF ، ووحدةYagi ، ويضم هوائيArduino Uno ذكي يتم التحكم فيه باستخدام تتمثل الإشكالية في كيفية توجيه الهوائي ديناميكيًا في الوقت الفعلي نحو مصدر الإشارة المطلوب لتحسين جودة الاستقبال.

لتحقيق ذلك، قمنا بتصميم نظام تحكم يُمكّن محركات السيرفو من تعديل اتجاه الهوائي بناءً على قوة الإشارة الملتقطة بواسطة أظهرت النتائج أن الهوائي يمكن توجيهه ديناميكيًا لتعظيم نسبة الإشارة إلى الضوضاء، مما يؤكد إمكانية التحكم .NRF وحدة في الوقت الحقيقي واختيار الإشارة الأفضل. ويُظهر هذا النظام إمكانيات كبيرة في مجالات الاتصالات وتتبع الإشارات، خاصة .في البيئات التي تكون فيها مصادر الإشارة متحركة أو محجوبة

، محركات سيرفو، هوائي ذكي، تتبع الإشارة LCD I2C ، شاشةNRF ، أردوينو أونو، وحدةYagi هوائي :الكلمات المفتاحية اللاسلكية**.**

Dedication:

To the one who believed in me before I believed in myself and taught me that education is a mission and not just a journey,

my dear mother.

To the one who made meals and desserts with love and ensured my psychological and mental stability,

my dear sister, Dr. Balssam.

To the one who rejoices in my joy and is saddened by my sadness, my little sister,

Aisha.

To the difference makers who turned an enthusiastic student into an engineer graduating today with pride and honor for the nation,

my teachers.

Salma Fedel .

Dedication :

دخول

إهداء إلى من كان لهم الفضل بعد الله في كل خطوةٍ خطوتها في مسيرتي العلمية

إلى والدي العزيزين تاج رأسي ... إلى من علّموني الصبر والثبات وزرعوا في قلبي الأمل والإصرار ومصدر قوتي وإلهامي

إلى أسرتي الكريمة التي كانت سندي ودعمي طوال الطريق

إلى أساتذتي الكرام الذين لم يبخلوا بعلمهم وتوجيههم إلى أصدقائي الذين شاركوني اللحظات الجميلة والصعبة

إليكم جميعا أهدي ثمرة هذا الجهد المتواضع راجيا من الله أن يكون بداية لما هو أعظم

Zakaria azzabi

Thanks and Appreciation :

This presented work was carried out within the faculty of technology of Hamma Lakhdar university

Above all , we thank God for reaching this stage ,

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And the most important of them all is our gratitude for our supervisor **Mr. .Hima Abdelkader** for directing this work ,

We have been honored to work with you and lucky cause you shared your skills, time and knowledge with us .

Last, we thank all the for his support and guidance .

Liset of shorts cuts and summaries:

FHSS	**frequency Hopping Spread Spectrum**
DSSS	**Direct Sequence Spread Spectrum**
NFC	**Near Field Communication**
IEEE802.11	**WIFI**
IEEE802.16	**WiMAX**
WLAN	**Wireless Local Area Network**
WPAN	**Wireless Personal Area Network**
WMAN	**Wireless Metropolitan Area Network**
WIMAX	**Worldwide Interoperability for Microwave Access**
WWAN	**Wireless Wide Area Network**
GSM	**Global System for Mobile Communications**
GMSK	**Gaussian Minimum Shift Keying**
OFDM	**Orthogonal Frequency Division Multiplexing**
CDMA	**Code Division Multiple Access**
NB-IOT	**Narrowband Internet of Things**
AM-FM	**Amplitude Modulation / Frequency Modulation**
SDA	**Serial Data**
SCL	**Serial Clock**
CE	**Chip Enable**
CSN	**Chip Select Not**
MOSI	**Master Out Slave In**
MISO	**Master In Slave Out**
SCK	**Serial Clock**

Abbreviations Used in the Project

Abbreviation	Full Meaning	Function / Description
NRF24L01	Nordic Radio Frequency 2.4GHz Low Power Transceiver	Wireless data transceiver module at 2.4GHz.
RF24	Radio Frequency 2.4GHz	Arduino library for controlling NRF24L01.
SPI	Serial Peripheral Interface	Communication protocol between Arduino and NRF24L01.
CE	Chip Enable	Switches the NRF24L01 between TX and RX modes.
CSN	Chip Select Not	Used to select the device in SPI communication.
SCK	Serial Clock	Clock line in SPI communication.
MOSI	Master Out Slave In	Data line from Arduino to NRF24L01.
MISO	Master In Slave Out	Data line from NRF24L01 to Arduino.
IRQ	Interrupt Request	Interrupt pin (often unused).
VCC	Voltage Common Collector	Power supply (3.3V only for NRF24L01).
GND	Ground	Electrical ground.
RPD	Received Power Detector	Detects if received signal strength is above -64 dBm.
RSSI	Received Signal Strength Indicator	Measures signal strength, typically in dBm (RPD is a substitute for NRF24L01).
Rx	Receive	Receiving data.
Tx	Transmit	Transmitting data.
LCD	Liquid Crystal Display	Used to display text output.
I2C	Inter-Integrated Circuit	Communication protocol used by LCD.
PWM	Pulse Width Modulation	Used to control servo motors.

PA_LEVEL	**Power Amplifier Level**	**Transmitting power level (LOW, HIGH, MAX).**
Millis ()	**Milliseconds since start**	**Returns time since Arduino started.**
delay ()	**Delay in milliseconds**	**Pauses code execution for a given time.**

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General Introduction

Introduction:

The field of communication technology has undergone a tremendous revolution in recent decades, and one of the most revolutionary inventions of our time is wireless communication. Wireless technologies have created the basis for a contemporary, networked world that powers everything from satellite links, remote sensors, and smart cities to cell phones and Wi-Fi by allowing data to be transferred via electromagnetic waves rather than physical cables.

Guglielmo Marconi's groundbreaking experiments and James Clerk Maxwell's theoretical contributions to the late 19th century are credited with giving rise to wireless communication. Since the first successful radio transmissions to the intricate wireless networks of today, the field has quickly changed, utilizing advanced protocols, digital modulation, and error correction to meet

modulation, error correction, and sophisticated protocols to satisfy the increasing need for communication that is quicker, more dependable, and more effective.

An essential part of any wireless communication system is the antenna. Antennas serve as the link between the environment and electronic systems. For transmission, they transform electrical signals into electromagnetic waves, and upon reception, they transform the waves back into electrical signals. Despite the apparent simplicity of the idea, antenna orientation and design have a big impact on data integrity, communication range, and signal strength.

Although they have many different forms and purposes, antennas can be broadly divided into two types:

Omnidirectional antennas:

These emit signals uniformly in every direction. They are frequently employed in settings where devices' relative positions are uncertain or subject to frequent change.

Directional antennas:

These focus the signal in a specific direction, allowing for stronger and more concentrated transmissions. Examples include parabolic dish antennas and Yagi antennas. While more efficient, they require precise alignment to maintain a strong connection with the intended receiver.

This results in signal fluctuation, a significant problem in wireless communication. The quality of the received signal can change dramatically as devices move or as environmental factors (like obstructions, interference, or reflections) change. Misalignment, even by a few degrees, can result in a significant drop in signal strength, increasing power consumption and data loss, especially for directional antennas.

The issue raised:

Researchers and engineers have resorted to smart antenna systems in order to solve this issue. In order to track the direction of the strongest signal and improve communication performance, these systems combine sensing, processing, and mechanical control to dynamically change the antenna's orientation in real time. This degree of flexibility is particularly crucial for applications involving remote or mobile devices, where static configurations are no longer adequate.

Designing and implementing a smart antenna system that can identify the optimal antenna orientation to receive the strongest signal is the aim of this project.

The system's goal in automating this process is to:

• Increase data transmission rates while preserving a steady signal strength.

• Reduce energy consumption because stronger signals require less power and retransmission;

• minimize transmission errors brought on by noise, interference, or weak signals; and improve the overall dependability and effectiveness of the communication process.

Our goal is to show how intelligent antenna control can enhance wireless communication performance, particularly in dynamic or uncertain environments.

• A promising first step toward future wireless systems that are faster, smarter, and use less energy is the smart antenna concept.

Display of Project presentation:

• The first chapter provides general information about wireless communications, including types and antennas.

• The second chapter discusses the tangible tools we employed.

• The coding process, installation, and the project's operation are covered in the third chapter, which also explains the function of each device.

• The project's realization and outcomes are covered in the fourth chapter.

Chapter I

Generality on wireless communication

1.1 Introduction:

The rise of wireless technologies, often referred to as wireless networks, offers new possibilities in the field of telecommunications. Wireless networks are based on communication using radio waves (radio and infrared) instead of traditional cables. There are several technologies that differ based on the frequency of transmission, as well as the speed and range of transmissions. Wireless networks make it easy to connect devices that are remote from each other, ranging from a few meters to several kilometers apart. Moreover, setting up such networks does not require extensive infrastructure modifications like those needed for wired networks (digging trenches for cable installation, wiring buildings, conduits, and connectors). This has led to the rapid development of these technologies. However, there are regulatory challenges related to radio-electric transmissions. Radio-electric transmissions serve a wide range of applications (military, scientific, amateur, etc.) but are susceptible to interference. That's why regulations are necessary in each country to define frequency bands and power levels for each category of use. Furthermore, radio waves are difficult to confine within a limited geographic area, making it relatively easy for unauthorized individuals to eavesdrop on the network if information is transmitted in plaintext (which is the default case). Therefore, it is essential to implement the necessary measures to ensure data confidentiality on wireless networks.

1. **Historically:**

The evolution of communication throughout history, leading to wireless communications, has gone through several key stages. In ancient times, humans relied on cave paintings, symbols, and early writing systems such as cuneiform (3000 BC) and hieroglyphics to convey messages.

Later, methods like carrier pigeons, smoke signals, and handwritten letters improved long-distance communication. In the 15th century, Gutenberg's printing press revolutionized information dissemination, followed by the rise of newspapers in the 17th century.

With the Industrial Revolution in the 19th century, the invention of the telegraph in 1837 enabled messages to be transmitted over long distances via wired connections. This was followed by the telephone in 1876, which allowed real-time voice communication.

Later, Marconi’s invention of the radio in 1895 marked the first step toward wireless communication. During the 20th century, advancements in radio and television broadcasting, along with the launch of satellites like "Sputnik" in 1957, paved the way for global communication networks. In the 1970s, the introduction of mobile phones and the rise of the internet in the 1990s revolutionized digital communication.

As technology advanced, wireless communications became the foundation of modern connectivity, evolving from first-generation (1G) mobile networks to the ultra-fast fifth-generation (5G) networks. Today, communication systems rely on cutting-edge technologies such as fiber optics, artificial intelligence, and satellite networks, making the world more interconnected than ever before Wireless communication frequencies are regulated by organizations such as the International Telecommunication Union (ITU) and national spectrum regulatory bodies, The frequency spectrum is divided into different bands, each designated for specific uses.

2 Definition of wireless networks:

A wireless network is a computer or digital network that connects different stations or systems to each other using radio waves. The wireless network can be associated with a telecommunications network to establish interconnections between nodes. The most commonly used standard for wireless networks today is the IEEE 802.11 standard. The geographical range of the waves is relatively limited due to the low transmitting power of current hardware solutions. For this reason, wireless networks have primarily developed as internal networks, specific to a building, either as a corporate network or a home network.

2.1 Advantages of deploying a wireless network:

Choice of connection location, as long as it remains within the network's coverage Flexibility: The connection is independent of the brand or technical specifications of the connected devices. Ease: No cables mean less clutter. Devices on the market tend to connect automatically Mobility: Users can move around without disconnecting from the network. Cost: Prices tend to decrease as the market evolves. It's hard to buy a laptop without integrated wireless network capability**.**

- **. For those responsible for deploying the wireless network:**

Reduced cable deployment, resulting in a decrease in cable investment and workload during installation. Ease and flexibility of deployment: Additional machines can connect without requiring dedicated spaces like RJ45 outlets. Whether there are 10 or 15 user machines, the difference is not as critical as with a wired network in terms of connection space (though it may differ in network analysis terms). Cost: A wireless solution can be significantly more cost-effective for a business However, a thorough analysis is required, taking into account the specific needs of the company's users B. Disadvantage of wireless networks

- **Limited Range:** Wireless networks have a limited coverage area compared to wired networks. The signal strength weakens as you move farther from the access point.
- **Interference:** Wireless signals can be prone to interference from other electronic devices or physical obstacles like walls, which can degrade the quality of the connection**.**
- **Security Concerns:** Wireless networks can be more vulnerable to security breaches if not properly configured. Unauthorized access, data interception, and other security risks are a concern.
- **Slower Speeds:** In some cases, wireless connections may be slower than wired connections, especially in crowded areas with many devices competing for bandwidth.
- **Reliability:** Wireless networks can be less reliable than wired networks, with the connection dropping or disruptions, particularly in high-traffic environments.
- **Setup and Maintenance:** Setting up and maintaining a wireless network can be more complex than a wired network, requiring careful configuration and monitoring.
- **Cost:** While wireless technology has become more affordable, setting up a wireless network can still involve costs for access points, routers, and security measures.
- **Limited Bandwidth:** Wireless networks may have limited bandwidth compared to wired connections, which can affect the performance of data-intensive applications.
- **Health Concerns**: Some people have concerns about potential health effects of long-term exposure to electromagnetic radiation from wireless devices, although scientific consensus on this matter is still inconclusive.
- **Compatibility**: Older devices may not support the latest wireless standards, which can lead to compatibility issues on the network.

2.3. Categories of Wireless Networks:

A wireless network is a network where at least two modes can communicate without a wared connection. These communication networks allow invers to access all traditional network services regardless of their geographic locations Wireless networks can be classified based on two criteria. The first criterion is the network's coverage area. Based on the interion, there are four categories: personal networks, local networks, metropolitan networks, and extended networks The second criterion is the network's infrastructure and adopted model. With respect to this criterion, wireless networks can be divided into networks with infrastructure and infrastructure

The second criterion is the network's infrastructure and adopted model. With respect to this criterion, wireless networks can be divided into networks with infrastructure and infrastructure-less networks. The following figure illustrates the various categories of wireless networks.

2.2.1 Wireless Personal Area Networks (WPANs):

Wireless Personal Area Networks, or WPANs, are wireless networks with very short ranges, typically around a dozen meters. They are commonly used to establish communication between devices on a person, such as a headset and a mobile phone. WPANs are also employed to connect computer equipment without wired connections, for example, linking a printer or a Personal Digital Assistant (PDA) to a desktop computer or enabling communication between two closely located machines. Several technologies can be used to implement these networks, including[1]:

- **Bluetooth:**

The Bluetooth standard (supported by IEEE 802.15.1) is a medium-speed technology that can achieve a maximum theoretical data rate of 1 Mbps (approximately 720 Kbps effective) with low energy consumption. Bluetooth operates in the 2.4 GHz frequency band and has a range of 10 to 30 meters. Its small component size allows it to be integrated into devices such as wireless keyboards, mice, hands-free kits or headsets, and for data transfer between PCs and mobile phones.

- **HomeRF:**

HomeRF was a network standard designed for domestic use to share internet access or transport DECT3 phone communications. It was launched by an industry group in 1998, including HP, IBM, Siemens, Proxima, Compaq, Intel, and Microsoft. HomeRF utilized a physical layer operating in the 2.4 GHz band, using Frequency-Hopping Spread Spectrum (FHSS) with 50 hops per second, and modulation types like 2FSK, or 4FSK The basic data rate was 1 Mbps or 2 Mbps, depending on the modulation used, with a typical range of about fifty meters. HomeRF did not achieve success and was abandoned in favor of Wi-Fi in 2003

- **ZigBee**:

The IEEE 802.15.4 standard offers a low-power, energy-efficient standard for the physical and data link layers, making in well-suited for small electronic devices (home appliances, audio equipment, toys, etc.), especially in sensor networks. ZigBee offers a relatively low data rate (around 100 Kbps) at a very low cost and extremely low power consumption.

- **Infrared Links:**

Infrared technology is also used in these types of networks. However, it is more susceptible to light interference compared to Bluetooth and requires direct line-of-sight between communicating devices.

2.2.2 Wireless Local Aera Network (WLAN):

Since the development of high-speed standards, wireless local area networks (WLAN) are generally used within businesses, universities, and also in private homes. These networks are primarily based on the following technologies[1]:

IEEE 802.11, WIFI (Wireless Fidelity):

IEEE 802.11 is a local wireless network standard proposed by the American standards organization IEEE. The 802.11 technology is generally regarded as the wireless version of 802.3 (Ethernet). The 802.11 technology has undergone many developments, notably with 802.11a and 802.11b, which offer improvements to the original standard by introducing CCK (Complementary Code Keying) modulation in the 2.4 GHz band. Two new data rates became available: 5.5 Mbps and 11 Mbps, with a range of several tens of meters. The 802.11b amendment is what made WIFI popular. Although 802.11b is still widely used, it has now been replaced by 802.11g, which is a direct improvement of 802.11b with a baseband data rate of 54 Mbps in the 2.4 GHz band.

Hiperlan 1 & 2: Developed by ETSI (European Telecommunications Standards Institute), Hiperlan is exclusively a European standard. Hiperlan technology operates in the 5 GHz frequency band, and the data rates vary depending on the version. Specifically, Hiperlan 1 provides a data rate of 20 Mbpm, while Hiperian 2offers a data rate of 54 Mbps, with a similar operational range to Wi-Fi (100 meters) [2]

2.2.3 Wireless metropolitan area network (WMAN):

Wireless Metropolitan Arca Networks (WMAN), more commonly known as Radio Local Loop (RLL) Networks hased on IEEE 802.16 technology have a range of a few tens of Kilometers (with a theriacal range of up to 50 km) and a theoretical radio transmission rate that can reach 74 Mbps for IEEE 802.16, better known by the commercial name WIMAX[2]

2.2.4 Wireless Wide Area Network (WWAN):

Wireless Wide Area Networks (WWAN) This category currently has relatively few technologies. The only available WWAN technologies are those that utilize geostationary or low-earth orbit satellites to relay information between multiple points around the globe. The main technologies are as follow

- **GSM:**

GSM stands for "Global System for Mobile Communication It is a standard jointly established by European operators since 1982 with the objective of developing a mobile telephony system that allows overseas communication, Communication takes place through a packet of waves with two frequencies 900 MHz and 1800 MHz. GSM is characterized by the digital nature of the network and the cellular configuration. The territory is divided into small cells interconnected with each other. Each cell is allocated a certain number of channels for communication

- **GPRS:**

GPRS (General Packet Radio Services) is a second-generation GSM packet-switched radio communication technology, often referred to as 2.5G. GPRS provides end-to-end IP connectivity, from the GPRS terminal to any IP network. Terminals can be seamlessly integrated with Internet networks. The data rate offered by this technology is approximately 171 Kbps.

- **UMTS:**

UMTS, short for "Universal Mobile Telecommunications System," refers to a new 3G mobile telephony standard. The principle of UMTS involves utilizing a broader frequency band to transmit more data and achieve higher data rates. In theory, it can reach speeds of up to 2 Mbps. the UMTS standard utilizes new frequency bands situated between 1900 and 2200 MHz. This technology enables the simultaneous transmission of data and thus offers significantly higher data rates compared to those achieved by GSM and GPRS [2]

- **LTE (Long Term Evolution):**

It is a technology adopted by the fourth generation 4G of mobile networks, capable of providing a theoretical download speed of 100 Mbps.

LTE (Long-Term Evolution) uses radio frequency bands with a width ranging from 1.4 MHz to 20 MHz, utilizing various frequency bands including 3.5 GHz. 2.6 GHz, 4 GHz, as well as 1800 MHz and 800 MHz depending on the country and environmental conditions. It can achieve a theoretical maximum downlink data rate of 300 Mbps for a 20 MHz bandwidth[2]

3.Conclusion:

This chapter provided a comprehensive overview of wireless communication networks, covering their various types, key characteristics, and detailed operational explanations. It clarified how different wireless networks function, the technologies they employ, and the unique features that distinguish them in terms of structure, performance, and application scope. The in-depth explanations helped highlight the fundamental differences between network types, offering a clearer understanding of how each is suited to specific communication needs. This foundational knowledge is essential for evaluating, designing, and improving wireless systems, especially as wireless technologies continue to expand across diverse sectors and applications.

Chapter II

The Hardware part

1.Introduction:

The importance of antennas has grown exponentially with the evolution of communication technologies. As demand for higher data rates, wider coverage, and more reliable connectivity increases, so does the need for more efficient and specialized antenna systems. Antennas not only affect the range and quality of communication but also influence the overall performance of wireless networks in terms of power consumption, bandwidth utilization, and signal clarity. Antennas come in various types, each designed for specific applications and frequency ranges. Common classifications include omnidirectional antennas, which radiate equally in all directions and are typically used in general-purpose broadcasting, and directional antennas, which focus energy in a specific direction to achieve greater range and better signal quality. Other types include microstrip (patch) antennas, Yagi-Uda antennas, dipole antennas, and array antennas, each with unique characteristics and use cases. Among these, directional antennas have garnered significant attention due to their ability to concentrate energy in a desired direction, reducing interference and enhancing signal strength. This focused transmission not only improves communication efficiency but also increases the signal-to-noise ratio (SNR), making them ideal for applications such as point-to-point communication, radar systems, and smart antenna technologies. [4]

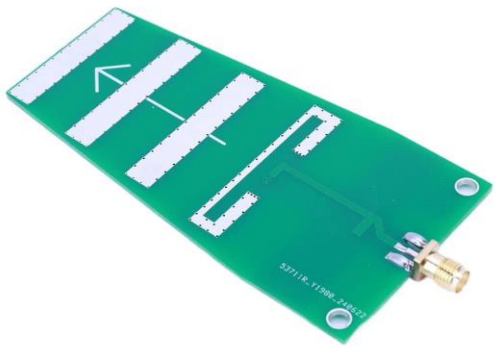
In our research, we focus on directional antennas because of their superior performance in targeted communication scenarios. Their advantages such as extended range, reduced interference, and improved bandwidth efficiency make them a preferred choice in modern wireless systems, particularly where precision and reliability are critical.

1) MATERIAL PARTS:

1.1).Yagi Antenna:

A Yagi-Uda antenna, commonly known as a Yagi antenna, is a highly directional, passive, and narrow-bandwidth antenna used primarily for long-range communication. It consists of a driven element (dipole), a reflector, and multiple directors arranged along a boom. The driven element receives or transmits radio waves, while the reflector enhances signal strength by directing energy forward, and the directors improve directionality and gain. Provides higher gain (typically

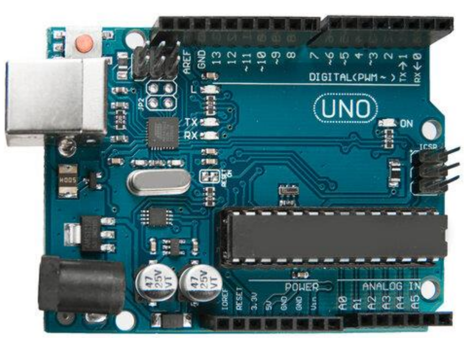
7–13 dB) compared to simple dipole antennas. Used for VHF and UHF communication, including TV reception, ham radio, and wireless networking. [5]



- **Figure 01 YAGI Antenna -**

1.2).Definition of Arduino board:

An Arduino board is an open-source microcontroller-based development platform designed for building electronic projects and embedded systems. It consists of a programmable microcontroller, input/output (I/O) pins, voltage regulators, communication interfaces, and a power management system. The board is programmed using the Arduino Integrated Development Environment (IDE), which supports C and C++ programming languages. [3]



- **Figure 02 Arduino UNO -**

1.2.1. Why Arduino UNO:

There are many microcontroller-based electronics boards available for programming electronics. All of these tools take care of the complex details of programming and integrate them into an easy-to-use layout. Similarly, the Arduino system simplifies working with microcontrollers while offering interested parties several advantages, including:

- (Low) Price: Arduino boards are relatively inexpensive compared to other platforms. The cheapest version of the Arduino module can be assembled by hand (pre-assembled Arduino boards cost less than 4,500 dinars).

- Multi-platform: The Arduino software, written in Java, runs on Windows, Macintosh, and Linux operating systems. Most microcontroller systems are limited to Windows

- . A clear and simple programming environment: The Arduino programming environment (the Arduino IDE software) is easy to use for beginners, yet flexible enough for advanced users to benefit from.

- Open-source and extensible software: The Arduino software and the Arduino language are published under an open-source license, available for expansion by experienced programmers. The Arduino module programming software is a cross-platform Java application (running on any operating system) that serves as a code editor and compiler and can transfer the program via the serial link (RS232, Bluetooth, or USB, depending on the module).

- Open-source and extensible hardware: Arduino boards are based on the Atmel ATMEGA8, ATMEGA168, and ATMEGA328 microcontrollers. The module schematics are published under a Creative Commons license, and experienced circuit designers can create their own versions of the Arduino boards, expanding and improving them. Even relatively inexperienced users can build a breadboard version of the Arduino board, the purpose of which is to understand how it works and save on costs.

1.3). Definition of a Servo Motor:

There are several types of electric motors, including stepper motors and servo motors. The latter include some really interesting models, such as the SG90 Servo. This servo can be ideal for first-time projects, practicing with this type of device, learning how to use it, simple robot control, and more. Also, its power requirements are very low, and it can even be powered from an Arduino board or a computer's USB port with 5V.

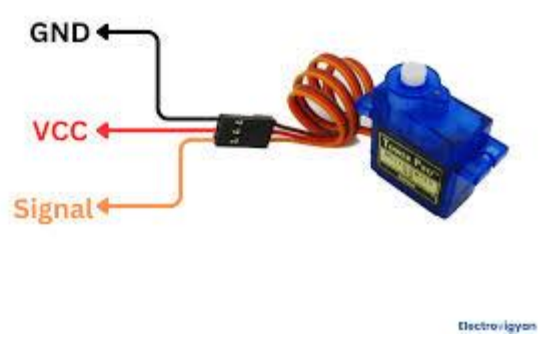
The SG90 is a miniature device, with very compact dimensions, making it easy to integrate into projects where space is at a premium. It is also economical and easy to use, with a very low power demand, so it can also be used in embedded IoT applications or other low-power applications. [6]

The SG90 Servo includes a universal S-type connector. It can fit most commercial devices. It consists of three wires, each colored to indicate its intended use:

Red: This is the positive power cable, or Vcc.(+)

Brown: This is the negative power cable, or GND.(-)

Orange: This is the cable that carries the PPM (Pulse Position Modulation) signal to control the servo motor. [6]



-Figure 03 Servo Motor -

Some models may also have a black, red, and white color combination. In this case, the diagram is GND-Vcc-PPM Signal, respectively.

SG90 Servo Features

Regarding the technical specifications of this servo motor, the SG90 Servo features the following:

Supported weight: 1.2 to 1.6 kg (sufficient for its small size(

Motor torque at 4.8 V: 1.2 kg/cm

Operating voltage: 4 - 7.2 V

Rotational speed at 4.8 V: 0.12 s/60°

Rotation angle: 120°

Function temperature range: -30°C and +60°C

Dimensions: 22 x 11.5 x 27 mm

Weight: 9 g or 10.6 g including cable and connector

Arduino compatible: Yes

Universal connector: Compatible with most radio control receivers (Futaba, JR, GWS, Cirrus, etc.).

1.5). Definition of NRF (Nordic RF Modules):

The NRF24L01 is a wireless transceiver RF module, where each module can send and receive data. Since it operates on the 2.4 GHz ISM band, the technology is approved for engineering applications in almost all countries. This module can cover 100 meters (200 feet) when operated efficiently, making it suitable for wireless remote-control projects.

The NRF24L01 module is powered by 3.3 Volts, so it can be easily used in both 3.2 Volts and 5 Volts systems. Each module has an address range of 125 to communicate with the other 6 modules and also allows several wireless units to communicate with each other in a specified location. Therefore, mesh and other types of networks use this module.

NRF24L01 is a radio transceiver module (SPI protocol) used to send and receive data at ISM operating frequency from 2.4 to 2.5 GHz. This transceiver module is composed of a frequency generator, beat controller, power amplifier, crystal oscillator modulator, and demodulator. It consumes only 11.3 mA at 0 dBm transmit power and consumes 13.5 mA in receive mode.

The high over-the-air data rate combined with sleep mode is highly preferred for ultra-low power applications. The internal voltage regulator controls the high-power rejection ratio and power band. The module is compact and can be easily used in confined spaces.

Operating Modes

It operates in 3 modes, which are transmitter mode, receiver mode, and transceiver (transmitter and receiver) mode. So, these modes are discussed below.

- In transmitting mode, when the power is 0dBm, then the NRF24L01 uses only 11.3mA current.
- While in receiving mode, it uses only 13.5mA current.
- In the transceiver mode, the NRF24L01 module is used for long-distance and quick transmission of data using the SPI protocol.

-Figure 04 -

1.6). Definition of LCD I2C:

An I2C LCD1602 is a device that can display text and characters on a 16x2 (16 columns and 2 rows) liquid crystal display (LCD) using the I2C protocol. You can use an I2C LCD1602 to show information from your Arduino projects, such as sensor readings, messages, menus, etc. The I2C module has a built-in PCF8574 I2C chip that converts I2C serial data to parallel data for the LCD display.

It consists of a normal LCD1602 and an I2C module that is attached to the back of the LCD. The I2C module is a chip that can expand the I/O ports of the Arduino using the I2C protocol. The I2C protocol is a serial communication protocol that uses two wires: SDA (serial data) and SCL (serial clock). The I2C protocol allows multiple devices to communicate with each other using only two wires and unique addresses.

The I2C module converts the signals from the Arduino into commands for the LCD. The LCD has 16x2 cells that can display characters or symbols. Each cell consists of 5x8 dots that can be turned on or off by applying voltage. The LCD can display different characters or symbols by turning on or off different combinations of dots. [8]

-Figure 05 LCD I2C -

* **Note**

After wiring the LCD, you should turn on the Arduino and adjust the contrast by rotating the potentiometer on the I2C module until the first row of rectangles appear to ensure proper LCD operation.

Conclusion:

In this chapter, we highlighted the YAGI antenna and the reason for we choose it

we focused on the Arduino uno device for its importance and relation to each one of the other devices by mentioning its basic parts (the hardware part), and we explained the operating principle of the Arduino board. then we mention all the devices used in the project in detail without forgetting its properties.

Chapter III

Implementation and Application

Introduction:

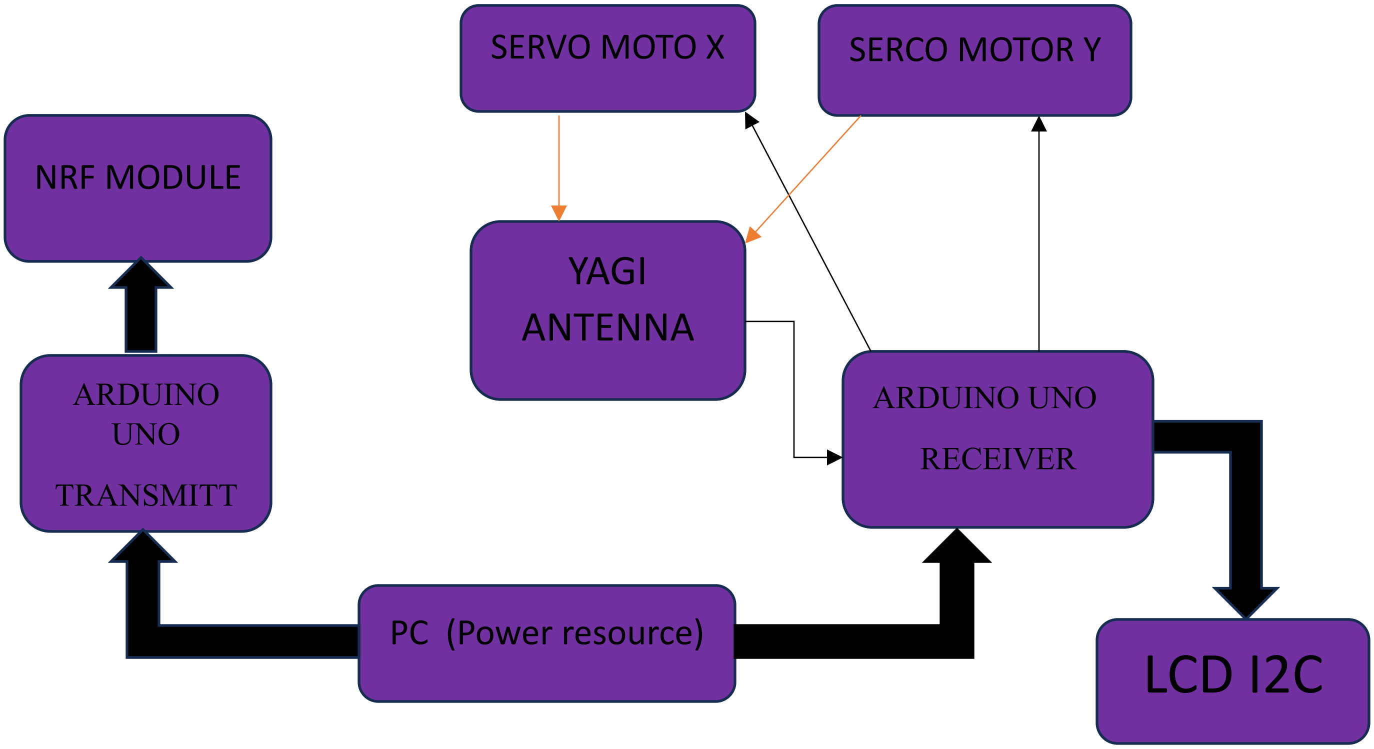
This chapter provides a thorough summary of the practical work completed during the project's implementation phase. This step converts the theoretical underpinnings and technical background covered in the earlier chapters into practical application. From the actual installation of hardware components to the creation and deployment of software systems, the implementation process comprised a number of crucial steps. To guarantee the functionality, dependability, and performance of the finished system, meticulous planning, testing, and integration were needed at each stage. It opens with a thorough description of the installation processes, covering device setup and selection, component configuration, and the difficulties that arose during the physical integration. The methods and instruments utilized to guarantee correct alignment, connectivity, The methods and instruments utilized to guarantee appropriate alignment, connectivity, and communication between system components are highlighted. The accomplishment of the project's goals depended on the successful completion of this phase, which forms the foundation for subsequent phases of development.

The software development process becomes the main focus after the hardware setup. This covers the platforms, languages, libraries, and programming environment in addition to a detailed explanation of the logic and code that have been implemented. Every step of the programming process is described, from creating and testing the source code to troubleshooting and performance optimization. This section also demonstrates how hardware and software were coordinated to operate as a single unit, allowing the system to operate as planned. This chapter covers technical implementation as well as the choices made at different points in time, the challenges encountered, and the solutions used. Every obstacle, whether it was a software limitation, hardware incompatibility, or integration problem, provided insightful information about the development process. In addition to documenting the finished functional system, the objective is to make transparent the process of its development through iterative testing and problem-solving. [10]

The reader will have a thorough understanding of the design, programming, and refinement of the entire system by the end of this chapter. In the context of wireless communication technologies, it serves as a crucial bridge connecting theory and real-world implementation by showing how a conceptual design can be turned into a fully functional prototype.

1. The conception of the system:

Diagram of the assembly of our project



-Figure 06- Synoptic diagram of the system -

2. How to make a smart antenna controlled using Arduino:

2.1 The Hardware part:

Our project consists of a transmitter, a receiver, and an I2C LCD1602 display. Our project is based on a starter architecture with the following features:

2.1.1 The Transmitter side:

How it works:

Constantly sends a brief message over the nRF24L01, like "Hello" or any other text.

Repeating:

Continuous transmission takes place inside a loop ().

Whether or not the message is received is irrelevant.

It is not necessary to receive any data.

The process is quicker and simpler because it doesn't use an acknowledgment of arrival (ACK).

Assembly details:

- **Transmitter Implementation:**

Description	Implemented on Arduino
CE - NRF24L01	Pin 9
CSN - NRF24L01	Pin 10
MOSI	Pin 11
MISO	Pin 12
SCK	Pin 13
VCC	3.3V
GND	GND

-Table 04 - Transmitter Input Table -

2.1.2 The receptor side:

How it works:

.The horizontal servos are moved to a designated corner

.The vertical servos are moved to a designated corner

.It counts the number of messages it receives after a brief period of listening

This angle is saved as the best angle if it is superior to the one before it returns to the angle that produced the strongest signal after finishing the entire scan

- ✓ **Assembly details:**
- **Receiver Implementation:**

2.2. Receiver Input Table:

Description	Implemented on Arduino
CE - NRF24L01	**Pin 9**
CSN - NRF24L01	**Pin 10**
MOSI	**Pin 11**
MISO	**Pin 12**
SCK	**Pin 13**
VCC	**3.3V**
GND	**GND**
Servo X	**Pin 3**
Servo Y	**Pin 5**
LCD I2C	**A4 (SDA), A5 (SCL)**

-table 05 -

2.1.3 The electrical diagram of the project:

- **ISIS:**

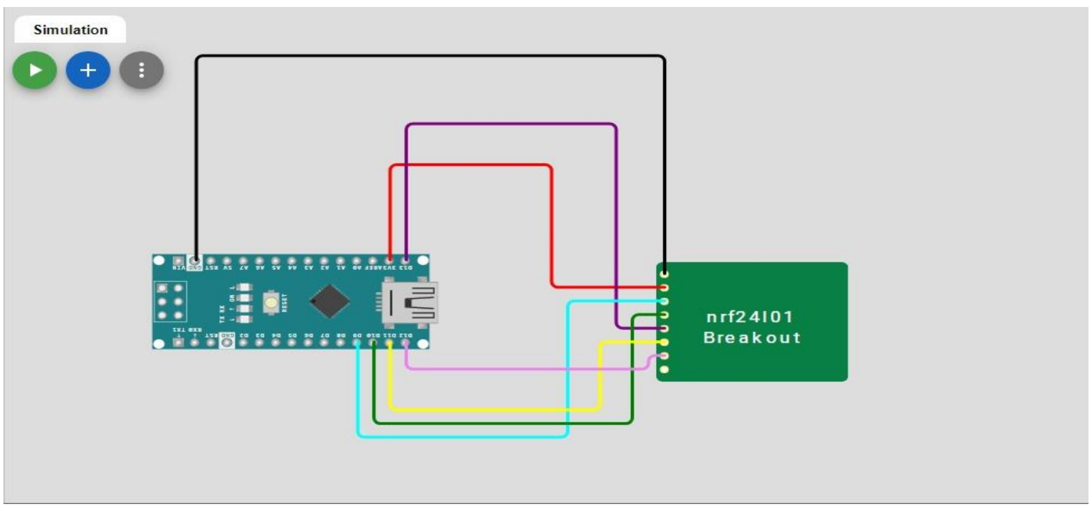
ISIS (Intelligent Schematic Input System) is the main connection for editing these electrical circuits. It also allows us to simulate previous plans. Thanks to it, we can also control the major aspect of the circuit graphics. [9]

- **ARES:**

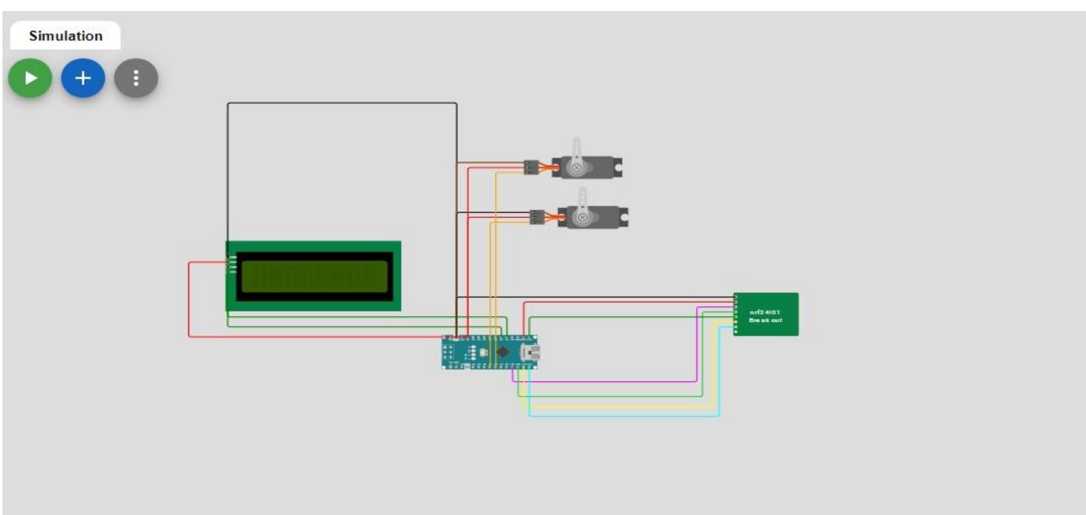
The ARES software is an editor and router that fully supports ISIS. The electrical system installed by ISIS can also be easily imported into ARES.

Read the PCB (Printed Circuit Board). This version of the circuit will be more suitable.

Efficient in terms of router operation, this software allows its installation. Automatically selects components and automatically completes the layout. [9]



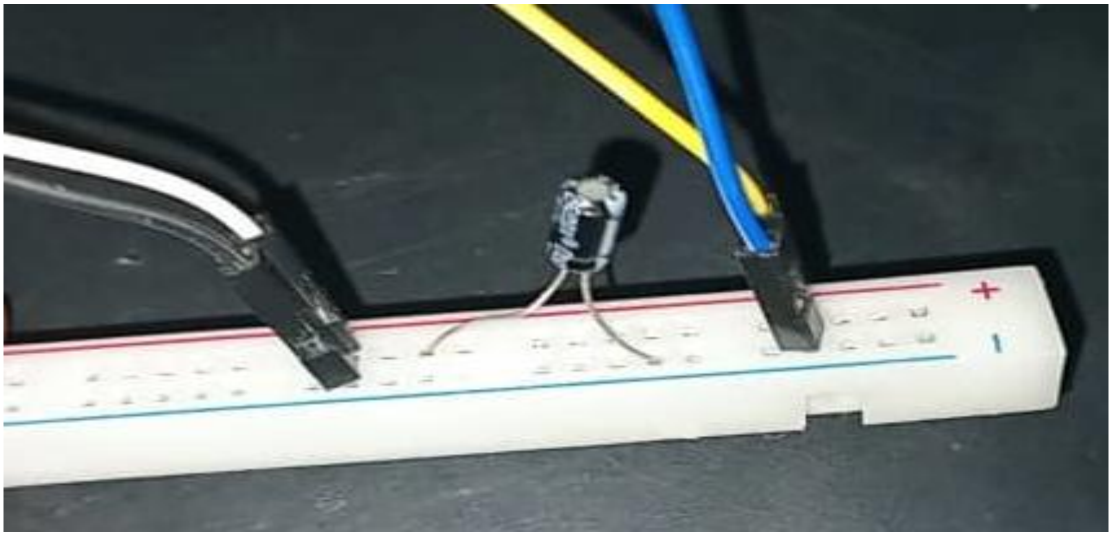
-Figure 07 The electrical diagram close -



-Figure 08 The electrical diagram –

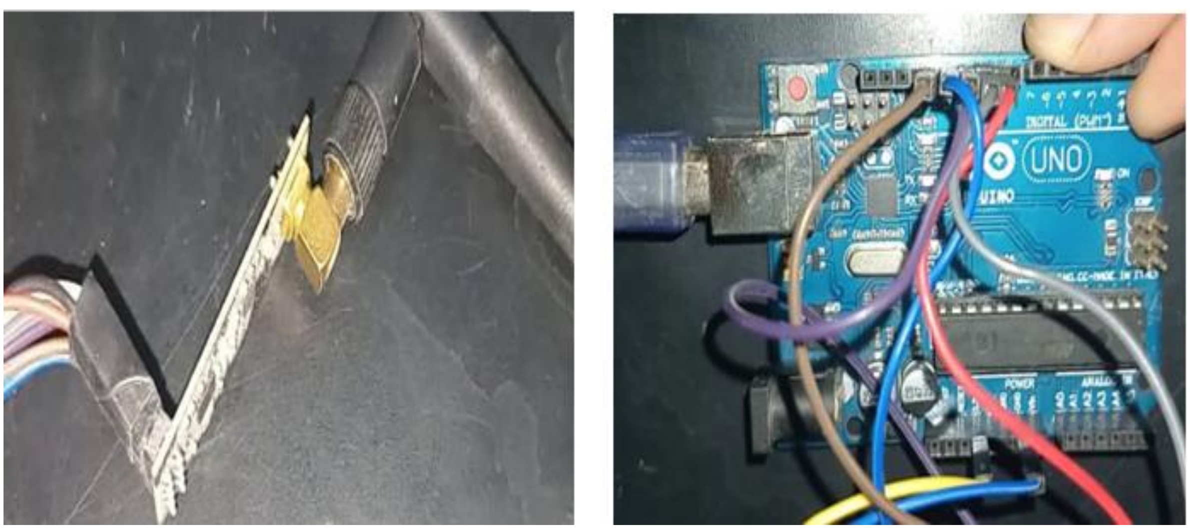
2.1.4 The installation:

- **First, connect the capacitor between VCC and GND.**



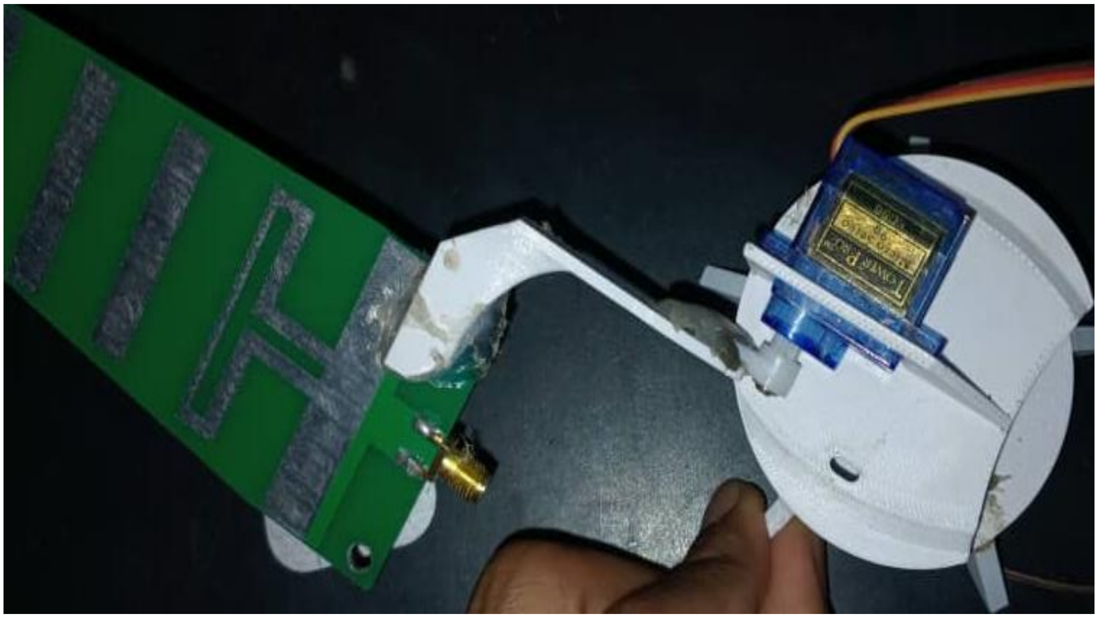
-Figure 09 VCC with GND -

- **Second, connect the NRF to the Arduino.**



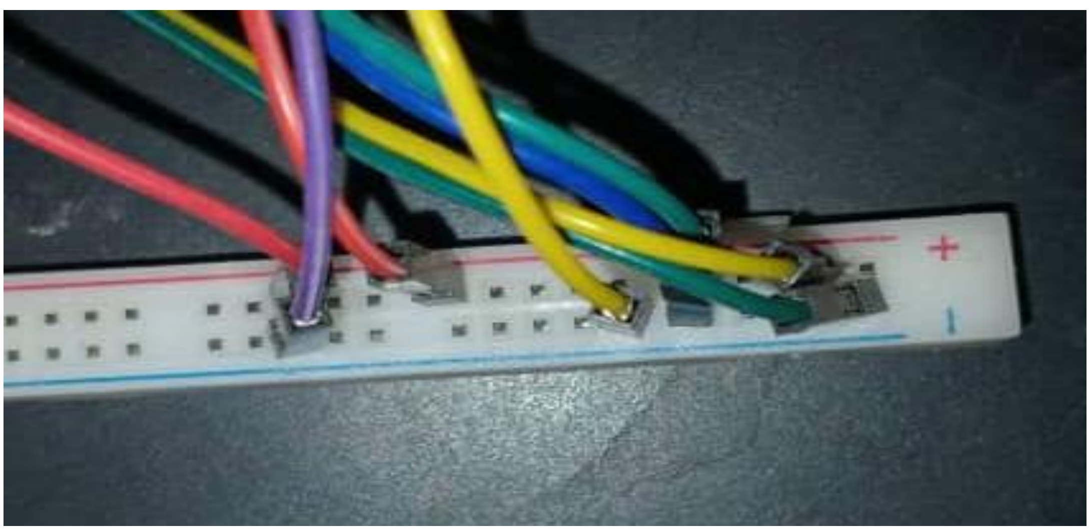
-Figure 10 connect the NRF to the Arduino -

- **Third, install the Yagi to the servo motors:**



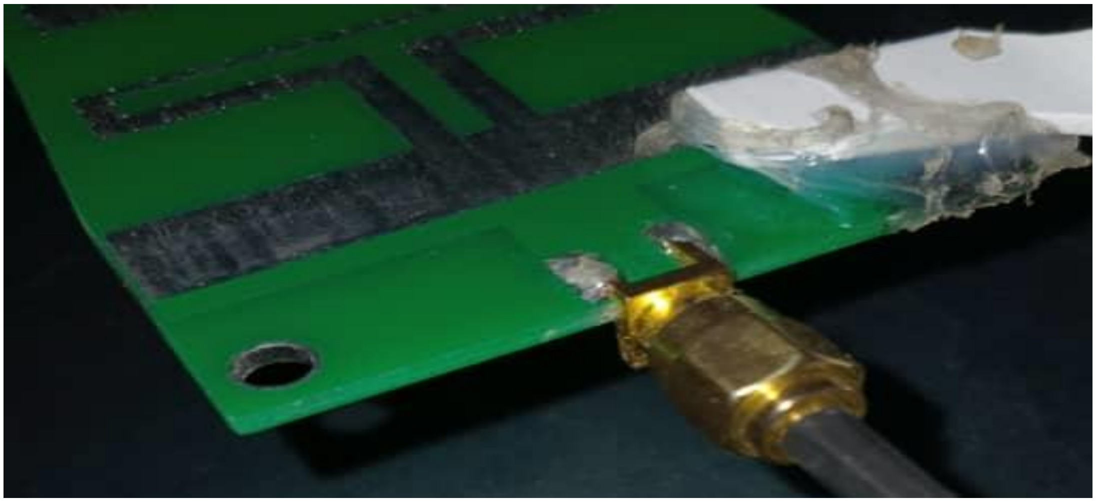
-Figure 11 Yagi with servo motors –

- **Connect both the X and Y servo to VCC and GND.**



-Figure 12 Yagi to the servo motors -

- **Connect the NRF with an SMA male to SMA female cable to the Yagi:**



-Figure 13: NRF with an SMA male to SMA female cable to the Yagi –

- **Connect all parts to the Arduino.**

- Figure 14 Arduino connected with all devices -

2.2 The Software Part:

2.2.1. The application used in the control:

2.2.1.1 Arduino IDE:

Such an acquisition board, which is based on its construction on a microcontroller, must be equipped with a programming interface, as is the case with our board. [10]

- **Programming Environment:**

The Arduino board's programming software serves as a code editor (a language similar to C). Once the program is typed or modified on the keyboard, it will be transferred and stored on the board via the USB connection. The USB cable both powers the board and carries the programming information, called the Arduino IDE. [12]

- **General Program Structure (Arduino IDE):**

Like any programming language, a flexible and simple interface is executable on any Arduino operating system based on C programming.

2.2.1.2 The Transmitter code - Using the nRF24L01 with the Arduino Uno:

In this file, we provide the transmitter code using the nRF24L01 module with the Arduino Uno board, along with a detailed explanation of each line of code in an organized table. [8]

- **Code explanation:**

Lining of code	Explanation
#include <SPI.h>	SPI protocol library necessary for communication with the nRF24L01 module
#include <nRF24L01.h>	nRF24L01 wireless module definition library
#include <RF24.h>	A library that facilitates interaction with the module
RF24 radio(9, 10);	Initialize the module and define the CE and CSN legs
const byte address[6] = "00001";	Communication address between the transmitter and receiver
radio.begin();	Start the module
radio.openWritingPipe(address);	Open the transmission channel using the specified address

radio.setAutoAck(false);	Disable the auto-confirmation feature (optional)
radio.setDataRate(RF24_250KBPS);	Select a low transmission speed to ensure signal stability
radio.setPALevel(RF24_PA_LOW);	Select a low power level to reduce interference
radio.stopListening();	Set the module to the transmission mode
const char text[] = "Hello";	Define the transmitted message
radio.write(&text, sizeof(text));	Send the message to the receiver
Serial.println("Message sent");	Display a message on the serial screen to confirm the transmission
delay(100);	Add a time delay between each transmission

-Table 04- Transmiter code –

2.2.1.3 The reciver code:

Explanation of the receiver code lines:

Line	Description
#include <SPI.h>	The SPI serial communication library necessary to operate the NRF24L01 module.
#include <nRF24L01.h>	A library for the NRF24L01 wireless transceiver module.
#include <RF24.h>	A library for controlling the NRF24L01 module.
#include <Wire.h>	An I2C protocol library for communicating with the display.
#include <LiquidCrystal_I2C.h>	An I2C LCD library.
#include <Servo.h>	A library for controlling servo motors.
RF24 radio(9, 10);	Create an object to control the NRF24L01 module using pins 9 and 10.
const byte address[6] = "00001";	A communication address between the transceiver modules.
LiquidCrystal_I2C lcd(0x27, 16, 2);	Create an object for the LCD with I2C address 0x27 and dimensions 16x2.
Servo servoH, servoV;	Define two servo motors for horizontal and vertical movement.
int angleH = 20;	Start angle for the horizontal motor.
int angleV = 20;	Start angle for the vertical motor.
int bestStrength = 0;	Strongest signal received so far.
int bestAngleH = 20;	The horizontal angle at which the best signal was obtained.
int bestAngleV = 20;	The vertical angle at which the best signal was obtained.

void setup()	A function that is executed once when the device is powered up.
Serial.begin(9600);	Start serial communication at 9600 baud.
lcd.init();	Initialize the LCD screen.
lcd.backlight();	Turn on the screen backlight.
servoH.attach(4);	Connect the horizontal motor to digital port 4.
servoV.attach(5);	Connect the vertical motor to digital port 5.
radio.begin();	Start the NRF24L01 module.
radio.openReadingPipe(0, address);	Open the data reception channel using the specified address.
radio.setAutoAck(false);	Disable the auto-answer feature from the other end.
radio.setDataRate(RF24_250KBPS);	Set the data transfer rate to 250 kbps.
radio.setPALevel(RF24_PA_LOW);	Set the transmit power level to low.
radio.startListening();	Start listening for received data.
lcd.setCursor(0, 0);	Set the cursor position in the first row on the screen.
lcd.print("Searching...");	Display the message "Searching..." on the screen.
void loop()	Main function that repeats continuously after setup.
for (angleH = 20; angleH <= 160; angleH += 10)	Loop to move the horizontal motor from 20 to 160 degrees.
servoH.write(angleH);	Move the horizontal motor to the current angle.
for (angleV = 20; angleV <= 160; angleV += 10)	Loop to move the vertical motor from 20 to 160 degrees.
servoV.write(angleV);	Move the vertical motor to the current angle.
while (millis() - startTime < 2000)	Measure the signal strength for two seconds.
if (radio.available())	Check if data is received.
radio.read(&text, sizeof(text));	Read and store the received data.
signalStrength++;	Increase the number of received signals.
if (signalStrength > bestStrength)	Check if this is the strongest signal received.
lcd.print("H:"); ...	Display the current angles and signal strength on the screen.
delay(500);	Delay between readings.
lcd.print("Best H:...");	Display the two best angles where the strongest signal was found.
delay(2000);	Wait before scanning again.

. **- Table 05-**

2.2.2 Transmitter-Receiver Communication Using NRF24L01

A. Transmitter:

Function: Sends test data continuously.

• **How it operates:**

• Sets the communication address (address) and initializes the RF24 library.

• Makes use of radio. to send a packet of data (in this case, the value of millis()), use write().

Data is sent every 50 milliseconds.

• It prints: if the transmission is successful. successfully sent.

• Otherwise, it prints: didn't send.

B. Receiver:

Function: Scans all angles to receive the data and analyze signal strength.

• How it operates:

• Uses a radio to initialize the receiver.StartListening ().

• Covers various angles by moving two servo motors (horizontal and vertical) in predetermined steps.

• It waits for servo stabilization (500 ms) at each angle.

Data is received for one second.

- Counts: • The quantity of packets received (count).

• How many of them possessed powerful

• The number of them with a strong radio signal (strongSignalCount).testRPD().

Determines a score: score is equal to packets received plus strong signals.

The best angle (highest score) is tracked.

• The servos are moved to the optimal angle after all angles have been scanned.

C. The RPD (Received Power Detector):

An NRF24L01 feature that determines the strength of the most recent signal received.

• The result of radio.testRPD() is:

• True (1): A strong signal is present if the signal strength is greater than -64 dBm.

• False (0): A weak signal is one that is less than -64 dBm.

D. Why Use the RPD:

- A packet count by itself isn't always accurate.
- RPD provides a more accurate assessment of signal quality than quantity alone.

An explanation of loops:

✓ For (int v = minAngle; v <= maxAngle; v += step) **is the outer loop**.
uses 20° increments to move the vertical servo (Y axis) from 20° to 160°.

✓ For (int h = minAngle; h <= maxAngle; h += step) **is the inner loop**.
moves the X axis (horizontal servo) within the same range.

•Within the loops that are nested:

Both servos should be moved to the current H & V.

To stabilize, wait 500 ms.

For one second, listen for incoming packets.

- Count: • The quantity of packets obtained.

• The quantity of powerful signals (as determined by RPD).

Compute the score.

• Save this angle as the new best if this score surpasses the previous best.

• Shift to the optimal signal angle.

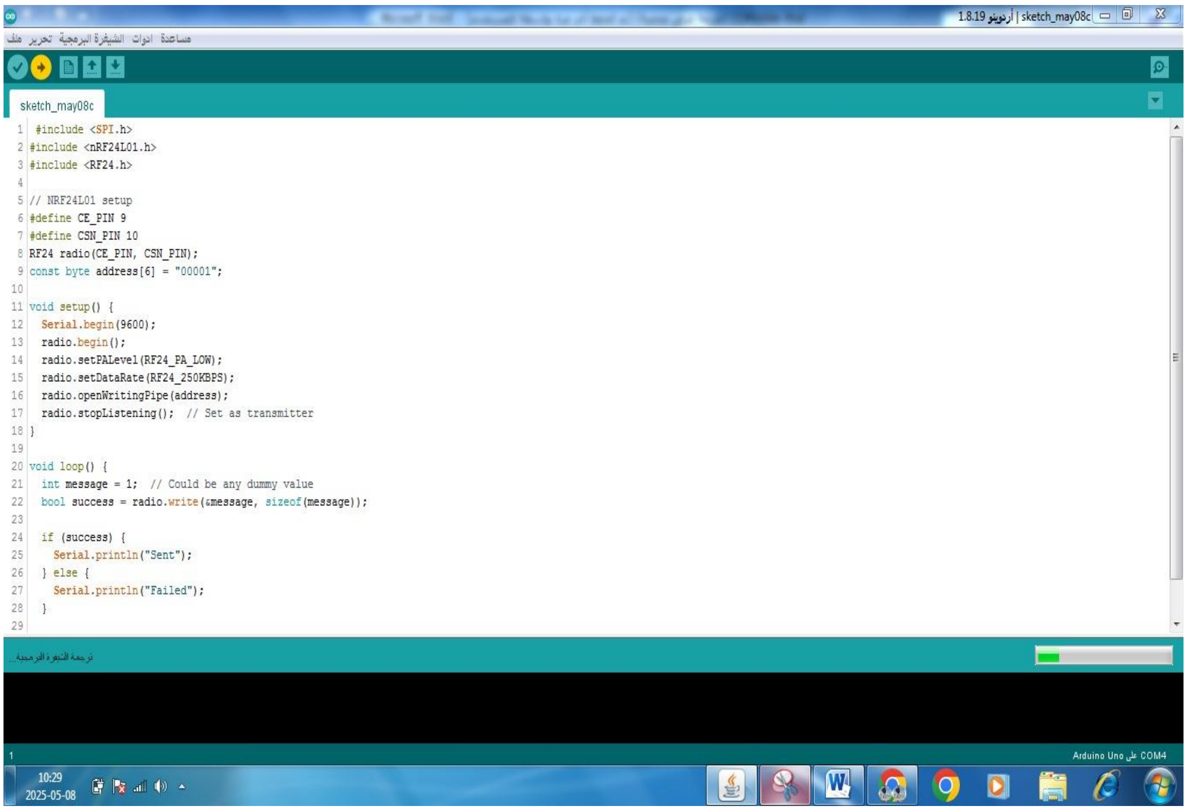
• Show the best outcome on the serial monitor and LCD

Program Injection (Steps in the arduino IDE):

Before sending the program to the board, you need to tell the software the name of the board and which port it's connected to. Choosing the board you're going to program isn't very complicated; the name of your board is indicated on it. For us, it's the "Uno" board.

Go to the "Tools" menu, then "Board."

Make sure the name "arduino/genuino Uno" is checked. If it isn't, check it. [12] [13]



-Figure 15 Program Injection -

5. Conclusion:

The structure of our antenna system was presented in this chapter, along with all the measurements, parts, and software needed to illustrate the circuits and how they work. We also covered the steps needed to develop an application that would control the antenna's movement and the specifics of putting our circuit together piece by piece until it was in its final configuration.

At last, we can move, identify whether a signal is present, and show the outcomes.

Chapter IV

Results and description

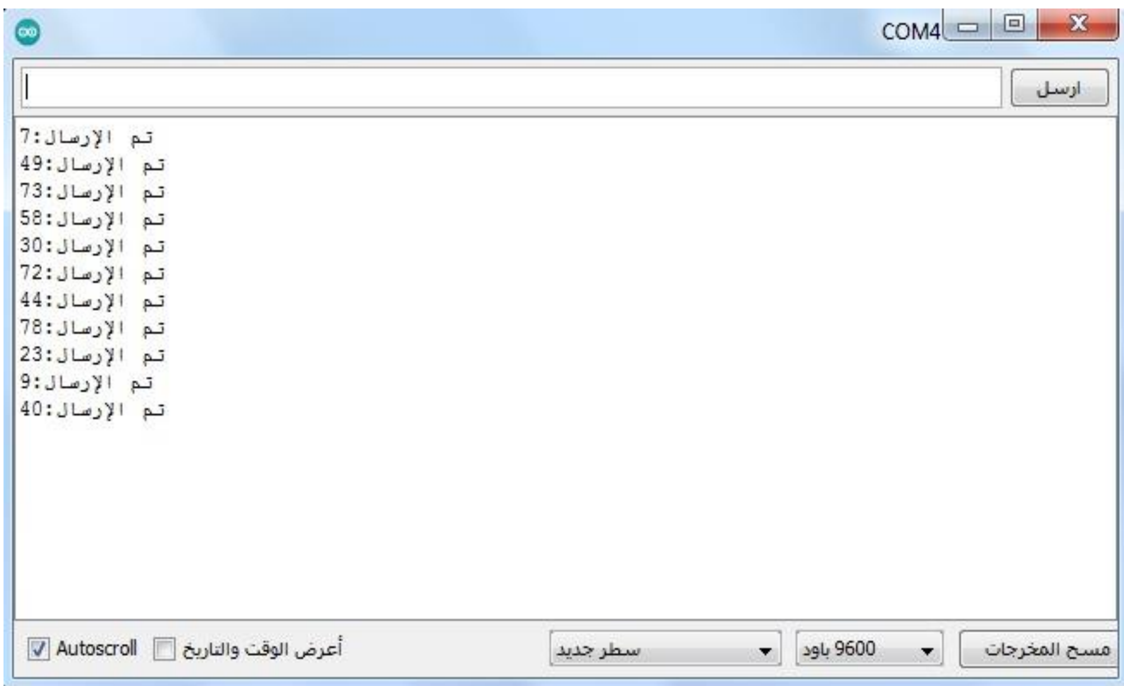
1.Inroduction:

In this chapter, we will run the project implemented in Chapter 3 to obtain and study the results. This will demonstrate the quality of the research we conducted.

2. installation & description of the operation:

- After installing the circuit mentioned in the previous chapter and executing the program, we performed the following steps:
  _ Place the transmitter at various distances

  _Receive data while determining the angle of the strongest signal. The results are shown in the following table.



-Figure 16 installation & description of the operation -

3. Transmit and receive interaction:

The Transmit Function:

Constantly sends a brief message over the nRF24L01

Continuous transmission takes place inside a loop ().

Whether or not the message is received is irrelevant.

It is not necessary to receive any data.

The process is quicker and simpler because it doesn't use an acknowledgment of arrival (ACK).

The receiver Function:

- Looks for corners using both vertical and horizontal servos.

It begins to listen at every corner to check if the sender is sending it messages.

Keeps track of how many messages were received over a given duration (e.g., 2 seconds).

- The signal at that corner gets stronger the more messages it gets.

Lastly, it records the corner where the strongest signal was received and shows it on the LCD

Item	**Transmitter**	**Receiver**
Function	**Sends a text message constantly**	**Receives messages and measures their number in every corner**
Protocol	**nRF24L01 without arrival confirmation**	**nRF24L01 in listening mode**
Iteration	**Approximately every 100 milliseconds**	**Listens for 2 seconds per corner**
Using the servo	**Not used**	**Moves the servo to determine the direction of reception**

LCD display	**No need**	**Angle display + signal strength**

-Table 06 -interaction-

The meaning of "signal strength" in this context:

It's the quantity of messages successfully received in a brief amount of time, not the signal strength (RSSI).

The more stable the connection at that angle, the higher the number.

In conclusion,

. messages are continuously sent by the transmitter

.The recipient counts the number of messages received while attempting various angles

The angle that conveys the most messages is deemed superior

The best angle and reception strength are displayed on the LCD screen

4. Results:

4.1. The Strongest Angle by Distance:

Distance (meters)	Horizontal angle (H)	Vertical Angle (V)	RX	STRONG
1	60°	0°	23	23
5	140°	20°	23	21
10	20°	40°	23	20
20	20°	20°	21	9
30	60°	60°	18	2

-table 07 -Angle / Distance -

4.2 Analysis:

Comparation:

Close Distance (1 meter and 5 meters):

- At close distances such as 1 meter and 5 meters, the signal is strong and stable across various angles, where packet count and signal strength are relatively uniform across most directions.
- This suggests that at close distances, the signal is more spread out, covering a wide range of angles.

Medium Distance (10 meters and 20 meters):

- At 10 meters and 20 meters, the angles closest to the strongest direction begin to converge more. In other words, adjacent angles become similar in strength and packet count, indicating that the signal is becoming more directional.
- Stronger directions start to become more defined, but the signal strength remains higher compared to the longer distances.

Far Distance (30 meters):

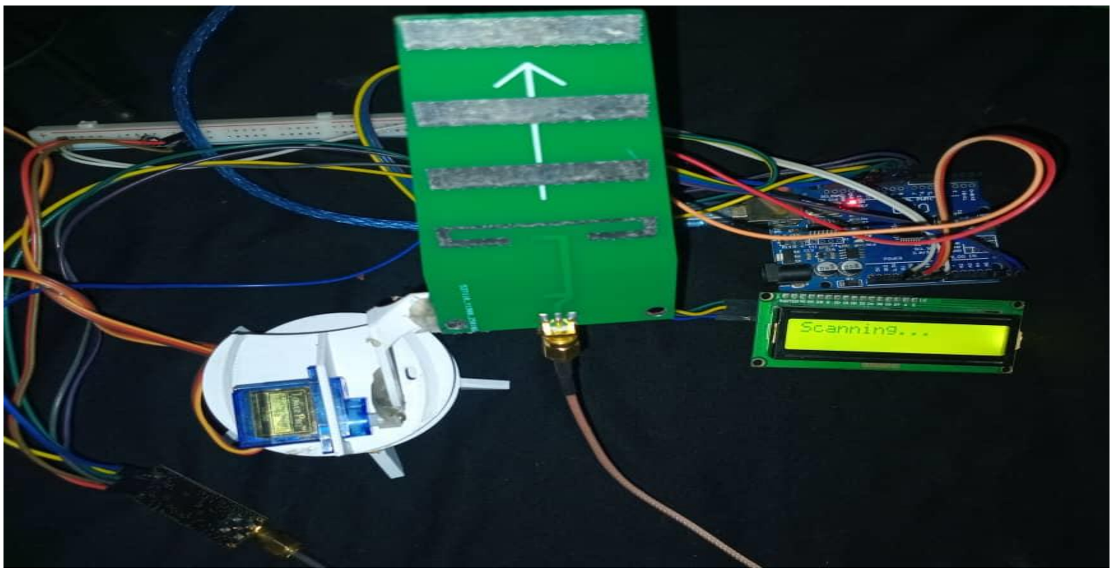
- At 30 meters, the signal becomes weak, but it is also more directional. This means that the connection becomes less stable and is concentrated on one specific direction, where the best angle for the connection appears.
- The signal strength drops significantly, but by aiming precisely at the best angle, the best connection can be found.

Revised Conclusion:

- At close distances (1 meter and 5 meters), the signal is wider and more stable, with similar strength and packet count across multiple angles.
- At medium distances (10 meters and 20 meters), the stronger angles converge, and the signal becomes more directional, with the optimal direction starting to emerge clearly.

- At far distances (30 meters), the signal becomes very weak but more focused on one particular angle, indicating the best connection direction. as Wi-Fi or Bluetooth) may occur.

5. Picture of the Project realization:



-Figure 17realization -

6. Problems and Challenges:

- The NRF24L01 module does not have a direct RSSI measurement, making it difficult to accurately determine signal strength.

- At short distances, the Yagi antenna is not precisely oriented because it receives from multiple directions.

- In open areas, the signal varies greatly from that in confined areas due to reflections.

- Interference and interference from other 2.4GHz signals (such as Wi-Fi or Bluetooth) may occur.

7. Conclusion:

Finally, after operating the system and through the results obtained that appear on the display screen, and after comparing the latter, we find that as the distance approaches, the reception angle expands, and as it moves away, it gradually decreases.

General Conclusion

Conclusion:

In this project, we combined our theoretical understanding of wireless communication with real-world experience developing embedded systems to investigate the design and implementation of a smart antenna system. The project's goal was to show how inexpensive parts like Arduino and ESP32 can be used to dynamically control a directional antenna, like a Yagi, in order to maximize wireless communication performance.

A theoretical foundation was established in the first chapter, which covered the fundamentals of wireless communication, its primary varieties, and the function of antennas in signal transmission and reception. Knowing the differences between directional and omnidirectional antennas made it easier to understand why directional antennas work better for long-range, focused communication the foundation of smart antenna systems.

We went into detail about the project's hardware in the second chapter. The ESP32 microcontroller, servo motor, LCD I2C display, Yagi antenna, NRF24L01 transceiver, Arduino Uno, and other components were shown with pictures and descriptions. Every part was chosen according to its role in creating a responsive antenna system, compatibility, and functionality. System logic and programming were the main topics of the third chapter. We described how the Arduino uses a servo motor to rotate the Yagi antenna in response to wireless signals, displaying user feedback on the LCD.

The code was dissected step by step, demonstrating how various modules work together to generate an intelligent response to the direction and strength of the signal. This project component verified that real-time antenna orientation control was feasible.

We included circuit diagrams and actual images of the finished system in the last chapter, which also detailed the system's actual wiring, assembly, and installation. Signal reliability was enhanced and the usefulness of directional antennas in dynamic wireless environments was demonstrated by the test results, which demonstrated that the antenna system could change its direction as intended. The correlation between distance and antenna reception behavior was one of the most important findings from our testing phase. In particular, we discovered that the effective reception angle decreases with increasing distance from the transmitter, while the angle at which the signal can be received increases with the receiver's proximity to the transmitter.

This outcome demonstrates the Yagi antenna's directional sensitivity and the significance of precise angular placement for long-distance wireless communication.

Additionally, it illustrates how intelligent antenna systems improve communication efficiency by adapting to different device distances in addition to aiding in signal direction. All things considered, this project shows how basic tools and programming can be used to implement smart antennas. It offers a strong foundation for more complex applications in signal optimization, remote control systems, and wireless networks.

This project provided an insight into the possibilities of adaptive communication systems by combining theory and practical application in a way that was both instructive and useful.

Annex

The code:

a) **The amateur code:**

```
#include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>

RF24 radio(9, 10); // CE = 9, CSN = 10
const byte address[6] = "00001"; //
void setup() {
  Serial.begin(9600);
  radio.begin();
  radio.openWritingPipe(address);     //
  radio.setAutoAck(false);       )
  radio.setDataRate(RF24_250KBPS);    // ة
  radio.setPALevel(RF24_PA_LOW);      //
  radio.stopListening();             //
}
void loop() {
  const char text[] = "Hello";        //
  radio.write(&text, sizeof(text));   //
  Serial.println("Message sent");
  delay(100);
}
```

b) **The receiver code:**

```
 #include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <Servo.h>

RF24 radio(9, 10); // CE, CSN
const byte address[6] = "00001";

LiquidCrystal_I2C lcd(0x27, 16, 2); //

Servo servoH, servoV;  //
int angleH = 20;       // ا
int angleV = 20;       //
```

```
int bestStrength = 0;
int bestAngleH = 20;
int bestAngleV = 20;

void setup() {
  Serial.begin(9600);
  lcd.init();
  lcd.backlight();

  servoH.attach(4); //
  servoV.attach(5); //

  radio.begin();
  radio.openReadingPipe(0, address);
  radio.setAutoAck(false);
  radio.setDataRate(RF24_250KBPS);
  radio.setPALevel(RF24_PA_LOW);
  radio.startListening();

  lcd.setCursor(0, 0);
  lcd.print("Searching...");
}

void loop() {
  int signalStrength = 0;
  unsigned long startTime = millis();

  //
  for (angleH = 20; angleH <= 160; angleH += 10) {
    servoH.write(angleH);  //
    delay(200);  //

    //
    for (angleV = 20; angleV <= 160; angleV += 10) {
      servoV.write(angleV);  //
      delay(200);  //

      //
signalStrength = 0;
      while (millis() - startTime < 2000) {
        if (radio.available()) {
          char text[32] = {0};
          radio.read(&text, sizeof(text));
```

```
        signalStrength++;
      }
    }

    //
    if (signalStrength > bestStrength) {
      bestStrength = signalStrength;
      bestAngleH = angleH;
      bestAngleV = angleV;
    }

    //
    lcd.setCursor(0, 1);
    lcd.print("H:");
    lcd.print(angleH);
    lcd.print(" V:");
    lcd.print(angleV);
    lcd.print(" S:");
    lcd.print(signalStrength);
    lcd.print("   ");

    delay(500);  //
  }
}

//
lcd.setCursor(0, 0);
lcd.print("Best H:");
lcd.print(bestAngleH);
lcd.print(" V:");
lcd.print(bestAngleV);
lcd.print(" S:");
```

```
  lcd.print(bestStrength);
   lcd.print("   ");

delay(2000);  //
   }
```

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