Automatic Antenna Alignment System
(AAAS)

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In the name of ALLAH, the Most Benevolent, the Most Courteous

CERTIFICATE OF CORRECTNESS AND APPROVAL

This is to officially state that the thesis work contained in this report

"Auto Antenna Alignment System"

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under my supervision and that in my judgement, it is fully ample, in scope and excellence, for the degree of Bachelor of Electrical Engineering in Military College of Signals, National University of Sciences and Technology (NUST), Islamabad.

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DECLARATION OF ORIGINALITY

We hereby declare that no portion of work presented in this thesis has been submitted in support of another award or qualification in either this institute or anywhere else.

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Allah Subhan'Wa'Tala is the sole guidance in all domains.

Our parents, colleagues and most of all our supervisor, Dr. Zeeshan Zahid without your guidance,

The group members, who through all adversities worked steadfastly.

Plagiarism Certificate (Turn it in Report)

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ABSTRACT

The efficiency of wireless communication systems heavily relies on the precise alignment of antennas. Manual Antenna alignment is one of the serious issue in correspondence framework after each terrible climate and downpour. This issue is extremely feverish in regions where weather conditions is blustery and breezy. After each windstorm there is a need to adjust all directional Antenna alignment physically. Subsequently this undertaking has been gotten to fulfill the rising need of programmed recieving antenna alignment framework and supplant manual rotation of Antenna alignment. Keeping this in view, this paper expects to develop an advanced Automatic Antenna Alignment System (AAS) designed to optimize the alignment process, thereby enhancing communication performance in various applications such as satellite communication, terrestrial point-to-point links. The proposed AAAS integrates state-of-the-art technologies including algorithms, computer vision techniques, and real-time feedback mechanisms to automate and refine antenna alignment procedures. Antenna alignment framework with ability to filter in both azimuthal and elevation plane, get signal strength and change itself as per maximum RSS. Furthermore, computer vision algorithms enable the AAAS to accurately detect and track antenna positions relative to their optimal orientation, even in challenging environmental conditions such as adverse weather or low visibility. Real-time feedback mechanisms ensure continuous monitoring and adjustment of antenna alignment to maintain optimal signal strength and reliability. This paper plans to give a top to bottom survey of antenna alignment with an array of any antenna to receive signals from a fixed transmitter, and adjust itself according to maximum RSS.

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CHAPTER 1: INTRODUCTION

In the fast-paced world of modern communication, seamless connectivity is not just a luxury; it's a necessity. Whether it's transmitting critical data, facilitating uninterrupted calls, or enabling high-speed internet access, the efficiency of communication systems hinges on the precise alignment of antennas [1]. However, traditional methods of antenna alignment often rely on manual adjustments, susceptible to human error, environmental factors, and time constraints. Enter the Automatic Antenna Alignment System (AAAS), a groundbreaking solution poised to revolutionize the way we optimize antenna performance[1]. By integrating cutting-edge technology with sophisticated algorithms, AAAS offers a streamlined approach to antenna alignment, eliminating the need for manual intervention and vastly improving efficiency and accuracy. At its core, AAAS employs a combination of sensors, actuators, and intelligent software to autonomously adjust antenna positions in real-time, ensuring optimal signal strength and reliability[2]. Whether deployed in telecommunications networks, satellite communication systems, or remote sensing applications, AAAS adapts to diverse environments and operating conditions with unparalleled precision. Beyond its technical prowess, the benefits of AAAS extend far and wide. From reducing maintenance costs and downtime to enhancing network resilience and scalability, its impact reverberates across industries, empowering businesses and communities with robust connectivity solutions.

1.1 Problem Statement

At present time antenna alignment is one of the major problem being faced due to bad weather conditions. In manual antenna alignment system, the maintenance service is expensive and wasting time. There are several factors that impact proper antenna alignment system as follow.

1.2 Weather

Weather considerations are paramount for the effective alignment and maintenance of antennas, especially in outdoor settings. Various weather factors can impact antenna performance and alignment accuracy. Strong winds, for instance, may cause antennas to sway or move out of alignment, necessitating adjustments to compensate for these movements. Heavy rain or moisture accumulation can degrade signal quality and damage system components, requiring proper weatherproofing measures to protect against water ingress. Snow and ice buildup can add weight to antennas and alter their mechanical properties, potentially causing misalignment or structural damage [3]. Extreme temperatures, fog, and atmospheric conditions can also affect signal propagation and antenna performance, requiring adjustments or adaptations during alignment tasks. Lightning strikes and electrical storms pose risks of equipment damage and power surges, necessitating the implementation of surge protection measures and lightning grounding systems. UV radiation from sunlight can degrade antenna materials and electronics over time, highlighting the importance of UV-resistant coatings and protective measures. Lastly, severe weather events such as hurricanes or tornadoes can cause extensive damage to antennas and alignment systems, emphasizing the need for robust structural design and emergency preparedness measures. Overall, accounting for weather conditions is crucial for ensuring the reliability, performance, and longevity of antenna alignment systems in diverse environmental settings.

1.3 Mounting Hardware

Mounting hardware is a foundational component of automatic antenna alignment systems, playing a pivotal role in ensuring the stability, precision, and reliability of antenna positioning. Firstly, the hardware must offer robust structural integrity to support the weight of antennas and withstand environmental factors like wind and temperature changes [3]. It should provide adjustability and flexibility to accommodate various antenna types and sizes, enabling precise alignment adjustments. Integrating motorized actuators and positioning mechanisms into the hardware facilitates automatic adjustment of antenna positions, enhancing accuracy and responsiveness. Moreover, compatibility with alignment sensors and feedback mechanisms is essential for real-time monitoring and control of antenna alignment [5]. Weatherproofing measures, including corrosion-resistant materials and protective coatings, safeguard the hardware against moisture and UV radiation, ensuring long-term durability. Simplified installation and maintenance features contribute to ease of deployment and reduce downtime for servicing. Compatibility with existing infrastructure streamlines integration efforts, while adherence to safety standards ensures the well-being of installers and maintenance personnel. Ultimately, selecting suitable mounting hardware is critical for optimizing the performance and longevity of auto antenna alignment systems in diverse operational environments.

1.4 Alignment equipment and procedure

Alignment equipment and procedures are pivotal elements within auto antenna alignment systems, crucial for achieving precise and reliable alignment of antennas. These systems rely on a variety of sophisticated tools and technologies, including alignment sensors, measurement tools, and motorized actuators. Alignment sensors, such as GPS receivers and inclinometers, provide real-time feedback on antenna position, azimuth, elevation, and tilt angles, enabling operators to make accurate adjustments [4]. Advanced algorithms and software analyze this data and automate the alignment process, controlling motorized actuators to achieve optimal alignment. Calibration procedures establish baseline parameters and ensure alignment accuracy, while regular checks help maintain alignment integrity over time. Environmental considerations, such as wind and temperature fluctuations, are factored into alignment procedures to account for dynamic conditions.

Safety protocols are paramount during alignment activities, with operators adhering to best practices and utilizing appropriate protective measures. Comprehensive documentation and reporting of alignment procedures facilitate record-keeping, compliance, and troubleshooting efforts. By adhering to these considerations, operators can ensure the effectiveness and reliability of auto antenna alignment systems in optimizing communication network performance.

1.5 Installer Fatigue and Frustration

It can be physically and mentally grueling to spend hours on a tower performing the same procedure over and over, and not improving the situation. Nine times out of ten the installer and their support people on the ground resign to the frustration and lack of discipline of proper alignment.

1.6 Proposed Solution

Following are the proposed solution.

1.6.1 Alignment system will be created with the help of two servo motor, Arduino UNO, buck converter (LM2596), shafts/rotors and TB6600 drivers.

1.6.2 Our vision is to write a program in C++ (Arduino) that scan functions in both azimuth and elevation to quickly scan the highest RSSI and lock the antenna there. e.g initiate the program with a starting point A0 degree(azimuth) and B0(elevation), Then read the RSSI value and store it, then move to A1(azimuth) and B0(elevation) , read the RSSI value and compare it with previous value, if greater then store the value as new RSS max value and repeat the process for all steps similarly.

1.6.3 Once azimuth is completed, then it should switch to elevation and repeat the same process. In the end it should lock the antenna where RSS value is max in all possible position of A (0 -120 degree) and B (0-120degree).

1.7 Working Principle

Antenna alignment can be done automatically using smart control device often works by selecting the strongest incoming signals. The antenna alignment can also be done manually. There are a lot of risk and effort in the manual method. Project is divided into different modulus and every module is inter-woven with the next module. The list of modules is as under

- Alignment system
- Integration of antenna with alignment system
- RSS sample checking
- Azimuth and elevation alignment
- GUI presentation parameters

1.7.1 Alignment system

An alignment system plays a vital role in precisely positioning components, such as antennas, to ensure optimal performance in applications like satellite communication and radar systems [7]. It incorporates sensors to capture alignment parameters such as azimuth and elevation angles, along with signal strength data. Control mechanisms then translate these parameters into physical adjustments, while algorithms analyze the collected data to assess alignment status and trigger corrective actions through a feedback loop. A user-friendly interface allows operators to interact with the system, displaying real-time alignment data and providing manual intervention options as necessary. Automation features streamline the process, and validation procedures guarantee alignment accuracy, ensuring the system operates at its peak efficiency. Alignment system will be created with help of 2 servo motor, TB6600 driver, buck converter (LM2596), Arduino and display

1.7.2 Integration of antenna with alignment system

The integration of antennas with the alignment system marks a pivotal advancement in communication technology, offering a seamless convergence of hardware and software to optimize performance. At its core, this integration facilitates the coordination of antenna movements with real-time adjustments, ensuring precise alignment for optimal signal reception and transmission [8]. Antenna will be integrated with alignment system in such a way that RSS received through antenna will be given as input to Arduino.

1.7.3 RSS sample checking

In an automated antenna alignment system, the verification of RSS (Received Signal Strength) samples holds pivotal importance for ensuring accurate antenna positioning to maintain dependable communication. Initially, the system acquires RSS data from the antenna's receiver, capturing signal strength measurements across a spectrum of azimuth and elevation angles. These gathered samples undergo thorough processing, where statistical analyses or signal processing techniques unveil any discernible patterns or fluctuations in signal strength. By comparing these RSS readings against established thresholds or reference values, the system evaluates alignment precision, pinpointing any deviations indicative of misalignment or interference. Following this assessment, the system provides feedback to the alignment mechanism, enabling real-time adjustments to optimize the antenna's orientation and enhance signal strength. This iterative process encompasses continuous RSS sampling, adjustment, and validation, ensuring that the antenna achieves the necessary precision in alignment to uphold optimal performance standards.

1.7.4 Azimuth and elevation alignment

Azimuth and elevation alignment play pivotal roles in the proper positioning of directional antennas, crucial for achieving peak performance in applications such as satellite communication and radar systems. Azimuth, indicating the horizontal direction measured clockwise from true north, determines how the antenna is oriented to face the intended target, like a satellite or radar target. Elevation, conversely, governs the vertical angle above the horizon, ensuring the antenna is appropriately tilted for optimal signal transmission or reception. Accurate alignment is essential to maximize signal strength, minimize interference, and sustain reliable communication or detection. In essence, azimuth and elevation alignment stand as indispensable prerequisites for enhancing the efficiency and precision of directional antennas across diverse technological landscapes. Azimuth and elevation alignment is done on the basis of continuous input received from antenna and Sensor through Arduino.

1.7.5 GUI presentation parameters

In designing a GUI for automatic antenna alignment, several key parameters are essential for optimizing user experience and alignment efficiency. Firstly, the interface should prioritize user-friendliness, featuring intuitive navigation and easily identifiable controls. Visual feedback mechanisms, such as real-time graphical representations and progress indicators, enhance user understanding of the alignment process. Interactive elements, like sliders or numerical input fields, enable precise adjustment of azimuth and elevation angles. Additionally, the GUI should offer alignment assistance through overlays or guides, along with error handling features to promptly address any alignment issues. Customization options cater to diverse user needs, while responsive design ensures compatibility across various devices. In the end all parameters are displayed on LCD attached with Arduino.

1.8 Objectives

Objectives are divided into the following two different types

1.8.1 General Objectives:

To build an innovative state of the art software integrated with hardware prototype controlled by Arduino, providing a smart automatic alignment system to replace manual rotation of antennas in different communication infrastructures. Primarily, the system should ensure optimal signal reception or transmission by precisely aligning the antenna, minimizing manual intervention, and reducing alignment time. User-friendly interfaces with intuitive controls and clear visual feedback contribute to ease of use, while accuracy and precision in alignment parameters guarantee high-performance outcomes. Additionally, adaptability to changing environmental conditions, robustness against various challenges, and cost-effectiveness are crucial considerations. Seamless integration with other systems, remote monitoring capabilities, and compliance with industry standards further enhance the system's effectiveness and reliability.

1.8.2 Academic Objectives:

Academic objectives are as follows:

1. Development of a smart and automatic Antenna Alignment system.
2. To increase productivity by working in an automated environment.
3. To learn and implement C ++ language.
4. To design a project that contributes to the welfare of communication infrastructure.

5. Explore potential applications of automatic antenna systems in various domains and assess their impact on industry practices and societal challenges.

1.9 Scope

This project finds its scope wherever there is detection of maximum signal strength for alignment of antennas. It is an innovating state of the art software integrated hardware prototype powered by machine language (C++) and antenna alignment techniques, providing cheap and time saving antenna alignment system.

1.10 Structure of Thesis

Chapter 2 contains the literature survey and related work done on basis of which antenna alignment system has been developed

Chapter 3 contains the construction and manufacturing of antenna alignment system

Chapter 4 contains the working principle of automatic antenna alignment system

Chapter 5 conclusion

Chapter 2: LITERATURE SURVEY

In modern communication systems, maintaining proper alignment of antennas is crucial for ensuring optimal signal strength and reception quality. Auto antenna alignment systems have emerged as a solution to streamline this process by automating the alignment adjustments, thereby reducing human intervention and ensuring consistent performance. This literature survey explores various aspects of auto antenna alignment systems, including their principles, technologies, applications, advantages, and challenges.

2.1 Principles of Auto Antenna Alignment Systems

Auto antenna alignment systems utilize various principles and techniques to automatically adjust the orientation of antennas. One common approach is based on feedback mechanisms such as signal strength or signal-to-noise ratio (SNR). These systems continuously monitor the received signal parameters and adjust the antenna alignment to maximize the signal quality. Another principle involves the use of GPS technology to determine the precise location of antennas and align them accordingly [9]. Additionally, some systems employ servo motors or actuators to physically adjust the antenna orientation based on feedback from sensors.

2.2 Technologies Used in Auto Antenna Alignment Systems

Following are the different types of technologies that are used in construction of different alignment systems.

2.2.1 GPS-Based Systems

GPS-based systems are integral to automatic antenna alignment, utilizing satellite positioning technology to pinpoint the precise location of the antenna and ensure accurate alignment. These systems leverage GPS receivers to capture signals from satellites, enabling the calculation of the antenna's coordinates in three-dimensional space, including latitude, longitude, and altitude [9]. With this data, azimuth and elevation angles can be calculated to orient the antenna towards the desired target, such as a communication satellite or radar beacon. Real-time positioning updates allow for dynamic adjustments to antenna orientation, compensating for motion-induced errors and ensuring continuous alignment optimization. Integration with control systems automates alignment processes, using GPS-derived coordinates to calculate target angles and translate them into physical adjustments. Redundant GPS receivers enhance reliability, while calibration processes validate alignment accuracy. In essence, GPS-based systems form the backbone of auto antenna alignment, facilitating precise and reliable communication, tracking, and navigation across diverse applications and environments.

2.2.2 Remote Sensing

In auto antenna alignment, leveraging remote sensing techniques enhances the precision and efficiency of the alignment process. Satellite imagery, LiDAR data, and radar imaging offer valuable insights into terrain features, obstacles, and environmental conditions that may affect antenna alignment [7]. By analyzing these remote sensing data sets, operators can identify optimal alignment locations, assess terrain elevation variations, and anticipate potential signal interference. Additionally, real-time weather monitoring provides crucial information about atmospheric conditions, guiding alignment adjustments to maintain signal quality. Integrating remote sensing data into auto antenna alignment systems empowers operators to make informed decisions, optimize alignment parameters, and ensure reliable communication links across diverse landscapes and environmental conditions.

2.2.3 Computer Vision

Computer vision technology presents a transformative approach to auto antenna alignment systems, offering advanced capabilities in real-time image processing and analysis. Through computer vision algorithms, these systems can recognize relevant features in captured images, such as landmarks or satellites, enabling precise calculation of alignment parameters like azimuth and elevation angles. Additionally, by detecting and tracking obstructive objects like buildings or trees, the system dynamically adjusts antenna positioning to optimize signal reception or transmission [9]. Machine learning algorithms further enhance alignment accuracy by recognizing patterns associated with optimal alignment in visual data. Depth estimation capabilities enable the system to assess terrain elevation, crucial for accurate alignment calculations in varied landscapes. Augmented Reality (AR) overlays provide intuitive visual guidance to operators during the alignment process, improving efficiency and precision. In essence, integrating computer vision into auto antenna alignment systems empowers operators with enhanced accuracy, efficiency, and automation, facilitating optimal performance across communication, tracking, and navigation applications.

2.2.4 Wireless Communication

Wireless communication technologies are vital components within auto antenna alignment systems, facilitating seamless interaction among system elements and remote operators. Wi-Fi, for instance, enables rapid communication between the alignment system and user interfaces, supporting real-time monitoring and parameter adjustments [10]. Bluetooth connectivity fosters short-range communication among system modules, ensuring smooth integration and data exchange. Cellular connectivity extends the system's accessibility, allowing remote monitoring and control from locations with cellular coverage. Satellite communication provides global connectivity, crucial for systems deployed in remote or maritime settings. RF communication technologies like Zigbee or LoRa offer low-power, long-range communication capabilities, well-suited for expansive deployments. Mesh networking further bolsters reliability and scalability by forming self-healing networks among system components. Leveraging these wireless technologies, auto antenna alignment systems ensure uninterrupted operation, facilitating precise alignment and optimal performance across diverse environments.

2.3 Applications of Auto Antenna Alignment Systems

Auto antenna alignment systems find applications across various industries and sectors, including telecommunications, broadcasting, satellite communications, and military operations. These systems are particularly useful in scenarios where manual alignment is impractical or time-consuming, such as deploying temporary communication links in emergency situations or optimizing the performance of mobile communication towers.

2.3.1 Advantages of Auto Antenna Alignment Systems

2.3.1.1 Time and Cost Savings

Manual antenna alignment often requires skilled technicians to spend considerable time adjusting antenna positions, especially in large-scale deployments or when dealing with complex environmental conditions. Auto antenna alignment systems present significant opportunities for time and cost savings when compared to manual methods. These systems streamline the alignment process, leading to reduced setup, adjustment, and maintenance times. By automating alignment procedures, they diminish the necessity for skilled technicians, thus lowering labor costs. Moreover, auto alignment systems enhance resource utilization and mitigate the risk of human error, resulting in enhanced operational efficiency and decreased downtime. Additionally, they contribute to prolonging equipment lifespan by ensuring precise alignment and minimizing wear and tear. Remote monitoring and troubleshooting capabilities further augment efficiency by enabling operators to supervise alignment processes and make adjustments from afar, thus reducing the need for onsite visits and associated travel expenses. In summary, auto antenna alignment systems offer tangible advantages in terms of time and cost efficiency, making them invaluable assets for organizations seeking to optimize their antenna infrastructure.

2.3.1.2 Improved Signal Quality

Automatic antenna alignment systems contribute significantly to improved signal quality by ensuring precise alignment, real-time adjustment, and minimized interference. These systems use sophisticated algorithms and feedback mechanisms to continuously monitor signal strength and quality, dynamically adjusting antenna positions to maintain optimal alignment. By maximizing signal strength, minimizing signal loss, and optimizing the link budget, automatic alignment systems enhance the received signal power while reducing noise and interference, resulting in clearer communication and better data transmission rates. Additionally, these systems are adaptable to environmental changes, such as weather or terrain, ensuring consistent signal quality even in challenging conditions. Overall, automatic antenna alignment systems play a crucial role in enhancing the reliability and performance of communication networks by optimizing signal quality.

2.3.1.3 Remote Monitoring and Control

Remote monitoring and control of automatic antenna alignment systems make it easy to keep an eye on how well antennas are working from a central place [10]. It helps fix any issues quickly by getting alerts about problems and adjusting antennas remotely. This saves time and money because operators don't have to visit each site in person. It also makes sure the antennas are always pointing the right way for the best signal without needing constant attention. With remote monitoring capabilities, operators can monitor and adjust antenna alignments from a centralized location, reducing the need for on-site visits.

2.3.1.4 Enhanced Reliability

Auto antenna alignment systems significantly enhance reliability by continuously monitoring signal strength, quality, and environmental conditions, ensuring optimal alignment at all times. With automatic adjustment capabilities, these systems dynamically adapt antenna positions to compensate for changes in factors like wind, temperature, or signal interference, thereby maintaining consistent performance and minimizing downtime. Proactive maintenance facilitated by remote monitoring allows operators to detect and address issues before they impact network reliability, preventing service disruptions. Moreover, by eliminating the potential for human error inherent in manual alignment methods, auto alignment systems ensure accuracy and reliability without the need for manual intervention. Their adaptability to changing conditions, consistent performance, and ability to minimize downtime collectively contribute to a more reliable communication infrastructure, enhancing user satisfaction and overall service quality.

2.4 Challenges and Limitations

Despite their advantages, auto antenna alignment systems face several challenges and limitations. which includes the following:

2.4.1 Integration Complexity

The integration complexity of auto antenna alignment systems arises from various factors spanning hardware, software, communication protocols, and compatibility considerations. Hardware integration involves the installation of motorized actuators, alignment sensors, and control units, often requiring specialized skills for physical setup and mechanical adjustments. Software integration entails developing algorithms for signal processing and feedback control, along with ensuring compatibility with existing network management systems. Communication protocols must be aligned to enable seamless data exchange with network infrastructure, necessitating protocol translation and security configuration. Compatibility with existing antenna hardware is crucial, involving assessments of mechanical and electrical interfaces to ensure smooth operation. Calibration and testing are essential post-integration steps to verify alignment accuracy and system reliability. Moreover, training operators and maintenance personnel on system operation and troubleshooting procedures is paramount for successful adoption. Despite these challenges, meticulous planning and collaboration can streamline the integration process, maximizing the benefits of auto antenna alignment systems in optimizing communication infrastructure.

2.4.2 Environmental Factors

Auto antenna alignment systems are affected by a range of environmental factors that can influence their performance and reliability. These factors include weather conditions like wind, rain, and temperature fluctuations, which can cause antenna movement or misalignment. Terrain features such as buildings and trees can obstruct line-of-sight communication paths, while electromagnetic interference from nearby electronic devices or RF sources can degrade signal quality. Additionally, the accuracy of GPS or geolocation data used for alignment may be impacted by factors like foliage or atmospheric disturbances. Solar radiation and sun position can affect antenna performance, especially in higher frequency bands, while temperature and humidity variations may impact system components. Seismic activity in certain regions can pose challenges to stability, requiring systems to withstand ground movement. Environmental degradation and corrosion from exposure to saltwater or pollutants can also affect system integrity over time. Addressing these environmental factors is crucial for ensuring the effectiveness and longevity of auto antenna alignment systems in diverse operating conditions.

2.4.3 Calibration and Maintenance

Calibration and maintenance are critical aspects of ensuring the ongoing accuracy and reliability of auto antenna alignment systems. Calibration involves establishing and verifying alignment parameters to meet predefined standards, typically through initial calibration processes that set baseline values and regular accuracy checks to ensure consistency. Fine-tuning adjustments may be necessary to correct any deviations found during these checks. Additionally, periodic recalibration is essential to account for environmental changes and equipment wear over time. Maintenance activities are equally vital, involving routine inspections, cleaning to prevent debris buildup, lubrication of moving parts, and protection from environmental factors. Software updates and continuous training for operators and maintenance personnel further contribute to system optimization and longevity. By adhering to comprehensive calibration and maintenance protocols, operators can maximize the performance and lifespan of auto antenna alignment systems, ensuring reliable signal quality and network performance.

2.4.4 Cost

Cost limitations of auto antenna alignment systems encompass various factors that impact their affordability and feasibility. Initially, the upfront investment required for purchasing and installing the system, inclusive of hardware components like actuators, sensors, and control units, can be substantial. Moreover, the complexity of the system, including sophisticated hardware and software features, may incur higher costs. Installation and integration expenses, covering deployment labor and configuration efforts, contribute significantly to the overall cost. Additionally, ongoing maintenance, support, and scalability considerations further add to the total cost of ownership. Despite the potential for operational efficiency gains and reduced labor costs, the ultimate cost-effectiveness of auto alignment systems hinges on factors like deployment scale, frequency of adjustments, and anticipated returns on investment. Mitigating cost limitations may involve exploring competitive pricing options, negotiating service agreements, and conducting thorough cost-benefit analyses to ensure optimal alignment of financial resources with operational needs.

2.5 Related Work

There are lot of papers published in the field of antenna alignment where some of them perform different types of alignment such as the satellite dish alignment while the mechanism for most of them is often based on measuring the received power beam. Unlike the published papers which summarized in Table I, the significant of this paper is shown in the design of control circuit which using the Arduino and the wireless technology used for the mechanism of alignment. Wibisono [7] presented a circuit diagram for satellite dish alignment where the architecture was based on AVR microcontroller. Chang [11] introduced simple design for detecting any unwanted movement of antenna and correcting the alignment of antenna using pensioner and specific algorithm operated by feeding input parameters. Singh [8] discussed the ability to use hybrid power source in automatic alignment in telecommunication system where the paper focused on the concept of aligning antenna without introducing real design. Adib [10] in his paper presented alignment of interference relative to the required displacement of antenna. Prasanna [9] presented simple design used for aligning TV antenna based on the GPS system. However, it does not use wireless connection monitoring and is not offering alignment of point to point link.

Chapter 3: Construction/Manufacturing of Antenna Alignment system

3.1 Construction of Alignment system:

The construction process of an antenna alignment system designed to autonomously adjust itself based on maximum received signal strength involves several essential steps and components. First, the hardware setup includes mounting the antenna on a stable platform and connecting servo motors, an Arduino Uno board, an LCD 20×4 display, and a buck converter for power regulation. Next, programming the Arduino involves developing firmware to control servo motors, process signal strength data, and display information on the LCD display. Signal strength measurement is crucial, achieved through RF receiver modules interfaced with the Arduino to provide real-time feedback. Calibration and testing follow, fine-tuning alignment algorithms and conducting rigorous tests under various conditions to validate accuracy and reliability. Integration and optimization bring all components together, ensuring seamless functionality and performance optimization. Finally, deployment includes proper installation, ongoing maintenance, and user training to ensure continued system operation and reliability in real-world applications. Through these steps, a robust antenna alignment system is constructed, capable of enhancing communication reliability and performance by optimizing antenna positioning for maximum signal reception.

3.2 Components Required:

3.2.1 Arduino Uno

The Arduino Uno is a popular microcontroller board based on the ATmega328P chip. It's widely used in the maker community for prototyping and DIY projects due to its simplicity and versatility. Its memory configuration includes 32 KB of Flash memory for program storage, 2 KB of SRAM for variables, and 1 KB of EEPROM for data retention. With 14 digital I/O pins, 6 of which support PWM output, the Arduino Uno facilitates interaction with a diverse array of digital devices. Additionally, it offers 6 analog input pins for reading analog signals from sensors or other analog devices. Operating at 5 volts and accepting an input voltage range of 7 to 12 volts, the Uno is compatible with a wide range of components. Its interfaces comprise USB for programming and power, a barrel jack for external power, and a reset button for program restarts. Programming the Uno is accomplished through the Arduino IDE, a user-friendly environment supporting C and C++ languages.

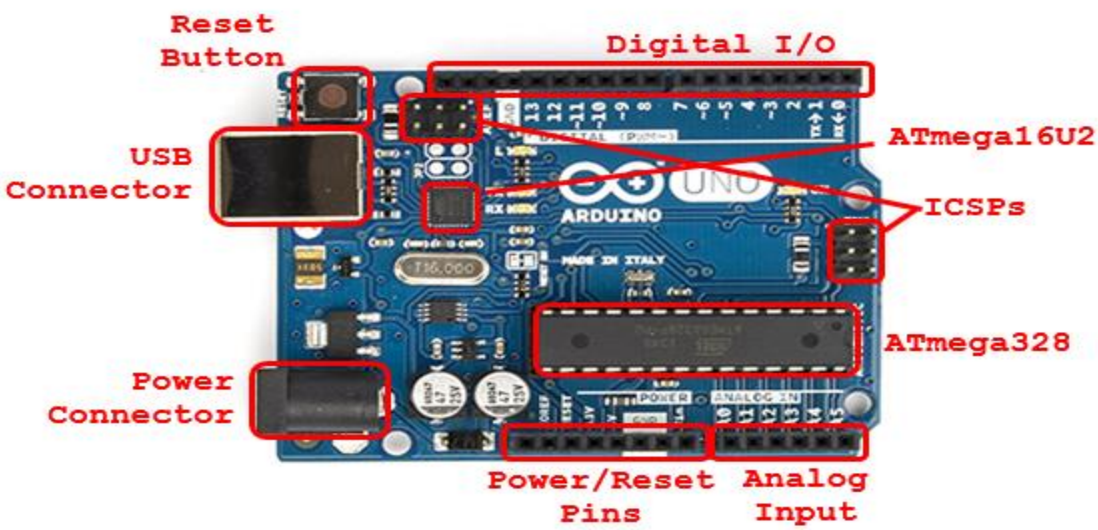

Fig 3.1: ATmega328P chip

3.2.2 Two MG945 Servo Motors

The MG945 servo motor is renowned for its high torque output and precise control, making it an ideal choice for applications requiring robust performance. Despite its compact size, it offers durability thanks to its construction with metal gears, ensuring reliable operation over extended periods. With a torque range typically between 10 to 12 kg-cm and a rotational speed of 0.17 to 0.20 seconds per 60 degrees, it provides the power and agility necessary for various tasks. Operating within a voltage range of 4.8 to 6.0 volts, it can handle higher voltages safely, offering versatility in different setups. Controlled via pulse width modulation (PWM) signals, it allows for smooth and accurate movement, with a rotation range of approximately 180 degrees. These specifications, combined with its compatibility with microcontroller platforms and cost-effective nature, make the MG945 servo motor a popular choice among hobbyists and professionals alike, suitable for robotics, automation, and remote control applications.

Fig 3.2: MG945 Servo Motor

3.2.3 LCD 20×4 Display

A 20×4 LCD Display is also used to display different parameters like error messages and signal strength in dBm.

3.2.4 LM2594 Buck Converter(12 to 5 volts inverter)

The LM2594 is a versatile buck (step-down) voltage regulator IC manufactured by Texas Instruments, renowned for its efficiency and reliability in step-down voltage conversion applications. With a wide input voltage range, it accommodates various power supply designs, ensuring stable output voltage regulation even amidst fluctuations in input voltage or load conditions. Its current limiting and thermal shutdown features offer added protection against excessive current draw and overheating, enhancing circuit safety. Operating at a fixed switching frequency, typically ranging from several hundred kilohertz to a few megahertz, it ensures efficient power conversion. Available in different package options to suit diverse PCB layout needs, the LM2594 is a go-to choice for applications such as battery charging, DC-DC conversion, and microcontroller voltage regulation, where efficient and reliable voltage conversion is paramount.

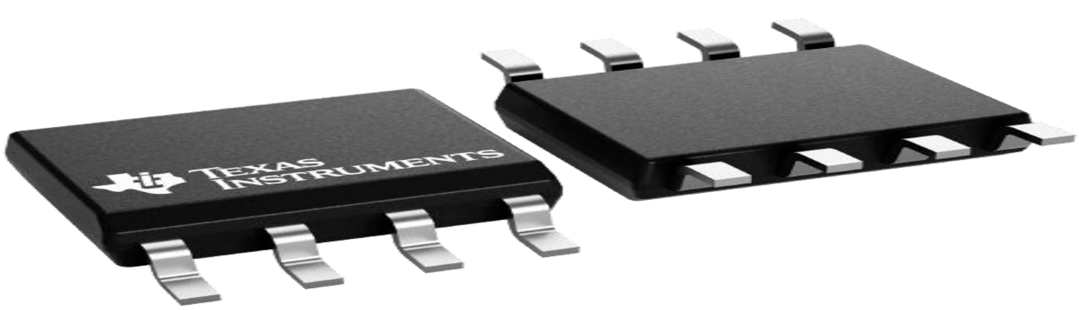

Fig 3.3: LM2594 Buck Converter

3.2.5 Antenna

A directional antenna is a type of antenna that radiates or receives electromagnetic waves preferentially in certain directions, giving it a higher gain in those directions compared to an omnidirectional antenna. These antennas are commonly used in various applications such as wireless communication, radar systems, radio astronomy, and more. They are designed to focus the signal in a specific direction, which can improve communication range, reduce interference, and increase signal strength.

3.2.6 Power Supply

A 12 Volt DC charger is used to give power to the Alignment system. Additionally, a 12 volt power battery is also used for backup. Following additional minor electrical things have also been used in the system.

1. Breadboard
2. Jumper Wires
3. Resistors and Capacitors (as needed)

3.3 Construction Steps

Following construction steps have been followed in the completion of this project.

3.3.1 Assemble the Hardware

Gather all necessary components, including the Arduino Uno, MG945 servo motors, jumper wires, and any additional peripherals. Arrange the components on a clean, stable surface, ensuring adequate space for assembly and operation.

3.3.2 Setting up the Arduino Uno

Place the Arduino Uno board on the chosen surface, ensuring it is stable and secure. Connect the Arduino Uno to a power source using a suitable power supply or USB cable, if applicable.

3.3.3 Connect the MG945 servo motors

Identify the three wires of each MG945 servo motor: ground (GND), power (VCC), and signal (control). Use jumper wires to connect each servo motor to the Arduino Uno board, ensuring correct wiring.

3.4 Servo Motor Connections:

Each MG945 servo motor typically has three wires:

3.4.1 Brown/Black: Ground (GND)

This wire is usually brown or black and is connected to the ground (GND) terminal of the circuit or power supply. It serves as the reference point for electrical signals and completes the circuit.

3.4.2 Red: Power (VCC)

The red wire is designated for power and is connected to the positive terminal (VCC) of the power supply or circuit. It provides the necessary electrical power to operate the servo motor.

3.4.3 Orange/Yellow: Signal (Control)

The orange or yellow wire is for the signal or control input. It carries the control signals from the microcontroller (such as Arduino) to the servo motor, instructing it to move to a specific position based on the input signal's characteristics.

By properly connecting these wires to the corresponding terminals on the servo motor and ensuring correct voltage levels and signal compatibility, the servo motor can be effectively controlled and utilized in various applications, including antenna alignment systems.

3.5 Arduino Uno Pin Connections

For each servo motor, you need to connect the ground (GND) and power (VCC) wires to the appropriate pins on the Arduino Uno. The signal wire will be connected to a digital pin on the Arduino for control.

3.6 Connections for Servo Motor 1

3.6.1 Brown/Black wire (GND)

Connect to any Ground (GND) pin on the Arduino Uno (e.g., GND pin on the digital side).

3.6.2 Red wire (VCC)

Connect to a 5V pin on the Arduino Uno (e.g., 5V pin on the digital side).

3.6.3 Orange/Yellow wire (Signal)

Connect to a digital pin on the Arduino Uno (e.g., Digital Pin 2).

3.7 Connections for Servo Motor 2:

3.7.1 Brown/Black wire (GND):

Connect to any Ground (GND) pin on the Arduino Uno (e.g., GND pin on the digital side).

3.7.2 Red wire (VCC):

Connect to a 5V pin on the Arduino Uno (e.g., 5V pin on the digital side).

3.7.3 Orange/Yellow wire (Signal):

Connect to a different digital pin on the Arduino Uno than the first servo motor (e.g., Digital Pin 3).

By following these connections, you can control both MG945 servo motors independently using the Arduino Uno. Make sure to refer to the pinout diagram of your Arduino Uno board to locate the appropriate pins for GND, 5V, and digital pins. Additionally, it's essential to power the servo motors with a stable power supply, which may involve using an external power source or a buck converter for higher current requirements.

3.8 Mounting of Servo motor

To ensure the accurate alignment of the antenna, it's crucial to mount the servo motors in a manner that allows for unrestricted rotation while securely holding the antenna in place. This process involves selecting stable mounting points and securing the servo motors firmly to these points using appropriate hardware. The orientation of the servo motors should align with the desired rotation axes of the antenna to enable precise control of azimuth and elevation movements. Additionally, it's important to avoid any obstructions that may impede the free movement of the servo motors. Once the servo motors are mounted, the antenna can be securely attached to their arms or shafts using suitable mounting brackets or fixtures. Testing the rotation of the servo motors ensures smooth movement and allows for fine-tuning of the alignment for optimal accuracy. Through these steps, the servo motors can effectively rotate the antenna, facilitating precise alignment for optimal signal reception.

3.9 Connection with LCD

Connect the LCD 20 display to the Arduino Uno. Pay attention to the pin configurations and make necessary connections.

3.10 LM2594 buck convertor

To wire the LM2594 buck converter for supplying a stable power source to the servo motors and adjust the output voltage to meet the motor's requirements, begin by identifying the input and output pins on the LM2594 module. Connect the VIN pin to the power source, ensuring the input voltage falls within the acceptable range. Then, link the VOUT pin to the power input (VCC) of the servo motors. Adjust the output voltage of the buck converter according to the motor's specifications to ensure optimal performance. This setup guarantees a consistent and regulated power supply for the servo motors, facilitating reliable operation in the antenna alignment system.

3.11 Write the Arduino Code

3.11.1 Develop the Arduino code to control the servo motors based on received signal strength.

3.11.2 Utilize appropriate libraries for servo motor control and LCD display.

3.11.3 Implement algorithms to measure the received signal strength and calculate the optimal antenna alignment angles.

3.11.4 Ensure the code is well-structured, commented, and error-handled for smooth operation.

3.12 Calibration and Testing

3.12.1 Calibrate the system :

Establish a controlled test environment with known signal sources. Begin by selecting a location with minimal interference and clear visibility to these sources, such as Wi-Fi routers or GPS satellites. Position the signal sources strategically within this environment, ensuring consistent emission of signals. Then, set up the antenna alignment system, ensuring all components are powered and operational. Capture signal strength data from each known source using the system and record the readings obtained. Analyze this data to compare the measured signal strengths with the expected values from the known sources. Adjust the alignment parameters, such as azimuth and elevation angles, iteratively based on the differences between measured and expected values. Repeat the calibration process multiple times, refining the parameters until the measured signal strengths closely match the expected values for all known sources. Validate the calibration by testing the system's performance with the signal sources placed at different locations within the test environment. Document the calibration results, including the adjustments made and the final alignment settings achieved, for future reference and troubleshooting.

3.12.2 Verify the functionality of the system

To verify the functionality of the system, closely monitor the LCD display for real-time signal strength readings and observe the movements of the servo motors. As the system operates, the LCD display should continuously update with accurate signal strength data retrieved from the antenna's orientation. Concurrently, the servo motors should respond accordingly, adjusting the antenna's position to optimize signal reception based on the received readings. Confirm that the servo motors move smoothly and precisely, aligning the antenna with changes in signal strength. Test the system under different conditions, such as altering the positions of known signal sources, to ensure its responsiveness and adaptability. Should any issues arise during testing, promptly troubleshoot and address them to maintain the system's performance integrity. Document the test results comprehensively, including observations and any corrective actions taken, to facilitate ongoing refinement and optimization of the system's functionality.

3.12.3 Fine-tuning

To achieve precise antenna alignment, it's crucial to fine-tune both the code and hardware settings of the system. In terms of code optimization, carefully review the Arduino code responsible for controlling the servo motors and processing signal strength data. Introduce adjustments or algorithms to enhance alignment accuracy based on signal strength readings. Parameters such as servo motor movement speed, sensitivity thresholds for signal strength, and error correction mechanisms should be fine-tuned to optimize performance. Concurrently, in hardware calibration, ensure the mechanical setup of the servo motors and antenna mount enables smooth and accurate movement. Address any physical constraints or obstructions that could affect alignment accuracy. Calibrate the servo motors to ensure precise movement in response to control signals from the Arduino. It's essential to calibrate the system's signal strength measurements to accurately reflect actual signal reception performance. Adjust sensitivity settings to filter noise and ensure reliable signal strength readings. Through thorough testing and validation in diverse environmental conditions, validate the system's accuracy and reliability. Use known signal sources to confirm precise alignment based on signal strength measurements. Embrace an iterative refinement approach, continually monitoring performance and gathering feedback to identify areas for improvement. Document all modifications made to the code and hardware settings during this fine-tuning process, maintaining version control to ensure reproducibility of previous configurations. Through these steps, the system can achieve optimal accuracy in aligning the antenna for maximum signal reception.

3.13 Integration and Optimization

3.13.1 Integrate all components into a compact and sturdy enclosure to protect them from environmental factors.

3.13.2 Optimize the system for power efficiency and durability.

3.13.3 Implement additional features such as remote control or automated alignment based on preset parameters, if desired.

Chapter 4: Working principle

4.1 General overview of the working principle:

4.1.1 Arduino commands servo motors based on feedback from the antenna.

4.1.2 Signal strength measurements are used to determine optimal antenna orientation.

4.1.3 System iterates through multiple azimuth and elevation angles to find maximum signal strength.

The working principle of this project has been divided into following phases.

4.2 Signal Strength Measurement:

In order to measure the signal strength the Arduino UNO will continuously check the received signal strength from the UHF directional antenna and compare it with predetermined value. The signal is received from UHF directional antenna and is processed through wifi module ESP28.The RSS value received by ESP28 in dbm is given to Arduino UNO. Arduino UNO will compare the RSS value with a predetermined value (-60dbm) of and then Arduino will store three values which are as mentioned. One is Position tilt, second is Position PAN and third is the strength of RSS.

4.3 Comparison and Adjustment:

The Arduino will receive the signal strength value at each step and compare it with the previously recorded signal strength values. If the current signal strength is higher than the previously recorded value, Arduino UNO will replace the old RSS value with new RSS value, and similarly the Position tilt and position PAN of that step where the RSS value is received, will also be replaced.

4.4 Algorithm Overview:

General code of the algorithm used for antenna alignment is as follow:

```
#include <SoftwareSerial.h>          /////A Library is called to establish a serial connection
                                     ///// on the digital pins of Arduino UNO.
```

```
#include <LiquidCrystal_I2C.h>    //////This library is called to print messages on an LCD screen
                                  /////using 12C back pack
#include <Servo.h>
#include <Wire.h>
                                  /////// Define software serial pins
#define RX_PIN 2
#define TX_PIN 3
Servo pan_servo;
Servo tilt_servo;
SoftwareSerial mySerial(RX_PIN, TX_PIN); // RX, TX
LiquidCrystal_I2C lcd(0x27,20,4);
String a;
int b;
int chk=0;
const int PAN_MIN = 120;
const int PAN_MAX = 150;
const int PAN_INC = 10;
const int TILT_MIN = 20;       //////////
const int TILT_MAX = 140;      //////////
const int TILT_INC = 10;
// max setings
int max_pan = 0;
int max_tilt = 0;
```

```
int max_rssi = -60.0;

void setup() {

                                    ////// Initialize serial communication

  Serial.begin(9600);          ///// Initialize software serial communication

  mySerial.begin(9600);

  pan_servo.attach(9);

  tilt_servo.attach(10);

  int getrssi();

   lcd.init();                 /////// initialize the lcd

  lcd.init();                             /////// Print a message to the LCD.

  lcd.backlight();

  lcd.setCursor(0,0);

  lcd.print("RSSI TRACKER");

}

Void loop () {

int pan_pos;

int tilt_pos;

pan_servo.write(max_pan);

if(chk==0)

{

  for (  pan_pos = PAN_MIN; pan_pos <= PAN_MAX; pan_pos = pan_pos + PAN_INC ) {

       lcd.setCursor(0,1);

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

```
  for (  tilt_pos = TILT_MIN; tilt_pos <= TILT_MAX; tilt_pos += TILT_INC ) {


    pan_servo.write(pan_pos);              ////// tell servo to go to position in variable 'pos'

    tilt_servo.write(tilt_pos);

    int rssi = getrssi();


    if ( rssi > max_rssi ) {

      max_rssi = rssi;

      max_pan = pan_pos;

      max_tilt = tilt_pos;

    }

    delay(500);

  }

  for (  tilt_pos = TILT_MAX; tilt_pos >= TILT_MIN; tilt_pos -= TILT_INC ) {

    tilt_servo.write(tilt_pos);

    delay(10);

  }

}

    lcd.setCursor(0,2);

lcd.print("moving to max rssi");

      lcd.setCursor(0,3);

lcd.print(max_rssi);

delay(500);
```

```
  pan_servo.write(max_pan);

  tilt_servo.write(max_tilt);

  chk=1;

}

}

int getrssi()

{

  if (mySerial.available())

  {

a=mySerial.readStringUntil('\n');


 b=(a.toInt());

 int rssi=b;

 Serial.println(b);                ///// Print the received integer


  lcd.setCursor(0,2);

  lcd.print("RSSI: ");

  lcd.print(rssi);

  return rssi;

  } ..

}
```

General code of the algorithm used to synchronize the transmitter ESP28 with Antenna Alignment System is as follow:

```
#include <WiFi.h>

// Replace with your network credentials

const char* ssid     = "Pass";

const char* password = "ses12345";


// Set web server port number to 80

WiFiServer server(80);


// Variable to store the HTTP request

String header;                              ////// Auxiliary variables to store the current output state

String output26State = "off";

String output27State = "off";    /////Assign output variables to GPIO pins

const int output26 = 26;

const int output27 = 27;


void setup() {

  Serial.begin(115200);

  /////// Initialize the output variables as outputs

  pinMode(output26, OUTPUT);

  pinMode(output27, OUTPUT);

  ////// Set outputs to LOW

  digitalWrite(output26, LOW);

  digital
```

```
#include <WiFi.h>            ////// Replace with your network credentials (STATION)
const char* ssid = "Pass";
const char* password = "ses12345";
void initWiFi() {
  WiFi.mode(WIFI_STA);
  WiFi.begin(ssid, password);
  Serial.print("Connecting to WiFi ..");
  while (WiFi.status() != WL_CONNECTED) {
    Serial.print('.');
    delay(1000);
  }
  Serial.println(WiFi.localIP());
  digitalWrite(2,HIGH);
}
void setup() {pinMode(2,OUTPUT);
digitalWrite(2,LOW);
  Serial.begin(9600);
  initWiFi();
  Serial.print("RRSI: ");
  Serial.println(WiFi.RSSI());
}
void loop() {
  Serial.println(WiFi.RSSI());
```

```
  delay(100);
}
```

4.5 Servo Motor Control:

The Arduino sends appropriate control signals to the servo motors to scan the complete area from 0-180 in azimuth degree and 0-90 degree in elevation, (the orientation of the antenna). The servo motors MG945 control the movement of the antenna in azimuth and elevation by converting electrical signals from the Arduino into mechanical motion.

Servo motors are rotary actuators that can rotate an output shaft to a specific angular position. This rotation is achieved by controlling the position of an internal rotor using feedback from a potentiometer or encoder. The Arduino sends control signals to the servo motors to specify the desired angular positions for azimuth and elevation. These control signals typically consist of pulse-width modulation (PWM) signals, which encode the target position as a pulse duration within a specific range. Inside the servo motor, there is a feedback mechanism (such as a potentiometer) that continuously monitors the position of the rotor. This feedback information is compared to the target position specified by the control signal. If there is a discrepancy between the actual position and the target position, the servo motor adjusts the rotor's position to minimize the error. It does this by modulating the power supplied to the motor coils, causing the rotor to rotate until the desired position is reached. Servo motors operate in a closed-loop control system, where feedback from the position sensor is used to continuously adjust the motor's output to maintain the desired position. This allows for precise and accurate control of the antenna's orientation. Separate servo motors are dedicated to controlling the azimuth and elevation movements of the antenna. The Arduino independently sends control signals to each servo motor based on the desired azimuth and elevation angles calculated from the received signal strength.

Overall, servo motors provide a reliable and precise mechanism for controlling the movement of the antenna in azimuth and elevation, ensuring optimal alignment for signal reception.

4.6 Feedback and Display:

The system continuously updates the LCD display with relevant information such as current signal strength, alignment status, and any error messages. This provides feedback to the user about the system's operation. On the LED display the RSS value at each step is visible, which gives us a general idea of the direction where RSS value will be maximum.

4.7 Continuous Monitoring and Adjustment:

The process of measuring signal strength, comparing it with the highest recorded value, and adjusting the antenna orientation continues in a loop, ensuring that the antenna remains aligned for optimal signal reception even if environmental conditions change.

By combining these components and principles, the system can autonomously align the antenna for maximum signal reception, making it suitable for applications such as long-range communication, satellite tracking, or Wi-Fi signal optimization.

Chapter 5: Conclusion

In this research paper /thesis we explained the complete construction of antenna alignment system using local available resources. In modern communication systems, the quest for optimal signal reception has always been paramount. The antenna alignment system presented in this project represents a significant stride towards achieving this goal. Through the seamless integration of servo motors MG945, an Arduino microcontroller, buck converter(LM2594), LED display and sophisticated signal processing algorithms. At the core of this system are servo motors, acting as vigilant guardians of connectivity. With each electrical impulse from the Arduino, they spring into action, guiding the antenna through the celestial expanse. Through feedback loops and control mechanisms, they ensure the antenna is poised to capture elusive signals. The system orchestrates a symphony of movements, meticulously aligning the antenna to capture the faintest radio frequency traversing around the antenna, which led to the successfull implementation of antenna alignment system using two servo motors for azimuth and elevation control and adjusting antenna according to maximum RSSI.

We were successful in achieving precise directional adjustments enhancing signal reception and transmission capabilities. This system will offer versatility and accuracy crucial for applications such as satellite communication, remote sensing and will have wide range of application across telecommunication industry. One of the key strength of our project lies in the adaptability and scalability. Its modular design allows for easy integration with different types and sizes of antennas as well as with diverse communication protocols and frequency bands without any modification in the basic algorthm and hradware of the system. Real time monitoring and adjustments capabilities ensure continuous and optimal antenna alignment, even in dynamic operating conditions.

As we stand on the precipice of tomorrow, we are reminded that the journey towards innovation is fraught with uncertainty. But it is in embracing the unknown that we truly unleash the full potential of human creativity. The antenna alignment system presented in this project is a testament to this ethos, a bold exploration of the uncharted territories of connectivity that lie beyond the horizon. As we gaze towards the future, let us remember that the quest for optimal signal reception is not merely a technical endeavor; it is a testament to the indomitable spirit of human curiosity and exploration.

Future enhancements could focus on automating the alignment process further. This project can further be developed to track drones inreal time on the basis of frequency. Every object that is having some frequency can be tracked through it. Morever advancement in servo motors technology such as high torque and speed capabilities, could further enhance the performance and responsiveness of the system. It merely marks the beginning of a new chapter in the quest for connectivity. As we peer beyond the horizon of possibility, we glimpse a future where communication knows no bounds, where signals traverse the globe with the speed of thought, and where the antenna alignment system will stand as a beacon of innovation in an ever-evolving landscape. Over all, this project demonstrates the effectiveness of servo motor based antenna alignment system in improving communication, reliability and performance. This project weaves together elements of creativity, metaphor, and reflection to provide a unique and thought-provoking perspective on the antenna alignment system for any purpose. The journey of the antenna alignment system is not the end but the beginning of a new chapter in the ongoing quest for connectivity and innovation. The system will serve as a catalyst for creativity and inspiration. Its success inspires future generations to dream big and pursue their passions.

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