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Intersection Of Domains: Designing A Remote-Controlled Dish Antenna

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Abstract

The advent of technology has instigated rapid advances in the field of communications, a prime example being the remote-controlled dish antenna, which embodies a parabolic design intended to intercept and concentrate electromagnetic waves onto a common focal point. The modification towards remote control mandates a core understanding of diverse technological realms as it involves an amalgamation of components and knowledge. This discourse probes into the nuanced design and implementation of a remote-controlled dish antenna, conceived around the core touchstones of a microcontroller and an array of complementary components. The research work signifies a compounding of several technological domains, including microcontroller programming, power electronics, wireless communication, and motor control, necessitating extensive proficiency in these areas and consequently, offering an invaluable foundation to the broader control system applications. The overarching aim of this research is to enable users to effectively control a dish antenna's positioning remotely, leveraging a Bluetooth HC-05 module for optimal convenience and accessibility. This revolutionary project relies on a PIC18F2550 microcontroller, a high-performance RISC CPU with integrated EEPROM and SRAM, which allows for flexible data storage and retrieval. Considering its compatibility with a variety of peripherals, the PIC18F2550 emerges as a logical choice, significantly enhancing the system's performance efficacy.

Keywords: Remote-controlled dish antenna; Communication; SRAM; PICI8F22550 Microcontroler; CPU

INTRODUCTION

The world presently is characterized by vast technological advancements that have transformed various aspects of lives. A key contributor to this development is the realm of communications technology, notably the evolution of the Remote-Controlled Dish Antenna (RCDA). This critical invention has found numerous applications, from television broadcasts to satellite communications and far beyond. The genesis of the Remote-Controlled Dish Antenna dates to the dawn of the satellite era. It was as early as 1957 when mankind launched the first artificial satellite, Sputnik, into orbit (Kumar & Katiyar, 2017). This necessitated the development of sophisticated technology capable of tracking this satellite, thereby announcing the birth of advanced antenna systems, such as the Remote-Controlled Dish Antenna. In its essence, a Remote-Controlled Dish Antenna is a parabolic antenna designed to receive and

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focus electromagnetic waves at a common focal point (Balakrishnan, 2012). By introducing remote capabilities, engineers enabled users to adjust the orientation of the antenna remotely, thereby enhancing its efficiency and convenience. The design process of the RCDA starts with the careful consideration of the antenna's function. Factors such as the intended frequency range, polarization orientation, and the appropriate beam width need to be defined (Vinoy, 2007). Once these parameters are set, the intricate mathematical modelling of the parabolic reflective shape is executed to ensure optimal performance. This includes calculations for the antenna feed, which sits at the focus point and captures the reflected signals (Kraus, 1986).

Furthermore, adding remote control capabilities to the antenna necessitated the integration of a robust motor system for azimuth and elevation adjustment. This augmentation required substantial engineering skill and knowledge in various domains, including mechanical, electrical and software engineering. The construction of an RCDA incorporates phases of testing, adjustment and calibration. Once the parabolic reflector's structure is assembled, the antenna feed is positioned at the focal point, and the motor and control devices are installed (Paul, 2014). A critical aspect of the fabrication process is the implementation of the tracking system, which enables the antenna to align itself to a particular satellite. Consequently, the Dish Antenna's performance depends on the accuracy of its design, construction, and its feed positioning. Hence, rigorous testing and re-calibrations are necessary to ensure the best reception quality. The evolution of RCDA has been momentous due to various innovations over the decades. Moreover, a recent study by Liu & Wang (2020) describes a refined model where these technologies were implemented for automatic alignment of satellite dish antennas. By combining the microcontroller's processing power with the Bluetooth module's wireless communication, their model reflects an increased level of automated control––an advancement that's paving the way for future innovations in this domain. According to Jackson et al. (2021), such implementations find use in an array of industries including telecommunication, broadcasting, and space research sectors, to name a few. The remote-control mechanism facilitates precise and hassle-free adjustment of dish antenna positions, thereby improving performance, service quality, and scope for innovation. Dix-Taylor *et al.* (2021) developed a dish positioning system using a Bluetooth module accepting instructions from an Android application. In their experiment, they achieved a significant degree of accuracy in positioning with better flexibility and convenience. A study by Oghogho, & Edeko, (2020) implemented a solar tracking system using a PIC 18F2550 microcontroller. Here, the positioning system used was similar to that of the dish antenna, hence demonstrating its versatility and effectiveness. Barisal and Gaur (2019) applied the PIC 18F2550 microcontroller and Bluetooth HC-05 module tandem in developing a prototype for such a system. The resultant device could locate and reposition the satellite dish, maximizing the quality and clarity of received signals. Utilizing Bluetooth connections, Tian et al. (2020) demonstrated that the technology provided a reliable medium of controlling dish antennas from a distance, eradicating the need for direct line-of-sight or complex cabled systems. Future-focused research by Jaiswal et al. (2021) argued that implementing such technology in broader broadcasting systems could transform the sector in terms of reception quality and system setup expenses. Contrarily, some studies cast doubt on the practical benefits of the technology. Notable among these is the development of lighter, more durable materials for the dish construction, the miniaturization of motor components and the simplification of user interfaces for the remote-control apparatus (Pattnaik, 2008).

METHODOLOGY

Procedure for the Implementation of the work

The advent of advanced technology such as the use of a remote-control dish antenna utilizing a PIC18F2550 microcontroller proposes immense benefits regarding tracking the objectives within the oscillating perimeters effectively. The use of components like Bluetooth HC-05 module, stepper motor NMA17, a transformer, motor driver A4988, voltage regulator LM7805, Limit switch, lithium battery 18650, diode(1N4007), electrolytic capacitor, and copper clad in its composition extends its vitality.

Bluetooth Module Hc-05

Bluetooth technology has revolutionized wireless communication. An example of such a development is the Bluetooth HC-05 module, a widely utilised medium for short-range communication. This module abides by Bluetooth 2.0 communication protocols, promoting easy integration into a variety of systems. The mathematical foundation of Bluetooth technology, including the HC-05, is centred on algorithms to hop frequencies quickly and achieve fast device connection using Figure 2.1. Frequency-hopping spread spectrum (FHSS) occurs over 79 different frequency bands across the $2.4GHz$ ISM band, hopping 1600 times per second. The mathematical equation that depicts this is $F = 2.402GHz + k * 1MHz$, where F is the frequency in GHz, and k is an integer from 0 to 78. Equally, the Bluetooth HC-05 module incorporates the Gaussian frequency-shift keying (GFSK) modulation scheme. GFSK minimizes the use of bandwidth by smoothing the signal’s phase changes, leading to a reduction in spectral width. In essence, this equation models the GFSK:

$$f(t) = f\_c + \Delta f * sin(\Phi(t))$$

Where $f(t)$ is the instantaneous frequency, f_c is the carrier frequency, Δf is the frequency deviation, and $\Phi(t)$ is the integrated data signal (Bao & Xia, 2015). The HC-05 Bluetooth module operates at a supply voltage varying between $3.6 - 6V$, with a standard voltage of 5V. It has a default baud rate of 9600bps, which allows for a transmission distance of approximately 10 metres. Additionally, the HC-05 module's electrical properties involve parameters like output power and working current. For instance, the module consummates a working current of 30mA, while its pairing mode current is 40mA, and the module’s average current during sleep mode is $1mA$. The output power is typically rated at $+4\ dBm$, which is vital for the module's operation within the effective distance. Interestingly, its power consumption relies on its operating modes. For example, in communication mode, the module operates at full power, requiring the entire $30 - 40mA$ of current. Conversely, the sleep mode current reduces to an average of $1mA$, minimising energy usage when the module is not actively utilised, contributing to a vastly improved battery lifespan.

Figure 2.1: Bluetooth Module

Battery Management System

A Battery Management System (BMS) is a system that manages a rechargeable battery's charging and discharging, specifically in electric vehicles to maintain safety, prolong battery life and maintain optimum performance (Yang *et al.*, 2020). One useful way of handling battery arrays is the 3-Series system or '3S'. This essay delves deeper into understanding the mathematical equation and electrical properties of 3S BMS. The primary role of a BMS includes measuring voltages and currents, estimating state-of-charge (SOC), stating health (SOH), and predicting remaining useful life (RUL). From a mathematical perspective, the simplest form of cell-balancing algorithm is the equalization of cell voltages. The equations for voltage, current, and temperature are typically expressed as:

- Voltage (Equalization) = $Vmax - Vcelli$
- Current = $\sum Icell\ i$
- Temperature = $\beta/(ln(R/R0) + \beta/T0) - 273.15$

Where $Vmax$ is the maximum desirable voltage, $Vcelli$ is the voltage of each cell, $Icell\ i$ is the current for each cell, R is the total resistance, and β and $R0$ are specific constants (Fridholm *et al.*, 2012). Although these equations are simple, they strongly assert the basis of cell balancing algorithms. The performance of a BMS is essentially dependent on its electrical properties – voltage, current, and temperature.

a. **Voltage:** Voltage management is crucial for a BMS. A small overvoltage can cause an electrolyte break-down leading to gas generation while excess undervoltage can cause electrode material dissolution. Thus, a precise voltage-balancing method is imperative to avoid the development of cell voltage irregularities.
b. **Current**: Current measurement helps to determine the SOC and is crucial for the estimation of RUL. Mismanagement, either chronic overcharging or complete discharging, can lead to degradation effects like corrosion, deformation and loss of active material.
c. **Temperature:** Temperature directly affects the performance, life, and safety of a battery pack. Batteries operating at a higher temperature charge effectively but degrade quicker. Hence, maintaining an optimum temperature is crucial for efficient battery management.

RESULTS AND DISCUSSION

Upon reflection, this project serves to enforce the benefits of utilizing a series of components to create a remote-control dish antenna system. The control granted by the microcontroller, the precision of the stepper motor, the seamless engagement offered by Bluetooth connectivity, the stability provided by the battery, and the structural integrity delivered by the copper clad, all these components brought together, form a highly efficient system. The PIC18F2550 microcontroller proved to be apt for processing the desired command. The Bluetooth HC-05 module displayed seamless integration with the smartphone application, paving the way for effective remote control. As anticipated, the lithium battery 18650 offered a sturdy power supply throughout the construction and testing phases. Some challenges encountered included perfect stability provision by the electrolytic capacitor and inconsistent readings from the voltage regulator LM7805. The A4988 driver faced issues with high loads but performed within expectations, directing the NEMA17 stepper motor meticulously.

Construction

Firstly, it is essential to comprehend the role and utility of these fundamental components in the construction process. The PIC18F2550 microcontroller acts as the central processing unit, governing all instructions, operations, and interactions within the hardware. It is essentially the heart of the system, controlling and sustaining functionality. The Bluetooth HC-05 module, a handy and popular device among wireless communication enthusiasts, enhances the system's range and control. It acts as the bridge between the antenna and the remote control by enhancing connectivity. The usage of a stepper motor, specifically a NEMA17, epitomizes the trend of miniaturization in technology. These smaller, more powerful motors present a significant advantage over their older counterparts due to their lower power consumption and improved precision, which is integral in achieving effective dish positioning. The motor driver A4988 translates digital pulses into the physical rotation of the stepper motor. Its job involves regulating the current flow in the motor windings, thereby controlling the motor's speed and direction. The transformer, an indispensable electrical device, is employed for stepping down the voltage to an appropriate level for the electronic components. The LM7805 voltage regulator ensures stable voltage, which is crucial to the microcontroller and other voltage-sensitive components, allowing the system to perform accurately and reliably. The limit switch is used as a safety feature, ensuring the dish's rotation is within a prescribed scope to prevent any mechanical or electrical malfunctions. The lithium battery 18650 powers the whole assembly with its high-energy density and long lifespan. Meanwhile, the electrolytic capacitor stores electric charge and smoothens the power supply, preventing any detrimental fluctuations, and the copper-clad board serves as the base for the circuit design, contributing to the system's durability and resilience. The method of constructing a remote-controlled dish antenna mainly involves designing the circuit on the copper-clad board, incorporating all the aforementioned components coherently. Soldering is done to ensure solid connections between components and to protect the join from corrosion. Once assembled, the completed circuit board is attached to the dish antenna. The pictures are displayed in Figure 3.1 on how it is implemented.

Figure 3.1: Installation process of the remote-control dish antenna

Operation of the system

The heart of the remote-control dish antenna's operation lies within the PIC18F2550 microcontroller. Known for its robust performance, this microcontroller is responsible for integrating the various components that make the dish antenna functional. Its high computing ability combined with desirable features like inbuilt analog to digital converters and data memory of 256 bytes results in efficient coordination of the operational units. Bluetooth HC-05 modules contribute significantly towards reshaping the operational patterns of dish antennas. Primarily, they facilitate the wireless transmission of commands from android applications to the dish antenna. The highly adaptable nature and a wider coverage area of the module reflect its compatibility with android technology, embedding fluidity in controlling the antenna's positions. Further, the operational dynamics of dish antennas are accentuated with the infusion of a stepper motor, NEMA17. Its seamless operation coordinated with the A4988 motor driver pivots the dish antenna to the required positions in real-time. The micro-step operation capability of the A4988 reinforces accurate and efficient positioning of the antenna, promising a stable signal reception. The addition of an android application as the control interface brings the advantages of digitalization to the setup. The user loads the antenna's positions onto the app, and with a simple command, the dish antenna is set moving to the desired direction. Its design is such that, once you receive a signal, it automatically registers the positional coordinates into its memory, marked numerically, for instance, 1,2 and 3. During the programming mode, these locations can be run sequentially, saving substantial power while retaining the convenience of signal reception. In the running mode, the user sends the desired position number via an android application. The antenna first reaches the zero point or the home position before proceeding to the required coordinates. Precisely, each repositioning manoeuvre begins with this homing function, adding an extra layer of precision control to the process. Moreover, the integration of a limit switch brings about enhanced functionality to the entire system. A simple mechanism yet effective, the limit switch informs the microcontroller when the antenna's position has reached its predetermined limits, i.e., when it has reached home. This real-time position calibration checks the motor's overly excessive movements, ensuring the optimal working of the PIC18F2550 and Bluetooth HC-05. Finally, the role of the lithium-ion 18650 backup battery is indispensable. It preserves the stored positions in the antenna's memory even when devoid of an external power source. Through its high energy density and low self-discharge, it safeguards the programming and ensures that the system configuration remains intact for the next operational cycle. The figure 1 shows the circuit diagram of the proposed remote-controlled dish.

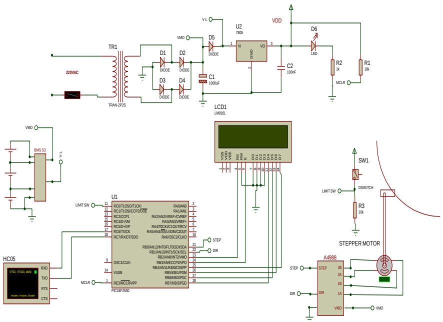

Figure 3.2: The proposed circuit diagram of Remote-Controlled Dish

Testing

After the construction phase, it is crucial to test each incorporated component to ensure the antenna's overall functionality. The PIC18F2550 microcontroller is tested with specific coded commands to verify proper command processing. The Bluetooth module HC-05 is paired with a smartphone application to confirm seamless connectivity for remote control. A multimeter is used to check the electrical components such as the voltage regulator LM7805, diode (1n4007), and electrolytic capacitor for accurate readings. Furthermore, the structural stability of the copper clad framework is checked.

CONCLUSION

The Dish Antenna's performance depends on the accuracy of its design, construction, and its feed positioning. In its essence, a Remote-Controlled Dish Antenna is a parabolic antenna designed to receive and focus electromagnetic waves at a common focal point. The chosen materials for the implementation process present an intriguing mesh of simple and advanced components. The primary material, a PIC18F2550 microcontroller, steers the operations of the antenna, reflecting a fundamental tenet of microcontroller programming. The choice of this microcontroller enables the antenna to efficaciously manage input and output functions, which are pivotal in the antenna's primary function. This project also incorporates a Bluetooth HC-05, which aligns itself with the domain of wireless communication. The Bluetooth module's purpose is twofold. Primarily, it is responsible for the wireless transmission of directional data to the PIC18F2550 microcontroller. Secondly, it works as a control module, managing the trigger commands for the stepper motor NEMA17. The vital role of motor control is perceptible in the incorporation of the NEMA17 stepper motor, controlled by an A4988 motor driver. This complex system, which ensures precision in antenna orientation, is regulated by the aforementioned PIC18F2550 microcontroller and Bluetooth HC-05. The project also shows a skilful application of power electronics through the utilisation of a transformer and voltage regulator LM7805. The transformer handles the varying AC voltage, stepping it down to manageable levels for system protection, while the regulator ensures stable DC output, pivotal for the operation of the microcontroller and other electronic components. Additionally, a limit switch, lithium battery 18650, electrolytic capacitor, and copper clad take part in the design. The limit switch, a significant safety measure, halts the motor movement after reaching its predefined limit, whereas the lithium battery 18650 provides the system with portable power.

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