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DESGIN AND IMPLEMENTATION OF SATELLITE TRACKING SYSTEM

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Abstract: With the development of Internet, and the increase of digital multimedia communication services, satellite communication is developing rapidly. Communications via low-orbit satellites are increasingly significant. Most of the existing automatic tracking schemes drive the tracking system based on the beacon signal or forwarded pilot signal transmitted by the received satellite. The Automatic antenna positioning system primarily functions to identify the source of signal. The system can detect signals of various types, recognizing specific signals and adjusting the antenna's position to optimize signal strength reception. Whenever the receiver receives the signal with minimum strength it automatically changes its position. Next, regulate the antenna to align with the target satellite, ensuring automatic tracking of low-orbit satellites with minimal deviation and reliable stability. Compared with traditional satellite ground stations, the system achieves low-cost and miniaturized automatic tracking of low-orbit satellites.

Index Terms - Satellite tracking, LEO, Satellite transmissions, AMSAT, Real-time tracking, Rotor.

I. INTRODUCTION

Wireless communication is being studied extensively and has attracted the attention of many researchers throughout the world. It's crucial to position the antenna in a way that maximizes signal strength to effectively receive the desired signal. Particularly for locating and tracking radio frequency signals and for automatically positioning an antenna to receive a desired radio frequency signal. Depending on the application one of several types of antennas can be utilized to implement a radio frequency link for a wireless communication system, Wherein the RF link may transmit and/or receive audio, encapsulate data, compressed video, or other data. Types of antennas may include omni, sector and directional antennas. The system may comprise an antenna module with a transmitting and receiving antenna and hardware components to rotate the motor. It is the measurement of power present in the received radio signal. It is a telemetry data sent from the receiver back to the transmitter.

To establish communication with Low Earth Orbit (LEO) satellites and the International Space Station (ISS), it's crucial to have precise information about their position in the sky, including azimuth, elevation, and frequency Doppler shift. This data allows antennas to point accurately towards the spacecraft, ensuring a stable and strong signal. However, due to the limited window of opportunity when these spacecrafts are visible from a specific location, an efficient tracking system is necessary.

Traditionally, there have been two main types of tracking systems: manual and automatic. Automatic tracking systems, also known as auto-tracking systems, operate without direct intervention from a radio operator. They rely on satellite tracking software to calculate and provide the necessary information about the azimuth, elevation, and frequency Doppler shift for each satellite or spacecraft. This data is then used to control the antenna rotor and adjust its position accordingly. Additionally, the frequency Doppler shift information is fed to the transceiver to maintain the correct frequency for communication.

Therefore, automatic tracking systems streamline the process of satellite communication by automatically adjusting antenna positions based on real-time satellite tracking data, minimizing the need for manual intervention and ensuring a stable and reliable connection.

II. PROBLEM STATEMENT

Ham radio, or amateur radio, involves using radio frequencies for various non-commercial activities like exchanging messages, experimenting with wireless technology, training oneself, recreational purposes, participating in radio sports and contests, and even for emergency communication. Many astronauts aboard the international space station (ISS) are licensed ham radio operators and often engage in conversations with other ham radio operators on earth during their free time. However, due to the high speed at which the ISS travels, there's a phenomenon called doppler shift that affects radio signals. For instance, if the ISS is transmitting at a frequency of 145.800 MHz, as it approaches your location, the frequency appears to shift higher by 3.5 khz, making it 145.8035 mhz. During the approximately 10-minute window when the ISS passes overhead, the frequency gradually shifts lower, reaching 145.7965 MHz as the ISS moves out of range. This shifting frequency can make it challenging to maintain a strong signal connection throughout the pass.

III. PROPOSED SYSTEM

The tracking system is an essential part of a ground station that constantly monitors the movement of satellite and locks the receiving antenna/receiving station to receive signals with maximum SNR in Ham Radio. A satellite tracking system comprises a rotating antenna system capable of movement in both azimuth (from 0° to 360°) and elevation (from 0° to 90°), alongside an electronic system that autonomously manages the movement of the antenna. Typically, a satellite receiving antenna is affixed atop the rotating antenna system and linked to the satellite receiver. During normal operation the receiving antenna automatically rotates, this receiving antenna is either mounted on roof tops, vehicle tops, etc. to acquire maximum signal of receiving signal from satellite. In case if the receiving antenna is not automatically tracked and locked in line with the desired satellite, the receiving station doesn't receive signals with good signal strength. This is achieved in three different modes viz: Manual mode, Computer mode and Fully Automated mode by interfacing with Orbitron software. Throughout all operational modes, the receiving antenna is affixed to the rotating arm of the antenna and is linked to the satellite receiver.

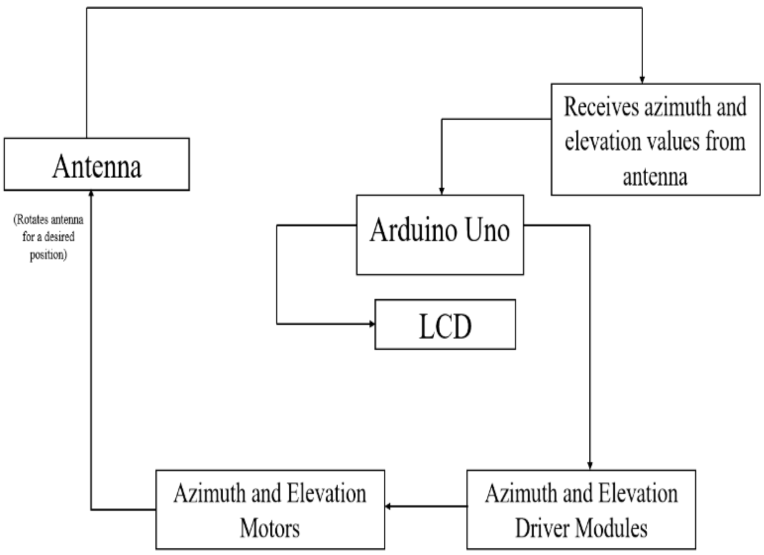
Manual mode: To ensure our control electronics and feedbacks are working right and all the interfaces are operating functional.

Computer mode: Along with the manual mode, we are ensuring the command signals through serial interface commands from GUI [Graphical User Interface) screen.

Fully automated mode: A third party open software called ORBITRON. It used to automatically set the commands to a satellite tracking system to track/lock the antenna.

IV. PROPOSED SYSTEM ARCHITECTURE

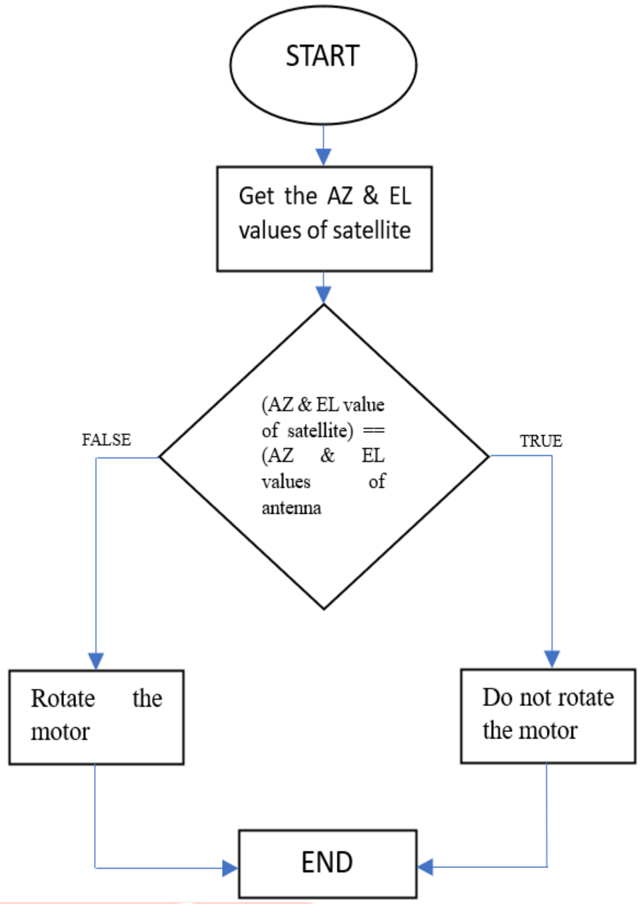
Fig. 1.1: Block diagram of the proposed system



V. FLOWCHART

When antenna starts to receiving the signal, AZ and EL values will be feed to microcontroller. The microcontroller checks whether the azimuth and elevation values of both antenna and satellites is equal, if the values are different i.e., not equal then the motors will be rotated to the desired angles for rotation of antenna once, it gets equal the motors stop rotating. This process is continued until the antenna receives the signals from satellites.

Fig. 1.2: Flow chart of the motors



VI. HARDWARE AND SOFTWARES USED

Hardware Components

Table. 1.1: List of Hardware Components Software Used

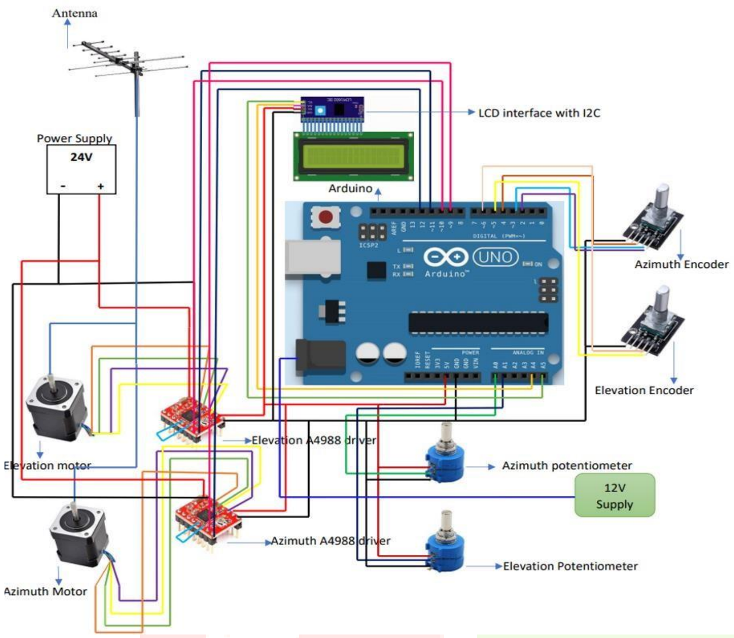
SL no.	Components	Specification
01.	Arduino Uno	ATmega328P
02.	Potentiometer	1OK ohm,3 Pin Potentiometer
03.	Rotary Encoder	PEC11R-12mm Incremental Encoder
04.	A4988 Module	Step and Direction control
05.	Motors	NEMA17 Stepper Motor
06.	Liquid Crystal Display	20x4 Character LCD Display
07.	I2C Bus	LCM 2004 IIC
08.	Power Adapter	12V, 2A

Table 1.2: List of Software Used

Sl.no	Software used	Specification
01.	Arduino IDE	IDE 1.8.12
02.	Orbitron	Orbitron 3.71

VII. CIRCUIT DIAGRAM

Fig. 1.3: Circuit diagram of the system



The fig 1.3 is the circuit diagram of the proposed system. It depicts the circuitry connection of each component with other. The schematic consists of Arduino UNO, Potentiometer, Encoder, NEMA23 motor, A4988 driver, Power supply (12V, 2A), LCD display and I2C bus interface. These components will work as explained in the above block diagrams mentioned in the methodology.

VIII. RESULTS

Here after integration of all the components, the power supply is turned on. For manual mode the input is fed from encoders, for computer mode the input is given through circle angle picker in user interface screen and for the fully automated mode the orbitron software is made use to obtain the azimuth and elevation value. This input will be displayed on LCD as command values i.e. azimuth and elevation command values. Also, the potentiometer feedback values i.e. azimuth and elevation feedback values will be displayed on the LCD. The motor keeps rotating when the difference between the command and feedback values is greater than seven. The motor stops rotating when the feedback is equal to the command value.

RESULTS OF MANUAL MODE

Fig. 1.4: Input value fed through encoder displays on LCD

Fig. 1.5: Azimuth feedback value made equal to command value

Fig. 1.6: Elevation feedback value made equal to command value

The above fig. 1.4 depicts the input value fed to the controller board through encoders, here the input values are displayed on LCD as command (cd) values. The input is fed through encoders, the same is displayed on LCD as cd i.e. command values. Here the command value is: Azimuth value = 78, Elevation value = 12 and the feedback value is: Azimuth value = 70, Elevation value = 07

Since the difference value between the azimuth and elevation feedback and command values is greater than five both the motors are in continuous spinning condition. On varying the potentiometer, the feedback value changes and the same will be displayed on LCD.

The fig. 1.5 depicts the changing of feedback values for azimuth direction through potentiometer to make the feedback value equal to command value is displayed on LCD with the arrow mark heading towards command value if feedback is to be increased the arrow head faces the opposite direction that is towards the feedback value if it is to be decreased. The fig. 1.6 depicts the changing of feedback values for elevation direction through potentiometer to make the feedback value equal to command value is displayed on LCD with the arrow mark facing upwards if feedback is to be increased and the arrow head faces the opposite direction that is downwards if it is to be decreased. When the command value becomes equal to the feedback value there is an equal operator displayed between the feedback and command value on LCD for both azimuth and elevation direction. When the feedback value becomes equal to the command values, then the motor stops. This condition is an indication of antenna being oriented properly towards the satellite.

RESULTS OF COMPUTER MODE

Fig. 1.7: The input is fed through circle angle picker in GUI [Graphical User Interface] screen

Fig. 1.8: Input value fed through circular angle picker displays on LCD

Fig. 1.9: Azimuth feedback value made equal to command value

Fig. 1.10: Elevation feedback value made equal to command value

The fig. 1.7 depicts input being fed through circle angle picker in GUI [Graphical User Interface] screen, that is communicated through serial port to control board. The same is displayed on LCD as cd i.e., command values shown in fig. 1.8 Here the command value is: Azimuth value = 78, Elevation value = 12 and the feedback value is: Azimuth value = 70, Elevation value = 07.

Since the difference value between the azimuth and elevation feedback and command values is greater than five both the motors are in continuous spinning condition. The fig. 1.9 shows varying the potentiometer the feedback value changes and the same i.e. updated values on changing will be displayed on LCD. The fig 1.10 shows the feedback value equal to the command values for both azimuth and elevation direction at this condition both the motor stops. This condition is an indication of antenna being oriented properly towards the satellite.

RESULTS OF FULLY AUTOMATED MODE

Fig. 1.11: Orbitron screen providing azimuth and elevation direction of selected satellite

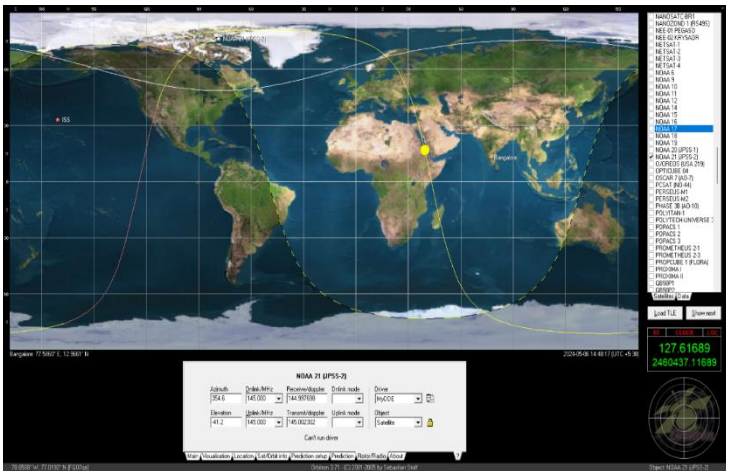


Fig. 1.12: Input value obtained through Orbitron displays on LCD

Fig. 1.13: Azimuth and Elevation feedback value made equal to command value

The fig. 1.11 shows the input being fed through Orbitron software. This software provides the azimuth and elevation position of the selected satellite. On launching the Orbitron software after selecting the satellite, the azimuth and elevation position of the chosen satellite will be communicated through serial port to control electronics board and the same is displayed on LCD as cd i.e. command values.

Here the satellite chosen is: ISS

Here the command value is: Azimuth value = 354.6, Elevation value = -41.2 and the feedback value is: Azimuth value = 354, Elevation value = 00

Here the input values obtained through Orbitron software has decimal values the command values on LCD are determined

as integer. Though the orbitron provides the negative value for azimuth direction, the command value for elevation direction is displayed as 0 in fig. 1.12. It is because the negative value indicates that the selected satellite is present on the other side of the globe and the antenna cannot be oriented toward that side.

Since the difference value between the azimuth and elevation feedback and command values is greater than five both the motors are in continuous spinning condition. On varying the potentiometer, the feedback value changes and the same will be displayed on LCD. When the feedback value becomes equal to the command values, then the motor stops and an equal operator is present between feedback and command values as in fig. 1.13. This condition is an indication of antenna being oriented properly towards the satellite.

IX. APPLICATIONS

- Both manual and auto tracking feature regarding the system will help to design a simple ground station.
- It is very much applicable for the Ham operators across India and all over the globe.
- Because of its portable nature very much applicable during the time of disaster management, political events, sports events etc.
- As a part of educational aid for students to bridge the educational gap.
- As a part of astronomy, used by astronauts to track and monitor stars.

X. ADVANTAGES

The system design includes the interfaces between personal computer, Atmega 328p (Arduino Mega), A4988 driver, BOURNS 3590 and B10K potentiometer in the antenna rotator system. It is easily synchronizing with the PC providing a better ecosystem for the user.

The system also provides tracking system for Amateur radio communication. It is also known as HAM radio communication. It uses radio frequency spectrum for non-commercial exchange of moss code, messages and emergency communication.

The proposed system is a Cost effective and a highly reliable system that uses three modes of Operation. A windows forms is created for controlling the position of antenna in the second mode. In the third mode the parameters like azimuth and elevation is obtained through a freely available Orbitron software. Because there are three modes of operation, failure in tracking in any one of the modes will be dealt using the other two. Hence it is reliable.

The system is very much compatible with our environment mainly because all the raw materials used for hardware and assembly of the system is available in our region, these factors reduce the overall cost of the system compared to existing model.

Portable system allows much better communication and can be taken at any remote areas where there is less signal interference which will be able to track the satellite more accurately.

In India there are predefined repeater stations in states Tamil Nadu (Chennai), Maharashtra, also there are repeaters in nearby countries like Nepal. If a Ham operator and one end tries to communicate with the Ham operator at a far distance the signal reaching the operator will be weaker, this system allows to use these repeater stations as an intermediate to enhance the signal strength so that the signal will be sent without any loss.

The system can be used for experiments with easy configurations anywhere and can be interfaced with computers for data transmission and reception making it very easy to set up.

Traditional tracking system were point-to-point i.e., from space station to ground station and from ground station to ground station only. But this system helps in communicating. from space station to ground station, from ground station to different repeater stations and among different Ham operators making it Point -to-Multipoint.

During critical condition, each Earth Station may be removed relatively quickly from a location and reinstalled somewhere else.

The motor system allows to control the speed of the rotator according to user demand, this function is achieved using gear train and DC motor controlling in our system. Speed control allows the user to move to destination tracking angle more conveniently.

XI. FUTURE WORK

The future work for this project is making weather proof. Need to design an electro material packaging to protect the whole rotatory system from rough weather and minimize from external EMI/EMC interfaces. It needs to be water proof and temperature resistant.

XII. CONCLUSION

By the usage of embedded system, the task of tracking the satellite is easier given that it is a dedicated system. The automatic antenna positioning system is mainly used to position the antenna without any human interface it automatically positions itself depending upon the received signal strength. Hence the communication speed as well as fading can be minimized. Thus, we can track the satellite in precise resolution of microsecond.

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