International Journal of Electronics Engineering Research.
ISSN 0975-6450 Volume 9, Number 2 (2017) pp. 151-158

http://www.ripublication.com

Speed Rate Corrected Antenna Azimuth Axis Positioning System

A. A. Mulla[a*] and P.N. Vasambekar[b]

[a]*Department of Electronics, Yashwantrao Chavan College of Science, Karad -415 124, India.*
[b]*Department of Electronics, Shivaji University, Kolhapur -416 004,India.*

Abstract

This paper presents developed antenna azimuth axis antenna positioning system. A Microchip PIC16F506 microcontroller is used for controlling the system. The positioning system is developed using spur type gears with the stepper motor. The potentiometers are used as a positioning sensor. The motor speed is controlled by using speed rate corrected method. Developed method is implemented and experimentally tested for X-band pyramidal horn antenna. The system requires less time for antenna alignment even if the angular positioning error is large. It is a low cost solution for fast and large antenna alignment for the desired satellite.

Keywords: Antenna control, PIC microcontroller, antenna positioning, motor speed control

INTRODUCTION

The antenna positioning system is needed to reduce the pointing error which will enable to receive highest signal strength. To receive signal from various sources such as satellites the adjustment of azimuth, elevation and polarization axes are essential. Generally, these axes are adjusted manually by labor/operator for different sources with the measurement of signal strength. This method is useful for the light weight antenna, however it is tedious, time consuming and out of capacity of the operator for the large and heavy antennas. Therefore, for positioning a system is needed to rotate the antenna axes at desired angle. With this view many researchers have developed number of antenna positioning systems.

Dimitrijevic S. and Antic Dragan designed the antenna system using robust fuzzy controller. It is useful to control the satellite antenna position in bounded external disturbances and it reduces the oscillation [1]. Nikolic Sasa et al. developed the antenna positioning system using an Orthogonal Legendre type filter. It is developed for azimuth and elevation axes with two stepper motors. The system is tested by implementing the PID and fuzzy controllers. The system parameters such as efficiency, speed and tracking accuracy are validated in laboratory [2]. Okumus H. I. et al. designed fuzzy and PID controllers using MATLAB/SIMULINK. It is developed around potentiometer, power amplifier, pre-amplifier, motor and load. It is observed that FLC (fuzzy logic controller) is more convenient than PID [3]. Rafael M. C. et al. developed system around GPS and Java with S3A and fuzzy controller. The antenna alignment in this system is completed within 3 minutes [4]. Okumus H. I. et al. proposed PID, FLC and self-tuning fuzzy logic controller (STFLC) using MATLAB/SIMULINK. It is observed that STFLC results better performance than FLC and PID [5]. Emad A. G. A. and Abdelrasoul Jabar A. developed full remote controlled positioning system for three axes (azimuth, elevation and polarization) of an antenna using stepper motors. System is useful for fast, accurate and precise alignment of the antenna [6].

In this paper, the azimuth axis pyramidal horn antenna positioning system is presented. System architecture, speed rate corrected method, flow chart and conclusion are given.

SYSTEM ARCHITECTURE

The two rotary potentiometers serve as input and output positioning sensors. The input potentiometer is used to set the azimuth angle. The output potentiometer is coupled to the antenna azimuth axis. It is used to check the actual azimuth angle of antenna. The potentiometer converts input angular displacement into the analog voltage which is further read by 16F506 and converted to digital form. The error in actual set point and current positioning angle is computed by this controller and correcting signal is send to the stepper motor driver via its port C. For zero computed error the motor is stopped. For error greater than zero it is rotated till error becomes zero. The speed rate corrected method is developed and implemented. It is implemented in the microcontroller to control the speed of the motor during positioning. The gears used couple pyramidal horn antenna to stepper motor and potentiometer. ULN2008 serves as current driver to stepper motor.

a. Potentiometer

The widely used sensors in the antenna control systems are the potentiometer, Optical Fiber Gyroscope (OFG), gyroscope and encoder [7-11]. A potentiometer is one of the cost effective sensor for measurement of the angle. In the present system two high resolution wire wound special ‘O’ type shaft potentiometers having resistance of 10K, 1.5 watt power rating and 1% linearity are used. They have similar characteristics. The input potentiometer has end stop at 320º±5º while the output potentiometer can rotate in complete circle (360º).

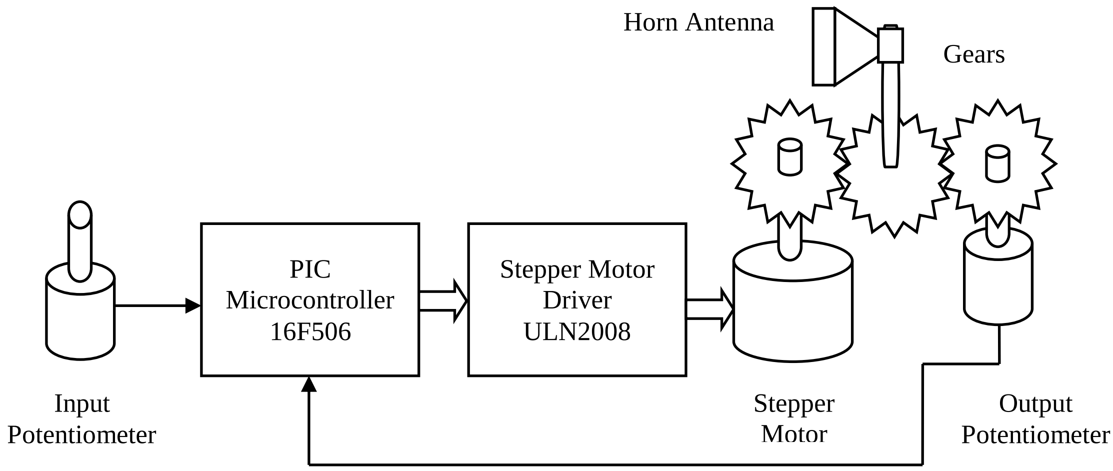

Figure 1 Architecture of Antenna Positioning System

b.Control Unit

The cost effective, low power, 8-bit CMOS, 14 pin Microchip PIC16F506 microcontroller is used as a control unit. It has on chip 3-channel 8-bit ADC, internal clock generator (4 MHz/8 MHz), 1024 word flash and 67 bytes SRAM [12]. The on chip ADC channel AN0 and AN1 are used to read the data from potentiometers. The ADCON0 and ADRES registers are used for ADC programming. The port C pins PC0-PC3 are connected to motor driver. The clock requirement is fulfilled by using internal on chip 8 MHz clock.

During programming following file register are used.
10H and 11H: Controlling the speed of the motor,
12H to 13H: Store the converted ADC data of the channel AN0 and AN1
14H to 1BH: Storing the stepper motor half stepping mode sequence
1CH: store the count of the half sequence
The indirect addressing mode with FSR register is used to access the stepper motor step sequence.

c. Stepper Motor

The hybrid stepper motor (step angle 1.8°) is used and it is connected in unipolar mode. Stepper motor has mainly three modes of rotations half step, full step and microstepping. Here a half stepping mode is chosen, so the step sequence are 09H, 08H, 0CH, 04H, 06H, 02H, 03H and 01H. Used stepper motor is coupled to the +12V supply and has required 300 mA phase current. Here, ULN2008 Darlington transistor array is used as current driver for the stepper motor. It has 8 buffers with the capacity of 500 mA and has on chip freewheeling diode. For boosting current capacity the buffers are connected in parallel.

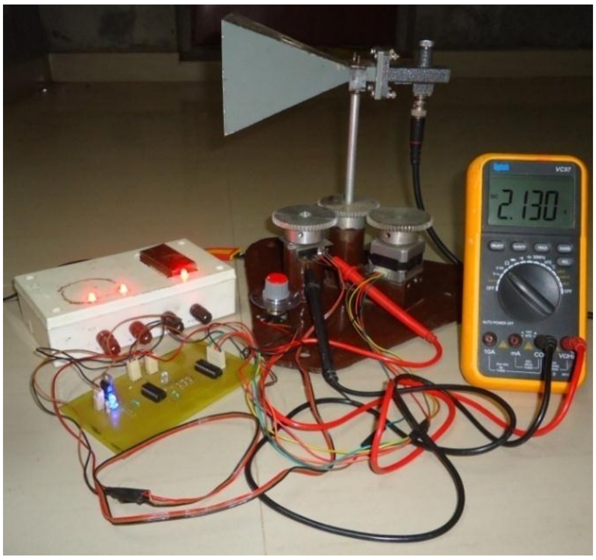

Figure 2 Experimental setup Antenna Positioning System

d. Gear

In the positioning system the gear also plays an important role. The positioning accuracy is depends on the types of the gears and its ratio. Here three spur gears are used. Low cost is advantage of it. It is connected between the stepper motor, output potentiometer and the antenna. The selected gears are same size and has 60 teethes. The gear ratio between the stepper motor to antenna and output potentiometer to the antenna are same and it is 1:1. Hence, system has resolution of 1.8° in full stepping mode and 0.9° in half stepping mode. Here the motor is rotate the azimuth axis in half stepping mode. The characteristics of both the potentiometers are same, therefore no further calibration is required.

The photograph of complete experimental system is presented in Figure 2.

SPEED RATE CORRECTED METHOD

Stepper motor is mainly used for positioning applications. Its stepping angle is constant as a result of its speed depends on the applied time delay of pulses. In the

antenna positioning applications, if the computed positioning error is maximum then it is require to rotate motor at the maximum speed and vice versa. So, fast positioning controlling positioning parameters speed and acceleration are required. But these two parameters depend on the motor speed. The speed of the motor depends on the delay in the step sequence. In this system the time delay is calculated by using the speed rate corrected method.
The speed rate corrected time delay (T_d) is given by,

$$T_d = K_p \times \varepsilon(v) \quad . \quad . \quad (1)$$

Where, K_p is delay constant, ε(v) is error and it is computed by using outputs of the potentiometers.
Therefore,

$$\varepsilon(v) = 255 - (v(o) - v(i)) \quad . \quad (2)$$

Where, v(o) is the output of the output potentiometer and v(i) is the output of the input potentiometer. Here the K_p is selected 10 mS. The microcontroller reads data of the potentiometer in analog form and converts it into digital form in the ranges from 00H – FFH (0-255). Therefore error is in between 0-255. The motor stops rotation if the positioning error becomes 0, it means input and positioning angles are matched.

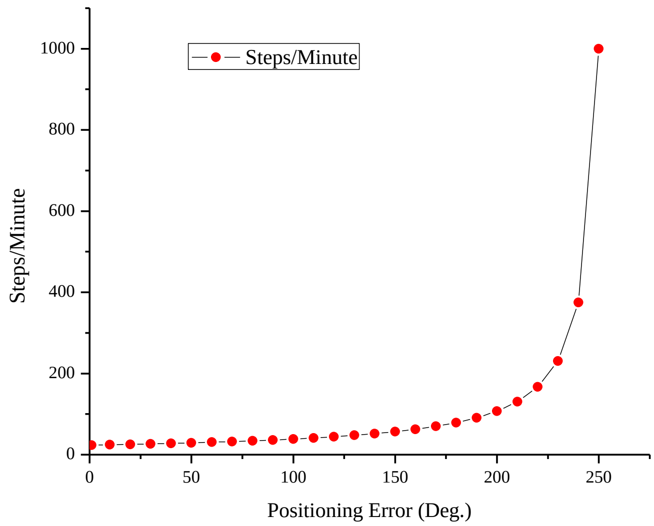

Figure 3 Calculated motor speed rate for different positioning error

Figure 3 shows the plot of the calculated motor speed (using equation 2) in the form steps/minute vs positioning error. It is seen that, increasing positioning error the motor speed in the form of steps per minutes are increased.

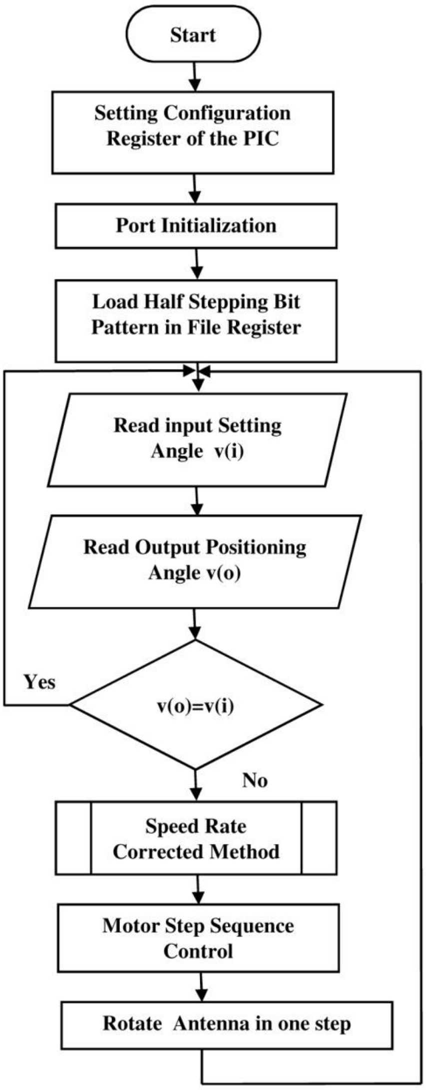

Figure 4 PIC 16F506 flowchart

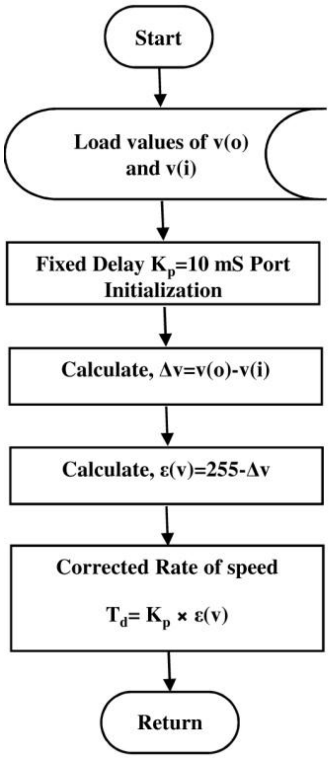

Figure 5 Speed Rate Corrected Method flowchart

SYSTEM FLOW CHART

The flow chart of the developed system is presented in Figure 4. The system software is developed in assembly language using the MPLAB IDE. The developed hex file is downloaded into the microcontroller program memory.

In the setting, the internal oscillator (8 MHz) and reset pin is configured by setting configure register bits MCLRE, IOSCFS and IntRC_OSC_RB4EN. Port C makes as an output during port initialization. Then store the half stepping bit pattern and count. Read the values of the input and output potentiometers using on chip ADC for input setting angle and actual positioning angle. The steps involves to convert analog data into digital using ADC are : using ADCON0 register make AN0 and AN1 ports as an analog, select internal clock, select channel and apply the start of conversion pulse

(GO), check the end of conversion (NOT_DONE). After the end of conversion store the results v(o) and v(i) in the given file registers.
The stepper motor is rotated in half stepping mode by loading sequence from file register using indirect addressing mode with FSR and INDF registers. A proposed method is executed if v(o)≠v(i), it means that input and positioning angles are not matched.
The rate corrected method flow chart is presented in Figure 5. Using this method corrected time delay is calculated and according to it a digital pulses are applied to the motor and motor speed rate has corrected.

CONCLUSION

A speed rate corrected algorithm is successfully developed and implemented. It is implemented by using PIC microcontroller 16F506 for pyramidal horn antenna. The developed system is tested experimentally for different input angles and the speed of the stepper motor is checked. It has observed that by increasing positioning error stepper motor speed is increased. Developed system is useful for the positioning azimuth axis of the antenna. The system requires less time for antenna alignment even if the positioning error is maximum. It is useful to the operator for fast antenna alignment to the desired satellite. The lost steps of motor are corrected and hence the positioning accuracy increased. Using this system operator can control any size of antenna by changing motor with its proper driver.

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