DESIGN OF A TWO DIMENSIONAL MICROPROCESSOR BASED PARABOLIC ANTENNA CONTROLLER

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ABSTRACT: *At the present time, as an outcome of the developing technologies, the needs for positioning and orientation of the parabolic antennas in which are widely used in home applications, satellite stations and different military applications are highly increased. In order to realized these kind of applications that need sensitivity and accuracy, microprocessor based closed loop control systems are used. In this work, a microprocessor based controller system is realized in order to position parabolic antenna in 90 cm. diameter. Also the parameters that influence the accuracy of the controller are discussed.*

INTRODUCTION

A parabolic antenna of a firing control radar in an anti-aircraft missile system as it follows the changing positions of the target. In order that the radar does not miss the target on operation, where the sensitivity and accuracy is most important, is carried out by processing the reference inputs and the feedback data related to the actual position of the target through complex computing algorithms in modern microprocessors. In this study a rather simple parabolic antenna control system is designed to investigate the parameters affecting the accuracy and sensitivity of the system response. In the project first of all, the dimensions of the antenna are selected and the mechanical part is designed and manufactured to direct the antenna to the desired angular positions then, suitable DC servomotors are selected and assembled and the driver circuits are designed. An optical sensors system having a rotating encoder is designed and assembled to the shaft as the feedback element control circuit which generates the command signals necessary for the position control, a keyboards and display units are also designed. Finally, a control software in assembler language is developed so that the designed control algorithms is processed in the selected microprocessor. Following the completion of the design, the system is tested and the results are analyzed.

STRUCTURE OF THE PARABOLIC ANTENNA CONTROL SYSTEM

A parabolic antenna control system is configured as a control system which computes the desired angular position of the antenna from the input data, and using these angles, then directs the parabolic antenna to the required position by means of the a built-in servomotor control mechanism. As seen in Fig.1 the system consists of a computation unit for the angular position, a servo control unit and the parabolic antenna itself. The trajectory position of the target (meridian of the satellite), geographical coordinates of the antenna (its parallel and meridian) and geographical reference (generally the compass-north) are used as the input data in the system [1].

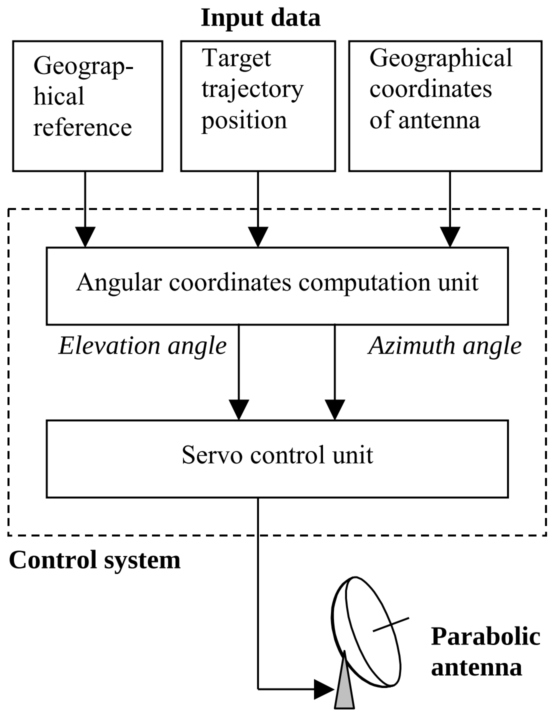

Fig.1 Block diagram of the parabolic antenna control system

Computation unit for angular coordinates may be a PC based computer program or a special computing unit. In this unit angular coordinates, to which the antenna is to be directed, are computed using the input data and sent as the input to the servo control unit. As seen from Fig.2 the servo control unit is composed of a multi input, multi output closed loop control mechanism which takes the angular coordinates as reference input. The actual position feedback from the antenna is processed with the reference input in the control algorithm and the control signal is generated to correctly position the parabolic antenna [2].

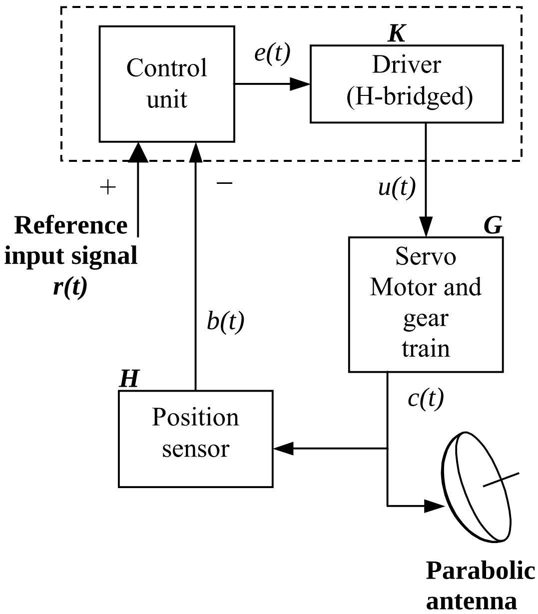

Fig.2 Block diagram of servo control unit

The control system positions the antenna to the angular coordinates which are computed from the input data by the servomotors and suitable gear trains. The control achieved by adjusting the angles of the elevation and azimuth as depicted in Fig.3.

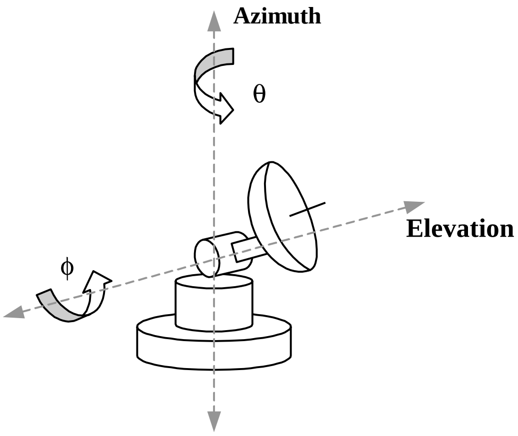

Fig.3 Azimuth and elevation angles [3]

Although the control system for a parabolic antenna is generally designed to be two dimensional for the adjustment of the angles of elevation and azimuth, it could be realised as three dimensional if the adjustment of the polarisation is also required.

CONTROLLER DESIGN

In the project the design of a microprocessor based controller is carried out in order to direct a parabolic antenna, 90 cm. in diameter, to the designed angular position. The designed controller is realised as two single input and single output closed loop control systems instead of a two-input and two-output system since the servomotor units which enable the parabolic antenna to change its angles of elevation and azimuth can be considered as two independent control systems taking the inputs from practically the same unit and performing very similar jobs. The angular coordinates are computed off-line and input to the system through a keyboard rather than using a built-in computation unit. The block diagram of the designed control system is seen in Fig.4.

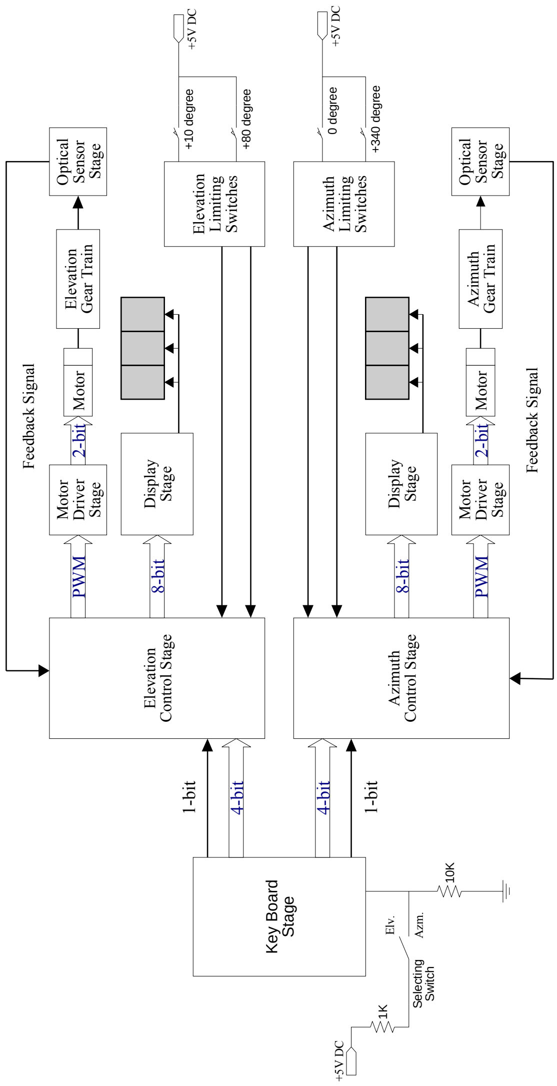

Fig.4 Block diagram of designed controlsystem

The system design is started, firstly, with the realization of the mechanical parts that hold the parabolic antenna and bring it to the desired angular position. The mechanical equipment is designed so that the two servomotors actuate the 90 cm. parabolic antenna in two dimensions, as seen in Fig.3. The photograph of the mechanical equipment is given in Fig.5.

By means of the elevation gear train the mechanical design enables the parabolic antenna to move 2,5 mm. upwards or downwards, depending on the direction of rotation of the motor shaft, as it rotates three times. As for the rolling gear train the gear coupled to the antenna moves by one tooth for each rotation of the motor shaft.

Fig.5 Mechanical equipment

In the mechanical configuration a total of four limiting switches are used to the movements in elevation or azimuth directions (2 for each direction). The limiting switches allow a movements in the range between 0° and 340° in azimuth and 10° and 80° in elevation directions. The two servomotors selected to move the antenna in two dimensions are of the permanent magnet type DC servomotors. Pulse width modulation (PWM) technique [4] is adopted for the control of the motors so that the deviations in the antenna positions are minimized. These deviations are caused by the unwanted rotations of the motor shaft due to the inertia effect as the control signal applied to the armature is suddenly cut-off as the motor is made to stop. The control signal based on pulse width modulation is generated by a software in the microprocessor.

In the system two H-bridged driver circuits containing power transistors MJE3055 NPN and MJE2955 PNP are designed to obtain the necessary 15 VDC voltage for driving the servomotors. For protection of the microprocessors, it is separated from the driver circuits by an optocoupler.

A set-up containing an optical encoder is accomplished to feed back the information concerning the load position to each of the controllers. Fig.6 shows the set-up of the feed back configuration for azimuth angle stage. Each optical encoder with a diameter of 50 cm. consists of a rotating disc having a certain number of notches on it. The disc used for the elevation-angle stage has 10 notch on it and 150 notch should be counted to represent a 1° rotation of the antenna. However, for the azimuth-angle stage the disc has 40 notches and the required number of notches for a 1° rotation of the antenna is 17.

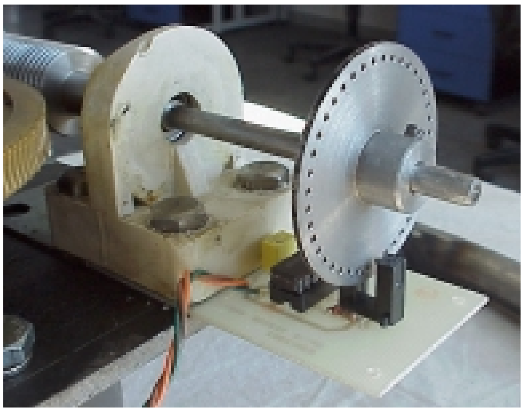

Fig.6 Azimuth-angle feedback configuration

For each of operation two identical single-input and single-output feedback controllers are designed. One of these is assigned for the control of angle of elevation, whereas the other controls the angle of azimuth. Each control unit use on 8-bit AT89C52 microprocessor for its wide availability and easy manipulation [5]. Each control unit takes the data for the angular position of the antenna as the input reference, and compares this value with the actual angular position feedback. Using the control algorithms, it determines both the direction and amount of the antenna rotation. Finally, the microprocessor converts this information into the form of pulse width modulated signals to be sent to the servomotor driver stages. To enable the user to input the data for the angular positions of the antenna, a keyboard with 16 keys is designed. Also designed are the two display units for the visualization of the data. Each 7-segment display unit has 3 digits [Fig.7]. Printed circuit boards are prepared to complete the hardware design. After completion of this stage, a control software for the microprocessor in assembler language is developed to implement the system algorithm, and it is tested.

Also included in the system capability is a fault-diagnosis mechanism to detect whether the servomotors are overloaded or PWM driving signals are absent.

As the final stage of the system realization a power supply unit is designed to obtain the 1,5A and 5 VDC, and 1A and 15 VDC supplies. The control box is shown is Fig.7.

graph shows deviations which occur at the end of the test of azimuth control for each angle.

Fig.7 Designed control box

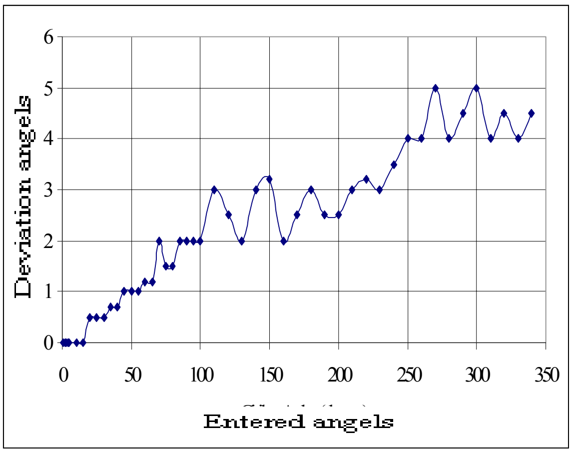

Fig.8 The graph shows deviations which occur entered angle values for azimuth control

TEST RESULTS

In this study which is carried out to investigate the parameters affecting the accuracy and sensitivity of the system response in a parabolic antenna control system, a rather simple antenna control system which is used to receive signals coming from communication satellites where on the geo-synchronous orbit, is designed. In the design, the control of the parabolic antenna is controlled by software, and for this aim different software algorithms are developed. Also, the circuits of system are designed.

After completion of the design, the sampling angle values for azimuth and elevation axis are determined, and for these values, the pulse numbers counted by related optical sensor are computed. Also an external counter is connected to the optical sensor output for understanding to how many the optical sensor counts really. However, the azimuth and elevation angle patterns are put in to suitable places of antenna equipment to determine how many angels the parabolic antenna rotates really. Then, the angle values determined for each axis are applied to both azimuth and elevation control stages.

When the application results of azimuth motion are investigated, the pulse numbers counted by external counter which is connected optical sensor output and the pulse numbers which computed by microprocessor are seen approximately similar for entered angle values.

Sometimes, one or two more pulses which are counted by external counter are determined, and it can be source by inertia which occurs at servomotor rotor. Also, when the application results are investigated, although the pulse numbers which are counted for each angle are approximately the same, a relatively linear angle deviations are seen at the end of the antenna rotation. A deviation value is 1° for 50°, 2° for 100°, 2,5° for 200° and 4,5° for 340°. In Fig.8, the graph shows deviations which occur at the end of the test of azimuth control for each angle.

In order to compensate the occurred angle deviations, first order, second order and third order curves are fitted to the deviation graph in Fig.8 by using MATLAB program, and according to angle deviations seen in Fig.8, the square errors are computed to determine which of these curves are used.

Here, square error for first order curve fitting,

$$K_1 = \sum_{i=1}^{48} (g_i - h1_i)^2 \tag{1}$$

$$K_1 = 9{,}31$$

Square error for second order curve fitting,

$$K_2 = \sum_{i=1}^{48} (g_i - h2_i)^2 \tag{2}$$

$$K_2 = 7{,}20$$

Square error for third order curve fitting,

$$K_3 = \sum_{i=1}^{48} (g_i - h3_i)^2 \tag{3}$$

$$K_3 = 6{,}76$$

are found. The end of the estimation, differences between obtained square errors are investigated to find the smallest square error. At the end of the investigation differences between square errors are found as following.

$$K_1 - K_2 = 9{,}31 - 7{,}20 = 2{,}21 \tag{4}$$

$$K_2 - K_3 = 7{,}20 - 6{,}76 = 0{,}44 \quad (5)$$

As seen from equation-4 and equation-5, it can be seen that difference between square errors which belong to first and second order curves is quite larger than difference between square errors which belong to second and third order curves. Also, we estimated that second order curve should be fitted to deviation curve in Fig.8, because of the difference square error which belong to second and third order curves is small.

In this process, angle deviation occurred at azimuth motion corrected by using second order curve in Fig.9. Polynomial of second order curve is below. Here, y-parameter shows an angle deviation and x-parameter shows azimuth angle which is entered to system.

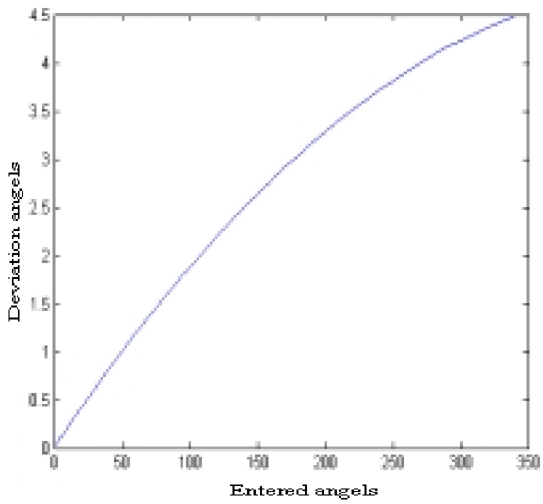

Fig.9 The second order curve which is fitted to azimuth deviation curve

$$y = -23.10^{-5}.x^2 + 21.10^{-3}.x + 1.10^{-2} \quad (6)$$

When obtained and corrected angle values are entered to system by subtraction deviation values obtained by the curve from angle values which antenna should position to, it can be seen that azimuth angle deviations are reduced to 1°.

But, polynomial couldn't be carried out by program and couldn't be added to system program because used AT89C52 microprocessor process with 8-bit only using positive integer and polynomial's coefficients given in the equation-6 belong to fitted curve.

When application results are examined for elevation motion, no more deviation is observed. Because the entered angle values and occurred motion amount is small.

CONCLUSION

Occurred error's reason in designed system is considered that gear group in system mechanic and optical sensor and rotary encoder set which is used at position feedback don't have sufficient sensitivity.

On the other hand, although system cost increases, when feedback layer which is designed one channel, exceptional and software weighty could be designed by two channel and high resolution integrated optical sensor and rotary encoder and by using external counter encoder which can count forward and backward according to the turning direction of motor or using specially developed position control integrated circuit which is much more suitable to aim and microprocessor which has larger data lines or Digital Signal Processor (DSP) using can effect the accuracy and sensitivity of system positively.

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