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ANN BASED ANGLE COMPUTATION UNIT FOR REDUCING THE POWER CONSUMPTION OF THE PARABOLIC ANTENNA CONTROLLER

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Abstract- The parabolic antenna controller is a control system which directs the antenna to the desired target automatically. A lot of different parabolic antenna controllers based on DSPs are proposed so far by the researchers, because the classical microcontroller sometimes remains insufficient because of the complex trigonometric angle computations. In these designs, it was taken into consideration by the researchers that sometimes sensitivity, sometimes accuracy, sometimes simplicity and sometimes power consumption of the system. In this study, a design of Artificial Neural Network (ANN) based angle computation unit for the parabolic antenna controller with two DC motors is presented, so that the complex mathematical computations and the hardwares are eliminated and also power consumption of entire control system is reduced.

Keywords: Neural Networks, Antenna Controller, Angle Computation Unit, Microcontroller, Power Consumption.

I. INTRODUCTION

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, digital signal processing (DSP) based closed loop control systems are used. For instance, 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 and DSPs.

In literature, a lot of different controller prototypes are suggested so far in order to position the parabolic antenna to the desired target, automatically. In these prototypes, researchers were given priorty sometimes to sensitivity, sometimes to accuracy, sometimes to simplicity and sometimes to power consumptions of the system [1, 2].

In this study, first of all a model of rather simple parabolic antenna control system with two DC motors as depicted in Figure 1 is designed to apply proposed ANN based angle computation unit. In order to this, 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 motors are selected and assembled and the driver circuits are designed. Then, 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 output of ANN based angle computation unit is tested [3].

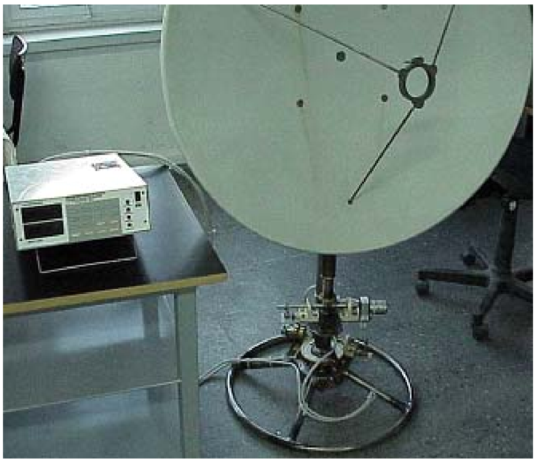

Figure 1. Designed parabolic antenna controller with two DC motors

The following section of this article, the structure of designed parabolic antenna control system is presented. In section III, the artificial neural network is explained theoretically. After that, the designing of the ANN based angle computation unit is presented. Results and discussions are explained in Section V. Finally, the conclusion is discussed in Section VI.

II. STRUCTURE OF THE CONTROLLER

An antenna control system with two DC motors 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 built-in two separate DC motor control mechanisms (Figure 2).

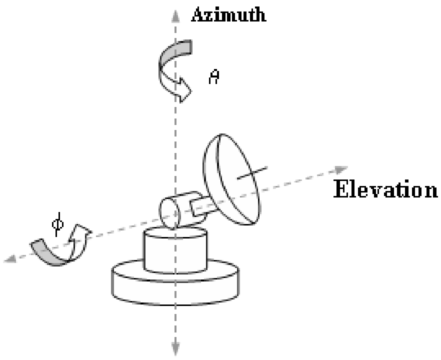

Figure 2. Azimut and elevation angles

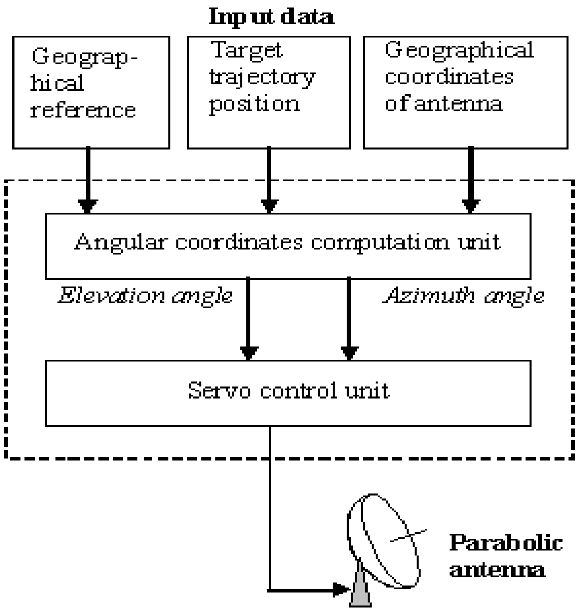

Figure 3. Block diagram of the designed parabolic antenna controller

As seen in Figure 3, the system consists of the computation unit for the angular position, the DC motor control unit and the parabolic antenna itself. The trajectory position of the target (e.g. 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 [4]. Computation unit for angular coordinates may be DSP based trigonometric computation 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 DC motor control unit. 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 correct position of the parabolic antenna [5].

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

In the project the design of a microprocessor based controller is carried out in order to direct a parabolic antenna to the desired angular position. The designed controller is realized as two single input and single output closed loop control systems 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 same unit and performing very similar jobs.

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.

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 movements in the range between 0º and 340º in azimuth and 10º and 80º 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 are designed to obtain the necessary 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.

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. 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.

III. DESIGN OF ANN BASED ANGLE COMPUTATION UNIT

The block diagram of the proposed ANN based angle computation unit is represented in Figure 4. This unit has been designed with two inputs and two outputs which are the longitude and latitude of the point on the earth and computed azimuth and elevation angles of the antenna.

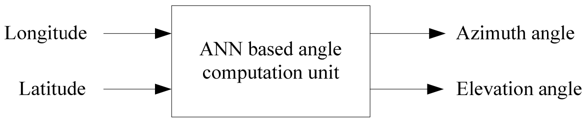

Figure 4. Block diagram of the ANN based angle computation unit

A. Assumptions

In order to design the proposed angle computation unit, following assumptions are considered:

1. The antenna will receive the signal that is transmitted by TurkSAT satellite located on 42ºE.
2. The geographic coordinates of the antenna may be on anywhere of Turkey (36º- 42ºN and 26º-45ºE)
3. As a position reference, it is accepted that the north is 0º, the east is 90º, the south is 180º and the west is 270º.

B. Obtain the Training and Test Data

To obtain the training and the test data, the ranges of latitude and longitude are divided as depicted in Figure 5. The intersection points of these latitudes and longitudes are chosen as the input training data. These data and their target training data are represented in Table 1. The randomly selected test data are also represented in Table 2.

Table 1. Training data for proposed ANN based angle computation unit

Input Training Data		Target Training Data	
Latitude (N)	Longitude (E)	Azimuth angle	Elevation angle
36	26	153.99	44.90
39	26	155.50	41.87
42	26	156.80	38.82
36	30	160.11	46.31
39	30	161.33	43.14
42	30	162.37	39.97
36	34	166.55	47.36
39	34	167.41	44.08
42	34	168.13	40.81
36	38	173.21	48.00
39	38	173.65	44.65
42	38	174.04	41.32
36	42	180.00	48.22
39	42	180.00	44.84
42	42	180.00	41.50
36	45	185.09	48.09
39	45	184.76	44.74
42	45	184.47	41.40

Table 2. Randomly selected test data

Test Data	
Latitude (N)	Longitude (E)
37	32
40	39
40	29
40	44
41	33

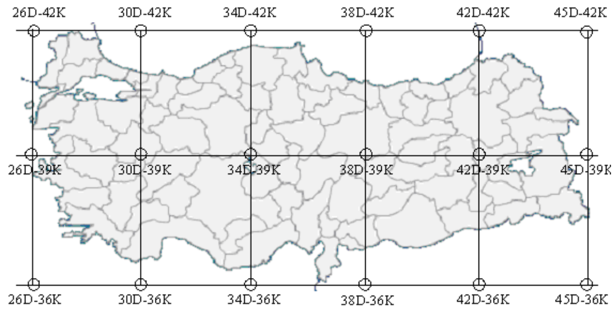

Figure 5. Process of obtaining the input test data

C. Proposed ANN Based Angle Computation Unit

Because there are two input parameters and two output parameters, three layered, two inputs and two outputs Multi Layered Perceptron (MLP) ANN is designed. This ANN structure includes two input layer neurons, five hidden layer neurons and two output layer neurons as depicted in Figure 6.

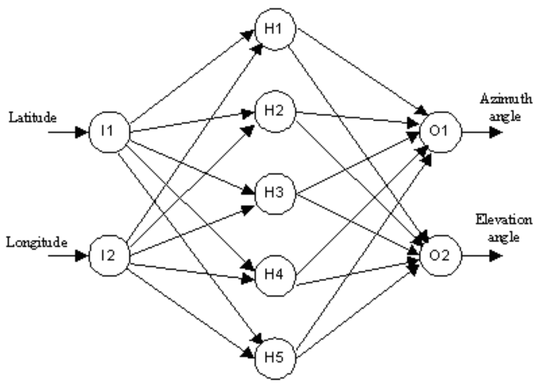

Figure 6. Structure of MLP-ANN

The linear transfer functions are used for input and output neurons. In the hidden layer, the tangent hyperbolic transfer functions are used. In this design, Fletcher-Reeves algorithm is used.

The ANN based angle computation unit is realized by using MCS-51 based microprocessor, AT89C52. After desiging of the software, the hardware of the control box which has microprocessors, displays, error detections and power cards is designed as depicted in Figure 5 [6].

Figure 5. ANN based antenna controller

The obtained results for the input training data are represented Table 3. The obtained results for the input test data are represented Table 4.

Table 3. Results of training data

Input training data		Target training data		Results angles	
Latitude (N)	Longitude (E)	Azimuth angle	Elevation angle	Azimuth angle	Elevation angle
36	26	153.99	44.90	154.0188	44.9607
39	26	155.50	41.87	155.3789	41.7802
42	26	156.80	38.82	156.8240	38.7661
36	30	160.11	46.31	160.2960	46.4101
39	30	161.33	43.14	161.3696	43.1520
42	30	162.37	39.97	162.6195	40.0364
36	34	166.55	47.36	166.2145	47.3027
39	34	167.41	44.08	167.2065	44.0572
42	34	168.13	40.81	168.2284	40.8853
36	38	173.21	48.00	172.9945	47.8707
39	38	173.65	44.65	173.6258	44.6200
42	38	174.04	41.32	174.0382	41.3533
36	42	180.00	48.22	180.2244	48.1431
39	42	180.00	44.84	180.2302	44.8299
42	42	180.00	41.50	179.9556	41.4486
36	45	185.09	48.09	185.1644	48.1914
39	45	184.76	44.74	184.8049	44.8229
42	45	184.47	41.40	184.2131	41.3657

Table 4. Results of test data

Input test data		Target test data		Results angles	
Latitude (N)	Longitude (E)	Azimuth angle	Elevation angle	Azimuth angle	Elevation angle
37	32	163.60	45.80	163.5192	45.8457
40	39	175.33	43.62	175.3913	43.5782
40	29	160.24	41.81	160.3494	41.7834
40	44	183.10	43.68	183.1959	43.6667
41	33	166.42	41.71	166.4325	41.7122

When the results are investigated from the tables, it is seen that the error of the training data is in the range of -0.2495º and 0.3355º. On the other hand the error of the test data is in the range of -0.1014º and 0.1293º.

The power consumption measurement from the ANN based controller realized by using the MCS-51 based microcontroller circuits is approximately 1 W (500 mW for azimuth controller and 500 mW for elevation controller). When it is evaluated that a DSP kit consumes approximately 10 W (as an example, 5V 2A for XtremeDSP Development Kit), it is seen that the power consumption is reduced by up to 90% as depicted in Figure 6 [6].

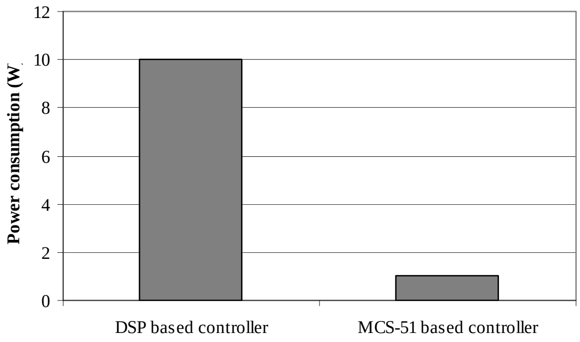

Figure 6. Comparison of power consumptions of DSP and MCS-51 based controllers

IV. CONCLUSIONS

In literature and practical studies in commercial markets, a lot of different parabolic antenna controllers based on microprocessors and DSPs are proposed so far by the researchers. In this design, the classical microcontroller and microprocessors sometimes remains insufficient because of the complex trigonometric angle computations. However, it was taken into consideration by the researchers that sometimes sensitivity, sometimes accuracy, sometimes simplicity and sometimes power consumptions of the antenna control system in these designs. In this study, the ANN based angle computation unit which may be realized by using the classical microprocessor AT89C52 is designed in order to reduce the power consumption of this unit used in the parabolic antenna controller according to the controllers that are designed with DSPs. At the end of the study, it is seen that the power consumption of this unit is significantly reduced.

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BIOGRAPHIES

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