Control Systems of a Turntable and Antenna Positioning Device in an Open Area Test Site

Ignatius Agung Wibowo, Mohammad Zarar bin Mohd Jenu,
Khairu Al-Amin bin Ibrahim, Fazliana binti Abu Bakar
Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia
86400 Parit Raja, Batu Pahat, Johor, Malaysia

***Abstract*- An open area test site (OATS) is a facility to measure radiated emissions of an electrical or electronic equipment in order to comply electromagnetic compatibility (EMC) requirements. In the measurement, the equipment under test (EUT) is placed in a turntable and the electromagnetic field radiated by the EUT is scanned using an antenna attached to a mast. The maximum radiation from the EUT is captured by rotating the turntable and vertically moving the antenna. This paper describes the development of the control systems of the scale models of a turntable and antenna positioning device. Stepper motor and dc motor are used to drive the turntable and antenna positioning device respectively. The motors are controlled by using microcontrollers. Speed and position control systems for both devices have been designed and the accuracies of the systems have been analyzed.**

I. INTRODUCTION

A radiated emission test measures electromagnetic emissions emanating from equipment under test (EUT) such as a cell phone, television, or computer set. This test verifies the EUT's ability to remain below specified electromagnetic emissions level during operation.

Radiated emission test must be performed at an open area test site (OATS) as defined in CISPR 16-1-4 and ANSI C63.7 [1][2]. The OATS is an open, flat, level area clear of reflecting objects and structures with metallic ground plane.

The configuration of the OATS for radiated emission measurement is shown in Figure 1.

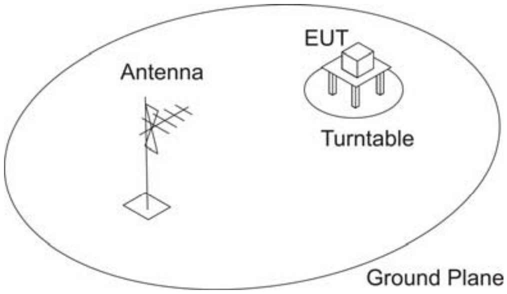

Figure 1. OATS configuration for radiated emission measurement

In the OATS operation, the turntable must be able to be rotated fully 360° at small increment angle to make the antenna receives maximum electromagnetic wave radiated from the EUT. For each incremental turntable angle, an antenna height scan must be performed to maximize the phase relationship between the direct and ground reflected waves received by the antenna.

Scale models of the turntable and antenna positioning device have been developed to assist the development of their control systems as shown in Figure 2 and Figure 3.

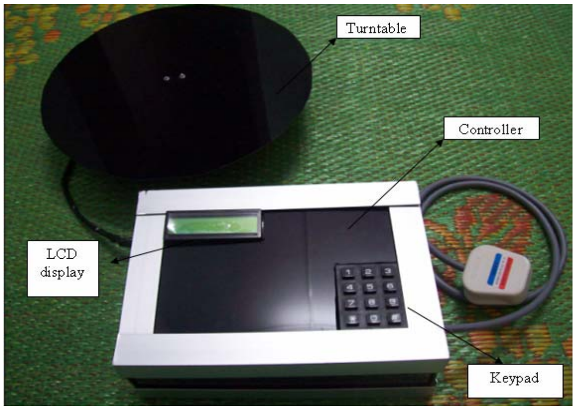

Figure 2. Scale model of the turntable

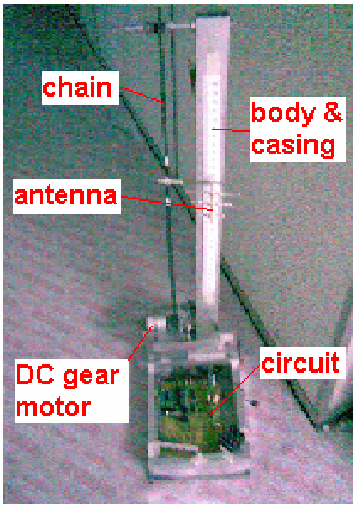

Figure 3. Scale model of the antenna positioning device

II. Turntable Development

The block diagram of the turntable control system is illustrated in Figure 4. Since it is an open-loop system, its accuracy relies on proper calibration of its controller which is programmed in the microcontroller.

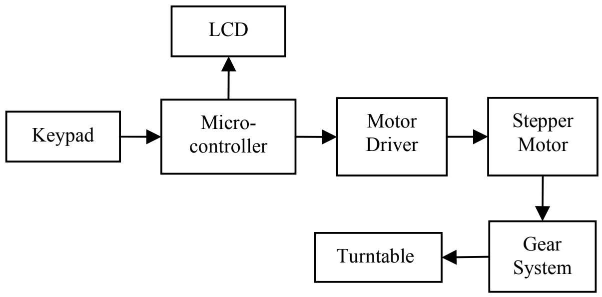

Figure 4. Block diagram of the turntable control system

In the turntable operation, the operator has to enter the desired angle, direction, and speed of rotation of the turntable to the system through buttons in the keypad. The microcontroller will detect the entered inputs and pass the data to the LCD circuit to display the operator's setting. The input data are also processed in the microcontroller to rotate the stepper motor through a motor driver. The stepper motor is connected to the turntable plate by a gear system. The step angle of the stepper motor is 1.8° per step.

Microcontroller PIC16F873 is used to control the turntable [3]. The circuit of the microcontroller is shown in Figure 5. The microcontroller has 28 pins. Four pins in port A which are RA0, RA1, RA2 and RA3 are connected to the key encoder and interact to the keypad. The other pins in port B which are RB0 to RB7 and pins in port C which are RC3, RC4 and RC5 are connected to the LCD circuit. The pins RC0, RC1 and RC2 are used for PWM signal, CCW and CW direction of the motor respectively. The function of the MCLR pin is to reset the microcontroller. Pins RA4 and RC7 are left unused.

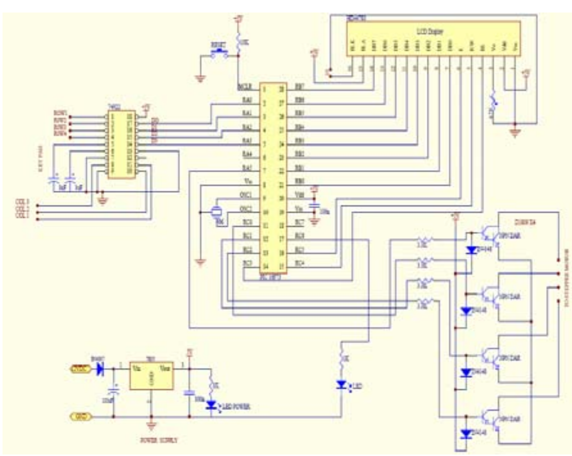

Figure 5. Microcontroller circuit of the turntable

The turntable is designed to have 3-speed setting. The speed of rotation is controlled using pulse width modulation (PWM) method.

III. Antenna Positioning device Development

The block diagram of the antenna positioning device control system is shown in Figure 6. This is a closed-loop position control system. A proportional controller is designed in the microcontroller.

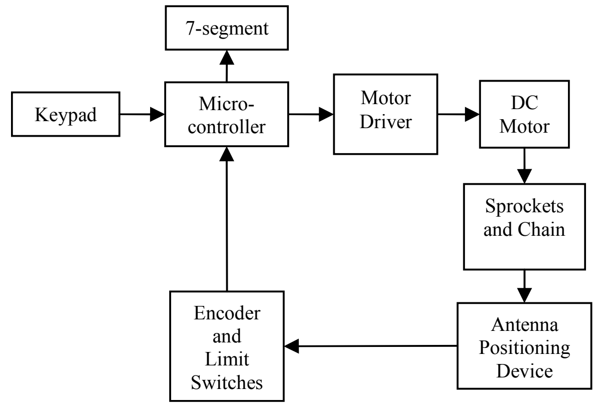

Figure 6. Block diagram of the antenna positioning device control system

The antenna positioning device operates when the keypad receives setting of antenna height and motion speed from the operator. The microcontroller receives the inputs and sends the data to the 7-segment circuit for displaying the desired antenna height. The microcontroller will process the data to control the rotation of the DC motor trough a motor driver. The antenna positioning device is driven by the DC motor through a sprockets and chain system.

The microcontroller used is PIC 16F877A [3] which has 40 pins for multipurpose usage. The circuit of the microcontroller is shown in Figure 7. Four of the six pins in port A which are RA0 to RA2 and RA4 is connected to the keypad and IR sensor of the encoder. The other pins in port B which is RB4 to RB7 is also connected to the keypad. Besides, the pins in port E which are RE0 and RE1 are used to connect limit switches to the microcontroller. The pins RC2, RC5 and RB1 act as the input for PWM, CCW and CW of the motor driver. Three of the eight pins in port C which are RC0, RC1, RC3 and RC4 are connected to the external switch which is for speed, automatic, manual, and go buttons. The function of the MCLR pin is to reset the microcontroller. On the other hand, all pins in port D which are RD0 to RD7 act as the output of the microcontroller. Some other ports of the microcontroller which are RA3, RA5, RC6, RC7, RB0, RB2 and RB3 are left unused.

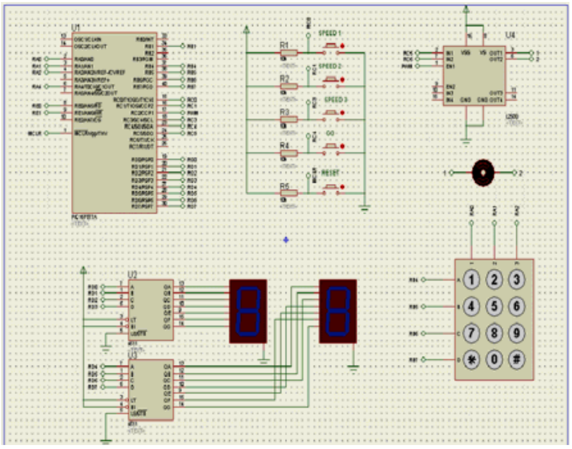

Figure 7. Microcontroller circuit of the antenna positioning device

The antenna positioning device also has 3-speed setting. The vertical motion speed is controlled using pulse width modulation (PWM) method.

IV. Results and Analysis

A series of tests have been performed to examine the accuracy of the speed and position control systems of the turntable and antenna positioning device as can be seen in Figure 8 and Figure 9.

Figure 8. Testing of the accuracy of the turntable

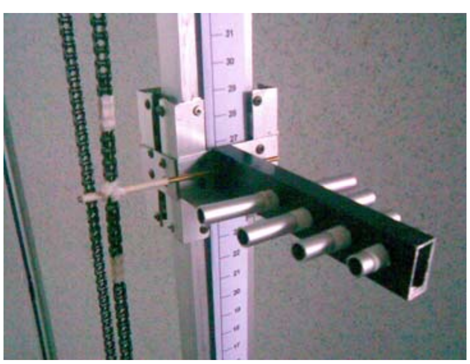

Figure 9. Testing of the accuracy of the antenna positioning device

The accuracy is calculated using the following formula [4]:

$$\text{Accuracy} = \left(1 - \left|\frac{Y_n - X_n}{Y_n}\right|\right) \times 100\% , \qquad (1)$$

where X_n is the measured value and Y_n is the expected value.

The results of the tests are summarized in Table I, II, III, and IV.

TABLE I

Accuracy of the Turntable Speed Control

Speed Level	Motor speed (rpm)		Accuracy (%)
	Calculated	Measured	
1	13.14	9.3	70.78
2	19.70	17.9	90.86
3	26.27	26.3	99.89

It can be seen from Table I that the accuracy of the speed control system of the turntable decreases at slower speeds. From examination to the turntable mechanism, the source of the inaccuracy comes from the friction in the moving parts including gears. The friction is constant for all speed setting. The friction will reduce the accuracy at low speed because the power delivered to the motor is proportional to the speed. The higher the speed the higher the power delivered. At low speed there is not enough power to overcome the friction which therefore decreases the accuracy. The use of stronger motor will remedy this problem.

TABLE II

Accuracy of the Turntable Position Control

Desired Angle (°)	No Load		With Load	
	Actual Position (cm)	Accuracy (%)	Actual Position (cm)	Accuracy (%)
20	22	90	25	75.00
30	33	90	38	73.33
45	47	95.56	53	82.22
60	67	88.33	68	86.67
180	185	97.22	185	97.22

Table II reveals that the introduction of a load to the turntable will decrease the accuracy of the position control. Considering that this is an open-loop system, the effect of the variable load cannot be compensated and hence deteriorates the accuracy. To overcome this problem a closed-loop system can be implemented.

TABLE III

Accuracy of the Antenna Positioning Device Speed Control

Speed Level	Motor speed (rpm)		
	Calculated	Measured	Accuracy (%)
1	52.35	48.5	92.65
2	73.30	72.6	99.05
3	94.23	96.8	97.27

Table III shows that the accuracies for various speed of the antenna positioning device are quite good as all of them are above 90%.

TABLE IV
ACCURACIES THE ANTENNA POSITIONING DEVICE POSITION CONTROL

Speed Level	Desired Position (cm)	No Load		With Load	
		Actual Position (cm)	Accuracy (%)	Actual Position (cm)	Accuracy (%)
1	35	35.1	99.71	34.8	99.43
2	26	25.8	99.23	25.9	99.62
3	20	19.8	99.00	19.8	99.00

The accuracies of the antenna positioning device position control for both no load and with load are excellent as all of them are above 99%. This is because the system is a closed-loop system therefore the effect of the load can be compensated.

V. CONCLUSIONS

The control systems of the turntable and antenna positioning device in an OATS have been presented. The overall performance of the systems is quite good. However, the turntable speed control system needs to be improved especially at slower speed.

ACKNOWLEDGMENT

The authors thank EMC Centre Universiti Tun Hussein Onn Malaysia Johor for providing facilities to do this research work.

REFERENCES

[1] CISPR 16-1-4, Specification for Radio Disturbance and Immunity Measuring Apparatus and Method, 2007

[2] ANSI C63.7, Guide for Construction of Open Area Test Sites for Performing Radiated Emission Measurement, 1998

[3] Microchip Technology Inc, PIC16F87X, 2001

[4] H.S. Kalsi, Electronic Instrumentation, Second Edition, Tata McGraw-Hill, New Delhi, 2004

[5] N.S. Nise, Control Systems Engineering, Fifth Edition, John Wiley & Sons, Asia, 2008

[6] R.C. Dorf & R.H. Bishop, Modern Control Systems, Eleventh Edition, Pearson Education International, 2008