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ANDROID BASED ANTENNA POSITIONING SYSTEM

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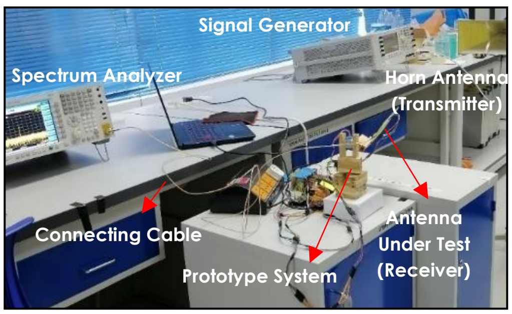
Graphical abstract



Abstract

To receipt the strongest possible signal, the antenna must be pointed at a precise angle in the direction of transmitter for effective wireless communication. If the movement of the antenna is controlled manually, there is a problem of aligning it at the optimum position to receive the strongest possible signal especially in remotely located areas. To overcome the difficulty of adjusting manually, Android Based Antenna Positioning System is proposed to remotely control the position of antenna by using an android phone. Two 12 V 28BYJ-48 stepper motors and ULN2003 drivers are demonstrated as a rotator to move the antenna in azimuth and elevation directions simultaneously. The commands provided from a web page through android phone are sent to the motors in real time via NodeMCU V3 microcontroller. MPU6050 sensor is mounted on the antenna to determine its position then the data collected is uploaded to Blynk application. When the antenna is positioned at specified direction in the direction of horn antenna (transmitter) based on the angles, speed and direction of motors' movement, the strongest possible signal strength of antenna at specific frequency of 2.4 GHz can be determined using spectrum analyzer. When the antenna is positioned at X=27.52˚, Y=285.63˚, and Z=171.71˚, it has the strongest signal strength of -36.62 dBm as well as the gain of 1.713 dB. The stronger the signal strength of antenna, the higher the gain and the higher the quality connection.

Keywords: Android phone, MPU6050 sensor, spectrum analyzer, stepper motors, web server

Abstrak

Antena perlulah diletakkan dalam kedudukan yang sama dengan arah satelit untuk menerima isyarat yang paling kuat dalam komunikasi tanpa wayar. Jika kedudukan antena dibetulkan secara manual, masalah menyelaraskannya pada sudut yang tepat untuk menerima isyarat yang paling kuat akan berlaku terutamanya di lokasi yang berjauhan. Untuk mengatasi kesusahan melaraskan kedudukan antena secara manual, "Sistem Penentukan Kedudukan Antena Berasaskan Android" dicadangkan untuk mengawal kedudukan antena dari jauh dengan menggunakan telefon bimbit android. Dua 12 V 28BYJ-48 motor stepper dan ULN2003 pemandu digunakan sebagai antena motor untuk mengerakkan antena tampalan dalam kedudukan melintang dan menegak serentak. Arahan daripada laman sesawang di telefon bimbit android diberikan kepada motor melalui NodeMCU V3 microcontroller.

MPU6050 sensor diletakkan atas antena untuk menentukan kedudukan antenna. Data yang dikumpulkan dimuat naik ke Blynk aplikasi. Jika antenna diletakkan pada kedudukan sudut yang tepat dan sama arah dengan antena tanduk (pemancar) berdasarkan arahan yang diberikan seperti sudut, arah dan kelajuan motor daripada telefon bimbit android, kekuatan antena isyarat yang paling kuat pada frekuensi 2.4 GHz dapat ditentukan melalui penganalisa spektrum. Apabila antena diletakkan pada kedudukan X=27.52˚, Y=285.63˚, dan Z=171.71˚, antena mempunyai isyarat yang paling kuat, iaitu -36.62 dBm dan penambahan antena yang paling tinggi, iaitu 1.713 dB. Semakin kuat kekuatan isyarat antena, semakin tinggi penambahan antena dan semakin bagus kualiti sambungan.

Kata kunci: 28BYJ-48 motor stepper, MPU6050 sensor, pelayan web, penganalisa spektrum, telefon bimbit android

1.0 INTRODUCTION

Nowadays, the performance of leading-edge communication system is demanding efficient, authentic and accurate antenna positioning. For establishing and maintaining the communication link, the antenna is employed by the base station and mobile station essentially [1]. A receiver antenna is required to be pointed to a certain satellite in the sky at a precise angle to receipt the strongest strength of signal of a particular frequency for effective wireless communication. For example, a log periodic antenna radiates or receives greater power in specific directions allowing enlarging performance and decreased interference from unwanted sources [2]. The maximum gain of directional antenna occurs in a single direction [3].

Antenna is used in many applications such as GPS tracking system, solar panels, radar, mass communication systems in moving vehicles and etc., hence it is difficult to be adjusted manually in these large applications. It is tedious, time consuming and out of capacity of the operators. Inaccurate positioning of antennas also will lead to network loss in some areas and loss of money to the service providers. Therefore, it needs to be directed by means of a remote control in order to improve the signal reception due to the transmitting towers are located in different directions. The orientation of the antenna can be controlled by a controller and a motor-driven rotating antenna through a communication connection such as a cable or a wireless link to receive better signal from different direction without more forces [4, 5].

It is very important to implement the antenna positioning system to reduce the pointing error and increase the coverage of signal in some area. The adjustment of azimuth and elevation axes are essential to receive signal from satellites. Normally, these axes are adjusted manually by operators for different sources based on the measurement of strength of signal. Several systems have been designed by other authors to solve the problem of adjusting the position of antenna manually.

Prajwal Basnet *et al*. [6] designed "Remote Alignment of Dish Positioning By Android Application" to control the position of the dish through a Bluetooth module HC05 which will attached on the receiver end for example any smart phone or Tablet etc. with Android OS upon a Graphical User Interface based on touch screen operation. Arduino ATMEGA328 microcontroller reads the received commands from the mobile unit through Bluetooth module and rotates the two servo motors which is attached to pan and tilt assembly in horizontal and vertical direction through a motor driver IC.

Mpuuga Abdu Nasser designed and implemented an android based automatic sector antenna positioning using ATMEGA328P that can position the antenna with the help of android application. User commands that are received by the Bluetooth receiver modem moves the antenna on the basis of input parameters provided such as number of steps. The commands that are sent through the mobile phone app for adjustments of antenna's position made by the stepper motor is based on the initial direction provided by magnetometer sensor which is Honeywell HMC5883L [7].

Jadhav Seema *et al*. [8] proposed a system to control a dish antenna position in horizontal and vertical direction automatically according to received signal from power meter. When power meter receives the maximum signal strength and give that output to microcontroller, the dish will rotate in that particular direction. Ginu Lawrence had developed a dish position controller using TV remote. The TV remote acts as a transmitter whose data is received by an IR receiver TSOP 1738 which is interfaced with ATMEGA 328 microcontroller. IR sensor is used to obtain remote commands that are fed to the microcontroller that decodes the data to rotate the two DC motors in vertical and horizontal direction through motor driver IC L293D [9].

Shubham Pathak *et al*. [10] developed a dish positioning system which is operated by using RF module. The control output signals are given to IC L293D driver circuit to move the two YURI 518R servo motors where the direction movement of the dish is indicated by two LEDs. An Automatic Antenna Positioning System is developed by M.Ilakkiya *et al*. [11] to identify the presence of a particular signal and change the position of the antenna to receive the desired signal strength automatically whenever the receiver RC832 receives the signal with minimum strength. The RSSI values from the receiver filters out the erroneous readings and determine which direction to move the servo motor. If the RSSI value is below the preset threshold value, the motor rotates otherwise it remains in the same position.

Prasanna Sugandhi *et al*. [12] presented the development of an automated system for aligning the parabolic reflector antennas for satellite communication. System checks whether the received data is valid or not and after validation of latitude and longitude specifics is received by GPS module, azimuth and elevation angle are calculated and the dish antenna is rotated by stepper motors to the direction needed. Recent from the studies of Manasa G R *et al*. [13] had developed antenna monitoring GUI system using Adafruit platform. Adafruit web application is used to check for the signal strength and drive the servo motor to a desired angle after compare with the previous signal strength. The antenna will remain stationary as long as the signal connection is formed.

Shweta Lande *et al*. [14] developed a dish positioning system which can operate by using mobile phone or personal computer through WiFi. C code is used to recognize the input code from the Wi-Fi module (transmitter) from AVR microcontroller to develop appropriate output signal for the servo motor to operate and change the dish in accurate angle. Khalid Makhdoomi developed an automatic antenna positioning system based on IoT to identify presence of a particular signal. GUI system is developed by IoT Gecko for monitoring antenna direction as well as transmitting new coordinates for motors to appropriately position the antenna to receive desired signal strength automatically [15].

Lastly, Neha Pravin Pophale proposed a system which enable the antenna detects a signal with the help of ultrasonic sensors which one of sensor acts like the transmitter while another sensor acts like receptor. When the strong signal is detected, DC motors will position the antenna and LCD module will display the value of signal detected and the strong signal's frequency will be loaded on the IoT Module [16].

The polarization of an antenna is determined by the wave radiated in a given direction and the power is not radiated equally in all directions [17]. Previous research shown the data acquisition system software controls the axis motors and synchronizes the vector network analyzer (VNA) to compute the RF level corresponding to different angular locations [18]. Therefore, spectrum analyzer uses antennas to collect RF signal and display amplitude which is strength of signal as it varies by signal frequency [19,20].

A controller regulates the step position accurately, the speed at which the motor moves from step to step and the torque generated by the motor. Servo motor is used for controlling and driving heavy loads but the cost of the motor is very high. DC motors rotate in specific angular direction and it is challenging to make them turn in small angles. Hence, stepper motor is the most suitable to be implemented in positioning system as it is designed to provide precise positioning control within an integer number of steps and no feedback is required to control it.

According to the existing system that had been proposed and designed by the previous authors, the position of antenna which is controlled by Bluetooth device via Android application has the limitation on range of detection. Besides, TV remote requires a line of sight between the transmitter and a receiver and a limited range of about 30 feet. Hence, IoT application should implement to increase the range of detection and remotely control the position of antenna from a very long distance. The antenna can receive the desired signals from all the direction by adjusting its position through the commands provided by a developed IoT application which is a web page from an android phone with just a fingertip via microcontroller as it brings convenience to people.

2.0 METHODOLOGY

Android Based Antenna Positioning System was designed to determine the signal strength of antenna at specific frequency of 2.4 GHz through spectrum analyzer when the antenna was rotated at specific angular position, speed and either in clockwise or anticlockwise direction based on the commands provided from android phone through a web page with identical IP address. NodeMCU V3 microcontroller was interfaced with two 12 V 28BYJ-48 stepper motors and ULN2003 drivers which acts as rotators to move the antenna in azimuth and elevation direction simultaneously. MPU6050 sensor module which was interfaced with another microcontroller was mounted on the antenna to determine its position. 16X2 LCD display was connected to microcontroller using IC2 module to show the position of the antenna in X, Y and Z direction in term of tilt angle. The measured tilt angle was sent to the Blynk application using Blynk cloud to store the collected data. Two microcontrollers were connected together using the GPIO pins of 3V3 and GND respectively. Figure 1 shown the connection of required components in building the prototype of Android Based Antenna Positioning System and Table 1 shown the required components of this system.

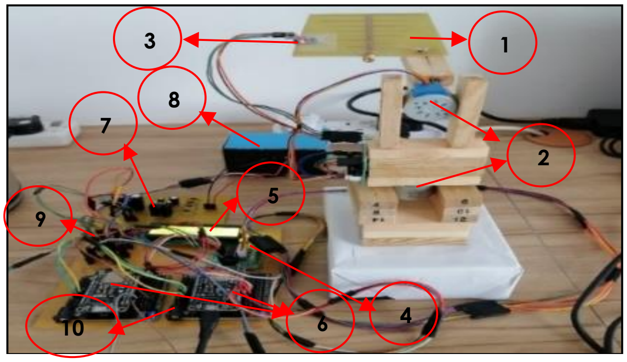


Figure 1 Android Based Antenna Positioning System Configuration

Table 1 Components of Android Based Antenna Positioning System

No.	Component
1	Antenna (Receiver)
2	28BYJ-48 Stepper Motors
3	MPU6050 Accelerometer and Gyroscope Sensor
4	ULN2003 Drivers
5	I2C 16x2 LCD Display
6	NodeMCU V3 Microcontroller
7	Power Supply (Rectifiers: 1N4007 diodes, Linear Voltage Regulators: LM7812CT and LM7805CT, Filter: 1000 µF, 1 µF, 470 µF and 10 µF electrolytic capacitor)
8	12 V-0-12 V transformer
9	Connectors (Header Pin Female)
10	Base Board NodeMCU V3 Microcontroller

3.0 RESULTS AND DISCUSSION

A. Power Supply

This experiment aims to obtain the desired regulated 12 V and 5 V power supply to respectively power up the two 28BYJ-48 stepper motors with ULN2003 drivers and I2C LCD display. Figures 2 shown the simulation results of 12 V and 5 V DC power supply that was obtained using Multisim software before the circuit was built on the breadboard. The purpose of simulation is to obtain the correct components for constructing a functional power supply and do comparison with experimental results.

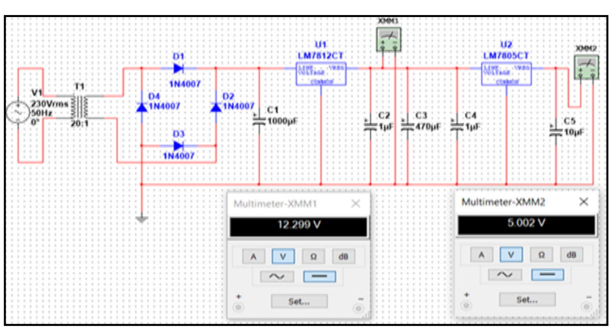


Figure 2 Simulation Results of 12 V and 5 V DC Power Supply Using Multisim

Figure 3 shown the PCB power supply which is tested well-functioning using multimeter to obtain desired output voltage of 12 V and 5 V power supply from AC power supply.

Figure 3 PCB Power Supply

Table 2 shown the comparison of obtained 12 V and 5 V power supply between simulation and practical results with their respectively power supply.

Table 2 Comparison of Obtained Power Supply Between Simulation Results and Practical Results

Simulation	Practical	Percentage Error (%)
Power Supply (V)		
12.299	12.050	$\left\lvert\frac{\text{Simulation Value} - \text{Practical Value}}{\text{Simulation Value}}\right\rvert \text{ x } 100\%$ $= \left\lvert\frac{12.299-12.050}{12.299}\right\rvert \text{ x } 100\% = 2.02$
5.002	5.060	$\left\lvert\frac{\text{Simulation Value} - \text{Practical Value}}{\text{Simulation Value}}\right\rvert \text{ x } 100\%$ $= \left\lvert\frac{5.002-5.060}{5.002}\right\rvert \text{ x } 100\% = 1.16$

Although the experimental results obtained which are 12.05 V and 5.06 V are slightly different as compared with the simulation results which are 12.299 V and 5.002 V respectively, but it is still acceptable and reasonable with very small percentage error which is less than the acceptable 5% error. This may due the components such as diodes and capacitors have different conditions and losses of power in the circuit when output voltage was measured practically.

B. Signal Strength Measurement and Calculated Gain of Antenna

When the system and android phone was connected to the same WiFi router, a identical IP address of 192.168.0.190 was obtained from Serial Monitor of Arduino IDE software and typed on Google Chrome. The web page for controlling the movement of the two motors simultaneously to position the antenna in direction with horn antenna (transmitter) at specific angle, speed and either in clockwise or counterclockwise direction through android phone was designed at shown Figure 4.

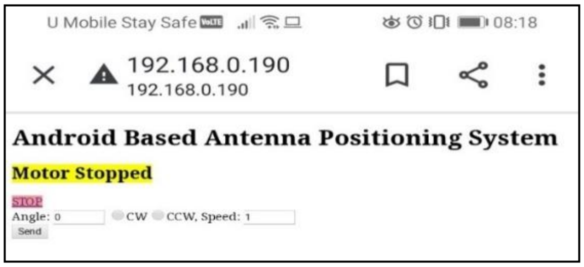


Figure 4 Web Page Shown on Screen of Android Phone

The movement of two motors can be controlled with any angles randomly without decimal numbers such as 10˚, 45˚, 58˚, 90˚, 78˚, 150˚, 189˚, 223˚, 325˚, 450˚, 549˚ and so forth as well as the speed of movement of motors can be set with any values such as 1, 5, 8, 13, 20, 30 and so forth. Initially, the speed factor is 1, as the speed factor increased, the motor will move in slower speed and take longer time to reach at that specific angle. The movement of the motors can be stopped at anytime by pressing the STOP button. Figure 5 shown the examples of input parameters given on the web page to position the antenna.

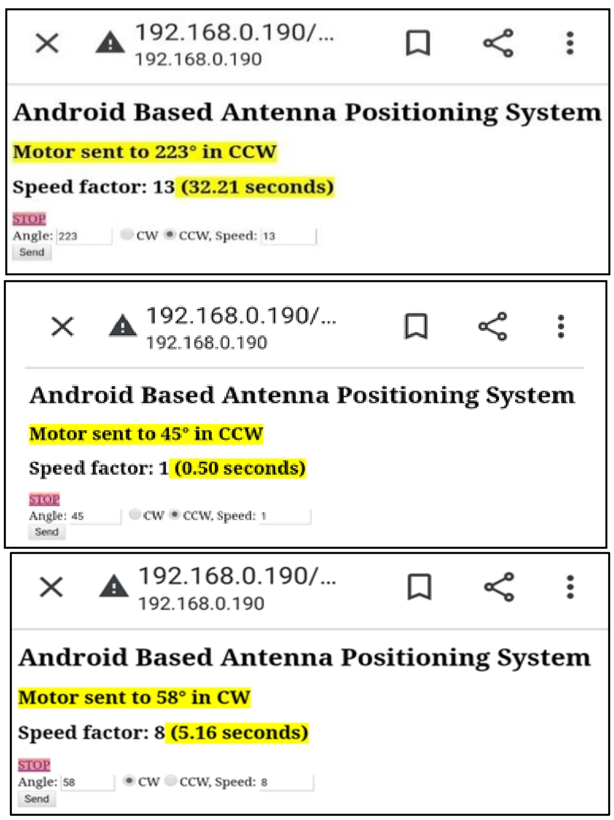


Figure 5 Examples of Input Parameters Given on the Web Page

When the antenna which was attached to one of the motors was controlled to reach at that specific direction in direction with transmitter, the MPU6050 sensor module will detect the angular position of the antenna at the same time the antenna was stopped to move and the data was sent to the Blynk application using Blynk cloud to be monitored and stored as shown Figure 6.

Figure 6 Examples of Collected Data Shown on Blynk Application

At the same time the angular position of antenna in tilt angle of X, Y and Z axes was shown on I2C LCD display.

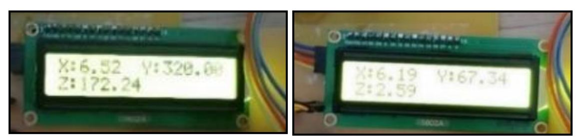


Figure 7 Examples of Angular Position of Antenna Shown on I2C LCD Display

Figure 8 shown the setup for measuring the signal strength of antenna using spectrum analyzer when the antenna under test (receiver) was positioned in the direction of horn antenna (transmitter) which was connected to a signal generator.

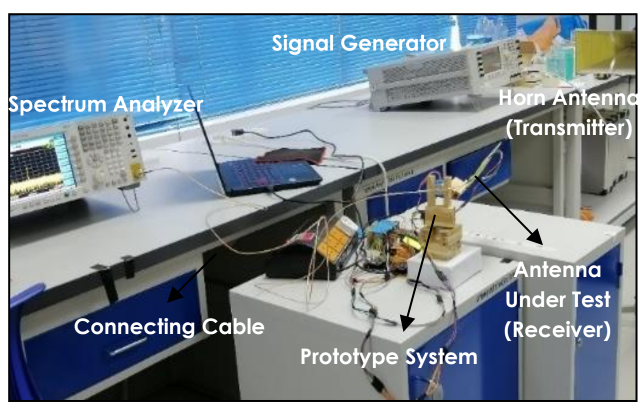


Figure 8 Setup of Signal Strength of Antenna Measurement

Initially, the antenna was positioned at an initial position that is X=167.50˚, Y=232.50˚ and Z=170.35˚ in direction with transmitter as shown Figure 9.

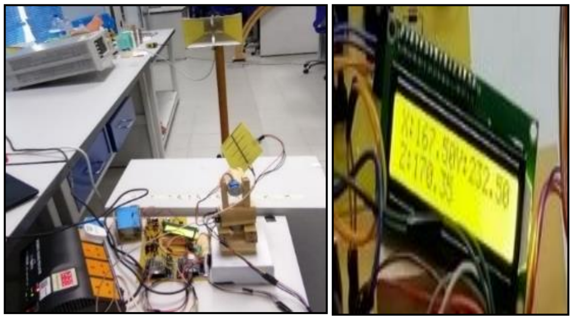


Figure 9 Initial Position of Antenna

Signal strength is referred to the transmitter power output as received by an antenna under test (receiver) at a distance of 1m from the transmitting antenna. The signal strength is shown on the spectrum analyzer in dBm.

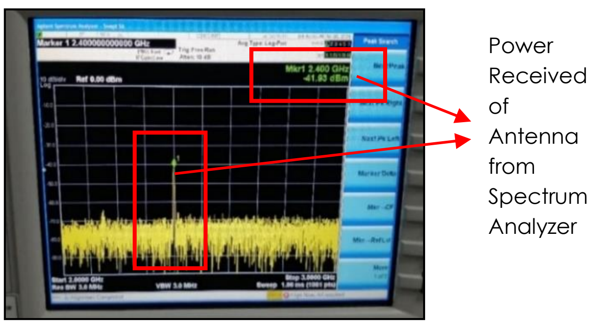


Figure 10 Power Received of Antenna at Initial Position

The antenna was positioned at different direction based on the input parameters provided from the mobile phone to determine at which position the antenna has the strongest possible signal strength at specific frequency of 2.4 GHz. After 20 set of different signal strength of antenna at different direction are obtained, the gain of antenna at different direction is calculated. After the power received by antenna from the horn antenna at a distance of 1 m is determined from the spectrum analyzer, antenna gain was then calculated which is corresponding to different direction of antenna positioned. For example, at initial position, the power received of antenna is -41.93 dBm. The calculated antenna gain is -0.942 dB. All the calculated antenna gain at different direction with respectively signal strength was tabulated as shown Table 3.

$$\lambda = \frac{c}{f} = \frac{3x10^8}{2.4 \times 10^9} = 0.125 \text{ m}$$

$$\text{Space loss [dB]} = 20 \log \left(\frac{4\pi D}{\lambda}\right) = 20 \log \left(\frac{4\pi(1)}{0.125}\right) = 40.046 \text{ dB}$$

$$\text{Antenna gain [dB]} = \frac{Power\ Received + Space\ loss}{2}$$

$$= \frac{-41.930\text{dBm} + 40.046\text{dB}}{2} = -0.942 \text{ dB}$$

Table 3 Measurement of Signal Strength And Calculated Gain Of Antenna At Different Angular Position

Angular Position			Signal Strength (dBm)	Antenna Gain (dB)
X (˚)	Y (˚)	Z (˚)		
167.50	232.50	170.35	-41.93	-0.942
318.87	86.71	357.13	-46.11	-3.032
113.69	265.33	169.45	-39.44	0.303
173.40	186.85	136.06	-49.14	-4.547
358.81	16.75	356.05	-46.23	-3.092
16.13	293.05	172.30	-36.97	1.538
27.52	285.63	171.71	-36.62	1.713
3.54	331.35	173.53	-41.24	-0.597
29.22	284.05	172.90	-38.27	0.888
169.26	226.57	169.82	-38.98	0.533
173.48	209.19	168.43	-38.63	0.708
176.67	169.23	17.02	-45.78	-2.867
177.05	148.56	4.82	-47.79	-3.872
178.14	153.85	3.78	-42.42	-1.187
108.55	267.56	172.76	-40.95	-0.452
179.00	153.71	2.02	-51.49	-5.722
182.27	130.45	358.06	-45.09	-2.522
330.67	85.35	357.38	-51.77	-5.862
357.84	47.82	358.04	-47.03	-3.492
14.17	303.40	170.55	-40.61	-0.282

As mentioned before, this system is designed to measure how strong a signal an antenna can send or receive in a specified direction at specific frequency of 2.4 GHz. Table 3 shown that the antenna will have different signal strength at any possible direction but the antenna will only possess the strongest signal at a specific direction. The changes of signal strength of antenna can be clearly observed directly from spectrum analyzer when the antenna is controlled to move in slower speed and different direction with either smaller or bigger increment of angle rotation.

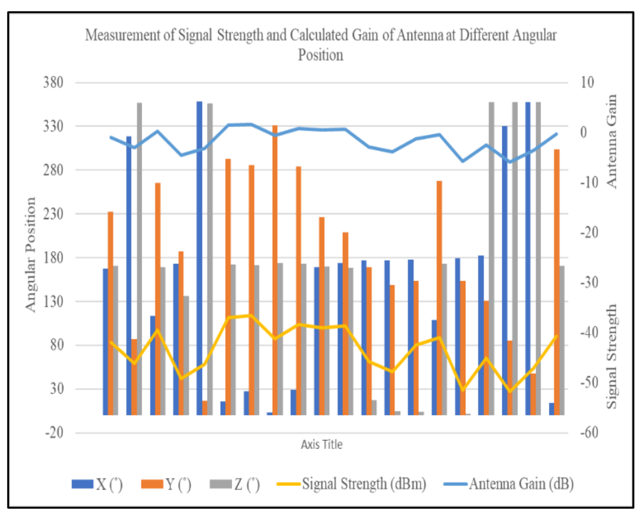


Figure 11 Graph of Measurement of Signal Strength and Calculated Gain of Antenna at Different Angular Position

Based on the results obtained from Figure 11, it is clearly shown that when the antenna is positioned at X=27.52˚, Y=285.63˚, and Z=171.71˚, it has the strongest signal strength of -36.62 dBm as well as the gain of 1.713 dB. The stronger the signal strength of antenna, the higher the antenna gain and the higher the quality connection. This system is implemented to measure the signal strength of a directional antenna where it radiates or receives higher power in specific directions, thus increasing performance and reducing interference from unwanted sources. A high gain antenna gives more of the transmitted power to be sent in the direction of the receiver, thus increasing the received signal strength. Signal strength is represented in -dBm unit, so the closer the value is to 0, the stronger the signal.

The antenna rotators can be remotely controlled with slower, medium or faster speed and different angle of rotation in different direction based on the input parameters provided from the android phone in order to enable the antenna to receipt the strongest possible signal when the antenna is pointed at a specified angle in the direction of transmitter. The slower the movement of motors and the smaller the angle of rotation of motors, the more accurate the signal strength of antenna at specific frequency will obtain from the spectrum analyzer.

However, this project has limitations such as the data received by microcontroller from a created web page via android phone to rotate one of the motors in adjusting the position of antenna may be affected by unnecessary delays caused by network unreliability. The communication is done through a Wi-Fi router and it may be affected by weather changes such as heavy rains. The construction of chosen motor with restriction of step size had limited the antenna to move in a smaller degree of angular position.

4.0 CONCLUSION

Android Based Antenna Positioning System is designed with an advanced technology to achieve the best possible position of antenna by remote operation. This system can be implemented to determine the position of antenna with the strongest possible signal strength from a spectrum analyzer when it is positioned at different direction in direction of transmitter. The gain is directly proportional to the signal strength and the quality connection. Although the project is successful, there are a few recommendations for improvement. In future, the positioning accuracy can be increased by correcting the lost steps of motor using a speed rate corrected algorithm. Hence, any size of the antenna can be controlled by changing the motor with its proper driver. In the nutshell, a useful and sustainable Android Based Antenna Positioning System has been successfully designed and developed. This system has very low development cost besides it is less power hungry. The user interface of the application is simple and easy to understand as operators just only need to key in the proper angle, speed and direction via the web page. The uses of IoT application in this system reduce the labor and maintenance cost as well as provide the benefit of time saving and reduce the poor signaling in certain areas due to the misalignment of position of antenna.

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