POSITION CONTROL OF ANTENNA EMITTER USING PID DIGITAL CONTROLLER

BY

LAI WEN HONG

A REPORT

SUBMITTED TO

Universiti Tunku Abdul Rahman

in partial fulfillment of the requirements

for the degree of

BACHELOR OF INFORMATION TECHNOLOGY (HONS)

COMPUTER ENGINEERING

Faculty of Information and Communication Technology
(Kampar Campus)

JAN 2020

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Date: _24 April 2020

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DECLARATION OF ORIGINALITY

I declare that this report entitled "**POSITION CONTROL OF ANTENNA EMITTER USING PID DIGITAL CONTROLLER**" is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

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First and foremost, I would like to express my highest appreciation to my supervisor, Ts Dr Ooi Chek Yee, who has given me an opportunity to undergo this amazing computer engineering course related project. This project has provided me experience on designing real life application and modelling its simulation for physical environment. Overall, the scope and challenge of this project is advantageous to me in my future research and career.

Furthermore, I also want to thank my family members and friends who support and motivate me all time because with their presence, I am able to complete this project successfully.

ABSTRACT

The main purpose of this project is to model simulation of antenna system with PID controller. This project covers the knowledge of control system engineering and the technique of using MATLAB software.

Inside the control system engineering part, there is a design process of control system which guides system developers to a right way of designing. This project focuses more on the sixth step of design process, the implementation of PID controller is one of the challenges in the section of sixth step, to yield stability of antenna system. There are many requirements taken based on time and frequency domain during the analysis of PID controller functioning on antenna system. Conversion of analogue into digital antenna system is last process of this project.

The MATLAB software is a useful tool of designing and simulating control system. In order to learn how to achieve the system balance, the primary key is to master the relevant graph plots which are very significant to estimate the system behaviour. This project emphasises the time domain standard, it has to be understood as it will help designers on determining gain needed, finding system stability and contributing on PID controller tuning, along the whole progression of this project.

The outcome of this project is the simulation results showing that the PID controller successfully improves the transient response and maintain zero steady state error, of the digital antenna system.

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CHAPTER 1: INTRODUCTION

1.1 Problem Statement

In this project, there are some motivation and problems to be solved. The first one is the requirements and methods used on improving the stability on control system. In the simulation modelling of the closed loop control system, there are two domains of analogue form to test its stability, namely time domain and frequency domain. These two domains have different graph plots with different data shown but they both are needed in the process of building stable system. Without considering two sides of requirements of the domains, the system will not get stable even though it looks fine from the perspective of the only one domain.

The second one is the tuning of PID controller on stabilizing control system. Nowadays, a lot of tuning methods of PID controller had been revealed to increase the effectiveness of the controller implemented in control system. Many of current case studies are mostly covered about the comparison between PID controller and other types of controller on certain system. Due to the lack of resource on differentiate various ways of PID controller tuning, it seems to be more necessary to conduct this kind of experiment to determine a good PID controller tuning method which is suitable to be developed in control system.

The last one is the difference of experimental and practical works of control system. Modelling simulation of a system is to predict the functioning of the system in real life. It cannot be denied that sometimes the practical result is not as successful as the experimental one because the simulation can be modified or generated perfectly. The ideal type obtained from modelling a control system is not possible to work in reality. Thus, at the process of demonstrating the result, there are still many conditions to be reflected from the real life such as the voltage required on producing the gains of controller, the time needed for the system to return to normal from disturbance and so on.

1.2 Background Information

A control system is a system that display desired output by performing accurate and stable process based on a provided input (ed. Nise 2011).

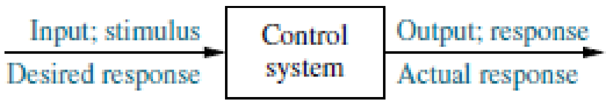

Figure 1.2.1 Simplified description of a control system

Figure 1.2.1 shows a simple control system, where the input is a desired response that a user requests and the output is an actual response coming out with performance. Control system is created based on some important reasons. First of all, power amplification is required when an input with low power is entered and an output needs a high power consumption to generate an action. For example, antenna system. The user rotates a knob which is the input using his own fingers power and then the antenna system will require huge power to change its position commanded by the user input. Besides, remote control is necessary when a user needs to do certain jobs in dangerous or polluted environment, such as a robot arm is designed to collect resources at a radioactive location. Furthermore, control system is also able to convert input form which bring convenience to users, for instance a brightness control has switch knob as input device, position of switch knob as input and light as output. Furthermore, the potential of compensation for disturbances is necessary in a good control system. Taking back the antenna system as example, this system is built at outdoor environment, there are a lot of disturbance upon it such as wind, storm, rain, noise and others. Assuming that wind pushes the antenna from its original position, the occurrence of that disturbance should be identified and the antenna is needed to be repositioned to its origin.

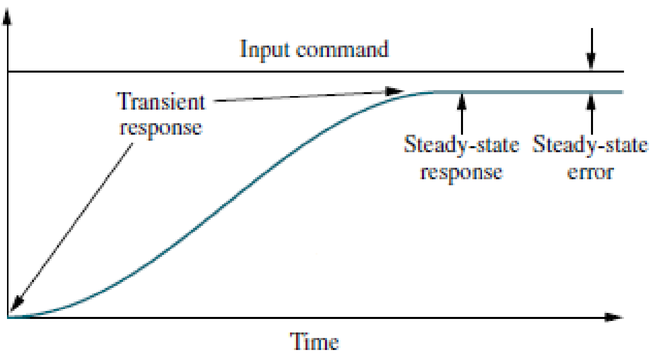

Figure 1.2.2 Simulation response after functioning a system

Figure 1.2.2 shows a graph that describe a response after a system is turned on from the beginning until the end of time. The transient response occurs after the system is activated, which is a moment after an input signal enters to the system (Electrical4U 2018). When the system reaches a stable state, the transient response will change steady-state response and then the steady-state error will appear. The growth of transient response is needed to look out in order to achieve a stable response and reduce the chance of malfunction in a system. The lesser the steady-state error, the more the chance reaching the need of input command which is desired state. The safety and convenience of the user are connected the steady-state error which is counted as significant condition in performance.

Control system is separated into two major forms namely: open loop control system and closed loop control system.

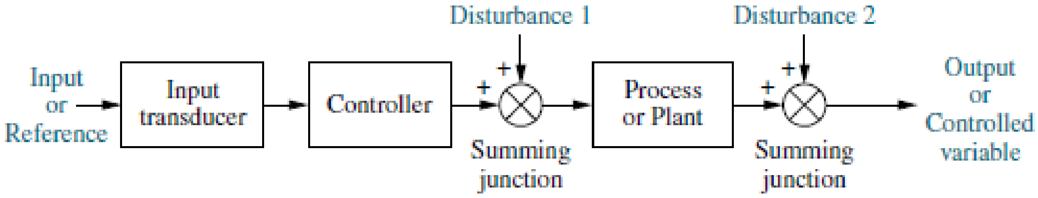

Figure 1.2.3 Open loop control system

Figure 1.2.3 shows a normal open loop control system. There are three blocks inside it which are an input transducer, a controller and a process. The input transducer converts the input form to another form that the controller can understand. The controller drives a process. The input represents the reference while the output represents controlled variable. Some signals of disturbances may appear and interfere the system on the way from controller to process, and from process to output through summing junction. This system will only collect input and generate output without respond to any feedback. This system cannot compensate and correct for any disturbances.

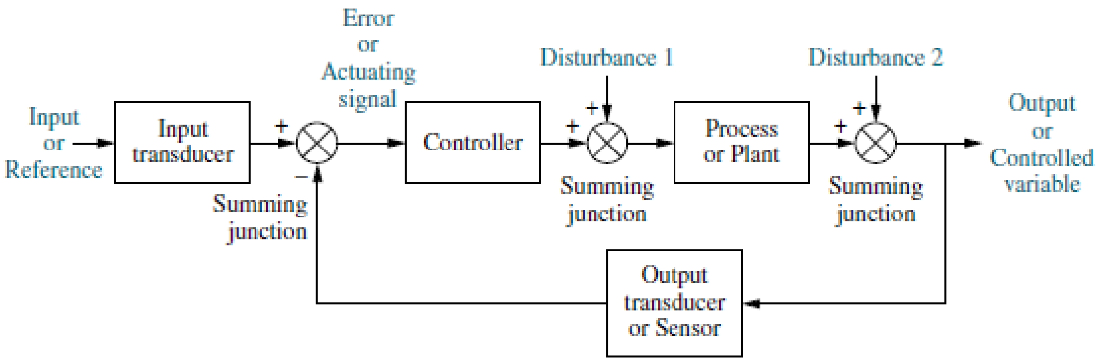

Figure 1.2.4 Closed loop control system

Figure 1.2.4 shows a normal closed loop control system. Comparing to open loop control system, an additional block is found in this system which is an output transducer. This system can overcome the disadvantages of open loop control system by recording the output response through output transducer, transferring back the record and then comparing that record with the input in summing junction. The controller drives the process to make correct adjustment if any dissimilarity found between the record and input, otherwise the controller will not drive the process since the output is the desired response. However, this system is more complicated and costlier due to its ability to make correction to the system by getting the feedback. After discussing about these two control systems, the blocks inside them have similar relationship with the components found in antenna position control system.

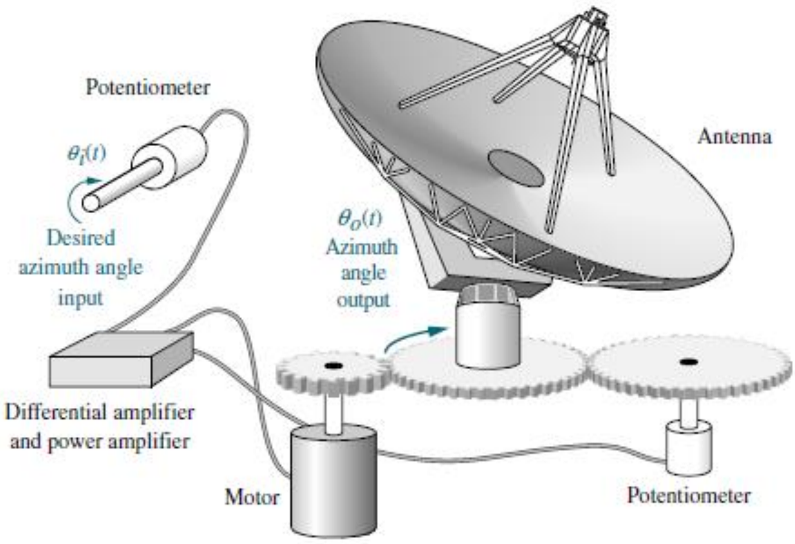

Figure 1.2.5 Layout of an antenna position control system

From Figure 1.2.4 and Figure 1.2.5, potentiometer which is to receive wanted angle input represents input transducer block, motor represents process block, positioning of antenna represents output or controlled variable, and so on.

Design of PID controller is important to yield stability for a closed loop control system.

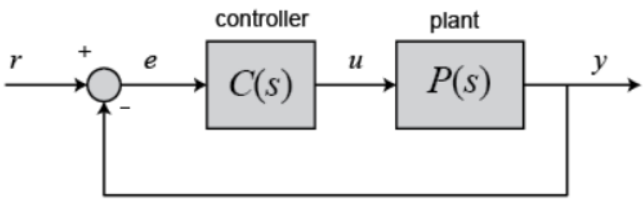

Figure 1.2.6 Design of closed loop control system with controller

In Figure 1.2.6, the controller receives the error input, e, which is the difference between the actual and desired output, and then produces control output, u, to the plant to generate new adjusted output. The three terms contained in PID controller are called proportional, integral and derivative terms. Each of them has their special characteristics on controlling the system response and they can be tuned in PI, PD or PID forms to overcome different patterns of system output error.

CL RESPONSE	RISE TIME	OVERSHOOT	SETTLING TIME	S-S ERROR
Kp	Decrease	Increase	Small Change	Decrease
Ki	Decrease	Increase	Increase	Decrease
Kd	Small Change	Decrease	Decrease	No Change

Figure 1.2.7 Tuning effect of each terms of PID controller

Figure 1.2.7 summarises the changes of the control system output response by the existence of proportional gain, Kp, integral gain, Ki, and derivative gain, Kd. Defining the response parameters which will be affected, rise time represents the time needed for the response to grow from specific low to high percent of its steady state value, overshoot is the response which surpasses its steady state value, settling time refers to the time used for the response to achieve its steady state and steady state error is the accuracy distance between actual and desired output.

Signal of a control system can be categorised into two types, which are analogue and digital. The most obvious dissimilarity between these both is the shape of wave: analogue signal is continuous and its wave is in sine form, while digital signal is discrete and it is signified by square wave. The knowledge and evaluation on analogue and digital technologies are significant in developing a control system with stable data transmission because each types of signal provides different benefits for certain system according to Figure 1.2.8.

Comparison chart

	Analog	Digital
Signal	Analog signal is a continuous signal which represents physical measurements.	Digital signals are discrete time signals generated by digital modulation.
Waves	Denoted by sine waves	Denoted by square waves
Representation	Uses continuous range of values to represent information	Uses discrete or discontinuous values to represent information
Example	Human voice in air, analog electronic devices.	Computers, CDs, DVDs, and other digital electronic devices.
Technology	Analog technology records waveforms as they are.	Samples analog waveforms into a limited set of numbers and records them.
Data transmissions	Subjected to deterioration by noise during transmission and write/read cycle.	Can be noise-immune without deterioration during transmission and write/read cycle.
Response to Noise	More likely to get affected reducing accuracy	Less affected since noise response are analog in nature
Flexibility	Analog hardware is not flexible.	Digital hardware is flexible in implementation.
Uses	Can be used in analog devices only. Best suited for audio and video transmission.	Best suited for Computing and digital electronics.
Applications	Thermometer	PCs, PDAs
Bandwidth	Analog signal processing can be done in real time and consumes less bandwidth.	There is no guarantee that digital signal processing can be done in real time and consumes more bandwidth to carry out the same information.
Memory	Stored in the form of wave signal	Stored in the form of binary bit
Power	Analog instrument draws large power	Digital instrument drawS only negligible power
Cost	Low cost and portable	Cost is high and not easily portable
Impedance	Low	High order of 100 megaohm
Errors	Analog instruments usually have a scale which is cramped at lower end and give considerable observational errors.	Digital instruments are free from observational errors like parallax and approximation errors.

Figure 1.2.8 Comparison chart between analogue and digital signals

Now, focusing on this project, namely "Position Control of Antenna Emitter Using PID Digital Controller". Technology in this generation is very modern, human's lifestyles are fully transformed after the existence of electronic devices, and antenna works primarily in today's communication system (ScienceProg 2014). Antenna is a transmitter and also a receptor of radio frequency signal, and its position control system brings a communication with high tracing accuracy (Parveen 2018). Antenna position control system is generally worked in many areas, for examples antennas, machines and computers, and it contributes to decrease much human power (Temelkovski & Achkoski 2014). Without it, our life will not appear wireless communication and data transmission using electronic devices. Thus, antenna system is always one of the most challenging design, and a lot of researchers still focus on the study of position control of antenna to further minimize the angle deviation after the rotation of antenna. In a nutshell, the understanding of control system is the basic education in producing an antenna system, and as nowadays humans are moving into the world of 5G, antenna system will become more and more necessary to function perfectly in both transmission and reception.

1.3 Project Objectives

The purpose of this project is to model correct and improved simulation about the antenna system using digital PID controller. One main objective of this project is to improve the stability of the position control of antenna emitter using digital PID controller. A control system must be built to be stable because it maintains the system providing good functionality and reducing insecure response. An unbalanced control system does not have insurance of long term usage, this kind of system may be loss of control and damaged mechanically at any time, resulting a waste of costs in design and construction. Therefore, modelling simulation is a proper practice to every designer before developing a real control system.

As explaining about stability, there are two sub-objectives divided from it. First one is to achieve suitable transient response and steady-state response for the stability of antenna position control system. In this project, transient response should be rapid to make sure that the antenna emitter reacts fast and changes position based on the rotated input. A fast responded control system can be able to show high working effectiveness and productivity. The high accuracy of steady-state response is important to guarantee that antenna emitter does not make excessive movement during its position changing. If a system cannot guarantee the avoidance of the accident like losing consistency or self-damaging, this kind of system will cause destruction on its own task and bring danger towards human.

Second one is to investigate a proper tuning method of controller on antenna system to justify the stability of the system. Closed loop control system is the better choice to build the antenna system because the system needs to periodically correct the positioning of the antenna emitter if any disturbance affected it. However, in order to further enhance the functioning of the antenna system, PID controller is necessary to be used on antenna system and then figure out a suitable tuning method of the controller to the system. Hence, the simulation results of this project will explain the difference between design of closed loop antenna system with and without PID controller, in term of stability.

1.4 Proposed Approach

This project is mainly focused on the study of simulation modelling. It is a research based project and the simulation results such as graph plots and mathematical calculations will be delivered at the end of this project.

In order to make the research of this project deeper, this project will be started developing from analogue form to digital form. During the process of creating closed loop control system, the knowledge of evaluating the equation of sub block, finding the gain range of the system, graph plotting of the system, and others, will be applied in this project. After that, the PID controller will also be implemented into the system and then the different tuning methods will be tried on the system to estimate the stable graph plots of time domain and frequency domain.

After completing analogue form of this project, it will be digitalised because there are some good signs shown that digital technology is more appropriate for the control system of this project, which are lesser noise, easier to keep signal value in binary form and easier to be commanded by computer and electronic devices. Hence, a digital closed loop antenna system will be presented at the end of this project in term of its block diagram, response of graph and transfer function.

CHAPTER 2: LITERATURE REVIEW

2.1 Literature Review

Position control of antenna can be carried out by various forms of studies, and there are two main types of researches that currently popular and are related to this project.

The first type is to talk about the comparison of simulation results between different controllers that implemented into antenna position control system. Fandakli and Okumus (2016) conducted a study of using three different controllers which are PID, fuzzy logic and sliding mode controller, to generate their simulation results and find out the best control method for antenna system. They obtained an uncontrolled system simulation result which has 0.784 settling time.

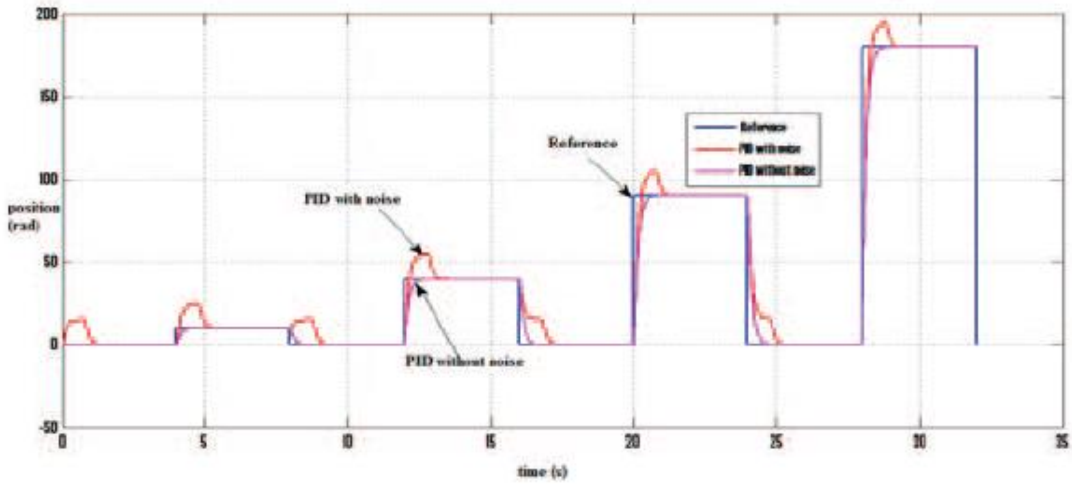

Figure 2.1.1 PID controller response with noise for different angles

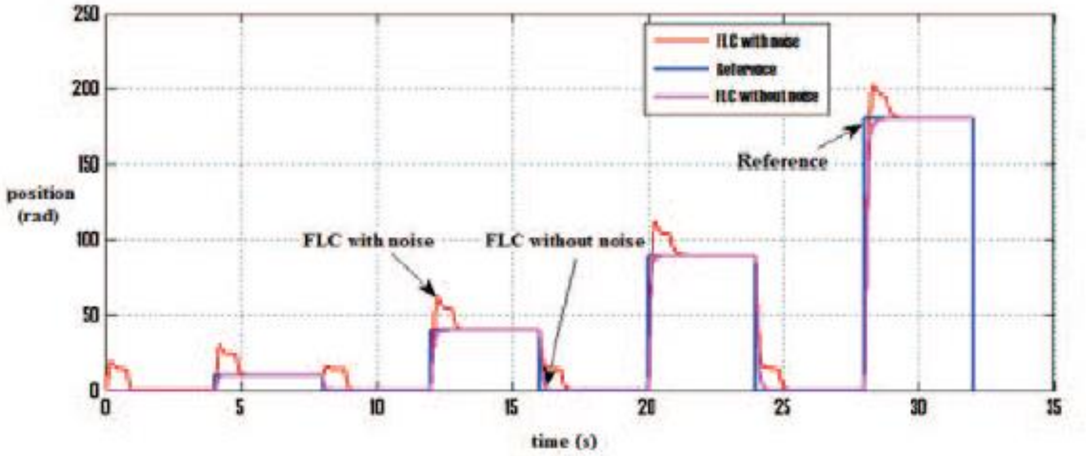

Figure 2.1.2 FLC response with noise for different angles

In Figure 2.1.1 and 2.1.2, they calculated settling time of all controllers where PID is 0.51 seconds, FLC is 0.33 seconds and SMC is 0.21 seconds. Based on their results, they concluded that sliding mode controller is the most suitable controller to be used in antenna system for position control. Next, there was also another sample which is same as the first type of study, carried out by Uthman and Sudin (2018). Their study was to compare and find the best controller with antenna position control system between PID and state-feedback controller.

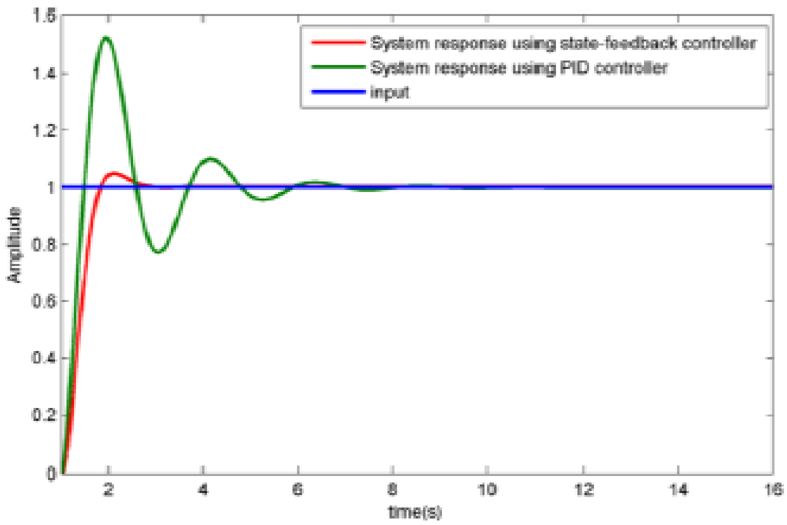

Figure 2.1.3 System response with PID and state-feedback controller

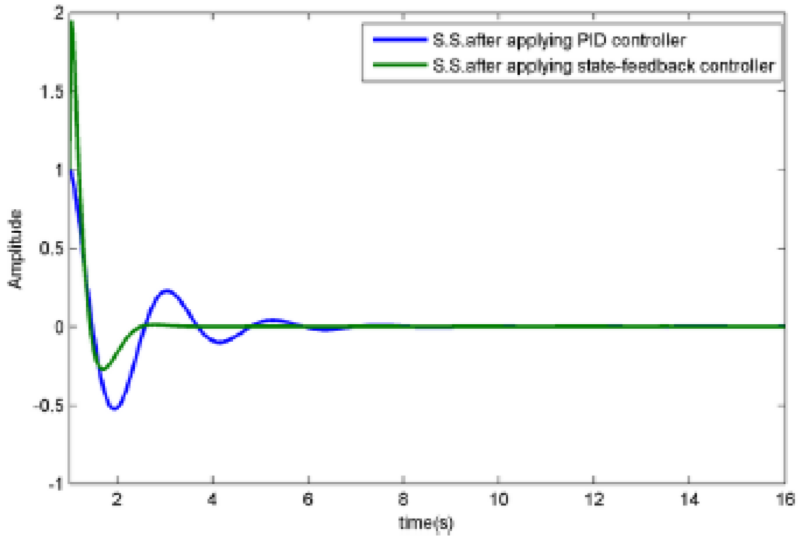

Figure 2.1.4 System steady-state error with PID and state-feedback controller

In Figure 2.1.3 and 2.1.4, it was obvious that state-feedback controller with antenna position control system was the best choice because it functioned with smaller overshoot and settling time, compared to PID controller, as well as no steady-state error found.

The second type is to discuss about the results of combining two controllers in antenna position control system. Although this kind of researches is not fully linked this project, it still involved the implementation of PID controller inside antenna position control system which can deliver some useful mathematical techniques to solve the equations of each subsystem. Adil (2014) completed a research of joining PID and fuzzy controllers for antenna system. He mentioned that PID controller is the most common traditional controller while fuzzy controller works more flexible than PID controller.

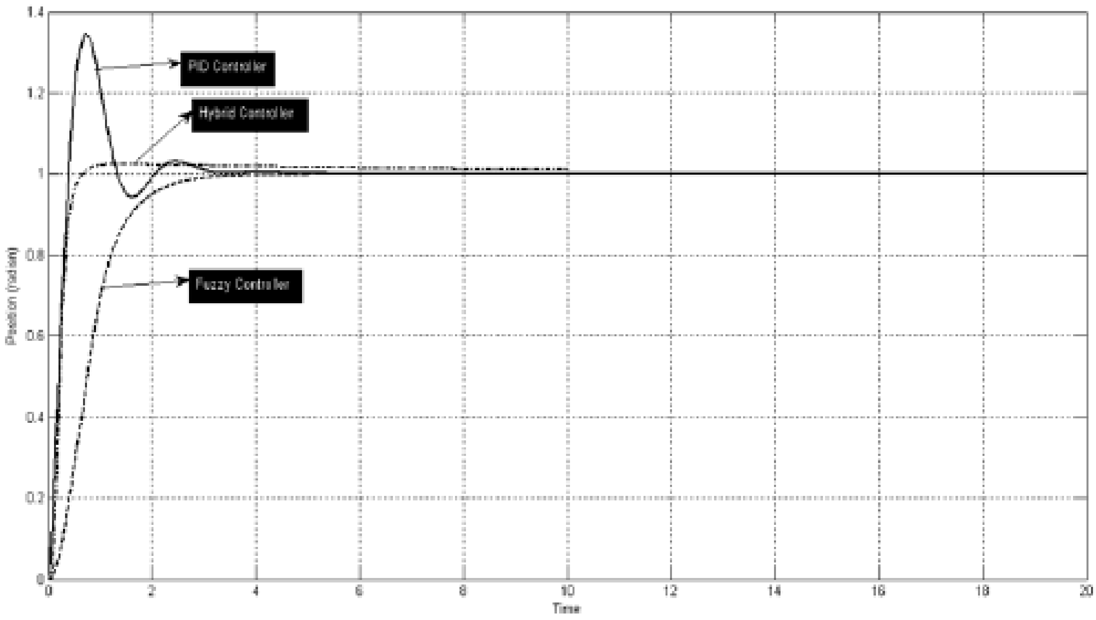

Figure 2.1.5 Step response of PID, fuzzy, and hybrid controllers

According to the graph shown in Figure 2.1.5, PID controller showed very fast response but it occurred a large overshoot, while fuzzy controller made no overshoot but its response was very slow. Adil created a combination of PID and fuzzy controller which namely hybrid controller, and this controller achieved moderate results where it responded in very short time and it just produced very minor overshoot. In the result, hybrid controller performed the best in term of fast rise time with unobvious error occurred. In next research, Chang et al (2011) made the comparison between with and without enhancing fuzzy controller in traditional antenna position control system which was functioned by PID controller. They proved that the system with enhanced fuzzy controller worked better than traditional one.

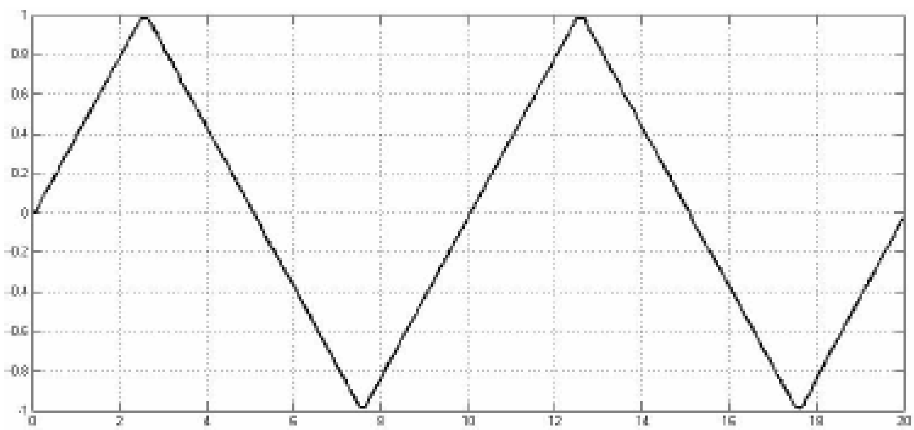

Figure 2.1.6 Output response with fuzzy PID controller

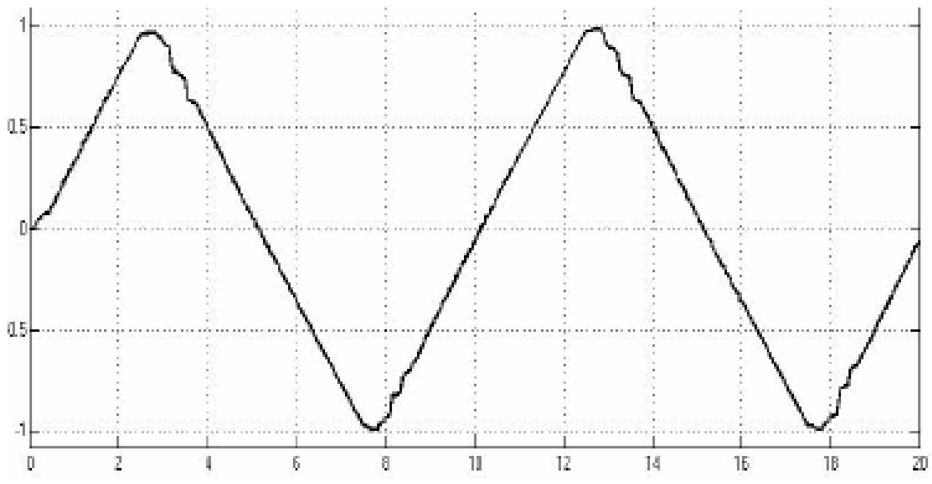

Figure 2.1.7 Output response with only PID controller

Comparing Figure 2.1.6 and Figure 2.1.7, the one with fuzzy PID control method generated more stable wave than the one with only PID control method, this showed that the performance of antenna position control system with fuzzy PID controller is better.

2.2 Critical Remarks of Previous Works

Based on the first type of study which was the performance comparison between different controller used in antenna system, they implemented same control system knowledge and standards to justify a good controller on antenna system, which are low overshoot, small settling time and zero steady-state error. This proves that the importance of these standards on judging the system performance. Besides, one of these studies also provided a tuning method into antenna system in order to perform fast settling time which enables short period restoration of the system back to origin, which is Ziegler-Nichols algorithm. For the second type of study called the performance comparison between single and combined controller added in antenna system, the strength inside them was that they obtained the results of antenna system with both single controller and combination of controller in order to justify that which design of controller was better to be selected. Overall, those designers had shown a similar good practice that they always investigate the antenna system from various kinds of design and implementation to determine the best way of designing their desired antenna system.

However, there were some weaknesses found inside these two types of researches. Firstly, the conditions set for their simulations were not strong enough to confirm that their antenna systems will function appropriately in real life. Other than focusing on the values of overshoot, settling time and steady state, the frequency domain standards which are gain and phrase margins, should also be counted into their system specifications. In addition, based on the graph plots shown in these researches, some of them presented their works in curve graph form but some others showed different shapes of graph. This will confuse readers on understanding the representation of various graph plots and this will also cause the readers' suspicion on the trueness of certain project done.

Last but not least, both types of research partially covered the theme of this project but they were still important to be the contents of this literature review because they contained the design method and simulation result of the antenna system using PID controller, and these will be huge help in this project.

2.3 Comparison Between Proposed Study and Previous Works

In this project, its development highly follows the steps of control system design process. This proves that the project is able to be completed under clear situation without skipping any important message, and this can reduce the number of mistakes happened during this process. In the previous works, they are lack of some information such as simplification of block diagram from multiple to single block, calculation of transfer function of control system and others, on the research paper and this shows that the designers may miss certain necessary stage to be done.

Furthermore, this project has the assist of a computer software called MATLAB. This software supports on solving the calculation of complex equation, building various types of block diagram, plotting graphs according to the transfer function inserted and also tuning the values of several species of compensator. With the existence of MATLAB software in this project, this guarantees that the results expected are successfully obtained and comparable to most of the facts explored on website or document, unlike the previous works, for example, the uncommon triangular wave shape on estimating the system stability.

Moreover, the digitalisation of antenna system is a major task to be accomplished because antenna system works more effective in digital space, referring to the comparison between analogue and digital signals. However, previous works stop their process after explaining the control system in analogue method only and this reflects that they abandoned the significances of digital antenna system for real life operation and working consistency. In order to achieve this goal, this project undergoes the process of converting antenna system from analogue to digital form.

3.1 Section A: Mathematical Function Calculation of Block Diagram of Antenna System

There are a few of original information given for this project which are Figure 3.1.1, Figure 3.1.2 and Table 3.1.1. From step 1 to 4 which are according to control system design process, are covered in Section A.

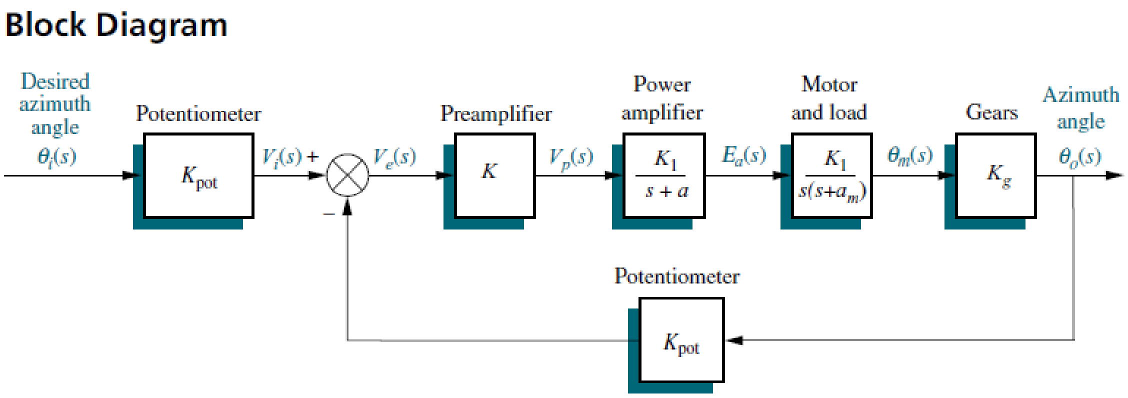

Figure 3.1.1 Block diagram of antenna system

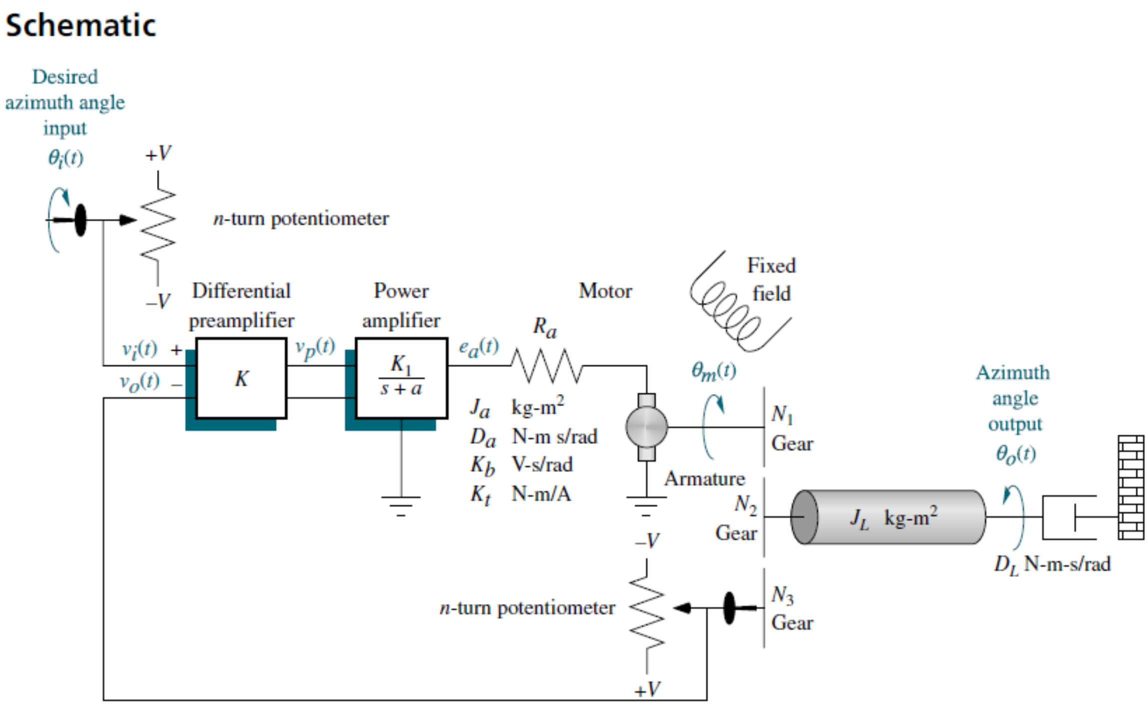

Figure 3.1.2 Schematic diagram of antenna system

Schematic Parameters

Parameter	Configuration	Definition	Unit
V	10	Voltages across potentiometer	V
n	1	Turns of potentiometer	-
K	-	Gain of preamplifier	-
K_1	150	Gain of power amplifier	-
a	150	Pole of power amplifier	-
R_a	5	Resistance of motor	ohm
J_a	0.05	Constant of motor inertial	kg-m^2
D_a	0.01	Constant of motor damping	N-m s/rad
K_b	1	Constant of back electromotive force	V-s/rad
K_t	1	Constant of motor torque	N-m/A
N_1	50	Teeth of Gear 1	-
N_2	250	Teeth of Gear 2	-
N_3	250	Teeth of Gear 3	-
J_L	5	Constant of load inertial	kg-m^2
D_L	3	Constant of load damping	N-m s/rad

Table 3.1.1 Schematic parameters of antenna system

Figure 3.1.1 shows that the antenna system of this project is consisted of 5 sub blocks and each of them has its own transfer function. To build the linkage between the block and schematic patterns of antenna system, block diagram parameters is required to be figured out. Therefore, this project is started by evaluating the calculation and transfer function of each sub blocks based on the resources given at Figure 3.1.1, Figure 3.1.2 and Table 3.1.1.

First of all, there are two potentiometers in the block diagram where one is at input way and another is at feedback way, and they have same transfer function which is a gain. The function of potentiometer is to convert angle form, $\theta_i(s)$, to voltage form, $V_i(s)$. The value of potentiometer gain, K_{pot}, is calculated in Calculation 3.1.1.

$$\frac{\theta_i(s)}{V_i(s)} = K_{pot} = \frac{V}{n\pi} = \frac{10}{1\pi} = 3.18$$

Calculation 3.1.1

Next, talking about the preamplifier, its job is to regulate its input voltage from potentiometer, $V_e(s)$, to an output voltage, $V_p(s)$, which is useable for power amplifier. The preamplifier gain,

K, is similar to proportional gain, K_p, of PID controller when PID controller is worked without integral and derivative gains. Hence, the gain takes 1 as default value and its value is adjustable because it affects the stability of antenna system. Calculation 3.1.2 shows the mathematical function of preamplifier.

$$\frac{V_p(s)}{V_e(s)} = K$$

Calculation 3.1.2

Then, moving on to the power amplifier, its transfer function is developed to change its input voltage from preamplifier, $V_p(s)$, to another voltage form, $E_a(s)$, that the motor can accept. The calculation of its mathematical function is provided in Calculation 3.1.3.

$$\frac{E_a(s)}{V_p(s)} = \frac{K_1}{s+a} = \frac{150}{s+150}$$

Calculation 3.1.3

After that, the fourth sub block is the motor and load and its schematic pattern is in Figure 3.1.3.

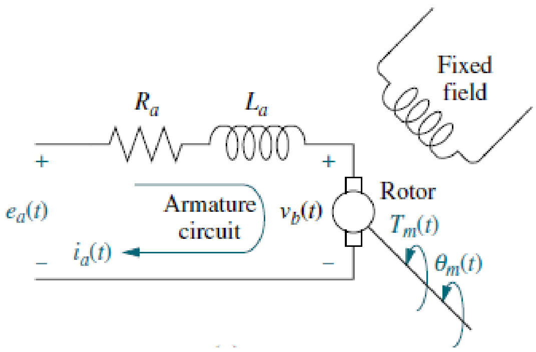

Figure 3.1.3 Schematic structure of DC motor

The motor produces mechanical output by the input voltage from power amplifier. Focusing on the input voltage of motor, $E_a(s)$, by using Kirchhoff's Voltage Law, its equation is created as Equation 3.1.1.

$$R_a I_a(s) + L_a s I_a(s) + V_b(s) = E_a(s)$$

Equation 3.1.1

From Equation 3.1.1, due to no configuration provided for input current, $I_a(s)$, the equation of relating motor torque constant, $T_m(s)$, and input current, is created as Equation 3.1.2.

$$I_a(s) = \frac{T_m(s)}{K_t}$$

Equation 3.1.2

By using Laplace transform, the back electromotive force equation is derived from velocity to position as Equation 3.1.3.

$$V_b(s) = K_b s \theta_m(s)$$

Equation 3.1.3

The uses of equivalent inertia, J_m, and damping, D_m, of motor which are linked with torque constant, produces an equation as Equation 3.1.4.

$$T_m(s) = (J_m s^2 + D_m s)\theta_m(s)$$

Equation 3.1.4

After substituting Equation 3.1.2 followed by Equation 3.1.3 and Equation 3.1.4, into Equation 3.1.1, the new format of the input voltage of motor is shown as Equation 3.1.5.

$$\frac{(R_a + L_a s)(J_m s^2 + D_m s)\theta_m(s)}{K_t} + K_b s \theta_m(s) = E_a(s)$$

Calculation 3.1.5

From Equation 3.1.5, there is an inductance, L_a, and it only contains very little effect towards this equation. After ignoring the inductance and performing last simplification, the mathematical function of motor is produced as Equation 3.1.6.

$$\frac{\theta_m(s)}{E_a(s)} = \frac{\frac{K_t}{R_a J_m}}{s[s + \frac{1}{J_m}(D_m + \frac{K_t K_b}{R_a})]}$$

Equation 3.1.6

The values of equivalent inertia, J_m, and equivalent damping, D_m, are evaluated in Calculation 3.1.4 and Calculation 3.1.5.

$$J_m = J_a + J_L(\frac{N_1}{N_2})^2 = 0.05 + 5\left(\frac{50}{250}\right)^2 = 0.25$$

Calculation 3.1.4

$$D_m = D_a + D_L(\frac{N_1}{N_2})^2 = 0.01 + 3\left(\frac{50}{250}\right)^2 = 0.13$$

Calculation 3.1.5

By using the values from schematic configurations and calculation results in motor part, the finalized mathematical function of motor is solved as Calculation 3.1.6.

$$\frac{\theta_m(s)}{E_a(s)} = \frac{K_m}{s(s+a_m)} = \frac{\frac{K_t}{R_a J_m}}{s[s+\frac{1}{J_m}(D_m + \frac{K_t K_b}{R_a})]} = \frac{\frac{1}{5(0.25)}}{s[s+\frac{1}{0.25}(0.13+\frac{1(1)}{5})]} = \frac{0.8}{s(s+1.32)}$$

Calculation 3.1.6

Lastly, observing Figure 3.1.4, Gear 1 teeth, N_1, and Gear 2 teeth, N_2, is functioned mutually. The value of the sub block of gear which is called gear ratio, K_g, is shown in Calculation 3.1.7.

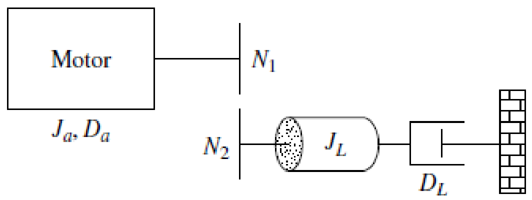

Figure 3.1.4 DC motor and rotational load

$$\frac{\theta_o(s)}{\theta_m(s)} = K_g = \frac{N_1}{N_2} = \frac{50}{250} = 0.2$$

Calculation 3.1.7

After solving all mathematical functions of sub block, the original and completed mathematical functions are differentiated at Table 3.1.2. From that table, every block diagram parameter is found and a new block diagram with completed mathematical functions is formed.

Sub Block	Mathematical Functions	
	Original	Completed
Potentiometer	K_{pot}	3.18

Preamplifier	K	K
Power amplifier	$\frac{K_1}{s+a}$	$\frac{150}{s+150}$
Motor and load	$\frac{K_m}{s(s+a_m)}$	$\frac{0.8}{s(s+1.32)}$
Gear	K_g	0.2

Table 3.1.2 Original and completed mathematical function of each sub block

Block Diagram Parameters			
Parameter	Configuration	Definition	Unit
K_{pot}	3.18	Gain of potentiometer	-
K	-	Gain of preamplifier	-
K_1	150	Gain of power amplifier	-
a	150	Pole of power amplifier	-
K_m	0.8	Gain of motor and load	-
a_m	1.32	Pole of motor and load	-
K_g	0.2	Gear ratio	-

Table 3.1.3 Block diagram parameters of antenna system

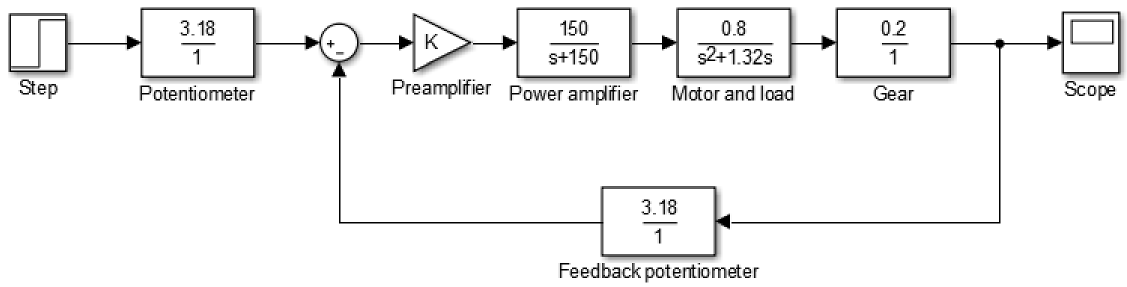

Figure 3.1.5 Block diagram of antenna system with completed mathematical functions

3.2 Section B: Design of Open Loop and Closed Loop Antenna System

In Section B, the open loop and closed loop antenna system designing, and the finding of preamplifier gain, K, which is to stabilize the system through specific requirements, are conducted. Overall, knowledge of step 5 which is mentioned in design process, will be adopted here.

Starting from the designing of open loop antenna system, the sub blocks involved are only power amplifier, motor and load, and gear. Figure 3.2.1 shows the designed open loop system. By using the block reduction technique, the transfer function of the open loop antenna system, $G(s)$, is summarised in Calculation 3.2.1. It does not require the potentiometer and preamplifier because this design does not loop back the output value for checking and thus, the gain, K, is need not to be implemented.

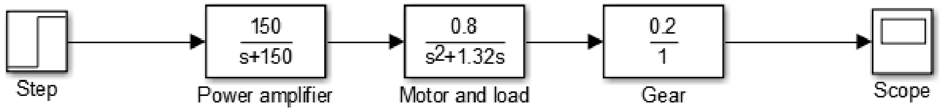

Figure 3.2.1 Original block diagram of open loop antenna system

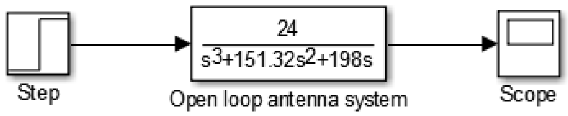

Figure 3.2.2 Final single block of open loop antenna system

$$G(s) = \frac{150}{s + 150} \times \frac{0.8}{s(s + 1.32)} \times 0.2 = \frac{24}{s^3 + 151.32s^2 + 198s}$$

Calculation 3.2.1

Secondly, for the closed loop antenna system development, the model is same as Figure 3.1.5 which involves the improvement of output response to reach desired response. Figure 3.2.4 displays the completed single block of the system. The transfer function without counting feedback, $KG(s)$, following by the final transfer function with feedback, $T(s)$, using Equation 3.2.1, are obtained at Calculation 3.2.2. The value of feedback, $H(s)$, is equal to 1.

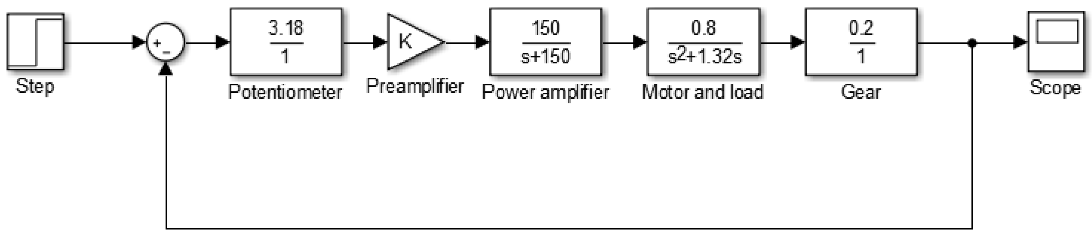

Figure 3.2.3 Adjusted blocks of closed loop antenna system with remained feedback

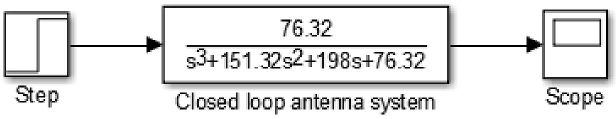

Figure 3.2.4 Final single block of closed loop antenna system ($K = 1$)

$$T(s) = \frac{KG(s)}{1 + KG(s)H(s)}$$

Equation 3.2.1

$$KG(s) = 3.18 \times K \times \frac{150}{s + 150} \times \frac{0.8}{s(s + 1.32)} \times 0.2 = \frac{76.32K}{s^3 + 151.32s^2 + 198s}$$

$$T(s) = \frac{\frac{76.32K}{s^3 + 151.32s^2 + 198s}}{1 + \frac{76.32K}{s^3 + 151.32s^2 + 198s}(1)} = \frac{76.32K}{s^3 + 151.32s^2 + 198s + 76.32K}$$

Calculation 3.2.2

In order to understand more about the characteristic between open loop and closed loop antenna systems, plotting step response graph for each type is a good method because there are some differences between the two graphs. The code of Appendix A is used with MATLAB software to generate the graphs of these systems and deliver the values of certain quantities.

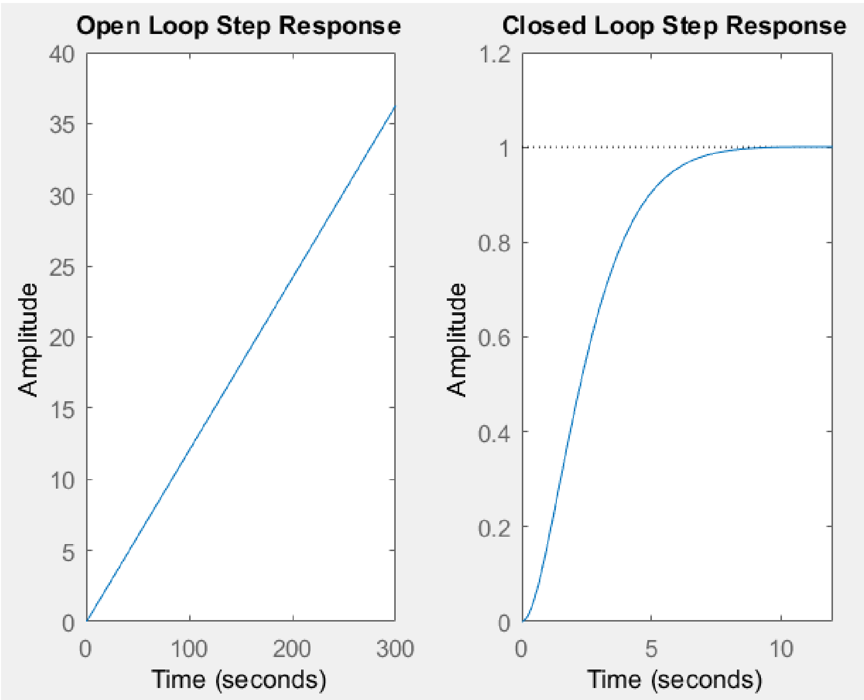

Figure 3.2.5 Step responses of open loop (left) and closed loop (right) antenna systems

```
ans =

Open Loop Transfer Function


g =

             24
  ----------------------
  s^3 + 151.3 s^2 + 198 s

Continuous-time transfer function.


ans =

        RiseTime: NaN
    SettlingTime: NaN
     SettlingMin: NaN
     SettlingMax: NaN
       Overshoot: NaN
      Undershoot: NaN
            Peak: Inf
        PeakTime: Inf
```

Figure 3.2.6 Step response information of open loop antenna system

```
ans =

Closed Loop Transfer Function


t =

                76.32
  ------------------------------
  s^3 + 151.3 s^2 + 198 s + 76.32

Continuous-time transfer function.


ans =

        RiseTime: 4.1889
    SettlingTime: 6.9505
     SettlingMin: 0.9026
     SettlingMax: 1.0005
       Overshoot: 0.0537
      Undershoot: 0
            Peak: 1.0005
        PeakTime: 11.4729
```

Figure 3.2.7 Step response information of closed loop antenna system

Observing the result of open loop antenna system from Figure 3.2.5 and Figure 3.2.6, the step response graph shows a ramp output and all information reflected towards this system are undefined. This indicates that this system does not have steady state and it is unstable. While looking through the closed loop system result, when the preamplifier gain, K, is set to 1, the graph shows a critically damped curve and its information are filled by different values. The curve in the graph reaches the steady state value which is 1 and then sticks on that value horizontally, this proves that the system is able to be stable once the overshoot is over. The end of curve of this system will always achieve the steady state value as long as the gain is tuned within its certain range. Therefore, this analysis concludes that closed loop antenna system is more suitable to be built for real time functioning.

3.3 Section C: Preamplifier Gain Finding of Closed Loop Antenna System

Talking about the preamplifier gain, K, it is important to figure out its range so that its value will not be over modified and the closed loop antenna system stability will be in controllable stage. There are several methods to find the maximum gain, K_{max}, but through the knowledge of root locus graph, Appendix B code is developed to find the value of maximum gain using MATLAB software. The code is to insert value starting from 1 sequentially into the gain of the closed loop transfer function until the nearest poles towards the line of imaginary axis at left half plane are pointed out, and then the latest value used in the gain will be the maximum gain value. Figure 3.3.1 shows the results of the position of targeted poles and value of maximum gain, and its value is 392.

```
ans =

Gain Finding Through Root Locus


poles =

   1.0e+02 *

  -1.5132 + 0.0000i
   0.0000 + 0.1409i
   0.0000 - 0.1409i


kmax_rl =

   392
```

Figure 3.3.1 Results of poles position and maximum gain value

There is a manual calculation way to solve the finding of maximum gain which is Routh Hurwitz criterion. It helps designer on calculating the range of gain to yield stability as well as counts designer the number of poles lying on the line of real axis. The unknown 'a's inside Routh table is needed to fill with the coefficients of the denominator in closed loop antenna system transfer function. In Table 3.3.1, if assuming the gain value, K, as positive, all values in first column are positive, except for the equation in s^1 row which may be positive, zero or negative. Therefore, that equation is taken into calculation to determine the value of maximum gain, K_{max}, by letting the equation to be smaller than zero. Calculation 3.3.1 shows the mathematical steps of finding gain value and the value obtained is 392 which is same to the value get from Appendix B code.

s^4	a_4	a_2	a_0
s^3	a_3	a_1	0
s^2	$\frac{-\begin{vmatrix} a_4 & a_2 \\ a_3 & a_1 \end{vmatrix}}{a_3} = b_1$	$\frac{-\begin{vmatrix} a_4 & a_0 \\ a_3 & 0 \end{vmatrix}}{a_3} = b_2$	$\frac{-\begin{vmatrix} a_4 & 0 \\ a_3 & 0 \end{vmatrix}}{a_3} = 0$
s^1	$\frac{-\begin{vmatrix} a_3 & a_1 \\ b_1 & b_2 \end{vmatrix}}{b_1} = c_1$	$\frac{-\begin{vmatrix} a_3 & 0 \\ b_1 & 0 \end{vmatrix}}{b_1} = 0$	$\frac{-\begin{vmatrix} a_3 & 0 \\ b_1 & 0 \end{vmatrix}}{b_1} = 0$
s^0	$\frac{-\begin{vmatrix} b_1 & b_2 \\ c_1 & 0 \end{vmatrix}}{c_1} = d_1$	$\frac{-\begin{vmatrix} b_1 & 0 \\ c_1 & 0 \end{vmatrix}}{c_1} = 0$	$\frac{-\begin{vmatrix} b_1 & 0 \\ c_1 & 0 \end{vmatrix}}{c_1} = 0$

Figure 3.3.2 Routh table

s^3	1	198
s^2	151.32	$76.32K$
s^1	$\dfrac{-\begin{vmatrix} 1 & 198 \\ 151.32 & 76.32K \end{vmatrix}}{151.32} = \dfrac{29961.36 - 76.32K}{151.32}$	0
s^0	$\dfrac{-\begin{vmatrix} 151.32 & 76.32K \\ \frac{29961.36 - 76.32K}{151.32} & 0 \end{vmatrix}}{\frac{29961.36 - 76.32K}{151.32}} = 76.32K$	0

Table 3.3.1 Completed Routh table of closed loop antenna system

$$\frac{29961.36 - 76.32K}{151.32} > 0$$

$$-76.32K > -29961.36$$

$$K < 392.58$$

$$K_{max} \approx 392$$

Calculation 3.3.1

To prove that the maximum gain, K_{max}, is true, its value can be set into the closed loop system to generate some graphs for observation. From Figure 3.3.3, there are several evidences to explain the correctness of maximum gain value. In the step response graph, the percent overshoot is 99.4 and this shows that the antenna system is almost unstable because the actual percent overshoot value that makes system to be totally unbalanced is 100. Besides, in the root locus graph, when zooming in the area where two curves intercept the imaginary axis, the poles nearly occur at the right half plane which indicates the unstable situation of the antenna system. In addition, adding more than 1 into the current maximum gain value and then implementing into the antenna system will display the non-steady graphs. For example, the step response starts oscillating at the right side of the graph and the root locus poles also occur in the right half plane, these are the senses of an unsteady system. The code of Appendix C provides the graph slots showing the differences between stable and unstable closed loop antenna system.

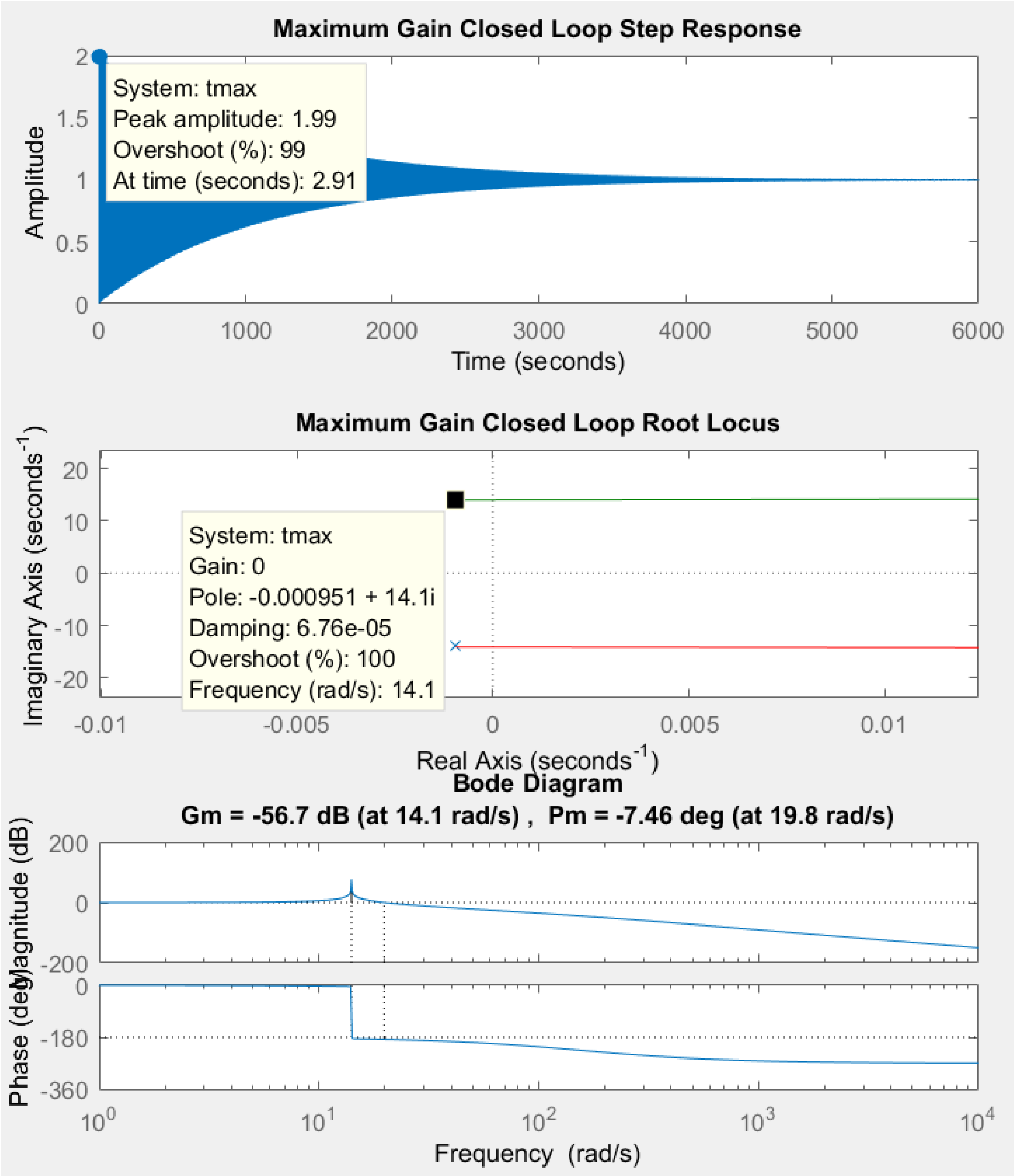

Figure 3.3.3 Step response, root locus and bode plot of closed loop antenna system with maximum preamplifier gain ($K_{max} = 392$)

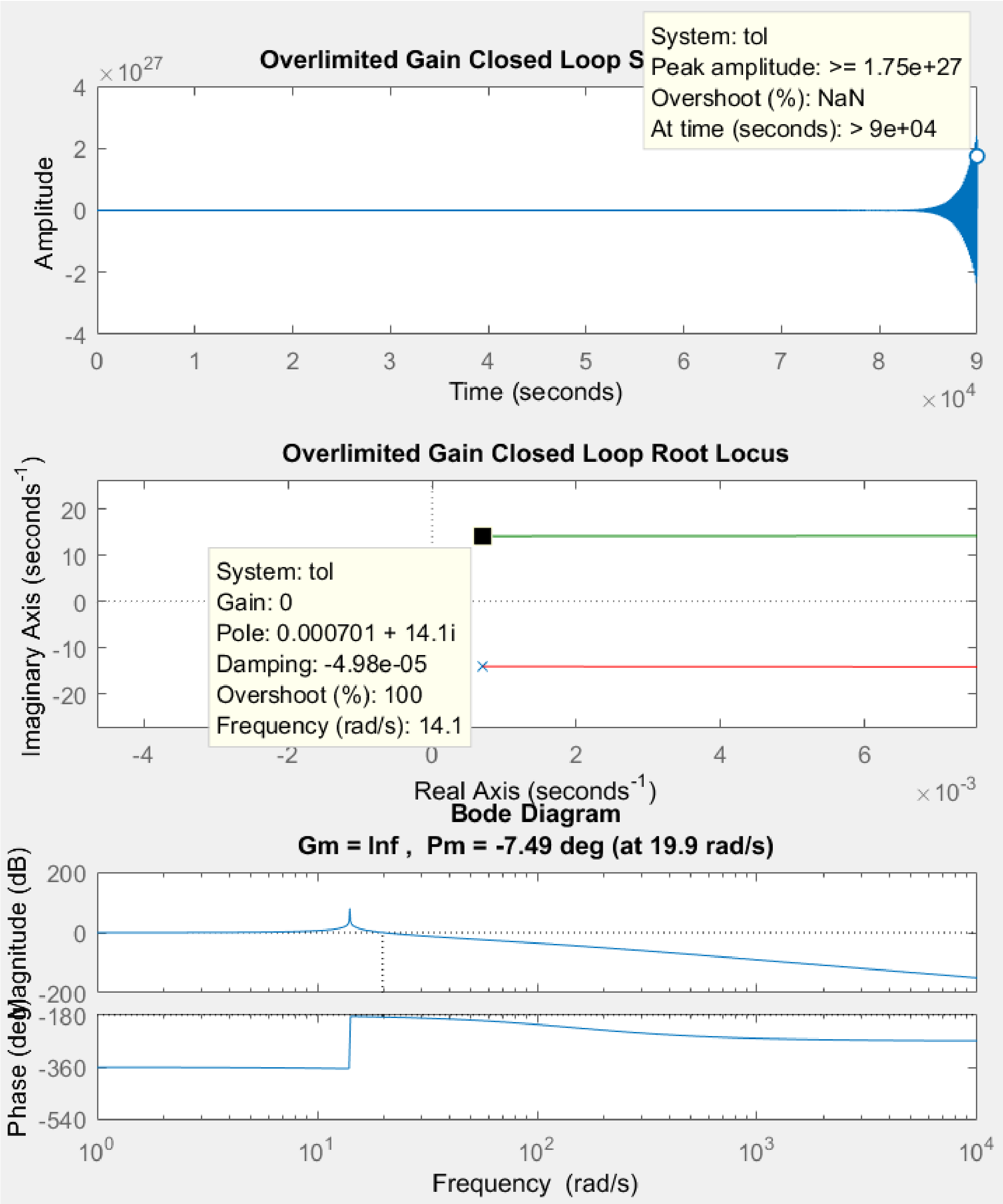

Figure 3.3.4 Step response, root locus and bode plot of unstable closed loop antenna system ($K > 392$)

```
ans =

Stable Closed Loop Antenna System


tmax =

               2.992e04
  ----------------------------------
  s^3 + 151.3 s^2 + 198 s + 2.992e04

Continuous-time transfer function.


ans =

        RiseTime: 0.0978
    SettlingTime: 4.1095e+03
     SettlingMin: 0.0112
     SettlingMax: 1.9903
       Overshoot: 99.0321
      Undershoot: 0
            Peak: 1.9903
        PeakTime: 2.9059
```

Figure 3.3.5 Step response information of stable closed loop antenna system ($K_{max} = 392$)

```
ans =

Unstable Closed Loop Antenna System


tol =

               2.999e04
  ----------------------------------
  s^3 + 151.3 s^2 + 198 s + 2.999e04

Continuous-time transfer function.


ans =

        RiseTime: NaN
    SettlingTime: NaN
     SettlingMin: NaN
     SettlingMax: NaN
       Overshoot: NaN
      Undershoot: NaN
            Peak: Inf
        PeakTime: Inf
```

Figure 3.3.6 Step response information of unstable closed loop antenna system ($K > 392$)

3.4 Section D: Tuning of PID Controller in Closed Loop Antenna System

The step 6 in the design process of antenna system is processed in this section. After having a completed design of closed loop antenna system, the system will be implemented PID controller to improve its stability. In this tuning section, there are two types of method applied, namely Ziegler Nichols tuning method and root locus tuning method. PID controller can be created in several forms such as P, PI, PD and PID types, but in order to provide full benefits from all terms in PID controller which are proportional gain, K_p, integral gain, K_i, and derivative gain, K_d, to the closed loop antenna system, this project aims to develop PID-type controller from two mentioned methods. In this case, for every final version of transfer function with PID controller, the preamplifier is replaced by PID controller or its gain, K, is set to 1. Equation 3.4.1 is the PID controller mathematical function.

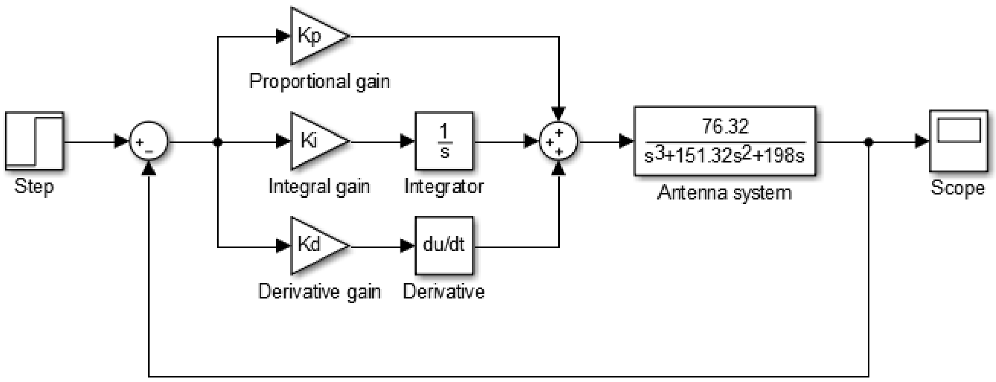

Figure 3.4.1 Closed loop antenna system with PID controller

$$C_{pid}(s) = K_p + \frac{K_i}{s} + K_d s$$

Equation 3.4.1

First and foremost, Ziegler Nichols method has its own tuning rule to be followed and thus it is popular and convenient for all designers, especially beginners, to study and understand system stability. The first step of this PID controller design method is to find out ultimate gain, K_u, which is the value to make the antenna system marginally stable. Using back the previous section work, the value of maximum gain, K_{max}, will be the value of ultimate gain which is 392, as the maximum gain also gives the system slightly stable. Then, the second step is to find the ultimate period, T_u. By enlarging the step response graph of the antenna system with ultimate gain within 1 to 50 seconds, every overshoot seems to be having the same peak percent. From there, ultimate period can be determined from the difference between the peak time of any two overshoots. Calculation 3.4.1 counts the values of proportional gain, integral gain, and derivative gain, through the tuning rule of PID control type in Figure 3.4.2, and also the closed loop antenna system transfer function with PID controller, $T_{znpid}(s)$. Appendix D code enlarges top left corner of the antenna system step response with ultimate gain to figure out ultimate period, while others are the graph plots of the antenna system after getting the tuning values of PID controller.

Control Type	Kp	Ki	Kd
P	0.5*Ku	-	-
PI	0.45*Ku	1.2*Kp/Tu	-
PID	0.6*Ku	2*Kp/Tu	Kp*Tu/8

Figure 3.4.2 Gain parameter calculation of Zeigler Nichols method

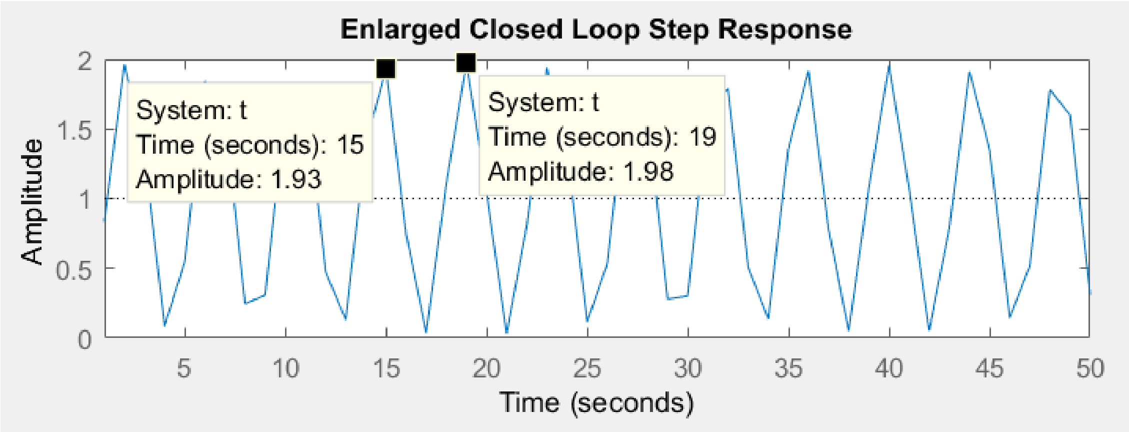

Figure 3.4.3 Enlarged step response graph of closed loop antenna system with ultimate gain (K_u = 392) within 1 to 50 seconds

$$K_u = 392, T_u = 4$$

$$K_p = 0.6 \times K_u = 0.6 \times 392 = 235.2$$

$$K_i = 2 \times \frac{K_p}{T_u} = 2 \times \frac{235.2}{4} = 117.6$$

$$K_d = K_p \times \frac{T_u}{8} = 235.2 \times \frac{4}{8} = 117.6$$

$$C_{znpid}(s) = 235.2 + \frac{117.6}{s} + 117.6s$$

$$T_{znpid}(s) = \frac{8975s^2 + 17950s + 8975}{s^4 + 151.32s^3 + 9173s^2 + 17950s + 8975}$$

Calculation 3.4.1

Next, root locus tuning method is learnt from a control engineering related book and it mainly requires the knowledge of understanding roles of pole and zero. To start this method, there are some requirements to be set up so that the PID compensated antenna system achieves them. The condition is, after PID controller is designed for antenna system, the system has to operate faster than its uncompensated form at 20 percent overshoot, and reach steady state from its output response. The first step is to adjust the preamplifier gain, K, of transfer function of uncompensated antenna system shown in Equation 3.4.2 using root locus graph to reaches 20 percent overshoot and observe the data shown on graph plots after completing the adjustment.

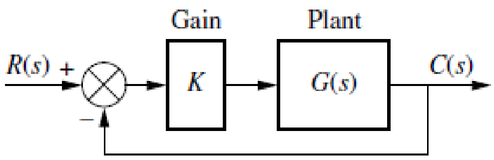

Figure 3.4.4 Uncompensated control system

$$K \times G(s) = \frac{76.32K}{s(s + 150)(s + 1.32)}$$

Equation 3.4.2

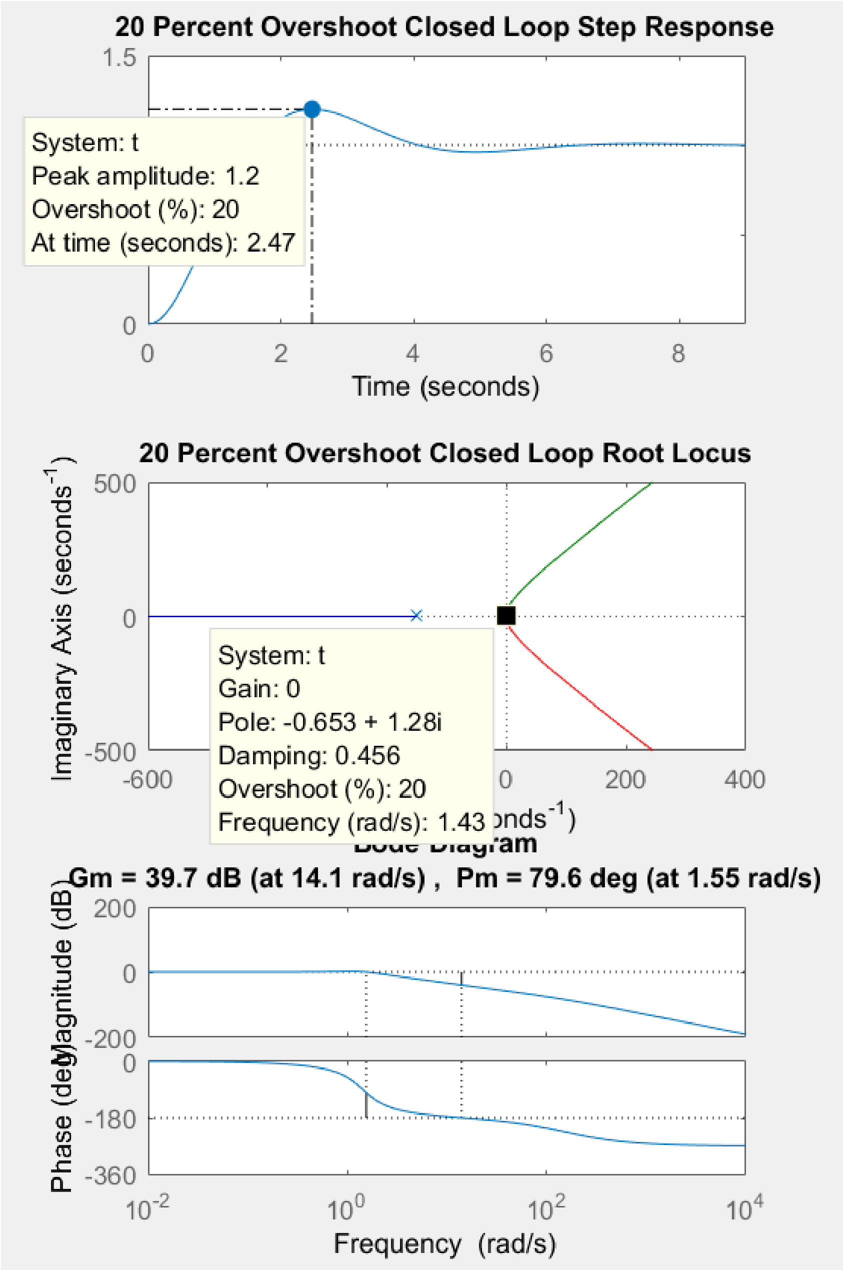

Figure 3.4.5 Graph results of closed loop antenna system with 20 percent overshoot

After implementing 4.04 gain value, Figure 3.4.5 shows that the graph plots of 20 percent overshoot antenna system are obtained. From the data of root locus graph, the dominant poles are allocated at $-0.653 \pm 1.28i$ and the damping ratio is 0.456, while from the step response graph, peak time of 20 percent overshoot is 2.47 seconds.

Next, to fasten the peak time, T_p, PD controller has to be developed first. After reducing the peak time to $\frac{2}{3}$ times of it, the desired peak time, T_{pde}, is used to calculate the imaginary value of desired dominant pole, ω_d. The real value of desired dominant pole, $\xi\omega_n$, is counted from obtaining an angle, θ, from the origin to the point of 0.456 damping ratio, ξ, shown in root locus and then substitute the angle inside the equation for calculation.

$$T_{pde} = \frac{2}{3}(T_p) = \frac{2}{3}(2.47) = 1.65$$

$$\omega_d = \frac{\pi}{T_{pde}} = \frac{\pi}{1.65} = 1.9$$

$$\theta = cos^{-1}(\xi) = cos^{-1}(0.456) = 62.87$$

$$\xi\omega_n = \frac{\omega_d}{tan(\theta)} = \frac{1.9}{tan(62.87)} = 0.97$$

Calculation 3.4.2

After getting the value of 1.65 desired peak time and $-0.97 \pm 1.9i$ desired dominant poles, the position of PD controller's zero has to be estimated by calculating with other uncompensated poles and zeros lying on the real axis. From the denominator part in Equation 3.4.2, there are three poles at left half plane which are 0, -150 and -1.32, while there is no zero found at numerator part. Calculation 3.4.3 evaluates the outputs of the new zero angle, θ_z, and position, Z_z.

The pole which is within the range of real part of desired dominant poles (< -0.97):

$$\theta_1 = 180 - \left[tan^{-1}\left(\frac{1.9}{0.97 - 0}\right)\right] = 117.05$$

The pole which is outside the range of real part of desired dominant poles (> -0.97):

$$\theta_2 = tan^{-1}\left(\frac{1.9}{1.32 - 0.97}\right) = 79.56$$

$$\theta_3 = tan^{-1}\left(\frac{1.9}{150 - 0.97}\right) = 0.73$$

$$\theta_z = 180 - (sum\ of\ pole\ angles) + (sum\ of\ zero\ angles)$$

$$\theta_z = 180 - (117.05 + 79.56 + 0.73) = -17.34$$

$$\frac{1.9}{Z_z - 0.97} = tan(17.34)$$

$$Z_z = 7.06$$

Calculation 3.4.3

Since new zero position had found, the PD controller transfer function, $C_{PD}(s)$, is display in Equation 3.4.2.

$$C_{PD}(s) = K(s + 7.06)$$

Equation 3.4.2

For further improvement on the stability of PD compensated system, the integral compensator is needed to remove steady state error. Any integral compensator that its zero is positioned close to the origin, can be applied. Lastly, using 0.01 as the zero position of integral compensator, the I controller transfer function, $C_I(s)$, the PID controller transfer function, $C_{rlpid}(s)$, and the PID compensated closed loop antenna system transfer function, $T_{rlpid}(s)$, are completed in Calculation 3.4.5, assuming the gain value K as 1.

$$C_I(s) = \frac{s + 0.01}{s}$$

$$C_{rlpid}(s) = \frac{K(s + 7.06)(s + 0.01)}{s}$$

$$C_{rlpid}(s) \times G(s) = \frac{76.32K(s + 7.06)(s + 0.01)}{s^2(s + 150)(s + 1.32)}$$

$$T_{rlpid}(s) = \frac{76.32s^2 + 539.6s + 5.39}{s^4 + 151.32s^3 + 274.3s^2 + 539.6s + 5.39}$$

Calculation 3.4.5

Based on the results acquired through Ziegler Nichols tuning method and root locus tuning method, Table 3.4.1 which is about the result of transfer functions of PID controller and antenna system, and stability parameters, is made to make clear comparison between them. Appendix D and E are the codes which display various types of graph showing the two antenna systems with different tuning methods.

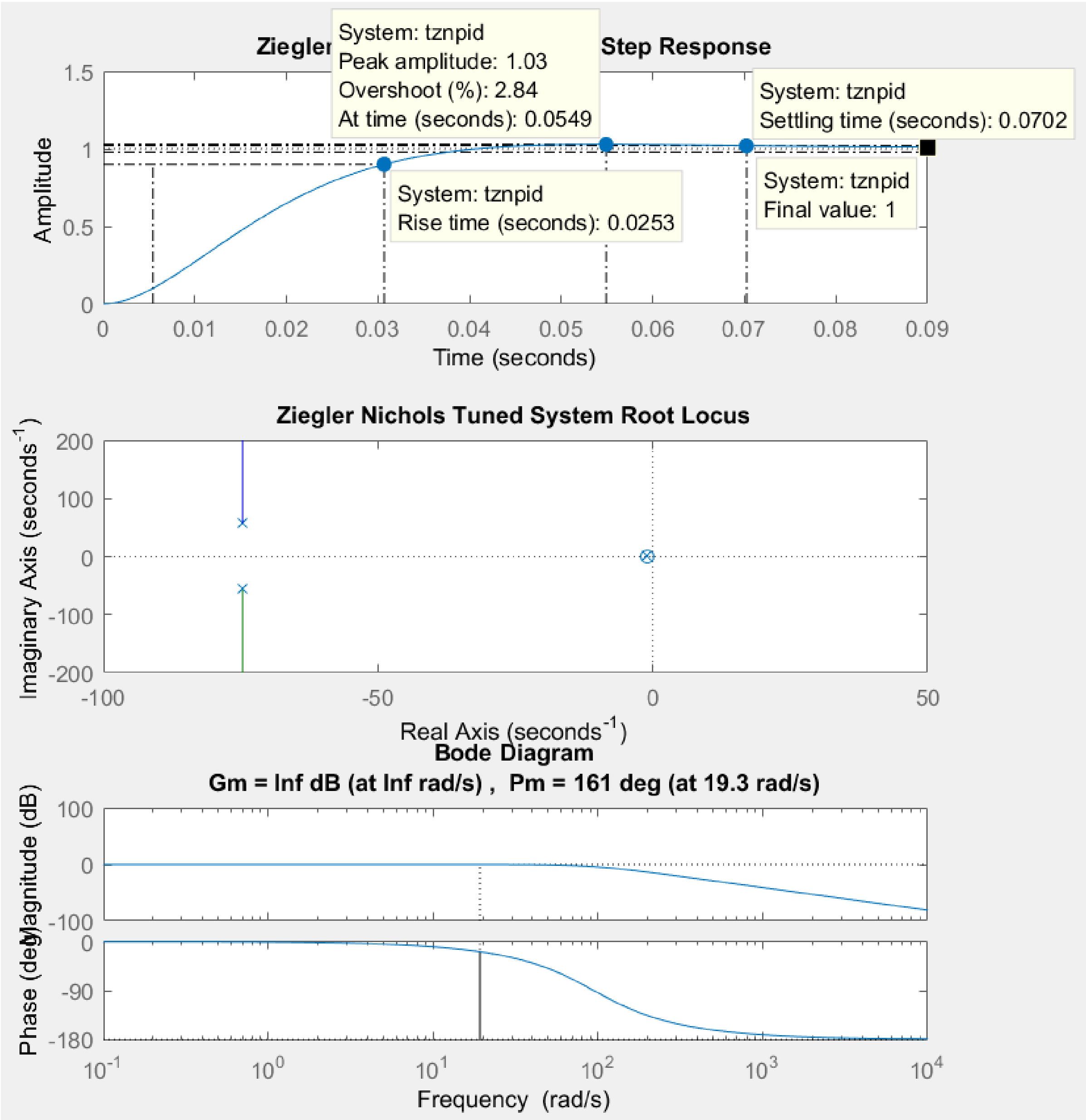

Figure 3.4.6 Graph plots of PID controlled antenna system with Ziegler Nichols tuning

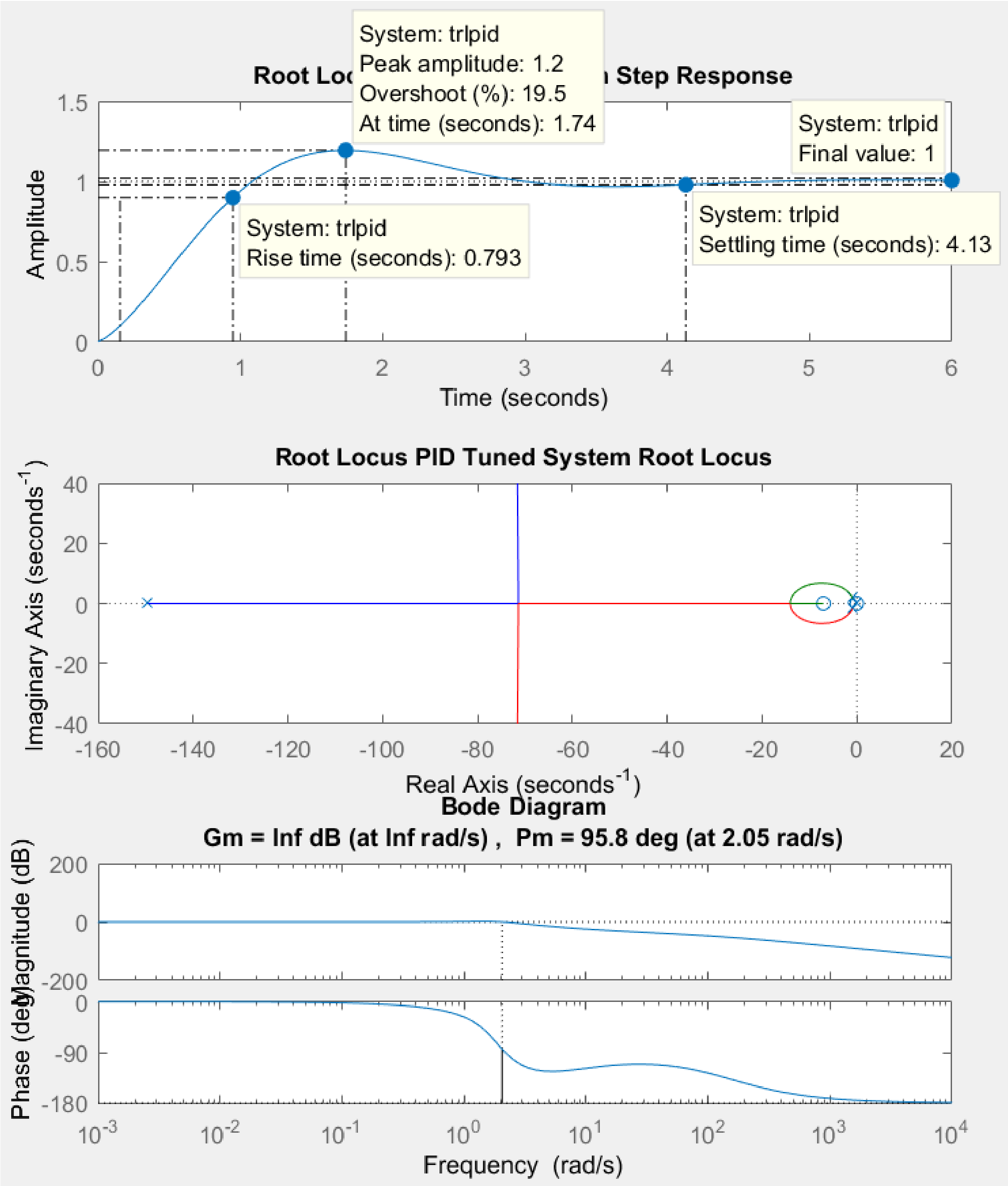

Figure 3.4.7 Graph plots of PID controlled antenna system with root locus tuning

Transfer Functions		
Tuning method	Ziegler Nichols tuning	Root Locus tuning
Proportional gain	235.2	7.07
Integral gain	117.6	0.07

Derivative gain	117.6	1
PID controller transfer function	$C_{znpid}(s) = 235.2 + \frac{117.6}{s} + 117.6s$	$C_{rlpid}(s) = \frac{1(s+7.06)(s+0.01)}{s}$
Closed loop antenna system with PID controller transfer function	$T_{znpid}(s) = \frac{8975s^2 + 17950s + 8975}{s^4 + 151.32s^3 + 9173s^2 + 17950s + 8975}$	$T_{rlpid}(s) = \frac{76.32s^2 + 539.6s + 5.39}{s^4 + 151.32s^3 + 274.3s^2 + 539.6s + 5.39}$
Stability Parameters		
Step response curve	Underdamped	Underdamped
Percent overshoot	2.84	19.5
Peak time (in second)	0.0549	1.74
Rise time (in second)	0.0253	0.793
Settling time (in second)	0.0702	4.13
Gain margin	Infinity	Infinity
Phase margin	161	95
Steady state value	1	1

Table 3.4.1 Transfer functions of PID controller and antenna system, and stability parameters

Based on Table 3.4.1, Ziegler Nichols tuning method uses higher control gain values than root locus tuning method in terms of proportional, integral and derivative. All outputs of Ziegler Nichols tuning in parameter part are greater than root locus tuning such as lower overshoot, faster rise and settling time, zero steady state error and others. But when comparing the requirement set for root locus tuning before and after conducting, the uncompensated system with 20 percent overshoot and 2.47 peak time, had been improved to PID compensated system with 19.4 overshoot and 1.74 peak time. Most importantly, that result of 1.74 peak time is very close to the desired peak time which is 1.65. This justifies that root locus tuning is more flexible than Ziegler Nichols tuning because Ziegler Nichols tuning can only evaluate the outputs in its own fixed formulas without considering the requirement provided.

In the conclusion, although Ziegler Nichols contains perfect results compared to root locus tuning, those results are ideal and the system with this tuning may not work as effective as its results shown. Therefore, root locus tuning is the better PID controller tuning method for antenna system.

3.5 Section E: Digitalisation of Antenna System

In order to enhance current analogue antenna system for physical operation, conversion of its signal type is needed. Analogue wave contains too much noises which are hard to filter out, this disturbs the accuracy of the data transferred, and then the signal is difficult to be stored in electronic devices for analysis and estimation. Therefore, the first stage of antenna system digitalisation is to alter the block diagram of analogue antenna system in Figure 3.2.3.

The new block needed for digital antenna system is digital computer which is used as input device to perform the analogue and digital wave conversions, and data sampling method, while the blocks to be removed are potentiometer and preamplifier, this block diagram is not included PID controller yet. There is some modification of the transfer function inside certain block. From Figure 3.5.1, the value of power amplifier is changed to 1 because, assuming that the distance between power amplifier and motor is long enough to make power amplifier as a pure gain, which will not affect the system process. Besides, the deduction of potentiometer and preamplifier is caused by the appearance of computer, absorbing both gains. 0.1 second is set for sampling interval.

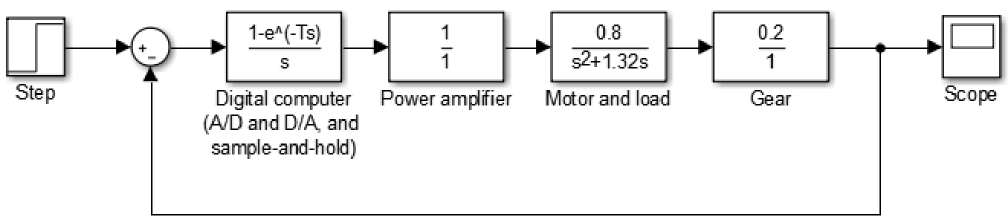

Figure 3.5.1 Block diagram of digital closed loop antenna system without controller

```
ans =

Digital Closed Loop Antenna System Without Controller


d_ztf =

  0.0007659 z^3 - 0.0007042 z^2 - 0.0007041 z + 0.0006423
  -------------------------------------------------------
      z^4 - 3.752 z^3 + 5.273 z^2 - 3.289 z + 0.7686

Sample time: 0.1 seconds
Discrete-time transfer function.


ans =

        RiseTime: 16.4000
    SettlingTime: 29.7000
     SettlingMin: 0.9010
     SettlingMax: 1.0000
       Overshoot: 0
      Undershoot: 0
            Peak: 1.0000
        PeakTime: 90.9000
```

Figure 3.5.2 Transfer function and step response information of digital closed loop antenna system without controller

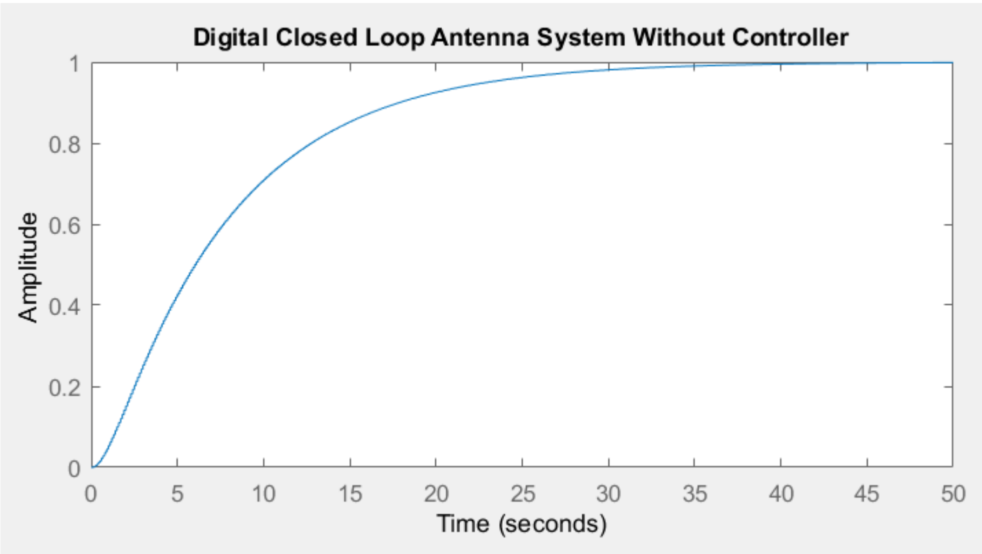

Figure 3.5.3 Step response of digital closed loop antenna system without controller

For the purpose of calculating the transfer function of this digital antenna system, the code of Appendix F is written and then executed using MATLAB software. Based on the step response information and graph displayed, although this digital antenna system seems balanced, these indicate that its performance is slow and low reliability, so PID controller is needed to further stabilize this system.

There are three patterns of PID controller tuning for the digital closed loop antenna system, namely PI, PD and PID. However, the root locus tuning method is eliminated for estimating values of PID controller because the format of current transfer function is z-transform and the hand-counting has high possibility getting calculation error. Hence, choosing proper applications provided from MATLAB software as evaluation tools is the best solution and the applications selected from this section are Control System Designer and PID Tuner.

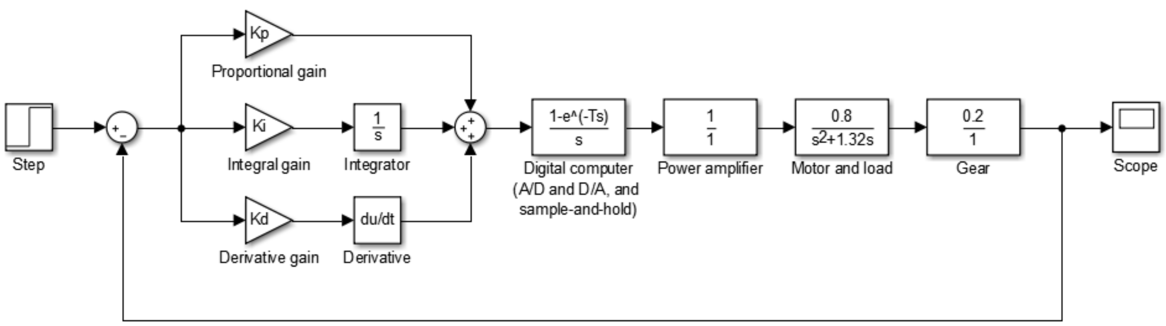

Figure 3.5.4 Block diagram of digital closed loop antenna system with PID controller

Figure 3.5.4 shows how the PID controller is inserted in the block diagram. Next, after importing digital antenna system transfer function to Control System Designer application and then selecting the PID controller as preferred compensator, the searching of suitable transfer functions of PI, PD and PID controller is started by keying in values of response time and transient behaviour. Every time an action of inputting these both values is made, the transfer function of the controller will be different and the application screen will demonstrate the graph plots of step response, root locus and bode plot, based on the effect of controller transfer function towards the digital antenna system.

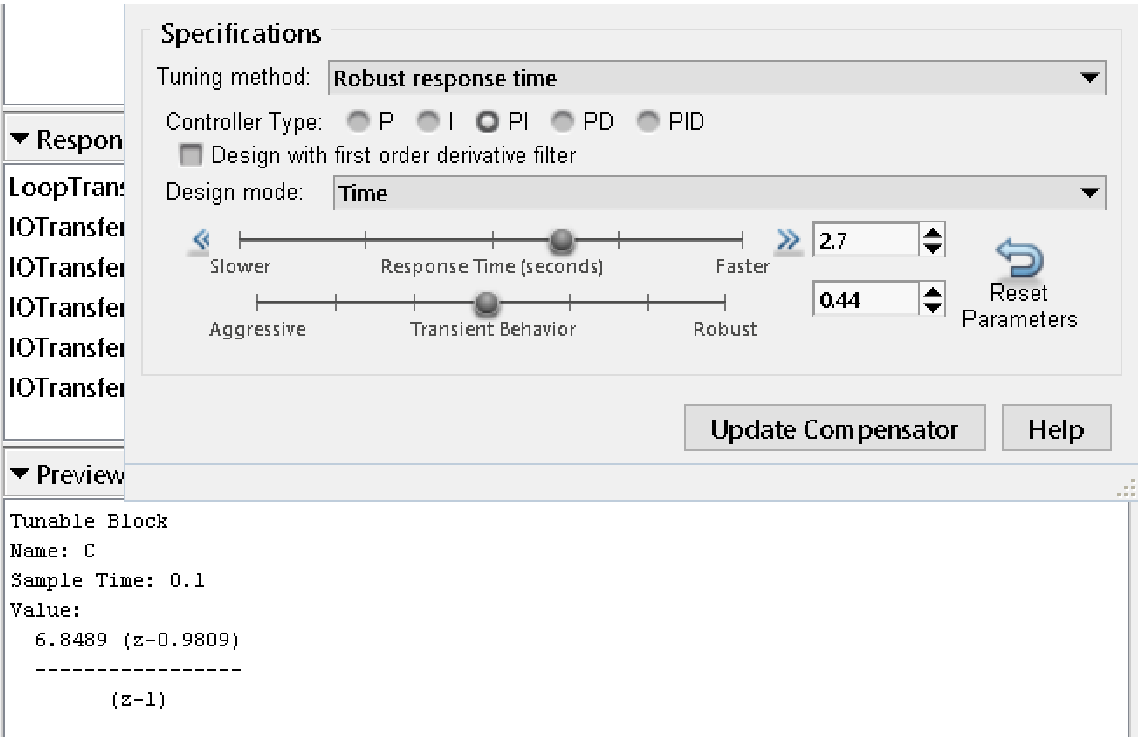

Figure 3.5.5 Response time and transient behaviour, and z-transform transfer function of PI controller (Control System Designer)

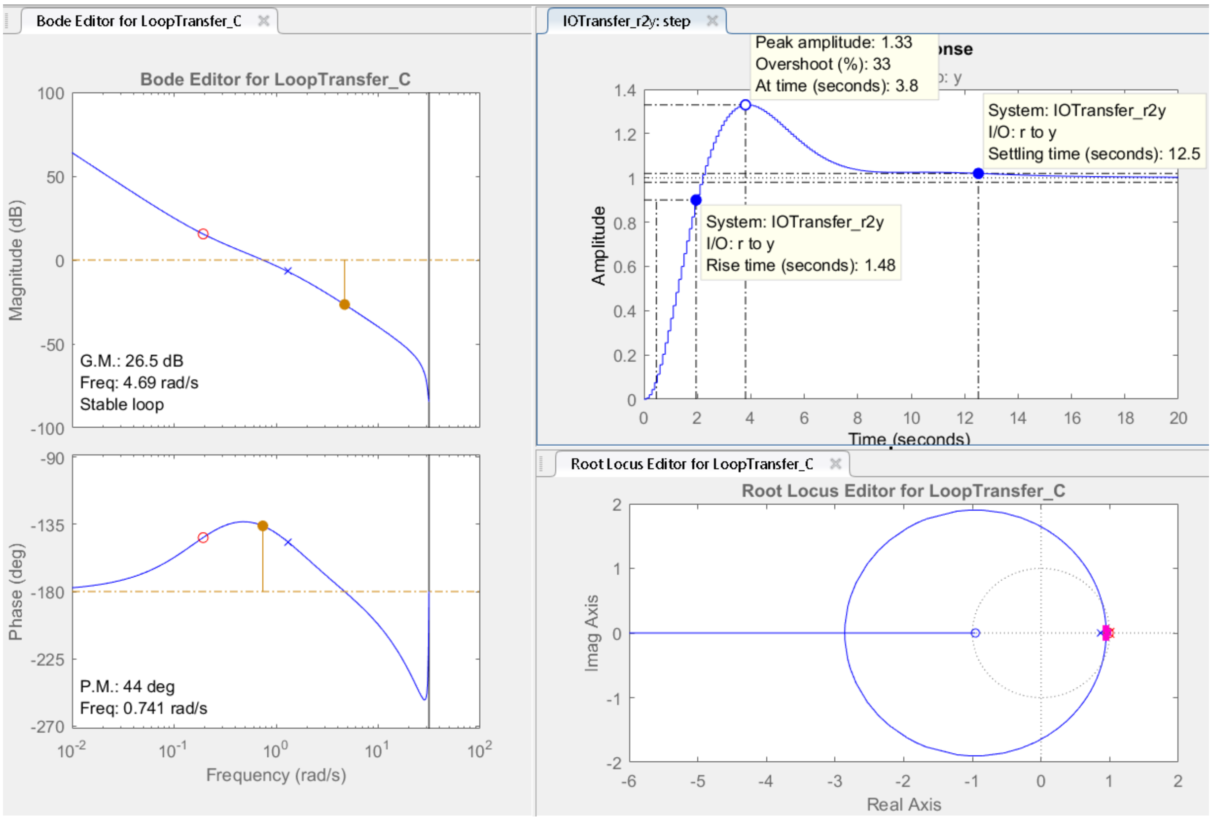

Figure 3.5.6 Graph plots of PI controlled antenna system (Control System Designer)

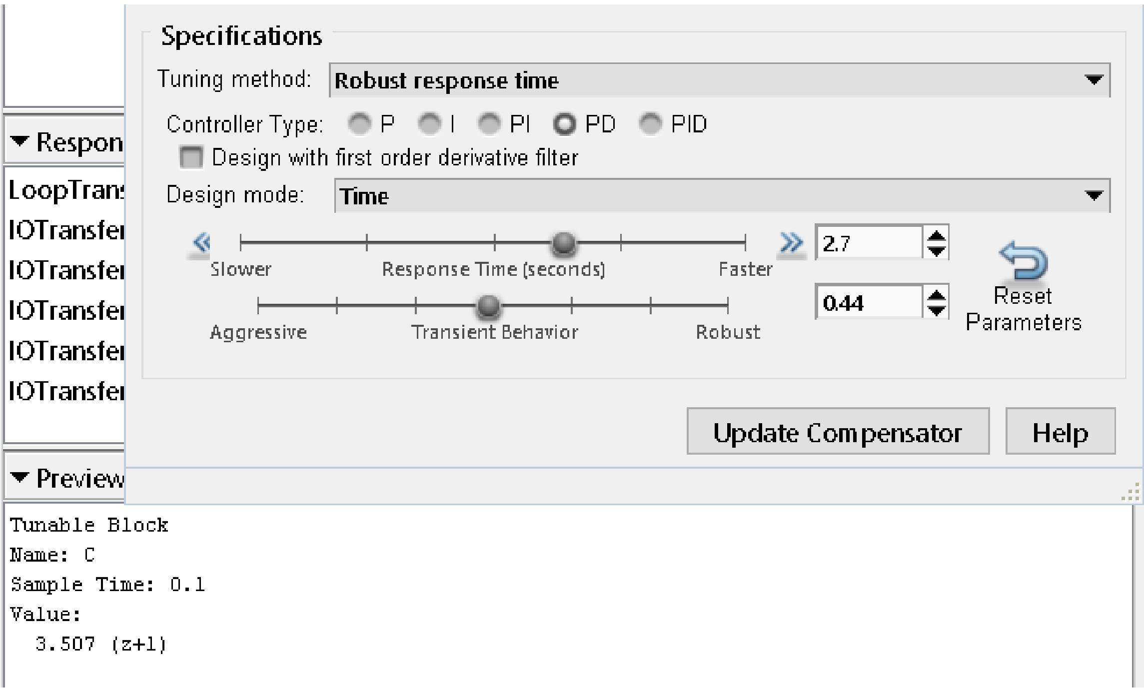

Figure 3.5.7 Response time and transient behaviour, and z-transform transfer function of PD controller (Control System Designer)

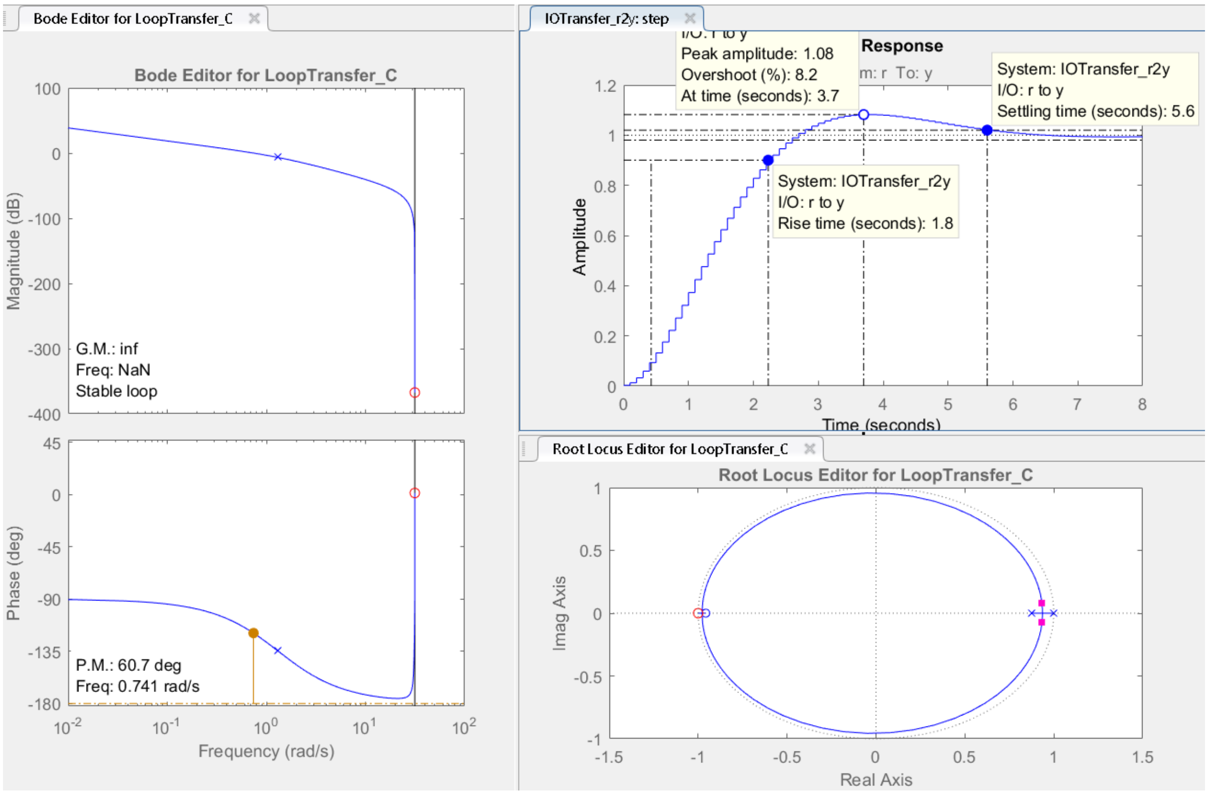

Figure 3.5.8 Graph plots of PD controlled antenna system (Control System Designer)

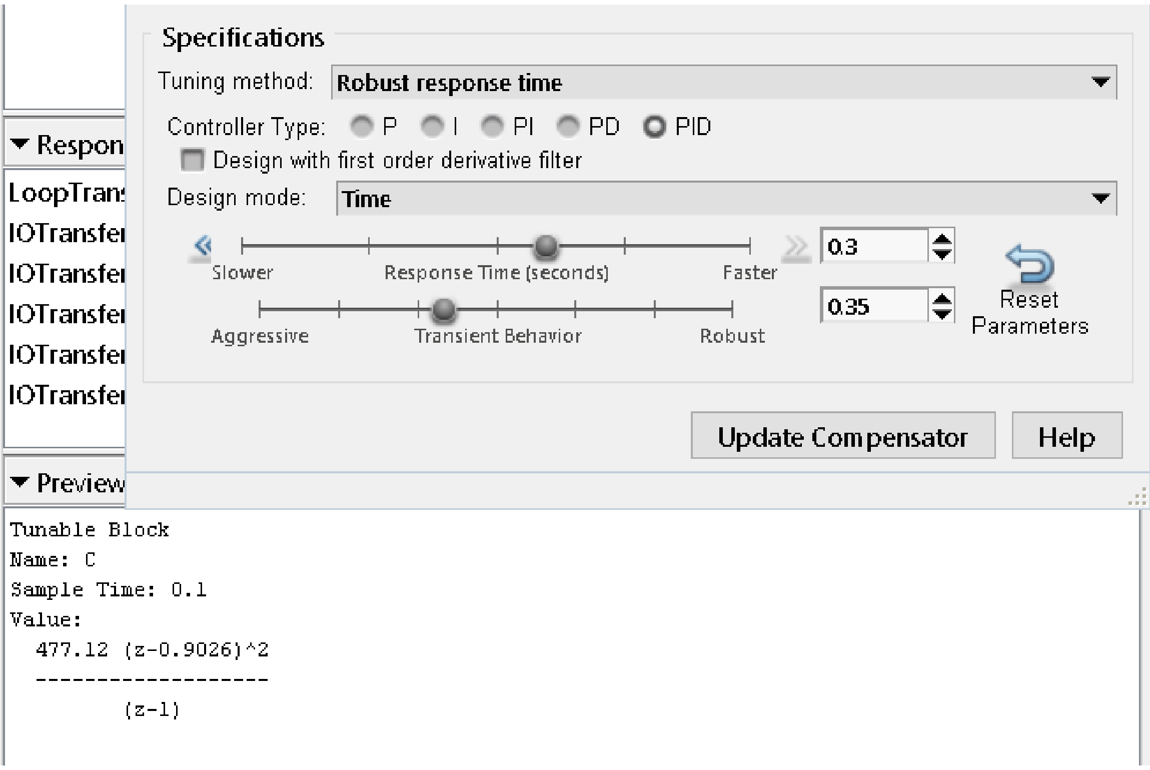

Figure 3.5.9 Response time and transient behaviour, and z-transform transfer function of PID controller (Control System Designer)

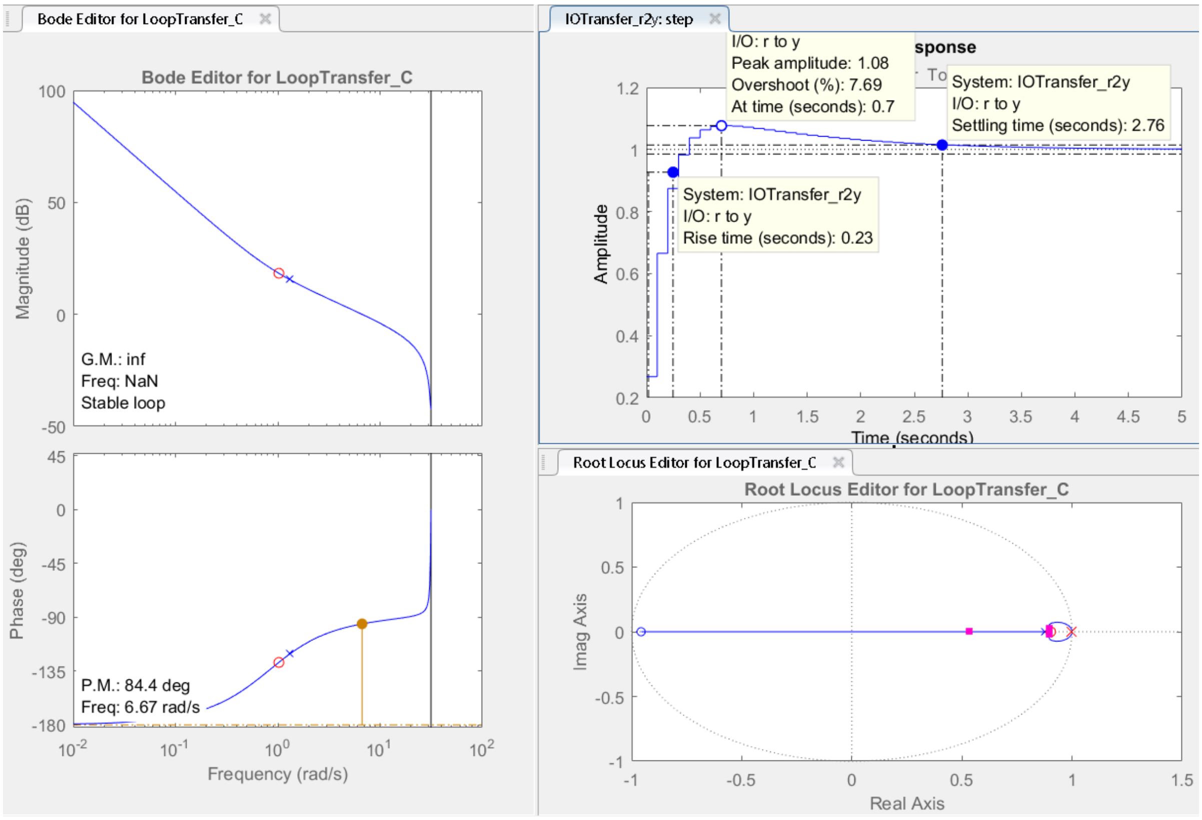

Figure 3.5.10 Graph plots of PID controlled antenna system (Control System Designer)

Nevertheless, getting more detailed, PID Tuner application is used to produce the proportional, integral and derivative gains respectively. First of all, digital antenna system transfer function is added into the application and then desired controller which is either one of PI, PD or PID controller, is chosen for gain estimation. Then, knowing that the response time and transient behaviour values had been fixed for each controller from Control System Designer application, both values are compulsory to put in as main conditions. Finally, each gain will be presented from the controller parameter tab and these steps are repeated for another two controllers. Actually, the step response information from PID Tuner application is similar to the information from Control System Designer application, this verifies that this gain value finding idea is correct and reasonable.

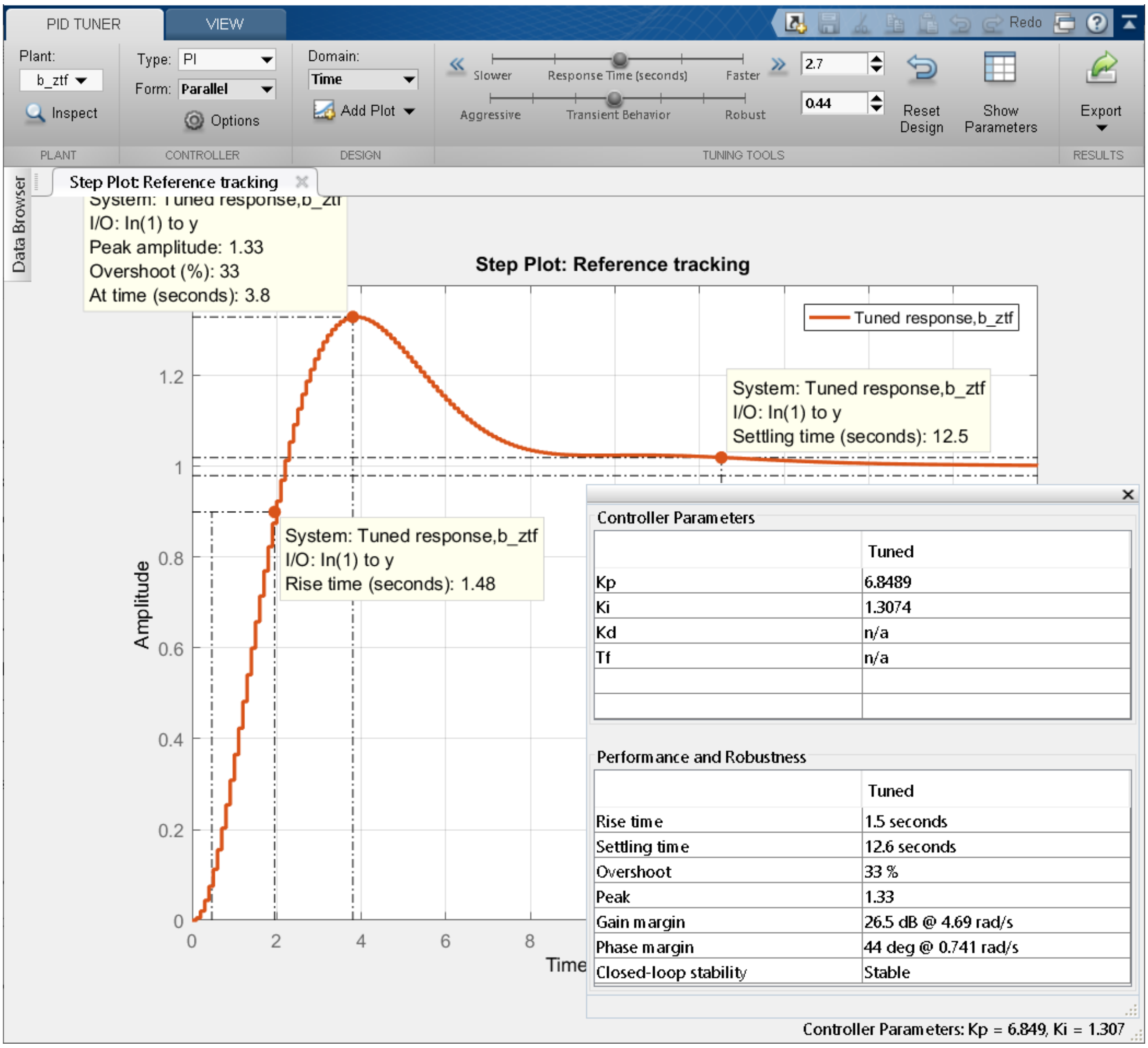

Figure 3.5.11 Step response, controller parameters, and performance and robustness of PI controlled antenna system (PID Tuner)

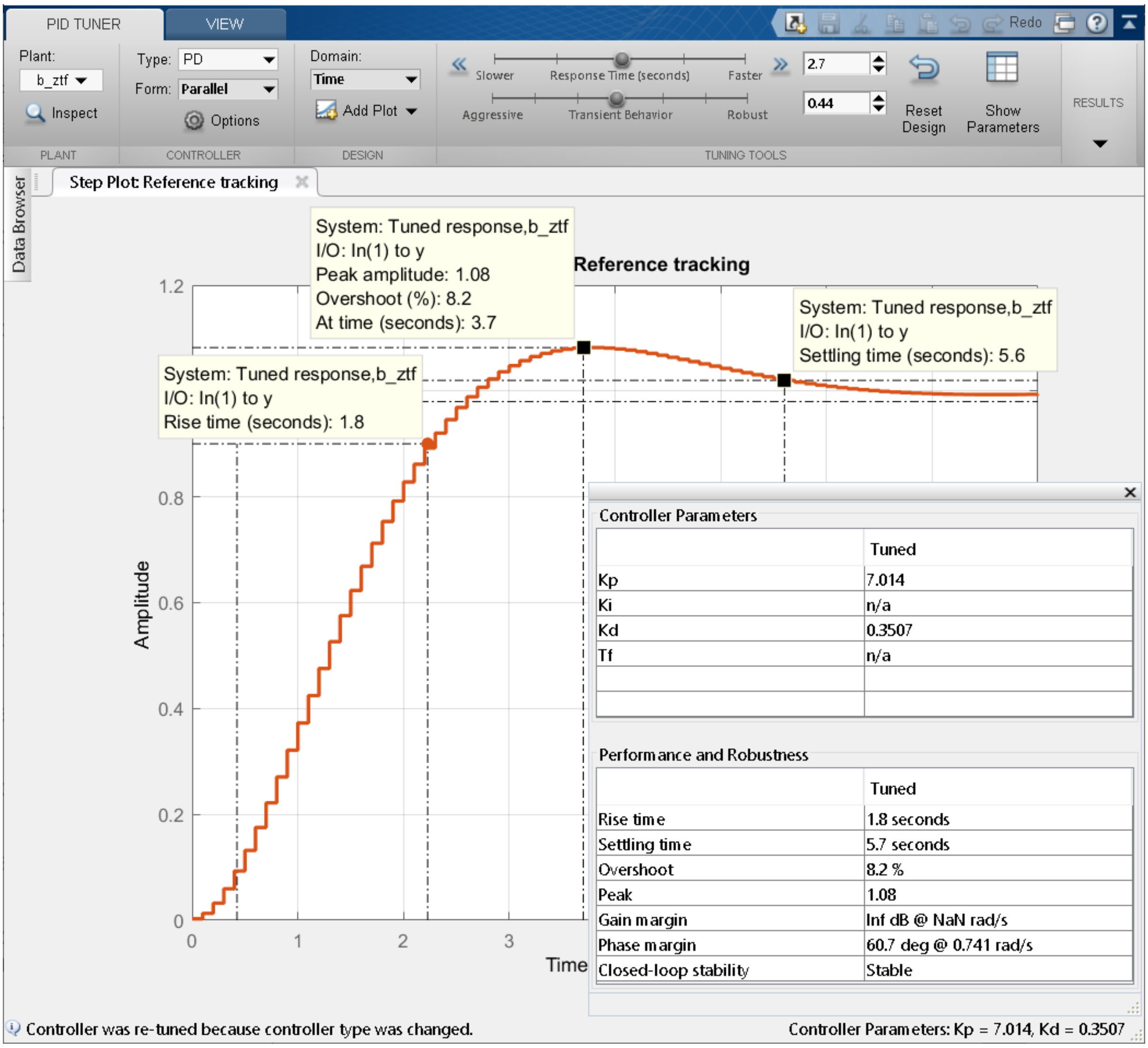

Figure 3.5.12 Step response, controller parameters, and performance and robustness of PD controlled antenna system (PID Tuner)

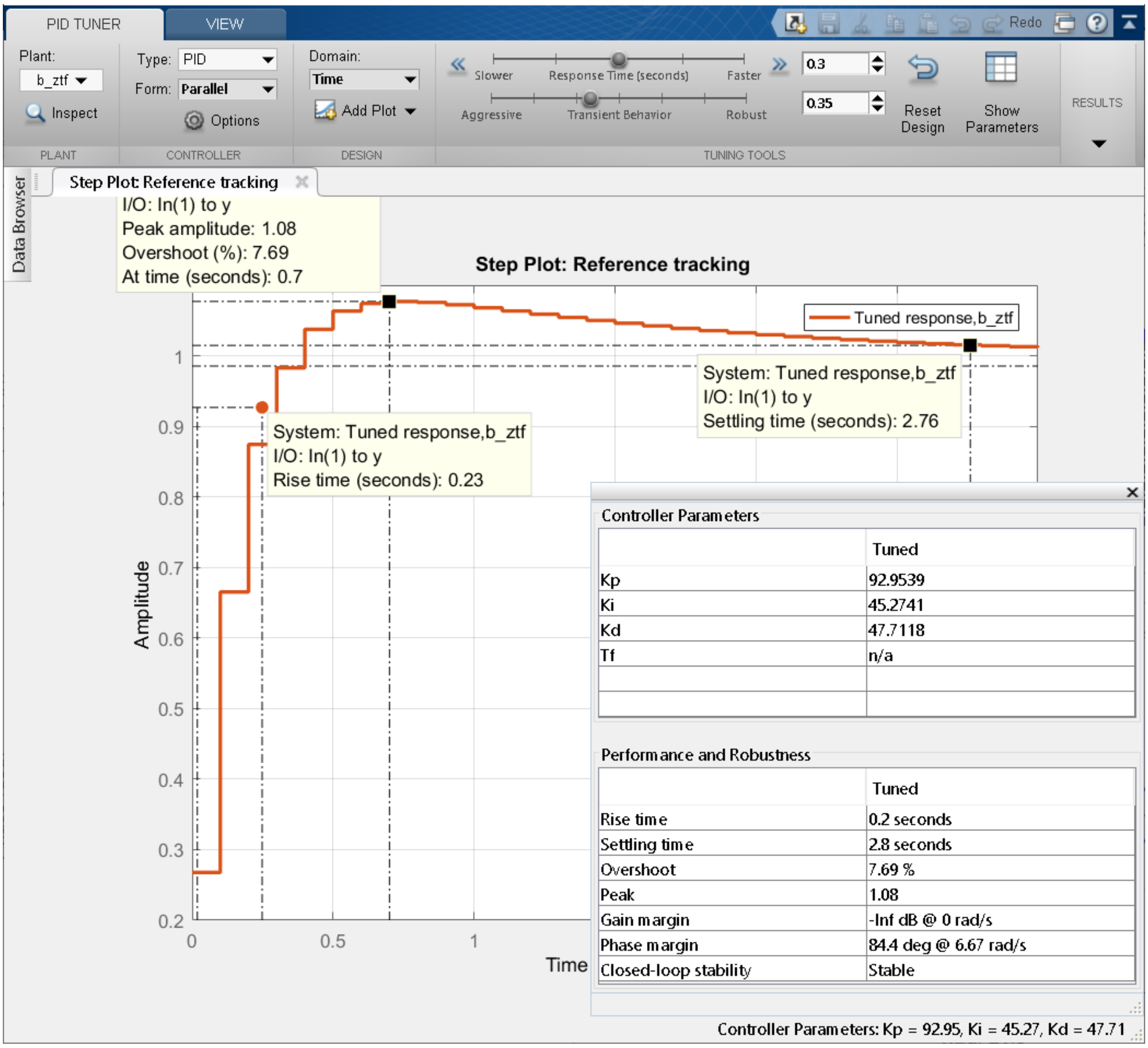

Figure 3.5.13 Step response, controller parameters, and performance and robustness of PID controlled antenna system (PID Tuner)

```
ans =

Digital Closed Loop Antenna System With PI Controller


d_ztf_pi =

  0.005246 z^5 - 0.01521 z^4 + 0.009877 z^3 + 0.009221 z^2 - 0.01344 z + 0.004315
  --------------------------------------------------------------------------------
      z^6 - 5.747 z^5 + 13.76 z^4 - 17.58 z^3 + 12.63 z^2 - 4.838 z + 0.7723

Sample time: 0.1 seconds
Discrete-time transfer function.


ans =

        RiseTime: 1.5000
    SettlingTime: 12.6000
     SettlingMin: 0.9237
     SettlingMax: 1.3300
       Overshoot: 33.0035
      Undershoot: 0
            Peak: 1.3300
        PeakTime: 3.8000
```

Figure 3.5.14 Transfer function and step response information of digital closed loop antenna system with PI controller

```
ans =

Digital Closed Loop Antenna System With PD Controller


d_ztf_pd =

  0.002686 z^4 + 0.0002166 z^3 - 0.004939 z^2 - 0.0002166 z + 0.002253
  --------------------------------------------------------------------
          1.003 z^4 - 3.752 z^3 + 5.268 z^2 - 3.289 z + 0.7702

Sample time: 0.1 seconds
Discrete-time transfer function.


ans =

        RiseTime: 1.8000
    SettlingTime: 5.7000
     SettlingMin: 0.9204
     SettlingMax: 1.0820
       Overshoot: 8.2007
      Undershoot: 0
            Peak: 1.0820
        PeakTime: 3.7000
```

Figure 3.5.15 Transfer function and step response information of digital closed loop antenna system with PD controller

```
ans =

Digital Closed Loop Antenna System With PID Controller


d_ztf_pid =

  0.2663 z^6 - 0.9919 z^5 + 1.14 z^4 + 0.05164 z^3 - 1.068 z^2 + 0.7845 z - 0.1819
  --------------------------------------------------------------------------------
     1.266 z^6 - 6.745 z^5 + 14.92 z^4 - 17.54 z^3 + 11.55 z^2 - 4.04 z + 0.586

Sample time: 0.1 seconds
Discrete-time transfer function.


ans =

        RiseTime: 0.3000
    SettlingTime: 3.1000
     SettlingMin: 0.9873
     SettlingMax: 1.0976
       Overshoot: 9.7593
      Undershoot: 0
            Peak: 1.0976
        PeakTime: 0.9000
```

Figure 3.5.16 Transfer function and step response information of digital closed loop antenna system with PID controller

Transfer Functions			
Controller type	PI	PD	PID
Proportional gain (PID Tuner)	6.849	7.014	92.9539
Integral gain (PID Tuner)	1.307	0	45.2741
Derivative gain (PID Tuner)	0	0.3507	47.7118
Controller z-transform transfer function	$\frac{6.8489(z-0.9809)}{(z-1)}$	$3.507(z+1)$	$\frac{477.12(z-0.9026)^2}{(z-1)}$

(Control System Designer)			
Closed loop antenna system with controller z-transform transfer function	$\frac{0.005246z^5 - 0.01521z^4 + 0.009877z^3 + 0.009221z^2 - 0.01344z + 0.004315}{z^6 - 5.747z^5 + 13.76z^4 - 17.58z^3 + 12.63z^2 - 4.838z + 0.7723}$	$\frac{0.002686z^4 + 0.0002166z^3 - 0.004939z^2 - 0.0002166z + 0.002253}{1.003z^4 - 3.752z^3 \; 5.268z^2 - 3.289z + 0.7702}$	$\frac{0.2663z^6 - 0.9919z^5 + 1.14z^4 + 0.05164z^3 - 1.068z^2 + 0.7845z - 0.1819}{1.266z^6 - 6.745z^5 + 14.92z^4 - 17.54z^3 + 11.55z^2 - 4.04z + 0.586}$
Stability Parameters (Control System Designer)			
Step response curve	Underdamped	Underdamped	Underdamped
Percent overshoot	33	8.2	7.69
Peak time (in second)	3.8	3.7	0.7
Rise time (in second)	1.48	1.8	0.23
Settling time (in second)	12.5	5.6	2.76
Gain margin	26.5	Infinity	Infinity
Phase margin	44	60.7	84.4
Steady state value	1 (Stable)	1 (Stable)	1 (Stable)

Table 3.5.1 Transfer functions of PI, PD and PID controller, and digital antenna system, and stability parameters

Using the code from Appendix F, every transfer function and step response graph of digital antenna system with PI, PD and PID controller is displayed. From Table 3.5.1, PID controlled digital antenna system has the best testing result compared to PI and PD controlled systems. Talking about digital antenna system with PI controller, it is fast responded towards the system stability adjustment but it hits very high overshoot and wastes long time to finish the adjustment. Next, digital antenna system with PD controller is opposite to the system with PI controller because it has slower rise time but better work on overshoot and settling time. Last but not least, PID controller is the best stability assistant for this digital antenna system as its statistics had shown that it helps on improving rise time, peak time, overshoot and settling time. On the other hand, the gain tuning of PID controller is the toughest due to the inclusion of those three gains, but this contributes a stable digital antenna system.

CHAPTER 4: DESIGN SPECIFICATIONS

It is very significant to explain the control system design methodology which must be arranged well during the way of completing this project.

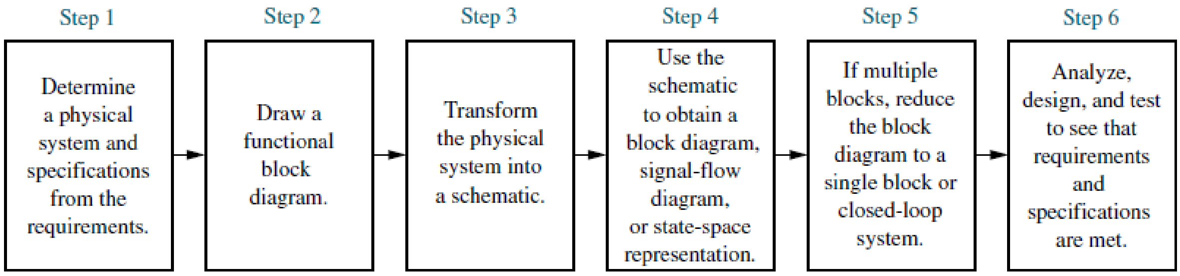

Figure 4.1 Design process of control system

From Figure 4.1, there are six steps contained. Firstly, the starting step is to convert requirements into system configuration and specification. From this project, the components and structural dimension of antenna system will be taken as design configurations, while appropriate transient response and steady-state response will be the model specifications. Next, the second step is to develop a functional block diagram. This step is to describe each hardware function of antenna system and relationship between each hardware. After that, the third step is to create a schematic diagram. This helps designer making plenty of possible assumptions and then figuring out beneficial mathematical equations for each stage of antenna system. Moving on to the fourth step which is to produce a mathematical model, a designer is compulsory to adopt several physical laws to connect every input and output of each block in antenna system so that the system will function properly. Once the outcome is not the desirable result, it means that the mathematical model used must be fixed or removed. Then, the fifth step is to remove multiple blocks from block diagram and sum up the mathematical functions simultaneously to make a single block which is either open loop or closed loop control system. Lastly, the sixth step is to analyse and design the system. In this phrase, designer will obtain the suitable transient response and steady-state response from the analysis of inserting wanted input and generating actual output.

This project requires the help of MATLAB software to generate the simulation. Mostly the simulations are displayed as graph plots and block diagrams. By coding the system, the software can produce the graph plots which are important for this project are step response, root locus and bode plot and each type of graph has its own characteristics. Step response graph shows the output response of a simulated system in time behaviour while the input increases from zero to one and its measurements which are needed for this project are the value of percent overshoot, rise time, settling time and steady state. Root locus graph is used to estimate the value of gain for system stability and present system response by the number and position of poles and zeros allocated. Bode plot displays both magnitude and phase graph which will provide the values of gain and phrase margin. Moreover, Simulink tool from MATLAB software is necessary for modelling open loop and closed loop antenna system, and also PID controlled antenna system in block diagram form. Thus, to define a good and stable antenna system, it should be built in closed loop form and achieve several conditions which are low overshoot, fast rise and settling times, zero steady state error, positive gain and phrase margins.

CHAPTER 5: PRELIMINARY WORK

Firstly, this project is to analyse the stability of antenna system using PID digital controller but it is started from the analogue standard. The reason is because the analogue standard is the most basic knowledge of building a control system. To transform from analogue to digital form, an analogue controller can be estimated with a digital controller because of the similarity of s-domain (analogue) and z-domain (digital) method. Therefore, analogue control system design is the primary stage before stepping on mastering the digital control system design. Control system digitalisation is arranged as final process of this project because this needs plenty of useful references from analogue building of antenna system such as those transfer functions and graph plots. When undergoing digitalisation, the concepts of calculating transfer functions of antenna system and PID controller, and understanding graph properties, are originally came from analogue standard.

Besides, the sixth step of the design process is the most important part as it involves the simulation modelling and analysis of system stability. From step 1 to 4, the progression is speeded up by the original information provided such as the antenna system configuration, the block diagram, the idea of implementing mathematical function to certain sub block, and so on. The design of open loop and closed loop antenna systems is the fifth step part and it is completed in short time because the closed loop system type must be chosen due to its characteristic of having feedback ability. The step 6 is the most complex and time consuming because it needs a lot of different understandings like the characteristic of graph plots, the working principle of PID controller, the tuning idea of controller and others, to make analysis. Without these, a designer can never fit controller in a control system to create a stable system, or the finished model cannot be performed in real life because of the lack of knowing certain parameters which should be concerned during simulation.

Furthermore, time domain is adopted more frequent than frequency domain in this project because its method is easier to be understood, and it also brings out more idea to define system stability. Taking Section C in Chapter 3 as example, while finding the maximum preamplifier gain value of closed loop antenna system, the root locus which is time response graph is used instead of bode plot, because the answer is obviously shown at the intersection between the graph curves and imaginary axis, while bode plot cannot directly estimate the exact value through its graph. Another example from Section D in Chapter 3, there is a tuning method called root locus tuning method and the reason of choosing this method is that it is more significant to be adopted with step response graph to evaluate the system stability with time. Hence, time domain standard is more effective on investigating the working of control system and solving time related constraints like rise time, peak time and settling time, to help the system getting balance with short period needed.

CHAPTER 6: CONCLUSION

This project had been completed successfully because it solved the stated problems in Chapter 1. First of all, during the design of the closed loop antenna system with PID controller, there are several conditions measured in the analysis part to choose a better controller. The conditions are not only included the common stability requirements like low overshoot, short time used and no steady state error, but also the logical thinking towards the functioning of antenna system in reality and the flexibility of the tuning method. Next, some popular tuning methods are implemented in this project to improve system stability such as Ziegler Nichols method. Even though manual tuning method had been removed in the progression because of the lack of experiences to develop PID controller, the root locus tuning method is found to make comparison with Ziegler Nichols method, and root locus tuning finally outputs fair results with achieving the requirement given. Last but not least, the ideal simulation from a control system does not mean that the system can also work perfectly in practical. From the result obtained from Ziegler Nichols method, it looks good but this method cannot guarantee that the antenna system can afford that high tempo operation which is within less than 1 seconds of responding, or else the system may settle down. Thus, instead of Ziegler Nichols method, root locus method is more logical to be used in antenna system.

This project system is ended with last stage of development which is digitalisation. During this process, the previous preferred tuning method called root locus tuning method, is out of consideration of finding gain values of controller because according to the transfer function of digital antenna system without controller, its equation has big order which is more than 3, this causes high difficulty of sketching the precise data required from the root locus graph and also calculating the finalised transfer function of this system. Thus, with the support of MATLAB software, whole information of digital antenna system with three controller types is outputted and PID controlled digital antenna system has the most excellent stability parameter following by PD and PI controlled system.

There are some contributions of this project. Firstly, the use of PID controller on control system is very general because it is one of the traditional and cheap controller. Through this project, it shows how important this common controller is to increase stability of the antenna system. Besides, this project compares the different tuning methods which are applicable to PID controller and the simulation are covered the consideration of both practical and experimental conditions. This comparison helps reader to understand more information and requirements on tuning controller. In the addition, currently a lot of systems are transformed from analogue state due to numerous advantages of digital system. This indicates that the work of digitalisation on antenna system is significant and modelling the simulation of digital controlled antenna system is the final achievement of this project.

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APPENDICES

Appendix A: Step response comparison between open loop and closed loop antenna system

```
'Step Response Comparison Between Open Loop And Closed Loop Antenna
System'

clc
num=24;
den=[1 151.32 198 0];

'Open Loop Transfer Function'

g=tf(num,den)
subplot(1,2,1);
stepinfo(g)
step(g);
title('Open Loop Step Response')

'Closed Loop Transfer Function'

k=1;
gt=3.18*k*g;
t=feedback(gt,1)
subplot(1,2,2);
stepinfo(t)
step(t);
title('Closed Loop Step Response')
```

Appendix B: Gain finding through root locus

```
'Gain Finding'

clc
num=24;
den=[1 151.32 198 0];
g=tf(num,den)

k=1;
gt=3.18*k*g;
t=feedback(gt,1)

'Gain Finding Through Root Locus'

k=1:10000;

for n=1:length(k);
den=[1 151.32 198 76.39*n];
poles=roots(den);
r=real(poles);

    if (max(r)>=0)
    poles
    kmax_rl=n-1
    break
    end

end
```

Appendix C: Graph comparison between stable and unstable closed loop antenna system

```
'Comparison Between Stable And Unstable Closed Loop Antenna System'

clc
num=24;
den=[1 151.32 198 0];
g=tf(num,den)

k=1;
gt=3.18*k*g;
t=feedback(gt,1)

'Stable Closed Loop Antenna System'
kmax=392;
tmax=feedback(g*(3.18)*kmax,1)
stepinfo(tmax)
subplot(3,2,1);
step(tmax);
title('Maximum Gain Closed Loop Step Response')
subplot(3,2,3);
rlocus(tmax);
title('Maximum Gain Closed Loop Root Locus')
subplot(3,2,5);
margin(tmax);

'Unstable Closed Loop Antenna System'
kol=393;
tol=feedback(g*(3.18)*kol,1)
stepinfo(tol)
subplot(3,2,2);
step(tol);
title('Overlimited Gain Closed Loop Step Response')
subplot(3,2,4);
rlocus(tol);
title('Overlimited Gain Closed Loop Root Locus')
subplot(3,2,6);
margin(tol);
```

Appendix D: Graph plots of the enlarged closed loop antenna system and the PID compensated closed loop antenna system with Ziegler Nichols tuning method

```
'Ziegler Nichols Tuning Method'

clc
num=24;
den=[1 151.32 198 0];
g=tf(num,den)

k=1;
kmax=392;
gt=3.18*kmax*g;
t=feedback(gt,1)

ku=392;
tu=4;

kznp=0.6*ku
tzni=tu/2;
tznd=tu/8;
kzni=kznp/tzni
kznd=tznd*kznp
cznpid=pid(kznp,kzni,kznd)
tznpid=feedback(g*(3.18)*k*cznpid,1)

subplot(3,2,1)
step(t,1:50)
title('Enlarged Closed Loop Step Response')
subplot(3,2,2)
step(tznpid)
title('Ziegler Nichols Tuned System Step Response')
subplot(3,2,4)
rlocus(tznpid)
title('Ziegler Nichols Tuned System Root Locus')
subplot(3,2,6)
margin(tznpid)
```

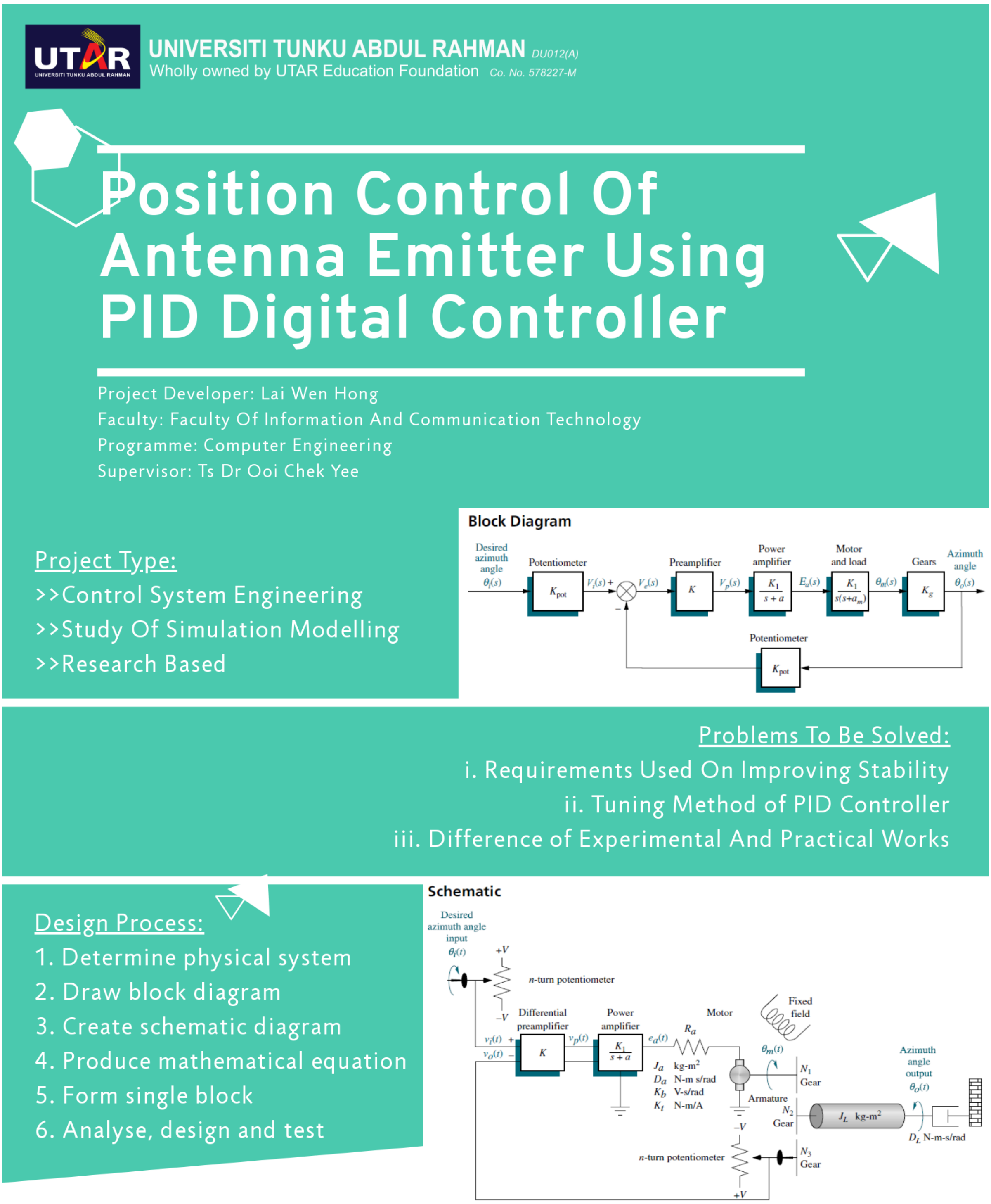
Appendix E: Graph plots of the 20 percent overshoot closed loop antenna system and the PID compensated closed loop antenna system with root locus tuning method

```
'Root Locus Tuning Method'

clc
k=4.04;
num=76.32*k;
den=[1 151.32 198 0];

g=tf(num,den)
t=feedback(g,1)

'20 Percent Overshoot'
subplot(3,2,1)
step(t)
title('20 Percent Overshoot Closed Loop Step Response')
subplot(3,2,3)
rlocus(t)
title('20 Percent Overshoot Closed Loop Root Locus')
subplot(3,2,5)
margin(t)

'PID Tuned'
krlpid=1;
numrlpid=[76.32*krlpid 539.58*krlpid 5.39*krlpid];
denrlpid=[1 151.32 198 0 0];

grlpid=tf(numrlpid,denrlpid)
trlpid=feedback(grlpid,1)

subplot(3,2,2)
step(trlpid)
title('Root Locus PID Tuned System Step Response')
subplot(3,2,4)
rlocus(trlpid)
title('Root Locus PID Tuned System Root Locus')
subplot(3,2,6)
margin(trlpid)
```

Appendix F: Step responses of various digital closed antenna systems with the presence and absence of PID controller

```
'Step Responses Of Various Digital Closed Loop Antenna Systems'

clc
s = tf('s');
z = tf('z');
% zoh = (1 - exp(-0.1*s))/s;
mnl = 0.8/(s^2 + 1.32*s);
gr = 0.2;
T = 0.1;

'Digital Closed Loop Antenna System Without Controller'

a_ztf = mnl*gr;
b_ztf = c2d(a_ztf,T,'zoh')
subplot(2,2,1);
stepinfo(b_ztf)
step(b_ztf);
title('Digital Closed Loop Antenna System Without Controller')

'Digital Closed Loop Antenna System With PI Controller'

pi = 6.8489*(z-0.9809)/(z-1)
c_ztf_pi = b_ztf * pi;
d_ztf_pi = c_ztf_pi/(1+c_ztf_pi)
subplot(2,2,2);
stepinfo(d_ztf_pi)
step(d_ztf_pi);
title('Digital Closed Loop Antenna System With PI Controller')

'Digital Closed Loop Antenna System With PD Controller'

pd = 3.507*(z+1)
c_ztf_pd = b_ztf * pd;
d_ztf_pd = c_ztf_pd/(1+c_ztf_pd)
subplot(2,2,3);
stepinfo(d_ztf_pd)
step(d_ztf_pd);
title('Digital Closed Loop Antenna System With PD Controller')

'Digital Closed Loop Antenna System With PID Controller'

pid = 347.69*(z-0.9026)^2/(z-1)
c_ztf_pid = b_ztf * pid;
d_ztf_pid = c_ztf_pid/(1+c_ztf_pid)
subplot(2,2,4);
stepinfo(d_ztf_pid)
step(d_ztf_pid);
title('Digital Closed Loop Antenna System With PID Controller')
```

POSTER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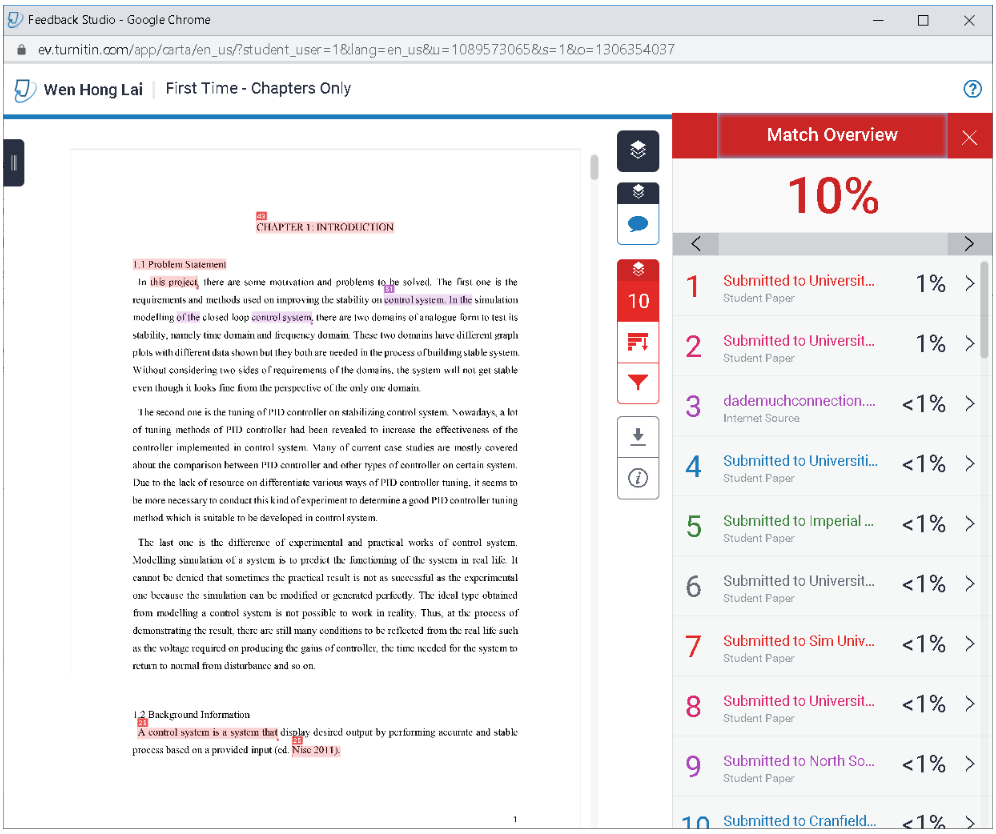
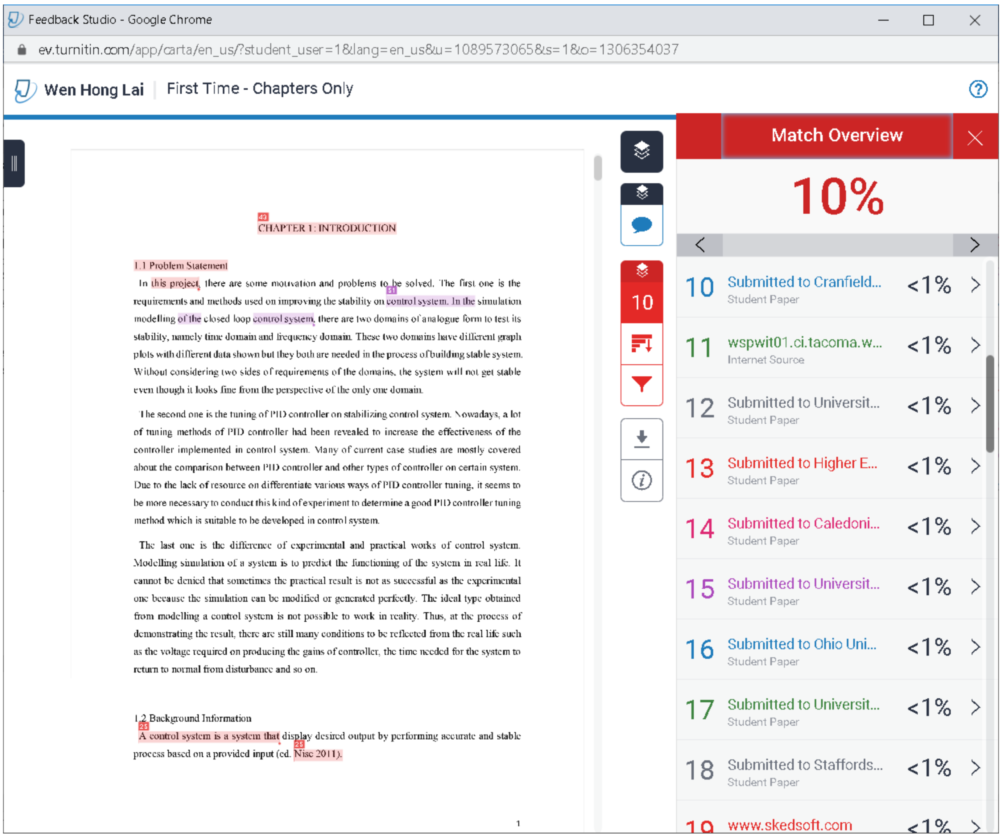
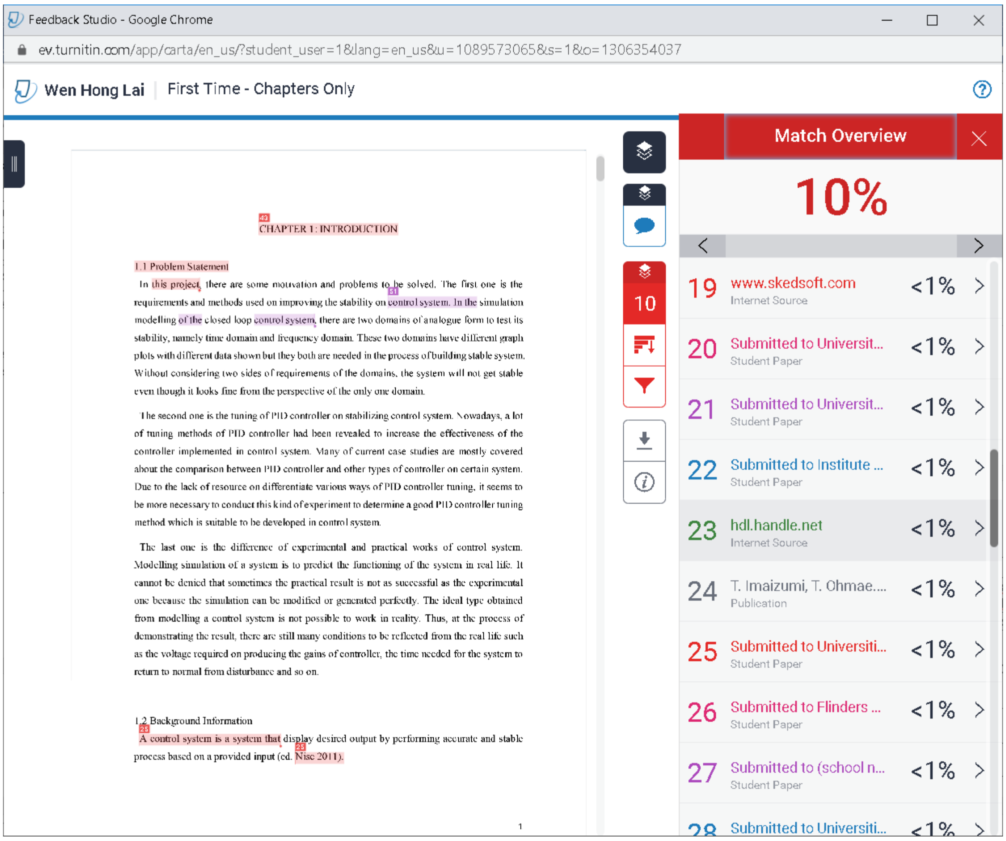
Position Control Of Antenna Emitter Using PID Digital Controller
Project Developer: Lai Wen Hong
Faculty: Faculty Of Information And Communication Technology
Programme: Computer Engineering
Supervisor: Ts Dr Ooi Chek Yee
Project Type:
>>Control System Engineering
>>Study Of Simulation Modelling
>>Research Based
Block Diagram
Desired azimuth angle
Potentiometer
Preamplifier
Power amplifier
Motor and load
Gears
Azimuth angle
Potentiometer
Problems To Be Solved:
i. Requirements Used On Improving Stability
ii. Tuning Method of PID Controller
iii. Difference of Experimental And Practical Works
Design Process:
1. Determine physical system
2. Draw block diagram
3. Create schematic diagram
4. Produce mathematical equation
5. Form single block
6. Analyse, design and test
Schematic
Desired azimuth angle input
n-turn potentiometer
Differential preamplifier
Power amplifier
Motor
Fixed field
Armature
Gear
Azimuth angle output
n-turn potentiometer

PLAGIARISM CHECK RESULT



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CHAPTER 1: INTRODUCTION
1.1 Problem Statement
In this project, there are some motivation and problems to be solved. The first one is the requirements and methods used on improving the stability on control system. In the simulation modelling of the closed loop control system, there are two domains of analogue form to test its stability, namely time domain and frequency domain. These two domains have different graph plots with different data shown but they both are needed in the process of building stable system. Without considering two sides of requirements of the domains, the system will not get stable even though it looks fine from the perspective of the only one domain.
The second one is the tuning of PID controller on stabilizing control system. Nowadays, a lot of tuning methods of PID controller had been revealed to increase the effectiveness of the controller implemented in control system. Many of current case studies are mostly covered about the comparison between PID controller and other types of controller on certain system. Due to the lack of resource on differentiate various ways of PID controller tuning, it seems to be more necessary to conduct this kind of experiment to determine a good PID controller tuning method which is suitable to be developed in control system.
The last one is the difference of experimental and practical works of control system. Modelling simulation of a system is to predict the functioning of the system in real life. It cannot be denied that sometimes the practical result is not as successful as the experimental one because the simulation can be modified or generated perfectly. The ideal type obtained from modelling a control system is not possible to work in reality. Thus, at the process of demonstrating the result, there are still many conditions to be reflected from the real life such as the voltage required on producing the gains of controller, the time needed for the system to return to normal from disturbance and so on.
1.2 Background Information
A control system is a system that display desired output by performing accurate and stable process based on a provided input (ed. Nise 2011).
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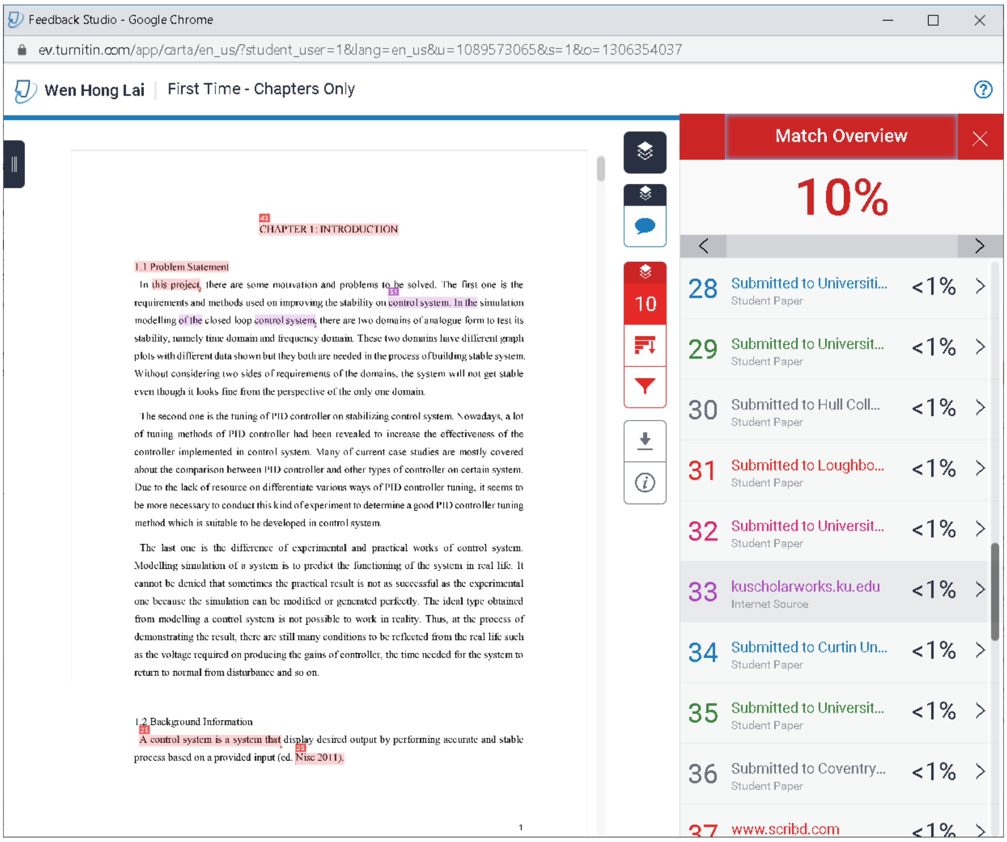
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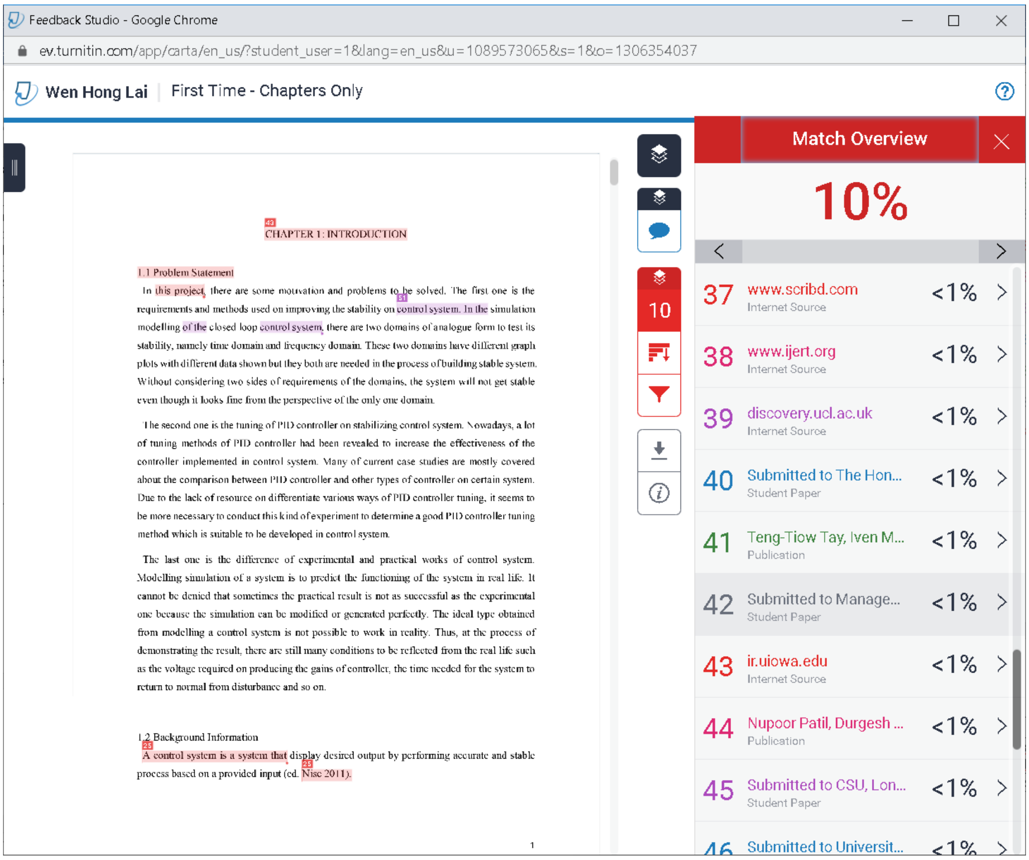
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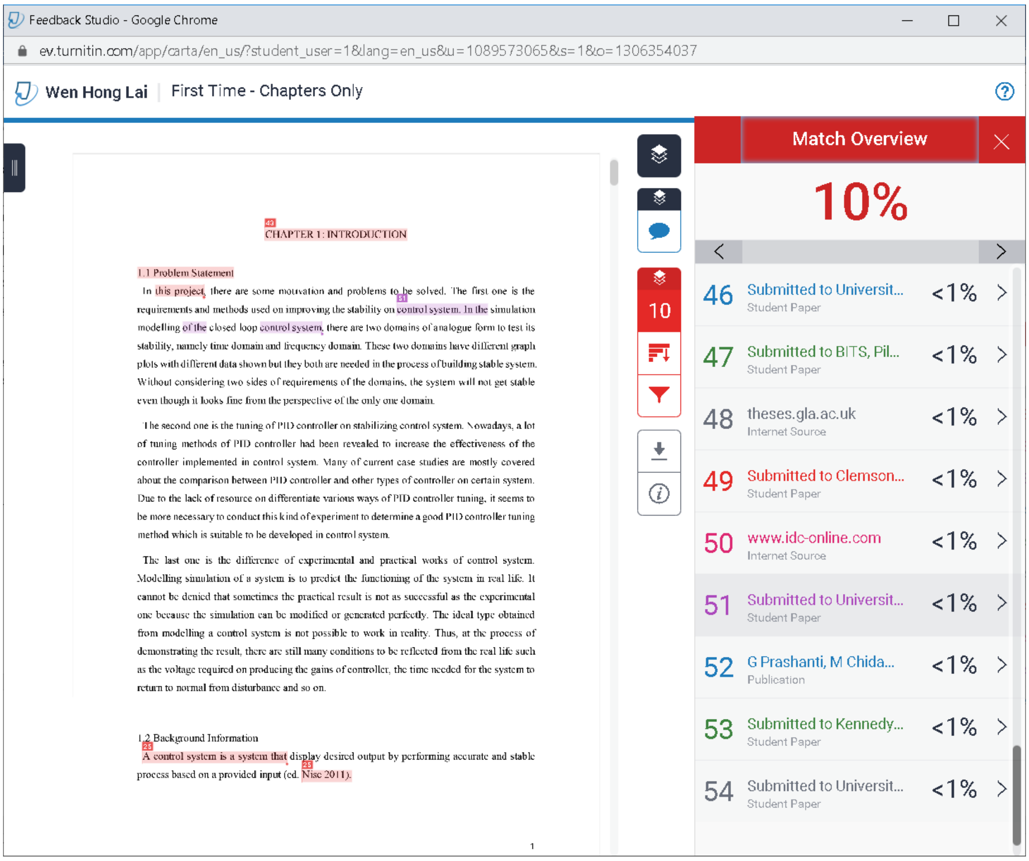
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ID Number(s)	16ACB02983
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Title of Final Year Project	POSITION CONTROL OF ANTENNA EMITTER USING PID DIGITAL CONTROLLER

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FINAL YEAR PROJECT WEEKLY REPORT

Trimester, Year: T3, Y3	**Study week no.: 2**
Student Name & ID: Lai Wen Hong 16ACB02983	
Supervisor: Ts Dr Ooi Chek Yee	
Project Title: Position Control of Antenna Emitter Using PID Digital Controller	

1. WORK DONE

- Read text books related to digital system design

2. WORK TO BE DONE

- Search online papers for reference

3. PROBLEMS ENCOUNTERED

- Experience new and challenging topic

4. SELF EVALUATION OF THE PROGRESS

- Try hard to understand more basic of digital technology

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

Trimester, Year: T3, Y3	**Study week no.: 4**
Student Name & ID: Lai Wen Hong 16ACB02983	
Supervisor: Ts Dr Ooi Chek Yee	
Project Title: Position Control of Antenna Emitter Using PID Digital Controller	

1. WORK DONE - Compare the study of text books with online papers - Revise FYP1 report work
2. WORK TO BE DONE - Write chapter 1 and 2 of FYP2 report
3. PROBLEMS ENCOUNTERED - Difficult to find online paper related digital system design
4. SELF EVALUATION OF THE PROGRESS - Have to self-learn MATLAB software for doing digitalization process

Supervisor’s signature

Student’s signature

FINAL YEAR PROJECT WEEKLY REPORT

Trimester, Year: T3, Y3	**Study week no.: 6**
Student Name & ID: Lai Wen Hong 16ACB02983	
Supervisor: Ts Dr Ooi Chek Yee	
Project Title: Position Control of Antenna Emitter Using PID Digital Controller	

1. WORK DONE - Consult supervisor for some idea on doing digital system design
2. WORK TO BE DONE - Start calculating the transfer function by hand writing
3. PROBLEMS ENCOUNTERED - Worry about the difficulty of calculating transfer function
4. SELF EVALUATION OF THE PROGRESS - Have to work faster as the process is huge

Supervisor's signature

LAI

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

Trimester, Year: T3, Y3	**Study week no.: 9**
Student Name & ID: Lai Wen Hong 16ACB02983	
Supervisor: Ts Dr Ooi Chek Yee	
Project Title: Position Control of Antenna Emitter Using PID Digital Controller	

1. WORK DONE

- Update supervisor about my progress of doing digital system

2. WORK TO BE DONE

- Try to use MATLAB for calculation

3. PROBLEMS ENCOUNTERED

- Does not have relevant research paper to refer

4. SELF EVALUATION OF THE PROGRESS

- Spend more time on FYP2 working

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

Trimester, Year: T3, Y3	**Study week no.: 12**
Student Name & ID: Lai Wen Hong 16ACB02983	
Supervisor: Ts Dr Ooi Chek Yee	
Project Title: Position Control of Antenna Emitter Using PID Digital Controller	

1. WORK DONE

- Work on more detailed process like finding gains of PID controller, comparison between different types of PID controller

2. WORK TO BE DONE

- Complete Chapter 3 as soon as possible

3. PROBLEMS ENCOUNTERED

- Waste time on finding suitable tuning for controller on digital system

4. SELF EVALUATION OF THE PROGRESS

- Able to finish FYP2 report on time

Supervisor's signature

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