Journal of Engineering and Technology Management 73 (2024)

Controller Design for Automated Antenna Alignment for Telecommunication Transceivers

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ABSTRACT

In telecommunication process, antenna alignment system is very difficult and it mostly affects the MW links due to environmental physical degradation or anomalies over a period. The basic method is to take the desired received signal level by means of an outdoor unit installed on tower top and analyzing the desired received signal level in indoor unit by means of a GUI interface. A new smart antenna system which automation is initiated when the transceivers receive weak signal strength and report the finding to processing comparator unit. The controller parameters are used in analytical modeling and huse control techniques have been researched to overcome adjacent overshoot problems for the transport link. This transfer function of antenna alignment system is applied tuned parameters of the PID controller and fractional order PID controller for stability, even when the original higher order or reduced order system is unstable. The PID parameters are obtained by using a robust response time technique. Fractional order PID controller is also applied in antenna alignment. All tuned PID controller parameters are compared and analyzed.

Keywords:
Antenna alignment model, Telecommunication Transceivers, PID Controller, Integral Square Error, fractional order PID controller.

1. INTRODUCTION

The most vital aspect that is desired in network connectivity is served by transmission links and its reliability is of extreme importance. It not only enables the connectivity of terminal and linking stations with the core network but also ensures traffic management functionality. Todays, transmission nodes being employed mostly utilize wired fiber optic links as well as wireless links in MW range. The design of controllers for the original system is lengthy and costly. Here, we take the input-output of the system in the form of transfer functions. The minimized order model controlling and complexity of the system is easier and gives the best result.

Many methods such as time moment and Markov's parameters [1], of model order reduction are available in both the time domain and frequency domain [4-9]. Padè approximation [2] method is the most important and initial method for understanding. The PID parameters are obtained by using robust response time with and without first order technique by MATLAB.

To minimize the order from higher order to lower order system, one evolutionary technique [9] is used from many available techniques. We are taking a model of a continuous time system for verifying the proposed method. We can a1so use it in a discrete model system through the conversion of a continuous system. In general practice two different stations are wirelessly linked by means of antenna on either end with proper Line of Sight (LOS). Multiple antennas can be utilized for redundancy with extension of Warm and Hot spares stand-by. The Quality of Service (QoS) pertaining to transmission link is measured by means of Received Signal Level (RSL) measured through either Multi-Meter or by means of a software provided by the antenna manufacturer [11,12]. All the aforementioned parameters must be in optimal level to establish a radio link. Because of misalignment far end terminal. In multiple surveys conducted [13], it can be deduced that the link alignment is not one off the job and there is a high possibility for antenna to lose its optimal directivity and hence misdirect the main beam. There could be multiple reasons behind the misalignment such as environmental conditions, wear and tear of mounts and obstruction in the path of two stations. This paper deals with analytical and numerical modeling of the antenna alignment prototype for performance optimization, a section of it has been included to investigate the interference. PID and FOPID controller technique used for prototype antenna alignment have built-in

PID controller. Realignment of antenna is measured with some derivative gain, steady state response, etc. and hence it directs to optimize the performance through mathematical modeling and by minimizing unexpected overshoot. Different automation techniques for numerous applications have been employed with the main focus on reestablish communication link with minimum down time. Gawronski [15] has worked with pointing and control challenges for large antennas and telescopes. There antenna control system consists of the rate and position feedback loops whose mechanism is developed using controllers like PI controller, Linear Quadratic Gaussian LQG, etc.

The tuned parameters of PID controller are used for the lower order transfer function of antenna alignment system. This tuned PID controller and fractional PID controller are used for reducing the settling time, rise time and peak time of the systems. PID parameters are obtained by using a using robust response time technique.

2. Automated antenna alignment

In this model; it is a pertinent RSL value which should be achieved by the antenna. It actuates the motor with a command u(t) that rotates the end-effector horizontally or vertically thus measuring its position y(t). It is done by means of a built-in encoder which calculates the error e(t) as a closed loop feedback system so that the e(t) becomes zero and the system can achieve r(t). Based on aforementioned DeH model a block diagram of the control loop feedback mechanism. It describes the control architecture for two microwave antennas with (1 þ 0) configuration placed to establish an MW link. If the RSL of the transceiver drops below the desired threshold; a microcontroller will be triggered to mechanize the end-effector. Inside the RCX controller; there is PID tuning mechanism with proportional gain K_p, Integral gain K_i and derivative gain K_d. Based on the feedback pat; controller will always measure the RSL and activate the SPDT relay to operate two motors pertaining to horizontal and vertical movements of antenna. Model initially published in Ref. [13] was based on this principle and during observation, on an average; 2 out of 6 times both motors were rotating beyond their optimum positioning, thus only achieving the desired RSL with low response time. That is, the system was giving an overshoot response to achieve the required RSL. For this reason, tuning the controller with lower derivative gain would be possible solution to remove this overshoot. Fig. 1 represents an analytical model Block diagram of prototype motor utilization (a) and Equivalent circuit of motor (b), where antenna alignment is done based on PID controller.

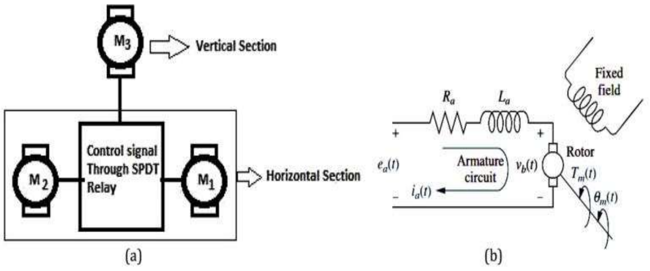


Fig.1 (a) Block diagram representation of prototype motor utilization (b) Equivalent circuit of motor.

3. Model Based Analysis and System Response of Prototype

Based on the mechanism, a generic block diagram of the control system is shown in Fig. 3(a) and (b). Detailed architectural analysis and further tuning for optimal performance is based on this model.

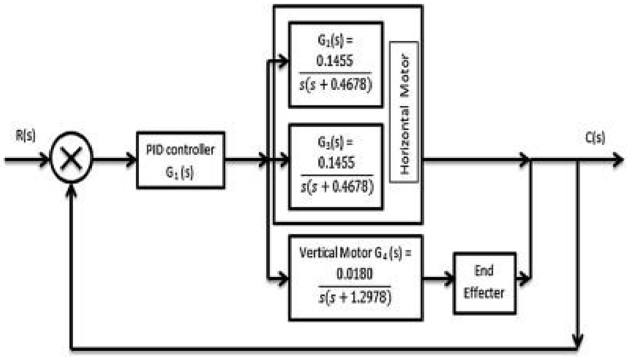


Fig.2 Block diagram representation of prototype detail structure with transfer function

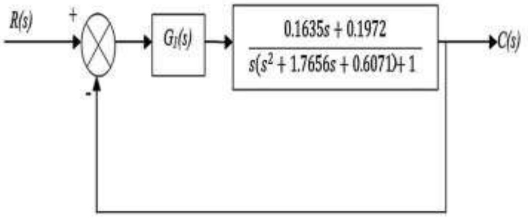


Fig.3 reduced transfer function of Block diagram representation

4. PID CONTROLLER:

The best parameters of proportional, derivative and integral controller can improve the performances of all aspects of the system. By using PID controller, we can improve the peak time, settling time, rise time and steady state errors. The proportional controller produces a steady state error and settles the gain. The integra1controller reduces the steady state error. The derivative controller reduces the rate of error.

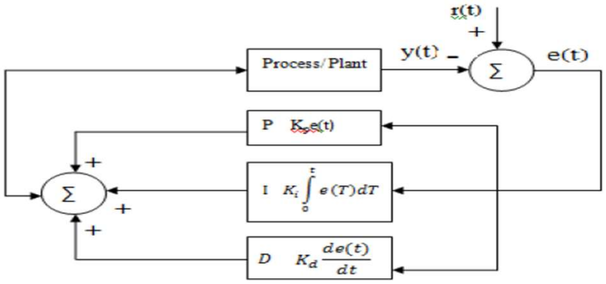


Fig-4: PID controller Block diagram

Robust Response Time:

Robust response time given k_p, k_i and k_d value with and without first order technique. The output of the above controller, the P, I and D controller method are added. Then the basic formula of PID controller is,

$$u(t) = k_p e(t) + k_i \int_0^t e(T)dT + k_d \frac{d}{dt} e(t)$$

5. Fractional Order PID controller

Fractional Order PID (FOPID) controller has picked up much consideration both from the scholarly and mechanical point of view, as in rule they are more adaptable in comparison with the standard PID controller, were standard PID controllers have 3 controllable parameters, FOPID presented 2 modem parameters [16, 17] for a add up to of 5 such parameters. FOPID controller can be spoken to as. The two extra parameters of integration and of subsidiary moreover made the tuning of the unused FOPID controller more complex. The Fractional PID controller is the most popular kind of PID controller because of its original characteristics. There are various kinds of FOPID controllers, such as PID (λ = 1, μ = 1), PD (λ = 0, μ = 1), PI (λ = 1, μ = 0), and the P controller (λ = 0, μ = 0). The graphical representation of the various PID controllers is shown in Figure 5.

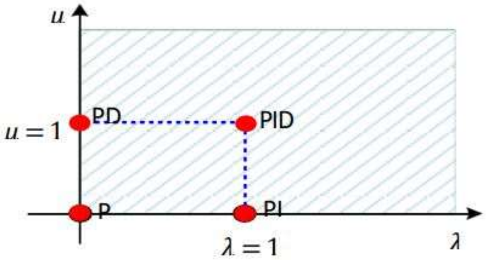


Fig.5: PID/PI$^{\lambda}$D$^{\mu}$ controllers' graphical representation.

6. NUMERICAL EXAMPLE:-

Example 1: Consider automated antenna Alignment for telecommunication transceivers type system [14]:

$$G(s)=\frac{0.1635s+0.1972}{s^3+1.7656s^2+0.6071s+1}$$

Bode plot, root locus and step response of open loop System of G(s) is show in fig.6.

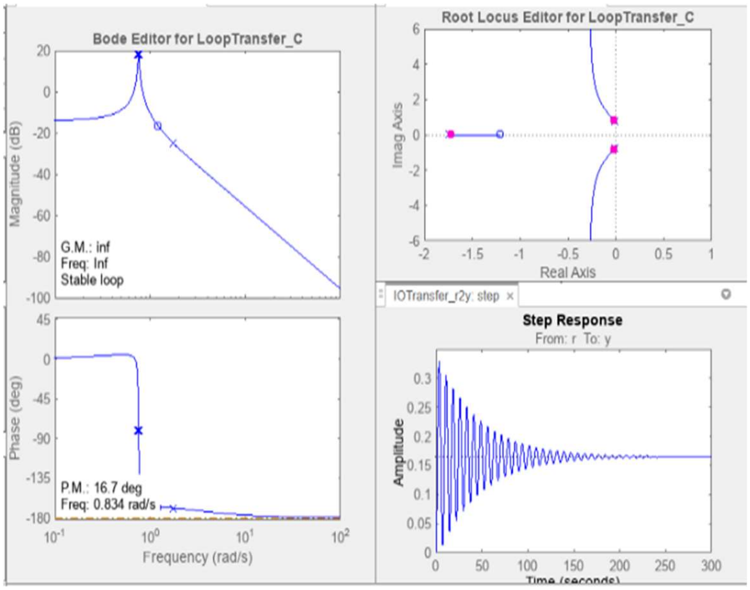


Fig. 6: System response - (a) Bode plot, (b) root locus, (c) step response of open loop step response for model.

The PID controller is designed. The tuned parameters of PID controller are obtained by using robust PID controller of SISOTOOL box. The transfer function of a PID controller is

$$C_{pid}(s)=0.4024+0.9357s+\frac{0.04422}{s}$$

The PID controller is applied with close loop of antenna alignment model same as fig. 3.

$$\frac{y}{r}=\frac{C_{pid}\,G}{1+\,C_{pid}G}$$

by SISOTOOL box. Now, again plot the bode plot, root locus and step response of close loop System with PID controller is show in fig.7

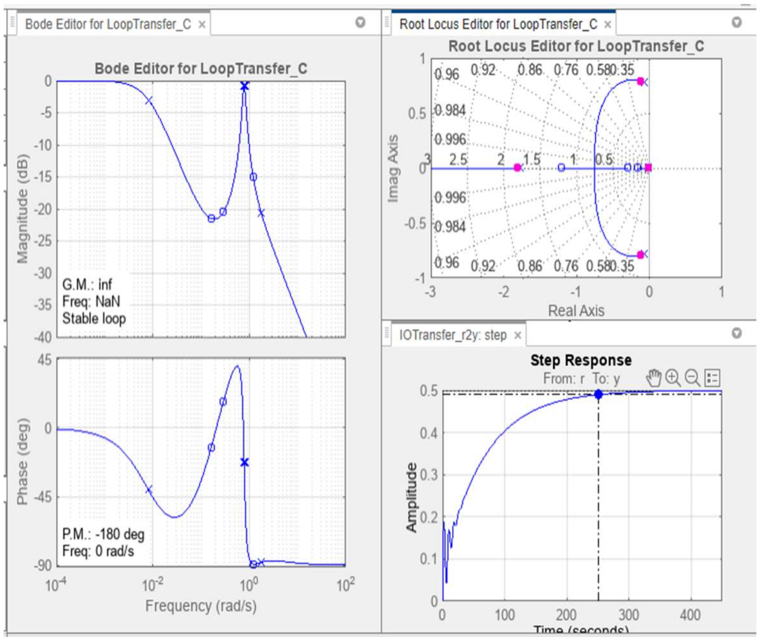
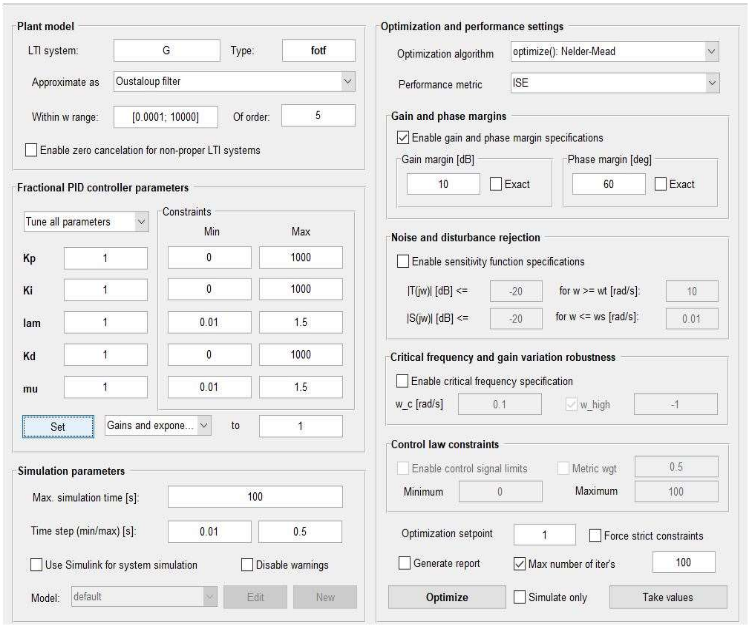


Fig. 7: System response - (a) Bode plot, (b) root locus, (c) step response of close loop step response for PID controller and system model.



Plant model

LTI system: G Type: fotf

Approximate as: Oustaloup filter

Within w range: [0.0001; 10000] Of order: 5

☐ Enable zero cancelation for non-proper LTI systems

Fractional PID controller parameters

Tune all parameters

		Min	Max
Kp	1	0	1000
Ki	1	0	1000
lam	1	0.01	1.5
Kd	1	0	1000
mu	1	0.01	1.5

Set Gains and expone... to 1

Simulation parameters

Max. simulation time [s]: 100

Time step (min/max) [s]: 0.01 0.5

☐ Use Simulink for system simulation ☐ Disable warnings

Model: default

Optimization and performance settings

Optimization algorithm: optimize(): Nelder-Mead

Performance metric: ISE

Gain and phase margins

☑ Enable gain and phase margin specifications

Gain margin [dB]: 10 ☐ Exact

Phase margin [deg]: 60 ☐ Exact

Noise and disturbance rejection

☐ Enable sensitivity function specifications

|T(jw)| [dB] <= -20 for w >= wt [rad/s]: 10

|S(jw)| [dB] <= -20 for w <= ws [rad/s]: 0.01

Critical frequency and gain variation robustness

☐ Enable critical frequency specification

w_c [rad/s] 0.1 ☑ w_high -1

Control law constraints

☐ Enable control signal limits ☐ Metric wgt 0.5

Minimum 0 Maximum 100

Optimization setpoint 1 ☐ Force strict constraints

☐ Generate report ☑ Max number of iter's 100

Fig. 8: Fractional order PID controller settings

The Nelder Mead optimization techniques use for finding parameter of FOPID. The antenna alignment system gain margin is 10 and phase margin is 60. The transfer function of FOPID show in below.

$$C_{fopid}(s) = \frac{3.3445s^{2.0116} + 1.2702s^{1.0062} + 0.24808}{s^{1.0062}}$$

$$\frac{y}{r} = \frac{C_{fopid}\, G}{1 + \ C_{fopid} G}$$

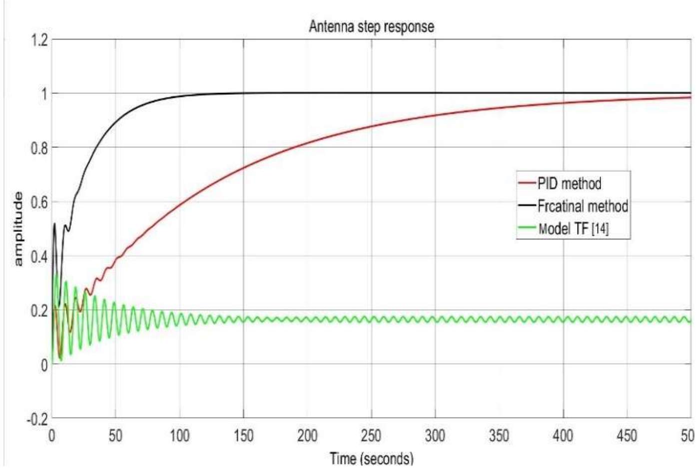


Fig. 9: Comparison of step response with controller system

The system performance is compare by step response of open loop system and close loop system with PID and FOPID show in figure 9.

The system performance with PID and FOPID are also compared with integral square error (ISE) and Integral absolute error (IAE) show in table.

$$\text{ISE}=\int_0^{\infty} e^2(t)dt$$

$$\text{IAE}=\int_0^{\infty} |e(t)|dt$$

Where e(t) is the error between step input and output of the control variable.

controller	ISE	IAE
PID	65.44	173.2
FOPID	10.54	30.94

Table 1: Comparison with ISE and IAE error

7. CONCLUSION

As a result of this work, a prototype has been put forward that optimally realigns an MW antenna link based on reasonable time and best RSL value. Numerous control architectures have been designed and tested on combinatorial tools that include loop antenna as an end-effector with 2-DOF, horizontal and vertical movement. In order to implement such automated solution, motor selection, mechanical housing, weather proofing of the motor, and wind velocity to withstand the motor in critical situation is important for long run operation. So that, PID and FOPID controller applied for fast movement. FOPID gives fast response and settled in unity. PID and FOPID methods is compared with step response graphically shown in Fig. 9. The bode plot, root locus and step response with and without PID controller for antenna alignment system show in fig. 7 and fig. 6, respectively. Performance also compares by ISE and IAE error in table 1. The FCM based reduced model is better because the ISE error is minimized. We applied the PID controller to improve the performance of the system to reduce the settling time, rise time and peak time.

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