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Performance Evaluation of a Location Control System for a Sea Going Vessel's Receiving Antenna

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***Abstract*—To ensure that vessels as a watercraft which is a means of transportation is kept afloat with maximum fighting efficiency and ease communication on a sea voyage. They are usually considered as a community due to the number of persons at any particular time working and living together on-board. The need for a control system that can be used on-board a vessel going on sea to communicate through satellite without interference or any form of disturbance during storm and free voyage is therefore of paramount importance in this regard. This paper presents how look-angle technique with respect to a spatial position of vessel to achieving receiver's dish location control. This was achieved by carrying out a simulation in Matlab Simulink software with not only reduced overshoots and settling times so also faster rise time as compared to Proportional Integral Differential controller. In a motorized parabolic dish satellite tracking application, the most common conventional method is the PID controller owing to its low cost and ease of implementation but it can only be designed for linear conditions using precise mathematical models. These days' researchers dwell more on areas of machine learning, deep learning and a host of others, it is deeply acknowledged in this work that a well-designed optimal linear controller can still give acceptable results at reduced system cost and complexity in addition to reliability and accuracy.**

Keywords—Evaluation, Location , , Look-angle, Spatial

INTRODUCTION

A communication satellite is an artificial satellite launched in space for the purpose of telecommunications. These satellite have several uses such as communication needs in television, telephone, radio, internet and military applications. At the moment, there are more than 2000 communication satellites in Earth's orbit, utilized by both private and government organizations [1]. The original signal being transmitted from the earth station to the satellite is called the uplink and is usually at a higher frequency (6GHz.). The retransmitted signal from the satellite to the receiving stations is called the downlink and is at a lower frequency (4GHz). The transmitter-receiver set in the satellite is known as a transponder. There are three altitude classifications for satellite orbits, [3], [6], and [5]. These include: Low Earth Orbit (160-1,600Km), Medium earth orbit (10,000-20,000Km), and the Geostationary orbit (35,786Km). Vessels which are means of communication are used as transportation on water; they are primarily for the movement of goods and services within national and international waters. Recently, vessels have been aggressively involved in the oil and gas exploration and storage at deep waters. Additionally, vessels have been equally designed specially as a Man-of-War to protect and police the territorial water ways against both internal and external aggressions. A vessel is operated and maintained by the ship's crew which comprises of the Captain, Engineers, Stewards, Medical and Logistics persons and so on. They are to ensure that the ship is kept afloat with the maximum fighting efficiency (Man-of-War). The crew members on-board a seagoing vessel has access to news and sporting events only when the ship is firmly secured to the Jetty side. This is because when at sea (Figure 1 refers), the mounted satellite TV antenna or dish on-board requires constants adjustment to be able to align and receive transmitted signals from the satellite feeds. This lacuna has attracted some researchers' attention with a view to providing solutions.

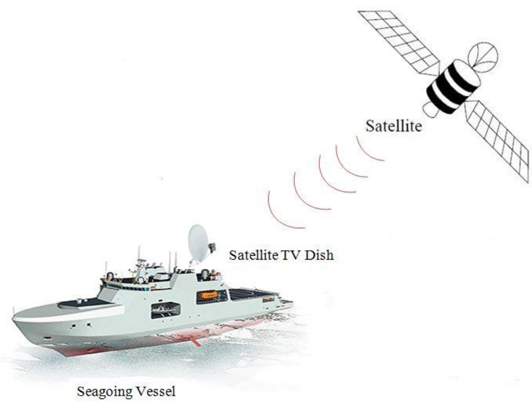

Figure 1: TV Receiver Dish on Seagoing Vessel Tracking Broadcasting Station's Satellite

[8], considered the case of overseas satellite telecommunication where the control system directs on-board motorized antenna towards a selected satellite in the presence of disturbances from the high sea waves. Fault Tolerant Control (FTC) system is designed to maintain the tracking functionality. The effectiveness of this method is tested using the ship simulator facility. However, the fault estimation has proved to be an extremely challenging task. Consequently, the team proposed the use of fault estimation in an adaptive reconfiguration system as future research. The adaptive control strategy [8], [1], [2], and [10] is an online control parameter estimation method based on certain system measured parameters and originated seven decades ago. The control method has been applied to systems with constant or varying uncertain parameters such as ship and aircraft steering, robots and processes control. An adaptive controller may be designed using either model reference method or the self-tuning method [8]. It is used by [1] for tracking control of a dish antenna system in order to establish reliable communication with a low orbit satellite. Simulation results have shown that the control system was stable and did well in eliminating disturbances. [7] Presented a Brushless DC (BLDC) motor drive performance with Adaptive Neuro-Fuzzy Interface System (ANFIS) controller under varying operating conditions. The dynamic characteristics of the BLDC motor such as speed, torque, current and voltage of the inverter components are observed and analysed. It is observed that the performance of the drive is improved with ANFIS controller when compared to PID controller. The main shortcoming of ANN in control of DC servomotors is that it usually treats the servo system like a black box. This means that it hides some vital information from the user such as on how it arrives at a conclusion thus making it extremely difficult for the designer to comprehend how it manages to handle the error in the system. [9] designed and implemented Fuzzy PID controller to track the changes occurred in position of DC motor. MATLAB/SIMULINK simulation results proved that the Fuzzy PID control method is more effective way to enhance stability of time domain performance of the DC motor. As future work, they propose that the position of DC motor can be controlled by using adaptive controllers like Neuro-Fuzzy. Model Predictive Control (MPC) and self-tuning regulator Fuzzy Logic Control (FLC) approaches were also used by [4] in their work of antenna azimuth position control. The FLC outperformed the PID controller based on reduced settling time and maximum overshoots. The main setbacks of FLC in control of DC servomotors are that it is difficult to generate accurate rule based and tuned

METHODOLOGY

The parabolic dish antenna's azimuth and elevation angles to the satellite are referred to as the look angle. These angles point the TV dish antenna directly to the satellite, while the look angles were computed with respect to spatial position of the Vessel as supplied by the GPS sensor module. Figure 6 shows the geometric relationship between the Satellite in space and the Earth Station (i.e. Parabolic Dish Antenna) with respect to the Centre of the earth.

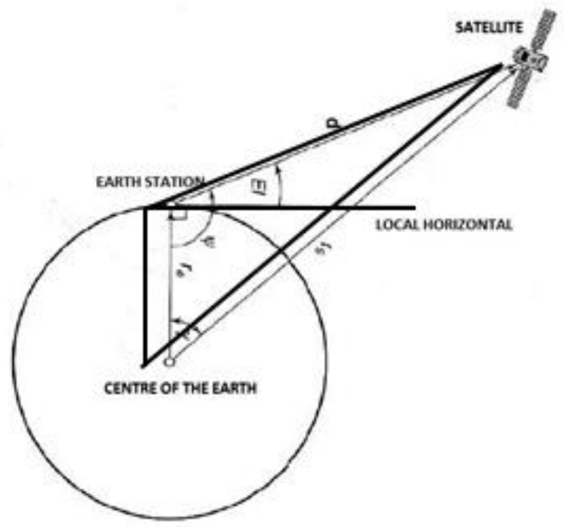

Figure 2: Geostationary Satellite and the Earth Station

In determining the elevation angle θ from the earth station to the satellite we have;

$$\boldsymbol{\theta} = cos^{-1}\{(Re+h_{GSO}/d)[1 - cos^{2}(B)\ cos^{2}(L_E)]^{1/2}\} \qquad (1)$$

And for the earth station azimuth angle to the satellite, an intermediate angle **A**$_i$ is found from;

$$\boldsymbol{A}_i = \sin^{-1}(\sin|B|/\sin\beta) \qquad (2)$$

Where $|\boldsymbol{B}|$ is the absolute value of the differential longitude,

$|\boldsymbol{B}| = |I_E - I_S|$ and $=\cos^{-1}[\cos(B)\cos(L_E)]$.

The azimuth angle $\boldsymbol{\varphi z}$ is determined from the intermediate angle $\boldsymbol{A}_i$ from one of four possible conditions based on the relative location of the earth station and the sub-satellite points (**SS**) on the earth's surface. The resulting equations to determine φz for each of the four conditions is given in Table 1.

Table 1: Azimuth Angle Estimation Conditions

S/No	Condition	Desired Azimuth Angle (φz)
1.	SS point on NE of Earth Station	A_i
2.	SS point on NW of Earth Station	360 - A_i
3.	SS point on SE of Earth Station	180 - A_i
4.	SS point on SW of Earth Station	180 + A_i

The principle of look angle determination with the aid of GPS sensor and subsequent rotation of the DC motors by the driver unit were employed to achieve desired output. Look angles (Elevation and Azimuth angles) of the designed location control system were manually estimated on-board an X seagoing vessel along I-channel, J, K- channel, L and M as well as N, O and P waters using Global Positioning System (GPS) receiver during patrol duties (The results are as shown on Table 2. The target satellite TV signal was the DSTV signal on intelsat 20 satellite located at 36ºE and the result obtained indicated slight and gradual dish movements along the azimuth axis while the movement along the elevation axis only occurred on few occasions particularly along the channels and at anchorage positions. The overall deduction was that the actual dish rotation in search of signal will be gradually and steadily. Thus, the dish rotation's sensitivity to deviation from line of sight with the space satellite must be high enough to detect the slight changes recorded.

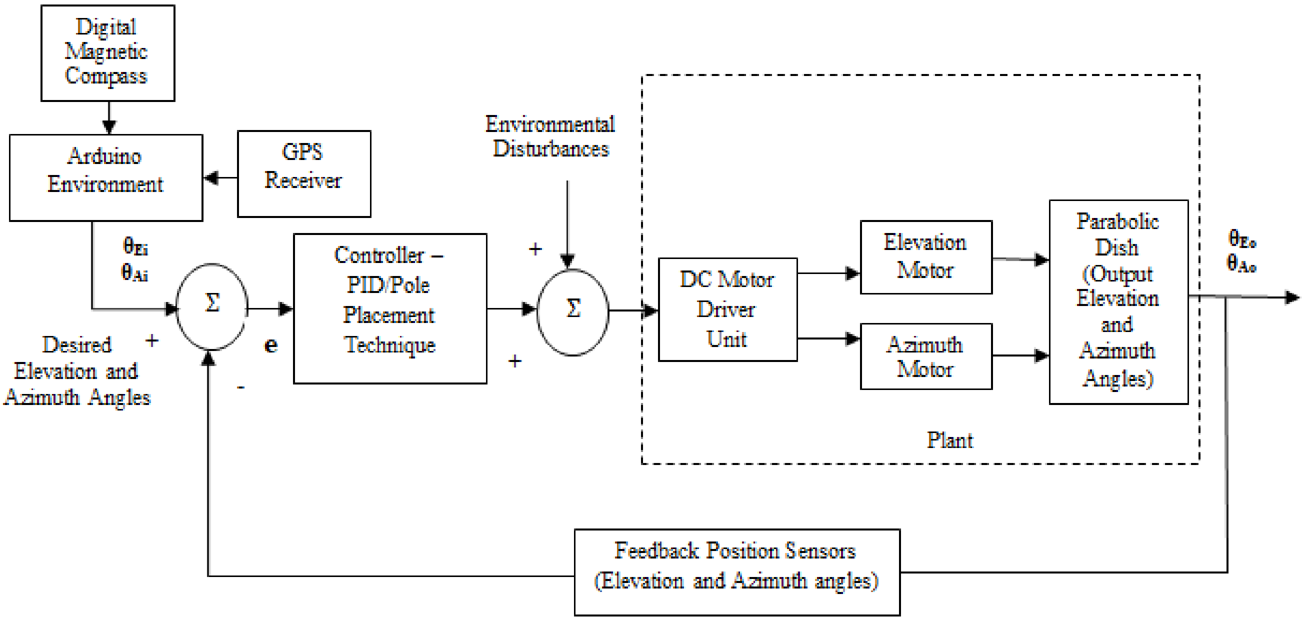

Figure 2: Block diagram of Satellite TV Antenna Control System

DISCUSSION AND RESULT

The designed pole placement by state feedback Control system has been addressed by simulation. Furthermore, its response has been compared with the PID controller in order to evaluate its performance. Meanwhile, in figure 3, the step response of the system showed improvement with the introduction of PID controller which significantly reduces the value of steady-state error, the rise time and the settling time. However, the response was not satisfactory on account of high overshoot.

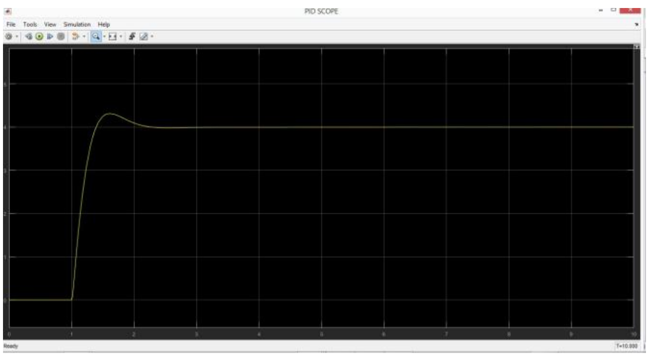

Figure 3:Proportional Integral Derivative (PID) controller Step response

Figure 4 shows the system response by applying Tuned PID Controller with the gain parameters set at (P = 1.617, I = 7.698 and D = 0.00605). It was observed that the tuned system response conformed to the system performance requirements.

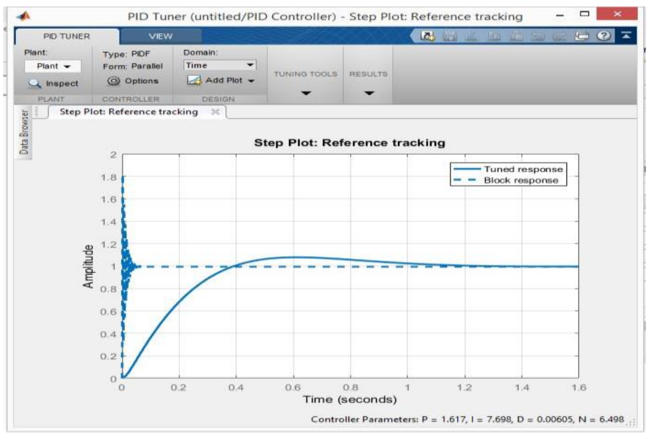

Figure 4:Tuned Proportional Integral Derivative (PID) controller Step response

A single MATLAB m-file was also developed to simulate the performance of the closed loop pole placement control technique for tracking set point commands and reducing the sensitivity of *ref* ω to load disturbances. From the simulation results it is seen that PPT controller provides response with faster settling times and reduced overshoots when compared to PID controller. The maximum overshoot with PPT is minimized to less than 4.0% while it was 23.5% with PID alone. The rise time is 0.2 seconds with PID controller and 0.9 seconds with the PPT for response to transit from 10% to 90% of the steady state value. Moreover, in addition to the strengths of PPT over PID, the PPT registered the best overall performance of 0.2seconds rise time, 5.0 % overshoot and 1 second settling time.

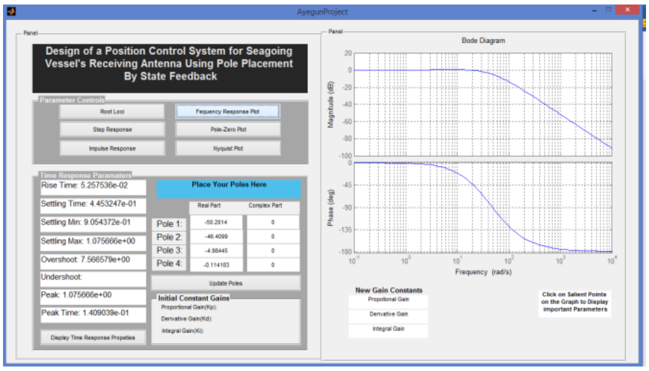

Figure 5:Pole Placement Technique (PPT) controller Bode Plot

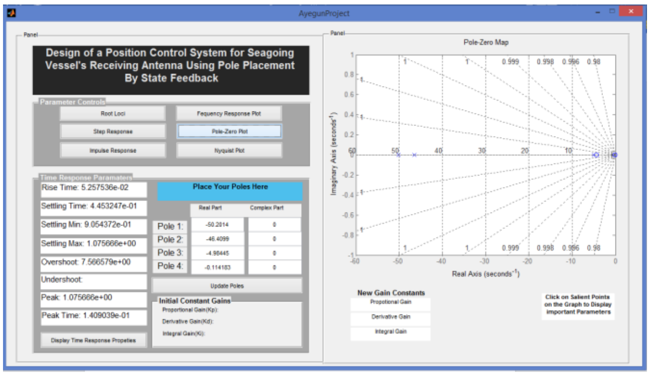

Figure 6:Pole Placement Technique (PPT) controller Pole-Zero Map

Table 2: Calculated Satellite TV Dish Elevation and Azimuth Angles at various positions at sea during voyage from I to K.

S/No	Dish Position	Latitude/Longtitude	Elevation	Azimuth
1.	I	4.5ºN/8.3ºE	57.99º	98.05º
2.	J	4.3ºN/7.2ºE	56.86º	97.74º
3.	K	6.3ºN/3.5ºE	52.68º	99.78º
4.	L	4.2ºN/6.2ºE	55.82º	97.71º
5.	M	4.8ºN/7.0ºE	56.57º	98.58º
6.	N	5.4ºN/5.0ºE	54.38º	98.89º
7.	O	6.2ºN/4.3ºE	53.52º	98.05º
8.	P	5.6ºN/4.9ºE	54.37º	98.11º

CONCLUSION

This paper has evaluated the performance of a location control system for sea going vessel's receiving antenna with the look angle estimated with respect to the spatial location of the vessel as supplied by the GPS sensor module. This simulation results shows that the PPT controller provides response with faster settling times and reduced overshoot when compared with PID controller. Moreso, in addition to the strength of PPT over PID, the PPT registered the best overall performance of 0.05 seconds rise time, 4.0% overshoot and 0.1s settling time.

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