International Journal of Electrical and Computer Engineering (IJECE)
Vol. 5, No. 2, April 2015, pp. 280~288
ISSN: 2088-8708

Improvement of Steptracking Algorithm Used Formobile Receiver System Via Satellite

Tran Van Hoi*, Nguyen Xuan Truong*, Bach Gia Duong**
* Broadcasting College 1, Radio the Voice of Viet Nam
**Electronics and Telecommunications Center, VNU University of Engineering and Technology

Article Info

Article history:

Received Jan 12, 2015
Revised Feb 9, 2015
Accepted Feb 20, 2015

Keyword:

Auto-tracking system
Discrete-time controller
Fuzzy PID controller
Sattelite communication
Step-tracking algorithm

ABSTRACT

In the mobile communication via satellite, received systems are mounted on the mobile device such as ship, train, car or airplane. In order to receive continuous signals, received antenna system must be steered in both the azimuthal and elevation angle to track a satellite. This paper proposes the improved step-tracking algorithm using for mobile receiver system viasatellite Vinasat I. This paper also presents the results of study, design and manufacture of the discrete-time controller system for the fast tracking of a satellite by applying an improved step tracking algorithm with fuzzy proportional integral derivativecontroller. Simulated and experimental results indicate that the system performances obtain from applying the improved step tracking algorithm and the fuzzy controller was better than traditional control systems.

Corresponding Author:

Tran Van Hoi,
Faculty of Electronics and CommunicationsTechnology,
Broadcasting College 1,
136 Quy Luu Road, Phu LyCity, Ha Nam Province, Viet Nam.
Email: tranvanhoi@vov.org.vn

1. INTRODUCTION

In the communication ways, satellite communication is known such as a means of providing not only fixed broadband and internet services but also provides mobile communication services and services of a new generation networks. The satellite received system shown in Figure 1, which consists of a satellite antenna, a low-noise block-down converter (LNB), a set-top box tuner, antenna control unit (ACU) and mechanical system.

In order to receive signal efficiently from the satellite, particularly, on a mobile satellite communication system, a satellite antenna must be controlled to track a target satellite accurately. Tracking capabilities depend on many parts, for example tracking algorithm, the beam width of the antennas, the speed of mobile motions and the response time of motor controller. One of the traditional tracking algorithm is used a step tracking algorithm [1]. However, algorithm was mainly applied for system, which has stable signal and not fading such as ship board system, fixed receiver system. Many antenna tracking system using step tracking algorithm have been implemented [1-4]. But tracking time is limited. This paper proposes improved steptracking algorithm by combining traditional steptracking algorithm with opened algorithm, which use global positioning system (GPS) receiver and angle sensor in order to descreasetracking time of controller.

Moreover, in the proportional integral derivative (PID) control system, due to the effects of noise and measurement errors as well as non-linear nature of the engine, leading to the calibration parameters of the PID controller is difficult to achieve good values, specially the response time is not optimal [2] [5]. Therefore, control system is performed by using a fuzzy controller todescrease response time.

To demonstrate the effectiveness of the system, the paper describes the design and fabrication of a control system, which has been capable of searching and satellite auto-tracking used for Vinasat-1 satellite. Under these conditions, the purpose of this paper is (i) to present satellite tracking algorithm, (ii) to propose improved step tracking algorithm (iii) to design and fabricate the satellite tracking control system and (iv) results and analysis.

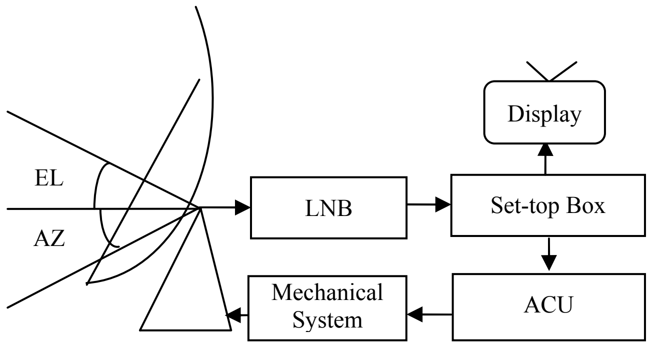

Figure 1. Configuration of satellite receiver system

2. SATELLITE TRACKING ALGORITHM

2.1. Satellite Searching Method

Satellite tracking control system divides into two function groups, namely searching and tracking control method [6], it is shown in Figure 2. There are two types of satellite searching method: Mechanical and electrical. In the mechanical method, both elevation and azimuth angles of fixed transmitter are controlled by pressing azimuth up and down keys or elevation right and left keys to drive a motor system. For electronic method, searching system is done automatically by rotating the antenna according to the elevation and azimuth angle, which was calculated.

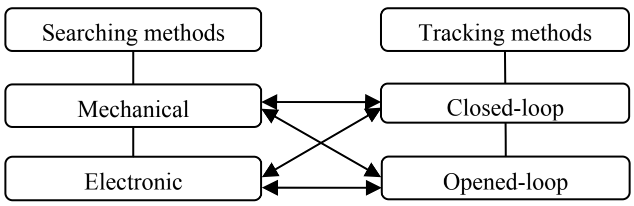

Figure 2. Satellite searching and tracking methods

To perform the process of finding a satellite, we must base on the parameters of the satellite and ground station. A ground station is located at a known point on the surface of the Earth is defined by latitude δ, and longitude λ. Geostationary satellite is determined by longitude λ_G and altitude above ground. These parameters can calculate the azimuth angle (angle measured east from north in the horizontal plane) and elevation angle (angle between the line of sight to the satellite and the local horizontal plane) of the line of sight (LOS) to the geostationary satellite. Based on these parameters can control automatically or manually the ground station antenna to capture the satellite.

2.2. Satellite Tracking Algorithm

There are two tracking algorithm, namely an opened-loop method and closed-loop method. The opened-loop uses information of mobile position from GPS receiver and angle sensors. In contrary, the closed-loop method utilizes the satellite signal to track it such as the step tracking algorithm. To increase the accuracy of the tracking process both opened-loop and closed-loop are used.

The diagram of step tracking algorithm is shown in Figure 3. The step tracking algorithm operation start when the antenna control system set initial step shift in any direction, then the received signal level will be used for comparison with the signal level before moving. If the received signal has increased, the antenna continues one-step shift in the same direction. If the received signal level has decreased, the antenna moves in the opposite direction. By step-by-step turns, the receiver antenna can track the point of the highest signal level [7].

Firstly, the control system operates in the manually or automatically search mode via parameters of ground stations and satellites. Then the system switches to tracking mode. In this mode, the control system will perform tracking process until AGC signal level is over the threshold level and tracking state keeps the idle stage. When the receiver system moves, if the AGC signal level drops between the threshold level, tracking system will move to searching mode.

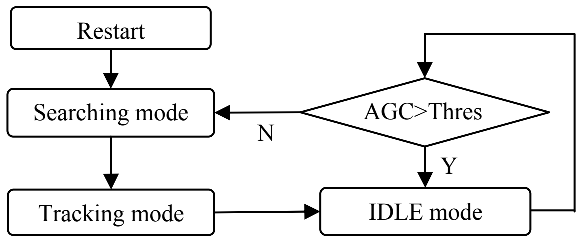

Figure 3. Diagram of step tracking algorithm

This algorithm has the advantages that the hardware configuration and the software are simple and low cost because this algorithm uses only feedback about the received signal level to the control facility. However, algorithm also has disadvantages that the received signal from the satellite to be stable and not fading, and when the receiver move on detour or intersection, the system will take time to search and track to stabilize the signal. To using effective the step tracking algorithm, we have combined with opened-loop algorithm. Diagram of proposed opened-loop algorithm is shown in Figure 4.

This algorithm uses the location information of receiver stations through high-accuracy GPS receiver combined with sensor systems elevation angle and azimuth angle. Information about longitude and latitude of the stations obtained from the GPS receiver to calculate the base elevation angle (EL1) and azimuth (AZ1) of the mobile stations. This value is compared with the elevation angle (EL2) and azimuth (AZ2) obtained from the angle sensors, which are located on the rotated axis of the antenna.

Opened-loop algorithms has the advantage of maintaining the tracking process when system moves with high speed and moves across the street. However, the disadvantages of this algorithm are accuracy depends on the accuracy of the GPS receiver, as well as the angle sensors and angle converters. Therefore, this method can combine with step tracking algorithms to take the advantage of the two methods.

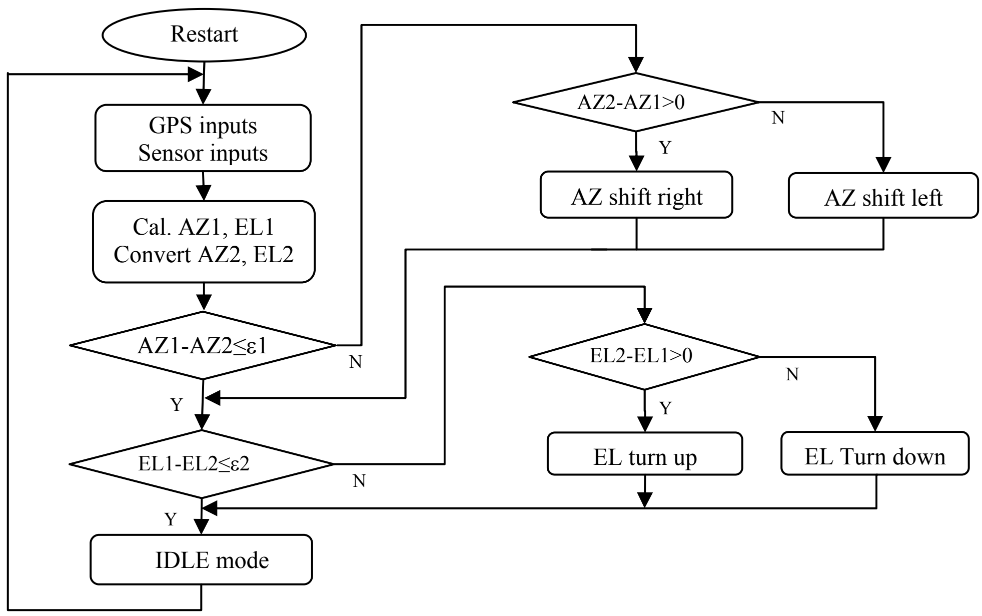

Figure 4. Diagram of opened-loop algorithm

3. PROPOSES IMPROVED STEP-TRACKING ALGORITHM

To take the advantages and restrict the dis advantages of the two methods above, the paper proposes improved tracking algorithm by combining step tracking and opened-loop algorithm, the algorithm diagram shown in Figure 5.

Firstly, the control system operates in the opened-loop traking mode. The parameters obtained from the GPS receiver and angle sensors will be calculated to adjust antenna elevation angle and azimuth angle to track the satellite. Then, the system switches to step tracking mode. In this mode, the control system will perform tracking process until AGC signal level is over the threshold level and tracking state keeps the idle stage. When the receiver system moves, if the AGC signal level drops below the threshold 1 due to moving or rounding of a vehicle, tracking system will switch to opened-loop tracking mode to reposition the antenna position, after that system shifts to step tracking mode. If the AGC signal level drops between the threshold 1 or threshold 2 levels, tracking system will shifts to step tracking mode.

Which threshold 2 is greater than threshold 1. When the AGC is greater than threshold 2, the system still obtains a stable signal. When the AGC signal level drops below the threshold 1 due to the received antenna is shifted completely different direction, and then the system will become disoriented. To reduce the searching and tracking time, the system needs to determine the azimuth and elevation angle of the antenna by switching to opened-loop mode. In this mode, the system calculates position combined with sensor systems to control the antenna to a new location and the system switches to step tracking to tuning the antenna position.

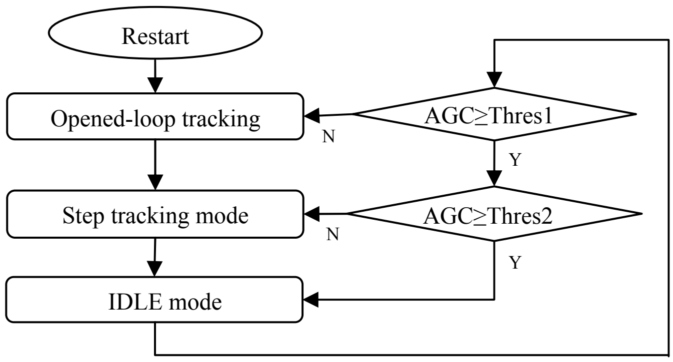

Figure 5. Diagram of improved step tracking algorithm

In step tracking algorithm, the tracking time come back to the steady state for a long time because the antenna has been completely changed direction and must be done from the searching mode. When combining algorithms are opened-loop tracking, elevation angle and azimuth are calculated in a very fast time, thus the tracking time is shorten and the received signal to ensure continuity.

4. DESIGN AND FABRICATION OF SATELLITE TRACKING CONTROL SYSTEM

The architecture of the tracking control system is shown in Figure 6. Center microcontroller receives signals from inputs such as keyboard, GPS receiver, AGC, angle sensors, encoder. After that, microcontroller implements control process using the combined tracking algorithm with fuzzy PID controller [7].

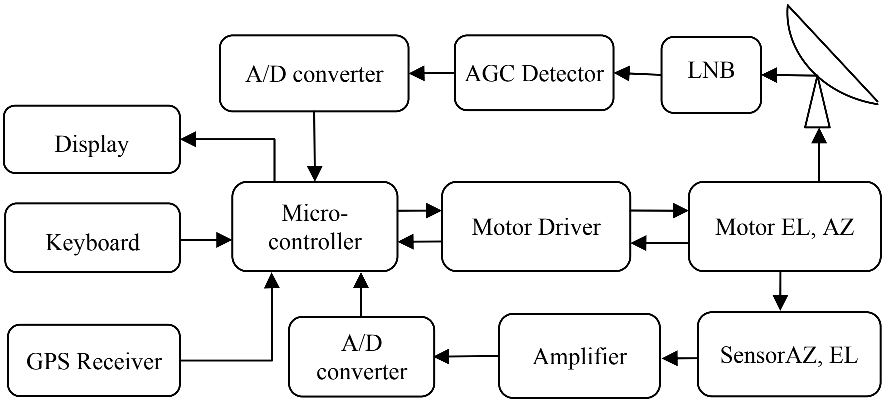

Figure 6. Block diagram of experimental configuration

To obtain the AGC signal level, the AGC detector provided the proportional signal level of AGC voltage. This AGC signal passed through the A/D converter to convert digital signal. Because the AGC signal range is very narrow, A/D converter must have a high accuracy with 12 bit resolution.

To calculating the elevation and azimuth angle of antenna, microcontroller read the latitude and longitude value of ground station from the GPS receiver and angle value from sensors. By comparison between the angle value of GPS and sensors, system controls the motor driving rotating new position.

The electronic scheme and tracking control system are shown in Figure 7. Motor driving circuit uses power transistor 2SC2581 and 2SA1106, which installed in the form of H-bridge. System uses microcontroller Atmega-128 that is 8 bit microcontroller [8].

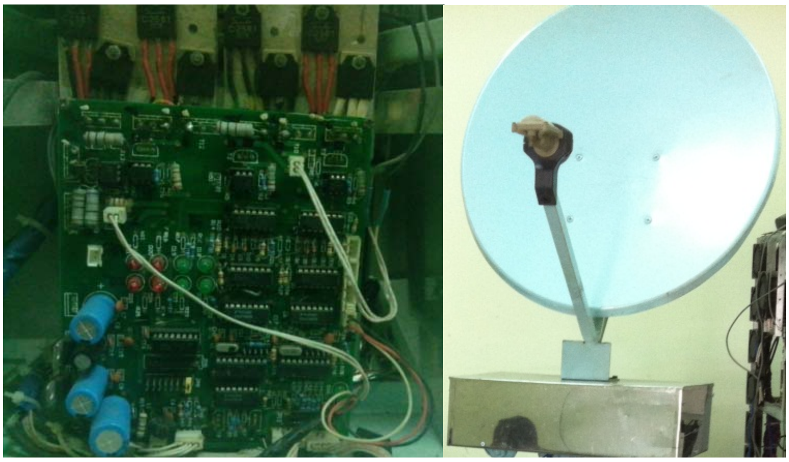

Figure 7. The electronic scheme and completed tracking control system

In order to confirm a performance of tracking algorithm and fuzzy controller, the parabola antenna with a diameter of 60cm is used for Vinasat 1 satellite. Mechanical system use two 24V-DC servo motors with speed of 1500 rpm, elevation range of rotation is from 0^0 to $90^0$and azimuth is from 0^0 to 355^0.

In the PID controll system, due to the effects of noise and measurement errors as well as non-linear nature of the engine, leading to the calibration parameters of the PID controller is difficult to achieve good value [9]. Therefore, a fine-tuning process is performed by a fuzzy controller before applying to the system controller.

ISSN: 2088-8708

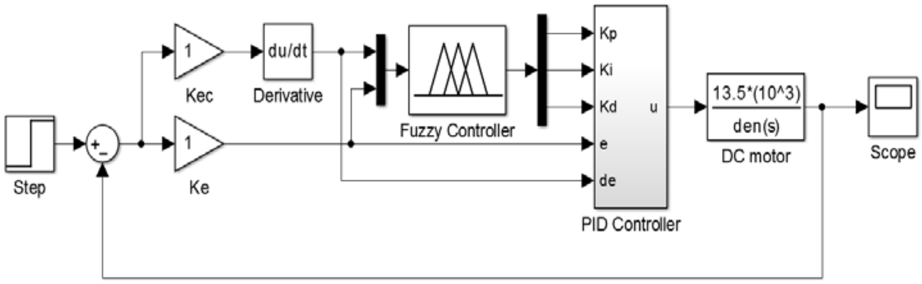

Figure 8. Simulink diagram fuzzy PID controller

The structure of the fuzzy PID controller is shown in Figure 8. Fuzzy controller will perform optimizing control parameters of PID controller based on the current parameters of the classical error (e) and the rate of the change of error (de/dt). Therefore, the input of the fuzzy controller includes control error signal e(t) and its derivative de(t). The outputs of the fuzzy controller are three PID parameters: K_P, K_I, K_D [10].

The simulated results of PID controller and fuzzy controller are shown in Figures 9 and 10. The result shows that the response of PID controller is oscillatory and long setting time, which can damage the system. But the response of fuzzy PID controller is better than PID controller.

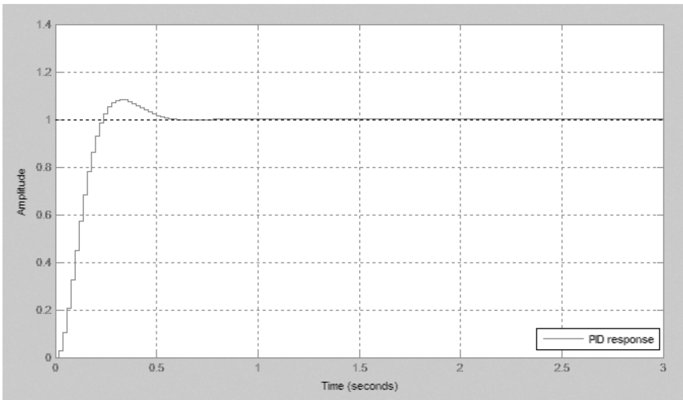

Figure 9. The step response of the PID controller

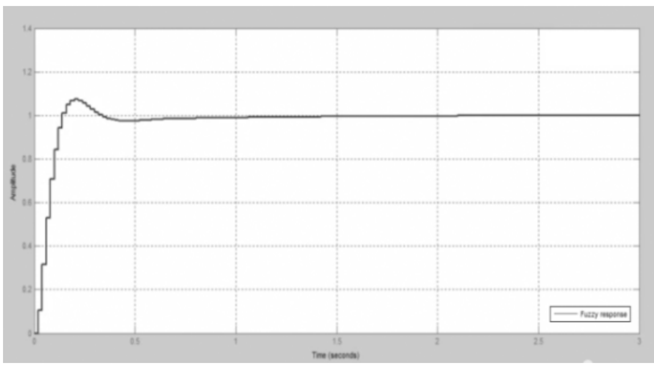

Figure 10. The step response of the fuzzy PID controller

5. RESULTS AND ANALYSIS

Figure 11 indicates variations of the AGC voltage versus time when using the PID controller and fuzzy PID controller. At the point of 10s, the time to reach the focus item is observed 0.8s in case of PID controller and 0.4s in case of fuzzy PID controller.

The results show that the AGC level curve is flatter than in case of PID controller.

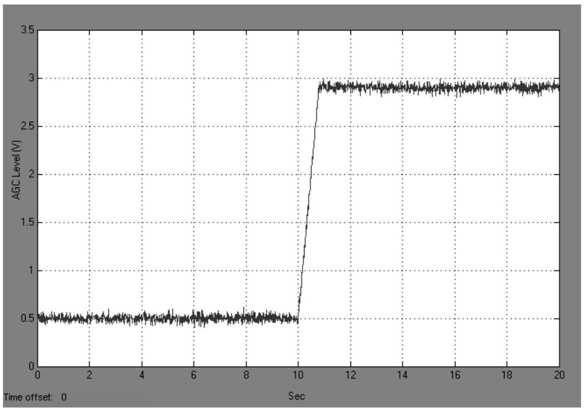

Figure 11. AGC level with PID controller (a)

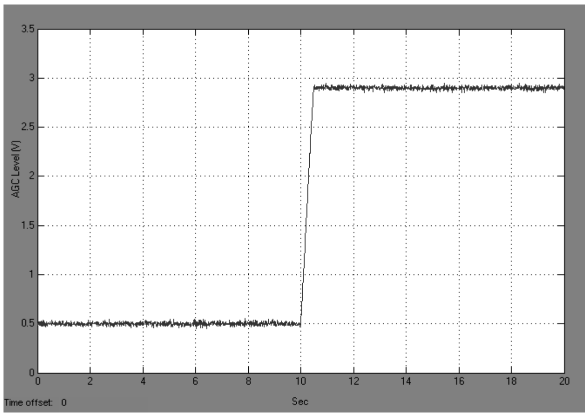

Figure 12. AGC level with fuzzy PID controller

Figures 13, 14 and 15 shows the tracking time using step-tracking, opened-loop algorithm and improved step tracking algorithm.The system performs searching mode in the time from 0 to 5 seconds, then moves to tracking mode and turn to stable mode. When the receiver system moves, the received antenna would be disoriented, so the system switches to tracking mode (at point A) and the time to track and return stable state takes about 2-4s when using step-tracking algorithm and about 0.5-0.7s when using opened-loop algorithm or improved step tracking algorithm.

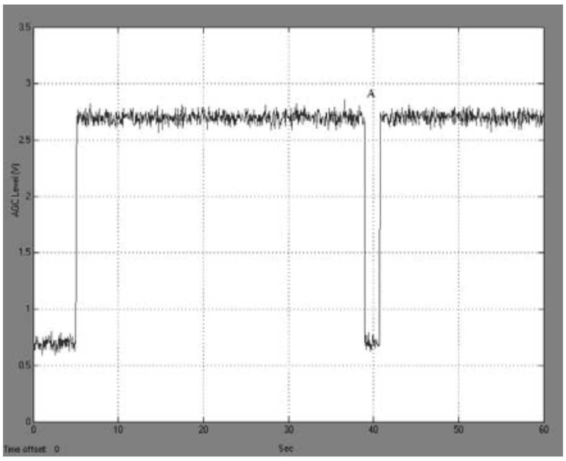

Figure 13. The tracking time using step-tracking algorithm

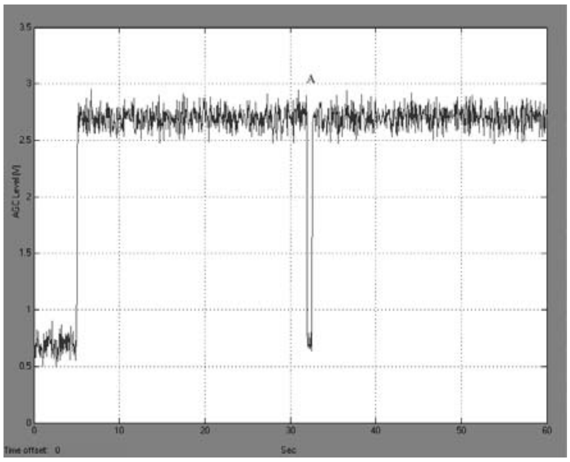

Figure 14. The tracking time using opened-loop algorithm

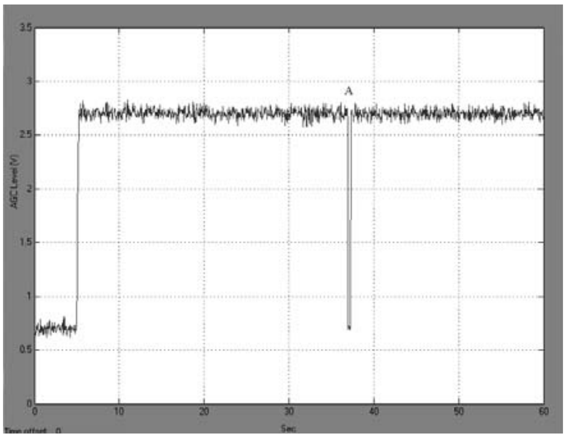

Figure 15. The tracking time using improved step tracking algorithm

From the Figures 14 and 15, we can see that when using the combined tracking algorithm the tracking time is shortened time equivalent when using opened-loop algorithm, but the quality of signal is more stable due to combining step-traking algorithm to tune the antenna position more accurately.

6. CONCLUSION

This paper proposed improved step tracking algorithm by combining step tracking and opened-loop algorithm to descrease tracking time. The paper also presented the study, design and fabrication of the searching and satellite auto-tracking system used for mobile satellite receiver. In order to descrease response time, the system also applied fuzzy control method to design self-tuning fuzzy PID controller. The result shows that the system applies improved tracking algorithm with fuzzy PID controller has a better performance in response time, tracking time.

Table 1. Comparison with the previous published

Ref	Controller	Tracking time	Response time
[1]	H_∞robustcontroller	0.6s	-
[2]	PI controller	0.6s	0.6s
This work	Fuzzy PID controller	0.5-0.7s	0.4s

ACKNOWLEDGEMENTS

The research has been sponsored by Vietnam Academy of Science and Technology and carried out at University of Engineering and Technology, VNU.

REFERENCES

[1] Chang-Ho C., Sang-Hyo L., Tae-Yong K., and Cheol L. “Antenna Control System Using Step Tracking Algorithm with H∞ Controller”.*International Journal of Control, Automation and System*. Vol 1, No. 1, pp 83-92, 2003.
[2] Myeongkyun Kim, Jinsoo Kim and Oh Yang. “Precise Attitude Control System Design for the Tracking of Parabolic Satellite Antenna”. *International Journal of Smart Home*. Vol. 7, No.5, pp. 275-290, 2013.
[3] Jinsoo Kim, Myeong Kyun Kim, Oh Yang. “Parabolic Satellite Tracking System”. *The 3rd International Conference on Circuits, Control, Communication, Electricity, Electronics, Energy, System, Signal and Simulation.* Vol. 25, pp. 123-126, 2013.
[4] Weimin Jia, Luyao Hao, Kai Du.“Step tracking algorithm based on finite difference stochastic approximation for SATCOM on-the-move”. *International Conference on Electric Information and Control Engineering.* pp. 2632 – 2635, 2011.
[5] Sobutyeh Rezanezhad. “Design of Fuzzy Optimized Controller for Satellite Attitude Control by Two State actuator to reduce Limit Cycle based on Takagi-Sugeno Method”. *International Journal of Electrical and Computer Engineering.*Vol 4, No 3, 2014.
[6] Nazzareno Diodato. “Satellite Communication”, chap.2, pp. 33-58. Intech, September, 2010.

[7] Luyao Hao, Minli Yao. SPSA-based step tracking algorithm for mobile DBS reception'. *Journal on Simulation Modelling Practice and Theory*. 2011n vol. 19, no. 2, pp. 837-846.
[8] Roop Singh Takur, E. Ramkumar. "Improving Quality of Vehicle Tracking Systems in Hill Stations Using IEEE 802.16 Networks". *International Journal of Electrical and Computer Engineering*. 2013, Vol 3, No 1.
[9] Kamal Y., Farid H., Amir M. "Design of Intelligent PID Controller for AVR System Using an Adaptive Neuro Fuzzy Inference System". *International Journal of Electrical and Computer Engineering.* 2014, Vol 4, No 5.
[10] Jium-Ming Lin, Po-Kuang Chang. "Intelligent Mobile Satellite Antenna Tracking System Design". *SICE Annual Conference.* 2008, pp. 2922-2927.

BIOGRAPHIES OF AUTHORS

Tran Van Hoi was born in Phu Ly City, Ha Nam Province, Viet Nam, in 1978. He received the B.S degree in telecommunication techniques from University of Transport and communications (UTC) in 2001. He received M.S degree in electronic wireless and communication from Le Quy DonTechnicalUniversity in 2004. Since 2001, He has been a lecturer in Broadcasting College 1, Radio the Voice of Viet Nam. Currenlly, He is a Ph.D student in VNU University of Engineering and Technology. His research interests involves in RF Analog Signal Processing, RF design, RF chip design, Satellite Communication, Automatic Control.
Email: tranvanhoi@vov.org.vn

Dr. Nguyen Xuan Truong was born in Ha Noi City, Viet Nam, in 1964. He completed his B.S degree in electronics and telecommunications from Ha Noi University of Science and Technology in 1986, M.S degree in 2002 and Ph.D. degree in 2009. Since 1986, He has been a lecturer in Broadcasting College 1, Voice of Viet Nam. His research interests involves in Analog and Digital Signal Processing, Television Technology, Satellite Communication, Automatic Control.
Email: nguyenxuantruong@vov.org.vn

Assoc. Prof. Bach Gia Duongwas born in Ha Dong Dist, Ha Noi Province, Viet Nam, in 1950. He received the B.S degree in radio physics in 1972 and the Ph.D. degree in wireless physics from University of Hanoi, in 1988. From 1988 to 1990, he was a research assistant in Leningrad University, Russia. From 1991 to 2005, he was a researcher in academy of air force. Since 2006 He is a lecturer and Head of electronics and telecommunication center, University of Engineering and Technology, Vietnam National University. His research focuses on RF Analog Signal Processing, RF chip design, Radar Engineering and Technology, Automatic Control.
Email: duongbg@vnu.edu.vn