

Design of ATP control system for space optical communication

Shizhong Ma*, Mingming Wang, Xiaohui Li

College of Electrical Engineering, North China University of Science and Technology, Caofeidian District, Tangshan City, Hebei Province, China

Abstract: This article first introduces the significance of studying space optical communication and the current research status at home and abroad, and gives a general discussion on the application prospects and development trends of space optical communication, and elaborates the necessity and importance of conducting optical communication research. Then, the working principle of ATP in space optical communication system is studied, the mathematical model of ATP control system is established according to the actual needs, and the ATP control system design of space optical communication is designed. By selecting appropriate motors and gyroscopes as the actuators and detection elements of the system, substituting the actual parameters for simulation analysis, and correcting and verifying the results, some useful results are obtained. The simulation results show the rationality and effectiveness of the ATP design scheme.

Keywords: Space optical communication; ATP; simulation; correction

1. Introduction

In 2002, Harbin Institute of Technology successfully developed the first comprehensive and comprehensive laser inter-satellite link simulation experiment system in China, which can simulate the laser link targeting, acquisition, tracking, communication, and performance index testing of inter-satellite laser links. Wuhan University first completed a 42M multi-service atmospheric laser communication test in China in 2006. In March 2007, it was the first in China to complete an all-airspace FSO automatic tracking servo system test. This is for the development of airborne, spaceborne laser communication systems, and ground band automation. The FSO system of target capture function creates the conditions. Compared with other wireless communications, free space optical communication has the advantages of not requiring a frequency license, wide frequency, low cost, good confidentiality, low bit error rate, fast installation, anti-electromagnetic interference, convenient and flexible networking. The FSO system solves the "last mile" access of broadband networks, realizes fiber-to-the-desktop, completes high-speed transmission of voice, data, and images, stimulates the voice service industry and interactive film and television transmission, and realizes "three-network integration". It is beneficial to the development of e-government, e-commerce, distance education and telemedicine, and has produced huge benefits. It has broad application fields and market prospects.

2. Mathematical model of space optical communication ATP system

The ATP control system generally uses a DC torque motor, and the speedometer speed loop is used to drive the gimbal in the azimuth and pitch directions. It provides low-speed and stable tracking capabilities, a wide speed range and high servo stiffness.

Copyright © 2020 Shizhong Ma *et al.*

doi: 10.18063/cse.v4i1.1134

This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License

(<http://creativecommons.org/licenses/by-nc/4.0/>), which permits non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

2.1 Mathematical model of gyroscope

The gyro in the system is used to measure the rotational angular velocity of the load axis. It is used to measure the angular velocity of the load axis after the locking loop is applied by the two-degree-of-freedom flexible gyro. The TN-3B gyroscope is selected for speed measurement in the system. According to the above analysis, it is a second-order link. The TN-3B gyroscope is selected and the transfer function of the gyro angular velocity is calculated according to the parameters:

$$G(s) = \frac{V(s)}{\omega(s)} = \frac{k_G \omega_G^2}{s^2 + 2\xi\omega_G s + \omega_G^2} = \frac{5.73}{8.4 \times 10^{-3} s^2 + 0.004s + 1}$$

2.2 Mathematical model of torque motor

Compared with ordinary servo motors, the use of DC torque motors as actuators in high-precision servo systems has many advantages. The DC torque motor has good mechanical rigidity, high mechanical resonance frequency, and can be directly coupled to the load. Therefore, using a DC torque motor to construct a tracking servo system is easy to achieve high-precision, wide-band stable operation, and low-speed performance is particularly good.

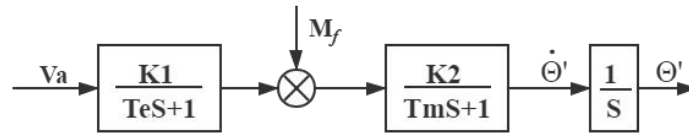


Figure 1. Motor transfer function block diagram

According to the experimental summary, J160LYX06J torque motor is selected, a According to the above motor parameters, k_1 , k_2 , T_e , T_m in the dynamic model of the torque motor can be calculated Wait for 4 parameters:

$$T_e=1.75\text{ms}, T_m=0.27\text{s}, K_1=0.64, K_2=0.27$$

3.Link performance analysis and correction

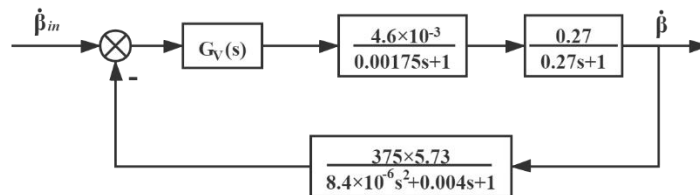


Figure 2. System model block diagram

A step signal of $10^\circ/\text{s}$ is added to the pitch axis speed loop. Since the input of the speed loop is digital, the input is a digital value of 375 of the step signal of $10^\circ/\text{s}$. As shown. As can be seen from the figure below, during the step response transition, there is no overshoot and the adjustment time is short, but there is a steady-state error.

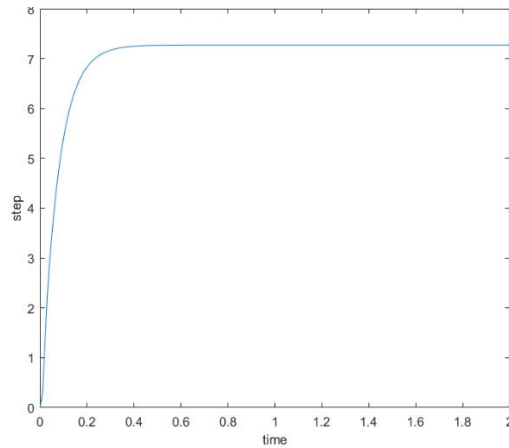


Figure 3. Speed loop step response before correction

The open-loop transfer function of the pitch axis speed loop is:

$$G(S) = \frac{2.6687}{0.00001S^3 + 0.0016S^2 + 0.2757S + 1}$$

The frequency characteristics of the speed loop open loop are shown below. From the figure, we can conclude that the system has a phase angle margin of 106.7 and an amplitude margin of 23.1 dB without correction. Although the system is stable, the crossing frequency is small and the high-frequency anti-interference ability is poor.

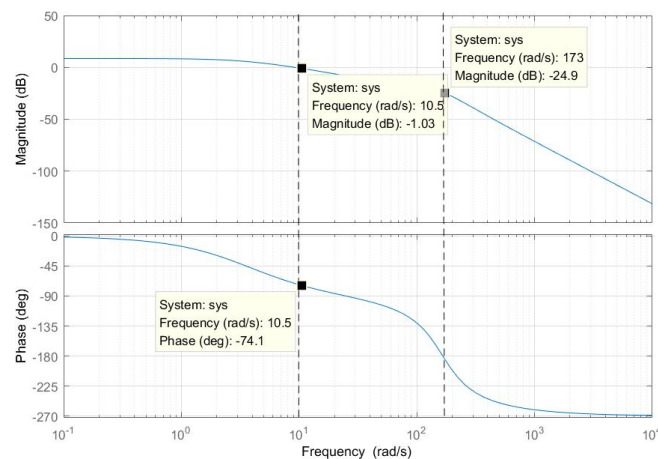


Figure 4. Open-loop frequency characteristics before speed loop correction

Select the crossing frequency $\omega_c = 60 \text{ rad/s}$, and the speed loop correction network transfer function is:

$$G(v) = 30 \times \left(\frac{1}{s} + \frac{0.16s + 1}{s + 1} \right)$$

After being calibrated, A pitch signal of $10^\circ/\text{s}$ is added to the pitch axis speed loop. During the correction of the step response transition, there is no overshoot and the adjustment time is increased, but the steady-state error is reduced, which can reach the category of a differenceless system.

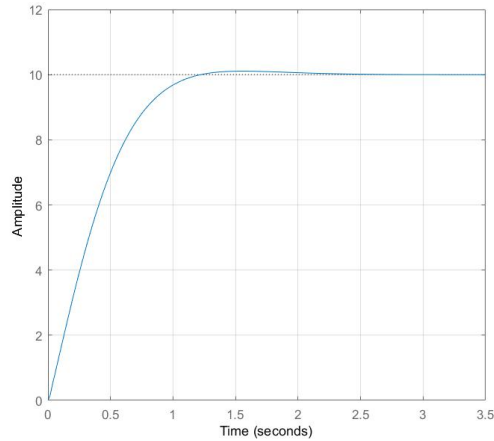


Figure 5. Step input response after speed loop correction

After applying the hysteresis correction, the open-loop frequency is shown in the following figure. The crossing frequency $\omega_c = 51.2 \text{ rad/s}$, the phase margin is 69° , the system is stable, and the high frequency anti-interference ability is increased.

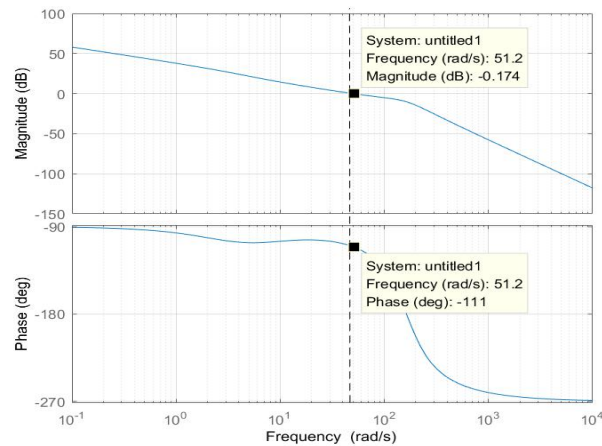


Figure 6. Open-loop frequency characteristics after speed loop correction

References

1. Oh S, Yoon Y, Kim M, Kim Y. ATP functional allocation for Korean radio based train control system [P]. Control, Automation and Systems (ICCAS); 2012. 12th International Conference on 2012.
2. Oh S, Yoon Y, Kim K, Kim Y. Design of ATP functions and communication interface specifications for Korean Radio-based Train Control System [P]; 2013.
3. Artika IM. Development of dual control allotopic expression system for subunit 8 of yeast *saccharomyces cerevisiae* mitochondrial ATP synthase [J]. HAYATI Journal of Biosciences 2011; 18(3).
4. Raj AAB, Selvi JAV, Raghavan S. Terrestrial free space line of sight optical communication (TFSLSOC) using adaptive control steering system with laser beam Tracking, Aligning and Positioning (ATP) [P]. Wireless Communication and Sensor Computing; 2010. ICWCSC 2010. International Conference on 2010.
5. Xing W, Liang YB, Liu S. The design and control of fine tracking loop of ATP system for free space laser communication [P]. Information Engineering and Computer Science (ICIECS); 2010. 2nd International Conference on 2010.
6. Anonymous. ATP oil & gas first in GoM to install ADS-B air traffic control system [J]. Ocean News Technology 2009; 15(6).
7. Anonymous. ATP oil & gas corporation; ATP first in gulf to install ADS-B air traffic control system [J]. Journal of Transportation 2009.
8. Funk GD, Huxtable AG, Lorier AR. ATP in central respiratory control: A three-part signaling system [J]. Respiratory Physiology & Neurobiology 2008; 164(1).
9. Whalen PA, Whalen PJ, Cairns JE. ATP monitoring technology for microbial growth control in potable water systems [P]. SPIE Defense + Commercial Sensing; 2006.