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Tracking Control Algorithm Model Design

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Abstract—The tracking control of LEO flight has two models, operation tracking of flight with known trajectory and vehicle tracking with dynamic trajectory. Tracking an aircraft with trajectory known, is mainly for the trajectory parameters, which are used to determine whether the flight path departures from the original setting or adjust the tracking position of receivers on the ground to get the transmitted data. Dynamic tracking has an unknown running track, tracking algorithms are related to the situation of the equipment, and the controlling process algorithm has high demands. In this paper, the writer designed a tracking algorithm for known trajectory under a tracking system, thus achieved good results on the applications.

Keywords- LEO; tracking; control; algorithm

1. Introduction

A tracking control system for tracking the flight paths of low-altitude aircraft, by changing the orientation of the antenna to make the running track of the tracking antenna the same flight path with the low altitude aircraft. Control of tracking antenna has a certain inertia, while the control signal has a certain lag effect during processing and transmission, during the control process we have to ensure the tracking accuracy, in addition to handle the advanced amount of control signals, more importantly, is to form an effective algorithm that can effectively control the tracking antenna, and meet the requirements of the tracking performance.

We use AC servo motor to control the receiving antenna in the control system, AC servo motor control is determined by the inverter based on the output of the controlling host, whose control signal depends on the output of algorithm control. The input parameters of the whole control algorithm come from the dynamic data acquisition of servo motor point. Data acquisition system installed in the motor controlling terminal of tracking antenna is a dynamic data acquisition, and is required to record the initiative position, and can save the current position when stops and give tips the next time it is launched. Data collection resource is set on the motor shaft which leads the tracking antenna, motor running starts up the data acquisition system, which pre-process the collected data and send them to a central control room by the appropriate encodings. After analysis and processing of data, the host in the control room output the corresponding control signal which is sent to the inverter under the requirements of algorithm model, thus control the motor through the inverter. Over the whole control process, the control accuracy is based on the level received signal gained of the tracking antenna, as long as the received signals meet the requirements, we can determine whether the tracking path has the same trajectory with aircraft trajectory.

2. Control Model Analysis

Control model is shown in Figure 1as follow:

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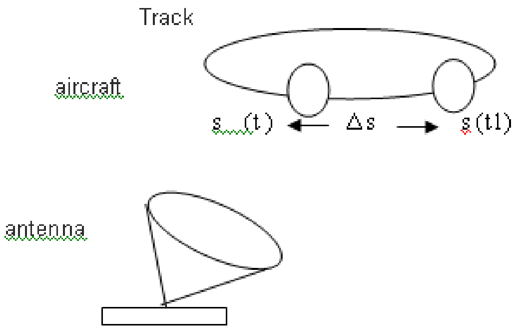

Figure 1. Tracking antennas and satellite movement diagram

The running track of LEO aircraft in space can be seen as the location of the mobile, that is:

$$S(t) = S(t1) + \Delta \tag{1}$$

S(t):the aircraft's location on the orbit at the current time t;

S(t1):the aircraft's location on the orbit at the current time t1;

ΔS:the position change on the orbital during the time t1-t

The location change of the LEO aircraft's trajectories in space is not linear but a curved orbit. When tracking of the tracking antenna, the curved orbit in space can be projected as a plane, so that the control of the tracking antenna turns to plane control. Tracking antenna has a motor to drive, which only has two direction of motor rotation and can be look as straight line sporting. Tracking of the corresponding track size in space can only let two groups of motors changing in two different directions at the same time, that is convert ΔS to ΔX and ΔY. By (1) it yields:

$$X(t) = X(t1) + \Delta X \tag{2}$$

$$Y(t) = Y(t1) + \Delta Y \tag{3}$$

The curved track projects onto the plane, and ΔS is very easy to convert into ΔX and ΔY, the model is shown in Figure 2 as follow:

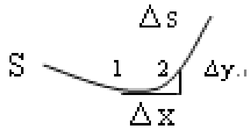

Figure 2: Diagram for trajectory's projection and control orbit

But this kind of controlling track will be presented to be zigzag, and will impact on tracking accuracy. If considering of the principles of digital integration, interpolation methods can be used for processing, but still we must notice that the speed of low-orbit vehicle is not constant, that is to say the radius of arc is not steady. Linear interpolation method can be:

$$\Delta S = \sqrt{(x2 - x1)^2 + (y2 - y1)^2} \tag{4}$$

The tracking path dealing with this model has two problems. Formula (4) shows ΔS is positive, when track changes it to be negative, we must consider the symbol of ΔS, which can be considered by the symbol of Δx and Δy, respectively, which in the algorithm processing is getting different judgments of them. In addition, when the data collection interval between them is too large so that the benefits of the received signal are instable, it will impact on the tracking accuracy. Based on this, we can increase the sampling frequency and control frequency, think it over after taking half value of Δx and Δy. Thus there is:

$$\Delta S = \sqrt{\left(\frac{x2 - x1}{2}\right)^2 + \left(\frac{y2 - y1}{2}\right)^2} \tag{5}$$

Using this algorithm, tracking effect has got some improvement, but still the accuracy can not meet requires. After analysis, considering the lag in the tracking process, we need to increase the volume of tracking control, but at the same time we need to combine the characteristics of drives, so that we can avoid negative effects of the inertia of tracking antenna. Consider comprehensively, we adjust the tracking control algorithms.

For the model, we take the control formula of original model as:

$$\Delta S^2 = \Delta x^2 + \Delta y^2 \tag{6}$$

Figure 2 shows, in the control model, for a single direction motor, this is a linear control, in the directions of X and Y, the trajectory of motor is actually a linear. After increase the control amount, it is required that we can not change the linear trajectory of the motor, but when the higher order terms increase, it is indeed an increase of the intensity of control volume. Because of the characteristics of variable values, X and Y must be less than 1, so after 2 times' and several times' variable treatments, the value must be substantially less than 1 time's treatment. The accumulated results just increase the extent of control amount with the direction not change, which does not appear to be a mutation but play a role for steady and strengthening. As the model in Figure 2, position changes after increasing the control amount:

$$\Delta x = \Delta x' + \Delta x'^2 + \Delta x'^3 \tag{7}$$

$$\Delta y = \Delta y' + \Delta y'^2 + \Delta y'^3 \tag{8}$$

According to this control mode, we can achieve better control effect.

3. The impact on the control precision by control mode

Algorithm for tracking control system has something to do with data acquisition, and also with the control model, control signal generation and transmission.

3.1. data acquisition and transmission

Data acquisition and transmission in LEO tracking control system plays an important role, data source is the motor speed, which after converted to digital signals by the sensor data need to be preprocessed. Data acquisition system is a set of embedded devices, to prevent errors in data conversion processes, the sensor signal in the conversion is Gray code. Considering the sensors set by tracking antenna have a long distant with data acquisition system, we use 422 standard transmissions between them. After data acquisition system receives the data, the data preprocessing can reduce the load on the host. Data acquisition system can be placed in parallel with the host, which can transmit the data to the host through serial port. Taking into account of the precision control of data acquisition and transmission, data processing can be separated with control algorithms, eliminating the impact on accuracy by error.

3.2. generate and output of control signals

I / O port outputs the control signals processed by the host, which are stated with dedicated digital and analog I / O card and are directly connected with the inverter. The inverter controls high power, and sets optical isolators between the weakness of I / O and the inverter. Motor speed is controlled by analog I / O, corresponding relationship between Δx , Δy and the motor control voltage has to be considered in the algorithm, and the control voltage between the two groups of motors is different, which we should pay particular attention to in the algorithm and the connection. The inverter has a programming system inside, considering the inertia of tracking system, we can set PID through the inverter, and through direct processing, bring convenience to the master algorithm model. Master algorithm will be much more complex with too many considerations, and also complex algorithm will affect the stability and reliability.

4. Conclusion

The algorithm model for tracking an aircraft with trajectory known aims at error analysis, adjusts the antenna orientation, and its different mechanical equipment and powered driver have a greater impact on the algorithm. However, by separating data acquisition, preprocessing and host controlling and drive controlling it have a positive effect to improve control precision, stability and reliability of the overall system. Driven by AC servo motor needs to use variable frequency controller, the quality of the performance of motor and inverter has a great impact on the control precision, and there are also individual differences exist between mechanical equipment and electrical control equipment, so when face the overall design of master algorithms and servo control program there should be adjusted parameters to on-the-spot system adjusting, which makes it to meet the design requirements.

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