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Preliminary Design of Autonomous Navigation based on Inter-satellite Link

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Abstract: Inter-satellite link (ISL) is an innovative way to achieve autonomous navigation. In this paper, preliminary design such as system design, ranging and communication technology, routing policy evaluation, and fusion algorithm are introduced to construct the process of autonomous navigation based on ISL.

Keywords: Autonomous Navigation; Inter-satellite Link; Orbit Prediction

1. Introduction

Autonomous navigation is the basic ability to realize processing independently for future navigation satellites, even in the absence of support from the ground control center. It mainly refers to the estimates of spaceborne ephemeris and clock errors [1-4]. On one hand, deal with the situation that ground control center being destructed by enemies. At this time, satellite requires the ability to broadcast satellite position and clock data to meet the accuracy requirements independently. On the other hand, the redundant satellite observations will also improve the ability of navigation service, which is realized by joint orbit determination. In addition, inter-satellite links observations of the satellite can also be used to provide data for current satellite-based integrity monitoring, as a new means to the constellation of independent monitoring.

The premise to achieve the above functions is ranging and communication through the terminal of inter-satellite link, thus achieving network topology construction, autonomous orbit determination, and time synchronization. This article will mainly focus on critical technologies of inter-satellite links and autonomous navigation including system design, communications technology, routing policy evaluation, and self-process, in order to provide a reference for the construction of future GNSS system.

2. System Design

Ranging and communications is the premise of autonomous navigation, as shown in Fig.1. By routing design, ranging information will be transmitted to the appropriate computing nodes. After deducting clock error of pseudo-range, integrity prediction pretreatment, orbit and clock error parameters are decoupled. And then, orbit ephemeris is obtained to realize autonomous navigation.

According to the program of autonomous navigation using inter-satellite links, the key design techniques that ranging and communication technology, network routing policy of inter-satellite links, and algorithm for autonomous navigation and time synchronization are realized.

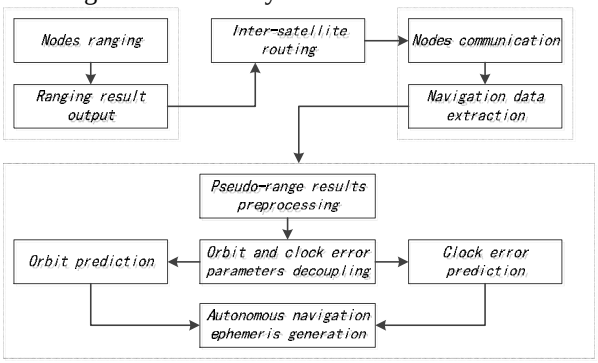

Figure 1. The program of autonomous navigation

3. Terminal Design for Ranging and Communication

According to the literature [5] and [6], higher frequencies (Ka, EHF and V-band) microwave links and greater capacity laser link will be the development direction of ISL.In high-frequency microwave link, the antenna beam could be narrow and the available band could be extended. The possibility of signal interference are reduced. The antennas and other equipment coule be miniaturized. Compared with microwave link, laser link could bring higher data rates to meet the needs of large-capacity transmission.The divergence angle of the laser beam is smaller than microwave beam, which will greatly increase the density of electromagnetic energy. Additionlly, the weight, volume and power consumption could be reduced. Meanwhile, its excellent anti-jamming performance is conducive to military applications. However, both microwave links and laser links need to raise the level of design capability on the following fileds:

(1) Improve the accuracy of ranging;
(2) Improving the anti-jamming capability;
(3) Improving the communication performance.

4. Network and Routing Strategy Design

Visibility between the satellites is mainly limited by the earth block, and the scanning angle of antenna[7, 8]. Visible satellites in the same orbital plane and different orbital planes are analyzed respectively. Transit routing and network topology design needs to start from the evaluation system. Currently two routing strategies are more commonly used, which are minimum hop routing strategy and minimum distance routing policy. Taking the autonomous orbit determination accuracy into account, DOP configuration is another important design factor in inter-satellite links.

5. Autonomous Navigation and time Synchronization Design

Basic processing for autonomous navigation and time synchronization is shown in figure2.

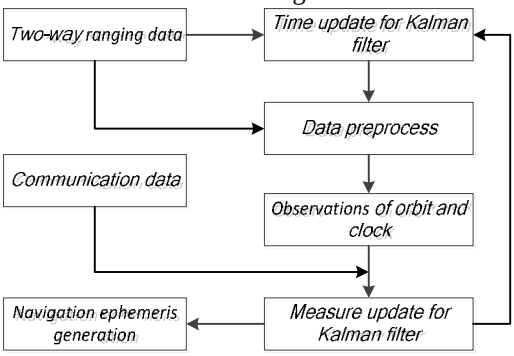

Figure 2. Process of autonomous navigation and time synchronization

(1) Start ranging for two-way satellite links to obtain pseudorange observations;
(2) Use pseudo-range system errors, and two-way pseudo-range data to achieve epoch naturalization, and then use the two-way pseudo to form orbit observations and time synchronization observables;
(3) Use orbit and clock errors to autonomously update parameters information of broadcast ephemeris.

Conclusion

In this paper, key technologies such as system design, communications technology, routing policy evaluation, and fusion algorithm are researched, which will provide reference for future ISL construction.

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