Paper ID: 16500
student

SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM (B2)
Advanced Space Communications and Navigation Systems (4)

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RESEARCH ON THE EF PHASE ESTIMATION X-RAY PULSARS RELATIVE NAVIGATION BASED SPATIAL STATES DETERMINATION OF FORMATION FLYING SPACECRAFTS

Abstract

Relative navigation for spacecrafts has received a great deal of attention recently because of its importance for space applications, especially for formation flights. One approach of relative navigation is to use the GNSS. However, GNSS signals are not available for deep space missions. Hence, an alternative solution is needed. A possibility is to use the signals emitted from X-ray celestial sources. One of the most reliable X-ray sources is pulsars. Relative navigation of spacecrafts may be accomplished by observing X-ray sources and indirectly determining the spacecrafts' relative position.

Employing X-ray pulsars for navigation has been studied in both contexts of absolute navigation, and relative navigation. It is shown that a key task in X-ray pulsar-based navigation is estimation of the pulse phase. In this work the epoch folding (EF) procedure is mathematically formulated, and it is shown how it results in retrieving the pulsar intensity. The procedure noise is analyzed, and its statistical properties such as its mean, variance, and autocorrelation function are presented. And then the pulse delay estimation problem is introduced, and it is explained how employing epoch folding, the relative position between two space vehicles, can be estimated. Based on epoch folding, a pulse delay estimators are proposed, and its performance is compared against the Cramér-Rao lower bound (CRLB). It is also investigated how imprecise absolute velocity data can affect the position estimation accuracy.

Then based on above research, the algorithm of relative navigation for formation flying spacecrafts using X-ray pulsars was investigated. And a novel relative navigation algorithm for multiple-satellite formation using X-ray pulsars measurements is proposed. The problem of relative navigation between formation flights utilizing X-ray pulsars measurements is investigated. The time difference of signal arrival (TDOA) is estimated by signal's cross-correlated processing, which is further used as measurement to achieve the relative navigation. A Constrained Adaptive Unscented Kalman Filter is employed to estimate the relative positions and velocities between the formation flights. Numerical simulations are performed to assess the proposed navigation algorithm. Furthermore, errors of the navigation are analyzed in order to improve the accuracy of this method.