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DEVELOPMENT OF SPACEBORNE GPS RECEIVER WITH REAL-TIME ORBIT DETERMINATION USING UNSCENTED KALMAN FILTER

Abstract

Spaceborne GPS receiver is used for not only a primary tracking system for precision orbit determination on ground but also a core equipment to provide real-time ephemeris for onboard attitude control in many missions. In general, the position and velocity accuracy of GPS navigation solution without dynamic filter has 25 m (1σ) and 0.5 m/s (1σ), respectively. However, GPS navigation solution from most of spaceborne GPS receiver has abnormal excursions of about 4 km and 3 m/s from normal error range for space operation. These excursions have a negative effect on the attitude control system. In this research, a spaceborne GPS receiver, which includes real-time orbit determination function using unscented Kalman filter(UKF), was developed to provide more accurate and robust real-time ephemeris. Dynamical orbit determination is a nonlinear problem where the perturbing factors are not easily modeled. Extended Kalman filter(EKF) is one of the favorable approaches as the navigational state estimator. However, the divergence due to modeling errors, which EKF highly depends on a predefined dynamic model, is a critical problem. In this research, UKF algorithm, which uses a finite number of sigma points to propagate the probability of state distribution, was implemented for the nonlinear dynamic process modeling. And also, optimal UKF algorithm based on Kalman minimum variance method was applied for real-time calculations. 7th order Runge-Kutta numerical integration was applied for orbit propagation and perturbations due to geopotential, gravity of the Sun and Moon, solar radiation pressure, and atmospheric drag were modeled. GPS navigation solution, which consists of position and velocity, was used as observation for UKF. The spaceborne GPS receiver hardware design is mainly built with the 12 channel L1 C/A code baseband correlator and 32-bit floating point DSP microprocessor. The performance test of real-time orbit determination using UKF was implemented based on hardware-in-the-loop simulations using spaceborne GPS receiver and GPS simulator. The results show that the accuracy of 10 m (1σ) in position and 0.1 m/s (1σ) in velocity can be acquired. In particular, since abnormal excursions which exist in GPS navigation solution are eliminated completely, more robust and integral ephemeris is available in real time.