Sigma Point Algorithm of the Kalman Filter in Spacecraft Autonomous Navigation

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Abstract. This paper describes the analysis of a RMS error of the state vector estimations, which contain the current coordinates and velocity of a spacecraft (SC). Moreover, it includes shift of the time scale and frequency of the onboard reference generator (RG). The estimates are transferred to the output of the navigation computer, where they are formed. The processing algorithm uses observation data in the form of pseudoranges and pseudovelocities according to several GNSS SC. The mathematical state model takes into account the presence of random fluctuations based on the SC acceleration components caused by SC orbit variations. Observation channels contain random errors in the form of white Gaussian noise. The variation model of RG frequency corresponds to the model of the rubidium frequency standard. The article shows that the sigma point Kalman filter provides a positioning RMS error of less than 1 m, a velocity model error of less than 0.01 m/s, a time scale shift of less than 1.9 ns, and a frequency instability of less than $3 \cdot 10^{-13}$, in conditions when SC moves in a highly elliptical orbit (HEO) at high values of GDOP and weak signals. The algorithm does not lose its efficiency even at incomplete constellations of GNSS SC up to several minutes.

Keywords: autonomous navigation system, spacecraft, coordinates estimation, onboard time scale bias, frequency instability, sigma point Kalman filter