Abstract

Over time, global navigation satellite systems (GNSS) have evolved into an integral component of everyday life. Among many other diverse applications, Aircraft navigation has significantly benefited from GNSS during different phases of flight. Ensuring reliability (or integrity) and continuity of GNSS services is of great importance to critical operations like aviation. To this end, this thesis develops robust and reliable GNSS algorithms for aircraft positioning.

It is well-documented in the literature that advanced navigation systems, such as multi-sensor integration and vector tracking, are more accurate than the traditional GNSS receiver. They also can address issues with frequent GNSS signal outages. The Kalman filter (KF) being an indispensable part of these systems, KF-based approaches to monitoring integrity have received considerable interest in recent years. In this context, the work in this thesis develops a receiver autonomous integrity monitoring (RAIM) algorithm in the range domain for a KF navigation processor of the GNSS receiver.

First, a computationally efficient KF RAIM algorithm is designed with three test statistics, justifying the reason for three simultaneous fault detection tests, and eliminating the assumption on test statistics in the existing literature. The KF protection level (PL) computation is appropriately modified, taking into account the contributions of all epochs. The proposed algorithm is tested with simulated Global Positioning System (GPS) measurements for unmanned aircraft flight paths in different parts of the world. It is shown to address a major challenge of range-based KF RAIM regarding growing computational burden over time. It also provides faster fault detection and lower PLs compared to that with a single fault detection test. The method, however, assumes single satellite failures and no time-correlated errors in the measurements.

The algorithm is further extended, accounting for time-correlated errors in the GNSS measurements, multi-satellite failures, and dual constellations (GPS and Navigation with Indian Constellation (NavIC)). Computational efficiency is retained. Extensive simulations over the Indian sub-continent show that KF solution separation RAIM has better performance than the proposed design, but is computationally much expensive. On the other hand, the proposed method offers satisfactory performance to a certain extent. Due to low architectural complexities, it has potential for real-time implementations in avionics, where resources are generally limited. Simulation results also indicate that addition of NavIC alongside GPS can substantially improve RAIM performance, particularly in poor geometries.

Having studied reliable methods, an adaptive scalar tracking architecture is described for GPS L1 and NavIC L5 signals to improve robustness. It enables variations of the tracking loop parameters of a standalone GNSS receiver with both dynamics and carrier to noise ratios. Next, a non-coherent vector receiver is designed. Performance of the developed algorithms is analyzed in detail with simulated GPS and NavIC signals for unmanned aircraft trajectories over the Indian mainland. Adaptive scalar tracking is shown to better handle dynamics than the traditional one with constant loop parameters.

But its tracking sensitivity is not improved. With a lower computational complexity, the adaptive receiver also provides performance comparable to that of its vector counterpart for C/N_0 at or above 30 dB-Hz.

Keywords: GNSS, Kalman filter, RAIM, GPS, NavIC, adaptive scalar tracking, vector tracking.