ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control (1) (5)

Author: Mr. Warren Soh
Magellan Aerospace, Canada, warren.soh@magellan.aero

Ms. Jennifer Michels
Magellan Aerospace, Canada, Jennifer.Michels@magellan.aero
Mr. Don Asquin
Magellan Aerospace, Canada, don.asquin@magellan.aero
Mr. Adam Vigneron
International Space University, Carleton University, Canada, adam.vigneron@spacegeneration.org
Dr. Anton de Ruiter
Canada, aderuiter@ryerson.ca
Mr. Ron Buckingham
Northeast Space Company, Canada, ron.buck@noreas.com

ONBOARD NAVIGATION FOR THE CANADIAN POLAR COMMUNICATION AND WEATHER SATELLITE IN TUNDRA ORBIT

Abstract

Geosynchronous communications and meteorological satellites have limited northern latitude coverage, specifically above 65 N latitude. This lack of secure, highly reliable, high capacity communication services and insufficient meteorological data over the Arctic region has prompted Canada to investigate new satellite solutions. Since 2008, the Canadian Space Agency (CSA) has spearheaded the Polar Communication and Weather (PCW) mission, slated to operate in a Highly Elliptical Orbit (HEO). A 24-hour, 90 inclination, Tundra orbit is a strong candidate; able to fill the communication and weather coverage gaps and allow continuous space weather monitoring in the Northern and Southern hemispheres. This orbit however, poses an operational challenge for GPS-based satellite orbit determination since the satellite is continuously above the GPS constellation and will experience frequent signal outages, especially when passing over the poles, aggravated by the constellation's inclination of 55.

Magellan Aerospace, Winnipeg in collaboration with Carleton University, has successfully developed an onboard navigation technology for PCW within a CSA-funded Space Technology Development Program. The real-time navigation flight software is robust, capable of position determination to within 15 m (RMS) of uncertainty, and has been developed to Technology Readiness Level 5 (TRL 5) using the Magellan closed-loop attitude and orbit software simulator that qualified SCISAT (launched 2002), CASSIOPE (launched 2013), and has now been updated for the RADARSAT Constellation Mission (2018). The navigation technology uses a modified and optimally tuned covariance driven Extended Kalman Filter (EKF) to estimate the orbit, fusing a high-fidelity gravitational model (24x24 WGS84 EGM96) and perturbation models with available raw GPS pseudo-range signals. The simulated 34dBHz threshold, 8-channel L1 single frequency receiver using dual antennas model demonstrated GPS side-lobe signals can be acquired in the Tundra orbit even with ionospheric attenuation. Hence the navigation solution maintains accuracy through non-Gaussian GPS signal outages, most notably at and around apogee, and converges to 130 m after experiencing unpredicted impulsive orbit accelerations. The technology was further verified by assessing the impact of specific perturbations and non-Gaussian pseudo-range measurement errors, particularly receiver clock errors modelled as steered or drifting depending on the current GPS visibility

and geometry, and the inclusion of GPS Space Vehicle ephemeris errors (in the absence of global correction values).

Finally, other nonlinear Bayesian filters (Unscented and Cubature) developed and evaluated for the Tundra orbit, fell short of expectations. The increased algorithm computation anticipated to better handle the non-Gaussian measurements did not show any significant improvements in navigation accuracy.