GPS Solut
DOI 10.1007/s10291-013-0343-7

ORIGINAL ARTICLE

An investigation of GNSS atomic clock behavior at short time intervals

Erin Griggs · E. Robert Kursinski · Dennis Akos

Received: 13 June 2013 / Accepted: 27 September 2013

Abstract A technique for obtaining clock measurements from individual GNSS satellites at short time intervals is presented. The methodology developed in this study allows for accurate satellite clock stability analysis without an ultra-stable clock at the ground receiver. Variations in the carrier phase caused by the satellite clock are isolated using a combination of common GNSS carrier-phase processing techniques. Furthermore, the white phase variations caused by the thermal noise of the collection and processing equipment are statistically modeled and removed, allowing for analysis of clock performance at subsecond intervals. Allan deviation analyses of signals collected from GPS and GLONASS satellites reveal distinct intervals of clock noise for timescales less than 100 s. The clock data collected from GPS Block IIA, IIR, IIR-M, and GLONASS satellites reveal similar stability performance at time periods greater than 20 s. The GLONASS clock stability in the 0.6–10 s range, however, is significantly worse than GPS. Applications that rely on ultra-stable clock behavior from the GLONASS satellites at these timescales may therefore require high-rate corrections to estimate and remove oscillator-based errors in the carrier phase.

Keywords Allan deviation · Clock analysis · GPS · GLONASS · Radio occultation

E. Griggs (✉) · D. Akos
University of Colorado, Boulder, CO 80309, USA
e-mail: erin.griggs@colorado.edu

E. R. Kursinski
Moog Advanced Missions and Science, Golden, CO 80401, USA

Introduction

The stability of GNSS satellite clocks is critical to precise timing and positioning applications. Corrections to the carrier phase from satellite clock instabilities can be necessary, as these variations limit the ability to distinguish delays from other sources. Radio occultation (RO) is a remote sensing technique that measures the delay in propagation of signals from the GPS satellites to infer physical characteristics about the atmosphere (Kursinski et al. 2000). GNSS RO has become one of the most important data sets for numerical weather prediction (Cardinali 2009). The addition of GLONASS is of particular interest for future occultation missions; more GNSS RO signal sources provide more frequent and denser sampling of the atmosphere, which improves weather forecasts (Harnisch et al. 2013). The GLONASS signals are frequency division multiple access and broadcast on different frequencies than GPS L1. Tracking the code division multiple access signals of GPS often results in lower signal-to-noise ratio (SNR) due to the overlapping spectra from each GPS satellite in view of the antenna (Bonnedal et al. 2012). GLONASS signals offer the potential of higher SNR, as their frequency bands are isolated from one another and from GPS L1.

Satellite clock instabilities cause variations in the carrier phase that will degrade the atmospheric profiling via RO if not properly characterized. A clock sampling interval of 1 s or less is required for single and undifferenced processing to achieve the highest quality excess atmospheric phase data for RO applications (Schreiner et al. 2009). Because a typical radio occultation event lasts approximately 100 s, knowledge of clock stability overtime intervals of 0.1–100 s is significant (Melbourne 2005). It is important to understand the behavior of GNSS satellite clocks as it influences