GNSS Clock Interpolation Impacts on Radio Occultation Bending Angle Retrieval

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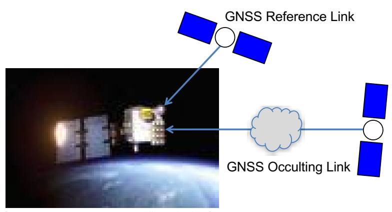
Abstract

We assess the impacts of GPS and GLONASS clock interpolation on retrieval of bending angle by radio occultation (RO) sensors. GNSS clock offsets from near-real time or post-processed solutions are typically sampled at 30 sec or longer intervals and must be interpolated for use in RO processing. Using 1 Hz GPS/GLONASS clock estimates from a global network solution as truth, we apply interpolation to evaluate how it affects the accuracy of the retrieved atmospheric bending angle. The results yield an average GPS and GLONASS RMS bending angle error of 1.43 microrad. Ground based 5 Hz tracking data are used to evaluate higher frequency GNSS transmitter clock variations up to 2 Hz. We use a single difference carrier phase processing approach that eliminates contributions from receiver clock, atmospheric delays, and geometry to a large extent to assess transmitter clock variations. The average RMS bending angle error resulting from these data is 1.73 microrad.

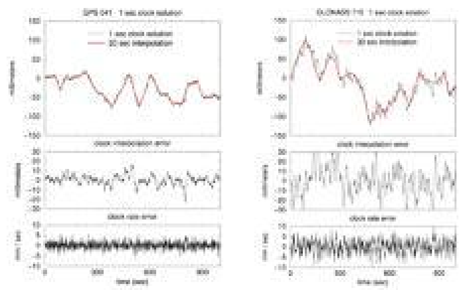
Background

- RO processing for near real-time applications typically uses single difference processing to remove effect of receiver clock
- Phase measurements from occulting link differenced with high elevation reference link (geometry illustrated below)
- GNSS clocks offsets are present in single difference observables and are introduced from external GNSS orbit/clock solutions
- Typically use 30 sec sampled GNSS clocks and apply piecewise linear interpolation between provided values



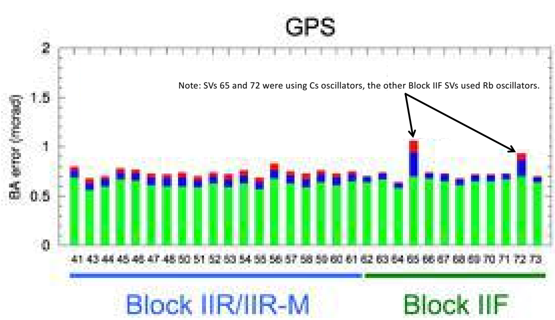
[COSMIC-2 image courtesy Surrey Satellite Technology]

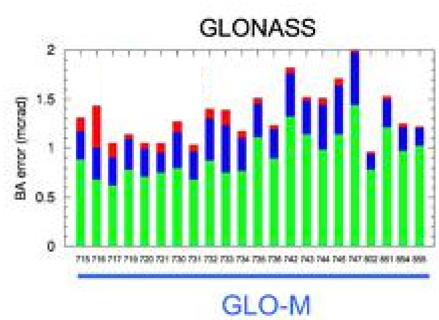
- Figures below show example 1 Hz GPS and GLONASS clocks and errors resulting from 30 sec piecewise linear interpolation
- RO bending angle error RMS may be directly calculated as RMS clock rate error divided by tangent point velocity (using 2.5 km/s)
- Calculation is valid for tangent point altitudes of 30-60 km



Bending Angle Error from Global Network Solution

- GNSS clock solution estimated at 1 Hz using tracking data from 35 ground stations over 24 hours
- Fixed orbits to CODE final product, estimated receiver station position (bias), receiver and transmitter clocks (per epoch), troposphere (zenith and gradient, every 15 min), GLONASS receiver-transmitter range bias (bias), phase biases (per arc)
- Station WTZR is reference clock
- Figures below show bending angle error incurred when interpolating 30 sec, 10 sec, and 3 sec sampled transmitter clocks
- For 30 sec interpolation, after including factor of sqrt(2) for single difference, GPS average is 1.06 microrad, GLONASS average 1.91 microrad, weighted average 1.43 microrad
- Results account for clock variations between 1/30 Hz and 0.5 Hz





Bending Angle Error from Terrestrial Measurement Data

- Processed 5 Hz carrier phase tracking data from five Septentrio receiver stations (Boulder x 2, Potsdam, Tahiti, Tel Aviv)
- Compute dual frequency ionosphere-free combination, remove quadratic fit every two min, apply 30 deg elevation cutoff, single difference using GPS reference link (randomly selected)
- Compute phase rate, this is approximately the GNSS clock rate
- Apply bandpass filter to phase (clock) rate data for 1/30 Hz to 2 Hz band, compute bending angle RMS by satellite
- For 30 sec clock interpolation, GPS average is 1.35 microrad, GLONASS 2.23 microrad, weighted average 1.73 microrad
- Considering 1/30 Hz to 2 Hz band adds 0.3 microrad to weighted average