



The Ticking Truth: How Subtle Clock Adjustments Influence GNSS Satellite Antenna Offset Estimates

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Realizing the terrestrial scale from Global Navigation Satellite System (GNSS) data requires precisely calibrated and highly stable satellite antenna phase centers. The results from the third International GNSS Service (IGS) reprocessing campaign, however, have raised renewed concerns about the long-term stability of the GNSS transmit antenna phase center relative to the spacecraft center of mass. Reevaluation of the satellite radial phase center offsets (z-PCOs) based on SINEX data from multiple IGS analysis centers revealed abrupt changes over time of up to 1 decimeter. Commonly cited reasons for time-varying z-PCO estimates are “aging” of the antenna and its radiation pattern, changing composition of the satellite constellation and ground network, and movement of the center of mass as propellant is consumed for satellite momentum dumps or orbital maneuvers. In this presentation, we shed light on another, yet unknown, effect arising from the drift of the satellite clock that prompts GNSS ground segment operators to adjust the clock frequency to ensure that the timing corrections in the satellite broadcast navigation message remain within the limits specified by the signal-in-space interface. The frequency adjustments are easily detectable in satellite clock bias estimates or broadcast clock correction parameters. However, this is only half the story; changing the clock frequency results in boresight angle-dependent lengthening or shortening of the carrier phase range, which the satellite antenna z-PCO parameter can almost perfectly absorb. As we will demonstrate through simulations and real-world examples from various GNSS spacecraft, a 4×10^{-10} correction applied to the onboard clock fundamental frequency (10.23 MHz) alters the estimated satellite z-PCOs for the standard ionosphere-free linear combination of L1 and L2/E5 by approximately 7 cm. The results indicate that satellite clock adjustments are the cause of the observed z-PCO jumps in the IGS “repro3” time series.