Anomalous Harmonics in the Spectra of GPS Position Estimates

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Abstract: Prior studies of the power spectra of GPS position time series have found pervasive seasonal signals against a power-law background of flicker noise plus white noise. Dong et al. (2002) estimated that less than half the observed GPS seasonal power can be explained by redistributions of geophysical fluid mass loads. Much of the residual variation is probably caused by unidentified GPS technique errors and analysis artifacts. Among possible mechanisms, Penna and Stewart (2003) have shown how unmodeled analysis errors at tidal frequencies (near 12- and 24-hour periods) can be aliased to longer periods very efficiently.
Signals near fortnightly, semiannual, and annual periods are expected to be most seriously affected.

We have examined spectra for the 167 sites of the International GNSS (Global Navigation Satellite Systems) Service (IGS) network having more than 200 weekly measurements during 1996.0-2006.0. The non-linear residuals of the weekly IGS solutions that were included in ITRF2005, the latest version of the International Terrestrial Reference Frame (ITRF), have been used. To improve the detection of common-mode signals, the normalized spectra of all sites have been stacked, then smoothed with a boxcar filter (full width of 0.05 cycle per year, cpy), for each local north (N), east (E), and height (H) component. The stacked, smoothed spectra are very similar for all three components. Peaks are evident at harmonics of about 1 cpy up to at least 6 cpy, but the peaks are not all at strictly 1.0 cpy intervals. Based on the 6th harmonic of the N spectrum, which is among the sharpest and largest, and assuming a linear overtone model, then a common fundamental of 1.040 ± 0.008 cpy can explain all peaks well, together with the expected annual and semiannual signals.
A flicker noise power-law continuum describes the background spectrum down to periods of a few months, after which the residuals become whiter.

Similar sub-seasonal tones are not apparent in the residuals of available satellite laser ranging (SLR) and very long baseline interferometry
(VLBI) sites, which are both an order of magnitude less numerous and dominated by white noise. There is weak evidence for a few isolated peaks near 1 cpy harmonics in the spectra of geophysical loadings, but these are much noisier than for GPS positions. Alternative explanations related to the GPS technique are suggested by the close coincidence of the period of the 1.040 cpy frequency, about 351.2 days, to the "GPS year"; i.e., the interval required for the constellation to repeat its inertial orientation with respect to the sun. This could indicate that the harmonics are a type of systematic error related to the satellite orbits. Mechanisms could involve orbit modeling defects or aliasing of site-dependent positioning biases modulated by the varying satellite geometry.