1 Analysis of GPS time-transfer data

Values for the offset between the host and travelling receivers are obtained for each laboratory, as follows.:

1. Accurate antenna coordinates are obtained for the travelling system antenna, by submitting RINEX observation files to the AusPOS online processing service operated by Geoscience Australia [1].
2. CCTF-format data for the portable system are regenerated using the precise antenna coordinates and the stored raw GPS and timing data.
3. Filter the CCTF data, removing tracks for which:
    - the track length is less than the full 780 seconds
    - a field has invalid data, as indicated by a 'sentinel' value *eg* MSIO = 999
4. We form the data set

$$\varepsilon(t) = [\mathrm{REF–SV}]_A(t) + [\mathrm{MDIO}]_A(t) - [\mathrm{REF–SV}]_B(t) - [\mathrm{MDIO}]_B(t) \qquad (1)$$

   comprising all filtered satellite tracks t common to both receivers A and B. The modelled ionosphere, [MDIO], is removed from [REF–SV] since it only adds noise in a zero-baseline comparison. Quantities appearing in square brackets are taken from the corresponding REFSV and MDIO data in the CCTF-format file.

5. We calculate a mean offset $\overline{\varepsilon(t)}$ for the comparison by linear regression where we include a linear as well as a constant term in the fit to $\varepsilon(t)$. The linear term accounts for any slow variation in offset between the two receivers. For completeness, we carry out the regression twice: once with all tracks weighted equally, and once weighting each track t by $[\mathrm{DSG}]_A(t)^{-2}$. The [DSG] values give the RMS scatter of one-second measurements of [REF–GPS] over a 13-minute track [2], and the weighted fit reduces the contribution of tracks with large scatter to $\overline{\varepsilon(t)}$.

   Analysis of many data sets using both weighted and unweighted fits shows good agreement, implying that the simple regression is not distorted by any outliers or other anomalies in the data set $\varepsilon(t)$. We therefore adopt the values of $\overline{\varepsilon(t)}$ obtained from the unweighted fits as an appropriate estimate of the mean offset in [REF–SV] between the two receivers.

   The mean value of the offset is evaluated at the midpoint of the data set.

6. We correct for any difference between delay values as reported by the host laboratory and as used internally by a GPS receiver. This correction is necessary to deal with cases where parameters were measured or corrected after the CCTF data were recorded. The delays reported by the host laboratory are always taken as the true values.

The delay correction applied in processing to generate the CCTF data is

$$[\text{REF–SV}] = (\text{REF–SV})_{\text{Raw}} - [\text{INT DLY}] - [\text{CAB DLY}] + [\text{REF DLY}] \qquad (2)$$

so that to account for changes in any of these delay parameters we calculate corrected values $[\text{REF–SV}]'$:

$$\begin{aligned} [\text{REF–SV}]' &= [\text{REF–SV}] + \delta \qquad (3) \\ \delta &= -[\text{INT DLY}]_{\text{Reported}} + [\text{INT DLY}]_{\text{Internal}} \\ &\quad - [\text{CAB DLY}]_{\text{Reported}} - \delta_X + [\text{CAB DLY}]_{\text{Internal}} \\ &\quad + [\text{REF DLY}]_{\text{Reported}} - [\text{REF DLY}]_{\text{Internal}} \end{aligned}$$

where δ_X is any additional correction that must be applied to the travelling receiver's CAB DLY (for example if the supplied line amplifier is used). We follow the convention that [CAB DLY] refers to the delay of the antenna cable only; [INT DLY] includes contributions from the internal delay of both the receiver and antenna, the latter being difficult to measure directly.

Combining (2) and (3) we obtain

$$\begin{aligned} \varepsilon(t)' &= [\text{REF–SV}]_A(t)' - [\text{REF–SV}]_B(t)' \qquad (4) \\ &= ([\text{REF–SV}]_A(t) + \delta_A) - ([\text{REF–SV}]_B(t) + \delta_B) \\ &= \varepsilon(t) + \delta_A - \delta_B \end{aligned}$$

so that the mean offset after correcting for delays is

$$\begin{aligned} \overline{\varepsilon(t)}' &= \overline{\varepsilon(t)} + \delta_A - \delta_B \\ &\equiv \Delta \end{aligned}$$

7. If all delays are known we expect the corrected offset Δ to be zero. Any non-zero value can therefore be used to transfer a calibrated value for the internal delay of one receiver to the other. From (3) and (4) we write

$$\begin{aligned} \varepsilon(t)'' &= \varepsilon(t)' - \Delta \text{ so that } \overline{\varepsilon(t)}'' = 0 \\ [\text{REF–SV}]_A'' &= [\text{REF–SV}]_A(t)' - [\text{INT DLY}]_{A,\text{ True}} + [\text{INT DLY}]_{A,\text{ Reported}} \\ [\text{INT DLY}]_{A,\text{ True}} &= [\text{INT DLY}]_{A,\text{ Reported}} + \Delta \end{aligned}$$

References

[1] http://www.ga.gov.au/earth-monitoring/geodesy/auspos-online-gps-processing-service.html