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CALIBRATION BY COLOCATED COMMON VIEW OF SATELLITE CLOCKS

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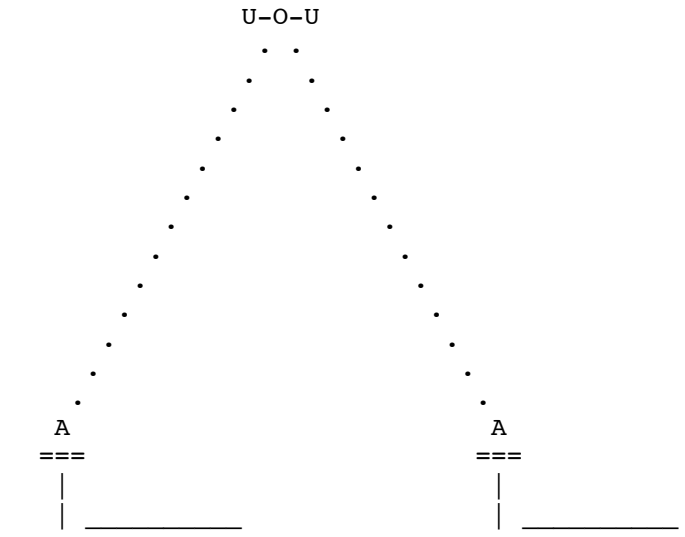
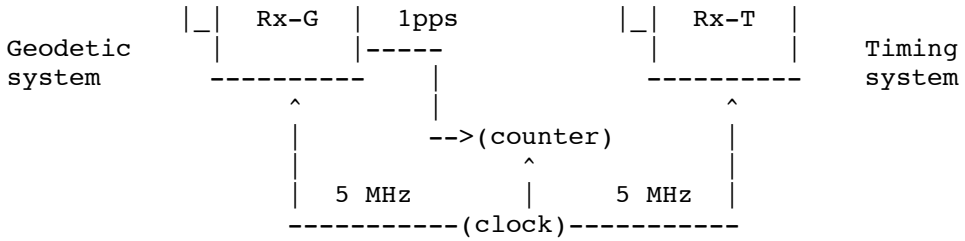
SUMMARY

Calibration of the timing delays in a geodetic GPS receiver system should be feasible relative to a GPS timing receiver system which has been calibrated "absolutely" by comparing satellite clock values observed simultaneously. The two receiver systems must be located in close proximity and all cable delays must be accurately known. If care is taken to apply equivalent analysis methods to both data sets, it should be possible to determine the end-to-end calibration delay through the geodetic system to the 1-ns level or better.

CCV CALIBRATION DESIGN

A schematic for calibration by the colocated common view (CCV) method is shown below. A geodetic GPS receiver/antenna system must be installed close to an operational timing receiver. In order to transfer "absolute" calibration to the geodetic system, it is necessary that the absolute delays through the timing system be accurately known (or accepted). A common frequency standard should be used for both systems. In order to preserve the geodetic calibration through subsequent power cyclings and internal clock resets, it is also necessary for receivers such as the AOA TurboRogue to monitor the 1 pps output continuously.





Given the large timing errors due to selective availability (S/A), it is essential that the two receivers be synchronized to make observations of the same satellites at common epochs. This can be done using an approach similar to the BIPM common view schedules for single channel timing receivers. Multi-channel timing receivers are obviously preferable. It should be noted that geodetic receivers collect and time tag observations according to broadcast GPS time.

ANALYSIS CONSIDERATIONS

Data from each receiver system can be analyzed to determine estimates for the observed satellite clocks relative to the receiver clocks. That is, the two estimated clock differences at a specific epoch can be represented as

```
Obs_G = Clk_sat - (Clk_ref + cable_G + calib_G)
```

for the geodetic system, and as

```
Obs_T = Clk_sat - (Clk_ref + cable_T + calib_T)
```

for the timing system. The notation is

```
Obs_G = estimated satellite clock difference from geodetic system
Obs_T = estimated satellite clock difference from timing system
Clk_sat = true satellite clock reading
Clk_ref = true station clock reading
cable_G = cable delay for 5 MHz input to geodetic receiver
cable_T = cable delay for 5 MHz input to timing receiver
calib_G = calibration bias for geodetic system
calib_T = calibration bias for timing system
```

It is assumed that the timing receiver calibration bias has been determined independently (presumably to the few-ns level). The cable delays must be accurately measured. Then the calibration bias of the geodetic system can be determined by

```
calib_G = (Obs_G - Obs_T) - (cable_G - cable_T) - calib_T
```

This calibration quantity accounts for the entire delay of the geodetic system from the effective phase center of the antenna to the point within the receiver where the data are time-tagged.

While this approach is straightforward and seemingly simple, considerable care must be taken to ensure that the observed satellite clock differences are comparable from the geodetic and timing systems. Otherwise, the inferred calibration bias will be corrupted. The most important components that must be considered are:

1) antenna locations -- The geocentric coordinates must be in the same

high-accuracy terrestrial reference frame and must account for the same deformational effects (e.g., solid Earth tides). Few cm (~0.1 ns) errors in antenna locations are readily attainable but much larger errors are common; time-varying tidal effects can be as large as ~0.5 m (~1.5 ns).

2) satellite orbits -- The same ephemerides must be used for both analyses or corrections must be applied for the effect of different ephemerides. Broadcast and IGS Final orbits differ at the few-meter level (5 ns or greater).

3) ionospheric propagation -- Normally, observed L1-L2 phase differences are used to correct for ionospheric delays in geodetic analyses. Delay differences with ionosphere models can be 10 ns or larger, sometimes much larger.

4) tropospheric propagation -- The total delay due to the neutral atmosphere is about 7 ns at the zenith and about three times larger at 20 degrees elevation.

Assuming that the geodetic and timing analysis procedures are properly matched, the estimated satellite clocks (Obs_G and Obs_T) should be determined with a precision of roughly 0.2 ns. It is likely, therefore, that the calibration error will be dominated by uncertainties in the cable delays (cable_G - cable_T) and the timing receiver calibration (calib_T).

DISCUSSION

Instrumental methods for delay calibration are also possible and desirable. Only in this way can the individual contributors to the delay be identified and characterized. The CCV analysis method, on the other hand, is independent (except for cable delays) and end-to-end. Thus, it is necessary to verify instrumental methods. It is also possible that the CCV method provides a more accurate determination, at least relative to an accepted timing receiver. However, it can only be applied at facilities equipped with calibrated timing receivers.