Report on the APMP Round-Robin GPS Common-View Time Transfer Receiver Intercomparison Experiment

Interim Appendix

1. Introduction

Between September 2000 and August 2001, NML coordinated an intercomparison of GPSCV time transfer receivers at APMP member institutes. The purpose of this experiment was to compare the internal receiver delays by circulating a common travelling receiver among the participating laboratories. At the time of the comparison, the internal delay of the travelling receiver was not accurately known, so the data only afforded a relative comparison.

A similar intercomparison exercise in the region was recently conducted by BIPM between NMIJ, NTSC, CRL, TL and NML. As part of this intercomparison, a BIPM TTS-2 multichannel CVGPS time-transfer receiver (BIPM H) was operated at NML for a short period in September 2002. The calibrated value for the internal delay of this receiver could be transferred to NML receivers, and subsequently to others from the APMP intercomparison by a reanalysis of recorded data.

This Appendix is preliminary for two reasons: firstly, it assumes that the internal delay of the BIPM H receiver is as stated in its internal setup files, and secondly the laboratories which participated in the second round of the intercomparison have not yet had an opportunity to comment on the results of the NML calculations. The appendix will be issued in final form when these laboratories have approved the NML calculations and BIPM has confirmed the internal delay of BIPM H.

2. Data Analysis

As in the original analysis of the APMP intercomparison, raw REF–GPS values from each receiver for each 780-second common-view track were corrected for any difference between delay parameters adopted by the receiver and those reported by the host laboratory:

$$\begin{aligned} \mathrm{REFGPS} &= \mathrm{REFGPS}_{\mathrm{raw}} - \Delta \\ \Delta &= (\delta_{\mathrm{INT}} + \delta_{\mathrm{ANT}} - \delta_{\mathrm{REF}})_{\mathrm{reported}} - (\delta_{\mathrm{INT}} + \delta_{\mathrm{ANT}} - \delta_{\mathrm{REF}})_{\mathrm{receiver}} \end{aligned}$$

where δ_{INT} is the internal delay of the receiver, δ_{ANT} is the time delay of the receiver's antenna and antenna cable, and δ_{REF} is the delay between the host realization of UTC 1 pps signal and the 1 pps input connector on the receiver. In practice, the separate contributions to δ_{ANT} from the antenna cable and the antenna itself are hard to separate; NML adopts the convention that δ_{ANT} represents the antenna cable delay only, equivalent to including the unknown antenna delay within the internal receiver delay. 'Reported' values are those reported directly to NML by the host laboratory, and 'receiver' values are those appearing in the CCTF-format data file header. This correction is necessary to account for revised or re-measured values of delay parameters obtained after the CCTF data was recorded. In all cases, reported values are taken to be correct.

Differences $\varepsilon(t)$ between REF–GPS values recorded by host and travelling receivers are calculated, discarding invalid tracks (for example, any incomplete track for either receiver):

$$\varepsilon(t) \quad = \quad \mathrm{REFGPS}_{\mathrm{Host}}(t) - \mathrm{REFGPS}_{\mathrm{Trav}}(t)$$

A least-squares linear fit to $\varepsilon(t)$ gives the mean offset evaluated at the midpoint of the recording period, a rate of change of this offset and the root mean square (RMS) deviation of the data about the fitted line. Raw data and calculations are available for inspection at ftp://time1.tip.csiro.au/pub/timedata/gps/APMP_data/GPS_calibration.

3. Transfer of Calibration

The travelling receiver circulated among APMP laboratories was an Allan Osborne TTR6 owned by NML with serial number 267. This receiver failed during the second round of the intercomparison and could not therefore be directly compared to BIPM H, the calibrated receiver circulated by BIPM. Instead, a second TTR6 receiver at NML with serial number 446 was first compared to BIPM H, yielding a calibrated internal delay of 53.5 ns, and 446 was then compared to 267 using previously recorded data. Internal delays obtained for 267 from data recorded at the beginning (September 1999) and end (May 2000) of the first round of the intercomparison were consistent, and a value of 58.6 ns was therefore adopted for the first round. A slightly different value was obtained from data recorded at the beginning of the second round (January 2001), and this value of 56.6 ns was therefore used.

4. Results

Results are presented in Figure 1 and Tables 1–3. These results show that the internal delays obtained for TTR6 receivers are generally consistent, falling within a range of approximately 50–60 ns. The most likely cause for the values for NAO, NRML and VMI falling outside this range is a misinterpretation by NML of the delay data provided by these laboratories, who are therefore encouraged to review NML's calculations available at the FTP site mentioned above. We note also that some laboratories appear to have adopted the value of 250 ns given for the antenna and antenna cable delay in the TTR6 user manual, which may indicate a differing convention for this quantity than that adopted by NML as described above.

It is not possible to give an uncertainty in the values obtained for internal receiver delays, as NML does not have details of the uncertainty in delay parameters as measured by the host institutes. We estimate a minimum uncertainty of ±2 ns, due to uncertainty in the internal delay adopted for the travelling receiver. This estimate should be increased by contributions from measurements of delay parameters as noted, and also from the comparison between travelling and host receivers. The latter contribution should be carefully evaluated with reference to the statistical properties of the corresponding recorded data.

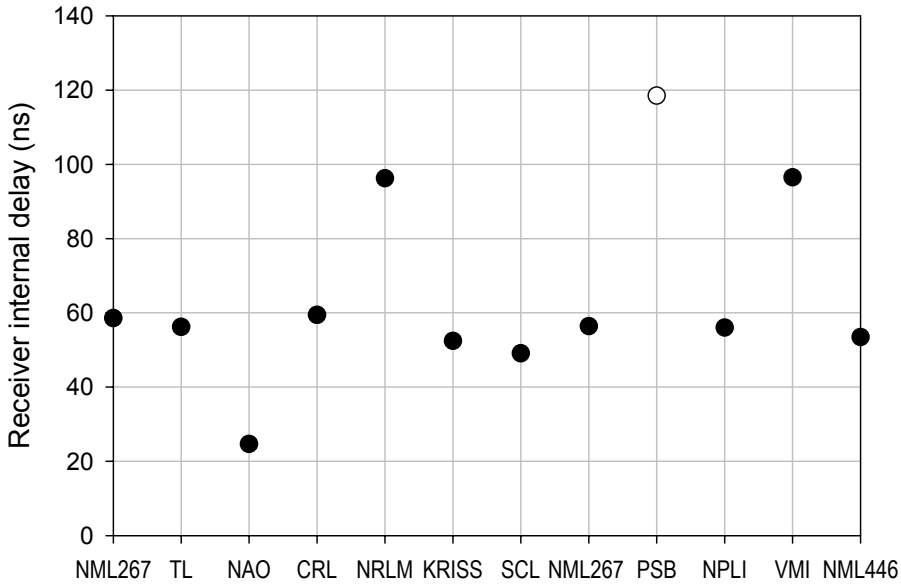

Figure 1: Results of the APMP round-robin intercomparison of GPS receivers. Values for the calibrated internal delay of Allan Osborne TTR6 (solid) and Austron 2200A (open) GPS receivers at participating APMP member institutes are shown, where the horizontal axis represents the chronological order of the intercomparison. A calibration was obtained for NML 446 by comparison with a receiver circulated by BIPM, and transferred by reanalyzing the data recorded at each participating institute and using reported values for antenna and cable delays.

Receiver	Type	Delay (ns)
NML 267	TTR6	58.6
TL	TTR6	56.2
NAO	TTR6	24.7
CRL	TTR6	59.4
NRLM	TTR6	96.2
KRISS	TTR6	52.5
SCL	TTR6	49.1
NML 267	TTR6	56.4
PSB	Austron	118.5
NPLI	TTR6	56.0
VMI	TTR6	96.5
NML 446	TTR6	53.5

Table 1: Results of the APMP round-robin intercomparison of GPS receivers. This data is shown graphically in Figure 1.

NMI	Start MJD	Stop MJD	Tracks	Offset (ns)	RMS (ns)	Slope (ps/day)
NML 9/99	51391.9	51417.0	734	9.3	3.4	-9±13
TL	51480.0	51497.0	348	6.2	3.0	62±38
NAO	51534.3	51547.0	413	-25.3	3.4	-146±42
CRL	51551.4	51567.0	415	9.7	3.9	80±32
NRLM	51571.2	51595.0	707	32.2	5.5	70±21
KRISS	51626.1	51644.0	689	2.5	3.9	42±27
SCL	51648.3	51662.3	256	-5.9	3.9	74±61
NML 5/00	51704.0	51736.0	324	9.5	3.4	-35±15
NML 1/01	51890.1	51941.0	1338	11.6	3.5	38±6
PSB	51990.0	52015.0	371	-23.5	19.2	-307±132
NPLI	52061.5	52064.1	42	-8.0	4.1	1609±740
VMI	52100.4	52124.0	629	46.5	2.1	-40±12

Table 2: Results of comparisons between the NML travelling GPSCV receiver and those of participating laboratories. The mean offset (host–travelling) and the RMS deviation about the fitted line are given in ns, and the slope of the line in ps/day. Three comparisons were conducted at NML between TTR6 serial numbers 446 (host) and 267 (travelling) receivers, and used to establish the calibrated internal delay for the latter.

NMI	Host receiver						Travelling receiver					
	Reported by NMI			Used by receiver			Reported by NMI			Used by receiver		
	INT	REF	CAB	INT	REF	CAB	INT	REF	CAB	INT	REF	CAB
NML 9/99	53.5	102.4	235	68	102	235	68	102.4	235	68	103	230
TL	50	51	229	50	51	229	58.6	51	235	68	51	235
NAO	50.	108	250	50	0	250	58.6	108	235	68	51	235
CRL	49.7	515.9	219.6	49.7	515.9	250	58.6	734.98	235	68	527.4	235
NRLM	64	89	250	64	89	250	58.6	0	235	68	0	235
KRISS	50	576	250	50	576	250	58.6	582	235	68	582	235
SCL	55	10	728	55	10	728	58.6	10	720	68	10	720
NML 5/00	53.5	79.1	235	68	79	235	68	79.9	235	68	79.6	235
NML 1/01	53.5	79.1	235	68	79	235	68	77.8	235	68	77.8	235
PSB	142	16	403	142	16	403	56.4	16	392	68	16	392
NPLI	64	53.8	250	64	0	250	56.4	20.8	235	68	16	235
VMI	50	38	250	50	23	250	56.4	68	235	68	68	235

Table 3: Values of delay parameters used in the APMP GPS receiver intercomparison.