Report on the APMP Round-Robin GPS Common-View Time Transfer Receiver Intercomparison Experiment: Round 2 - March 2001 to July 2001

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Introduction

The purpose of this intercomparison is to compare the electronic delays between (and including) the antenna and the reference input of the GPS common view time transfer receivers used for the realisation of UTC at several laboratories in the Asia-Pacific region.

It is difficult to measure these delays directly, since to do so would require signals from GPS satellites to be simulated and injected into the antennas. The equipment required for this task is very expensive, and could not easily be shipped between laboratories.

Instead, an Allen-Osborne model TTR6 GPS common-view time transfer receiver (serial # 267) belonging to NML was shipped in sequence to the following laboratories during the period October 1999 to May 2000:

Start: National Measurement Laboratory, Australia (NML)
Telecommunications Laboratory, Taiwan (TL)
National Astronomical Observatory, Japan (NAO)
Communications Research Laboratory, Japan (CRL)
National Research Laboratory of Metrology, Japan (NRLM)
Korea Research Institute of Standards and Science (KRISS)
The Government of the Hong Kong Special Administrative Region Standards and Calibration Laboratory, Hong Kong, China (SCL)

Finish: National Measurement Laboratory, Australia (NML)

The results of this intercomparison have been presented in an informal report: "Report on the APMP Round-Robin GPS Common-View Time Transfer Receiver Intercomparison Experiment: Round 1 - October 1999 to May 2000"

A second intercomparison including APMP laboratories which were not included in the first round was commenced in the second half of 2000, but was terminated in late 2000 due to repeated technical failures in the AoA TTR6 travelling GPS receiver. No useful results were obtained during this effort.

The travelling GPS receiver was repaired at NML and another attempt was commenced in March 2001, including the following APMP laboratories:

Productivity and Services Board, Singapore (PSB)
National Physical Laboratory, India (NPLI)
Vietnam Metrology Institute, Vietnam (VMI)

Several more laboratories were scheduled to participate in the second round, but the travelling GPS receiver unfortunately failed yet again after the VMI visit in July 2001. The receiver was again returned to NML, but could not be repaired and will be returned to the manufacturer for repair.

The travelling receiver was shipped with an antenna and antenna cables. The electronic delay of the antenna cables was measured at NML, and each laboratory was encouraged to check this measurement. A notebook PC was provided, and it was equipped with software and cables for configuration of, and data downloading from, the TTR6 receiver.

The CCTF-format data files generated by the travelling GPS receiver, as well as those generated by the time transfer receiver of each host laboratory, were emailed to NML. Each laboratory also provided detailed information concerning the delays between their realisation of UTC and each receiver.

The aim of the data processing at NML was to compare the epoch of the local realisation of UTC as measured by the host time transfer receiver with that measured by the travelling time transfer receiver. If all measurements were made perfectly and all delays were accurately known, the difference between the two measurements at each laboratory should be zero.

If the internal delay of any of the participating receivers is known, the internal delays of all other participating receivers may be calculated using the results of this intercomparison.

Data processing
Each participating laboratory sent to NML the CCTF-format data generated by their own GPSCV receiver (the "Host" receiver) and that generated by the NML travelling receiver.

The data were processed as follows:

1) The raw "Reference – GPS" ($REFGPS_{raw}$) values from each receiver for each 780 second common-view track were corrected for the difference, if any, between the delay parameters reported by the host laboratory, and the actual parameters reported by the receiver in the CCTF data file:

   $$REFGPS = REFGPS_{raw} - \Delta$$

   Where

   $$\Delta = (\delta_{INT} + \delta_{ANT} - \delta_{REF})_{Reported} - (\delta_{INT} + \delta_{ANT} - \delta_{REF})_{Receiver}$$

   and

   δ_{INT} = the internal time delay of the GPSCV receiver (ns)
   δ_{ANT} = the time delay of the receiver's antenna and antenna cable (ns)
   δ_{REF} = the delay between the UTC(Host laboratory) 1 pps signal and the "1 pps input" BNC connector on the GPSCV receiver (ns)

and the subscripts "Reported" and "Receiver" refer respectively to the values reported directly to NML by the host laboratory and those actually appearing in the CCTF data files generated by the GPSCV receivers. This separation of "Reported" and "Receiver" values was necessary in order to deal with cases where parameters were measured or corrected after the CCTF data was recorded. It should be clearly understood that the "Reported" values are assumed to be the correct values.

The combined delay δ_{ANT} of the antenna and antenna cable is difficult to measure accurately. Consequently, NML follows the convention that δ_{ANT} represents the time delay of the antenna cable only, and the unknown intrinsic time delay attributable to the antenna is incorporated in the value (equally difficult to measure) for the internal delay of the receiver.

2) The differences $\varepsilon(t)$ between the corrected REFGPS values for the host and travelling GPS receivers were calculated for each common-view track with starting time t:

$$\varepsilon(t) = REFGPS_{Host}(t) - REFGPS_{Trav}(t)$$

3) Values for $\varepsilon(t)$ for tracks where one or both receivers failed to maintain lock on the satellite for the full 780 seconds were discarded. Values for $\varepsilon(t)$ at times during which the data was invalid for any other reason reported by the host laboratory were also discarded.

4) A least squares fit was performed on the differences $\varepsilon(t)$, and the mean and slope of the line of best fit, along with the root-mean-square (RMS) deviations of the data about this line and the standard deviation of the mean, were recorded.

The raw data and "Mathematica" calculation files are available for inspection at:

ftp://time1.tip.csiro.au/pub/timedata/gps/APMP_data/GPS_Calibration/

Results and discussion

The results of the data processing are presented in table 1, the differences calculated in processing step 2 (above) are plotted in figure 1, and the values for the delay parameters are presented in table 2. In the present report the data from the previous round of the intercomparison is included for completeness.

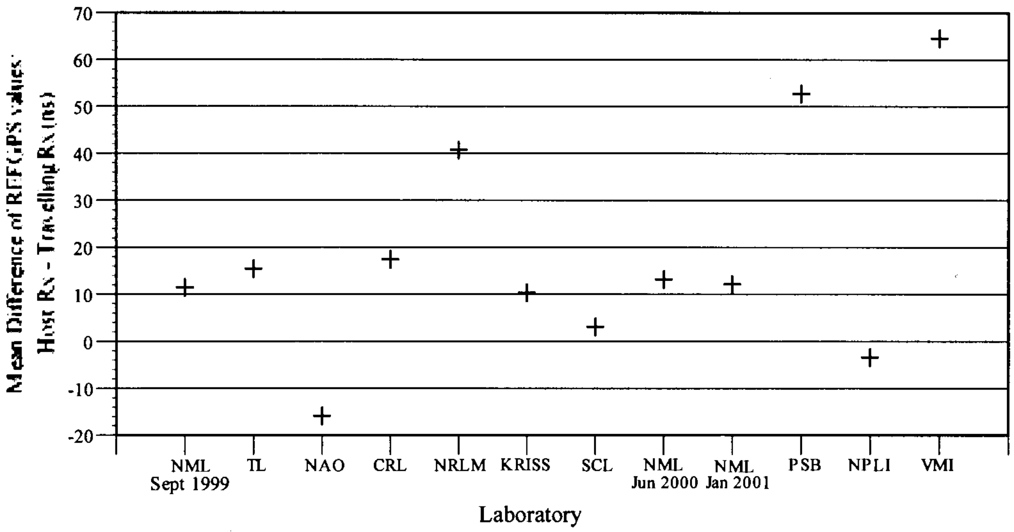

Figure 1: Results of comparisons between the NML travelling GPSCV receiver and those of the participating laboratories (see also table 1).

The value (68 ns) for the internal delay of the NML Travelling GPSCV TTR6 receiver was determined from the BIPM round-robin intercomparison of such receivers, which took place in 1996 (BIPM Rapport-97/1). There is unfortunately some evidence that an error was made at NML during this intercomparison, and because of this, and the poor records kept at NML at that time, this value for the internal delay of the receiver should be regarded as unreliable. This is why the reported value for the NML host GPSCV receiver (also a TTR6) is 50 ns, rather than 68 ns.

Although the travelling GPS receiver failed after the VMI visit, the data obtained up to this point are probably reliable, since the RMS deviations of the Mean Differences (table 1) are at the expected level, with the exception of the PSB value. However, inspection of the PSB raw data shows that the increased noise is probably due to PSB's Austron receiver.

The results of the two APMP intercomparisons do not yet represent an absolute calibration of each participating receiver. However, if one or more of the participating laboratories are presently confident that the reported value for the internal delay of their GPSCV receiver has been correctly determined by some other means, then these results may be used to transfer this calibration to the receivers belonging to the other participating laboratories. The same principle applies if any of the participating GPSCV receivers are calibrated at a later date.

Conclusion

It is intended that the travelling GPS receiver will be repaired by the manufacturer and then sent to BIPM for calibration, which will then subsequently allow NML to calibrate their host TTR6 receiver. It will then be a simple matter to transfer this calibration to the participating APMP laboratories using the data presented in this report.

The reliability problems with the travelling TTR6 receiver have highlighted the need for a more robust system for this work. If funding can be obtained, NML proposes to build a portable version of their GPS time transfer system based on a dual frequency Topcon/Javad receiver. The NML dual frequency system is presently operating at NML, MSL and SIRIM, and is reliable.

Acknowledgments

NML is very grateful for the excellent and highly professional cooperation of the staff of the laboratories which participated in this experiment. We also thank the Chairman of the APMP Technical Committee on Time and Frequency, Dr C. S. Liao of TL, for his encouragement and support.

Laboratory	Start MJD	End MJD	Mean Difference of REFGPS values: Host Rx – Travelling Rx (ns)	Slope of line of best fit (ps/day)	RMS Deviation σ (ns)	# of Tracks N	Standard Error in the Mean $\frac{\sigma}{\sqrt{N}}$ (ns)
NML (Sep 1999)	51388	51417	12.3	-34 ± 14	3.4	840	0.12
TL	51480	51496	16.3	-13 ± 32	3.0	348	0.16
NAO	51512	51546	-15.0	-32 ± 70	3.3	1205	0.10
CRL	51551	51566	18.3	30 ± 30	3.9	415	0.19
NRLM	51569	51594	41.5	31 ± 30	5.5	775	0.20
KRISS	51626	51643	11.2	30 ± 29	3.9	689	0.15
SCL	51648	51662	4.0	-22 ± 60	3.9	256	0.24
NML (Jun 2000)	51704	51735	14.0	-27 ± 16	3.4	324	0.19
NML (Jan 2001)	51890	51941	13.0	37 ± 6	3.5	1538	0.09
PSB	51990	52014	53.6	-125 ± 22	21.7	385	1.11
NPLI	52061	52064	-2.6	1614 ± 761	4.1	42	0.63
VMI	52100	52123	65.4	-33 ± 12	2.1	657	0.08

Table 1: Results of comparisons between the NML travelling GPSCV receiver and those of the participating laboratories (see also figure 1).

Laboratory	Host Receiver Type	Host Receiver Serial #	Reported Host Receiver Parameters (ns)			Entered Host Receiver Parameters (ns)			Reported Trav Receiver Parameters (ns)			Entered Trav Receiver Parameters (ns)		
			Int Delay	Ref Delay	Ant Delay	Int Delay	Ref Delay	Ant Delay	Int Delay	Ref Delay	Ant Delay	Int Delay	Ref Delay	Ant Delay
NML (Sept 1999)	AoA TTR6	446	50	102	235	68	102	235	68	102	234.5	68	102	230
TL	AoA TTR6	461	50	51	229	50	51	229	68	51	234.5	68	51	235
NAO	AoA TTR6	276	50	106	250	50	0	250	68	106	234.5	68	51	235
CRL	AoA TTR6	418	49.7	515.9	219.6	49.7	515.9	250	68	734.98	234.5	68	527.4	235
NRLM	AoA TTR6	457	64	89	250	64	89	250	68	0	234.5	68	0	235
KRISS	AoA TTR6	415	50	576	250	50	576	250	68	582	234.5	68	582	235
SCL	AoA TTR6	417	55	10	728	55	10	728	68	10	720	68	10	720[1]
NML (June 2000)	AoA TTR6	446	50	79	235	68	79	235	68	79.6	235	68	79.6	235
NML (Jan 2001)	AoA TTR6	446	50	79	235	68	79	235	68	77.8	235	68	77.8	235
PSB	Austron 2200A	4P-161		16	403	142	16	403	68	16	234.5	68	16	392
NPLI	AoA TTR6	464		53.8	250	64	0	250	68	20.8	234.5	68	16	235
VMI	AoA TTR6	462	50	38	250	50	23	250	68	68	234.5	68	68	235

Notes:

1) The NML Antenna cables were not used at SCL because they were not long enough.

Table 2: Delay values provided by participating laboratories ("Reported" values) and values obtained from the raw CCTF output files of the participating GPSCV receivers. The parameters labelled "Entered" were those that were output by the receivers into their CCTF-format data files.