Rapport AOS-2007/01

Polish Academy of Sciences

Space Research Centre

Astrogeodynamical Observatory Borowiec

DETERMINATION OF THE DIFFERENTIAL TIME CORRECTION FOR GPS TIME RECEIVER TTS-3 FOR LATVIA

J. Nawrocki

March 2007

Astrogeodynamical Observatory Borowiec, Space Research Centre, 62-035 Kórnik, Poland;
e-mail: nawrocki@cbk.poznan.pl

Abstract

The Astrogeodynamical Observatory (AOS) of Space Research Centre differentially calibrate GPS C/A-code receivers before their shipment to end-users. From March 3 to 6, 2006 the AOS has conducted a differential calibration exercise of C/A-code part of TTS-3 receiver before ~~it~~ shipment to Latvia. The calibration was done using as reference the AOS TTS-2 time receiver. The AOS C/A-code reference receiver was several times calibrated in the past against Paris Observatory (OP) GPS receiver with an uncertainty of a few nanoseconds.

INTRODUCTION

The Astrogeodynamical Observatory (AOS) of Space Research Centre specializes in the development of GNSS time transfer receivers. After a popular TTS-2 GPS C/A-code multi-channel receiver the AOS has developed a new one, the TTS-3 GPS/GLONASS/WAAS/EGNOS C/A- and P-code 40 channel unit.

Before shipment to end-users, both types of the receivers are differentially calibrated for C/A-code against the AOS TTS-2 SN 023 on-line receiver. The AOS C/A-code reference receiver was several times calibrated in the past against Paris Observatory (OP) GPS receiver with an uncertainty of a few nanoseconds [1, 2, 3, 4].
The OP was chosen as reference because it serves as reference laboratory for International Office of Weights and Measures (BIPM) GPS calibration trips. Also over the last twenty years the OP GPS time receiver has been compared several times with the NIST absolutely-calibrated reference GPS time receiver. The difference between these two has never exceeded a few nanoseconds [3].

Differential calibration of new time receivers before shipment to end-users

- improve the accuracy of the access to UTC of participating laboratories;
- provide valuable information about the stability of GPS time equipment;
- serve as provisional differential calibrations of the two-way equipment at the laboratories.

GPS P3 and GLONASS C/A- and P-codes of TTS-3 are not yet calibrated by the AOS. This will be done in near future when related procedures will be developed and reference GLONASS receiver will be defined.
From March 3 to 6, 2006 the AOS has conducted a differential calibration exercise of C/A-code part of TTS-3 SN 013 receiver before it shipment to Time, Frequency and Acoustical Laboratory of Latvian National Metrology Centre (LNMC), in Riga, Latvia.

This report reproduces the approach developed by the BIPM, and widely recognized as a standard procedure for differential calibration of GPS timing equipment [1, 2, 3].

EQUIPMENT

Details of the receivers involved are provided in Table 1. More information about the set-up of equipment at each location is provided in Appendix I.

Table 1. GPS equipment involved in this comparison.

Laboratory	Receiver Maker	Receiver Type	Receiver Ser. No
AOS	AOS	TTS-2	023
LNMC	AOS	TTS-3	013

Delays of antenna cable SMM-001 belonging to LNMC receiver was measured using pulse method with the Stanford Research SR-620 counter steered by the frequency from cesium HP standard [5]. The cable was shipped to LNMC with the receiver.

CONDITIONS OF COMPARISON

For the present comparison the AOS laboratory supplied: (a) a 10 MHz reference signal; and (b) a series of 1 s pulses from the local reference, UTC(AOS), via a cable of known delay. The LNMC receiver was connected to the same clock as the local receiver and the antenna of the LNMC receiver was placed close to the local antenna. The differential coordinates of the antenna phase centres were known with standard uncertainties (1σ) of a few millimeters. Both receivers involved in this exercise used 0.5 V trigger level for measuring the beginning of the rising 1pps pulse.

RESULTS

The processing of the comparison data obtained at AOS consists first of computing, for each track *i*, the time differences:

$$\mathrm{d}t_i = [UTC(\mathrm{AOS}) - GPS\ time]_{\mathrm{TTS\text{-}2},i} - [UTC(\mathrm{AOS}) - GPS\ time]_{\mathrm{TTS\text{-}3},i}\ .$$

The noise of the time series $\mathrm{d}t_i$ was analyzed using the modified Allan variance. The white phase noise was exhibited up to an averaging interval of about one day. This illustrates Figure 1.

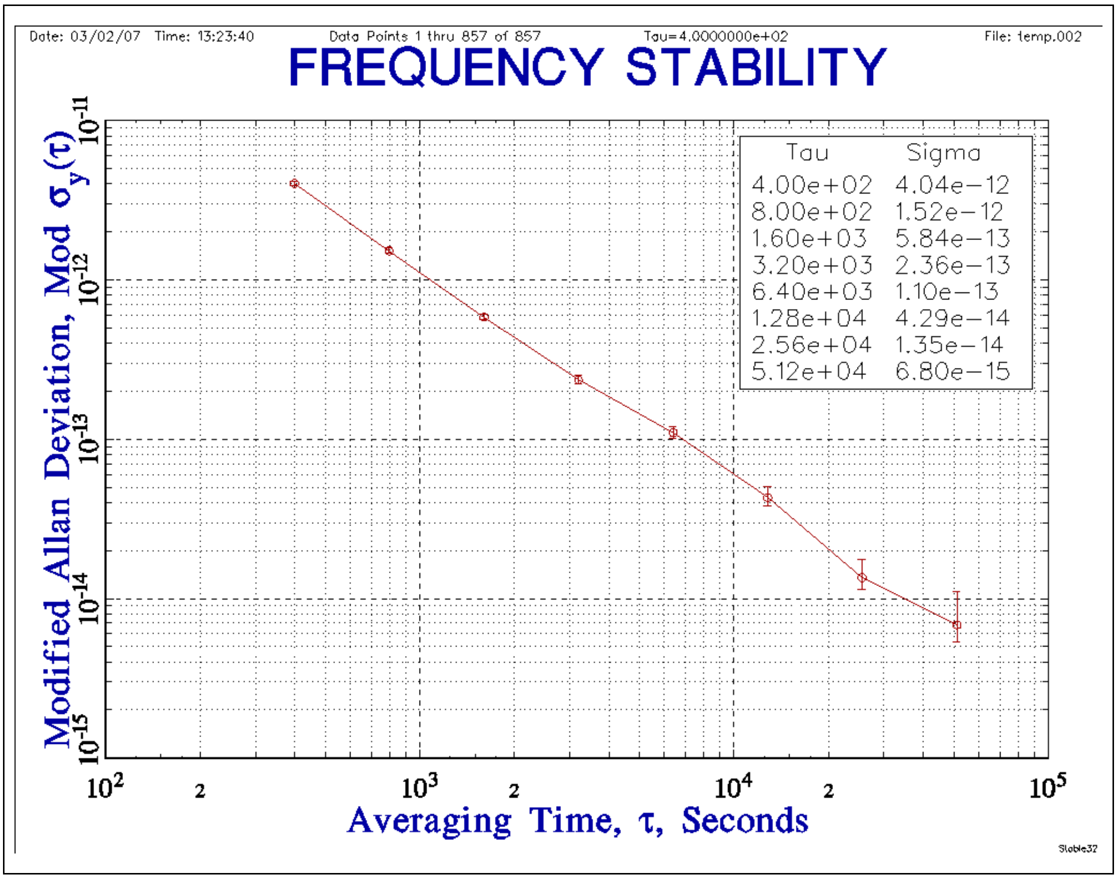


Figure 1. Square root of the modified Allan variance of the time series dt_i for the period: 03 March 2006 to 6 March 2006.

The one-day averages of d$t_{,i}$ are reported in Figure 2 and Appendix II. The next step was to compute mean offsets for the full duration of comparison at each location, and the corresponding standard deviations of individual common view measurements, see Table 2. The level of noise for one-day averaging period is reported also in Table 2.

Table 2. Mean offset d*t* for the full duration of the comparison.

Period	Total number of common views	Mean offset /ns	Standard deviation of individual common view observations /ns	Level of noise for 1 day /ns	Dispersion of daily mean /ns
03/03/06 - 06/03/06	857	+32.01	1.09	0.2	0.24

[UTC(AOS) – (GPS Time) $_{TTS-2}$] – [UTC(AOS) – (GPS Time) $_{TTS-3}$]

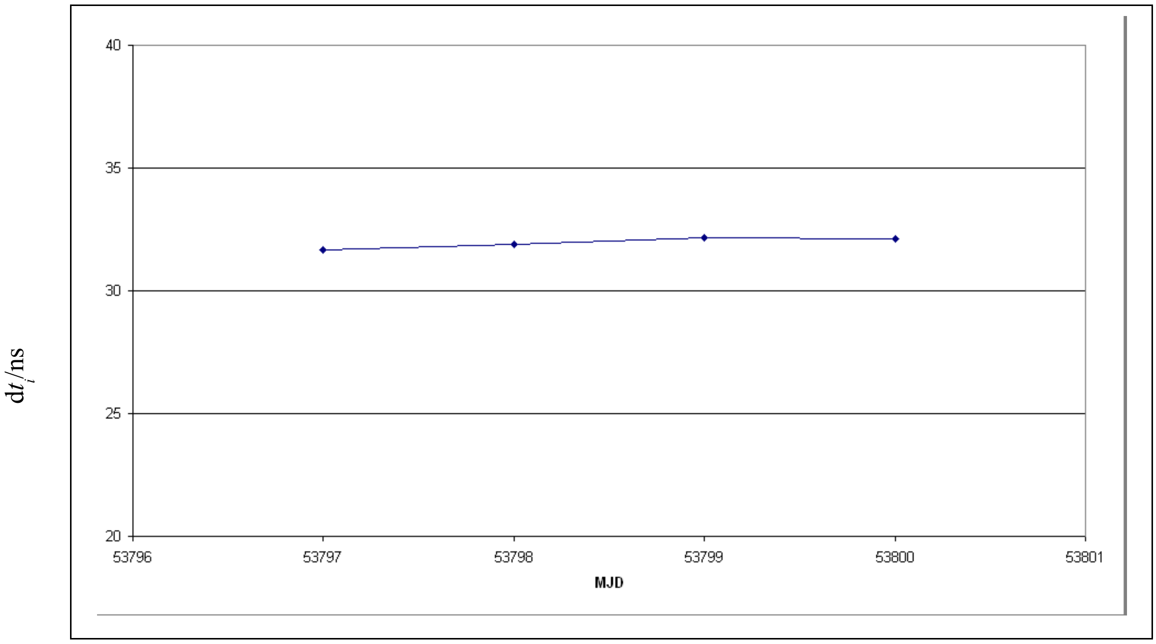


Figure 2. Daily averages of $\mathrm{d}t_i$ (see also Appendix II).

From Table 2 we derived differential time correction which should be made (added) to time difference derived during the GPS C/A-code comparison of the time scales kept by the LNMC and other laboratories previously calibrated against the OP [1, 2]. The results are summarized in Table 3.

Table 3. Differential time correction *d* to be added to [*clock* LNMS – *UTC*(AOS)], and its estimated uncertainty *u*(*d*) for the period of comparison (1σ), for C/A-code GPS time transfer.

[*clock* LNMS – *UTC*(*k*)]	*d*	*u*(*d*)
[*clock* LNMS – *UTC*(AOS)]	+32.0	5.0
[*clock* LNMS – *UTC*(*k*)]	+32.0	5.0

Although the calibration conducted at the AOS gave excellent results regarding uncertainty (see Table 2), the uncertainty given in this table is conservative.

CONCLUSION

The differential calibration of LNMC TTS-3 time receiver at the AOS was performed under good conditions. This was a calibration involving only C/A-code part of TTS-3. GPS P3 and GLONASS C/A- and P-codes of TTS-3 are not yet calibrated by the AOS. This will be done in near future when related procedures will be developed and reference GLONASS receiver will be defined.

The differential correction for LNMC receiver is large, and readjustment of the delay of GPS time equipment was implemented into the receiver.
Although the uncertainty of reported here differential calibration is excellent, the final uncertainty for TTS-3 GPS C/A-code time transfer from LNMC location is larger. It is mainly driven by the fact that the LNMC GPS time equipment was calibrated outside the LNMC. This uncertainty will be reduced when GPS differential calibration exercise will be conducted directly at the LNMC location in Riga.

Acknowledgements

The author wishes to express his gratitude to the BIPM for providing advise and help during preparation of this report.

REFERENCES

1. W. Lewandowski, "Determination of the differential time correction between GPS time equipment located at the Observatoire de Paris, Paris, France, and the Astronomical Latitude Observatory, Borowiec, Poland ", *BIPM Report -95/12*, September 1995, 11 pages.
2. W. Lewandowski and L. Tisserand, “Determination of the differential time corrections for GPS time equipment located at the OP, PTB, AOS, KRISS, CRL, NIST, USNO and APL”, Rapport BIPM-2004/06, 31 p.
3. W. Lewandowski and L. Tisserand, “Determination of the differential time corrections for GPS time equipment located at the OP, PTB, AOS, KRISS, CRL, NIST, USNO and APL”, Rapport BIPM-2004/06, 31 p
4. J. Nawrocki, P. Nogaś, A. Foks, P. Mielnik, W. Lewandowski, „Calibration of GPS time equipment in Poland”, *Proc. 19th EFTF*, 2005, Besancon, France, CD-Rom.
5. G. de Jong, "Measuring the propagation time of coaxial cables used with GPS receivers," *Proc. 17th PTTI,* pp. 223-232, December 1985.

Appendix I: Set-up of equipment at AOS

BIPM GPS calibration information sheet

Laboratory:	AOS
Date and hour of the beginning of measurements:	**03.03.2006 (MJD: 53797), 19:30 UTC**
Date and hour of the end of measurements:	**06.03.2006 (MJD: 53800), 08:10 UTC**

Receiver setup information		
	Reference:	**Calibrated:**
• Maker:	AOS	AOS
• Type:	TTS-2	TTS-3
• Serial number:	S/N 023	S/N 013
• Receiver internal delay (GPS) :	-7.7 ns	0.0 (not calibrated)
• Receiver internal delay (GLO) :	-	-
• Antenna cable identification:	A-001	SMM-001
Corresponding cable delay :	149.3 ns ± 0.3 ns	194,9 ns ± 0,4 ns
• UTC cable identification:	T-014	F-001
Corresponding cable delay :	20.4 ns ± 0.3 ns	94.8 ns ± 0.3 ns
Delay to local UTC :	20.4 ns	94.8 ns
• Receiver trigger level:	0.5 V	0.5 V
• Coordinates reference frame:	ITRF 88	ITRF 88
Latitude or X m	3738369.22 m	3738369.26 m
Longitude or Y m	1148164.25 m	1148161.57 m
Height or Z m	5021810.46 m	5021810.81 m

Antenna information		
	Reference:	**Calibrated:**
• Maker:	3S Navigation	JNS
• Type:	TSA-100	MarAnt+
• Serial number:	0016	2161
If the antenna is temperature stabilised		
• Set temperature value :	40.5°C (105°F)	-

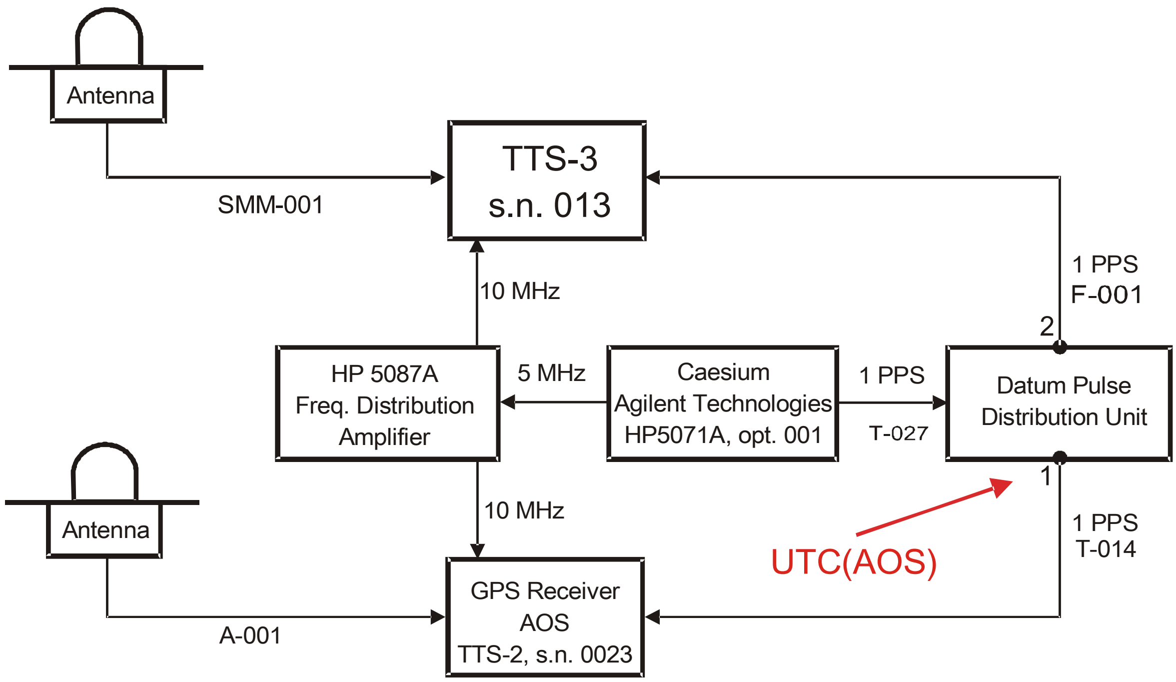
Calibrated antenna cable information	
• Maker:	Andrews
• Type:	CNT-400-1000
• Is it a phase stabilised cable:	Yes
• Length of cable outside the building :	5 m

General information	
• Rise time of the local UTC pulse:	5 ns
• Is the laboratory air conditioned:	Yes
• Set temperature value and uncertainty :	22±1 deg
• Set humidity value and uncertainty :	-

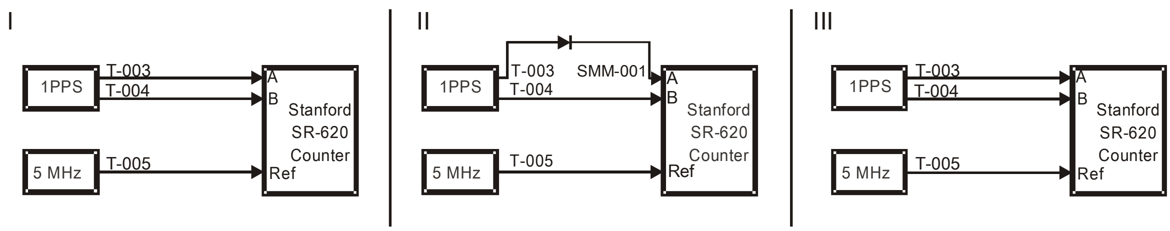
Cable delay control		
Cable identification	delay measured by BIPM	Delay measured by local method
-	-	-

Plot of the experiment set-up:

Link to the local UTC of both receivers and Antenna positions



Description of the local method of cable delay measurement:



Pulse method of measurement used for antenna and 1pps cables.

Test cable delay = Meas_II – (Meas_I + Meas_III)/2, trig. level = 0.5 V

Appendix II: Daily averages of dt_i at the AOS

MJD	Mean offset /ns	Standard deviation of individual common view observations /ns	Standard deviation of the mean /ns	Number of individual common views
53797	31.66	1.22	0.12	107
53798	31.87	1.00	0.06	270
53799	32.18	1.12	0.07	277
52800	32.12	1.02	0.07	203