AOS STUDIES ON USE OF PPP TECHNIQUE FOR TIME TRANSFER

P. Lejba, J. Nawrocki, D. Lemański, and P. Nogaś

Space Research Centre, Astrogeodynamical Observatory (AOS), Borowiec, ul. Drapałka 4, 62-035 Kórnik, Poland
Tel: +48 61 8170 187 (ext. 17), Fax: +48 61 8170 219
E-mail: *plejba@cbk.poznan.pl*

Abstract

This work concerns the clock parameter determination of four timing receivers TTS-4 (SN112 AOS and SN126 AOS) and ASHTECH Z-XII3T (PTB and USNO) by use of the Precise Point Positioning (PPP) technique for three time links: AOS-PTB, AOS-USNO, and PTB-USNO. The receiver clock parameters were calculated for the period from July 1 to July 28, 2011, with 7-day and 14-day solutions, and from July 1 to 31, 2011, with one- month solution. RINEX data files which include phase and code GPS data (PTB and USNO) and GPS/GLONASS data (AOS) were recorded in 30-second intervals. Additionally, the comparison for a very short time link of the main primary receiver TTS-4 (SN 112) and the experimental receiver TTS-4 (SN 126) was performed based on GPS and GLONASS data recorded in the period September 17-26, 2011. Both of the receivers were developed by AOS and PikTime.

Currently PPP is one of the main time transfer methods used at AOS. It is an important tool and alternative for other time transfer techniques realized by AOS such as GPS CV, GLONASS CV and TWSTFT.

INTRODUCTION

In this paper, the results of analysis of the GPS and GLONASS 30-seconds RINEX data by use of the Precise Point Positioning **[1,2]** technique are presented. All analyzed data were collected by four timing receivers. Two TTS-4 **[3]** receivers, SN 112, which is the primary receiver, and SN 126, which is the secondary receiver (used for experiments), are both at AOS. Two other receivers are ASHTECH Z-XII3T's, working at PTB and USNO. All laboratories are equipped with H-masers. All calculations were made in several modes: 7-day and 14-day solutions for the period from July 1 to July 28, 2011, and a one-month solution for all of July 2011. In all of these modes, the computations were done for three time links: AOS-PTB (medium distance), AOS-USNO (very long distance) and PTB-USNO (very long distance) (Figure 1). In the last step, the comparison of two TTS-4 receivers was made basing on GPS and GLONASS data for the period September 17-26, 2011; the 10-day solution was applied for a very short baseline, approximately 15 m. All computations were performed by means of the Natural Resource of Canada GPS Precise Point Positioning (GPS-PPP) software **[4]**, release 052011; ESA's *sp3* precise orbits and *clk* products were used. The details of the computations are presented in the next section.

The results obtained for TTS-4 receivers presented in this paper show good quality for the data gathered by them which is essential for advanced future works with GNSS systems of the new generation like Galileo or COMPASS.

OPTIONS AND PARAMETERS PROCESSED

The RINEX data for AOS were downloaded directly from the receivers; the data for PTB and USNO were downloaded from the CDDIS data base: *ftp://cddis.gsfc.nasa.gov/pub/gps/data/daily*. The 7-day solution means that seven 24-hour files of data were combined into one file. The same method was applied for 14-day and one-month solutions. All data files contained GPS observations.

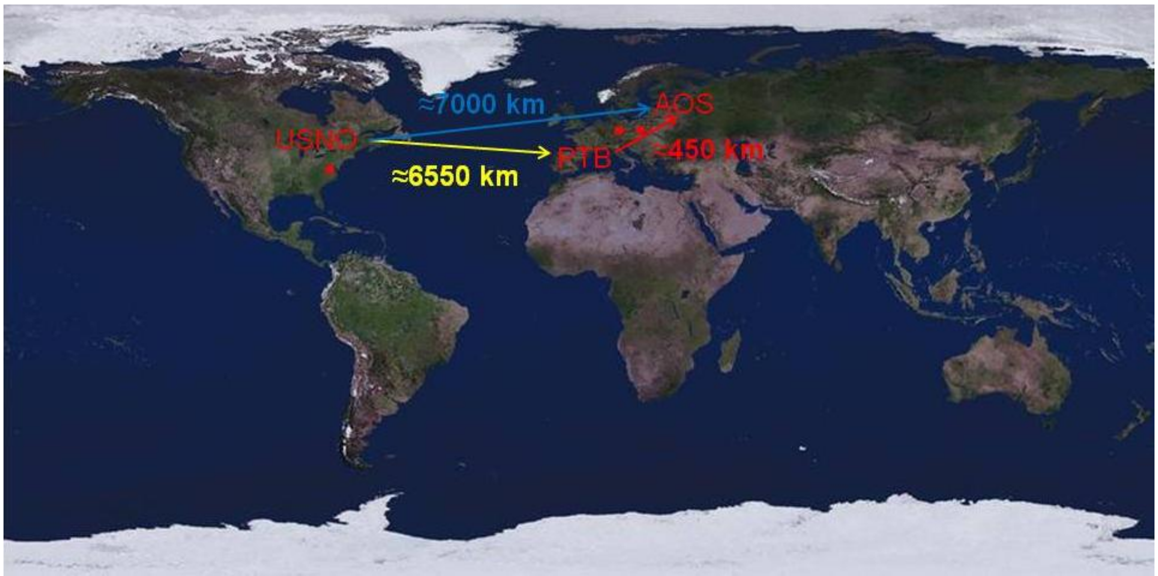

Figure 1. Time links: AOS-PTB (red line), AOS-USNO (blue line), PTB-USNO (yellow line).

In Table 1, the main parameters and options of NRC GPS-PPP software are shown. One of the most important parameters is the number of analyzed days of data (UT DAYS OBSERVED). The number of UT days must be equal to the number of analyzed days of data + one day. It means that for a 7-day solution it has to be 8 days, and for a 14-day solution 15 days, respectively. However, the number of the analyzed days cannot be greater than 44 (44+1=45, see Table 1).

The software takes into account both code and phase observations (GPS/GLONASS). Three types of frequency can be chosen for analysis: L1, L2, or L3. All processing was carried for L3 in static mode, in reference to the ITRF2008 frame and was based on GPS/GLONASS 15-minute *sp3* and 30-second *clk* files produced by ESA downloaded from the CDDIS data base:
ftp://cddis.gsfc.nasa.gov/pub/gps/products.

Table 1. An example of parameters of the NRC GPS-PPP software for the 7-day solution.

NAME of PARAMETER		**PROCESSED VALUE**
UT DAYS OBSERVED	(1-45)	8
USER DYNAMICS	(1=STATIC, 2=KINEMATIC)	1
OBSERVATION TO PROCESS	(1=COD, 2=C&P)	2
FREQUENCY TO PROCESS	(1=L1, 2=L2, 3=L3)	3
SATELLITE EPHEMERIS INPUT	(1=BRD, 2=SP3)	2
SATELLITE PRODUCT	(1=NO, 2=PrcClk, 3=MRTCA)	2
SATELLITE CLOCK INTERPOLATION	(1=NO, 2=YES)	1
IONOSPHERIC GRID INPUT	(1=NO, 2=YES)	1
SOLVE STATION COORDINATES	(1=NO, 2=YES)	2
SOLVE TROPOSPHERE	(1=NO, 2-5=RW MM/HR) (+100=grad)	105
BACKWARD SOLUTION	(1=NO, 2=YES)	2
REFERENCE SYSTEM	(1=NAD83, 2=ITRF)	2
COORDINATE SYSTEM	(1=ELLIPSOIDAL, 2=CARTESIAN)	1
A-PRIORI PSEUDORANGE SIGMA	(m)	5.000
A-PRIORI CARRIER PHASE SIGMA	(m)	0.010
LATITUDE	(ddmmss.sss,+N) or ECEF X (m)	0.000
LONGITUDE	(ddmmss.sss,+E) or ECEF X (m)	0.000
HEIGHT	(m) or ECEF Z (m)	0.000
ANTENNA HEIGHT	(m)	0.000
CUTOFF ELEVATION	(deg)	5.000
GDOP CUTOFF	(deg)	20.000

PPP MODE – ANALYSIS AND RESULTS

In Figures 2 to 4, results of PPP computations of AOS-PTB, AOS-USNO, and PTB-USNO time links are presented for 7-day (all data combined into four RINEX data files), 14-day (all data combined into two RINEX data files), and one-month (all data concatenated into one RINEX data file) solutions respectively. The results cover the period from July 1 to July 28, 2011, for 7-day and 14-day solutions and from July 1 to 31, 2011, for the one-month solution.

For better clarity of all figures, the results are shifted by +499 ns for AOS-PTB and -445 ns for PTB-USNO. All calculations were based on GPS data only. A gap in the case of AOS-PTB and PTB-USNO time links means a lack of observations for PTB during the analyzed interval. Some irregularities in the figures are due to synchronization failure and inaccuracies of the *sp3* and *clk* files.

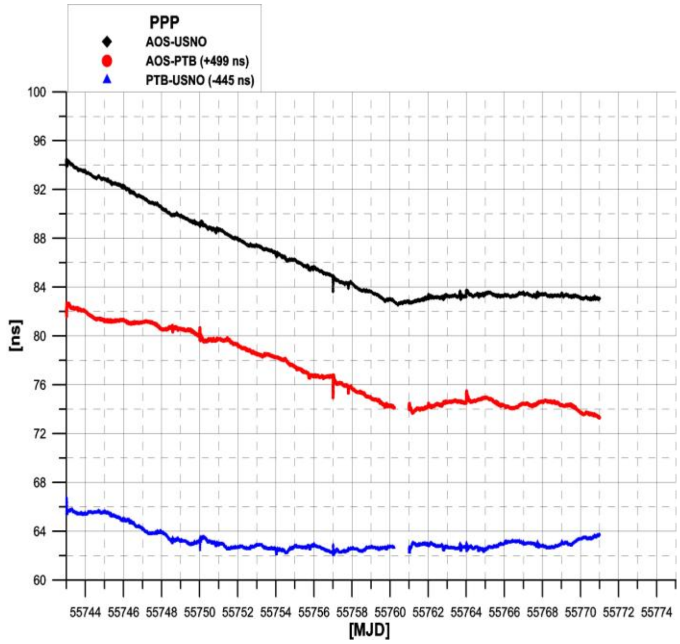

Figure 2. PPP 7-day solutions for AOS-USNO (black), AOS-PTB (red), and PTB-USNO (blue).

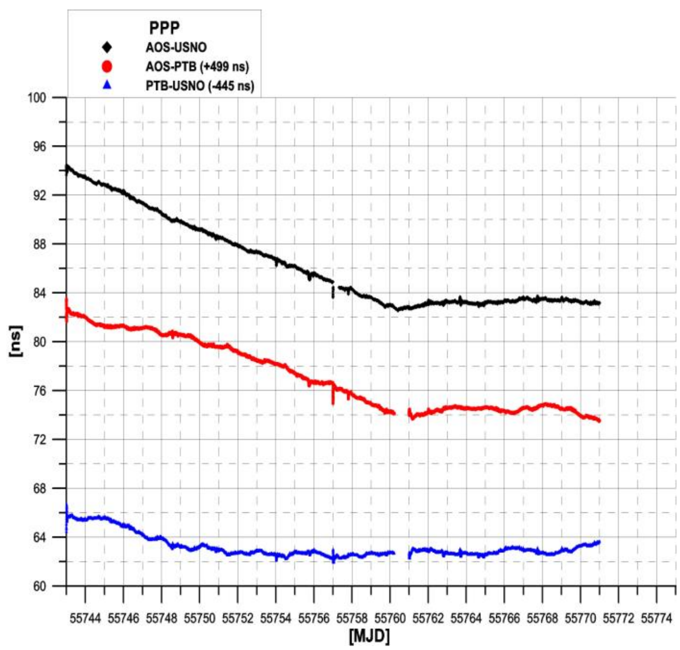

Figure 3. PPP 14-day solution for AOS-USNO (black), AOS-PTB (red), and PTB-USNO (blue).

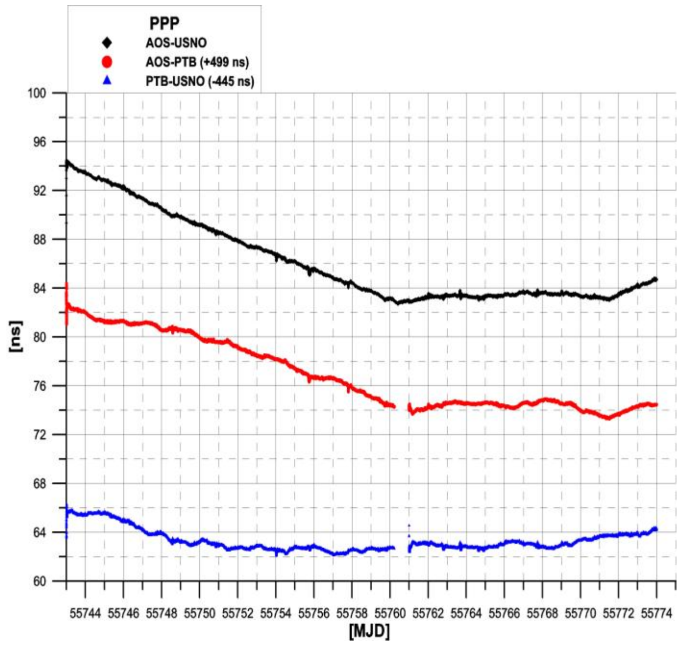

Figure 4. PPP one-month solution for AOS-USNO (black), AOS-PTB (red), and PTB-USNO (blue).

In Figures 5 to 13, time deviation results of analyzed time links are presented for 7-day (Figures 5-7), 14-day (Figures 8-10), and one-month solutions (Figures 11-13). In all cases for all time links the time stability is at the level of 0.1 ns for an averaging time of one day.

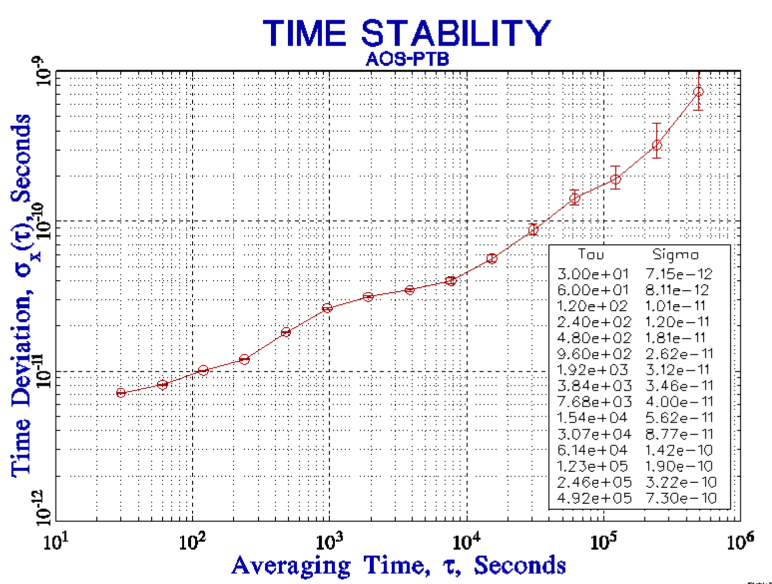

Figure 5. Time deviation for AOS-PTB (7-day solution).

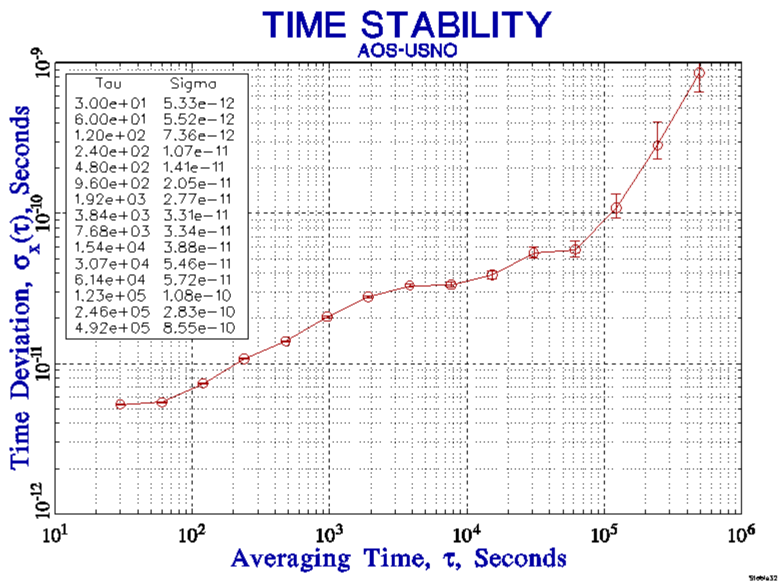

Figure 6. Time deviation for AOS-USNO (7-day solution).

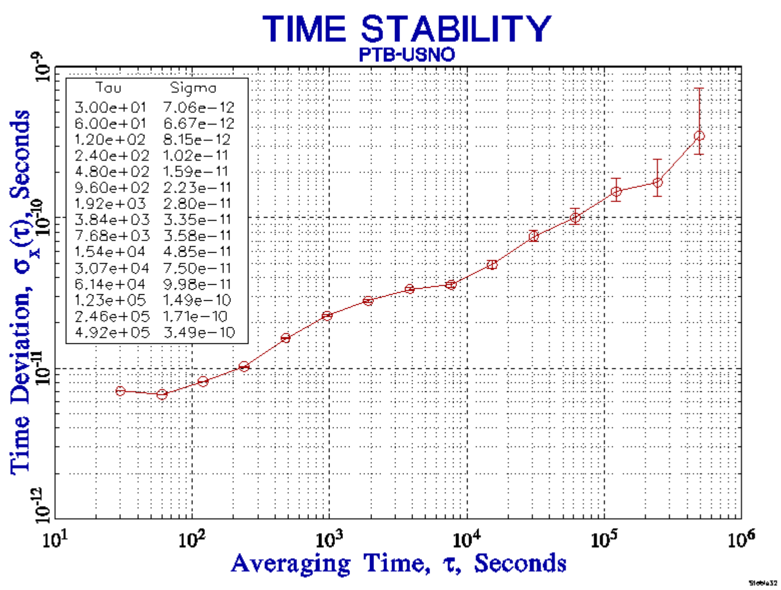

Figure 7. Time deviation for PTB-USNO (7-day solution).

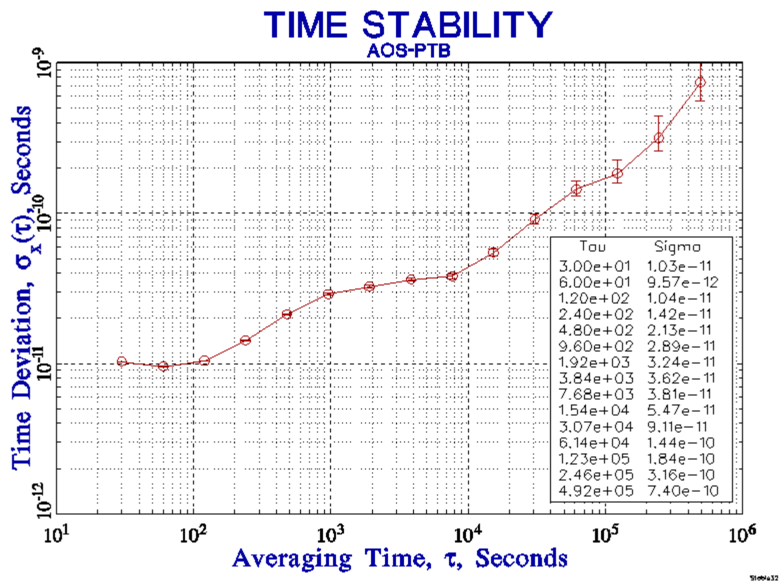

Figure 8. Time deviation for AOS-PTB (14-day solution).

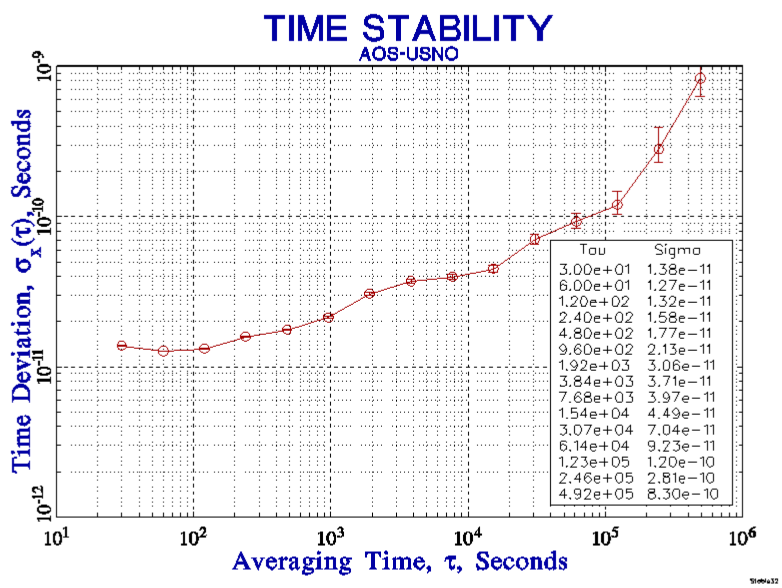

Figure 9. Time deviation for AOS-USNO (14-day solution).

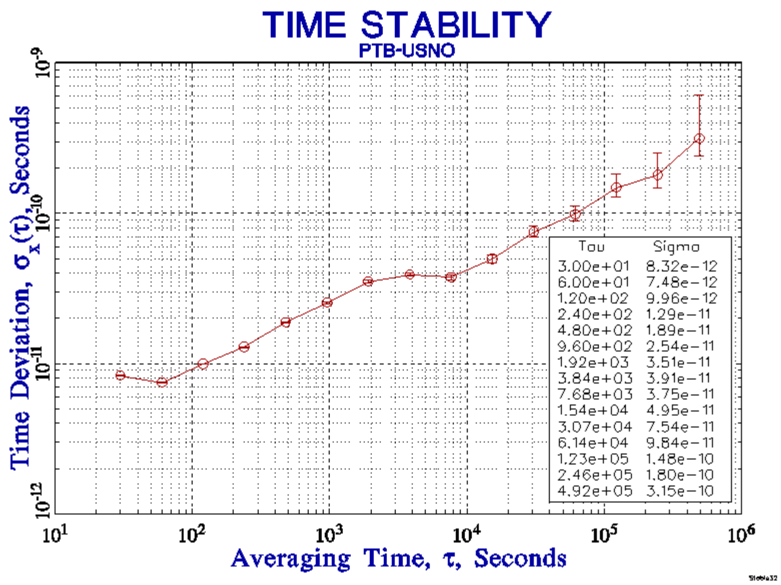

Figure 10. Time deviation for PTB-USNO (14-day solution).

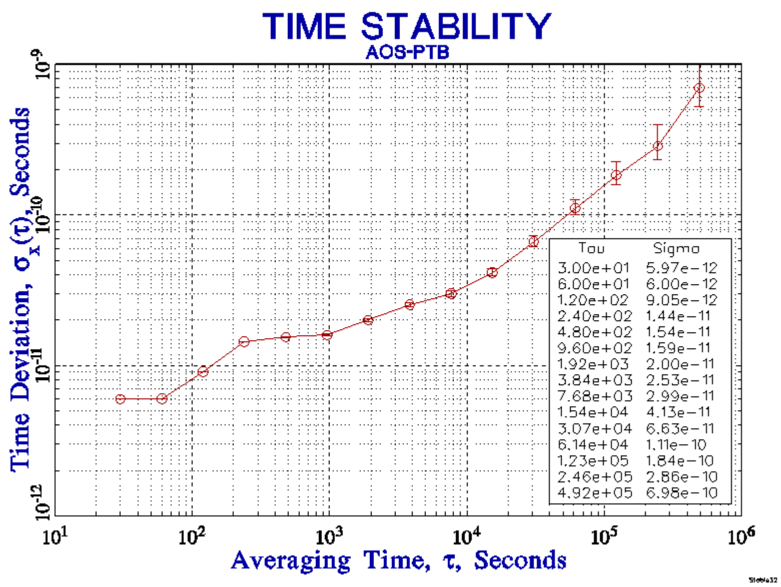

Figure 11. Time deviation for AOS-PTB (one-month solution).

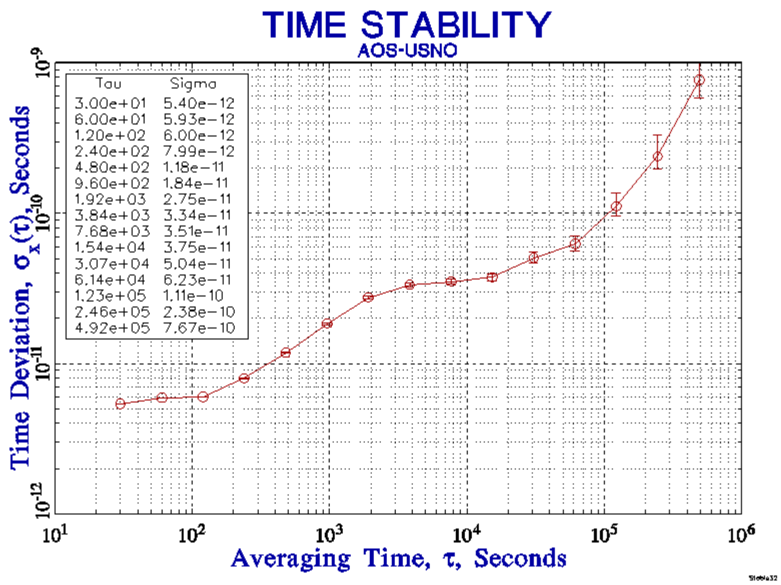

Figure 12. Time deviation for AOS-USNO (one-month solution).

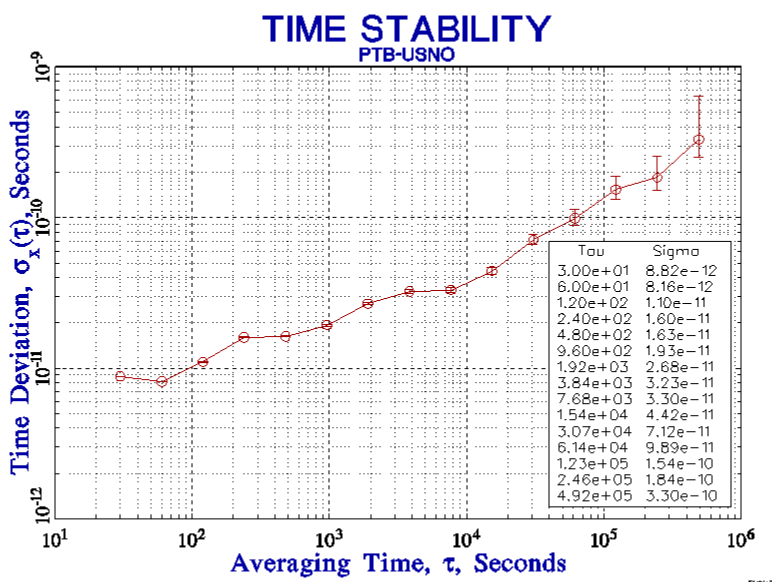

Figure 13. Time deviation for PTB-USNO (one-month solution).

Table 2 shows the RMS for all cases calculated from 24-hour solutions by least squares estimation. In general, all links give comparable results in all modes. The RMS are at the level of 0.01-0.02 ns.

Table 2. RMS of solutions for all analyzed time links.

Time Link	7 days	14 days	1 month
AOS-PTB	0.01-0.1	0.01-0.1	0.01-0.1
AOS-USNO	0.02-0.1	0.01-0.1	0.01-0.1
PTB-USNO	0.02-0.09	0.01-0.11	0.01-0.1

In the next step, an experimental analysis was made at AOS, using a very short link consisting of two TTS-4 receivers: SN 112 which is the main receiver at AOS, and the SN 126 receiver which is in testing mode. Both of the receivers are mounted on the roof of the main building of the AOS (Figure 14).

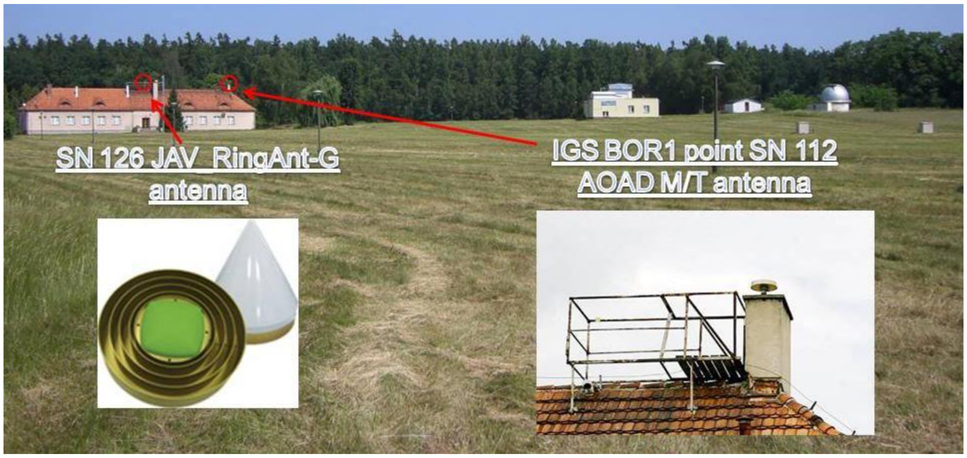

Figure 14. Time link SN 112-SN 126 built in AOS.

The TTS-4 SN 112 was connected to the choke ring AOAD M/T antenna (IGS BOR1 point). TTS-4 SN 126 was working with a Javad GRANT-G3T antenna. The distance between the antennas is about 15 m. Receiver clocks are synchronized by 1 pps (1 pulse per second) and frequency signals (20 and 10 MHz respectively) from the reference standard, an active hydrogen maser CH1-75A, the main clock at the AOS.

The computations were performed for 10-day GPS and GLONASS data separately, for the period from Sept. 17 to Sept. 26, 2011, based on ESA's *sp3* and *clk* files containing GPS and GLONASS products. The 10-day solution means, that also in this case, 24-hour RINEX files were combined into one 10-day file of data. The results of PPP calculations for the SN112-SN126 time link are shown in Figure 15.

According to Figure 15, phase discontinuities are visible in both cases; this results from frequent restarts of the experimental SN 126. However, for GPS they are at the level of 1 ns, and for the GLONASS solution they are equal to 5 ns approximately. The differences in clock readings obtained for GPS are much smaller than for the GLONASS solution. The authors relate it to the multifrequency of the GLONASS system.

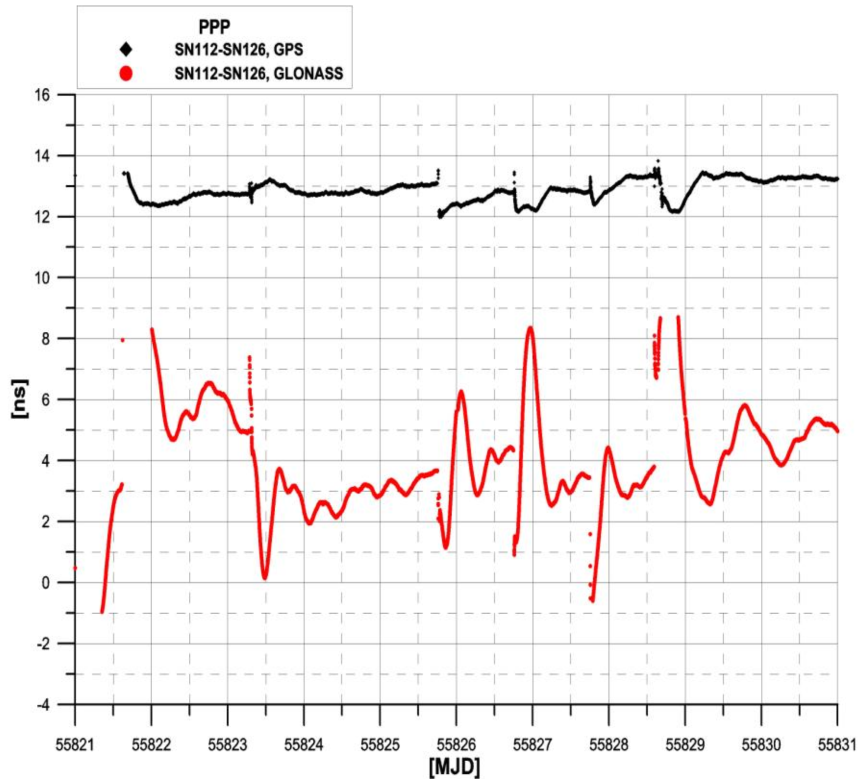

Figure 15. 10-day PPP solution for link SN 112-SN 126, based on GPS (black) and GLONASS measurements (in red).

In Table 3, the RMS of 10-day solutions of the SN112-SN126 link are presented. Also in this case, RMS were calculated from 24-hour solutions by least squares estimation. For GPS, RMS are about 2 times lower than for GLONASS; this is presented in Figure 16.

Table 3. RMS for the solution of the SN112-SN126 link.

	10 days	
SN112-SN126	GPS	GLONASS
	0.01-0.32	0.04-0.64

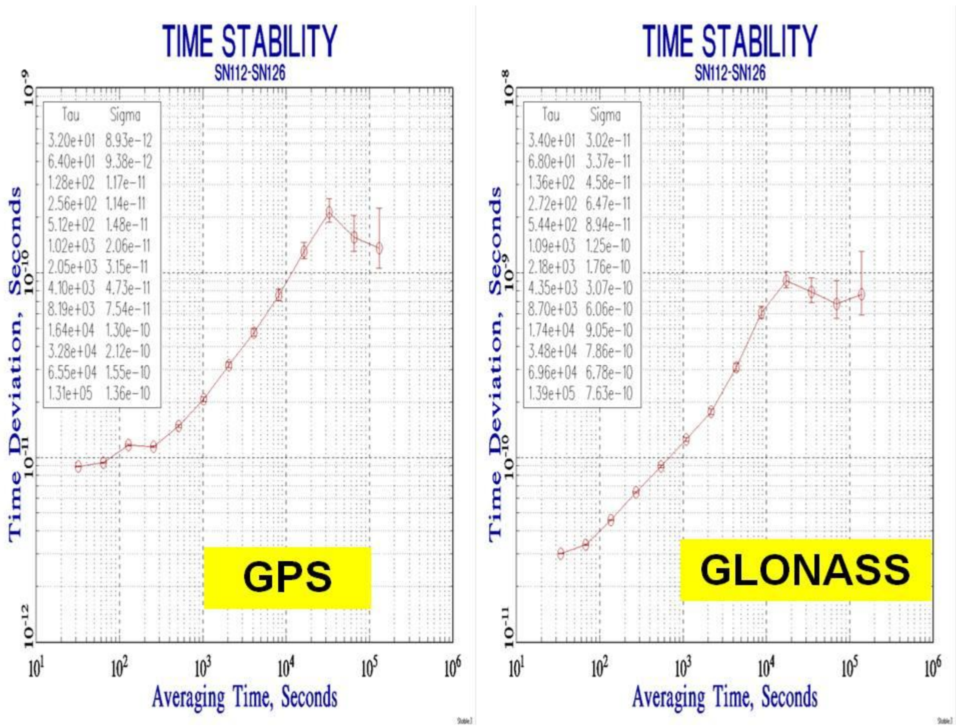

Figure 16. Time deviation for SN112-SN126 link (10-day solution).

SUMMARY AND CONCLUSIONS

The results presented in this paper show that AOS is ready to realize continuous use of the PPP technique for time transfer. The NRC GPS-PPP software used for this purpose is a very flexible tool for timing applications. The code of the program can be easy adapted for required conditions. The initial results are in good agreement with results presented by others authors. The stability for GPS is from about 0.01 ns to 0.11 ns depending on the interval of estimation. The stability is better for GPS (RMS of 0.01 ns) than for GLONASS (RMS of 0.6 ns). In the near future, AOS will use the PPP method for calculations in 24-hour mode (with 24-hour latency) for better control of antenna position and the stability of the reference clock based on both GPS and GLONASS observations. The next step will concentrate on the use of Galileo and COMPASS data, and combined GPS+GLONASS, GPS+Galileo solutions. As an independent method, the PPP allows for the verification of other time transfer techniques like GPS CV, GLONASS CV and TWSTFT realized by AOS. The PPP technique is a very good alternative for calibration of a future glass fiber link GUM(Warsaw)-AOS. The application of the PPP method will improve and strengthen the quality of the Polish time scales UTC(AOS), UTC(PL), and TA(PL).

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