RECENT ACTIVITIES IN THE FIELD OF TIME AND FREQUENCY IN POLAND

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Abstract

The work of main time laboratories in Poland concentrates on the improvement of national time scales UTC (PL) and TA (PL), and the development of new time receivers. The Polish Independent Atomic Time Scale TA (PL) is obtained as the weighted average of about eight atomic clocks working at different laboratories in Poland, and its long-term stability is about $5 \cdot 10^{-15}$. In the recent years, the important achievement was the development of the TTS-2 multi-channel GPS time receiver based on Motorola VP Oncore engine. At present, a new time transfer receiver based on Javad Legacy card is under development. This paper provides the first results obtained with TTS-3.

INTRODUCTION

The focal points of the research work in time and frequency metrology in Poland are:

- Time and Frequency Department of Central Office of Measures (GUM) in Warsaw,
- Astrogeodynamical Observatory (AOS) in Borowiec near Poznań.

The work of above laboratories concentrates on the following issues:

- improvement of national time scale UTC (PL) and TA (PL),
- development of time transfer receivers.

In the recent years, the important accomplishment was the founding of the Polish Independent Atomic Time Scale TA (PL) obtained as the weighted average of about eight atomic clocks working at different laboratories in Poland. The TA (PL) is developed in cooperation with Lithuania. The long-term stability of the TA (PL) is in the range of $5 \cdot 10^{-15}$. Further developments concentrate on the realization of UTC (PL), which will be related to TA (PL). The possibility of using TA (PL) for prediction and forming UTC (PL) will allow the accuracy of Polish realization of UTC in the range of tens of nanoseconds.

Another important work was the development of multi-channel GPS receiver based on Motorola VP Oncore engine (TTS-2, Time Transfer System -2). At present, our work on time transfer focuses on TTS-3 time receiver based on the Javad Legacy card. The aim is to develop a time receiver which

will integrate observations of all available navigation satellites: GPS, GLONASS, WAAS, and EGNOS.

TIME SCALES

Until the year 2001, two Polish laboratories participated in International Atomic Time (TAI) and Coordinated Universal time (UTC): the Time and Frequency Laboratory of the Central Office of Measures (GUM), and the Astrogeodynamical Observatory of the Polish Academy of Sciences (AOS).

Their time scales were based on single cesium clocks, which were neither stable enough nor accurate enough to provide a local realization of UTC with an accuracy of several tens of nanoseconds **[1,2]**.

In recent years, a number of high-quality cesium Hewlett-Packard HP 5071A clocks, mostly high-performance versions, have been installed at several Polish public and commercial institutions. The idea thus developed to start to compare data from all available clocks in the country, using a precise method of time transfer **[3]**. An appropriate tool was already available: a GPS multi-channel receiver TTS-2 (Time Transfer System 2) constructed at AOS Borowiec in cooperation with the Bureau International des Poids et Measures (BIPM) in Sèvres **[4]**. The uncertainty of comparisons between the participating laboratories is currently between 2 ns and 5 ns (root-mean-square, rms). Common-view observational data are gathered weekly, and a weighted average of the indications from all participating clocks is computed at the end of each month, using an especially developed algorithm **[5].** In this way, the independent Polish atomic time scale has been computed since August 1999 and officially published in the BIPM's *Circular T* since 4 July 2001. The aims of the new time scale are:

- to improve the stability and accuracy of the Polish national time scale UTC (PL);
- to connect local atomic clocks, operating at number of institutions, to Polish Official Time;
- to enable estimation of the quality of the participating atomic clocks;
- to increase the number of Polish clocks participating in TAI.

In the realization of Polish Independent Atomic Time Scale participate:

- Time and Frequency Laboratory of the Central Office of Measures (GUM), Warsaw: three Cs clocks;
- Astrogeodynamical Observatory of the Polish Academy of Sciences (AOS), Borowiec: one Cs clock;
- National Institute of Telecommunication (IŁ), Warsaw: two Cs clocks;
- Central Laboratory of the Polish Telecom (TPSA), Warsaw: one Cs clock;
- Tele-Radio Research Institute (ITR), Warsaw: one Cs clock.

Also participating in the formation of TA (PL) since 1 January 2001 is:

- Time and Frequency Standard Laboratory of the Semiconductor Physics Institute (LT), Vilnius, Lithuania: one Cs clock.

This constitutes an ensemble of nine Cs clocks, most of which are of type HP 5071A. Several other Polish institutions are expected in the near future to contribute to this ensemble with their Cs clocks and hydrogen masers. Clocks at the GUM are compared using an HP5335A electronic counter. Clocks from other laboratories are compared using multi-channel GPS receivers, the TTS-2s, manufactured at the AOS. UTC (PL) and TA (PL) are linked to UTC and TAI through the GUM also by means of a TTS-2. The long-term stability of the TA (PL) is in the range of $5 \cdot 10^{-15}$ (see Figures 1 and 2).

It is expected that in the near future five new clocks will be added to the TA (PL) ensemble. These will be from
Polish Telecom (one HP 5071A), Toruń University (one HM), the Polish Army (one HP5071A, one HM), and Lithuania (one HP 5071A).

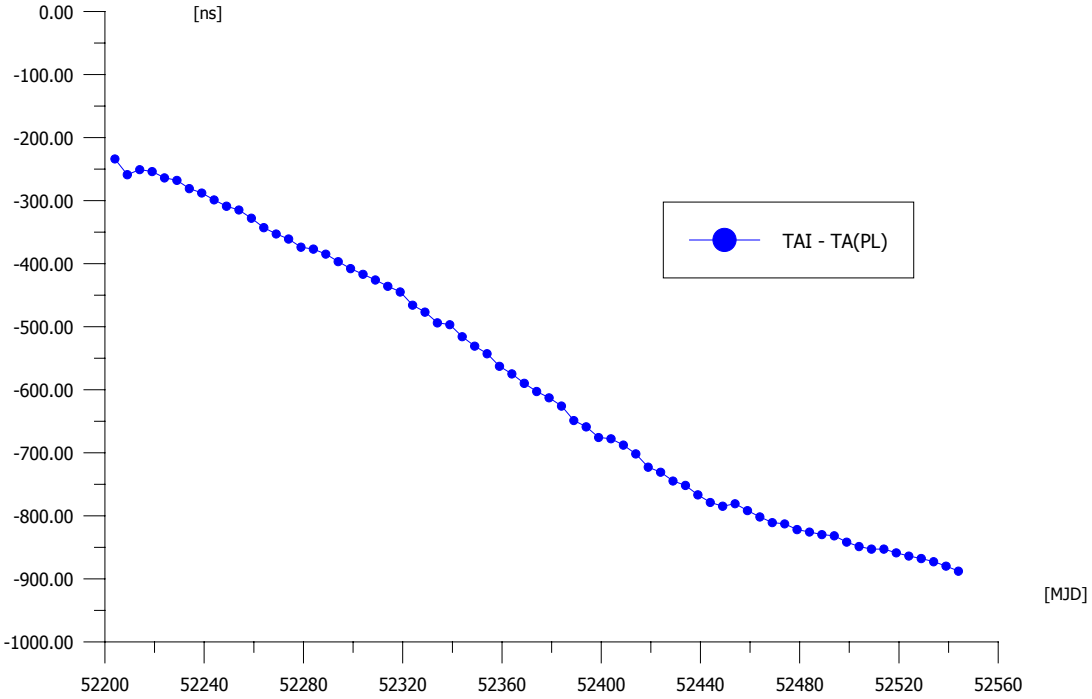

Figure 1. Differences between TAI and TA (PL) for about 1 year.

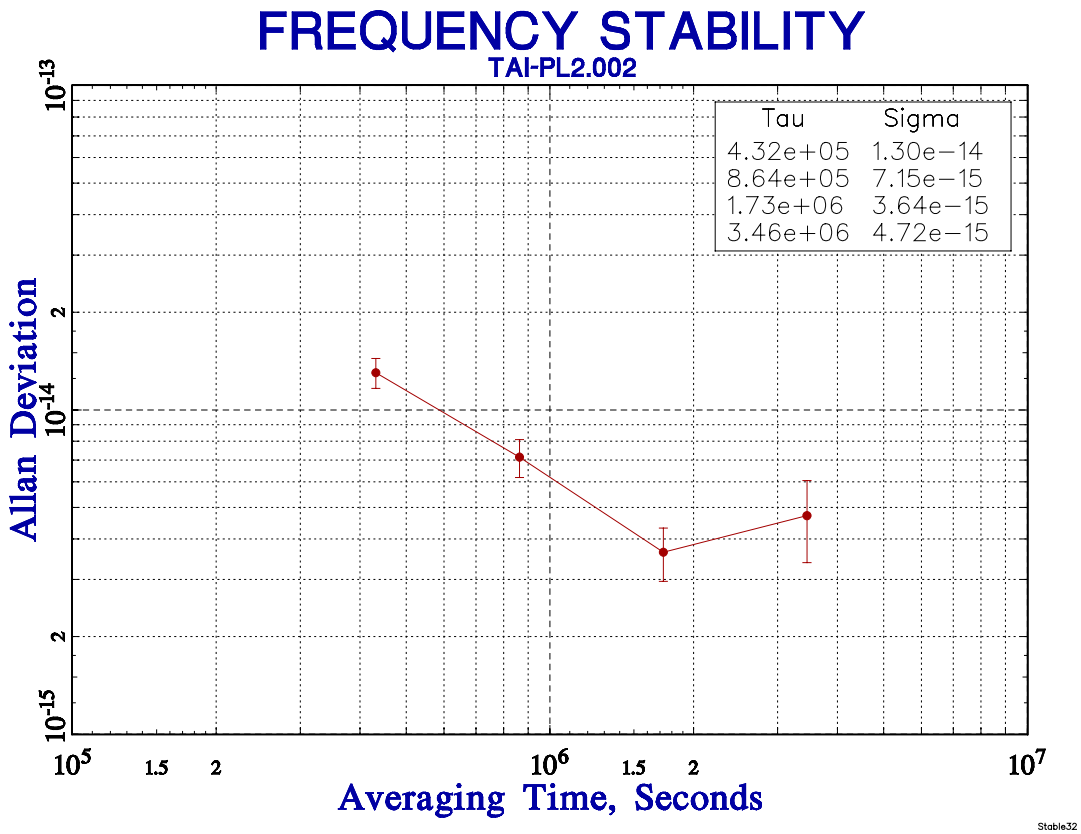

Figure 2. Frequency stability of the differences [TAI – TA (PL)].

RECEIVERS

The AOS for many years has been developing time transfer receivers. The TTS-2 (Time Transfer System -2) multi-channel GPS receivers based on Motorola VP Oncore engine **[4,6]** are now working at:

- United States Naval Observatory (USNO): two receivers,
- Bureau International des Poids et Measures (BIPM): two receivers,
- Semiconductor Physics Institute (SPI), Lithuania: one receiver,
- National Institute of Standards (NIS), Egypt: one receiver,
- Naval Research Laboratory (NRL), USA: one receiver,
- Observatorio Naval Buenos Aires (ONBA), Argentina: one receiver,
- Astrogeodynamical Observatory (AOS), Borowiec Poland: two receivers,
- Swiss Office of Metrology (SOM), Bern: one receiver,
- Observatoire de la Côte d'Azur (OCA), France: one receiver,
- Main Office for Mesures (GUM), Warsaw: two receivers,
- Institute of Communication (IŁ), Warsaw, Poland: two receivers,
- Central Laboratory of Polish Telecom. (CBR), Warsaw, Poland: one receiver,
- Military Center for Metrology, Zielonka, Poland: one receiver,
- Bundesamt fur Eich – und Vermessungswessn (BEV), Austria: one receiver,
- Observatório Nacional (ONRJ), Brazil: one receiver,
- National Institute of Standards and Technology (NIST), USA: two receivers,
- Centro Nacional de Metrologia (SENACYT), Panama: one receiver .

The performance of TTS-2 in single-channel mode is similar to that of the original NBS (National Bureau of Standards) GPS receiver. After correction for ionospheric delays and precise ephemerides, the root-mean-square noise level for baselines of up to 8,000 km is about 3.0 ns; in the multi-channel mode it is even better. The TTS-2 receivers can be equipped with temperature-stabilized antennas and a temperature-stabilized chamber for the Motorola card.

At present, work focuses on TTS-3 time receiver based on the Javad Legacy EGGD engine. The aim is to develop a time receiver that will integrate observations of all available navigation satellites: GPS, GLONASS, WAAS, and EGNOS.

The main features of the new TTS-3 are:

- 40 channels, all-in-view, L1 GPS, L1/L2 GPS, L1/L2 GLONASS, WAAS, EGNOS,
- up to 112 MB of on-board data storage (removable CompactFlash card), input/output,
- four high-speed RS232 serial ports (up to 460.8 Kbps),
- full-duplex 10BASE-T Ethernet port,
- full-speed USB device port (12 Mbps),
- External Reference Frequency input/output,
- two 1PPS outputs (LVTTL) synchronized to GPS time, GLONASS time, or UTC,
- two Event Marker inputs,
- the system is working under LINUX providing multitasking and better integration with networks.

Software of TTS-3 applies all requirements of CCTF. Data are provided in the standard CCTF format. Results obtained with the new TTS-3
in GPS multi-channel C/A code mode are similar to those obtained with TTS-2.

First experiments with TTS-3 using reconstructed GPS P-code and measurements of ionosphere were conducted at the AOS. An on-site comparison for a period of about 1 week of TTS-3 multi-channel GPS "P-code" results with TTS-2 multi-channel GPS C/A-code results is provided on Figure 3. An apparent time step around MJD 52580 is due to the changes in the hardware setup and not to behavior of receivers. A typical daily standard deviation for this comparison is 2.3 ns.

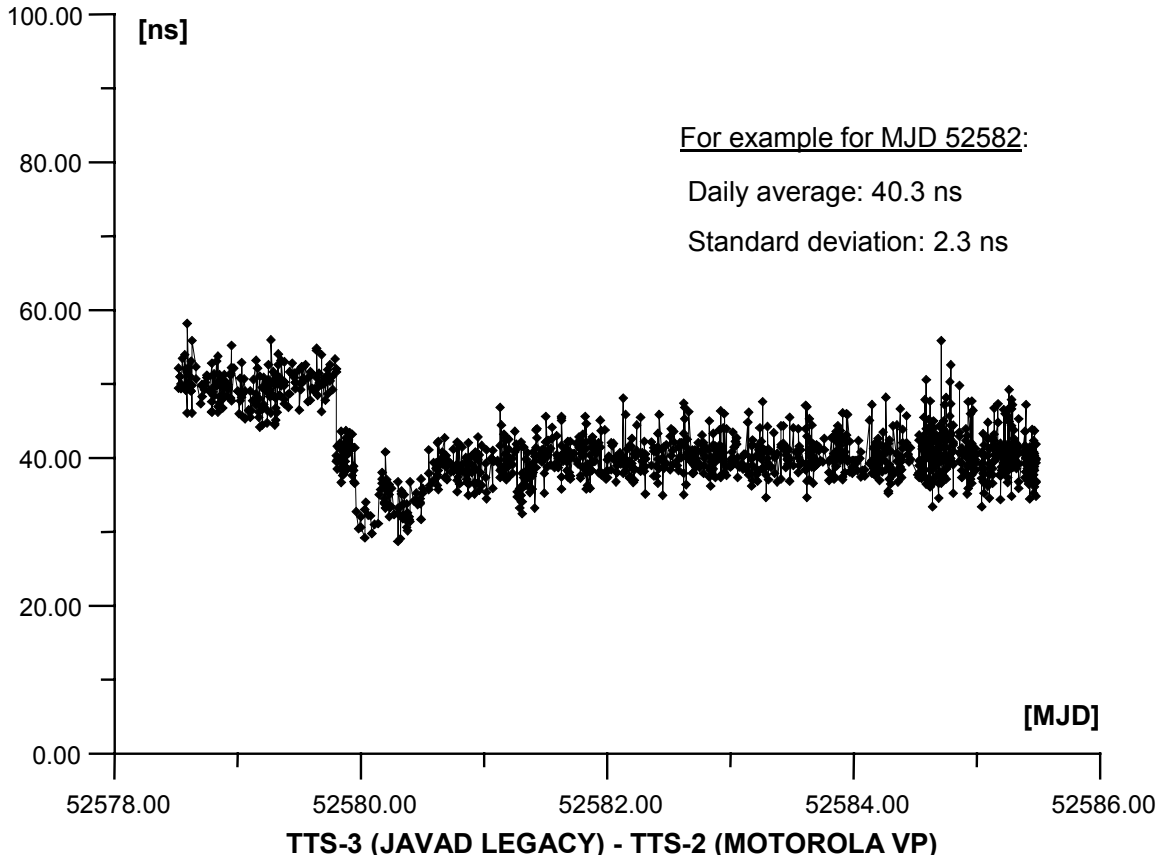

Figure 3. On-site multi-channel comparison of TTS-3 working in reconstructed GPS P-code mode with TTS-2 (GPS C/A-code).

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