CALIBRATION OF THE BEV GPS RECEIVER BY USING TWSTFT

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Abstract

At BEV, in cooperation with PTB and Joanneum Research/TU Graz and the support of BIPM, we have done a calibration of the BEV reference GPS time receiver by using Two-way Satellite Time and Frequency Transfer (TWSTFT). Due to antenna changes, a new calibration of the BEV receiver was necessary. This receiver is the first GPS receiver with calibration through TWSTFT and used for UTC computation. This new calibration technique improves the value of the UTC-UTC (BEV) uncertainty in the Circular T from 5.3 ns down to 3.6 ns.

INTRODUCTION

The Bundesamt für Eich-und Vermessungswesen (BEV) is the National Metrology Institute of Austria and contributes with their atomic clocks to the international time to maintain UTC. BEV uses single-frequency multi-channel GPS time receivers. One TTS-2 receiver is the reference receiver and used for the international time comparison for UTC. A second TTS-2 receiver is used as a backup. In 2007, major changes in the setup of the GPS time receivers were done at BEV. Due to an antenna failure of the reference receiver and many data disturbances at our second receiver, we decided to exchange both antennas. Therefore, it was necessary to recalibrate the receivers. The latest calibration campaign for GPS receivers organized by BIPM and performed in 2006 was also not useful anymore for this purpose. So a suitable possibility to recalibrate the GPS reference receiver had to be explored.

The Joanneum Research GmbH in Graz/Austria offers the service of carrying out Two-way Satellite Time and Frequency Transfer (TWSTFT) with portable measurement equipment. Normally, this equipment is used for calibration of TWSTFT stations. The high accuracy of TWSTFT measurements and the possibility of time scale comparison with nanosecond accuracy were the reasons to discuss the calibration of our GPS receiver with a TWSTFT time link comparison **[1]**. In October 2007, a TWSTFT measurement campaign was carried out by Joanneum Research GmbH in collaboration with the University of Technology Graz and the support of the Physikalisch-Technische Bundesanstalt (PTB). The main purpose of this campaign was to directly compare the physical realization of UTC at BEV with UTC (PTB) and to use these measurements for a calibration of the BEV reference GPS receiver. We expected that, due to this highly accurate measurement technique, we could improve the Type B uncertainty of our time link listed in Circular T.

TIME TRANSFER BETWEEN BEV AND PTB BY TWSTFT

The Joanneum Research GmbH carried out the TWSTFT campaign between PTB and BEV from 9 to 31 October 2007. The campaign started at the site of the time & frequency laboratory of the University of Technology Graz at the Observatory Lustbuehel with TWSTFT measurements from the fixed satellite ground station TUG01 versus the portable station TUG03. Then TUG03 was transported to BEV and thereafter to PTB. At both sites, TWSTFT measurements with the PTB reference station PTB04 were performed. After the measurements at the BEV site and the PTB site, the campaign was finished with a second measurement series in Graz to verify the stability of the portable equipment throughout the campaign **[2]**. At BEV, the measurements were done from 10 to 11 October for 24 hours. The setup of the portable station at BEV is depicted in Figures 1 and 2. The GPS receiver from BEV and the TWSTFT station use coherent 1 PPS signals from the master cesium clock. Figure 3 illustrates the block diagram of TUG03's indoor setup at the BEV site.

Figure 1. Bernd Blanzano and Werner Mache during installation of the TUG03 antenna on top of the BEV building.

Started in the afternoon of the first day at BEV (MJD 54383), the TWSTFT measurements between BEV and PTB were continued overnight till the afternoon of the second day. During the same time, link comparisons via GPS AV (all-in-view) technique **[3]** were done. So at BEV we had simultaneous time comparisons by TWSTFT and the GPS technique. First, a linear regression over the 121 TWSTFT data points was calculated. To compare the TWSTFT values with a reported reference point in BIPM's Circular T 238, the TWSTFT value for 11 October 2007, 0h UTC (MJD 54384.0) was interpolated. So the result via TWSTFT is UTC (PTB) – UTC (BEV) = -50.586 ns (see Figure 4).

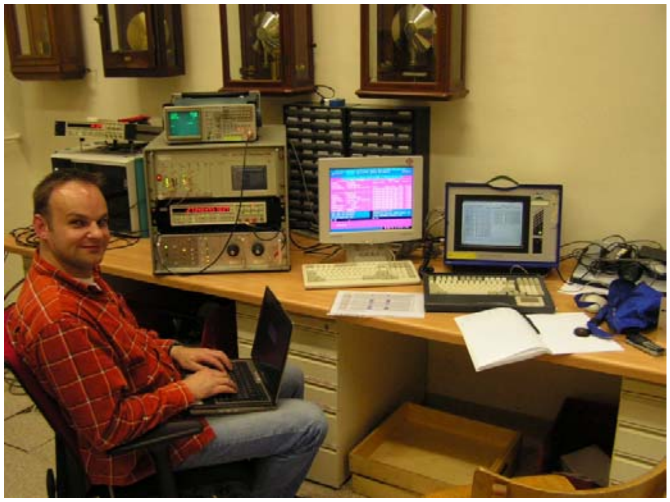

Figure 2. Jürgen Becker beside the TUG03 indoor setup in the time & frequency laboratory of BEV.

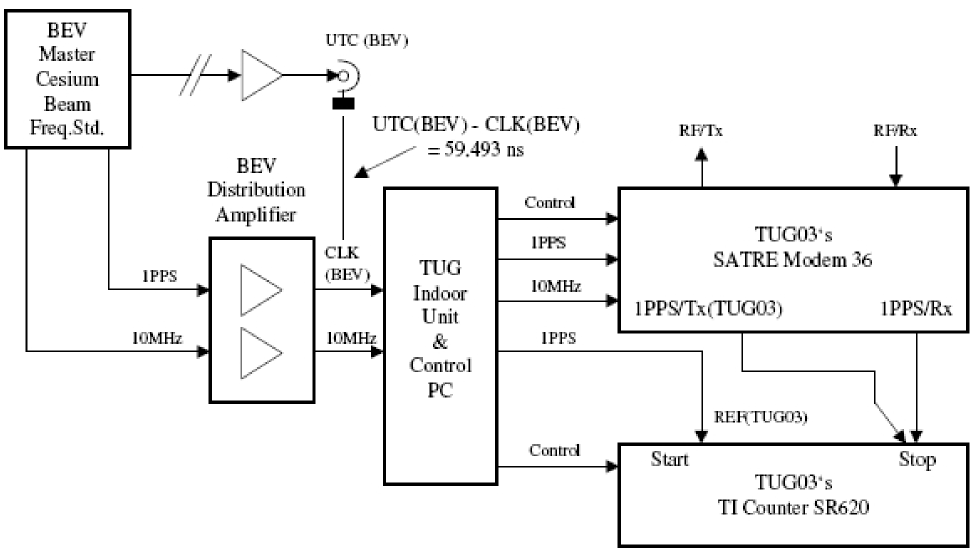

Figure 3. Block diagram of the TUG03 indoor setup at BEV.

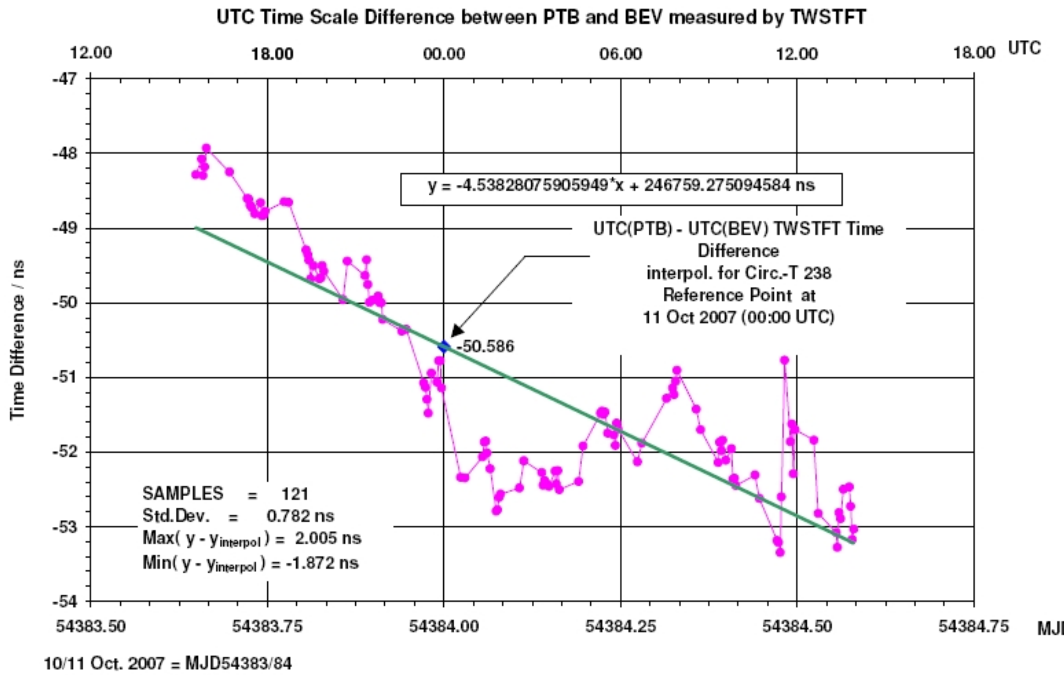

Figure 4. TWSTFT measurements between BEV and PTB (pink dots). The green line is the linear regression.

THE CALIBRATION AND UNCERTAINTY RESULTS

We have used the result of the TWSTFT measurements for the calibration of our GPS receivers (reference receiver TTS-2 No.24 and backup receiver TTS-2 No.55). The calibration value was calculated based on the difference of the TWSTFT measurements between BEV and PTB and the related Circular T values.

Derived from the Circular T 238, the difference between the reported time transfer values between BEV and PTB was calculated; [UTC – UTC (PTB)] - [UTC – UTC (BEV)] = -38.3 ns. Comparing the TWSTFT measurement versus the Circular T 238 result, we got as a total difference -50.586 ns - (-38.3 ns) = -12.3 ns. With this result we adjusted the current INT DLY parameter of our GPS reference receiver to the reported -27.3 ns **[4]**. Comparing the measurement data of the GPS reference receiver and the GPS backup receiver, we also got the new INT DLY parameter for the second receiver. At first, we estimated the value for the uncertainty u_B of the calibrated GPS receiver with following calculation:

$$u_B = \sqrt{u_A(BEV)^2 + u_A(PTB)^2 + u_B(PTB)^2 + u_{TWSTFT}{}^2} = \sqrt{1.5\, ns^2 + 0.2\, ns^2 + 0.9\, ns^2 + 0.782\, ns^2} = 1.93\, ns\,.$$

Also at BIPM the TWSTFT measurement report and the computation of the calibration value was studied, and Z. Jiang and F. Arias looked for improvements of the calibration quantity and uncertainty estimation **[5]**. Analyzing the prevailing calibration results, the linear regression may be affected by nonlinear variations and noises in the master clocks' differences, and the calibration calculation uses only one point of Circular T 238. As displayed in Figure 5, the GPS time transfer data used for Circular T 238 was disturbed around MJD 54384. In addition, there is also a gap in the PTB GPS data file at this period.

The value on MJD 54384 of Circular T used for our calibration calculation was affected by the disturbance and the gap in the GPS data.

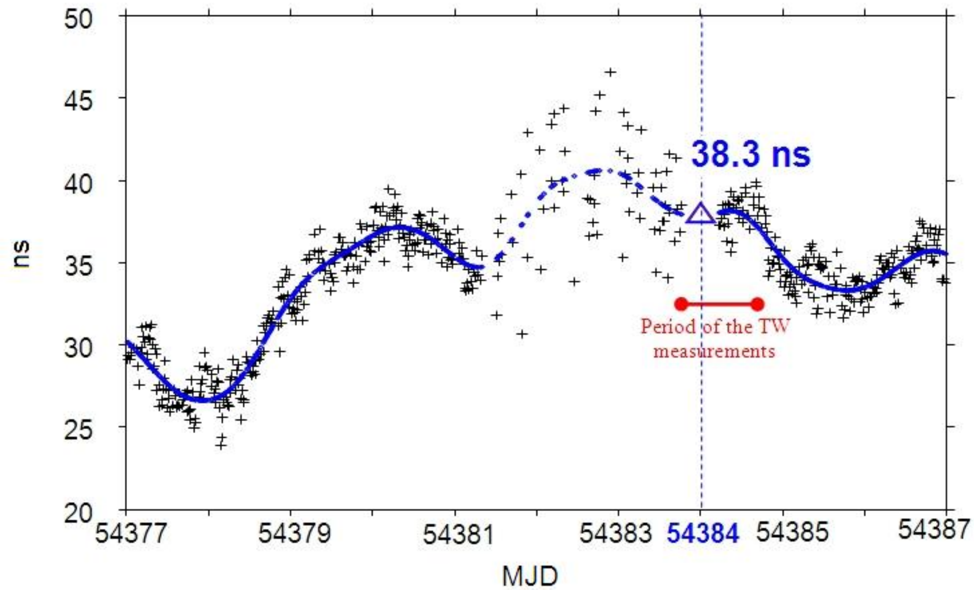

Figure 5. GPS AV time transfer link between BEV and PTB used for Circular T 238.

At BIPM, a new procedure which was proposed for transfer the TWSTFT calibration to GPS PPP receivers was used to improve the BEV GPS receiver calibration **[6]**. The principal idea to improve the calibration is to use only the common undisturbed part of TWSTFT and GPS data to compute the difference between TWSTFT and GPS. This calculation gives 26 differences of the two links, with TWSTFT measurements interpolated onto the GPS epochs. The mean value of the difference is -13.982 ns and the standard deviation is ±0.964 ns. The standard deviation of the mean value is ±0.964 ns/√26 = ±0.198 ns. Finally, the total uncertainty of TWSTFT measurement and the link comparison is estimated to be 1 ns.

The BIPM suggested using the expanded uncertainty u_B = 3 ns (roughly three-sigma confidence level) for the described calibration campaign. This expanded uncertainty was chosen to take into account the long-term stability of the GPS receivers. The final INT DLY parameter for the GPS reference receiver is -29.0 ns.

SUMMARY AND FURTHER IMPROVEMENTS

The BEV GPS receiver is the first receiver of his kind which was calibrated by TWSTFT measurements. We adjusted the GPS reference receiver with the new INT DLY parameter -29.0 ns. The BIPM will consider the new value of 3 ns for the GPS link uncertainty in the Circular T report. So this new calibration technique improves the value of the UTC – UTC (BEV) uncertainty in the Circular T from 5.3 ns down to 3.6 ns. This calibration campaign was a costly but accurate method to get excellent results for the GPS receiver calibration.

Further improvement of the calibration is possible by increasing the number of data points and, thus, the duration of the TWSTFT measurements up to more than 1 day.

To find out the aging of the GPS receiver, we plan to repeat this receiver calibration by TWSTFT in about 2-3 years.

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