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 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 calibration 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 to the international time comparisons 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. The second TTS-2 receiver is used as a back-up. In 2007 a lot of changes in the setup of the GPS time receivers were done at BEV. Due to antenna failure of the reference receiver and big data disturbances at our second receiver we changed both antennas. Therefore it was necessary to recalibrate the receivers. The latest calibration campaign for GPS receivers organized by BIPM in 2006 was also not useful anymore. So we looked for another possibility to calibrate the changed GPS reference receiver.

The Joanneum Research GmbH in Graz/Austria offers the possibility to carry out Two-way Satellite Time and Frequency Transfer (TWSTFT) with portable measurement equipment. Normally this equipment is used for calibration campaigns of TWSTFT stations. The high accuracy of TWSTFT measurements and the ensuing possibility of time scale comparison with nanosecond accuracy was the reason to think about the calibration of our GPS receiver with a TWSTFT time link comparison [4]. 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 UTC time scale of BEV and PTB and to use these measurements for the GPS receiver calibration. We expected that due to this high 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 9th to 31st October 2007. The campaign started at the site of the time & frequency laboratory of the University of Technology Graz at the Observatory Lustbuehel in Graz with TWSTFT measurements of the fixed satellite terminal TUG01 versus the portable TWSTFT terminal TUG03. After the measurements at the BEV site and the PTB site the campaign was finished by a second measurement series in Graz to verify the consistency of the portable equipment throughout the campaign [1]. At BEV the measurements were done from 10th to 11th October for 24 hours. The set-up of the portable station at BEV is depicted in Figure 1 and 2. The GPS receiver from BEV and the TWSTFT station use the same 1 PPS signal from the master cesium clock. Figure 3 illustrates the block diagram of TUG03´s indoor setup at BEV site.

Figure 1: The installed TUG03 antenna on top of the BEV building (some more words to tell what is what in the picture ?)

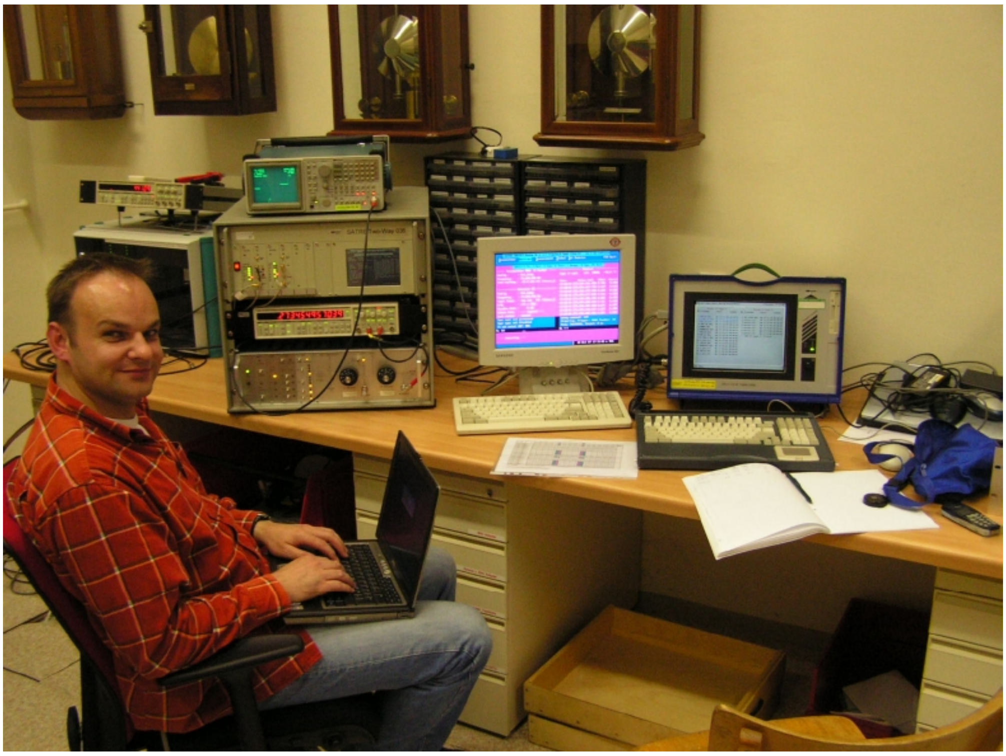

Figure 2: TUG03 indoor set-up in the time & frequency laboratory of BEV (some more words to tell what is what in the picture ?)

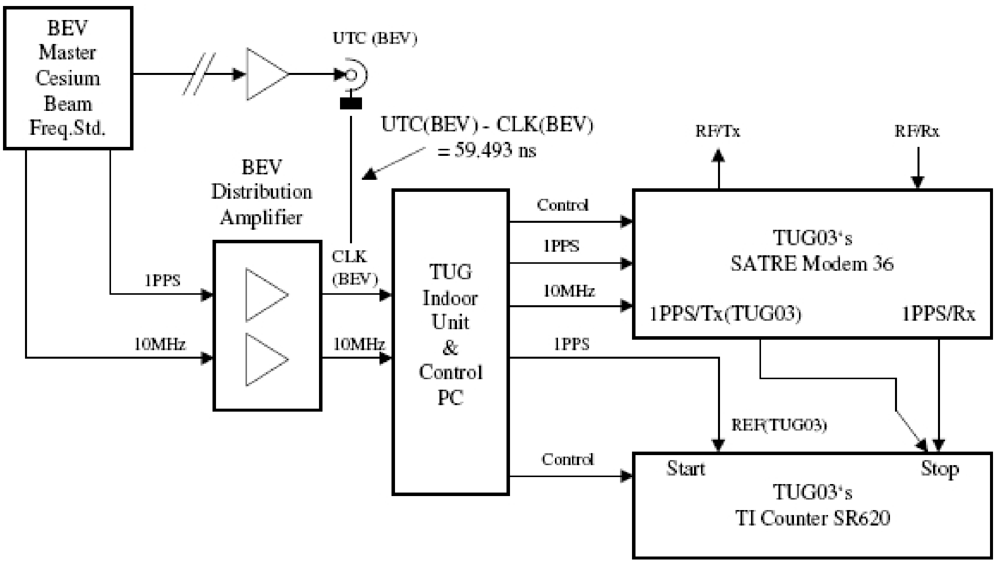

Figure 3: Block diagram of TUG03 indoor set-up at BEV (some more words to tell what is what in the picture. For ex RF, Tx , which epoch is related to the 59.493 ns and what is it, not clear ?)

Started in the afternoon of the first day the TWSTFT measurements were continued overnight till the afternoon of the second day. At the same time the common time (common clocks ?) comparisons via GPS AV time link were done. So at BEV we had simultaneous time comparisons by TWSTFT and GPS technique. For the first evaluation of these measurements 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 MJD 54383 (11th October 2007), 0h UTC was interpolated. The result is -50.586 ns and this is the value for UTC(PTB)-UTC(BEV) via TWSTFT (see Figure 4).

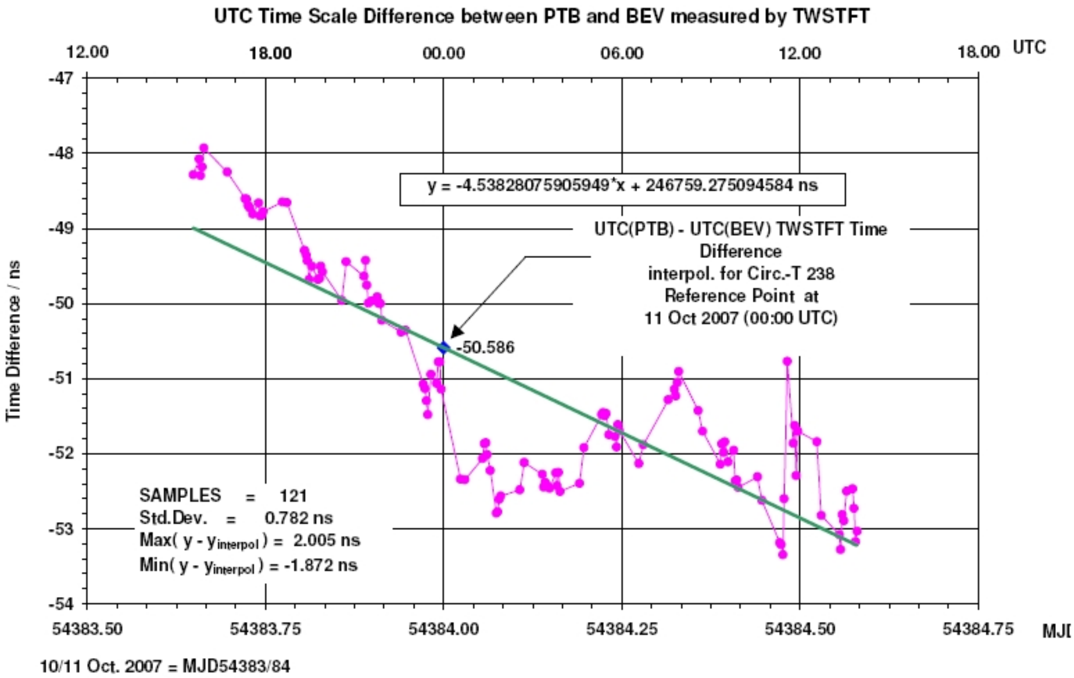

Figure 4: TWSTFT measurements between BEV and PTB (pink). The green line is the linear regression.

THE CALIBRATION AND UNCERTAINTY RESULTS

We have used the result of the TWSTFT measurements for calibration of our GPS receivers (reference receiver TTS-2 No.24 and back-up 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.

Deriving 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 Circular T 238 result we got as 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 [2]. Comparing the measurement data of the GPS reference receiver and the GPS back-up receiver we got also 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 [3]. Analyzing the prevailing calibration results the linear regression may be affected by non linear variations and noises in the master clocks' differences and the calibration calculation uses only one point of the Circular T 238. As displayed in Figure 5 the GPS time transfer data used for Circular T 238 was disturbed round about the 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.

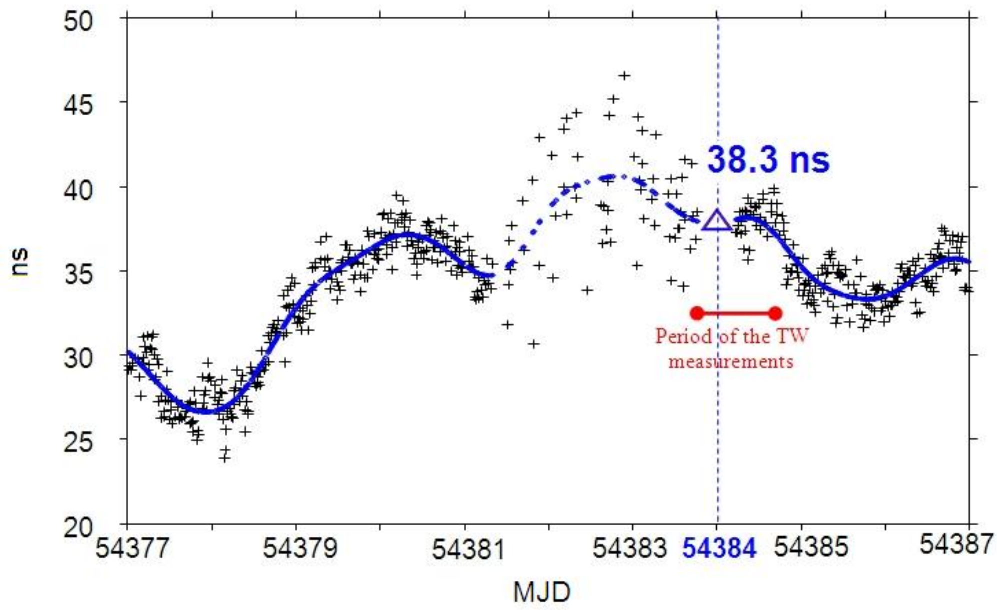

Figure 5: GPS AV time transfer link between BEV and PTB used for Circular T 238

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. 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. So 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 with 1 ns.

The BIPM suggested to use the expanded uncertainty u_B = 3 ns (three-sigma confidence level) for the described calibration campaign. The final INT DLY parameter for the GPS reference receiver is -29.0 ns.

SUMMERY AND FURTHER IMPROVEMENTS

The BEV GPS receiver is the first receiver which was calibrated by TWSTFT measurements and used in the UTC generation. We adjusted the GPS reference receiver with the new INT DLY parameter -29.0 ns. The BIPM applies the new value of 3 ns for the GPS link uncertainty in the Circular T report. So this new calibration 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 one 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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