

BIPM Comparison of Time Transfer Techniques

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Abstract— Clock comparison for International Atomic Time (TAI) is based on common views of satellites of the GPS constellation and on the technique of two-way satellite time and frequency transfer (TWSTFT). All the TWSTFT links are backed up by the GPS ones. Due to the duplicity of techniques in many baselines, the international network of time links is today highly redundant. The improvement of GPS satellite ephemerides and clock values produced by the International GNSS Service (IGS) might lead to the utilisation of the all-in-view (AV) method for the computation of GPS links instead of the common-view (CV) one currently used for TAI. Studies started at the BIPM to validate the GPS AV method for introduction in the calculation of TAI. To assist related studies, we developed a procedure to compare the links measured with different techniques and calculated with different methods. Results of these comparisons obtained since January 2005 are published on the BIPM ftp site, with monthly updates after the calculation of BIPM Circular T.

I. INTRODUCTION

To compute the international reference time scales International Atomic Time (TAI) and Coordinated Universal Time (UTC), the BIPM gathers clock and clock comparison data every month through the TAI time transfer network comprised today of 56 laboratories. Various time transfer techniques are used for clock comparison in TAI; while GPS single-frequency C/A code observations are still dominant, the number of GPS multi-channel, dual-frequency receivers reporting data for TAI is increasing, and the TWSTFT links are reaching their maximum capabilities. Figure 1 shows the network of international time links as on March 2004; figure 2 gives the contribution of the different techniques. Many time links are computed simultaneously with more than one technique, but no profit of this redundancy is taken for the computation. However, in these cases the “official” links are backed-up with the additional link to verify the continuity and the quality of the links. The updated information of the time links used for the calculation of TAI is provided in Section 6 of Circular T. Link comparisons are calculated on a routine basis to investigate the biases and the discrepancies between different measurement techniques.

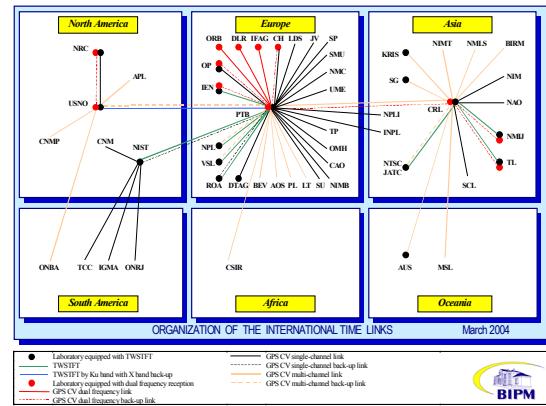


Figure 1. International network of time links

Jiang and Petit [1] proposed the application of the all-in-view method to the calculation of GPS time links for TAI. This proposal is under study at the CCTF Working Group on TAI, who established two special study groups for this task. With the aim of completing the analyses at the BIPM and of providing results to the study groups, comparison of time links computed with the two methods are posted on the BIPM ftp site.

II. AVAILABILITY OF TIME TRANSFER DATA, LINK AND LINK COMPARISON RESULTS VIA INTERNET

Different level of data and results are provided on open access through the internet at:

<http://www.bipm.org/en/scientific/tai>

In addition to the files containing the GPS raw data provided by the time laboratories, files are published in sub-directory “Data” with data acquired since January 2005 corrected by using the IGS orbits in all cases and the ionosphere corrections in the cases of single-frequency GPS receivers.

With the aim of exploring the method of all-in-view for the computation of GPS time links, and its eventual introduction in TAI instead of the common-view method [2] used at present, extensive link comparisons have been performed in the term of one year. First results have been presented by Jiang and Petit [1]. In order to assist the CCTF WG on TAI and its study groups on GPS all-in-view time transfer and link optimisation, it was decided to publish link computation and comparison results on the BIPM ftp site. Results of time links and of link comparisons are accessible in sub-directories (see Figure 3). Only results of links where both, TWSTFT and GPS techniques are available are published. Time link results involve official links for TAI and also those used as a back-up.

Link and link comparison files are arranged in monthly sub-directories, directly accessible by

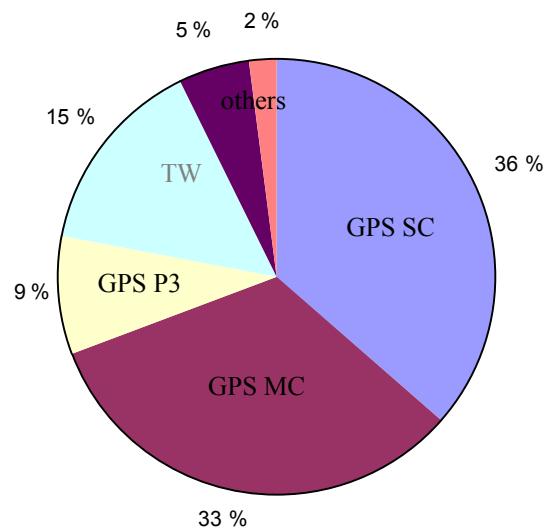
<ftp://tai.bipm.org/TimeLink/LkC>

For each month, a summary with all published links and some statistical parameters is provided. For a pair of laboratories Labj, Labk results of the links (TAI official and back-up ones) are provided in the form of plots (sub-directory “Lnk”), and results of the comparison of the link with GPS all-in-view versus GPS common-view, in the form of data files and plots are provided in sub-directory “Dlk”.

The link and link comparison results are updated after the publication of BIPM Circular T. It should be noted that these files are non-official products of the BIPM. The goal of their publication is to assist to studies on time transfer, such as the long term stability of a technique, the implementation of AV time transfer method, the redundancy of the TAI time links etc.

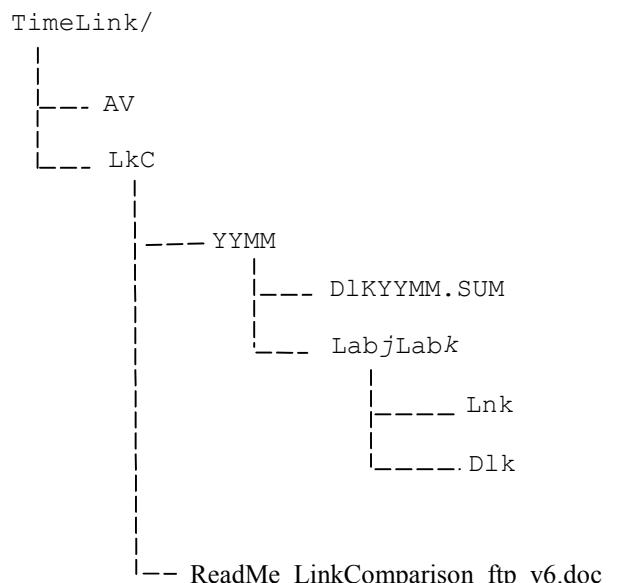
Two kind of plots are made available: link computation and link comparison. Each plot consists of 4 sub-figures. In the cases of the link computation, they respectively represent (a) the link raw data as well as the results of a smoothing; (b) the residuals of the raw data against the smoothing; (c) the Modified Allan Deviation of the raw data, and (d) the Time Deviation. Figure 4 shows an example of a TWSTFT link for April 2005; between standard MJDs 53464-53489. Raw data collected start 7 days before the first standard MJD and end 2 days after the last standard MJD. In the case of link comparison, the up figure shows the tow links; the middle one is the differences of the two links; the two down ones are the Modified Allan Deviation and Time Deviation of the differences. For details, for example, the definition of the each quantity, the legends etc. please refer to the file:

ReadMe_LinkComparison_ftp_v6.doc.



TW: Two Way Satellite Time and Frequency Transfer
 GPS SC: single-frequency single-channel C/A code GPS time transfer
 GPS MC: single-frequency multi-channel C/A code GPS time transfer
 GPS P3: dual-frequency multi-channel P3 code GPS time transfer
 Others: GPS time observation and internal links

Figure 2. Techniques of time transfer used for clock comparison in TAI



AV: documents of GPS all in view
 LkC: main directory of the link and link comparison
 YYMM: year and month, for example 0501
 DlkYYMM.Sum: summary of monthly link comparison
 LabjLabk: link between the pair of laboratories j and k
 Lnk: sub-directory with results of time links
 Dlk: sub-directory with results of link comparisons

Figure 3. Structure of the main directory and sub-directories

III. EXAMPLES OF THE TIME LINK COMPARISON

We give in this section some examples of the link computation and comparison. We do not analyse here the concerned results but only indicate how to interpret them.

Figure 5 is the comparisons of TW link with GPS P3 computed separately with the common view and all in view methods. The value sigma indicates the standard deviation of all points plotted in the middle figure. It can be seen that the sigma of the link differences for GPS P3 is 0.622 ns by CV against 0.594 ns by AV. Not shown here, but available on the ftp site, the comparison of TW with GPS MC yields sigma values of the link differences as 0.821 ns by CV against 0.740 ns by AV. This is to be interpreted as follows: the AV technique provides a better consistency with the TW link than the CV technique, in both of P3 and MC cases. Figure 6 shows the Figure 6 shows the comparison AV – CV for a multi-channel link (left) and for a GPS P3 link (right).

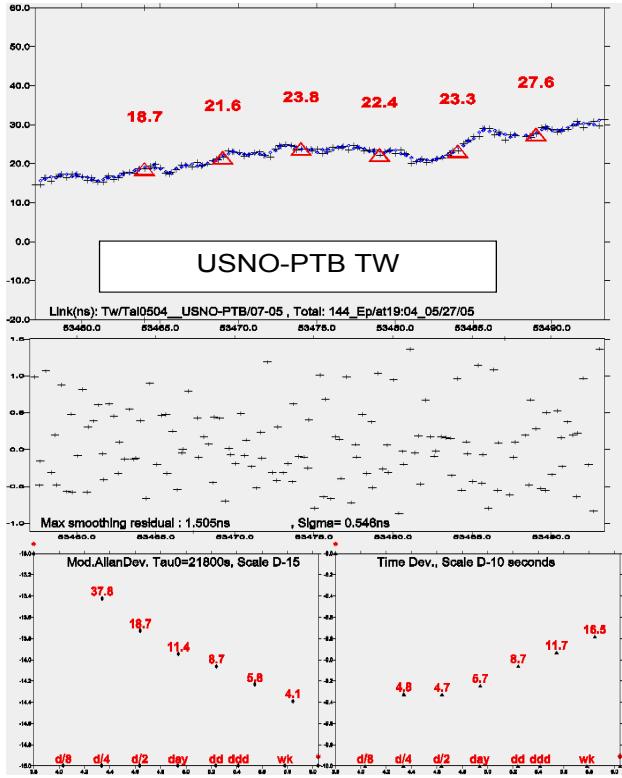


Figure 4. USNO-PTB TW link computation

Link and link comparison results have been partially published monthly since the January 2005 on the BIPM ftp site. Available after the Circular T each month, it is a non-official service of the BIPM.

REFERENCES

- [1] Jiang Z., Petit G., Time transfer with GPS satellite all in view, Proc. ATF2004.
- [2] Allan D., M. M. Weiss, "Accurate time and frequency transfer during common-view of a GPS satellite", Proc. 1980 Frequency Control Symp. pp. 334-336, 1980.

IV. CONCLUSION

The BIPM time section has developed a procedure for the time link comparisons. It serves several purposes: backing up the TAI time links, studies on the all in view time transfer, comparison and combination of different time transfer techniques.

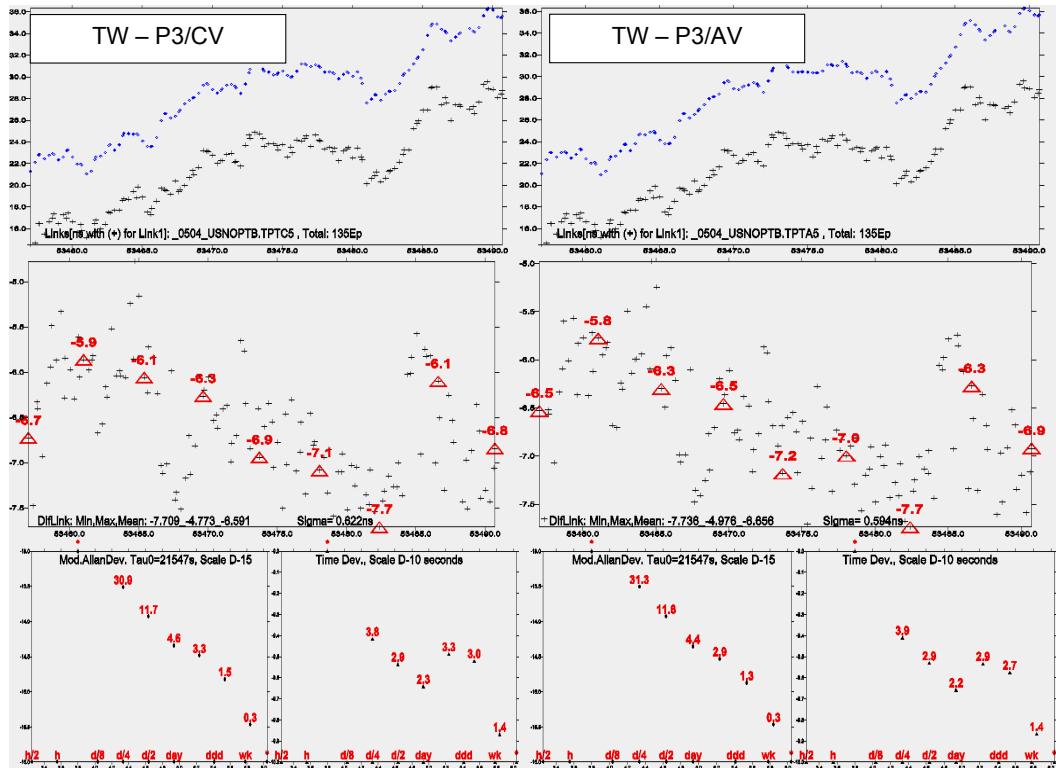


Figure 5. USNO-PTB: Link comparisons of TW and GPS P3 computed separately with AV and CV

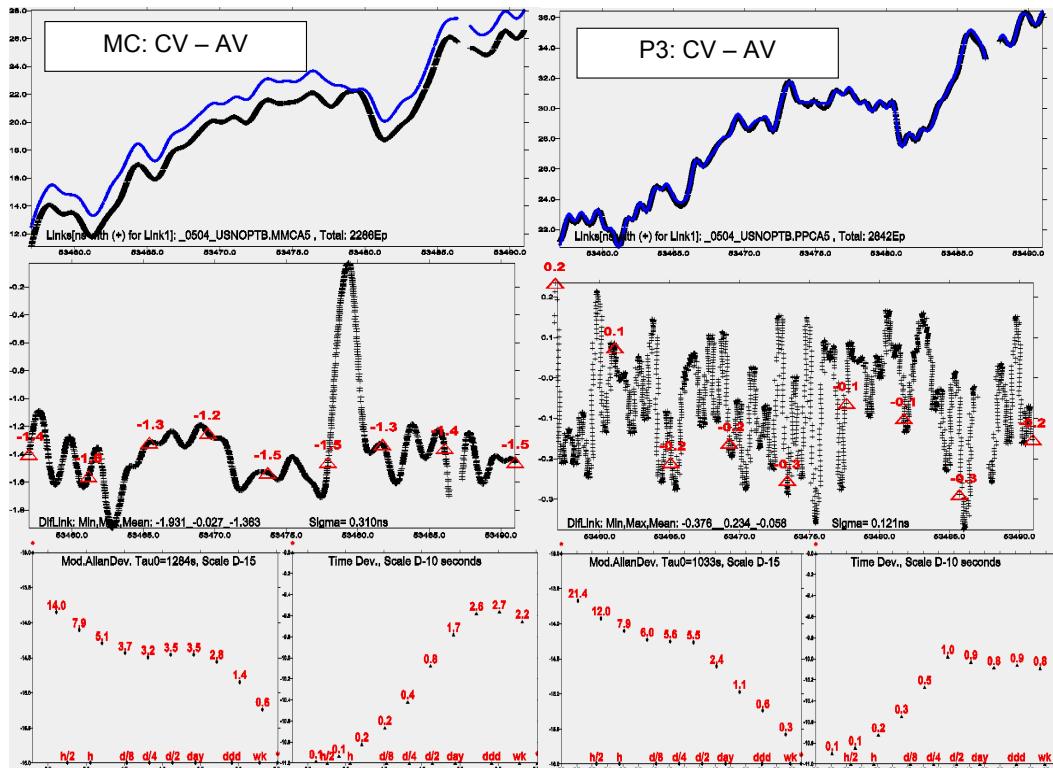


Figure 6. USNO-PTB: Link comparisons of GPS MC and P3 computed separately with AV and CV