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Comparison of primary and secondary frequency standards used for TAI

Gérard Petit*(1) and Gianna Panfilo (1)
(1) Bureau International des Poids et Mesures, 92312 Sèvres, France

The BIPM generates International Atomic Time (TAI), from which is derived UTC Universal Time Coordinated as well as another post-processed timescale TT(BIPM). These timescales get their accuracy from primary frequency standards (PFS) that aim at realizing the SI second and, since 2013, by secondary frequency standards (SFS) as approved by the Consultative Committee for Time and Frequency (CCTF). Over the last decade the number of contributions by high accuracy PFS (Cs fountains) has increased regularly from ~50 evaluations in the early 2010 to more than 100 in 2020-2021. In addition, SFS contributions to TAI which started with one Rb fountain in 2013 now include seven optical frequency standards from six different laboratories and have become significant in estimating the accuracy of TAI. In this paper we study the statistics of the results of PFS and SFS evaluations compared to their stated uncertainties, and we discuss the resulting accuracy of TAI and TT(BIPM) which directly depends on the PFS and SFS uncertainties. This work updates a previous similar study conducted one decade ago [1].

A first analysis is to study the consistency of the ensemble of PFS and SFS evaluations with TT(BIPM), a timescale which can be considered as a moving average of all available frequency standards. In the previous publication [1], it was shown that the distribution of PFS in 2012 was consistent with respect to the stated standard uncertainties of the evaluations. We here report the evolution of the results over the recent years:

A second approach is to compare pairs of PFS which are evaluated simultaneously, or nearly simultaneously, in different laboratories or in the same laboratory when two or more PFS or SFS are available. The previous publication [1] concluded that no significant inconsistency in the stated uncertainties could be evidenced and we here update this study. The set of exactly simultaneous measurements can also be used to test the relative performance of different frequency transfer techniques. We show that in some cases the frequency transfer uncertainty is significant and could be improved with new techniques.

Based on the present level of PFS and SFS evaluations by contributing laboratories and on possible developments in the coming years, we discuss the possible evolution of the accuracy of TAI and TT(BIPM) in view of a future redefinition of the SI second, as envisioned by the CCTF in its 22nd meeting [2].

1. G. Petit, G. Panfilo, "Comparison of frequency standards used for TAI," *IEEE Trans. IM*, 62(6), 1550-1555, 2013.

2. https://www.bipm.org/en/committees/cc/cctf/22-_1-2020.