Merging Maser and Cesium Clocks In Timescales

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A variety of ways exist to combine clocks with different characteristics in a timescale. At the US Naval Observatory, for example, a process called dynamic weighting is used [1], which generates a timescale from a frequency scale that weighs recent maser data relatively higher than older maser data. A Kalman Filter could assign different phase, frequency, and frequency drift process noises to the different clock types [2]. In this paper we use an ensemble of cesium and maser clocks to construct a timescale that is based upon an average of masers that are detrended against a cesium-only frequency scale, and also one which is based upon an average of masers being steered to the cesium timescale.

The cesium timescale will be modeled with the BIPM's timescale algos [3], with a Kalman filter [2], and with an ARIMA model [4]. The masers will be detrended with a Kalman filter. For comparisons, the three algorithms used for the cesium timescale will be applied to the combined maser plus cesium ensemble with no distinction made between the types of clocks.

EAL is generated as a free-running average of secondary standards. All clocks are detrended with a predictive model which assumes each clock's behavior with respect to EAL over any given month is a linear extrapolation of its behavior during the previous month. EAL is generated from a weighted average of the difference between the predictions and observations. Weights are according to their inverse variance of their mean-removed frequency with regards to EAL over the past year; however no clock is allowed to exceed a maximum weight. TAI is generated by frequency steers of EAL to primary frequency standards; historically these are all in the same direction and of approximately equal magnitude. One of the strong points of this algorithm is that it is robust in the presence of time transfer noise, and through its ultimate steering to the primary standards it meets the key requirement of realizing the SI second. However, the algorithm would require adjustment because it is noted that the linear predictor is not optimal for masers, and has been shown that a parabolic predictor is better for them [5].

In combining clocks from remote laboratories, a key issue is the time transfer noise. Most of the clocks contributing to TAI do so via a Two Way Satellite Time Transfer (TWSTT) link, however an increasing number are also being used with a technique that is far more precise on subdaily scales - Precise Point Positioning (PPP)[6]. This currently uses GPS Carrier Phase to achieve precisions of 20 ps at 5-minutes and 100 ps at a day; with the advent of improved receivers, other GNSS systems, new signals, and new frequencies it will improve and be more robust.

A final consideration would be the complexity and robustness of the algorithm. This can be and will be studied in simulations, although the authors fully recognize that operations in the field often reveal failures modes not anticipated in the simulations.

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