SIM Time Scale: 10 years of operation

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***Abstract* — The *Inter-American Metrology System* (SIM) is one of the world´s five major Regional Metrology Organizations (RMO´s). Starting in 2005, the SIM Time and Frequency Metrology Working Group (SIM TFWG) developed a time and frequency comparison network for the Americas (SIMTN). Currently 23 NMIs from SIM region participate on the SIMTN. Since 2008 the SIM TFWG is producing a time scale called SIM Time Scale (SIMT). SIMT is an averaged time scale computed in near real-time (every hour) from time difference data that the SIMTN produces and publishes every 10 minutes. In this paper, a SIMT evaluation based on data from August 2016 to January 2018 is presented.**

***Index Terms* — Time Scales, international comparison, atomic clocks.**

I. Introduction

The measurement of time is of the utmost importance for many applications, including: global satellite navigation systems, communication networks, electric power transportation, astronomy, electronic transaction, and national defense and security. Both, the SIM Time Network (SIMTN) and the SIM Time Scale (SIMT) have led to better coordination and cooperation in the Americas in time and frequency metrology. The SIMT is believed to be the first multinational time scale whose results are computed and published in real time via the Internet, and 2018 will mark its 10-year anniversary. Within the SIM region, SIMT complements Coordinated Universal Time (UTC) by providing real-time support to operational timing and calibration systems. SIMT is sufficiently stable to measure the stability of most SIM local time scales and provides a good approximation of the UTC timing accuracy (±10 ns). We show in this paper how the reliability, accuracy, and stability of SIMT has improved during its 10 years of operation.

II. The SIMTN

The SIMTN became operational in 2005, and 23 nations have joined the network as of December 2017. The SIMTN continuously compare the time scales of all SIM local time scales with each other and produces measurement results in near real time [1]. The comparisons are performed via the global positioning system (GPS) common-view and all-in-view techniques with multichannel single-frequency (L1 band) receivers. SIMTN servers are located at National Research Council (NRC) in Canada, National Institute of Standards and Technology (NIST) in the USA and the Centro Nacional de Metrología (CENAM) in Mexico. The three SIMTN servers host identical software that processes and publishes measurement data whenever requested by a user (https://tf.nist.gov/sim).

III. The SIMT

The large number of local time scales at SIM region made it attractive to generate a composite time scale that could be distributed and shared. Work on SIMT began in early 2008 at CENAM and it has been refined through the years. SIMT is continuously operated and it is made publicly available in real time via the Internet. It includes local NMI time scales, SIM(k), as single clocks in the SIMT ensemble and it is not dependent on the time scale maintained by any individual national metrology institute (NMI). SIMT has been designed to be an instantly accessible reference standard that can be used to monitor the performance of the local SIM(k) scales and operational timing system in the short, medium and long terms.

The SIMT algorithm is published in [2]. It is designed to use exponential filtering to predict the time and frequency differences of SIMT(k) with respect to the averaged time scale. Clocks are weighted in terms of the inverse of their Allan deviation. The weighting criteria were modified in 2012 [3] to include an accuracy factor given by the inverse of the $|\langle \Delta f \rangle|$, where $|*|$ and $\langle * \rangle$ means absolute value and average value of $*$, respectfully. The Δf term is the frequency difference during the previous 240 hours between SIMT(k) and SIMT. Because SIMT is not steered to agree with UTC or any of the individual UTC(k) time scales, it can be considered to be a free running time scale.

IV. SIMT Performance

To evaluate the performance of the SIMT scale, we use the national time scale of Mexico, UTC(CNM), as a "common clock" to compute the time differences UTC – UTC(CNM), UTCr – UTC(CNM) and SIMT – UTC(CNM). The UTCr time scale is "rapid" UTC, a version of UTC that is published weekly with daily values [4], as opposed to UTC which is published monthly with values given at 5-d intervals. Figure 1 shows the time differences of UTC(CNM) with respect to UTC, UTCr and SIMT scales from October 2015 to January 2018, showing that SIMT is in good agreement with both UTC and UTCr for medium and long-term intervals. However, in the short term it can be noticed that SIMT is less stable than UTC or UTCr. This is due to two main reasons. First, the number of clocks used to produce SIMT is significant smaller than the number of clocks used to compute UTC or UTCr scales. Second, the short-term noise in data produced with the SIMTN is larger than the noise in data used to calculate the UTC or UTCr. That is primarily because the SIM time transfer systems are single frequency (L1 band) Global Positioning System (GPS) receivers, as opposed to the multi-frequency GPS receivers and two-way satellite time transfer systems used by many NMIs to contribute to UTC and UTCr.

Figure 2 shows the time differences of UTC – SIMT, UTCr – SIMT and UTC – UTCr. Those time differences were obtained by utilizing UTC(CNM) as a “common clock”. The outlier on the UTCr – SIMT graph near Modified Julian Date (MJD) 57750 is due to an erroneous UTCr published value.

Figure 3 shows the frequency instabilities of the UTC – UTC(CNM), SIMT – UTC(CNM), UTCr – UTC(CNM), UTC – SIMT, UTCr – SIMT and UTC – UTCr time differences. In the short and medium-term the three most stable comparisons are UTC – UTCr, UTC – SIMT and UTCr – UTC, in that order. On the other hand, the stabilities of the time differences of UTC(CNM) with respect to UTC, UTCr and SIMT are almost equivalent. This implies that SIMT, for the purposes of evaluating the frequency stability of UTC(CNM), is an equivalent reference to UTC and UTCr, and is more readily accessible.

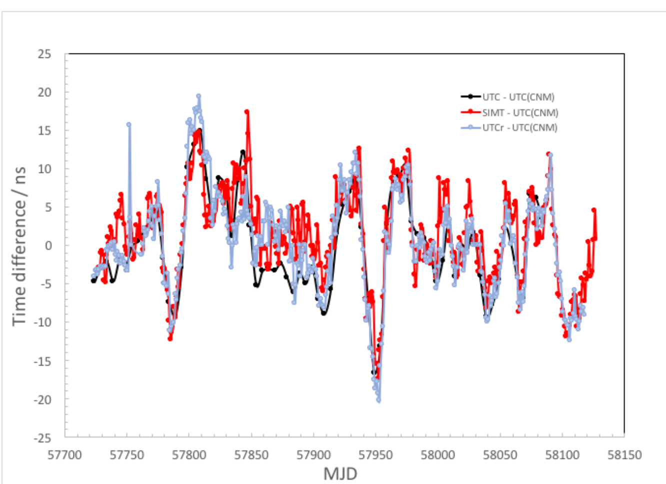

Figure 1. Time differences of the CENAM´s time scale UTC(CNM) with respect to the UTC, UTCr and SIMT scales from August 2016 to January 2018.

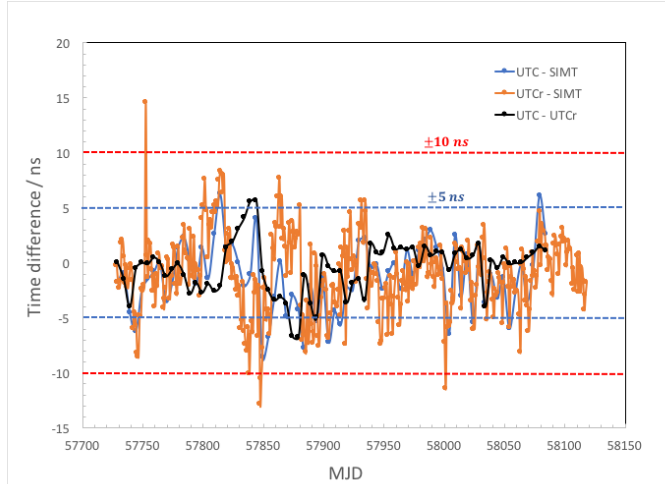

Figure 2. Time differences of UTC – SIMT, UTCr – SIMT and UTC – UTCr with UTC(CNM) as a “common clock”.

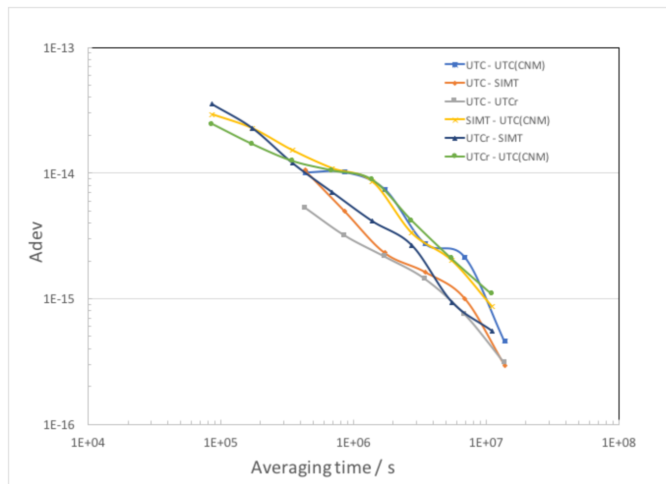

Figure 3. Frequency stabilities for the time differences UTC – UTC(CNM), SIMT – UTC(CNM), UTCr – UTC(CNM), UTC – SIMT, UTCr – SIMT and UTC – UTCr.

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