IEN "G. Ferraris" Revised: October 2004

Report on TWSTFT activities at IEN

Operations of IEN01 TWSTFT station

During the period October 2003 – October 2004, the IEN TWSTFT station IEN01 was operated almost continuously both on the European and the Transatlantic link. The station is composed by a SSE Transceiver, a MITREX modem, a Time Interval Counter (TIC) and an automation PC. The MITREX modem is driven by a 10 MHz sinewave signal coming from a H maser (internal name HM2(IEN)) and the 1PPSTX-UTC(IEN) measurements are taken before each European and Transatlantic sessions. (see [1] for details)

The automation software can be simply reconfigured to manage different measurements schedules. The data analysis software includes a quadratic fitting routine for the 1s data, with a filter for the outliers. After a first fit run, data whose residuals are 3σ out of the average are removed from the dataset and then the fit is recalculated. The actual data number contributing to the final fit value is reported in the ITU file (SMP field). When this number is less than 60, the corresponding fit value is removed from the ITU file. (This feature has been introduced since MJD 53262)

The TWSTFT measurement results (1s and processed ITU file) are made available on the IEN FTP server immediately after each measurement session. The files content is periodically surveyed and any change made on the files after their publication is logged.

Intensive schedule

Since July 2003, IEN TWSTFT station has followed the daily schedule for both European and Transatlantic link. Since MJD 53065 (January 2004), the IEN station has joined the intensive schedule (4 measurements per day, at 0, 8, 14 and 16 UTC) as suggested at TWSTFT PS meeting in 2003 [3].

The increased number of measurements allowed a better characterization of the stability of the TWSTFT links; in fact, if the modem is driven by a high stability H maser, for integration times shorter than 1 day the TWSTFT link noise is usually larger with respect to the clock noise and an estimation of the TWSTFT link short term stability is simply achieved with a statistical analysis on the TWSTFT time differences.

In the following analysis the time differences between the H maser driving the IEN MITREX modem and a remote clock are calculated using the TWSTFT formula specified in [2] (the UTC(IEN) time scale, generated by the output of an Agilent 5071A cesium clock is not stable enough for such an analysis). Disregarding the REFDELAY(IEN) value in the TWSTFT formula, the TWSTFT time differences are directly referred to the HM2(IEN). Figure 1 reports time difference data for 4 links; the plots show some residual diurnal oscillations (up to 2 ns peak to peak), which appear intermittently on different links. The source of these oscillations is not well recognised, but they are likely due to the effect of environmental conditions.

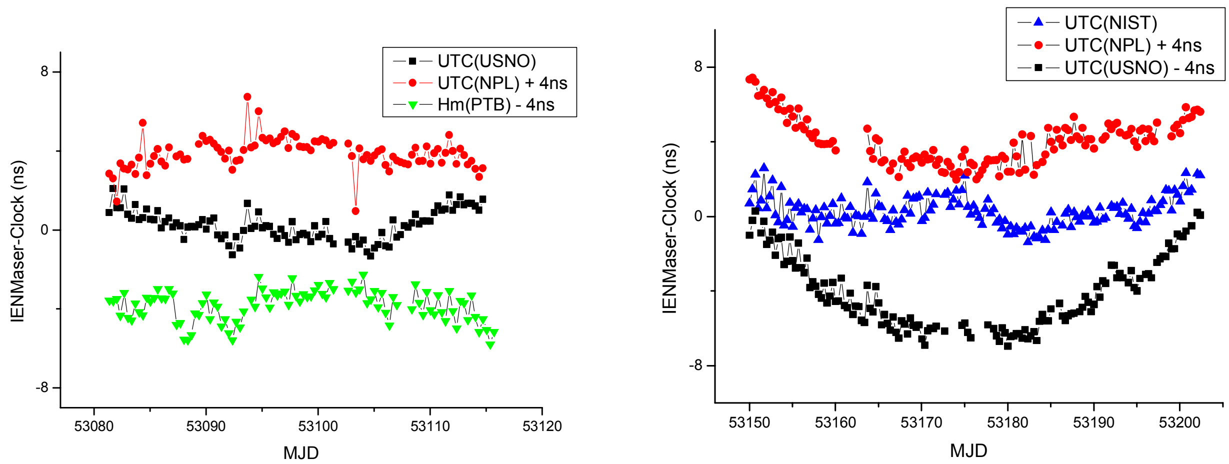

Figure 1. TWSTFT time differences (after a time slope removal) for two different periods (Spring –Summer 2004)

The stability analysis was carried out using the TWSTFT time differences between HM2(IEN) and, respectively, UTC(NIST), UTC(USNO), UTC(NPL) and the H maser which drives the TWSTFT modem at PTB (the PTB H maser data are accessed disregarding the REFDELAY(PTB) value). To simplify the Allan deviation calculation only the TWSTFT equally spaced measurements (at 0, 8 and 16 UTC) were used. Figure 2 shows the ADEV plots (calculated using data of the period MJD 531250-53202); the ADEV slope (τ^{-1}) suggests that the main contribution, up to 5 days, is due to the link noise.

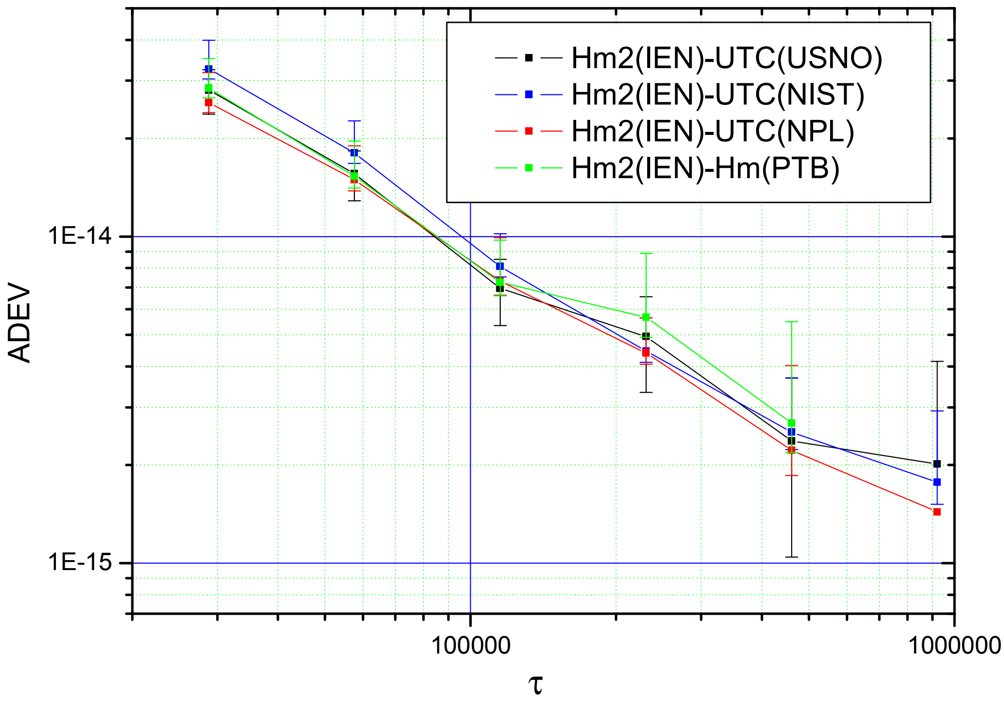

Figure 2. Stability plot of the TWSTFT time differences between HM2(IEN) and some remote clocks.
(Data interval MJD 53150-53202)

The calculated ADEV value is about $\sigma_y(\tau) = 8\cdot10^{-10}\ \tau^{-1}$ ($\sigma_y(\tau) = 1\cdot10^{-14}$ at 1 day) for USNO, NPL and PTB data; the NIST data shows a bit more noise ($\sigma_y(\tau) = 1\cdot10^{-9}\ \tau^{-1}$).

Figure 3 allows a deeper look into the TWSTFT IEN-PTB link stability; it reports the MDEV and TDEV plots, calculated taking $\tau_0 = 28800$ s. The MDEV and TDEV behaviour shows the typical signature of the white phase noise up to $1\cdot10^5$ s and of the flicker phase noise from $1\cdot10^5$ s $5\cdot10^5$ s with an estimated TDEV flicker floor of 200-300 ps.

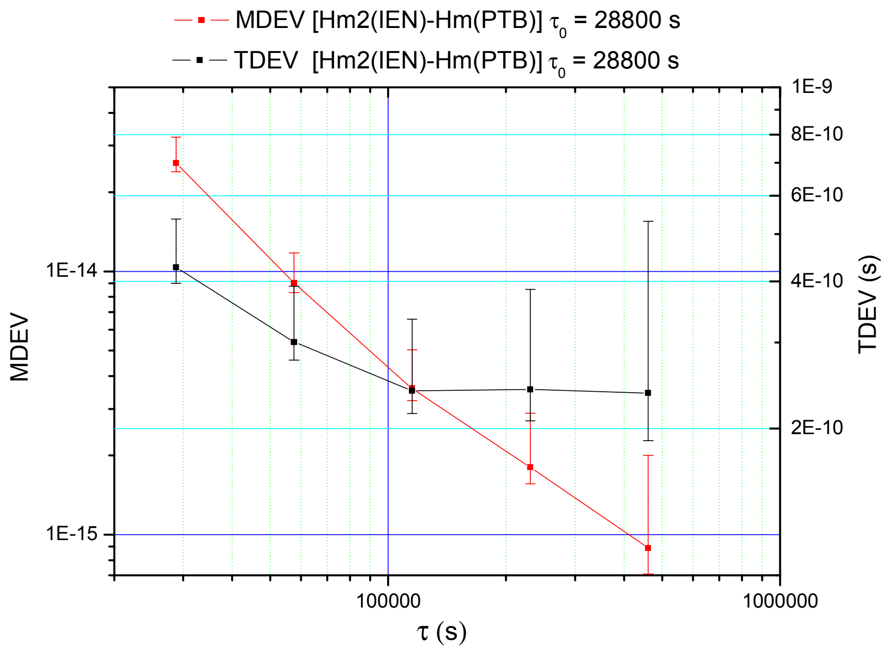

Figure 3. MDEV and TDEV plots (calculated taking τ_0 = 28800 s) of the TWSTFT time differences HM2(IEN)-HM(PTB) (Data Interval MJD 53030-53080).

Calibration of TWSTFT links involving IEN

During 2003, the IEN-PTB link was calibrated with a travelling TWSTFT station. Details on the calibration campaign, which was performed in the framework of the ESA GSTB V1 program, are reported in [1].

At the calibration epoch, the European link was operated with the IS706 satellite. In September 2003, Intelsat moved the TWSTFT service to the IS903 satellite, which uses different TX and RX frequencies. At PTB the different RX frequency required the change of the RX hardware; the delay change due to the hardware replacement, together with the possible delay change due to the operation of IEN01 at different TX and RX frequencies, was evaluated using different techniques (details are reported in [1]). The Sagnac delay was also recalculated, taking into account the different position of IS903.

The CALR(IEN) value coming from the IEN-PTB link calibration and the ESDVAR(IEN) and the ESDVAR(PTB) values due to the satellite change were published in the ITU file since MJD53065; the overall uncertainty of the IEN-PTB link calibration, coming from the calibration activity with the travelling station and from the ESDVARs calculation, was evaluated as 1 ns (1σ). The final CALR(IEN) value published in the ITU file includes the new Sagnac delay for IS903 and then the S = 1 formula [2] has to be used for the time scale difference calculation.

As the TWSTFT IEN-PTB link is used for TAI calculation, it is now reported in the circular T with the smallest uncertainty with respect to the all links contributing to TAI [5].

In January 2004, IEN and NIST calculated a calibration constant for the IEN-NIST TWSTFT link using the BIPM Circular T data. The calibration constant was calculated using a 90 days period (since MJD 52944 to MJD 53034), as the average difference between the Circular T and TWSTFT data taken at the BIPM standard dates. The calibration constant (CALR(IEN) = -553.5 ns) was published in the ITU file since MJD 53073, with the uncertainty commonly assigned to such calibrations (5 ns (1σ)).

At the end of July 2004, a strong interfering signal appeared on the IS903 satellite transatlantic transponder, preventing the reception by the USA stations of the TWSTFT signals transmitted from Europe. To overcome the problem, Intelsat assigned slightly different (few MHz apart from the old ones) TX and RX frequencies for the TWSTFT transatlantic link.

The interference problem and the subsequent frequency change occurred during the vacation period; this prevented the IEN station to participate in the transatlantic link since MJD 53214 to MJD 53235. Afterwards, the IEN station had been reconfigured to operate on the new frequencies and the TX power was increased by 2 dB, to reach the same power level of the other European stations received in the USA.

Comparisons with GPS Common view and circular T data (Figure 4) show a time jump (about 16 ns) occurred when the IEN station restarted its measurements on the new EU-USA frequencies. The source of this jump has been not yet recognised, but jumps of similar magnitude occurred also for other EU-USA links [6], indicate a possible change of the satellite transponder delay.

At the moment the IEN ITU files are not corrected for this jump (proposals for a correction strategy should come from the 2004 TWSTFT Participating Station meeting).

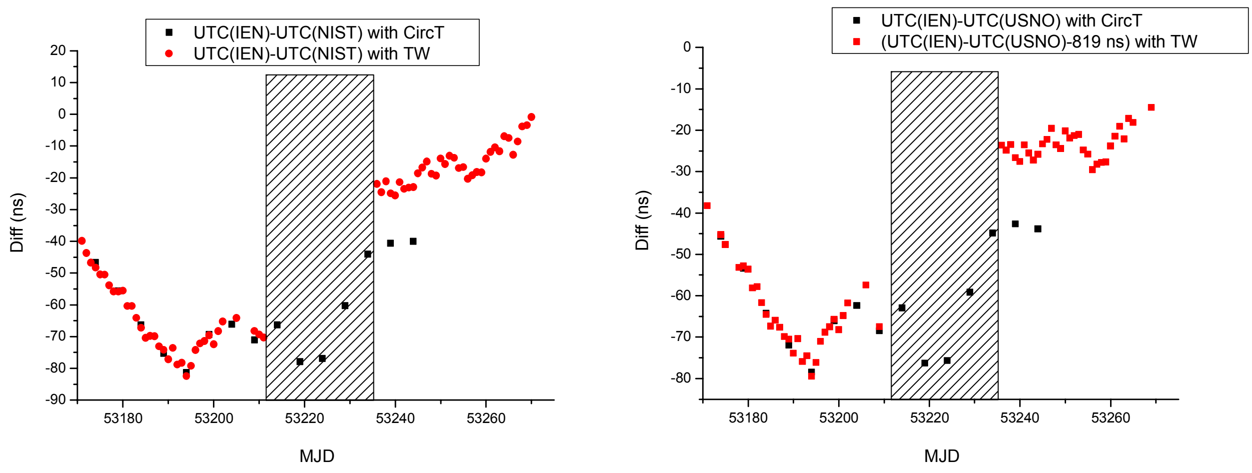

Figure 4. Comparison of the UTC(IEN)-UTC(NIST) and UTC(IEN)-UTC(USNO) time differences using TWSTFT and Circular T

A preliminary analysis of the stability of the Europe-USA link, carried out with the same technique described in the previous paragraphs (Figure 5), shows that after the interference event and the frequency change, the IEN-USNO link became slightly noisier.

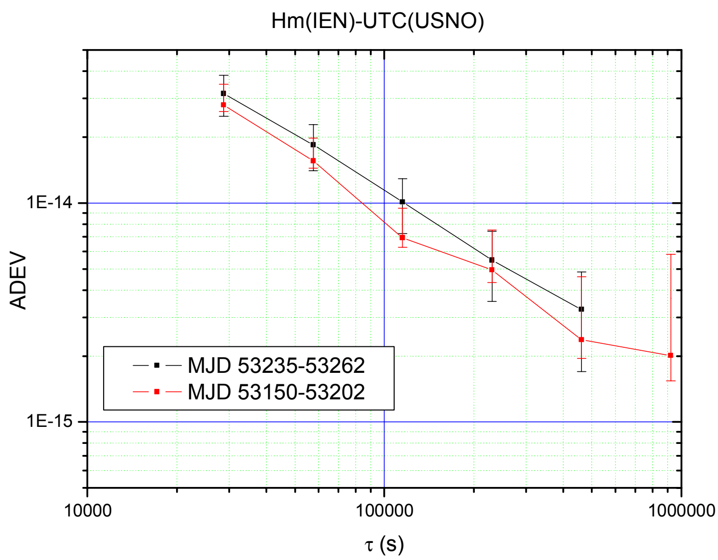

Figure 5. Stability calculated using HM2(IEN)-UTC(USNO) data before and after the interference problem occurred on the IS903 transatlantic transponder

Primary frequency standard comparison

The H maser driving the IEN modem (HM2(IEN)) is the same maser that is commonly used to operate the caesium fountain primary frequency standard (IEN-CsF1) [4]. This configuration allow, disregarding the term REFDELAY(IEN) in the TWSTFT formula [2], to relate directly the frequency of the maser driving IEN-CsF1 with a remote clock without using UTC(IEN) as a transfer clock. In 2003 some experimental comparisons involving IEN-CSF1 were preformed [3] and a new one, involving several laboratories in Europe and USA, is foreseen in November 2004.

Installation and testing of a new TWSTFT station at IEN

The installation and testing of a new complete TWSTFT measurement system at IEN (proposed name IEN02) is going to be concluded. The installation process had a very long stop because the IEN02 intended transceiver (a SSE K-star model) failed just after the installation. After a unsuccessful repair attempt, the transceiver was definitively discarded and a new transceiver was purchased.

In the present configuration, the IEN02 system is composed by a Anacom Transceiver, a SATRE modem and an automation PC. The transceiver is a Anasat 4W SeKu model, equipped with the external frequency reference option; it covers the whole frequency range used by Telecom Ku-band satellites without any hardware change.

The SATRE modem is the s/n 079, with the dual receiver option; the current software version is the 4.11.0, installed with the support of TimeTech last June. The modem is driven by the 10 MHz sinewave and the 1PPS signals coming from the H maser HM2(IEN), the SATRE 1PPSTX signal is sent to an external counter which provides the 1PPSTX-UTC(IEN) measurement.

The automation software, is capable to manage automatically all the station operations, making available the 1s and the processed ITU files on a FTP site. It also contains a routine that automatically corrects for the time tag bug affecting the SATRE internal counter.

The approval for operation was requested to Intelsat, which has just registered the station with the name IEN02. Waiting for the approval, the station is currently operated in the receive only mode, allowing a test of all the equipment set-up, including the automation software.

The new station was mainly intended to provide a backup to the IEN01 station, which is composed by very old devices. However IEN location offers a clear visibility on the PAS-4 satellite (8° above the horizon), which is involved in a TWSTFT experiment between VSL and TL. During a test performed in January 2004 (before the fatal failure of the SSE transceiver) the signal from TL was successfully received with a satisfactory C/No.

When IEN02 will be fully operational, IEN will have the possibility to operate at the same time the Europe-Europe, Europe-USA and Europe-Pacific links.

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References

[1] F. Cordara, L. Lorini, V. Pettiti, P. Tavella, D. Piester, J. Becker, T. Polewka, G. De Jong, O. Koudelka, H. Ressler, B. Blanzano, C. Karel, "Calibration of the IEN-PTB TWSTFT link with a portable reference station", Proceedings of the EFTF04, Guildford (UK), 5-7 April 2004 (in press)

[2] Recommendation ITU-R TF.1153

[3] W. Lewandowski. Report of the 11th meeting of the CCTF working group on TWSTFT, Teddington, UK, 9 and 10 October 2003

[4] F. Levi, L. Lorini, D. Calonico and A. Godone, " IEN-CsF1 accuracy evaluation and two way frequency comparison". To appear on IEEE transactions on UFFC.

[5] See for example. Circular T n. 200

[6] T. Parker, A. Bauch, W. Lewandowski. Personal communications