Time Transfer by Laser Link T2L2

Experimental campaigns - Data center

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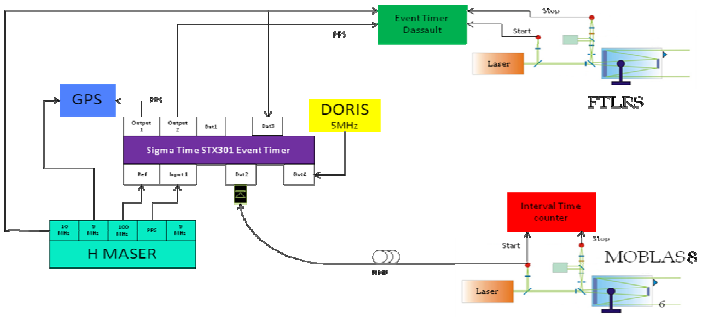
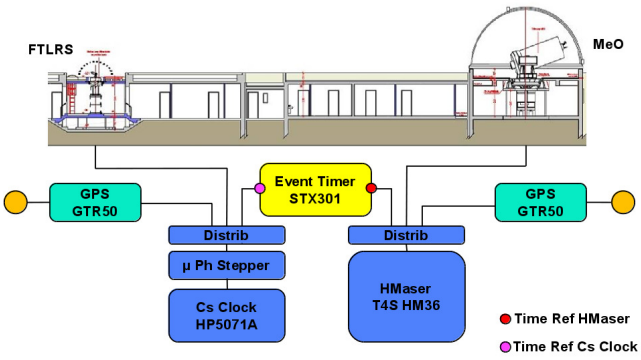
T2L2 (Time Transfer by Laser Link), developed by both CNES and OCA permits the synchronization of remote ultra stable clocks over intercontinental distances. The principle is derived from laser telemetry technology with dedicated space equipment deigned to record arrival times of laser pulses at the satellite.

From the launch in 2008, several campaigns were done to demonstrate both the ultimate time accuracy and time stability capabilities. One of them is a ground to ground time transfer campaign done at Tahiti. The experimental setup includes the Moblas 8 and FTLRS Laser Stations, a Hydrogen Maser, a GPS time transfer unit, a DORIS system and the T2L2 Calibration station (event timer, time distribution). The H-Maser, the FTLRS station and the calibration station was installed at UPF especially for that experiment while the Moblas 8 station and the DORIS equipment are installed on the UPF site definitively. The Hydrogen Maser is used as the nominal low noise time reference for the FTLRS station and for the T2L2 calibration equipment. The central equipment of the time and frequency reference of the whole setting-up is the T2L2 calibration station made from a SigmaTime Event Timer.



More than 400 passes was acquired during the campaign. From the start time of the Moblas 8 station measured by the T2L2 event timer, one has obtained a ground to space time transfer with a repeatability error of only 150 ps. As compared to the time transfer that would have been obtained by the moblas8 station without external event timer, this result is an improvement greater than 2 orders of magnitude. The ground to ground time transfer between Moblas8 and FTLRS has a repeatability error between passes acquired simultaneously better than 65 ps rms.

One has also done a collocation campaign at OCA between the FTLRS and the MeO stations, both connected to 2 independent time references (atomic clocks and GPS time receivers).

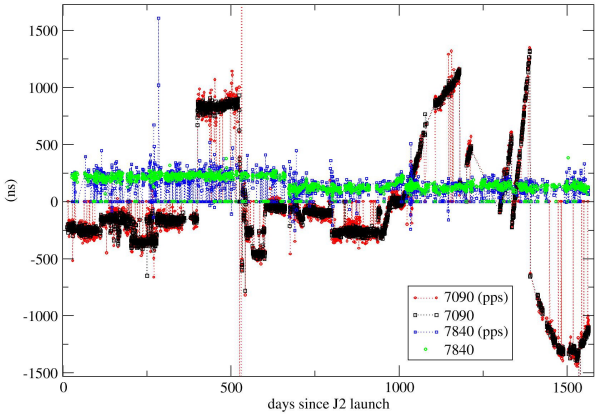


The whole experiment has been calibrated with the T2L2 calibration station and also a dedicated calibration process led by Observatoire de Paris. The experiment permits to directly compare results obtained from T2L2, GPS and also the comparisons measured with the T2L2 calibration station. One has respectively measured a difference between T2L2 and GPS against the calibration station of 166 ps and 865 ps. These results give a good agreement as compared to the global uncertainty of the whole setup which is evaluated to 200 ps for T2L2 and 2 ns for GPS.

OCA and CNES have developed an analysis center (called CMS hereafter, as "Centre de Mission Scientifique") dedicated to the data processing for the Time Transfer by Laser Link (T2L2) space experiment. The role of this center is to ensure the continuous processing of data (based on a daily flow) and to offer some services to the community. As a time transfer technique based on laser telemetry, T2L2/Jason2 allows for links between ground time systems and the satellite clock. But the ultimate goal is to transfer time, via Jason2, between Satellite Laser Ranging (SLR) systems around the world (see the network of the International Laser Ranging Service (ILRS) available on the web).

About 22 laser stations provide full rate (FR) data to the CMS via the CDDIS and EDC data centers (ILRS), while CNES sends satellite data (orbit, attitude, and T2L2 raw data) every day. For each laser station, the CMS provides a history of data in terms of quantity and quality (see the web site: https://t2l2.oca.eu/).

Since 2008, the primary product of the CMS has been the calculation of the time synchronization between the satellite clock system and the laser ranging data at each pass. As a result, the average synchronization per pass is available at each SLR station, from the beginning of the mission (see figure against, for both Yarragadee and Herstmonceux SLR systems). An approximate time scale was calculated, which is near the GPS one to a precision level of 100 ns.



For each station pass, the CMS provides the stability of the ground-to-space time transfer using the Allan variance estimator. Best link calculations indicate stability of a few pico seconds for integration times of some tens of seconds. The worst stability, of a few nano seconds, are obtained with stations using a resolution of dates of 100 ns. This result however is very encouraging, because it will permit to use the full SLR network for time transfer at least at this level.

Time transfer between SLR stations in the common view mode has been developped also. The resulting data base has a resolution of 1 second and is using the onboard time scale (referenced to the DORIS oscillator); it is available since 2008 for 8 SLR stations when others are under processing currently. In order to establish a precise estimation of the repeatability of the time transfer between SLR systems, apart from the problem of accuracy, several campaigns have been conducted on the Grasse site. Our two SLR systems, MeO and the French Transportable Laser Ranging Station (FTLRS), have been involved; to avoid noises both SLR systems shared the same ground clock system. Over one pass, the CMS provide time transfers with a precision of 5-30 ps rms, whereas repeatability, from one pass to another, is established to 50-80 ps.

Finally, the CMS is gradually established a database (ground to space time transfers computed every second, available using an onboard time scale) to allow the estimation of links between ground SLR stations that are requested by users. In addition, the "triplets" data (ground date, onboard date and time travel) were saved as files using the international CRD format. The time transfer in the non common view mode will be developed to take advantage of the complete laser network.