Performances of T2L2 on J2

Topic : Precise Orbit Determination and geoid applications

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ABSTRACT

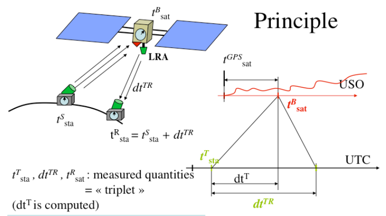
The T2L2 (Time Transfer by Laser Link) project, developed by CNES and OCA will permit the synchronization of remote ultra stable clocks and the determination of their performances over continental distances (the satellite must be in common view). The principle is derived from laser telemetry technology with a dedicated space equipment deigned to record arrival time of laser pulses at the satellite. T2L2 acquired the first laser pulses a few days after the launch of Jason2 (July, 2008).

Fisrt analysis permitted to validate some important characteristics of the instrument such as sensitivity, noise, dynamic, event timer precision and ground to space time stability. See: *Exertier et al., Adv. Space Res. « DORIS Special Issue », 2010.*

Between 2009 and 2010, we realized a dedicated experiment in order to measure the precision and exactness of a time transfer between to SLR (Satellite Laser Ranging) systems; we used the French Transportable Laser Ranging System on the one hand, and the MeO-7845 Grasse Station on the over hand. Both systems, located at Grasse-Observatory, used the same ground clock.

The stability of the ground to ground time transfer via the space equipement has been established to 70 ps over several J2 passes (from April, 27 to May, 15). The excactness has been estimated by comparing the computed offset (mean value of 157 ns) and the in situ measurement (by optical fiber) of the « distance » between both SLT systems; the difference is of 45 ps.

Principle



$$X_A = \frac{t_S + t_R}{2} - t_B + \tau_{\text{Relativity}} + \tau_{\text{Atmosphere}} + \tau_{Instrument}$$

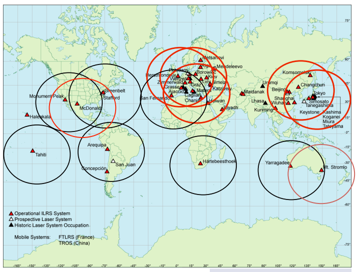
The mass of the T2L2 space equipment is 8 kg for the electronic module which is inside the satellite and 1.5 kg for the photo detection module located outside. Jason-2 is a French-American follow-on mission to Jason-1 and Topex/Poseidon. Conducted by NASA and CNES, its goal is to study the internal structure and dynamics of ocean currents. The satellite was placed on a 1,336 Km orbit with 66° inclination by a Delta launcher. The time interval between two ground passes varies from 2 to 14 hours.

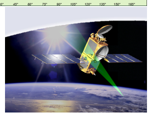
The space instrument is based on a photo detector and an event timer linked to the space clock. A Laser Ranging Array (LRA) is also used to reflect the laser pulse toward the laser station. This LRA is provided by the CNES & JPL agencies, basically as orbit determination system in addition to the GPS and DORIS orbitography space techniques [4]. The space clock is an ultra-stable oscillator (USO, Quartz) coming from the DORIS (Doppler Orbitography and Radio-positioning Integrated on Satellite) equipment.

T2L2 is a two way time transfer technique based on the timing of optical pulses emitted by an SLR (Satellite Laser Ranging) station and detected by a dedicated space instrument [1], [2]. T2L2 was accepted as a passenger instrument on the Altimetry Jason-2 satellite in 2005 [3].

Basically, T2L2 realizes a ground to space time transfer between the ground clock linked to the laser station and the space clock of the satellite. The ground to ground time transfer between several remote clocks at ground is obtained through these individual space to ground time transfers. It can be obtained in a common view mode, when the distance between the laser stations is smaller than roughly 5000 Km, or in a non-common view mode when the distance is larger.

The ground segment of the experiment is a laser station able to time both start and return times with a resolution of 1 ps. The laser stations track the satellite as soon as it is in the right field of view (at a distance of less than 5000 Km) during the whole duration of the pass (maximum duration of about 1000 s).





47 SLR stations around the network
34 fired on Jason2
22 are regularly sending full rate data for T2L2

On-board data

Since the begining of the mission, T2L2 is aquiring roughly 150,000 to 250,000 dates of pulse per day, consisting in solar noise events, laser pulses, and GPS PPS. CNES is providing us 1-day files of on-board dates with a time delay of 1-2 days. A first data treatment has to be processed before all. The goal is to compute for each acquired event its aproximated GPS date. That permits to permanently establish a phase link between the GPS and DORIS time scales on the one hand, and to estimate the value of the frequency *f* on the other hand. After processing, the precision of the phase link and of the frequency has been estimated at 0.3 *µsec* and 1.10^{-11} (*Δf/f* over 5000 sec), respectively.

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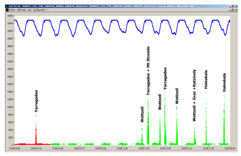
Ground SLR full rate data

Since 1998, the International Laser Ranging Service (ILRS) is assuming a multi-satellite tracking for geosciences and Solar system purposes from a network of around 35 ground SLR stations.

For the T2L2 mission, SLR stations are providing us the full rate ranging data (via the European Data Center based in Muenchen, Germany and the CDDIS, US); some of the SLR stations have deployed a H-Maser clock as time device, notably Changchun (China), Hersmonceux (UK), Matera (I), Koganei (J), Wettzell (G), FTLRS (Paris and Grasse), and Grasse-7845 (F).

The precision of the start dates is of 5-15 ps, whereas the precision of the time travels of the light (the ranges) is of 25-35 ps for the best SLR systems [4]. In addition, the time stability over a satellite pass (arround 1000 seconds) should be at the picosecond level and at 15-20 ps, respectively for H-Maser and Cesium. According to the T2L2 principle, the measured time travel is very important, in providing the estimate of the arrival date of the laser beam (at the satellite) from the start date noted at ground. Obviously, its proper error budget must be included in the equation of time transfer, in addition to the precision of the ground and space clocks, and to the overall data corrections.

SLR stations which are poviding us full rate ranging data on Jason2 are able to observ betweeen 10 and 80 passes per month. In average, each pass is of 600-700 second duration and provides arround 1000-2000 ranges; much of SLR systems are using a 10Hz acquisition mode, but some have a 100Hz or a KiloHz mode).

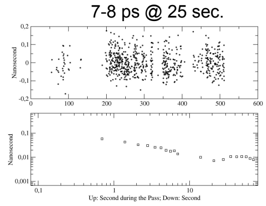


one day onboard measurement

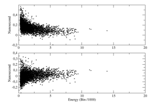
« Triplets »

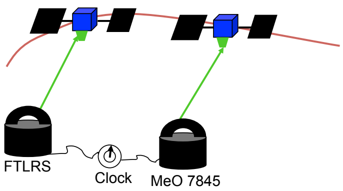
For a given laser pulse emitted by the laser station one get two dates (start & return) at ground and one date at the satellite, thus forming a set of 3 dates called a "triplet". From a triplet, we can extract the time delay between the ground clock and the space clock, whereas a serie of triplets permit to estimate the stability of the ground to space time transfer.

Stability of a ground to space time transfer (H-Maser clock on ground) : 7-8 ps @ 25 sec.

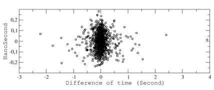


time walk of the (T2L2) diode



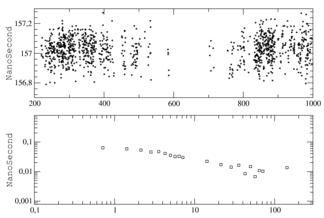


Time Transfer via T2L2, in common view : dt < 5 sec.



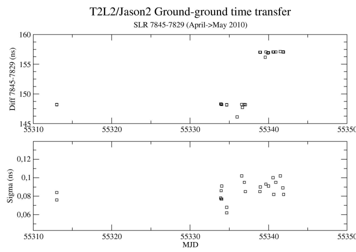
OVER 1 PASS : the stability of the ground to ground time transfer (with 2 SLR systems : MeO-7845 and FTLRS) is of :

15-20 ps @ 45 sec.

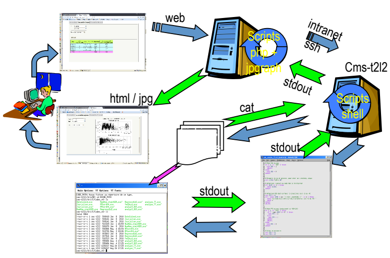


OVER 1 MONTH : the RMS of the available ground to ground time transfers is of :

75 ps



T2L2 on the web : https://t2l2.oca.eu/



CONCLUSION

A first ground to ground time transfer experiment has been realized with success between two SLR stations via the T2L2 space equipment which has been installed on board Jason2 at 1335 Km altitude.

As a time transfer on a common view, the space clock (the Quartz DORIS USO), the stability of which is of 1ps over 10 seconds, has been used to measure the difference of dates between successive laser events. In the same time, the same ground clock has been used for both SLR stations (H-Maser) to date each emitted laser pulses. Over one month (12 common passes), we get an overall rms of 70 ps.

This first experience of time transfer allowed to estimate a mean ground time offset between both SLR systems, at that level of accuracy : without drift (because the ground clock is the same), the mean value is of 157 ns.

In addition, we measured the in situ distance between the SLR's by using optical fibers : the difference between the T2L2 value and the in situ one is of 45 ps, that gives the order of exactness.

REFERENCES

1.Samain, E. et al., *International Journal of Modern Physics D,* **17** (7), 1043-1054, 2008
2.Exertier, P. et al., Status of T2L2, *Adv. Space Res. - Doris Special Issue », 2010*