Time Transfer by Laser Link T2L2 : Micro-Satellite - Galiléo

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Abstract
The T2L2 experiment [1, 2] allows the synchronisation of remote clocks on Earth, and the monitoring of a satellite clock, with a time stability of the order of 1 ps over 1000 s and a time accuracy better than 100 ps. The principle is based on the propagation of light pulses between the clocks to synchronise. Some new timer, a new design of the optical space segment and the definition of a new time origin allow direct accurate time transfer without external time calibration. T2L2 will be then able to measure the performances of ground clocks having a stability in the range of $3\ 10^{-15}$ over the visibility period of a satellite at 700 km. One can also accumulate the data of several passages of the satellite to reach a stability in the $3\ 10^{-17}$ range over ten days.

1. Principle

The Earth clock and the satellite clock to synchronize are linked respectively to a laser station and to a T2L2 space equipment (figure 1). This equipment is constituted of a photo-detection device, a time tagging unit and a retroreflector. The laser station emits some light pulses in the satellite direction. The retroreflector array returns a fraction of the received photons to the station. The station records the start time of the light pulses and the return time after reflection from the satellite. The satellite time tagging unit measures the board arrival time of the light pulses. For a given light pulse emitted from station A, the offset X_A between clock A and the satellite clock can be computed. For another light pulse emitted from a station B, X_B can be also computed. Time transfer between ground clocks A and B is deduced from the difference between X_A and X_B.

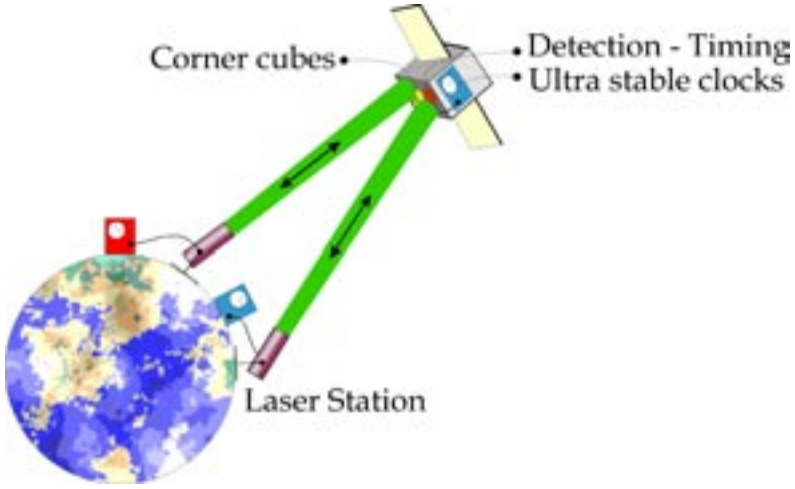

Figure 1 : T2L2 Principle.

2. Status

The T2L2 project was accepted in 1998 in the framework of ACES on ISS (Atomic Clocks ensemble in Space) [3]. Since that time, T2L2 was taken away from ACES because the mass budget, the power dissipation, the power consumption and the price of ACES was beyond the specifications allocated (the specifications allocated at the beginning of one of the two clocks (PHARAO) were not large enough. Some instruments had to be descoped : T2L2 was one of these instruments because it was redundant with the microwave link (although its performances were better) and because it was sensitive to the weather conditions.

In 2001 T2L2 was proposed for a CNES Micro-satellite from the Myriade family. Myriade is a small platform able to carry up a 40 kg payload. In this context, T2L2 onboard Myriade would be a dedicated experiment only for a ground time transfer. The phase A study has been accepted in the very beginning of 2002.The phase B study of the space instrument T2L2, that had been initiated during the ACES program, is still running now in the new context of the micro-satellite and will be finished during the year 2003.

In 2001, T2L2 was also proposed for the first prototype Galileo named GSTB V2. The aim here, would be to measure and characterize the space clocks and to validate the microwave link which will be used in the framework of Galileo.

3. Instrumentation

The T2L2 space payload comprises the following elements :

- A detection unit based on an avalanche photo-diode working in a Geiger mode.
- A time tagging unit able to time the photo-diode output in the satellite clock time scale with a precision better than 2 ps.
- A Rubidium clock having a time stability better than $10^{-12}\ \tau^{-1/2}$.
- A retro-reflector array constituted of (depending on the carrier) :
    - 100 small corner cubes put on a concave surface (400 km)
    - 1 high index corner cube having a diameter of 100 mm (800 km)
    - 1 hollow corner having a diameter of 200 mm (20 000 km)

The total weight is 20 kg and the power consumption of the whole payload is 50 Watts.

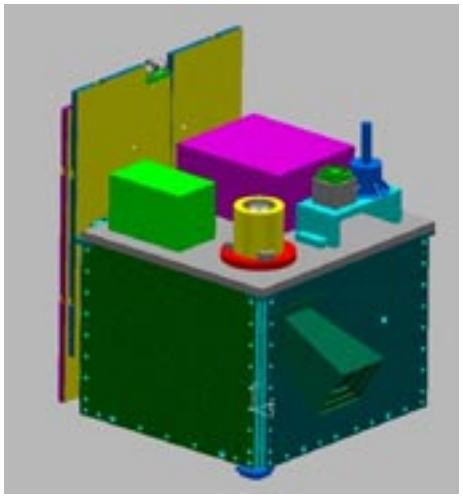

Figure 2 : Micro satellite Myriade

The ground segment of the experiment is a laser station with a specific T2L2 ground instrumentation (figure 3). This instrumentation allows accurate timing of the laser pulses in the frame of the ground clock. It comprises :
- A detection and accurate time tagging unit
- A GPS rubidium clock
- A meteorological station

Figure 3 : Ground equipment

4. Applications and conclusions

T2L2 will allow time transfer between remote clocks with an improvement of two orders of magnitude as compared to the actual microwave links. Because the new space and ground clock generations are reaching time stability and accuracy in the range of 10^{-16} [4], it is crucial to develop new time transfer techniques having a very low noise. T2L2 will also be able to validate and calibrate new microwave links actually under development.

In the continuity of T2L2, a one way laser ranging in the solar system was proposed to the French space agency in 2001 [5]. A clock, a time tagging unit and a photo-detection system are implemented on board a spatial vehicle orbiting around the Sun or a planet [6] (figure 4). The principle of the experiment lies on the measure of the propagation duration of laser pulses emitted from an Earth laser station to the spacecraft. These laser pulses are timed on Earth and on board the spacecraft, respectively in the time scale of the terrestrial clock and in the time scale of the orbiter clock. The distance between the Earth and the orbiter is computed from the difference between the start time and the arrival time on board. Since the link budget depends on the distance to the power two as compared to the power four for the classical two-ways laser ranging, measurements at the scale of the solar system can be envisioned. In this framework, a

collaboration with the Astrod (Astrodynamical Space Test of relativity using optical devices) program is also envision [7]. TIPO would be one of the instrument of the Astrod payload.

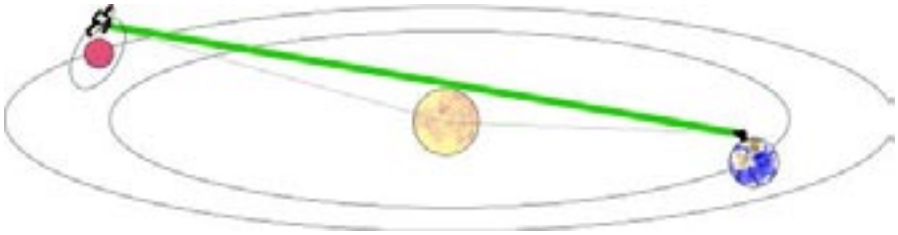

Figure 4 : TIPO : a one way laser ranging project in the solar system

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[1] Fridelance P., Samain E.,Time Transfer by laser link experiment on MIR, *Metrologia*, 1995, **32**, 27-33.

[2] Fridelance P., Samain E., T2L2 : A new optical time transfer generation, Experimental Astronomy 1997, **7**, 191-207

[3] E. Samain, P. Fridelance, Proposal in response to ESA announcement of Opportunity for External Mounted Payload ***during the Early Space Station Utilisation Period : Time Transfert by Laser Link T2L2,ESA Proposal,1997.***

[4] Salomon C. et al, C.R. Acad Sci Paris, t. 2 Série IV, 1313-1330, 2001.

[5] Samain E. & al, Télémétrie InterPlanétaire Optique TIPO, Proposition de recherche scientifique spatiale, CNES, 2001.

[6] E. Samain, One way laser ranging in the solar system, the TIPO Project (Télémétrie InterPlanétaire Optique), to be published EGS, 2002.

[7] Wei-Tou Ni, « Proceedings of the first International ASTROD symposium on laser astrodynamics, space test of relativity and gravitational – Wave astronomy », International journal of modern physics, 2002.