Current performances and developments of MéO laser station

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Located on the "plateau de Calern" in France, the MéO station (for "Métrologie Optique") is dedicated to optical links. Thanks to its 1.54 m telescope, MéO is very well suited to range targets having poor link budget such as the moon or high altitude satellite. Its fast motorization permits also to track LEO and HEO satellite.

Laser ranging on RadioAstron

The MeO performances are well adapted to obtain echoes on RadioAstron, a VLBI space antenna. This project is led by the Astro Space Center of Lebedev Physical Institute in Moscow. Launched in 2011, the spacecraft is orbiting with a high eccentricity: initially its perigee was 400 km and its apogee was 330 000 km. This elliptical orbit around the earth allows having different lengths of baseline and at best a fringe size of 7 µarcsec.

SLR on RadioAstron should solve some scientific tasks like a highly accurate definition of the gravitational fields. Indeed the spacecraft motion is influenced for the most part by gravitational fields of the earth and the moon. In the apogee, its motion will be influenced mainly by lower (J2, J3) harmonics of the earth gravitational field. SLR would also test the gravitational redshift with an accuracy one or two orders of magnitude higher than the last measurement (Gravity Probe A, accuracy of 70 parts in a million).

5 technics are used for the navigation of RadioAstron. However the current position accuracy is more or less 600 meters which is not sufficient for solving astrometrical problems. Navigation difficulties are due to the uncertainty of the gravitational field at large distances from earth but also to the location of the laser retroreflector array which limits time of using SLR only to special sessions.

The laser ranging array is situated on the back panel of the spacecraft and is composed of 100 corner cubes on an area of around 0.18 m2. With MéO, we obtained the first laser echoes on RadioAstron the 15^{th} November 2011. We had 31 normal points. However since this first echoes, we obtained only 10 trackings with a total of 374 normal points. Only 2 stations have performed: a Russian experimental station on the Northern Caucasus and the Grasse station. Return rate are 20% when RadioAstron is at 50 000 km and then it decreases to 2% at 250 000 km.

During the same night we can have laser echoes on the moon and nothing on RadioAstron. A bad orientation of the retroreflector array is hardly probable due to the pointing accuracy of the spacecraft and a poor link budget is for the moment the only way to explain the results.

The laser ranging on RadioAstron is very difficult and we suggest that the tracking effort have to be done only by station designed for lunar laser ranging. The use of a camera is also a good solution to point correctly RadioAstron. To be more efficient, we suggest to implement the "real time exchange protocol" between stations able to track RadioAstron in order to share the bias in time and the stations status.

Adaptive Optic

In collaboration with ONERA, an adaptive system for the MéO station is currently studied since 2010. Without Adaptive Optic (AO), the laser beacon on the lunar surface is between 2 to 10 km, depending on the atmospheric conditions. If the telescope was diffraction limited, we could have a spot in the range of 200 m. With correction only on the down link, we could reduce the detection field of view by a factor 10 and so improve the S/N by the same factor. With correction on the up link, an improvement of a factor of 100 is expected. However, two difficulties have to be overcomed. A high energy deformable mirror is needed which is quite expensive. Velocity aberration introduces an angular shift between the uplink and the downlink. So if this angle is greater than the isoplanetisme area, two different corrections are needed between up and down link. 2 campaigns have been done in 2012 and a test bench has been implemented. The final bench is scheduled to be implemented in 2013.

Coherent laser ranging: Mini-DOLL project

The adaptive optical bench could be used in the future for coherent optical link such as the project named mini-DOLL. Lead by the Observatoire de Paris-Syrte, objective is to demonstrate the feasibility of a coherent laser laser through turbulent atmosphere. Compared to pulsed link, coherent link could improve by a factor 4 the performances. This could have application for time and frequency transfer but also for deep space telecommunication. The main drawbacks are sensitivity to atmospheric turbulence and a need of power.

The measurement technique is based on heterodyne interferometry. A first ground-ground experiment has been done in 2009 on a corner cube placed at 2.5 km. A measurement resolution well below the mm has been obtained. The measurement stability at 1ms was around 45 nm which is quite encouraging.

To realize a coherent link on a satellite, it is compulsory to detect and to compensate the cycle jumps induced by the scintillation. For that, we need to have a site where the turbulence is low but also to use adaptive optic. There are also new difficulties compared to the ground-ground measurement.

Due to the low power reflected, a high powered laser is needed. Due to the long time of flight, the laser has to be stabilized. And finally, due to the spacecraft motion, the Doppler effect has to be corrected. For that we need a tunable laser to correct the 12 GHz of frequency variation at a speed around 120 MHz/s. This ambitious experiment is currently tested with the MéO station.