The achievements of the dedicated Compass SLR system with 1m aperture telescope: GEO satellite daylight tracking and Laser Time Transfer (LTT)

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Abstract

Since 2008, Shanghai Observatory began to construct the dedicated SLR system with 1 meter aperture telescope for tracking Chinese Compass satellite from 20,000 to 40,000km with the precision of 2~3cm. Now the dedicated SLR system has the ability to routinely track Compass satellites at the night and daytime. This paper presents the achievements and measuring results of the SLR system: daylight tracking Compass GEO/IGSO satellites and the LTT experiments with improved LTT payload onboard IGSO satellite.

1 Introduction

Shanghai observatory has been building the 1 meter laser ranging system for the Chinese regional satellite navigation system (COMPASS) in Beijing since 2008 and the main performances of this laser system is following: 1) Receiving telescope: 1000 mm; 2) Transmitting telescope: 300 mm; 3) Nd:YAG laser: 150mJ@532nm, 250ps pulse width, 20 Hz; 4) Targets: GEO/IGSO/MEO, 20,000~40,000km; 5) Ranging precision: 2~3cm; 6) Daylight tracking ability; 7) Laser Time Transfer (LTT).

In Jan. 2009, the 1m aperture telescope was installed and Figure1 shows the 1 meter aperture telescope in the assembly shop. After finishing servo-tracking control system, the laser system, coude path system and electronical control system, the dedicated Compass laser ranging system successfully got the returns from Lageos, GPS36, Glonass, Giove at night-time in March 2009. On 21 April 2009, returns are obtained firstly from COMPASS GEO2 satellite at night-time and the range is about 3,8800Km at the precision of about 2cm.

Figure1 The view of the 1 meter aperture telescope

This paper will introduce the following two achievements of the Compass SLR system, GEO/IGSO satellite daylight tracking and Laser Time Transfer for IGSO satellite.

2 GEO/IGSO satellites daylight tracking

Technologies are solved for daylight tracking: 1) Good performances of tracking and pointing of telescope mount; 2) Space filter: receiving field of view of 24~45 arc second; 3) Spectrum filter: Narrower filter with 0.15nm band width, Transparency of central wavelength of over 50%; 4) Parallelism of transmitting and receiving path with better than 5 arc second; 5) Daylight Laser beam monitor.

Two computer controlling mode

For increasing the stability of tracking and pointing of 1 meter telescope mount, one computer is used for the telescope control to track satellites and stars and another computer is used for laser ranging operation and both software interfaces can be seen from the Figure2. According to the above operating mode, the tracking accuracy is less than 1 arc second for tracking High Earth Orbit satellites, especially in daylight and pointing accuracy is better than 3 arc second after star calibration. Figure3 shows the tracking error of 1 meter telescope mount.

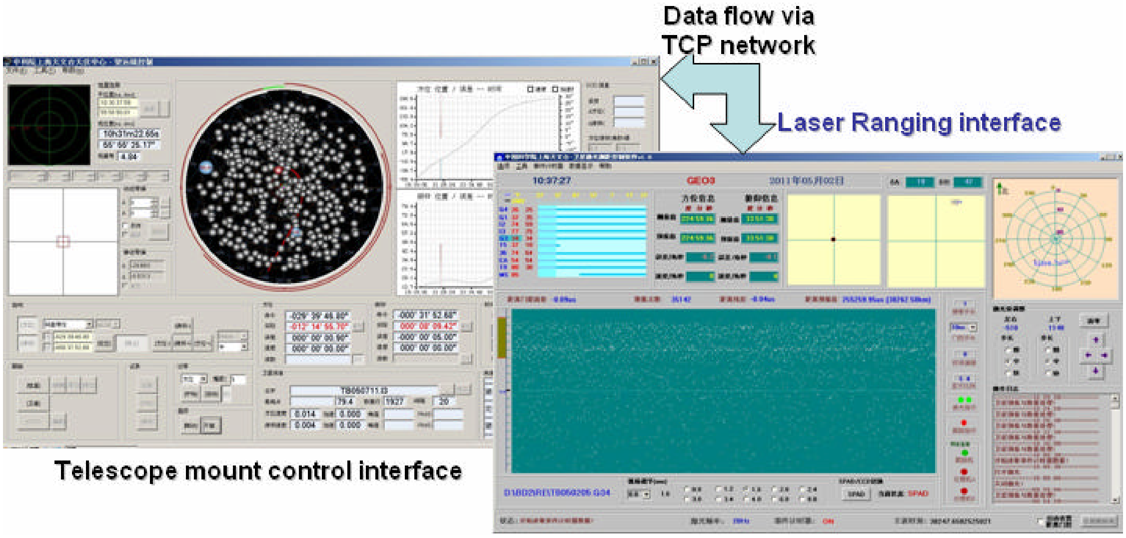


Figure 2 The software interface of laser ranging and telescope mount controlling

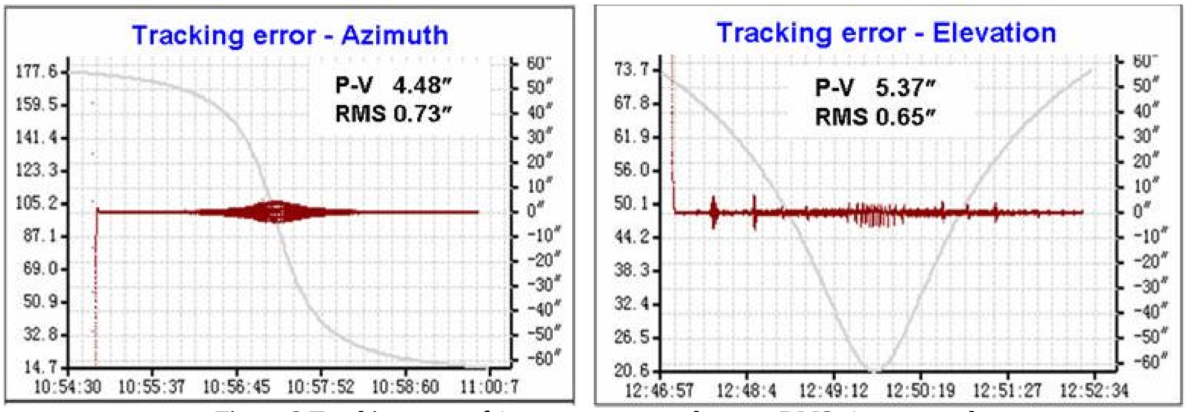


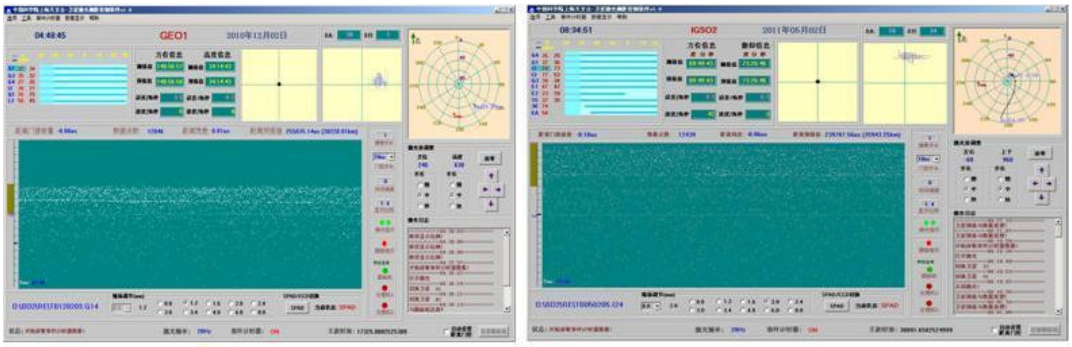
Figure 3 Tracking error of 1 meter aperture telescope, RMS<1 arc second

Other methods tested for daylight tracking

Before daylight tracking experiments, we successively tested the methods of space filter, spectrum filter, range gate and laser beam monitor during laser ranging at nighttime and then daylight laser ranging experiments were implemented for Lageos, Etalon, Glonass, Compass M1.

Laser ranging results from GEO/IGSO in daylight

On 1 April 2010, laser returns from Compass GEO satellite at daylight are firstly obtained and the measuring range is about 38,000km. Through further improving the laser ranging system, many passes of Compass GEO and IGSO satellite are measured successfully. Figure 4 shows the results of daylight tracking to Compass GEO1 and IGSO2 satellites and the local time is 12h am and 4h pm respectively.



GEO satellite daylight tracking, range: 38,000Km   IGSO satellite daylight tracking, range: 35,900Km

Figure 4 Daylight tracking real-time ranging interfaces for GEO and IGSO satellite

3 Laser Time Transfer for IGSO satellites

In Dec. 2007, Shanghai Observatory have successfully actualized Laser Time Transfer (LTT) experiment at Changchun SLR station (60cm aperture telescope) for Compass-M1 satellite (altitude 21,500km)[1][2].

New LTT payload

Based on the above experiment, some improved technologies are applied for the new LTT payloads, such as one gate mode adopted, two different FOV used, narrower filter etc. After the Compass IGSO1 satellite (altitude 36,000km) with improved LTT payloads was launched, the first measuring experiment was implemented successfully by using the 1 meter laser ranging system at the end of August in 2010 and the clock difference between satellite and ground was obtained. Compared to LTT experiment of Compass-M1 satellite, the performances of the new LTT payload on Compass IGSO1 and Laser Ranging system on ground are more advanced. And LTT measurement is also performed easily. Figure 5 is the view of photo-detector on the new LTT payload and its main performances.

Main performances of new photo-detector

- ✧ Dual-SPAD detector
- ✧ 500g, <2W, 105× 70× 80mm
- ✧ Two Field of View: 15°/11°,
  for different background noise
- ✧ 40A bandwidth filter

Figure 5 The photo-detector of the new LTT payload

Laser Fire Control

For simplifying the design of LTT payload on satellite, the gate mode for detector is different from the one in routinely SLR, adopting a fixed range gate (about 70ns after start pulse). To reduce the effect of noises, the laser fire time on ground must be accurately calculated according to laser pulse flight time, predicted clock difference between space and ground, system delays, etc. Let the laser pulse arrive at the detector on onboard, just after the gate pulse of detector.

For strictly controlling laser fire time, the laser on ground should be actively switched, and laser with passive or pass-active switched cannot be used. The firing jitter of the new laser in this system is about 10ns and meets the requirement of LTT measurement.

Measuring Results

Table1 lists the some results of LTT measurement for Compass IGSO satellite and Fig.6 shows the clock difference. The measuring precision of the LTT experiment is more or less 300ps.

Table 1 Some results from new LTT

Date	Points	Pass(min)	Precision(ps)	Slope of Clock Difference
2010.08.30	315	10.1	283.1	2.322E-10
2010.09.21	2672	156.2	311.5	-3.636E-10
2010.09.22	4830	251.0	315.1	-3.567 E-10
2010.11.01	4345	47.6	296.6	-3.572E-10
2010.11.02	7396	59.2	299.82	-3.571E-10

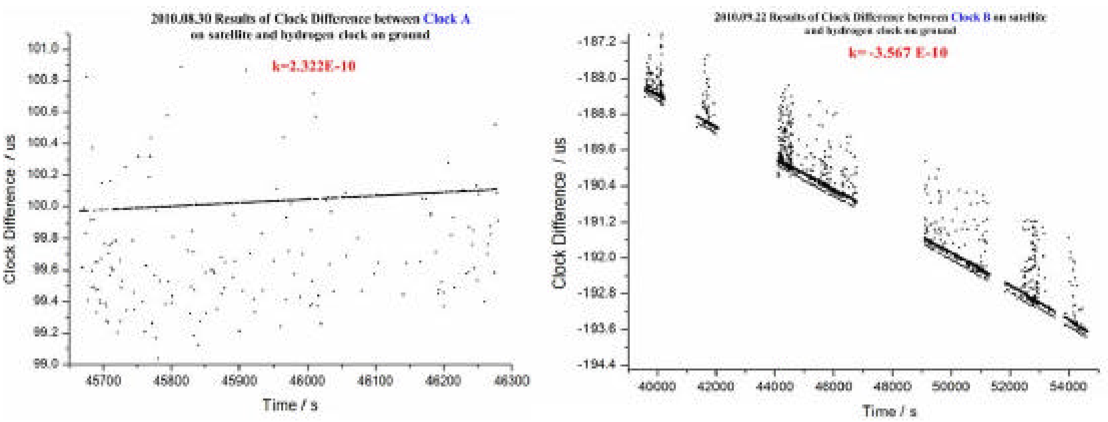


Figure 6 Results of Clock Difference between satellite and ground

4 Summary

The dedicated Compass SLR system in Beijing has being playing an important role in tracking Compass satellites (nighttime and daylight) for calibrating the microwave or radio ranging technique and the precise orbit determination of satellites. It is the first time to implement LTT experiment on IGOS1 satellite (altitude 36,000km) at the precision of more or less 300ps. The drift and stability of frequency onboard are about 10E-10 and 10E-13 respectively. Compass IGSO3 with the same LTT payload was launched and the LTT experiment was implemented successfully with the precision of 280ps in May 2011. Through LTT between satellite and ground, time synchronization for different stations on ground in the Chinese regions or beyond China will be carried out in the future.

References

Yang Fumin, 2008: *The preliminary results of Laser Time Transfer (LTT) Experiment*, Proceedings of the 16th International Workshop on Laser Ranging

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