DAYLIGHT TRACKING GNSS IN THE CHANGCHUN SLR STATION.

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Abstract: The Changchun SLR station has gained experience of tracking high orbiting satellites, and has upgraded to track GNSS satellites(GEO\IGSO\MEO) in daytime. The system uses an iris, a narrowband filter and a daytime camera system to capture and adjust the laser beam in daytime. With the dome open, the heating of sunlight affects telescope pointing and sensor temperature, introducing error. Experiments were taken on the error.The presentation will introduce the technical developments and the observation obtained. The navigation satellites SLR observation data is applied in the clock bias calculated.

1. Introduction

Daylight tracking GNSS satellites is attention by the international laser ranging service(ILRS). The daylight ranging data have important applications in many aspects. Currently, GNSS constellations maily include the GPS, GLONASS, Galileo, CCOMPASS, QZSS, IRNSS. These satellites consist GEO, IGSO and MEO satellites. Now, many international advanced satellite laser ranging stations have been achieved daylight tracking GNSS satellites.

Daylight tracking GNSS satellites is difficult, the SNR(signal to noise ratio)is too low. It is hard to identify valid returns even in background noise .With the dome open, the heating of sunlight affects telescope pointing and sensor temperature, introducing telescope pointing error. We do a lot of experiments for taken on the error and improved. Upgrade control software for identify valid returns. The Changchun SLR had the capability to track GNSS during daytime.

2. GNSS Tracking Improvements

In daytime, because of the background noise, it is difficult to require the effective data, especially high orbit satellites(GNSS). Changchun SLR station has upgraded the satellite laser ranging system in order to adapt the daylight tracking GNSS satellites. The system used smaller receiver field of view at daylight, a narrowband filter. A camera system(PCO-1600) is applied to capture and adjust the laser beam in daytime.

2.1 The smaller receiver field of view

In Changchun SLR System, we use spatial filtering to reduce the background noise. Remote control is used in the adjustable iris (0.2mm-7mm). The field of view is in a range of 23″-420″. The smaller receiver field of view is for daylight tracking to reduce the background noise in order to acquire the effective echo signals.

2.2 Spectrum Filter

Another measure to reduce noise in the daylight background is application of narrowband interference filter in the receiver optical path.

Tab.2.2.1. The main parameters of spectrum filter

Name	The parameters
Central Wavelength	531.955nm
Transmission	>75%
Bandwidth	0.15±0.1nm
Size	Φ25.0±0.25nm
Operating Temperature	23℃

As the filter need steady temperature to ensure its performances, we manufactured a constant temperature box. The application of 0.15nm narrow interference filter and the constant temperature box could cut more background noise and make the filter working in a constant temperature environment.

2.3. The CCD for Monitorring laser beam in daylight

For the small receiving field of view, we use the high sensitivity CCD and the technology of synchronization trigger spectral filtering methods and achieved the backscattering laser beam real-time monitoring that ensure the optical path of transmitting and receiving is parallel.

A new CCD camera is installed to monitor transmit laser beam for laser beam pointing and divergence improvement. The background light is strong in the daytime, so it is difficult to require the daylight KHz laser beam imaging real-time. It resolved the problem of too much background noise in the daytime and used the high sensitivity CCD camera in the system. Table1 indicates the main specialty of the CCD camera that we tested. Figure1 is the photo of CCD camera used in the system (PCO 1600).

Tab.2.3.1. CCD camera specialty (PCO 1600)

resolution (hor x ver)	1600×1200
pixel size (hor x ver)	7.4um×7.4um
sensor format(mm^2)	12.2×9.0
spectral range(nm)	320-1000
peak quantum efficiency	55%(500nm)
exposure time(s)	500ns-47days
max. exposures in one image	500000
max. modulation frequency	50KHz

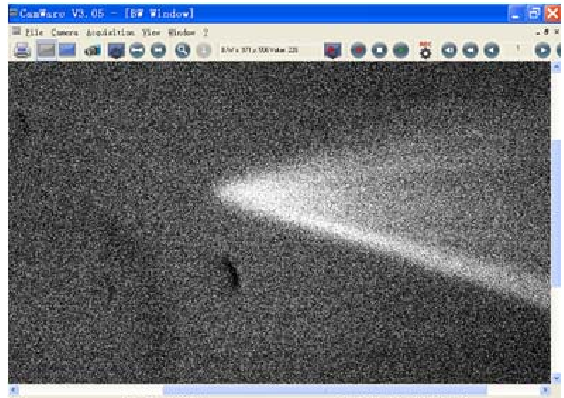

Fig.2.3.1. The laser beam in daylight

3. Telescope Pointing Stability Improvement

In daytime, the telescope is located in the open dome when it is tracking the satellites. It existes the horizontal axis error, the vertical axis error, the collimation axis error and the encoder zero error. Due to the sunlight and the changes of the external environment, the horizontal axis, transmitting axis andt receiving axis of the system will produce the change. It cause the telescope pointing changes in daytime. Also, telescope frame will produce deformation by the uneven irradiation of the sun and cause the telescope to point bias.We have used many methods to reduce the effect of external environment.

(1) Improve the level stability of telescope horizontal axis.

The level of telescope rely on the three foot to support and adjust the three by a pair of adjusting mechanism. Because the equipment has been used for a long time, this adjusting structure is easy to be affected by the temperature change. In the daylight satellite-laser ranging, due to the strong sunlight irradiation, it will cause the three foot uneven heating and lead to the telescope level stability. Fig.3.1 is the level stability changes of telescope.

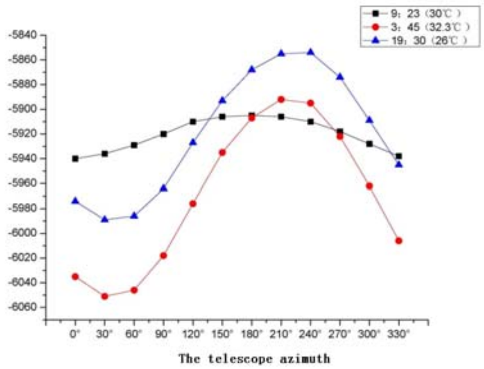

Fig.3.1. The changes of telescope stability

We use effective ways to solve this problem and improve the telescope stability.

- Change the telescope support to reduce the impact of structural design.
- Strengthen auxiliary support to improve telescope leveling.

(2)Telescope mount anti-reflection sunlight treatment.

The anti-reflection sunlight treatment is done to reflex the irradiation of sunlight that prevent the sun exposure causesing the telescope frame deformation. Then it will improve the stability of telescope pointing.

- Use reflection membrane on the telescope.
- Close telescope tube to reduce thermal interference while not in use.

(3)Track stars in daytime to improve the telescope pointing stability.

Through tracking the stellar in daytime, we obtain the data for the pointing model and research the other factors in the model that improve the effectiveness of the model. Then we can achieve the correction of the telescope pointing model in daytime and improve the stability of the telescope pointing.

The sky background noise is one of the biggest difficulty in daytime. If we want to acquire the images of stars, we must solve the strong background noise first. According to the characteristics of the sky background in daytime and the starst radiation, we used spectral filtering technology to reduce the sky background noise and prevent CCD saturation. Improve the signal-to-noise ratio of the target and background noise. Fig.3 is the image of Polaris acquired in daytime.

Fig.3.2. The image of Polaris in daytime

4. GNSS Observation Results

Through the upgrades of Changchun SLR system, the stability of telescope pointing and the capabilities of the ranging system has been increased obviously in daytime. Changchun SLR station has the ability to track GNSS satellites in daytime. In 2014, 6841passes GNSS satellites data have been acquired, of which 1414 passes in daytime. The table 4.1 is the observation data results for GNSS in 2014.

Tab.4.1 Observation Results for GNSS

Name	Daylight	Night	Total
Compass	70	534	604
GIOVEA	1	8	9
Galileo	227	466	693
GLONASS	1098	4118	5216
IRNSS	0	33	33
QZS	15	207	222
GPS	3	61	64
Total	1414	5427	6841

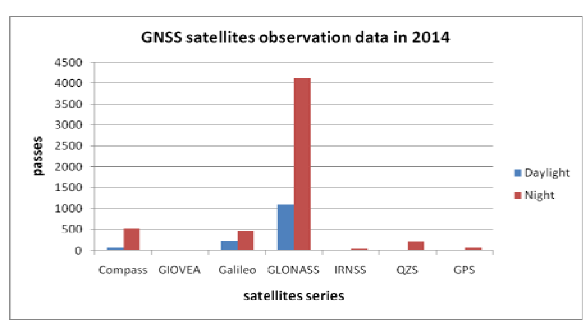

Fig.4.1 GNSS satellites observation data

During the daytime, the synchronization orbit satellites have been tracked successfully and the effective observation data has been required. The Fig4.2 is the picture of synchronous satellite(compass-G1) tracking.

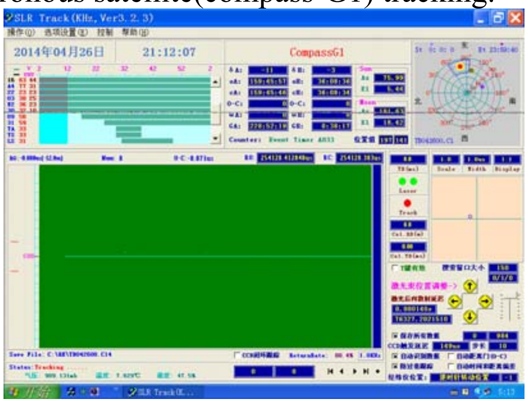

Fig.4.2 The picture of synchronous satellite(compass-G1) tracking

The observation data quantity of high orbit satellites increases significantly in 2014 that is compared with the dada in 2013, especially for the high orbit satellites.

Tab.4.2 The comparison of observation data in 2013 and 2014

Years / Passes	2013	2014
Total passes	14134	18658
Daylight	3910	6713
Night(high)	5574	8383
Daylight(high)	709	2174

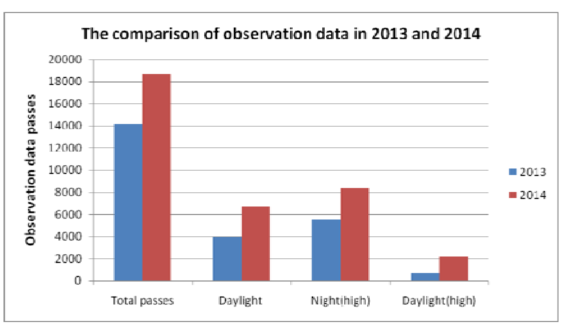

Fig.4.3 The comparison of observation data in 2013 and 2014

5. Application example

The clock bias of navigation satellite can be calculated by combine the SLR and pseudorange. The SLR technology through measure the time of laser pulses round trip flight between satellite and station to determine the range. It is an active method and just required a corn reflector equipped on the satellite to send the laser back.So the range measured will not contain any clock bias of the satellite. But in navigation receiver the range obtained by using a passive way. It measures the time of C/A or P code broadcast from satellite to receiver. The range contained the clock offset both of satellite and receiver, so it called pseudorange. Therefore, after corrected the basic error like ionosphere delay and system delay etc. of SLR range data and pseudorange data. It's possible to distinguish the clock bias of navigation satellite by combine these two kinds of range technology. Fig.5.1 indicate the comparison of COMPASS-G1 clock bias calculated by our method and the final clock products from GFZ.We can find that the variation trendsof the clock bias meets well in the calculated time span.

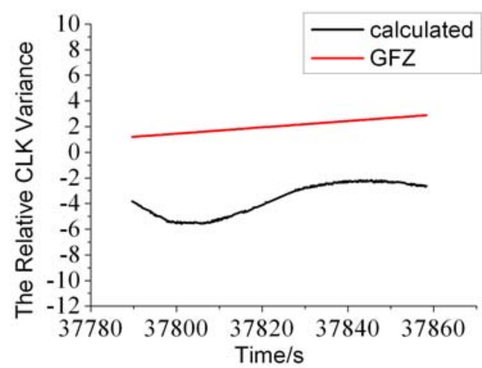

Fig.5.1 The comparison of calculatedsatellite clock bias and GFZ clock products of COMPASS-G1

6. Summary

Through the analysis of the factors affecting the telescope pointing accuracy, use effective methods to improve the stability of the telescope level and reduce the influence of the sunlight and the external environment in the daytime. The upgrade to GNSS satellites tracking of Changchun Observatory is successful. The Changchun SLR system has the capability to track GNSS satellites during the daytime, although this requires good weather conditions and the operator have the patience and experience. The navigation satellites SLR observation data is applied in the clock bias calculated. It’s possible to distinguish the clock bias of navigation satellite by combine these two kinds of range technology.

7. Reference

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