Design of LRA for Compass GEO and IGSO Satellites and Observations

Chen Wanzhen, Yang Fumin, Zhang Zhongping, Wang Yuanming, Zhang Haifeng, ,Li Pu
(Shanghai Observatory, Chinese Academy of Sciences, Shanghai, China)

Abstract

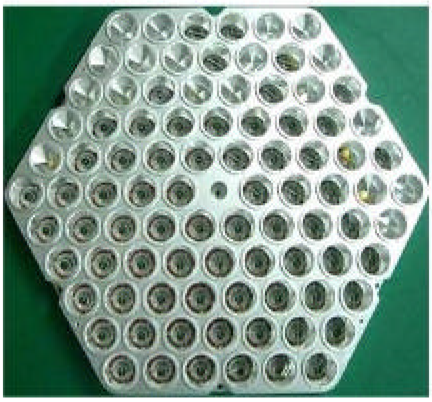
Geostationary orbit (GEO) and Inclined Geostationary orbit (IGSO) satellites are important parts in the Chinese regional satellite navigation system (COMPASS). All of those satellites will be equipped with LRA designed and manufactured by Shanghai Astronomical Observatory for calibrating the microwave, radio measuring techniques and precision orbital determination. This paper introduces the characteristics of LRA of Compass GEO and IGSO satellites and the method of inclined installing LRA for GEO satellites. The observation to GEO and IGSO satellites by the dedicated Compass SLR system with 1 meter aperture telescope are also presented.

1 Introduction

COMPASS is the Chinese regional satellite navigation system and the constellation will consist of 5 GEO, 3 IGSO and 4 MEO satellites. At last workshop, Yang Fumin reported the LRA on Compass MEO orbital satellites and the observations by using the 60 cm aperture SLR system in Changchun. This paper will introduce the characteristics of LRA on Compass GEO and IGSO satellites and the observations by the dedicated Compass SLR system with 1 meter aperture telescope. Considering Compass GEO satellites mainly serving for Chinese region, a method of inclined installing LRA was adopted for increasing LRA reflective area for Chinese SLR stations, with the normal direction of LRA pointing to the Chinese continent rather than the geocenter. The theoretical calculation and measuring results show that the method of inclined installing LRA is very effective.

2 Design and Performance of the LRA for Compass GEO and IGSO satellite

The orbital altitude of the Compass GEO and IGSO satellites is 36,000Km and compensation of the velocity aberration: 0.6 arc-seconds dihedral offsets with uncertainty of about 0.5 arc-seconds. Due to farther than Compass MEO, the design of LRA on GEO and IGSO satellites should be more efficient in order to get enough laser returns. For High Earth Orbital satellites, the critical angle of incoming laser beam to the corner cubes almost does not appear during the observation, so the all the surfaces of the corner cubes are without coating and each corner cube was in an independent chamber, fixed into the planar base made of aluminum alloy material. Figure 1 shows the view of LRA on the Compass GEO and IGSO satellites and its main parameters. The LRA of Compass GEO and IGSO satellites is the hexagon array to reduce the returned pulse spread and to achieve better ranging precision and the effective reflective area is about 770 cm^2 that is two times than the one of Compass MEO.



Size	49×43×3.0cm
Diameter of corner cube	33mm
Number of corner cube	90
Reflective area	770cm^2
Dihedral offset	0.6″
Weight	5.0 kg

Figure 1 The view of LRA of Compass GEO and IGSO and its main parameters

For testing the optical performances of LRA, Shanghai Observatory imported the ZYGO interferometer and established special laboratory. Each corner cube of LRA must be carefully measured to insure the high quality before installed. Figure 2 shows the ZYGO interferometer and one of the measurements.

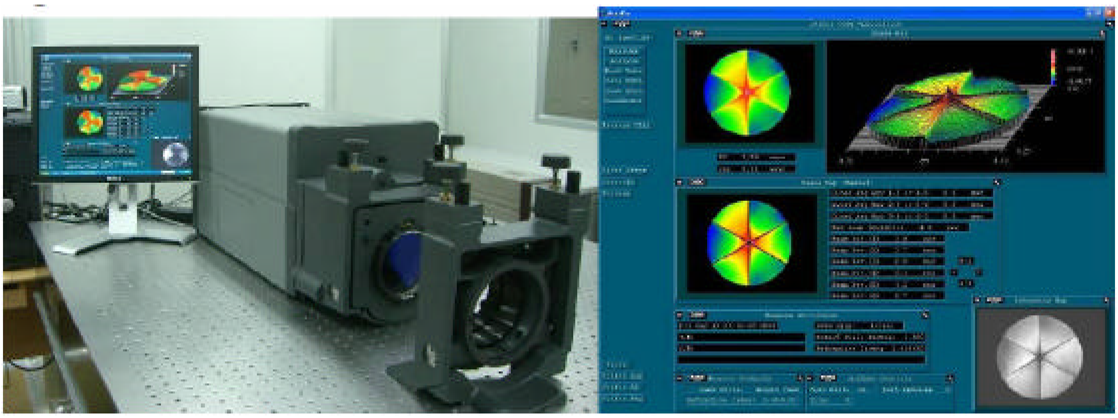


Figure 3 Optical performance testing of LRA with ZYGO interferometer

3 Calculation of the incidence angle of LRA inclined installed

In order to increase the effective reflective areas for Chinese region, the method of LRA inclined installed is adopted to make the normal direction of LRA pointing to the Chinese continent rather than the earth's center. Figure 3 shows the relative place of satellite (S), ground station (O) and the intersection of the normal of LRA and ground (C) in the geocentric coordinate system (E-XYZ) and the coordinates are (a_S, b_S), (a_O, b_O), (a_C, b_C) respectively.

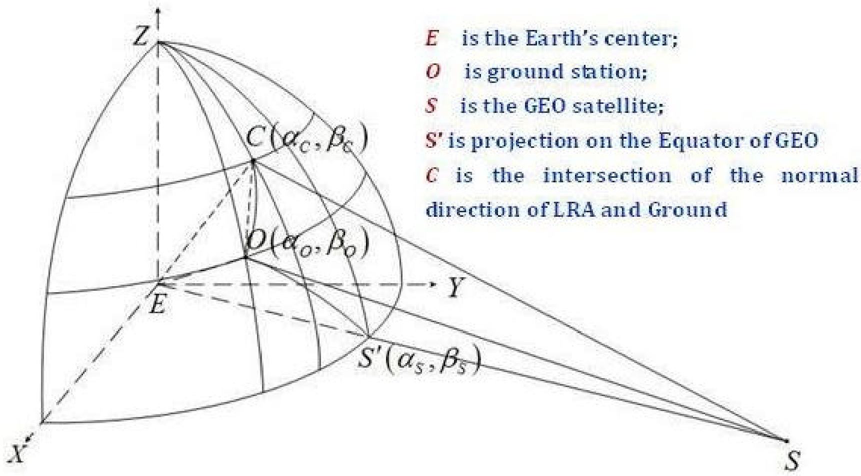


Figure 3 Diagram of the relative place of satellite, ground station and the intersection of the normal of LRA and ground

For the normal of LRA oriented to the Earth's center, the incidence angle (i) can be calculated by the following formula:

$$i = \arcsin\left(\frac{R_E}{R_{SO}}\sin\left(\arccos\left(\cos b_0 \cos\left(a_S - a_O\right)\right)\right)\right)$$

$$R_{SO} = \sqrt{R_E^2 + \left(R_E^2 + h_S\right)^2 - 2R_E\left(R_E + h_S\right)\cos\left(\angle OES\right)}$$

Where, R_E is the radius of the Earth, R_{SO} is the slant distance from ground station to satellite, h_S is the satellite height above sea level, (a_O , b_O) is the coordinates of ground station, (a_S , b_S) (for GEO satellite, $b_O = 0$) is the coordinates of the satellite.

If the normal of LRA of Compass GEO satellites points to the intersection C (a_C , b_C), the incidence angle can be calculated by using formulas of spherical triangle:

$$i_C = \arccos\left(\left(R_{SC}^2 + R_{SO}^2 - l_{CO}^2\right)/2R_{SC}R_{SO}\right)$$

Where

$$R_{SC} = \sqrt{R_E^2 + \left(R_E^2 + h_S\right)^2 - 2R_E\left(R_E + h_S\right)\cos\left(b_C\right)\cos\left(a_S - a_C\right)}$$

$$R_{SO} = \sqrt{R_E^2 + \left(R_E^2 + h_S\right)^2 - 2R_E\left(R_E + h_S\right)\cos\left(\angle OES\right)}, \quad l_{CO} = 2R_E \sin\left(\angle OC/2\right)$$

$$\cos\left(\angle OC\right) = \cos\left(90^\circ - b_O\right)\cos\left(90^\circ - b_C\right) + \sin\left(90^\circ - b_O\right)\sin\left(90^\circ - b_C\right)\cos\left(a_C - a_O\right)$$

$$= \sin b_O \sin b_C + \cos b_O \cos b_C \cos\left(a_C - a_O\right)$$

Where, i_C is the incidence angle between ground station (O) and the satellite (S), R_{SC} is the slant distance from the intersection (C) to the satellite, l_{CO} is the curve distance from station to the intersection (C).

Considering the Compass tracking network consisting of several independent SLR system on ground, so the geometrical center of several SLR stations on ground is chose as the normal of LRA directing to point (C). Based on the coordinates of the intersection and Compass GEO satellites, the inclined angle of LRA of all GEO satellites is less than 7 degree. Table 1 shows the increasing rate of effective area for different position GEO satellites and ground stations after the LRA of GEO satellites inclined installed. The effective areas are increased up to 20.56% at the maximum. Although the increasing rate is not very much for every satellite, it is considerable significant for ground stations.

Table 1 The increasing rate of effective areas for different GEO satellites and stations

	GEO Satellite A	**GEO Satellite B**	**GEO Satellite C**
Ground Station 1	**20.56%**	**15.73%**	**10.36%**
Ground Station 2	**13.37%**	**7.07%**	**1.50%**
Ground Station 3	**8.66%**	**7.08%**	**12.34%**

4 Observations

Up to now, there are several Compass GEO and IGSO satellites launched into different positions over the equator in last year and this year. The laser tracking for these satellites has been done at a new dedicated Compass SLR station located in Beijing since April 2009 and a great amount of laser tracking data were obtained. The parameters of the dedicated SLR system can be seen from another report in this workshop. Figure 4 shows two passes of measuring results (Compass GEO2 and IGSO3) by the dedicated SLR system. For GEO2 satellite, the average returns per minute are about 38.

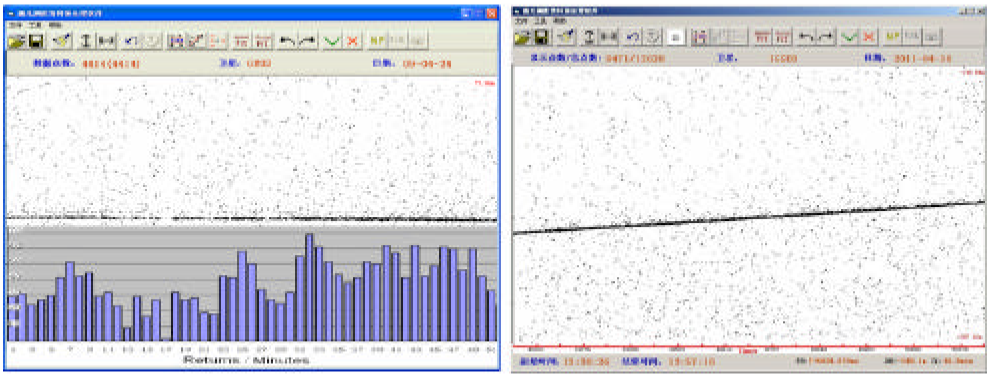


Figure 4 Measuring results from GEO and IGSO satellites by dedicated SLR system

Shanghai SLR station also tracked some passes of these satellites with the new kHz laser ranging system (1.5 mJ energy in 532nm, 15 ps pulse width, 1 kHz repetition). Figure 5 shows the measuring results of Compass GEO1 and IGSO1 by using Shanghai kHz SLR system. For GEO1 satellite, the average returns per minute are about 580.

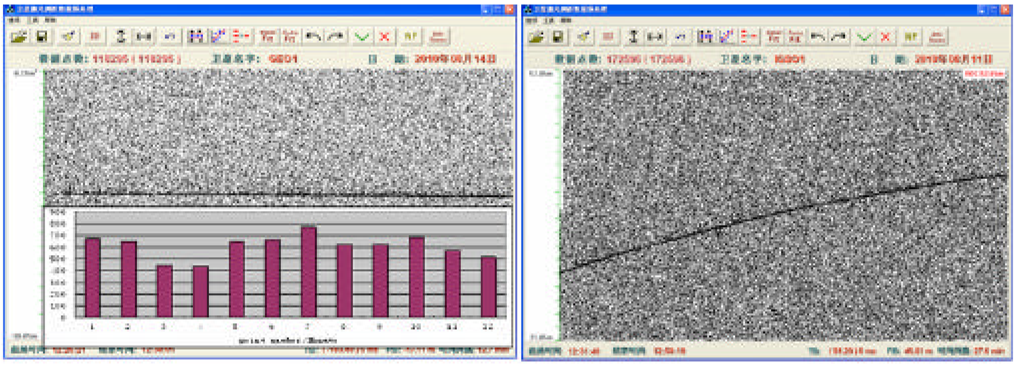


Figure 5 Measuring results of GEO and IGSO1 satellites by Shanghai kHz SLR system

5 Conclusion

Shanghai Observatory has accomplished 14 sets of LRA for Compass satellites and 8 satellites have been launched into the different orbit. A great amount of laser tracking data was obtained by using the Compass SLR system and the significant role was played in calibrating the microwave, radio measuring techniques and Compass satellite precise orbit determination. During the design of LRA for GEO satellites, the method of inclined installing LRA is adopted to make its normal direction point to the stations on ground, not to the Earth's center. This original way of installation makes the reflective area and returns increased effectively. Measuring results show that the performances of LRA on COMPASS satellites are well. The methods of design and manufacture of LRA on COMPASS satellites have successfully applied to other satellites.

Reference

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Correspondence

Zhang Zhongping
No.80, Nandan Road, Shanghai, China
zzp@shao.ac.cn