Laser Retro-reflector Arrays on the Compass Satellites

Yang Fumin, Chen Wanzhen, Wang Yuanming, Li Pu
Shanghai Astronomical Observatory, Chinese Academy of Sciences, China
yangfm@shao.ac.cn / Fax: +86-21-64696290

Abstract

"COMPASS" is the regional satellite navigation system in China, and the constellation will consist of 12 satellites, of which 5 GEO, 3 IGSO and 4 MEO. The effective reflective areas of LRAs for these satellites are 770cm^2 for GEO and IGSO, 360cm^2 for MEO respectively. The diameter of the corner cubes is 33mm. Each corner cube is uncoated both on front and back faces. The paper presents the characteristics of the LRAs of the COMPASS satellites.

Introduction

The COMPASS, the Chinese name is Beidou , is the regional satellite navigation system in China, which will cover the most areas of the East Asia region, and expect to be operational by 2011.The COMPASS constellation will consist of 12 satellites with different orbital altitudes. There will be 5 GEO, 3 IGSO and 4 MEO. The orbital altitudes for GEO and IGSO are 36000 km, while 21500 km for MEO. All of those satellites will be equipped with the laser retro-reflector array (LRA) for precise orbit determination.

The experimental COMPASS satellite M1 with a MEO orbit was launched on April 13, 2007 (UTC). The LRA onboard COMPASS-M1 has been successfully tracked by the ILRS stations since December 2008. Fig. 1 is the drawing of COMPASS-M1.

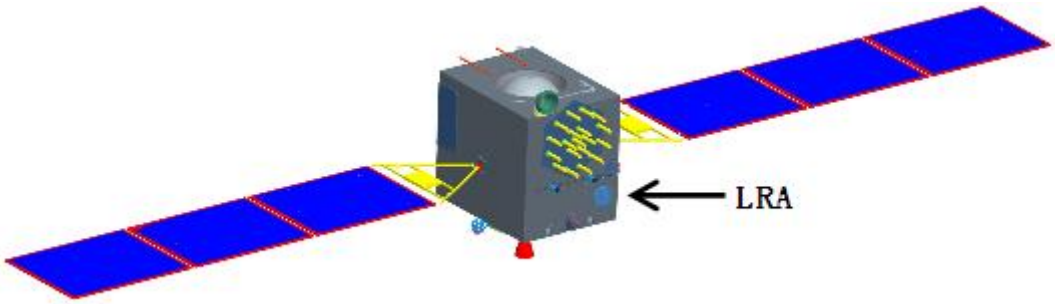

Figure 1. Drawing of COMPASS-M1 Navigation Satellite

Design and Performance of the LRA

The orbital altitude of the COMPASS-M1 is 21500 km, so the velocity aberration for the COMPASS-M1 is about 5.2 arc seconds. We choose the diameter of the corner cubes for the COMPASS-M1 and COMPASS satellites follow-on is 33 mm, equals to 1.3 inches. For compensation of the velocity aberration, the 0.6 arc seconds (±0.3″) dihedral offsets were adopted for the COMPASS-M1's corner cubes. All the surfaces of the corner cubes are without coating. The fused silica material for the corner cubes was made by the Shanghai LengGuang Co. in China. Fig. 2 and Table 1 show the photos and parameters of the

COMPASS-M1 (MEO) and the COMPASS GEO/IGSO respectively. We choose the hexagon array for the GEO/IGSO in order to reduce the returned pulse spread and to achieve better ranging precision.

Figure 2. The LRAs on MEO and GEO/IGSO

Table 1. Parameters of COMPASS-M1 (MEO) and COMPASS GEO/IGSO

	M1(MEO)	GEO/IGSO
Size	31.6×28 cm	49×43cm
Diameter of corner cube	33mm	33mm
Number	42	90
Reflective area	360cm^2	770cm^2
Dihedral offset	0.6″	0.5″
Weight	2.45 kg	5.0 kg

The optical performance of each corner cube must be carefully measured by the ZYGO interferometer in our laboratory. Fig. 3 shows the ZYGO and one of the measurements. The LRA must pass all the space environmental simulation testing. Fig. 4 shows one of the testing.

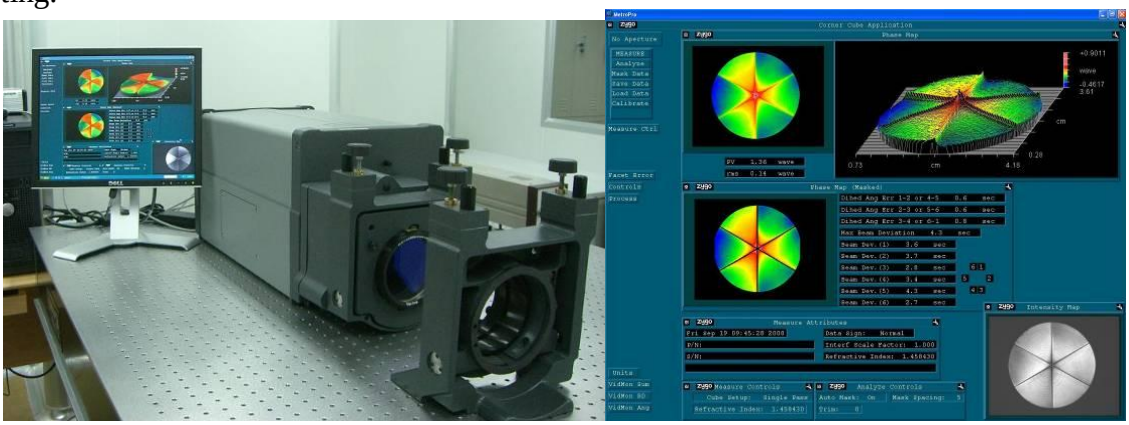

Figure 3. Testing of LRA's optical performance with ZYGO interferometer

Figure 4. Environmental testing of LRA

Table 2 and 3 list the cross section, range and signal strength and the parameters of the LRA on different satellites respectively from Dr. David Arnold (private communication).

Table 2. Cross section, range and signal for different satellites (by David Arnold)

Sat.	Cross section	Range (0 deg.)	Range^4	Signal strength	Range (45 deg.)	Range^4	Signal strength
Lageos	15	5.8	1	1.000	6.8	1	1.000
Etalon	55	19.0	115	.032	20.5	82	.044
GPS	19	20.0	141	.009	21.5	100	.012
GIOVE-A	45	23.9	288	.010	25.4	195	.015
Glonass	80	19.0	115	.046	20.5	82	.065
Compass-M1	80	21.0	189	.028	23.0	131	.041
ETS-8	140	36.0	1484	.0063	37.6	935	.010

Table 3. Parameters of LRA on different satellites (by David Arnold)

Satellite	Cube Number	Diameter (inch)	Coating	Dihedral Offset	Vendor
Lageos1	422	1.5	uncoat	1.25	Perkin-Elmer
Lageos2	422	1.5	uncoat	1.25	Zygo
Etalon	2140	1.06	coat	-	IPIE
GPS	32	1.06	coat	-	IPIE
GIOVE-A	76	1.06	coat	-	IPIE
Glonass	132	1.06	coat	-	IPIE
Compass-M1	42	1.3	uncoat	0.6	SHAO
ETS-8	36	1.6	uncoat	0.5	ITE
Perkin-Elmer Headquarters-- Waltham, MA, USA ZYGO Zygo Corp., Middlefield, CT, USA IPIE Institute for Precision Instrument Engineering, Russia SHAO Shanghai Astronomical Observatory, China. ITE ITE, Inc., Laurel, MD, USA					

The Observations of the COMPASS-M1 at the Changchun Station

The Changchun SLR station was chosen for the experiment of the COMPASS-M1 LRA ranging and the laser time transfer (LTT) in the beginning of 2007. Some upgrading was done before the launch. A new powerful mode-locked Nd:YAG laser with 100-150 mJ in 532 nm, 250 ps, 20 Hz was borrowed from the North China Research Institute of Electro-Optic (NCRIEO) in Beijing (Fig. 5). A 210mm diameter transmitter was installed to replace the old 150 mm transmitter for smaller beam divergence, and the new Coude mirrors were used (Fig.6).

Figure 5. Active-active mode-locked Nd:YAG laser

Figure 6. Changchun SLR Telescope

The laser ranging experiment to the COMPASS-M1 has been successful from the beginning. Fig. 7 shows the real-time display of the COMPASS-M1 tracking on May 1, 2007. Fig. 8 shows the range residuals of the COMPASS-M1 on September 5, 2007.

Fig. 9 shows the range residuals after fitting, and about 18550 returns with the range precision of 24 mm were obtained during 2 hours.

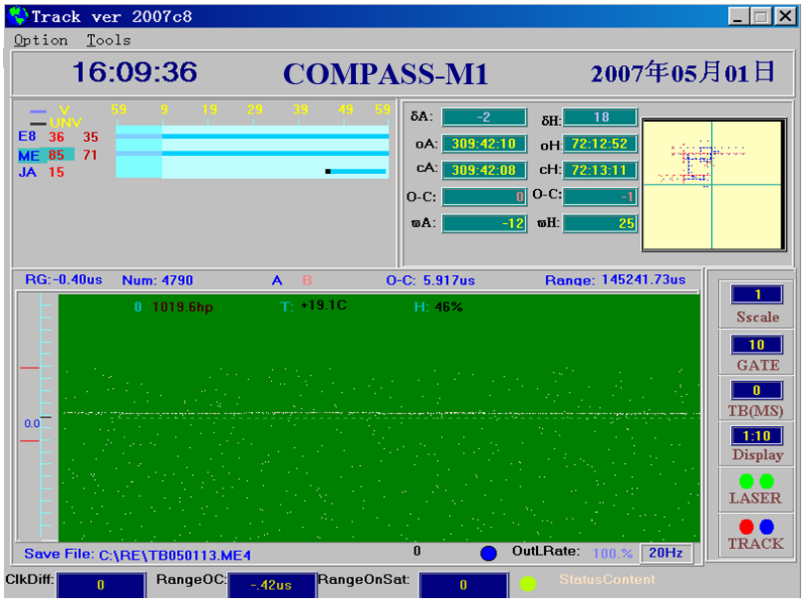

Figure 7. Real-time display for Compass-M1 tracking on May 1, 2007

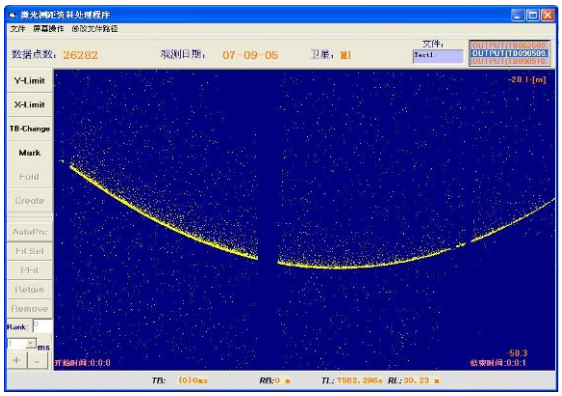

Figure 8. Range residuals of Compass-M1 on Sept. 5, 2007

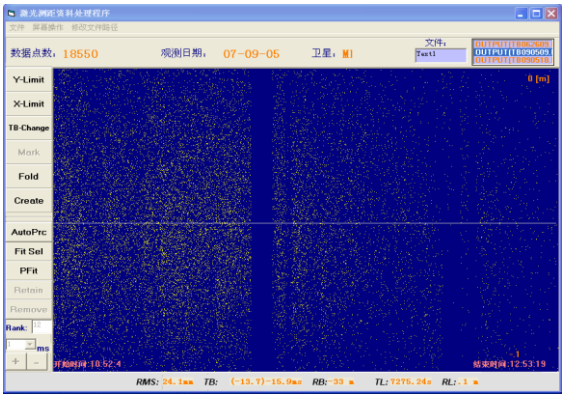

Figure 9. Range residuals after data fitting

The comparison of the return signal strength among the GNSS satellites had been done during several nights. The return signal strengths from COMPASS-M1 were much stronger than those signals from GPS-35/36 and GLOVE-A when these satellites were at the same elevations. More careful comparison of the signal strengths among the GNSS satellites have been carried out by some of the ILRS stations since December 2008.

Summary

The shape and parameters of 12 sets of the LRAs of the COMPASS satellites are introduced in this paper.

（1） It is shown from the ranging data of the COMPASS-M1 at the Changchun station that the performance of the LRA of the COMPASS-M1 is excellent, and the return signal strength from the COMPASS-M1 is much stronger than those from GPS-35/36 and GIOVE-A.

（2） The uncoated corner cubes are fine for the high orbit satellites, such as GNSS and GEO satellites.