Progress in SHAO 65m Radio Telescope Antenna

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***Abstract*-The SHAO 65m radio telescope is the largest fully steerable radio telescope antenna in China, operating at decimeter to millimeter wavelength. This paper describes the design, main technical feature and progress in construction of the telescope antenna.**

I. INTRODUCTION

In accordance with the demands of the radio astronomy research as well as the needs of Chinese Lunar exploration and deep space exploration missions, a fully steerable 65m radio telescope with the advanced state of art is being built. It will be located at Sheshan Station, Shanghai Astronomical Observatory (SHAO), in Songjiang County, about 30km far away from Shanghai center.

The SHAO 65m radio telescope antenna is a shaped Cassegrain antenna, operating in the frequency range from 1 to 50GHz. To realize such frequency coverage, seven receivers are adopted, including two dual band ones (S/X and X/Ka). For Phase I construction, the telescope antenna will work below X band using homology method[1]. And in Phase II, active surface will be employed to enhance performance at higher frequency. After over 3-year construction, the Phase I is almost finished. Table I gives a summary of basic parameters of the SHAO 65m radio telescope antenna.

II. TECHNICAL FEATURES

A. Optics

The SHAO 65m radio telescope antenna has a sub-reflector of 6.5m in diameter, illuminated by feeds of 13 degree half opening angle. The reflectors are shaped[2] to achieve higher

TABLE I
BASIC PROPERTY OF THE SHAO 65M RADIO TELESCOPE ANTENNA.

Aperture	65m
Frequency band	L, S, C, X, Ku, K, Ka and Q dual band observation for S/X and X/Ka band)
Optics	Shaped Cassegrain, f/D(Main-reflector)=0.32, f/D(effective)=2.2
Antenna efficiency (at best elevation angle)	⩾55~65% (L-K Band); ⩾50% (Ka Band) ⩾45% (Q Band)
Main reflector	Single panel surface accuracy ≤ 0.10 mm rms Total accuracy ⩽0.6 mm rms (without active surface, best elevation angle)
Sub-reflector	Single panel surface accuracy ≤ 0.05 mm rms Total surface accuracy ≤ 0.1 mm rms.
Maximum slew rates and acceleration	Azimuth: 0.5 (°)/s, 0.25 (°)/s^2 Elevation: 0.3 (°)/s, 0.15 (°)/s^2
Travel range	Azimuth: ⩾270°, Elevation: +5°~ +88°
Tracking& Pointing accuracy	High accuracy: ⩽ 3 arc-seconds, rms (wind speed⩽ 4m/s, temperature variation⩽2°C/h)

Figure 1. The SHAO 65m radio telescope antenna.

aperture efficiency (~70%) and control the first sidelobe level below -20dB, minimize the VSWR via reduce center illumination, and decrease the spillover from the edge of the main-reflector, which contributes low side lobes and low antenna noise temperature. An additional merit of shaped configuration is that it is less sensitive to illumination variance from the feed, which is nearly inevitable for wideband feed.

The corrugated horns are used for all feeds, including two dual band ones for S/X and X/Ka bands.

B. Mechanical Structure

The antenna design is based on the classical wheel-and-track configuration (Fig. 1 and 2), consisting of reflector (main and sub- reflector), mount and feed cabin.

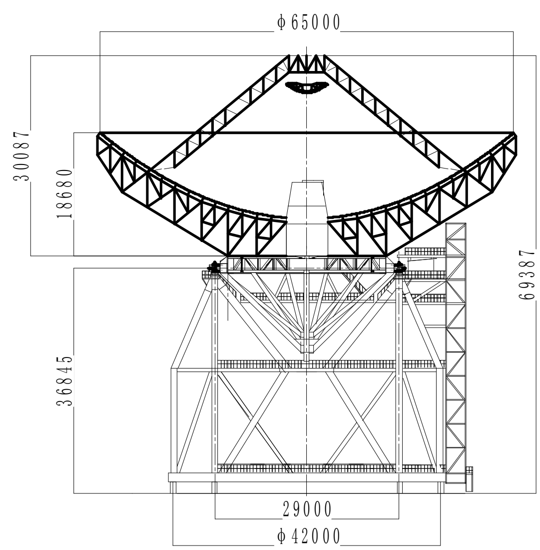


Figure 2 Mechanical drawing of the SHAO 65m radio telescope antenna.

The main reflector consists of 1008 solid aluminum panels and a backstructure. 1104 actuators are mounted on the backstructure to support the 1008 panels with 4-point support for each panel. The high accuracy panels with slot ribs are adopted to realize the surface accuracy ≤ 0.1 mm rms.

The sub-reflector surface consists of 25 solid panels, adopting double layer honeycomb sandwich structure to realize a surface accuracy ≤ 0.05 mm rms. The sub-reflector adopts 6-UPS parallel mechanism to accomplish 5 freedom degrees adjustment in real time for the sub-reflector when the antenna rotates in elevation.

An elevation over azimuth mount with wheel track configuration is adopted in the mount design. The antenna mount is space struss composing rectangular beam. Azimuth structure is supported by 6 groups of wheel. Combination structure of double layer octagonal beam and conical space struss is introduced in antenna support design. The mount structure is symmetrical, and the azimuth and elevation axes intersecting at one point in space.

8 motors are used for azimuth driving and 4 motors for elevation. The elevation driver suspends on the elevation gear. The azimuth and elevation driving devices adopt electric antibacklash to eliminate backlash, all the driving boxes adopt planetary gear reducer. Encoder connection adopts leading axis from the centre of rotation to improve connection precision.

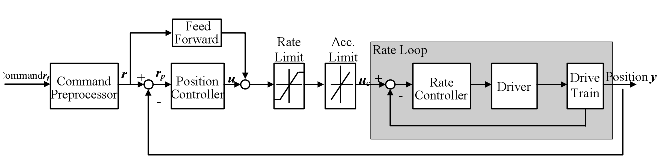
32 sections of track, made of high quality alloy steel, are assembled by welding to form the whole track on the site, with plane accuracy less than 0.45mm rms.

C. Servo System

Servo system is a high performance fully digital control system. It can be remote controlled by main controller and automatic working without any local operator. Servo system adopts multi-motor pre-tension anti-backlash drive mode，a classical three feedback loops (position, rate and torque) control architecture. It also has high accuracy encoder (32bit resolution and 1 arcsec system accuracy), high performance safety inter-lock logic, satisfied in EMC, and site environment flexibility. Blended control methods (CPP+FF+PID) are used now and a robust controller (LQG) will be applied for improving tracking accuracy (the aim is 2 arcsec) in near future.

D. Feed Switching

The SHAO 65m redio telescope antenna operates at L, S, C, X, Ku, K, Ka and Q bands, and all feeds locate at the second



* CPP=Command Pre-processor
FF=feedforward
LQG=Linear Quadratic Gauss

Figure 3. Diagram of servo system.

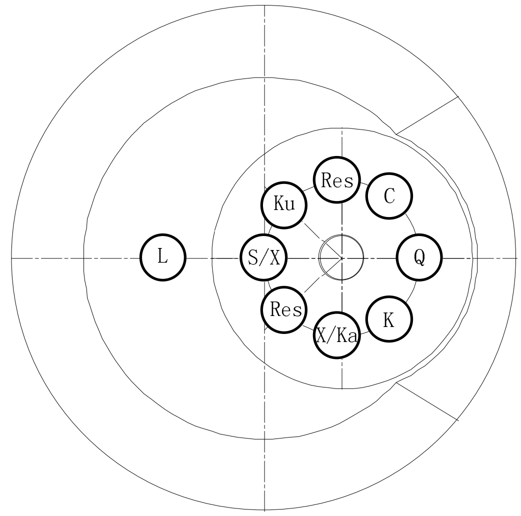


Figure.4 Top View of Feed Placement.

focus. To realize feed switching effectively, a combination scheme is adopted. For the L-band feed, because of its huge physical size, it is placed offset the second focus. And when L-band observation is required, the sub-reflector will point to it. All other feeds are placed at a turret of 2m diameter and frequency switching is achieved by rotating the feed turret. The structure schematic diagrams are shown in Fig. 4. As shown in Fig. 4, two vacant positions are reserved on the turret for further update.

III. PROGRESS IN CONSTRUCTION

The milestone of SHAO 65m radio telescope antenna are listed in Table II.

Table II
MILESTONES OF SHAO 65M RADIO TELESCOPE ANTENNA.

No.	Time	Description
1	January 2009	Kicking off
2	September 2009	Passed the international review
3	October 2010	Started antenna assembling
4	July 2012	Completed antenna assembling
5	October 2012	A series of measurements were made and the L, S/X, C band feeds debugging completed.
6	June 2013	Phase I construction acceptance

Fig. 5 shows the pictures of the whole assembling process.

(a) 2011.05 (b) 2011.10

(c) 2011.10

(d) 2012.03

(e) 2012.04

(f) 2012.10

Figure 5 Assembly of the SHAO 65m radio telescope antenna.

After the dish assembly completion, the measurement of the total surface accuracy was made and the result showed that, accuracies of 0.571mm rms and 1.13mm rms were achieved at 50degree and 10 degree elevation respectively. Fig. 6 gives the comparison between measured pattern and simulation at X band.

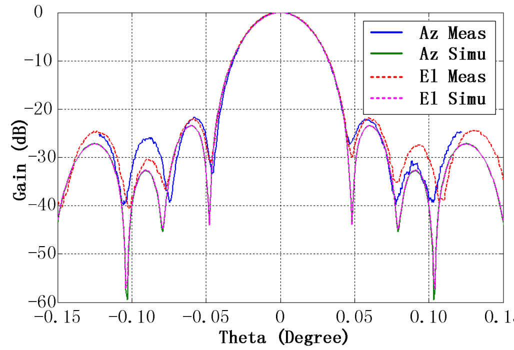


Figure 6. Measured X-band pattern

IV. Conclusion

After four-year design, manufacture, assembling, integration, and debugging, the Phase I construction of the SHAO 65m radio telescope antenna is nearly completed.

References

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[3] "Shanghai 65m Radiotelescope Antenna System Design Document," report, 2009.