Design of the 4.5m Polar Axis Antenna for China Spectral Radio Heliograph Array

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***Abstract-The 4.5*m polar axis antenna with polar Axis mount and dual circular polarization ultra-wideband feed over 0.4-2GHz for China Spectral Radio Heliograph (CSRH) array is presented in the paper. The CSRH array and specifications of 4.5m polar axis antenna are introduced. The detailed design procedure about antenna system together with the structure of polar Axis mount, ultra-wideband feed, parabolic reflector and consideration for practical installation are described. The voltage standing wave ratio (VSWR) and radiation patterns of the feed for 4.5-m antenna have been tested, and the measured efficiency of the 4.5-m reflector antenna is better than 40%, The performance fulfills application requirements.**

I. INTRODUCTION

The sun is very important for human. She supplies light and heat constantly for life on earth just like the earth's mother. But the sun's activity has a significant impact on the earth and human. Such as the rainfall at an area has some correlation with the variation cycle of macula, and also the electromagnetic wave produced when solar flare breaking out can result in the discontinuous of radio-communication. The radio wave radiated by sun has different characteristics, so it's a very important method for the sun research by the radio observations with the radio-wave[1].

Chinese Solar Radio heliograph project（CSRH） observes the activity of the sun and explores the coronal atmosphere with high resolution over 0.4-15GHz[2]. The scientific goals include the instantaneous high-energy phenomenon, the Coronal magnetic field and the structure of solar atmosphere[3]. By confirming the source area features of solar flare and mass ejection of the coronal materials, we can understand the solar dynamic transition zone and the Coronal.

Construction of CSRH are planned into two stages：the phase I of CSRH is comprised of 40 reflector antennas with 4.5-m dishes from 0.4-2GHz and the phase Ⅱ of CSRH is comprised of 60 reflector antennas with 2-m dishes from 2 -15GHz. CSRH is located in Inner Mongolia about 400km away from Beijing. All the 100 antennas are mounted equatorially and spread in $3\times3km^2$ areas, a radio quiet zone surrounded by hills [4]. The 4.5m antenna array is shown in Figure.1[5]. The reflector antennas are arranged in three spiral beams in the plane with same height to get good UV coverage. The electrical specifications of the dual polarization feed are summarized in Table 1.

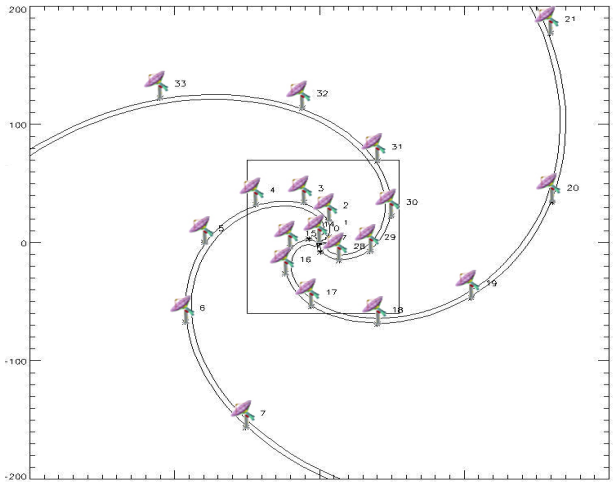


Figure.1. 4.5-m Radio Telescope Antenna Array.

Tab.1. Specifications of the 4.5m antenna

Items	Parameters
Antenna type	Polar Axis Antenna
Diameter	4.5m
Diameter ratio (f/d)	0.4
Frequency band	0.4~2.0 GHz
Antenna efficiency	40%
First side-lobe level	≤-14dB
Polarization	Dual-CP
Surface accuracy	≤ 3mm
Pointing accuracy	≤9′ (R.M.S)
Travel range (Equatorial)	-95°~95°
Travel range (Latitude)	30°~ 48°

In this paper, detailed design of the constituted antenna is presented, including ultra-wideband dual circular polarized feed, parabolic reflector, polar mount, together with the measured results of the antenna.

II. ANTENNA DESIGN

A. Antenna System

The 4.5m antenna consists of the antenna feed, the reflector, mount, pedestal, and servo control system. The reflector is paraboliod, assembled with 12 identical fan-shaped reflectors and the framework. And the mount consists of latitude support saddle, latitude bearing, latitude gear, declination gear, equatorial driving device, latitude driving device, and a counter weight[6].

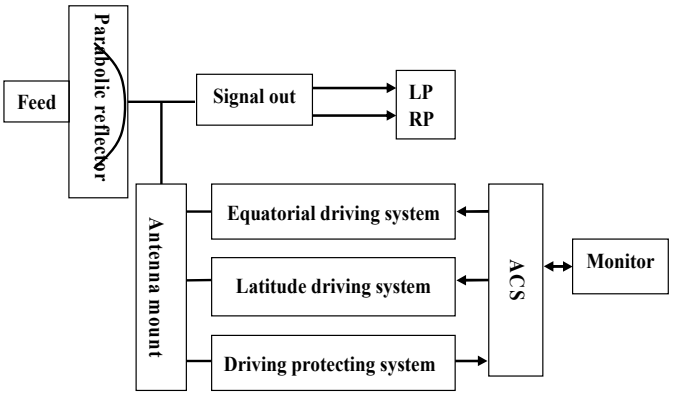


Figure.2. 4.5-m Antenna System.

The servo control system consists of the control circuit, the equatorial power amplifier, the latitude power amplifier, the outward interface and so on. Figure.2 shows the system composition block diagram.

B. Polar Axis Mount

The polar axis mount is also called the equator mount, which consists of two axes. The down axis is called the latitude axis because it parallel with the earth's rotational axis. And the upper axis is called the equatorial axis[6]. This mount is widely used in the radio telescopes because of its ease to tracking a fixed star. The antenna can be kept aiming at the object star just by rotating the latitude axis.

The 4.5m antenna uses the equator mount, which consists of the latitude axis device, the equatorial axis device, and the foundation. Figure.3 shows the structure form of the mount. The latitude axis and the equatorial axis cross at a point. The merit of this kind mount is that only the equatorial axis balance is needed.

C. Parabolic Reflector

The CSRH antenna uses a front-fed parabolic reflector of 4.5m diameter, and 0.4 f/D ratio, corresponding to an illumination angle of 128°.

Figure.4 gives the structure of the parabolic reflector. It consists of reflector, radial beam unit, and centrosome.

The reflector is assembled with 12 identical fan-shaped mesh panels and the framework. The merit of the mesh panel is the good consistency and surface accuracy[7].

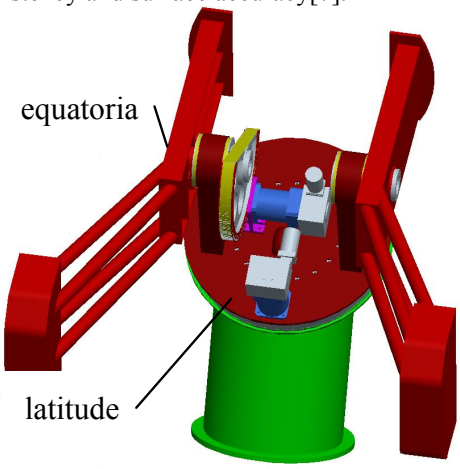


Figure.3. Structure of polar Mount.

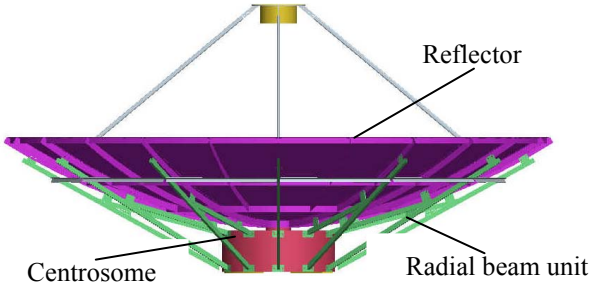


Figure.4. Structure of polar Mount.

To make sure that the panel has a good manufacture precision, uses the high-precision mould and frock are adopted in every manufacture procedure. All of the above ensure that the antenna has good rebuilt precision and a low air drag coefficient.

D. Ultra-wideband Feed

As a wideband feed, both the impedance and radiation requirement should be fulfilled over the operating band, including return loss, illumination pattern and phase center[8]. Frequency independent antennas are good candidates to satisfy the first two requirements, and the conception that using a set of Log-Periodic antennas for the feed has been implemented in a few projects. However, the inconstant phase center results in pattern degradation and efficiency loss, which becomes unacceptable when the operating band is very wide. The idea inspired by the Eleven feed that implementing a ground plane to stabilize the phase center was introduced in CSRH array feed design[8][9][10].

Photograph of the ultra-wideband feed is shown in Figure.5. The dimensions of the feed are 465mm (l) ×465mm (w) ×185mm (h), including 20mm feed radome and bridge height. The radiation part of the feed is machined from metal plate with 3mm thickness to enhance mechanical performance and only supported by Teflon posts at certain points to reduce loss.

III. MEASUREMENT RESULTS

Photograph of the fixed 4.5m polar axis antenna is shown in Figure.6. The measured VSWR with 90° hybrid of the UWB feed are shown in Figure.7, and the measured patterns of the 4.5m polar axis antenna over operating band are shown in Figure.8[11]. It can be seen that a VSWR below 1.7 was achieved, and the first side-lobe level is better than -14dB.

The measured antenna efficiency on 4.5-m reflector antenna is shown in Figure.9 and it is better than 40% over the operating band.

Figure.5. Photograph of the 0.4-2GHz UWB feed.

Figure.6. Photograph of the 4.5m polar axis antenna.

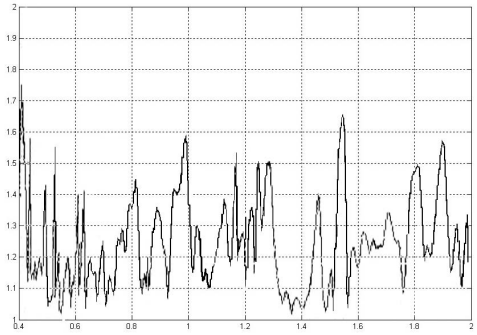
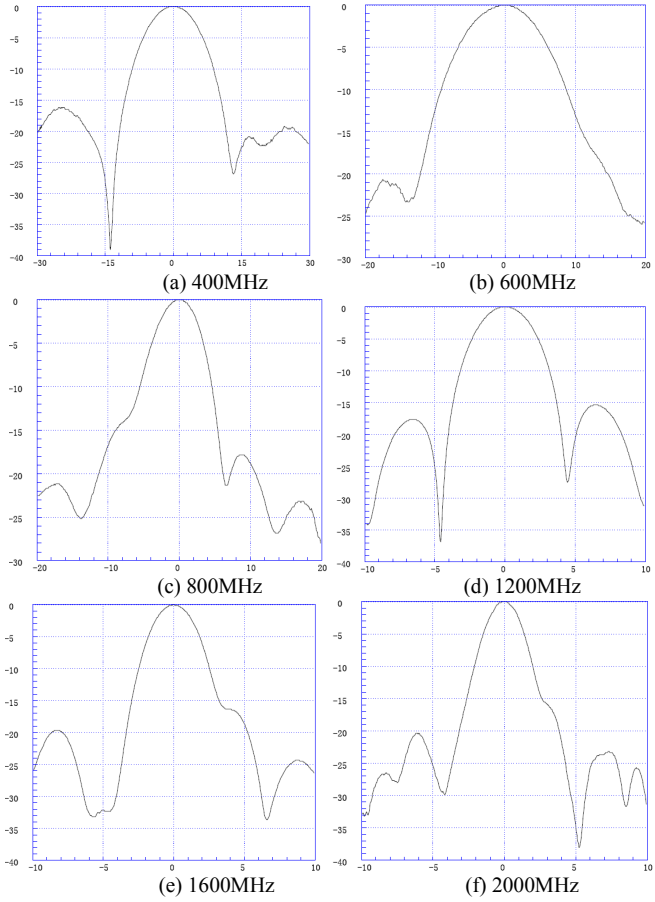


Figure.7. Measured VSWR of the UWB feed.



(a) 400MHz (b) 600MHz (c) 800MHz (d) 1200MHz (e) 1600MHz (f) 2000MHz

Figure.8. Measured patterns of the 4.5m antenna

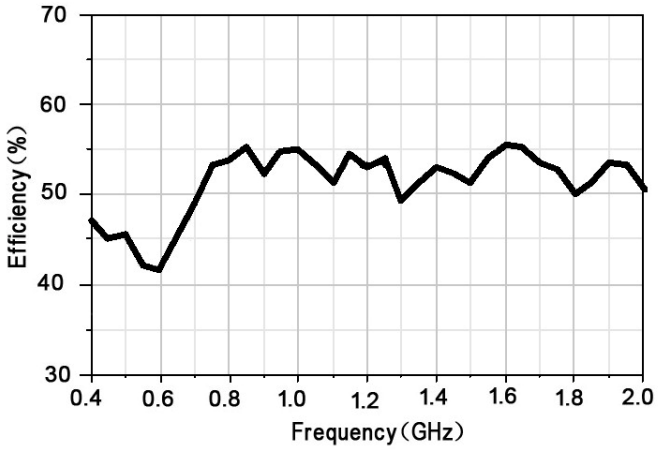


Figure.9. Measured antenna efficiency on 4.5-m antenna.

IV. SUMMARY

In this paper, the 4.5-m polar axis antenna with polar Axis mount and dual circular polarization ultra-wideband feed over 0.4-2GHz for CSRH array is presented. Several key technologies are solved, such as dual circular polarization ultra-wideband and high efficiency feed technology[12], low loss feed network, new concept design on the polar axis mount. The measured results show that the performance fulfills application requirements.

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