An Introduction to the Miyun 50m Radio Telescope

C. Jin, H. Wang & X. Zhang

(*National Astronomical Observatories, Chinese Academy of Sciences, Beijing* 100012)

Abstract The National Astronomical Observatories of China is planning to build a 50m radio telescope at Miyun Station. In this paper, we briefly introduce the scientific motives and the design specifications of this radio telescope. The primary scientific motive is the gravitational wave detection by long-time monitoring of a group of millisecond pulsars. A digital backend like COBRA (Kramer et al. 2001) is under consideration. Other applications of the telescope are also introduced.

1 Introduction

Pulsars are rotating neutron stars. Since first discoveries more than 30 years ago, it has become a very attractive object to astronomer because of the extreme density and activity. We can consider a pulsar, especially millisecond pulsar (Backer et al. 1982), as a very precise natrual clock on the sky. Early in 1979, Detweiler considered the influence of gravitational wave on this natrual pulsar clock, and suggested the method to detect gravitational wave by mornitoring pulsar periods (Detweiler 1979) . A group in Princeton has made long term monitoring of millisecond pulsar using the Aricebo telescope. They had reached an accuracy which is comparable with that of atomic clock (Paspi, Taylor, & Ryba 1994) . However, the sensitivity requirement made such experiments only could be performed with few large radio telescopes. But these large telescopes are always occupied with various observational tasks, thus could not be fully devoted into pulsar observations.

In 2000, Prof. Wang Shouguan has proposed to build a low-cost L-band 50m pulsar radio telescope at the Miyun Station. The main scientific motive is the gravitational wave detection, by doing long-time mornitoring of millisecond pulsars. With the relatively large collecting area, this telescope could carry out other astronomical observations (e.g IPS, SNR) . And it also could act as an element, to join the current VLBI array.

We introduce the 50m telescope in this paper. In the following section, we describe the design specifications and expected performation of the telescope. In the third section, the status of the project is introduced. In the fourth section, other possible astronomical applications are introduced. In the last section, a summary is given.

2 Design Specifications and Expected Performance

2.1 Design Specifications

Considering the sensitivity requirement for pulsar observations and the limited budget available, we have decided to build a L-band 50m radio telescope. The main design specifications are presented in Table 1.

COBRA-Coherent On-line Baseband Recorder for Astronomy.

IPS - Interplanetary Scintillation.

Table 1 The main design specification of the 50m radio telescope

Dish diameter	:	50 m
Mounting	:	Altitute-Azimuth
Surface	:	Aluminium plate (inner 30 m) Welded metal mesh (outer part)
RMS surface accuracy	:	1 mm (inner 30 m) 3 mm (outer part)
Short wavelength limit	:	2 cm (inner 30 m)
Pointing accuracy	:	19 arcsec
Slew rates (elevation)	:	0.5 degree per second
Slew rates (azimuth)	:	1.0 degree per second
Optics	:	Prime focus, f/D= 0.35

Large bandwidth is needed to meet the sensitivity requirement for pulsar observations. The ionized ISM, through with the radio signal propagates before reaching us, would cause a dispersion to the received signal. This despersion effect would then lead to a smearing of the pulses when observing on earth with a finite bandwidth. One method to reduce this dispersion is to divide the observing bandwidth into small channels, and then record the signals from the small channels separately. After that, the signals from different channels are combined together, taking the time-delay among the channels caused by the dispersion effect into account. This method could reduce the dispersion to a large extent, and is widely use for many years. But small residual smearing still resides within each channel, and the response time of the filters prevent dividing the observing bandwidth into more narrower channels. The coherent de-dispersion method (Hankins & Rickett 1975) can, in principle, remove the dispersion completely when the dispersion measure is known in advance. This method require the phase information of the signal to be kept during the data processing procedure. However, the required large computational power made this method routinely implemented possible only in recent years. The de-dispersion calculation could be done in hardware (Backer et al. 1997) or software (Stairs et al. 2000), eighter on-line or off-line. Jodrell Bank now are developing a Coherent On-line Baseband Recorder for Astronomy (COBRA), which will perform the pulsar data processing on-line in software (Kramer et al. 2001) .

We plan to equit the new 50m radio telescope with a COBRA-like digital backend system, but with a wider bandwidth of 300 MHz. The NAOC and JBO have signed a Memoremdum of Understanding concerning cooparation on developing the receiver system for this 50m telescope. The pre-detection votage data will be sampled and processed on-line, these offers large flexibility to the data processing.

2.2 Expected performance

Table 2 Expected performance at L-band

Antenna Efficiency	:	50%
System Temperature	:	30K
Center Frequency	:	1665 MHz (18cm)
Bandwidth	:	300 MHz
Sensitivity	:	0.3 mJy (30minutes, 300MHz)

The expected performance of the 50 m radio telescope at L-band is presented in Table 2. At L-band, the whole aperture will be used, the total effective collecting area is about 1000 squre meters. The lower limit of observable flux density is 0.3mJy, with 30 minutes integration time and 300 MHz observing bandwidth. If we extend the integration time to 10 hours, then the sensitivity would be 0.07mJy. With sensitivity like this, more than 30 millisecond pulsars could be monitored. This is esential to our prime scientific objective – the gravitational wave detection.

3 Status of the Project

In the second half of 2001, we invited four domestic institutes to make conceptual design for this 50 m radio telescope. By comparing their designs and considering their background in telescope-related domain, we have chosen the 54th institute to build the telescope for us. Their conceptual design is shown in Fig 1. This is a traditional wheel-on-track system. The r.m.s. error of the surface within central 30 meter is 1 mm, thus the telescope can work up to 15 GHz.

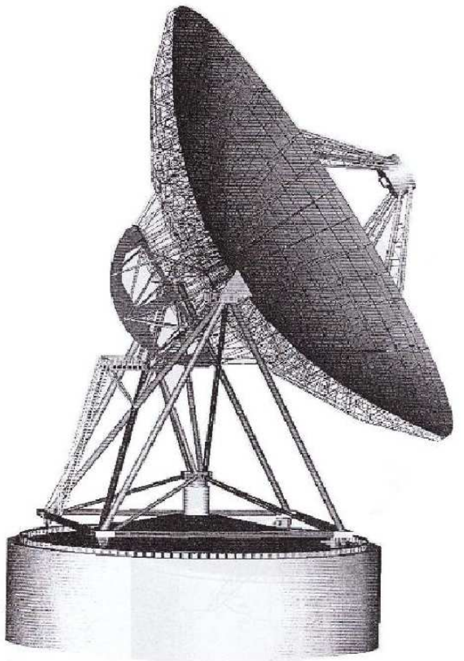

Fig. 1 The conceptual design of the 50m radio telescope

The NAOC and the 54th institute have signed the contract of building the 50m telescope. The construction of the telescope is schedueled to be completed at the beginning of 2005.

4 Other Astronomical Applications

4.1 IPS Observations

The first IPS observation was carried out at Miyun Station with the MSRT radio telescope (Wu, Zhang, & Zheng 2001) . With the relatively large collecting area, the 50m telescope could also do IPS observations. And larger collecting area could be obtained by combining the signals from the MSRT and the 50 m telescope together.

4.2 Extending the MSRT and a VLBI unit

The 50 m will be located near the current MSRT. The MSRT is an east-west earth rotation synthesis array, consisting of 28 9 m radio telescopes. The sensitivity of the array will be increased by a factor of 2 after the signal from the 50 m telescope is combined.

Due to its location and relative large collecting area, the 50 m telescope could join the current VLBI array. The 50 m telescope covers most of the EVN working frequencies. The antenna locations of the current EVN and the 50 m telescope is shown in Figure 2. The 50 m telescope will contribute mostly on the longer baselines.

Fig. 2 The EVN and the Miyun station. The circled position is the Miyun Station.

4.3 Space missions

The telescope could work up to 15 GHz, and it is the largest singal dish in China. If equipped with proper receiver and transmitter, it then could act as a ground station to telecommunicate & receiving data for space missions (e.g. the coming WSO project) .

5 Summary

We introduced the new 50m L-band pulsar radio telescope. The main scientific motive is gravitational wave detection, by long-time mornitoring of a group of millisecond pulsars. With the relatively large collecting area, this 50m radio telescope could carry out other astronomical observations, e.g. IPS, SNR, etc. The telescope could also join the current VLBI array. Being the largest singal dish in China, it could also work as a ground station for space missions.

ACKNOWLEDGEMENTS We thank the four domestic institutes that participated in this project. The figures about the conceptual design of the telescope were provided by the 54th institute.

References

Backer D.C., Kulkarni S.R., Heiles C., et al., Nature, 1982, 300, 615
Baker D.C., Dexter M.R., Zepka A., et al., PASP, 1997, 109, 61
Detweiler S., ApJ, 1979, 234, 1100
Hankins T.H., Rickett B.J., In: Methods of Computational Physics. Radio Astronomy. New York: Academic Press, 1975, 14, 55
Kramer M., Lyne A.G., Joshi B.C., et al., Contribution to SKA/RFI mitigation workshop, Boon, 2001
Paspi V.M., Taylor J.H., Ryba M.F. ApJ, 1994, 428, 713
Stairs I.H., Splaver E.M., Thorsett S.E., et al., MNRAS, 2000, 314, 459
Wu J., Zhang X., Zheng Y., ApSS, 2001, 278, 189