Introduction to FAST - Five Hundred meter Aperture Spherical radio Telescope

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Abstract

FAST, Five hundred meter Aperture Spherical radio Telescope, is the Chinese effort for the international project SKA. The innovative engineering concept and design pave a new road to realizing huge single dish in the most effective way. Funding for Project FAST has been approved by the National Development and Reform Commission NDRC in July of 2007. Being the most sensitive radio telescope, FAST will enable astronomers to jumpstart many of science goals, for example, the natural hydrogen line surveying in distant galaxies, detecting faint pulsars, looking for the first star shining, hearing the possible signal from other civilizations and etc.

1. Introduction

A tentative project, the Large Telescope (LT), which nowadays is referred to as the Square Kilometre Array (SKA), was proposed by astronomers from 10 countries including China at the General Assembly of the International Union of Radio Science (URSI) in 1993, beginning a worldwide effort to develop the scientific goals and technical specifications for a next generation radio telescope. Different technological solutions have been brought forward and studied by institutes participating in the SKA, and will be selected and integrated into the final instrument. FAST to be built in a karst depression in Guizhou province of southwest China is the Chinese engineering concept proposed and extensively investigated since 1994 for realizing the SKA units. Cooperating with Chinese and international astronomical communities, FAST team of the National Astronomical Observatories has successfully conducted studies on the critical technologies including site surveying, an active reflector, a light-weight feed support system, remote and accurate measurements, control and receivers.

An international review and advisory conference on science and technology of FAST was held in Beijing in March of 2006. The review panel unanimously concludes that the very exciting FAST Project is feasible and recommends that the project moves forward to the next phase of detailed design and construction as soon as possible. Funding for project FAST finally has been approved by the National Development and Reform Commission, NDRC, in July of 2007. The approved budget is now CNY 627M and the construction period is 5.5 years from the foundation in early 2009.

2. FAST Sciences

Being the world largest filled-aperture telescope located at an extremely radio quiet site, the FAST science impact on astronomy will be extraordinary, and will certainly also revolutionize other areas of the natural sciences. Its unique contributions to science may not yet be fully redictable at present. The headline science topics as discussed upon in 2007 are as follows [1]:

- Large-scale surveys for HI emission from galaxies. The FAST sensitivity with an interference-free observing period of 1 h would enable an HI survey of galaxies out to a red-shift of 0.7, which can constrain the equation of state of the Dark Energy and help understand the evolution of galaxies.

- Pulsar surveys. High sensitivity and larger sky coverage compared with Arecibo make FAST a powerful tool for detecting those weak emission pulsars at large distances, like millisecond pulsars, binary pulsars, double pulsars, extragalactic pulsars, etc. It is estimated that FAST equipped with multi-beam receivers would detect some 7000 pulsars in the Milky Way Galaxy in less than a year of observing time. FAST would be able to detect some tens of pulsars in M31 with about 10 h of observing time. Other galaxies in the local group, like M33, might also turn up positive detections.

- Molecular line emissions. About 20 percent of molecular lines are observed in centimeter and decimeter bands. The operating frequencies of FAST cover 17 lines, including hydroxyl, methyl alcohol (CH3OH), formaldehyde (HCHO), etc. FAST is able to make deep surveys of the molecular masers in our galaxy as well as in the other distant galaxies. Most distant OH mega-masers observed by the Arecibo at z ~ 0.6, a similarly bright object would be detected by the FAST at z ~ 1.

- Very Long Baseline Interferometry. The image sensitivity of VLBA alone at L band is 80 μJy/beam. HSA, High Sensitivity Array which consists of full VLBA, Effelsberg and GBT 100, and VLA, gives a sensitivity of 5.5 μJy, the sensitivity would be 3.1μJy, if Arecibo is replaced by FAST. This will promise a new avenue for scientific discovery.

3. General technical specifications

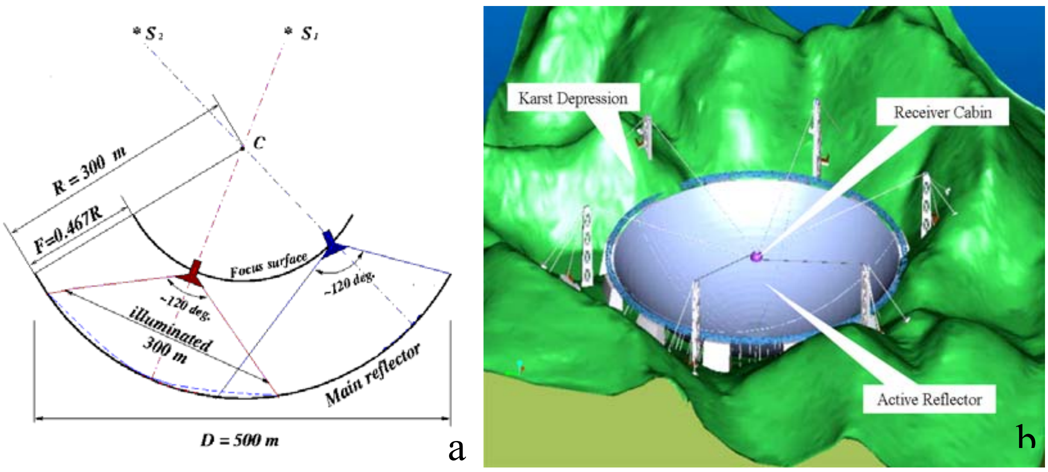

Fig.1 (a) Optical geometry, (b) FAST 3-D model

FAST is an Aricibo-type spherical telescope. Figure 1b shows its three outstanding features: the unique karst depressions found in south Guizhou as the sites [2], the active main reflector of 500 m which directly corrects for spherical aberration [3], and the light-weight focus cabin driven by cables and a servomechanism [4] plus a parallel robot as a secondary adjustable system to carry the most precise parts of the receivers. Inside the cabin, multi-beam and multi-band receivers will be installed covering a frequency range of 70MHz - 3 GHz. The telescope will be equipped with a variety of instruments and terminals for different scientific proposes. The main technical specifications of FAST are listed in table 1.

Table 1 FAST main technical specification

Spherical reflector：Radius ~ 300m, Aperture ~ 500m, Opening angle 110 ~120°
Illuminated aperture：D_{ill} =300m
Focal ratio：f/D =0.467
Sky coverage：zenith angle 40°, tracking range 6 ~ 8h
Frequency：70 MHz - 3 GHz（up to 8GHz, future upgrading）
Sensitivity (L-Band) ：A/T ~ 2000, Tsys ~ 20 K
Resolution (L-Band) ：2.9′
Multi-beam (L-Band) ：19, beam number of future FPA >100
Slewing：<10min
Pointing accuracy：8″

Deep depression and focus cabin suspension system enable FAST reflector a large opening angle, therefore, enable the telescope a large zenith angle up to 40° with full 300 m illuminated area. Larger zenith angle up to 60° is feasible as particular feeding technology, such as Focal Plane Array, is employed at the focus in the future, which will extend the sky-coverage of FAST beyond the galactic center. The raw sensitivity at L – band, the core band for most significant sciences of FAST, reaches 2000 $m^2 K^{-1}$, owing to the huge collecting area and up-to-date receiving system. Nineteen beams of horn-based receivers at the band are planned to increase survey efficiency. Maximum slewing is set as 10 minutes which is restricted by power of high-voltage electromotor as the longest travel of focus cabin is required across the space.

4. Critical technologies

A feasibility study of critical technologies started in the National Astronomical Observatories since 1994. More than a hundred scientists and engineers from 20 institutions are involved in this joint research. These critical technologies to be employed in future construction have been certified and are listed as bellow:

- Site surveying. The practical way to build a large spherical telescope is to make extensive use of existing depressions which are usually found in karst regions. Since 1994, site surveying started in Guizhou province, including geo-morphological features and the distribution of the karst depressions, climate, engineering environment, social environment, and radio interference. Depression Dawodang has been selected as the site of the antenna, having a diameter ~ 800m and location at N25.647222º E106.85583°.

- Active reflector: The central part of a spherical surface is very nearly a paraboloid of revolution when a proper focal length is chosen. If the focal length is set to be 0.467R, the maximum deviation will be minimized to 0.67 m within the 300 m illuminated aperture (Fig.1a). Triangular segmentation of the surface is employed. All the sides of the triangles are small sects from the great circles on the neutral spherical cap. There are ~ 4600 triangular panels in total on the surface supported by a cable mesh composed of ~7000 strands of steel cables. This results in ~2400 nodes in the network, therefore, ~2400 driving cables down-tied to winches on the ground. During observations, winches adjust these cables to shape the reflector according to feedback from the ranging system for the control.

- Cabin suspension. Focus cabin is suspended by six towers and six cable-capstan drives, providing the preliminary positioning via evaluation of the actual position of the cabin and length variations of suspension cables. This is realized through a closed loop control with a controller bandwidth below the basic mechanical resonance modes of the cables (0.18 Hz). An “elevator-type” counterweight is introduced for each tower to counteract the steady state cable force and reduce the power consumption. There is no intention to control the “natural” tilt of focus cabin in the design. Instead, the difference between it and the required tilt is mainly compensated by a “slow” rotator, so called X-Y positioner, to which six “fast” Stewart actuators, the secondary adjustable system, are attached to correct the remaining pointing errors.

- Receivers. The active main reflector design enables the use of feeds at the primary focus. In the current design, 9 sets of receivers will be used to cover frequencies 70 MHz - 3Ghz. Log-periodic feeds will be used for frequencies lower than 1GHz. At frequencies higher than 1GHz, feed horns will be employed. In particular, a 19-beam multi-horn receiver is planned for L-band. For frequencies higher than 0.5GHz, the receiver will be cooled. The IF signals will be transmitted down to observing building via optical fibres. FAST will be equipped with dedicated digital backends for various observing modes, including pulsar de-dispersion, spectral line, SETI and VLBI observations.

5. Acknowledgments

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6. References

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