Design of Antenna Array for the L-band Phased Array Feed for FAST

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Abstract-**The Five-hundred-meter Aperture Spherical radio Telescope (FAST), which is currently under construction, is proposed to be equipped with phased array feed (PAF) to improve survey speed and compensate for the feed cabin vibration, and a study is underway for this. In this paper, the L-band FAST PAF plan is introduced，and the design of antenna array element is presented in detail. The measured results of the fabricated element validate the element design.**

I. INTRODUCTION

The concept of phased array feeds (PAFs), implementing a small phased array with digital beamforming network as the feed of radio telescope, is an emerging technology in radio astronomy to realize fast sky survey. Compared with traditional cluster horn feeds, PAFs are capable of continuous field-of-view (FoV), much more simultaneous beams of similar performance, and the capability of RFI mitigation [1-3]. Currently, a series of development of PAF are underway and many progresses have been reported [3-7]. For the abuilding Five-hundred-meter Aperture Spherical radio Telescope (FAST), PAF will provide a great enhancement in L-band observation than the schemed 19-beam cluster feed receiver.

Key preliminary performance requirements for a PAF on FAST are shown in Table I. The goal is a PAF with more than 100 simultaneous beams overlapped at 3dB points, covering a continuous 0.6×0.6 deg^2 FoV at L-band. All LNAs will be cryogenically cooled to realize low system temperature and highest sensitivity possibly. Such a system will be more efficient for wide-field sky surveys.

By the early of 2013, preliminary design of the L-band antenna array is completed and the fabrication for the FAST PAF prototype of smaller scale is ongoing. The prototype will be tested in 2014, and an array element has been manufactured and tested. The results are presented in this paper.

TABLE I
PERFORMANCE SPECIFICATION FOR L-BAND FAST PAF

Parameter	Quantity
Operating frequency range	1.05 ~1.45GHz
Instantaneous bandwidth	≥ 500 MHz
Effective f/D	0.4611
Field of view	0.6 *0.6 deg^2
Simultaneous beams	≥ 100
System noise temperature	25 K
Aperture efficiency	≥ 55% (in 300m diameter)
Low noise amplifier	Cryogenic

II. ARRAY CONFIGURATION

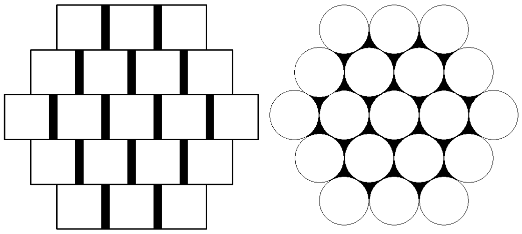
Based on the focal field analysis in conjugate with FAST optics [8], the reflected incident waves converge in a circular region of 2.6m in diameter at the focal plane at L-band. To effectively capture incident wave from different directions, a dense array is required to fill this region. For FAST PAF, a hexagonally arranged array of 217 dual-polarization elements is going to be adopted, with 0.66λ element spacing through optimization.

III. ELEMENT DESIGN

For phased array antenna, mutual coupling effect plays an important role in design. Ideas either utilizing or pressing this effect has been implemented in antenna design. Since the bandwidth of FAST PAF is not very challenging and the element spacing is larger than 0.5λ, mutual coupling reduction scheme is preferred.

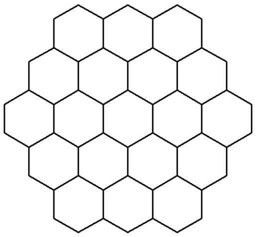
The term cavity-backed dipole, which is a combination of dipole and cavity, has better wideband property than dipole and symmetrical radiation pattern, which contributes to improve the illumination efficiency as a feed. Besides above merits, the cavity is introduced to increase isolation between elements in FAST PAF design.

The shape of the cavity is one of the key parameter in element design. Diagram of arrays of hexagonal arrangement consist of distinct cavity-backed dipoles are shown in Fig.1. Due to the physical confliction at each corner, interspaces between square cavities in the same row are the largest among the three candidates. Thus this kind of cavity accommodates better to rectangular arranged arrays. Circular cavity suits both rectangular and hexagonal arrangement, however, gaps between elements are inevitable. Hexagonal cavity makes full use of the array aperture and the increment in cavity aperture slightly improves the gain. Fig.2 gives a pattern comparison between the circular and hexagonal cavity-backed dipoles satisfying the same element spacing.



(a) Rectangular

(b) Circular



(c) Hexagonal

Figure 1. Interspaces between elements caused by different cavities.

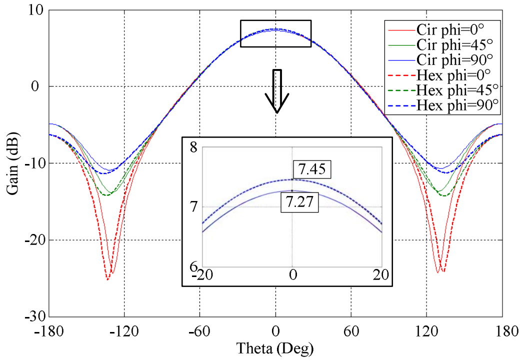


Figure 2. Comparison of patterns in free space between circular and hexagonal cavity-backed dipoles.

As Fig.2 shows, the hexagonal cavity dose not distort the symmetry of pattern and the corresponding gain is about 0.2dB higher than circular one. Since the gain relates to the effective receiving area, the hexagonal cavity-backed dipole intuitively capture more incident wave with the same element spacing.

A view of the hexagonal cavity-backed dipole from the top side is given in Fig. 5.

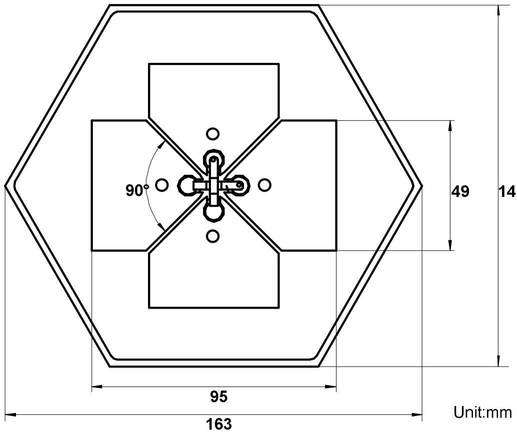


Figure 5. Mechanical drawing of the hexagonal cavity-backed dipole.

The hexagonal cavity is 50mm in height, and 141mm in diameter of the inscribed circle. Two orthogonally placed bowtie dipoles are employed as the radiator on the aperture of the cavity. The arms are design with a 90 degree opening angle and 49mm wide at the end point, 37.5mm long, and 1mm thick.

IV. MEASUREMENT RESULTS

Fig. 4 gives a photograph of the fabricated hexagonal cavity-backed dipole. A match plate of 70mm in diameter is employed at the top for lower VSWR, supported by four Teflon posts.

The measured results are shown in Fig.5 and Fig. 6. The measured reflection coefficients are below -15dB over the operating band.

Fig. 6 shows the normalized modeled and measured patterns at 1.25GHz. It is observed that the symmetry of measured pattern is not as excellent as simulation. This is caused by an imperfect balun. To make space for cables and LNAs, the feed gap is design to be 20mm long, resulting in balun degradation and modest pattern distortion. And a reduction in feed gap has been made to mitigate this effect in further design.

Figure 4. Photograph of the hexagonal cavity-backed dipole

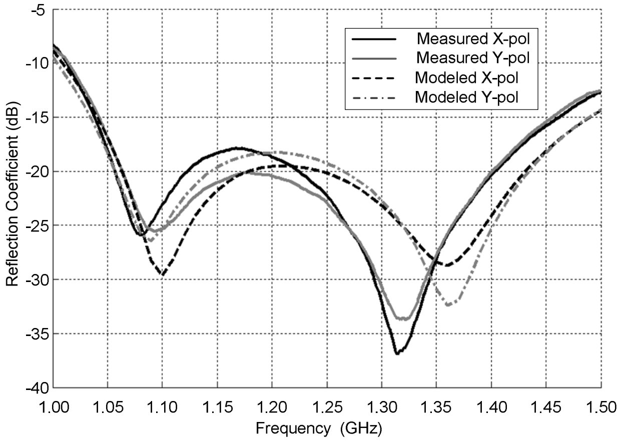


Figure 5. Measured and modeled reflection coefficient of the hexagonal cavity-backed dipole.

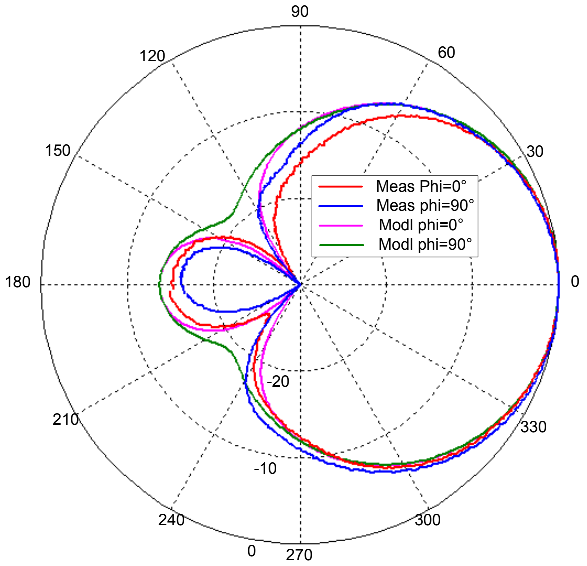


Figure 6. Measured and modeled pattern of the hexagonal cavity-backed dipole.

V. CONCLUSION

A study on PAFs for the FAST is underway. Consideration and design of the antenna array is present in this paper. The measured results of the fabricated element validate the design and a 19-element array is being manufactured.

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