URSI AP-RASC, Sydney, Australia, 17-22 August 2025

GPU-Based Key Technologies Research and Implementation of Real-Time PAF Digital Backend for FAST

Yuanqi Guo[(1)]
(1) National Astronomical Observatories, Chinese Academy of Sciences, Beijing, 100101, China, e-mail: yqguo@bao.ac.cn

Phased Array Feeds (PAFs) represent a significant innovation in modern radio astronomy observations, offering distinct advantages over traditional multi-beam feed systems. By leveraging advanced digital signal processing methods, PAF technology enables continuous large-field-of-view coverage and rapid sky survey capabilities, which significantly enhance the efficiency of telescope observations and provide more powerful tools for astronomical research.

In a PAF system, the digital backend plays a crucial role. It processes signals received from each array element, applying complex algorithms to perform high-precision beamforming and optimization. Research into key technologies for PAF digital backends is essential not only for improving system performance but also for advancing PAF technology itself.

In recent years, the rapid advancements in computer technology have opened up new opportunities for digital signal processing. The rise of Graphics Processing Unit (GPU) technology and High-Performance Computing (HPC) systems has enabled GPU-based parallel computing to replace traditional Application-Specific Integrated Circuits (ASICs) and Field-Programmable Gate Arrays (FPGAs) at lower costs and with shorter development cycles. This technological shift offers more flexible and efficient solutions for developing real-time PAF digital backends [1].

In response to the observational requirements of the Five-hundred-meter Aperture Spherical Telescope (FAST) [2], we conducted in-depth research on multiple key technologies for PAF digital backends using GPU-based parallel computing technology. Firstly, we addressed the issue of distributing and transmitting multi-channel high-speed digital signals. To ensure the timing precision and data integrity during signal transmission, we developed comprehensive multi-threaded data reception codes and optimized the receiving speed. Secondly, through software algorithms, we resolved the real-time signal synchronization and calibration issues among multiple signals across acquisition cards and within individual card, which is crucial for ensuring the accuracy of beamforming. Additionally, we designed and implemented digital beamforming algorithms in both time and frequency domains while exploring their respective applicability and advantages. By integrating these technologies, we successfully implemented a 24-channel PAF real-time digital backend system with 500MHz bandwidth and 8-bit quantization on a GPU server, and completed joint testing with our 19-element PAF fronted system. This accomplishment not only demonstrates the feasibility of GPU-based real-time processing solutions but also lays a solid foundation for the development of larger-scale PAF systems for FAST.

Currently, we are developing a more challenging 100+ unit dual-polarization PAF system for FAST. Over the next several years, we will focus on completing a comprehensive upgrade of the PAF backend system for FAST. With the comprehensive completion of the FAST core array [3] construction and the development and deployment of advanced digital backend equipment, the observational capabilities and sky survey efficiency of FAST will be significantly enhanced, thereby providing robust technical support for a more diverse range of astronomical observation needs.

1. K. F. Warnick, R. Maaskant, M. V. Ivashina, D. B. Davidson, and B. D. Jeffs, “Interferometric Arrays and Synthesis Imaging,” in *Phased Arrays for Radio Astronomy, Remote Sensing, and Satellite Communications*, Cambridge: Cambridge University Press, 2018, pp. 420–443.

2. Jiang, P., Yue, Y., Gan, H. *et al.* Commissioning progress of the FAST. *Sci. China Phys. Mech. Astron.* **62**, 959502 (2019), doi:10.1007/s11433-018-9376-1.

3. Jiang, P., Chen, R. R., Gan, H. Q., et al. 2024. The FAST Core Array. *Astronomical Techniques and Instruments*, 1(2): 84−94, doi:10.61977/ati2024012.