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

# Real-time Pulse Search and Positioning Method for Baseband Data Based on Matched Filtering

Yingrou Zhan[(1), (2)], Ran Duan* [(1)], Fei Liu[(1)], Xiaoyun Ma[(1)], Shiling Yu[(1), (2)], Pei Wang[(1)], and Di Li[(1), (3), (4)]
(1) National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100101, People's Republic of China
(2) University of Chinese Academy of Sciences, Beijing 100049, People's Republic of China
(3) Department of Astronomy, Tsinghua University, Beijing 100084, People's Republic of China
(4) Zhejiang Lab, Hangzhou, Zhejiang 311121, People's Republic of China

## Abstract

Fast radio bursts (FRBs) are intense radio transients that hold significant potential for astrophysical studies. High-time-resolution pulse searching opens new possibilities for detecting narrow and faint pulses. However, the exponential growth in data volume presents considerable challenges for real-time processing. This paper proposes a real-time pulse search and positioning method based on matched filtering for baseband data processing. The method demonstrates superior performance in both pulse detection efficiency and dispersion tolerance compared to traditional approaches. Using GPU acceleration, it achieves real-time processing of 1 ns resolution baseband data, enabling the detection of narrower and fainter pulse signals. Validation using FRB 121102 baseband data revealed our method's capability to identify all previously known pulses and discover three new pulses, demonstrating its potential in advancing astrophysical research.

## 1. Introduction

Fast radio bursts are millisecond-duration radio transients that emit enormous energy in extremely short timespans. Their detection and analysis are crucial for understanding their origins and applications, such as testing Einstein's equivalence principle. As of 2024 May, 813 FRBs have been detected, yet their origins remain a significant astrophysical mystery. High-time-resolution pulse searching has become crucial for studying narrow and faint pulses, promising substantial improvements in detection efficiency and accuracy. However traditional methods struggle with the computational demands of real-time processing for high-resolution baseband data.

## 2. Methodology

The proposed method employs matched filtering to perform real-time cross-correlation between simulated dispersed pulse signals and baseband data. The method efficiently highlights pulse signals while suppressing noise. The matched-filter generation process including Fourier transform, dispersion simulation, and inverse Fourier transform. Figure 1 outlines the real-time pulse search and positioning system, which integrates matched filtering at the front end to preselect effective data segments for dedispersion and further analysis. This design minimizes computational and storage requirements.

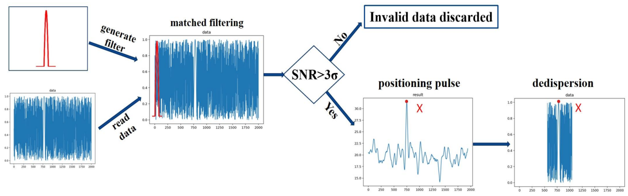


**Fig.1.** Demonstration diagram of pulse search and positioning method based on matched filtering.

## 3. Results and Discussion

### 3.1 Performance Optimization

Simulated FRB baseband data were used to evaluate the detection efficiency of matched filtering under different pulse widths, bandwidths, and SNR conditions. It is found that using filters with narrow pulse width or narrow bandwidth, or using multiple filters with adjacent frequency ranges, can improve detection efficiency.

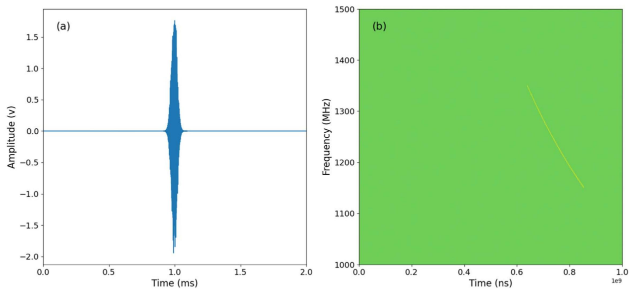


**Fig.2.** Simulated dispersed single-pulse signal: (a) pulse signal without dispersion; and (b) pulse signal with dispersion.

### 3.2 Comparison with Traditional Methods

We conducted a comparative experiment between this method and the traditional coherent de-dispersion algorithm and found that the matched filter method exhibits higher pulse detection efficiency and has higher dispersion robustness.

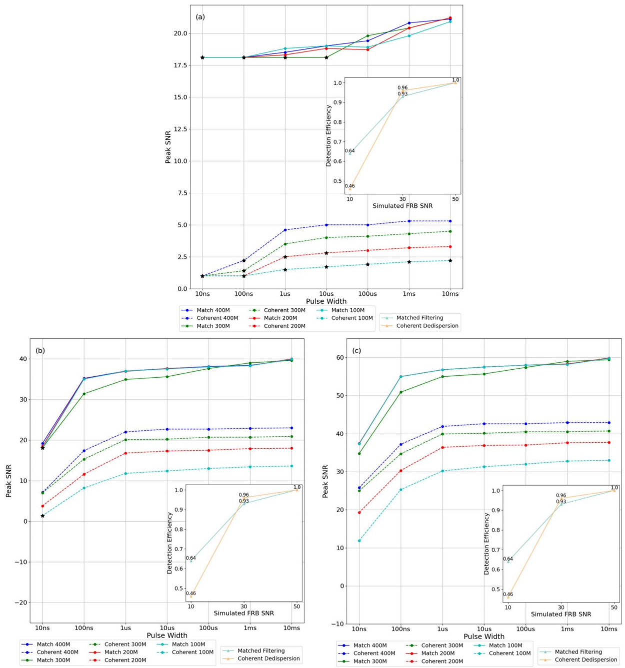


**Fig 3.** Comparison of the peak SNR outputs after processing simulated FRB signals using two methodsds.

## 3.3 Real Data Validation

The method was further validated using FRB 121102 baseband data from the FAST telescope. All known pulses were successfully recovered, and three new pulses were discovered (Figure 3), highlighting the method's effectiveness in real-world applications. Additionally, the processing reduced the required data volume by over 39% compared to traditional approaches, significantly alleviating computational and storage demands.

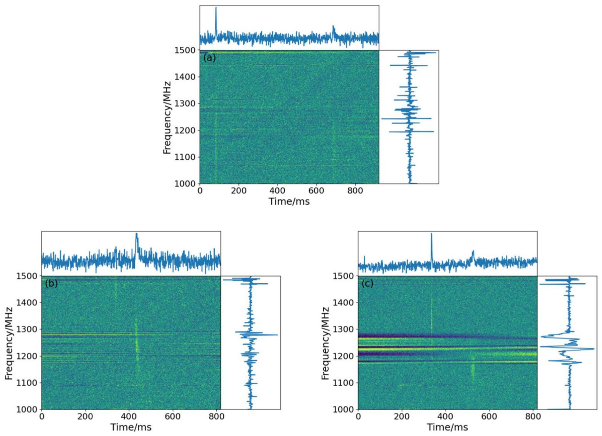


**Fig 4.** Time-frequency waterfall diagram of the newly discovered pulse signal in the FRB baseband data.

## 3.4 Accelerated Algorithm

The algorithm's performance was significantly enhanced through GPU parallelism, enabling real-time pulse search and detection in large volumes of high-time-resolution baseband data.

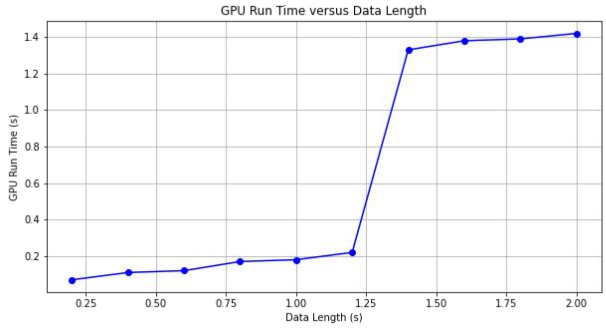


**Fig 5.** Computation time for data sets of different temporal lengths.

## 4. Conclusions

We have presented a real-time pulse search and positioning method that effectively addresses the challenges of processing high-time-resolution baseband data. The method shows significant advantages in:
- Real-time processing capability for 1 ns resolution data
- Enhanced pulse detection efficiency
- Improved dispersion tolerance
- Reduced computational and storage requirements

These characteristics make it particularly suitable for large-scale pulse detection applications and the exploration of narrow, faint pulse signals.

## 6. Acknowledgements

We would like to express our sincere gratitude to the Chinese Academy of Sciences South America Center for Astronomy (CASSACA) for their funding support and collaboration throughout this research. This work was also supported by the National Key R\&D Program of China under grant No. 2023YFB4503302 and the National Natural Science Foundation of China under grant No. 11988101.

## References

[1] Amiri M, Andersen B C, Andrew S, et al. Updating the first CHIME/FRB catalog of fast radio bursts with baseband data[J]. The Astrophysical Journal, 2024, 969(2): 145.
[2] Amiri M, Bandura K, Berger P, et al. The CHIME fast radio burst project: system overview[J]. The Astrophysical Journal, 2018, 863(1): 48.
[3] Bailes M. The discovery and scientific potential of fast radio bursts[J]. Science, 2022, 378(6620): eabj3043.
[4] Deneva J S, Stovall K, McLaughlin M A, et al. New discoveries from the Arecibo 327 MHz drift pulsar survey radio transient search[J]. The Astrophysical Journal, 2016, 821(1): 10.
[5] Gupta V, Flynn C, Farah W, et al. The ultranarrow FRB20191107B, and the origins of FRB scattering[J]. Monthly Notices of the Royal Astronomical Society, 2022, 514(4): 5866-5878.