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Design and Commissioning of the AARTFAAC all-sky monitor

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ABSTRACT

The Amsterdam-ASTRON Radio Transients Facility And Analysis Center (AARTFAAC) array is a sensitive, all-sky radio imager based on the Low Frequency Array (LOFAR). It will provide images in near real-time with sub arcmin resolutions at low radio frequencies, which will be monitored for short and bright radio transients. On detection of a transient, low latency triggers will be generated for LOFAR, which can carry out follow-up observations. In this paper, we describe the implementation of the instrumentation, and its capabilities.

Key words. Radio Interferometry - Imaging - Radio Transients - Correlators

1. Introduction

The AARTFAAC radio transient monitor is a leading effort among a group of new radio telescopes with similar functionalities as the wide field monitors at higher energies. They are characterized by having moderate resolution and sensitivity as compared to contemporary telescopes, with extremely wide fields of view (typically all sky), high availabilities and autonomous calibration and imaging. The latter requirements make their implementations challenging. The antenna elements used to achieve the wide fields of view are typically dipoles, however, their low individual sensitivities requires an order of magnitude larger number of elements in the array. Bringing the resulting large number of data streams to a central location, as well as their correlation thus poses a significant I/O and compute challenge. The wide fields of view at the sensitivities of operation also result in direction dependent effects on the incoming signals, mostly due to the ionosphere. These pose a challenge to calibration, especially when carried out in an autonomous manner.

In this paper, we describe the implementation of the instrumentation for the AARTFAAC array, and the commissioning of its various subsystems. Section 2 describes the array and the receiving antenna elements, its relationship with LOFAR, and introduces the full architecture of the instrument. Section 3 describes the hardware implementation in the field which allows creating a data path in parallel to LOFAR. This makes AARTFAAC processing independent of LOFAR to a large extent. In Section 4, we describe the implementation of a real-time, GPU based correlator for AARTFAAC, while Section 5 details the real-time, autonomous calibration and imaging implementation. Section 6 describes our control system for the full instrument, which also interfaces with LOFAR. In Section 7 we present performance metrics of the instrument as a whole.

2. The AARTFAAC array

- Requirements for transient detection
- Station description, Analog bandwidth, antenna field of view
- RSP signal processing, available bit modes
- AARTFAAC-12 array configuration
- Effect of regular lofar observations on AARTFAAC, fraction of time spent by LOFAR in HBA, LBA_OUTER, LBA_INNER mode
- AARTFAAC system specs.

3. Station level hardware for piggy-back operation

- URI board description, data coupling scheme, constraints on achievable bandwidth
- The uniboard data reformatting (transpose), uniboard data transfer, output data format
- Available diagnostics, performance, commissioning tests

4. The AARTFAAC real-time correlator

- Correlation for transit mode observations: logical blocks.
- Description of processing flow.
- Motivation of chosen architecture for implementation.
- Supported time and frequency binning, motivation of choice.
- Required compute and memory bandwidth.
- Synchronization of incoming data (input buffer), output data format.
- Commissioning tests, performance.

5. Real-time calibration and imaging

- Architecture, implementation choices, performance
- Unit test architecture
- Interface to TraP

6. The AARTFAAC control interface

- Control system description
- Interface with LOFAR
- Monitoring interface: AARTFAAC webpage

7. Results

- Long term performance of the entire system based on logs.
- Performance in various bit-modes, with different number of subbands, expected sensitivity

8. Discussion

9. Conclusions

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