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ASKAP Commissioning Update, November 2017

In this issue, we report on a breakthrough in data capture at Pawsey that has allowed routine operations with 16 antennas. In addition, we take a close look at the beam weights software framework that was recently deployed.

Early science operations

This month saw the resumption of operations after another extended outage during which significant improvements were made to the correlator data capture software. We are now using 16 antennas with 240 MHz of bandwidth, 36 beams and 7.4 second correlator cycles, producing a total data rate of 392 MB/s. This is a record for the ASKAP system and we would like to thank all the CASS and Pawsey staff involved.

One of the first observations in this mode was a repeat of the SMC field using all available baselines, which should provide the best HI image of the region ever made.

Breakthrough in Pawsey data ingest

Previously, one of the main concerns over the impending release of ASKAP-18 next year was the fact that our data capture system (known as the ingest pipeline) seemed to reach a performance limit at 12 antennas. This came about because the total time to process a single correlator cycle exceeded the cycle time itself.

We initially suspected filesystem I/O to be the main cause of performance issues, but the recent change to writing one file per beam reduced file output to be a negligible part of the total processing time for each thread.

As described in the last issue, data ingest is a complicated process that involves several sub-tasks and the current implementation does not fully reflect the final design model. However, it is important to understand the limits of the present system before making significant changes.

Upgrading the ingest cluster operating system

Data from the observatory are captured at Pawsey by a special-purpose mini-cluster of 16 nodes. The idea is that the real-time component of the system should be isolated from the rest of the supercomputing environment to provide maximum performance and reliability.

In October this year, Pawsey system administrators (in consultation with CASS software engineers) deployed a major operating system upgrade to bring these nodes up to the current Linux distribution release. This was done both as part of regular maintenance and to make debugging of the problems mentioned above easier.

Although Pawsey benchmarks showed that this change should be seamless, our testing of ASKAP code on the new operating system revealed that performance had degraded even further. While this prevented normal telescope operations, it also provided an opportunity to study the problem in more detail. After several weeks of effort, a solution has been found and some additional improvements have been made along the way.

Complexities of cluster job management

ASKAP ingest uses a software standard known as Message Passing Interface (MPI) for parallel processing. In the past we had seen occasional crashes within MPI libraries, and unexplained short-term increases in the execution time by factors of 5 or more. After the upgrade, we started to see crashes at start-up and much worse performance overall.

Modern supercomputing systems are designed to support multiple simultaneous users, each of which might be running complex, multi-CPU processing jobs. Managing these requirements is the responsibility of batch-queue software that handles job scheduling and execution. The ingest cluster software suite included the standard Pawsey scheduling system (based on a package called slurm). Although we had previously launched jobs directly, some interdependence remained between slurm and MPI.

Extensive investigation by Pawsey exerts revealed a conflict between the scheduling system and the MPI library that caused unexpected behaviour. Although the interaction between these two software packages is complex, the problem was solved by compiling the MPI libraries with slurm support disabled and using an alternative method to launch jobs via the network.

Additional improvements

After solving the job control problems, we were rewarded with an immediate increase in processing capacity. The next natural step was to introduce parallel processing into the most time-consuming serial task left in the ingest pipeline – calculation of fringe rotator parameters and residuals. Although this task will eventually be migrated elsewhere, the change is useful in the short term.

Since these combined updates, we have been able to capture data from 16 antennas and have not seen any of the transient performance problems noticed in the past. Although the solutions are largely work-arounds, care will be taken to ensure that they are documented and can be factored into future upgrades.

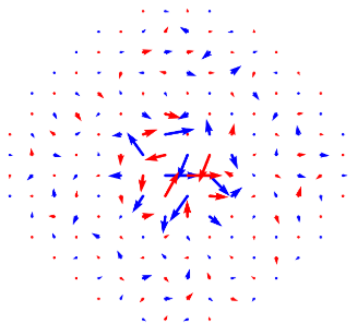
Managing beamformer weights

Beamforming and associated metadata tracking is an important operational task for ASKAP. Until now, we have been using stand-alone python code to create beamformer weights and store them on a central file server that all beamformer control computers can access. Although functional, this system did not include archiving and was not scalable, so a new solution was needed.

Weights service deployment and testing

The ASKAP beam weights service is a software framework backed by a relational database that is designed to manage the creation, maintenance, use and archiving of beamformer weights. It provides telescope operators with a unified interface that works at the level of beam "footprints", abstracting away the details of file storage and providing full metadata tracking.

The first milestone in the development of this system was to replicate the existing beamforming algorithm in which we use observations of the Sun to calculate maximum sensitivity weights.



Beamformer weights for a central beam (colours represent polarisations), created using the new software service

Extensive testing was done to ensure that the new system produced numerically equivalent weights to the previous code. Initial deployment brought to light some issues with file name conventions, but these were quickly solved. One immediate benefit is that the new system fully supports multi-node parallel processing, which makes weight calculation several times faster and much easier for the operator to manage.

Weights service feature roadmap

Now that the weights service framework possesses the same basic functionality as previous code, we can begin to add new features. High on the list of priorities is compensation for low-gain PAF ports and integration of gain corrections using the on-dish calibration system.

One of the main causes of poor beam sensitivity is thought to be the presence of low-gain PAF ports. Due to the large number of low-noise amplifiers present in ASKAP, we must expect failures and that repairs will have to wait until scheduled maintenance. Unfortunately, the standard maximum sensitivity algorithm tends to over-weight failed ports because their noise and signal contributions are both low. Visiting neutrino astronomy expert Mieke Bouwhuis developed a conditioning step that corrects the noise level of low-gain ports using an eigen-value decomposition approach. We would like to deploy this change as soon as possible.

Next in line is integration of automatic beamformer weight updates based on measured changes to port gains made using the on-dish calibration system (installation of which was completed several days ago). The method has been verified on single antennas and should greatly reduce overheads associated with beam maintenance.

While this work is underway, we are investigating the stability of the on-dish calibration system itself, to see which test parameters are required to make the best possible measurements of gradual changes and discrete steps in PAF port characteristics.

We have also developed a way to interpolate weights in frequency space to correct for channels impacted by RFI.

Commissioning schedule

The next intensive commissioning session is scheduled for Nov 17-26. During this time, we will finalise documentation on existing fringe rotator code in advance of testing a new, centralised method. Components of this new system are already under test in Marsfield.

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