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ASKAP Commissioning Update, October 2017

In this issue, we take a detailed look at the work required to support operations beyond early science with more than 12 antennas. This includes updates to the fringe rotator control system and implementation of ASKAP's real-time calibration service.

Correlator output data rate

During full operation the ASKAP correlator will compute visibilities from 630 baselines, 36 beams, 16200 frequency channels and 4 polarisations. These are transmitted from the observatory to the Pawsey centre every 5 seconds at a total data rate of roughly 2.5 GB/s.

The visibilities arrive asynchronously in UDP packets and must be merged with telescope metadata, then assembled into a CASA measurement set.

The real-time processing paradigm

Because of the high data rate, it was decided that ASKAP will not store raw spectral line visibilities. In fact, file access times are a significant fraction of the total calibration and imaging task. Therefore, ASKAP's science data pipeline was designed with the philosophy of "one read and one write". This means that there is only one chance to produce a high-quality image, rather than the usual process of iteration.

Within a few years it may be the case that an upgraded processing platform will be able to store visibility data, but until resources for such a system become available, we continue working towards a real-time pipeline.

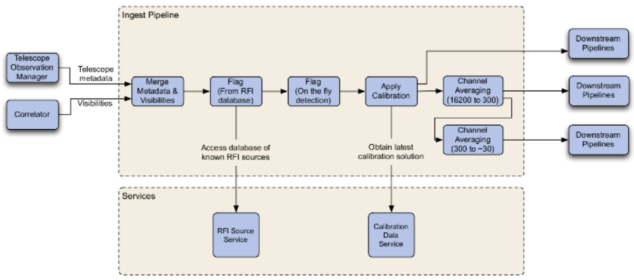
Data capture at Pawsey

The first challenge is to get data from the MRO onto a scratch disk at Pawsey. Since the collective transfer rate exceeds the capacity of a single 10 Gb ethernet link, the data must be distributed over more than one compute node. This suits the physical configuration of the correlator, which has 7 blocks of 12 chassis, each with its own 1 Gb uplink. Currently we send the output of each block to a different "ingest" node at Pawsey, but the division of work can be configured differently if required.

Until recently, all data packets from the correlator were gathered using MPI (Message Passing Interface) code into memory buffers controlled by a single thread that was also responsible for flagging and writing the data to disk, as well as computing the fringe rotator parameters that are sent to the hardware.

We now write one file per beam by splitting the data after the MPI merge. This makes filesystem access a negligible operation for each of the 36 data streams and has improved reliability, but tests show that the current configuration does not scale beyond 12 antennas. Although there is scope for optimisation, support for all 36 antennas requires relocation of ingest logic into independent subsystems.

Another way to improve throughput could be to split files by frequency instead of beams. This better matches the hardware architecture, but is less compatible with the science data pipeline. Testing will be needed to show which scheme performs better in practice.



Schematic diagram of the ingest pipeline

Continuous calibration

To produce images in real time, the array needs to be kept continuously calibrated. This means that the calibration solutions are known at any given time and can be applied to incoming visibilities without delay.

This requirement precludes the use of traditional phase calibration methods (periodically looking at a reference source near the science target). Instead, ASKAP plans to use a sky model to perform continuous in-field self-calibration, on the basis that any part of the sky will contain sufficient flux within our wide field of view.

Unfortunately, the sensitivity of the full array is required to make this strategy viable. With BETA and the ASKAP-12 early science array, we have resorted to more traditional bandpass calibration methods and trust that the gain solutions remain stable over periods of roughly 12 hours.

The situation is complicated by having 36 beams that must all be calibrated independently, resulting in a large amount of overhead (and hence the inability to phase calibrate on small time intervals).

It might also be feasible to use a hybrid approach where bandpass calibration observations are done on relatively long intervals and the sky model is used for phase calibration in between.

Creating a model of the sky

The software infrastructure for storing a sky model and supplying information to the calibration task is largely complete, but the model itself does not yet exist. There have been no previous surveys of the entire Southern sky at ASKAP's frequency and spatial resolution, so we must bootstrap the sky model using our own data. The best way to do this is currently being discussed and may involve a dedicated, shallow pilot survey.

The sky model will be updated as more data are obtained, but this process must involve careful quality control so as not to introduce systematic changes during the middle of a large-scale survey.

Key software infrastructure

Several important software subsystems will be commissioned in the next few months. In addition to the sky model service, these include the fringe rotator control system and the beam weights database. These features will enable integration of more antennas and testing of the high-frequency filter (1400-1800 MHz) and several zoom modes that provide more than the standard 18.5 kHz frequency resolution across a reduced bandwidth.

Delay tracking & fringe rotation

ASKAP's beamformer firmware includes coarse delay and fringe rotator modules. These are designed to be driven synchronously with updated parameters loaded into the beamformer every data frame boundary. This will ensure the visibilities are always correctly delay compensated.

The current software controls all fringe rotator inputs from the ingest pipeline, which allows a residual correction to be calculated and applied to the visibilities in real time. This was important for BETA and early commissioning when we needed to verify low-level quantities such as the units of the delay steps.

The ingest pipeline currently flags data for several cycles after a fringe rotator update is sent. This is because the correlator has an internal latency of a few cycles and we do not attempt to predict exactly when the transition to the new parameters will occur.

When we switch to the new system, fringe rotator parameters will be computed and sent to the beamformers without the ingest pipeline involved. This avoids the need to flag data every update, but it also means the residual correction cannot be applied and there will be small delay steps of approximately 0.2 ns between 1 MHz channels because of the finite resolution of the hardware delay module.

The switch to the new fringe rotation system is expected to occur before the end of the year and will involve a period of extensive validation.

Supporting zoom modes and frequency agility

All frequency modes require different firmware and switching between bands also requires new beamformer weights. These are currently time-consuming to calculate, but the new on-dish calibration system should decrease overheads significantly.

Changing firmware also requires full re-synchronisation of the array, a complicated process that involves the entire digital backend. This is currently done by hand, but will need to be automated for scheduling blocks. We will need to develop logic to catch subtle failure modes at this stage. On the other hand, automating the procedure will reduce the likelihood of operator error.

Some testing is also required to verify that narrow channels in zoom modes are properly handled in the firmware, ingest pipeline and ultimately the measurement set output as well as the science data pipeline.

Commissioning and testing

Although the present system is likely to be capable of early science operations with 300 MHz of bandwidth, we would like to implement the changes described above and test everything on the 12-antenna array. This allows comparison with a known system, providing a chance to find problems before adding more antennas. This work will be done in conjunction with early science operations.

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