CSIRO ASTRONOMY AND SPACE SCIENCE
www.csiro.au

ASKAP Commissioning Update, March 2018

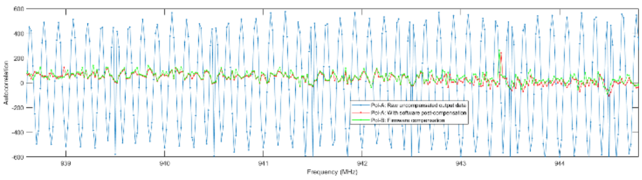
In this issue, we describe improvements that will be made to ensure optimal fixed-point precision is maintained throughout the digital signal path. We also outline several topics for discussion at the upcoming early science forum and SST PI meetings.

Passband ripple correction

Several months ago, the FLASH team made us aware of a problem with ASKAP early science data – a systematic sinusoidal ripple in the passband. Upon closer inspection, this looked very similar to an issue we thought had been fixed on the BETA prototype. Investigation revealed that this problem was a symptom of sub-optimal signal levels in the beamformer.

Polyphase filter-bank characteristics

ASKAP's signal processing pipeline includes a coarse filter-bank stage after digitisation. This provides 1 MHz channels to the beamformer so that we can specify frequency-dependent beamformer weights. The filter-bank is designed to have very sharp channel edges, to avoid the signal from one channel leaking into the next. Designing the optimal channel shape requires selecting a set of numerical coefficients somewhat like Fourier series components. It is therefore impossible to create a completely square channel– there will always be a residual ripple due to the finite number of coefficients. However, since the coefficients are known, we can precisely predict this effect and correct for it, either in the firmware itself or in software after the data are received from the correlator.



Passband response with and without ripple correction

Historical approach to ripple correction

In the BETA system, we used a software-based ripple correction module in the ingest pipeline. For ASKAP, this was moved into firmware to lighten the processing load on the ingest cluster. One key difference between the two was that the firmware uses integer arithmetic, while the Pawsey ingest pipeline applied the correction after the data had been converted to floating point numbers. The integer-based correction in firmware only works correctly if the input signal has sufficient power to utilise most of the bits used to represent the signal. If the power level is too high or low, the correction cannot be accurately applied.

Because the digital system involves a lengthy sequence of stages (filter-banks, accumulation, etc.) that can alter the numerical scale of their inputs, it is difficult to ensure a consistent level is maintained end-to-end. The fact that the ripple correction is not working in the current system was strong evidence of deeper numerical scaling issues. Incorrect scaling could lead to several other problems including loss of correlator efficiency (due to a reduction in the effective number of bits) or, in the other direction, clipping of strong signals (particularly RFI).

Scaling improvements and monitoring

The current system does not explicitly monitor signal power levels after digitisation. At the front of the signal chain we set the input RF signal levels using variable attenuators so that we have suitable sampling precision while maintaining headroom for RFI. Most of the subsequent processing logic was designed to have unity gain, but with respect to a sinusoidal input, rather than the random noise that is characteristic of astronomical sources. The beamformer itself adds a further complication to this, since it can alter the signal level significantly unless the weighted sum of phased array feed ports is scaled by an appropriate factor.

In response to this issue, our engineers are improving the scaling logic and implementing an RMS monitoring module that will be included at the input to the correlator. We will be able to tune the signal levels and monitor the output, creating a closed-loop control system.

Several other improvements will be made to ensure that scaling is done consistently through the entire length of the digital signal processing chain. This includes the storage of our beam weights as integers rather than floating point numbers, to provide better visibility of their effect on the signal level.

Fringe rotator upgrade progress

Workshop tests of the new fringe rotator control system continued this past month, using a noise generator to validate basic functions. These tests have revealed problems with the phase tracking system - in particular, residual steps likely due to timing inconsistencies between the requested and applied fringe rotator parameters.

Although we had hoped to begin testing on the telescope by now, it is important to understand these low-level issues before moving to astronomical sources.

ASKAP early science update

With the commencement of the cosmology survey (described in the previous issue) and the impending mid-year release of an 18-antenna array, the original ASKAP early science plan has almost been fulfilled. We have not yet fully utilised the broad-band nature of the telescope due to practical limitations with storage and re-use of beamformer weights and access to the highest-frequency filter, but we have managed to provide deep multi-night spectral line data sets for a few chosen fields and many shorter observations of specific targets of interest with up to 240 MHz of bandwidth.

Images made by the survey science teams are beginning to reach the expected sensitivity limits (integrating down as expected with the number of observing hours) given the measured system equivalent flux density. Although this is very encouraging, we are aware of several areas for improvement which require additional research. These include improving our primary beam correction and X-Y phase calibration.

Next steps towards full system delivery

Once the fringe rotator upgrades are complete, we will spend some time validating the system by repeating observations of previous target fields and then finish the backlog of requested observations (roughly 300 hours) including the cosmology survey. The next priority will be integrating another batch of antennas to allow operation as an array of 18, with several spares and options for selecting longer or shorter baselines.

At this point, the data rate will be too large to keep spectral line visibilities on disk for long. The nature of the early science program must therefore evolve into something more like our eventual operations model, where at least some of the data processing is done by CSIRO staff and online averaged modes are available.

Science team principal investigator meeting

On the 26th of March, we will be hosting a workshop for Survey Science Team principal investigators. One purpose is to circulate the terms of reference for an upcoming review of SST observing proposals, which will allow them to incorporate as-built system performance estimates and known limitations in areas such as commensal observing, where these differ to the original specification.

We will also be requesting that the science teams help define a workable pathway from the current system capabilities to a fully operational ASKAP by specifying pilot projects of increasing scope (rather than focusing completely on the end goal of a multi-year survey). In the lead-up to this meeting, we would like to pose the following questions for discussion:

1) What are the key modes of data capture required to meet your scientific requirements (continuum averaging, zooms, channel selection, etc.)?
2) What key features of the data processing software should we focus development on?
3) Would you trade observation duty cycle for the ability to process data on disk in sub-real time?

We would also like to discuss the way in which future observations are planned, scheduled and prioritised. As above, this is likely to involve pilot surveys, combined with a mechanism to quickly request smaller projects of around 24 hours observing time. These would be assessed by the project scientist and the operations team and scheduled on a best-efforts basis with technical feasibility and commissioning value being the primary deciding factors.

This builds on the success of a similar, informal process that has been used during the initial early science phase. It also allows for the fact that we need science targets to validate the performance of the telescope but must be able to cope with configuration changes that could make large-scale surveys impractical during commissioning.

CONTACT US
t 1300 363 400
+61 3 9545 2176
e csiroenquiries@csiro.au
w www.csiro.au

FOR FURTHER INFORMATION
CSIRO Astronomy and Space Science
Aidan Hotan
t +61 8 6436 8543
e aidan.hotan@csiro.au
w www.csiro.au/askap