ASKAP Commissioning Update, July 2018

In this issue, we describe observations designed to measure system performance parameters in advance of pilot survey planning. We also give an update on the work required to complete array release 3.

Preparing for pilot surveys

ASKAP was designed from its inception to be a powerful survey telescope. However, it is worth noting that large-scale surveys have historically been done on very mature telescopes after years of operational experience.

Surveys are easy to configure in the sense that they require repeated observations with the same parameters over a large area of sky. On the other hand, they also require high reliability and a deep understanding of instrument performance.

Because of the large investment in time, it is important to consider survey observing strategies carefully. This is especially true with ASKAP's large data volumes, to understand whether multiple science goals can be met with one set of observations.

While thermal noise is easily predicted, sensitivity or dynamic range is often limited by the presence of artefacts that are much more difficult to predict in advance. Experience with real data is required to ensure that a survey will address its science goals.

For these reasons, we will begin full operation of ASKAP with pilot surveys of limited scope – 400 hours for the two major projects and 200 hours for the rest. It is important that these pilot surveys be designed in such a way as to verify strategies and performance before we embark on several more years of observing.

Measuring system performance

ASKAP's key advantage has always been its high survey speed. However, this parameter is a complex combination of more fundamental system performance indicators. In addition, many parameters (such as aperture illumination) traditionally determined by fixed hardware design are made variable by ASKAP's phased array feed technology. This gives us much more flexibility, but also much more parameter space to explore.

The pilot survey program is designed to validate full-scale survey strategies and must itself be informed by detailed measurements of performance.

Some of the key factors include:

1) System Equivalent Flux Density (SEFD) as a function of frequency across the 700-1800 MHz band, and a measure of its uncertainty (electronic beamforming makes this number a function of the beam weights).

2) Field of View (FoV) of ASKAP's phased array feeds as a function of frequency (also determined by the beam forming process). This includes deciding whether to interleave multiple beam footprints to make the sensitivity profile more uniform and whether we need to reduce the field of view at the highest frequency band.

3) Beam shape and stability – we will make use of an On-Dish Calibration (ODC) system to stabilise beam shapes, but still need to ensure that the beam formation process produces consistent beams across all antennas even in the presence of hardware differences (occasional failures of a few elements out of 188 in each PAF must be expected).

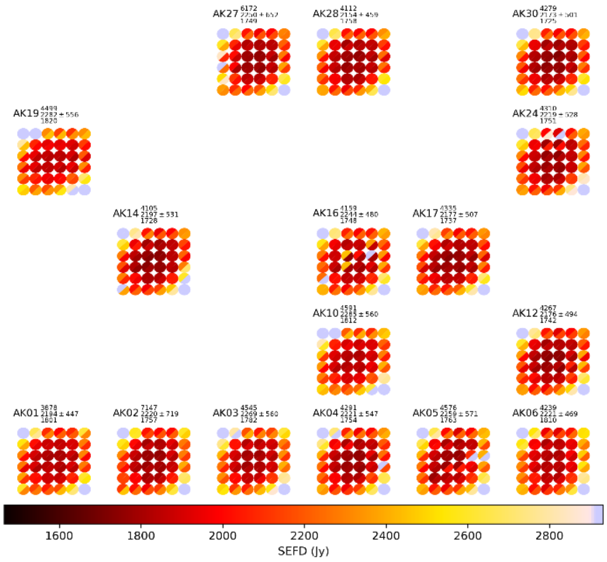
We also know that off-axis beams suffer from coma distortion. Optimising for maximum sensitivity will not produce the circular Gaussian profile typically assumed by imaging software. ASKAPsoft will support more accurate methods of primary beam correction, but to use these we need to supply models of the primary beams informed by measurements. Alternatively, we could adjust the beam forming algorithm to better match the circular Gaussian approximation. Both options are being investigated.

Commissioning observations

ASKAP's commissioning program includes high-profile early science observations, but it also involves measuring all the parameters described above. We do this by using flux calibrator sources and holography to make repeated measurements of beam-related properties.

For example, to measure field of view, we form beams using a standard footprint configuration and a sequence of expanding spacings that push the outer beams up to and over the edge of the PAF. Using flux calibrator sources to measure the SEFD of these beams allows us to map the sensitivity profile of an antenna and determine its FoV. This must be repeated at multiple observing frequencies.

In addition, holography observations (described in the last issue of this newsletter) provide a direct measure of the voltage beam pattern and are an excellent way to measure beam shape. Compact holography raster grids can be used to measure the primary beam shape in detail and larger, coarsely-sampled grids can be used to measure side-lobe levels and asymmetries away from the beam centre.



Plot showing an SEFD test where all beams on 16 active antennas have been measured. This shows the consistency of beams formed on all antennas. Similar observations with different beam spacings can be used to determine FoV.

These commissioning observations also lead to the development of key diagnostics that can be used to monitor system performance during surveys. With 36 antennas and 36 beams per antenna, monitoring data quality in real time is a challenge. Observations associated with the SEFD test shown above take several hours to complete, but we can use these to calibrate other, less time-consuming diagnostics.

Pilot survey timeline

With the current configuration of 16 antennas, we have sufficient baselines to begin understanding ASKAP's performance in detail. This has been a primary focus of the ASKAP Commissioning and Early Science (ACES) team over the past month. Factors such as the SEFD and FoV are not expected to change as we include more antennas in the array, so we can spend time to measure them before pilot surveys commence.

The first round of pilot surveys will begin in Q1 2019. Survey strategies will be determined in consultation with the science teams during meetings scheduled to begin in October 2018.

Over the last month we have obtained SEFD measurements for at least four different footprints in each of three different frequency bands, along with holography on a standard footprint in each band. These data will be analysed and compiled into a report on system performance for distribution prior to the first technical working group meeting in October.

Completing array release 3

Several key components of array release 3 have now been successfully commissioned. These include the new fringe tracking system and support for routine observations in the upper frequency band. Outstanding items include support for independent phase tracking of each beam and zoom modes that exchange bandwidth for increased frequency resolution.

Implementation of zoom modes is now underway and requires relatively small changes to existing software libraries. The low-level implementation of zoom modes in firmware is quite different to the standard mode, requiring longer filter-banks and additional parallel processing. Higher-level software needs to keep track of an extra sub-band parameter to ensure that fringe tracking is done correctly in these modes.

In addition to these system-level changes, array release 3 also requires integration of more antennas. This will happen in August 2018 to coincide with the delivery of another batch of digital electronics to the observatory.

We will move 8 antennas from the commissioning array over to the main array (for a total of 24) and replace the commissioning array antennas with newly-installed systems so that single-dish verification tests can begin. The new antennas in the main array will be connected to the correlator and then have their positions measured accurately with respect to the existing antennas.

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