ASKAP Industry briefing

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Outline

• Introduction
  • ASKAP specifications
  • Analog System specifications
  • Design constraints

• ASKAP prototype PAF receiver system
  • Design Options
  • Solution

• Key challenges and future directions
  • Mass production and testing of receiver packages
  • Component cooling
  • Integrated receivers (‘system-on-a-chip’)
## ASKAP Design Goals:
- High-dynamic range
- Wide field-of-view imaging

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of dishes</td>
<td>36</td>
</tr>
<tr>
<td>Dish diameter</td>
<td>12 m</td>
</tr>
<tr>
<td>Max baseline</td>
<td>6 km</td>
</tr>
<tr>
<td>Resolution</td>
<td>30&quot;</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>65 m²/Kelvin</td>
</tr>
<tr>
<td>Speed</td>
<td>$1.3 \times 10^5$ m⁴/Kelvin²/deg²</td>
</tr>
<tr>
<td>$T_{\text{SYS}}/\eta$</td>
<td>63 Kelvin</td>
</tr>
<tr>
<td>(eg. $T_{\text{SYS}} = 50$ K, $\eta = 80%$)</td>
<td></td>
</tr>
<tr>
<td>Observing frequency</td>
<td>700 – 1800 MHz</td>
</tr>
<tr>
<td>Field of View</td>
<td>30 deg²</td>
</tr>
<tr>
<td>Processed Bandwidth</td>
<td>300 MHz</td>
</tr>
<tr>
<td>Spectral channels</td>
<td>16 k</td>
</tr>
<tr>
<td>Focal Plane Phased Array</td>
<td>188 receiver channels</td>
</tr>
</tbody>
</table>
Analog System specifications

- **Phased array receiver size**
  - Receiver elements ~200 per antenna

- **Frequencies**
  - RF band 700 – 1800 MHz
  - Instantaneous bandwidth 300 MHz
  - Sampled band 424 – 724 MHz
  - Sample clock 768 MHz

- **Low-noise amplifiers**
  - Amplifier noise temperature 40 Kelvin
  - Amplifier gain 27 dB

- **System gain**
  - Nominal total nett gain 72 dB

- **Output power (to digitiser)**
  - Nominal IF output power -19 ±1 dBm into 50 Ohms
Design constraints

• Relatively long f/D ratio (f/D = 0.5)
• PAF receiver weight must be less than 200kg
• High attenuation in coax cable from prime focus to pedestal
  17dB at 0.7GHz
  31dB at 1.8GHz
• Minimise RFI generated
• Maximise RFI immunity
Design options

• Conversion scheme
  • Dual conversion
    OR
  • Direct conversion

• Analog RF (IF) signal transmission
  • Over optical fibre
    OR
  • Over coaxial cable

• Receiver architecture options
  • (1) Frequency conversion and sampler at the focus
    OR
  • (2) Frequency conversion at the focus and sampler in the pedestal
    OR
  • (3) Frequency conversion and sampler in the pedestal

Dual conversion receiver - requires 2 LOs

Direct conversion (I&Q) receiver - requires 1 LO
(1) Frequency conversion and sampler at the focus

- LNA
- RF gain
- RF filters
- Frequency Conversion*
- A/D

*Dual conversion OR Direct conversion I&Q

Focus → Cable wraps → Pedestal

Sampled IF on optical fibre
(2) Frequency conversion at the focus, sampler in the pedestal

- LNA
- RF gain
- RF filters
- Frequency Conversion
- A/D
- Cable wraps
- Pedestal
- IF on copper
- OR
- IF on optical fibre

*Dual conversion
(3) Frequency conversion and sampler in the pedestal

- LNA
- RF gain
- RF filters
- Focus
- RF on copper
- OR
- RF on optical fibre
- Cable wraps
- Frequency Conversion*
  *Dual conversion
  OR
  Direct conversion I&Q
- Pedestal
- A/D
ASKAP Analog System architecture

- Frequency conversion and sampler in the pedestal
- Analog RF signal transmission over coaxial cable
- Dual conversion (superheterodyne) receiver
ASKAP Analog System architecture with 200 receiver elements
Prime Focus package
Key challenges and future directions

- Mass production and testing of receiver packages
  - With ~200 receiver elements per antenna
Key challenges and future directions

- Mass production and testing of receiver packages
  - With ~200 receiver elements per antenna
- Component cooling
  - Low-noise amplifier dissipation: 120 mW
  - Cryogenic cooling of critical components of the receiver electronics (eg. low-noise amplifiers) significantly improves receiver sensitivity
  - Cryogenic cooling is especially important at higher frequencies - where the potential improvement in system sensitivity is greater
    - Cryogenic cooling to 20 Kelvin or 70 Kelvin.
    - Cooling of the whole receiver package or distributed cooling of individual low-noise amplifiers.
Key challenges and future directions

- Mass production and testing of receiver packages
  - With ~200 receiver elements per antenna
- Component cooling
  - Low-noise amplifier dissipation: 120 mW

<table>
<thead>
<tr>
<th>Component</th>
<th>Heat load (Watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation load: Cold plate</td>
<td>6</td>
</tr>
<tr>
<td>Radiation load: Amplifier Bodies</td>
<td>4</td>
</tr>
<tr>
<td>Radiation from epoxied feed throughs</td>
<td>0.4</td>
</tr>
<tr>
<td>200 off low-noise amplifiers (3V/40mA each)</td>
<td>24</td>
</tr>
<tr>
<td>Bias wiring for 200 amplifiers</td>
<td>11</td>
</tr>
<tr>
<td>400 Feed pins from focal plane array</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total heat load for receiver with 200 LNAs</strong></td>
<td><strong>50 Watts</strong></td>
</tr>
</tbody>
</table>
Component cooling – using commercial cryo-coolers

- Checker-board FPA
- 10 off CryoTel GT coolers
- Vacuum chamber internal supports
- 200 Amplifiers mounted on cold plate
- Hermetic feed-throughs
- RF feed through plate with SMA hermetic connectors
Component cooling – distributed cooling of individual low-noise amplifiers

- Micro cooler
- Gas lines
- Vacuum Chamber
- Removable endplates
- O-Ring seals
- Adjustable support
- Epoxy sealed hermetic lead through
- Electronics board
Component cooling – with an array of micro-coolers

Vacuum Valve ready for connection to pump
MEMS microcooler

Fabrication of a micro cryogenic cooler using MEMS-technology

- Size: 30 mm x 2.2 mm x 0.5 mm
- Nett cooling power: 10 mW @ 96 K

Fig. 3. 3D-view of a part of the CFHX and cross-section of the CFHX.

Fig. 4. Pressure test samples. Left: single channel, the width is 780 μm. Right: various tested samples glued onto stainless steel connection plates.
Key challenges and future directions

• Mass production and testing of receiver packages
  • With ~200 receiver elements per antenna
• Component cooling
• Integrated receivers (‘system-on-a-chip’)
Key challenges and future directions

Current receiver architecture

- LNA
- RF gain
- RF filters
- Focus
- Cable wraps
- Pedestal
- RF on copper
- Frequency Conversion*
- A/D

*Dual conversion
Key challenges and future directions

Preferred receiver architecture

- Frequency conversion and sampler at the focus
- Digital signal transmission over optical fibre
- Direct conversion (I&Q) receiver
Integrated receivers: System-on-a-chip
Australia Telescope National Facility

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Web: www.atnf.csiro.au

Thank you