The development of a CSIRO MKIII wideband phased array feed

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Introduction

The motivation for this design was to develop a 40 element array as a technology demonstrator for SKA survey.

It has also become a demonstrator for a possible future upgrade of ASKAP and a potential cryogenic PAF for the Parkes Radio Telescope.

Frequency range optimized for 0.65-1.65GHz.

We have not considered cooling.

This design was intended for a low RFI environment.

The LNAs use commercial HEMT transistors.
The RF signal path

Full Bandwidth to here

~70dB gain to here
The design process

- Constrain the length of the elements to ensure low loss
- With an infinite array, optimize the element geometry to achieve maximum boresight return loss
- Design the edge elements such that the impedance at the edges resembles that of an infinite array
- Check infinite array performance is acceptable over angles required for good dish illumination
- Check array/LNA noise match
Simulated Element Loss (HFSS)

I’m not convinced this is realistic!

![Graph showing infinite array boresight resistive loss (not including reflection loss)]
A full 80 port EM simulation of the 5x4 PAF was performed in order to accurately model finite size effects.

This simulation was combined with a Microwave Office simulation of the LNA to model noise covariance matrices and embedded element patterns.

The noise simulation exhibits very close agreement with the infinite array simulation for most of the band.
Simulated Array Performance on a Parkes Like Dish

![Graph showing noise temperature vs frequency for different scenarios (T amplifier, T infinite array, T uniform, T receiver 5x4, + spillover, + sky (Tsyst), Tsys/efficiency).]
Dish Antenna Efficiency when Illuminated by the Array

- Blue line: MaxSNR weights
- Orange line: Max Efficiency weights

Frequency (GHz)

Efficiency ($\eta$)

Values range from 0.5 to 2 GHz and 0.5 to 1 for efficiency.
PAF modelled beam patterns using on dish Max SNR weights
The LNA design
LNA noise temperature measurements

![Graph showing measured differential noise temperature vs frequency](image)
The Analogue Beamformer

The analogue beamformer consists of a simple summing network to simulate an equal weights beamformer.

Analogue beamformer measurements with the liquid Nitrogen load did not prove very successful.

To determine whether the load or the beamformer was to blame we decided to try the analogue beamformer in the Parkes aperture array setup.
Analogue Beamformer Noise Temperature

![Graph showing noise temperature vs. frequency for different array configurations.](image)

- **Rocket Array Pol A**
- **Rocket Array Pol B**
- **ASKAP ADE 5x4**
- **Rocket Array Simulation**

The graph includes a calibration plane and indicates a multiplication factor of 10 at certain points.
Change in noise from uniform to dish weights

Results using the Parkes aperture array digital backend
The array was installed on the Parkes 64m antenna in May for a three day measurement campaign.

We used Virgo to derive MaxSNR beamforming weights and to measure $\text{Tsys}/\eta$.

Using pyramidal absorber as a hot load and the sky as a cold load we measured the system temperature.

We would have liked to use an adjacent 12m antenna as a reference for holography. However due to the large delay between signals the phase wrap in the 1MHz frequency bins was too great.

A vertex radiator was used as a channel to channel calibrator.
On dish measurements

5x4 'Rocket' PAF on the Parkes 64m Telescope

Noise Temperature (K)

Frequency (MHz)

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On dish measurements: Intermodulation products, the culprit?

*Parkes 64m Telescope 5x4 PAF Intermodulation Products*

- **Spectrum**
- **Second Order Products**
- **Third Order Products**
Summary

The PAF seems to be functioning as expected in aperture array tests however more work need to be done on reconciling the on dish measurements with simulation.

At the moment our major effort is aimed towards improving post LNA dynamic range in order to tolerate high levels of RFI.

We aim in the near future to start working towards a cryogenic array for the Parkes telescope as well as working with a semiconductor foundry to produce custom LNA MMICs.
Thank you

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