

Array noise temperature measurements at the Parkes PAF Test-bed Facility

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Outline

- Basics of Aperture Array Tsys Measurement
- Test-bed and development
- Prototyping approach
- Test-bed electronics
- Recent improvements Radiation shield
- Measurement accuracy
- Selected results
- Brief ASKAP latest news



Basics of Aperture Array Tsys Measurement

- Measure Tsys of phased array feeds in aperture array mode
 - Broadside beam reasonable representation of T_{rec} for PAF excitation?

• Y-factor measurement
$$Y = \frac{P_{hot}}{P_{cold}} = \frac{k(T_{rec} + T_{hot})BG}{k(T_{rec} + T_{cold})BG}$$

- P_{hot}: Absorber over array ~300 K
- P_{cold}: Sky ~7 K
- Result independent of G and B
 - But G needs to be stable for hot and cold





Test-bed Location

Parkes

- First (dish) PAF test-bed: Marsfield 2006
- Moved to Parkes
 - Lower RFI
 - Interferometry with the 64m (400m baseline)







Development of the facility 2009-2013

- Open technique no shield
 - Hot load coverage calculated from modelled patterns
- In-situ (fixed-adaptive, Jeffs 2008) beamforming
 - Radiator in load to produce a more predictable beam – max SNR.
 - Chippendale, A. P. et al. PASA, 2014 Measuring Noise Temperatures of Phased-Array Antennas for Astronomy at CSIRO

Jeffs, B. D. et al. Signal Processing for Phased Array Feeds in Radio Astronomical Telescopes *IEEE J. Sel. Topics Signal Process.*, **2008**, *2*, 635-646



Prototyping Approach 5x4 Arrays

- Reduced size array (40/188)
 - 5x4 by two polarizations
 - ~500x500 mm
- Pros
 - Less electronics
 - No active cooling needed
- Cons



• Less directive \rightarrow Increases Y factor uncertainties

• EG: 'BETA' design

Test Configuration	Elts.	700 MHz	1000 MHz
Aperture T _{sys}	40	80 K	47 K
Aperture T _{sys}	188	64 K	45 K
Focus of Dish Τ _{sys} /η	188	108 K	75 K



Test-bed Electronics

ASKAP prototype back end shared with a PAF on the dish

Antenna/LNA



- Designed for radio quiet environment
 - Parkes has more RFI than the ASKAP site
 - Gain settings non-optimal below 1 GHz



Recent developments Radiation shield

Mounted on PAF and removable





- Minimizes ground pickup
- Hot load fills the beam
- Focussing radiator moved higher



Recent developments

Current setup in focussing radiator position





Measurement Accuracy

The need for uncertainty analysis

- Measurement Purpose
 - Refine modelling
 - Refine fabrication
 - Does it meet specifications?
- How accurate do we need to be?
 - Refinements: Comparisons of similar arrays
 - Specifications: Some fraction of the spec value. Hard to put a figure on it.
- BUT we need to know how accurate!



Radio Sky Approach

- Sun work when low or set
- The galaxy work when it is low or set
- Use model of the radio sky and model or measured beam to estimate T_{hot}



De Oliveira-Costa 2008

De Oliveira-Costa, A.; Tegmark, M.; Gaensler, B. M.; Jonas, J.; Landecker, T. L. & Reich, P. A model of diffuse Galactic radio emission from 10 MHz to 100 GHz Monthly Notices of the Royal Astronomical Society, Blackwell Publishing Ltd, 2008, 388, 247-260 **Robert Minchin Google drive**



Radio Sky Models from Chippendale et al. PASA 2014



Uncertainties Hot load

- Coverage
 - Applicable for tests without radiation shield
 - Pattern estimates using array size
 - \rightarrow dominant uncertainty at ~8 K (95% confidence)
 - Modelled radiation pattern is better
- Black body temperature
 - Rely on physical temperature: ~1.6 K (95% confidence)
 - IR thermometer check of uniformity
 - Contributes 0.2 to 0.4 K to $u(T_{rec})$ (95% confidence)



Uncertainties RFI

- Time peaks
 - Flag integration cycles
- Frequency peaks
- Flag if ≥ 2 correlations have peaks





Receiver Issues

Stability and back end Tsys contribution

- Measurement takes ~30min
- Sequence of states (chosen to cancel linear drift):
 - Focussing radiator
 - Hot load
 - Cold load (sky)
 - Hot load
 - Focussing radiator



Receiver Issues

Stability and back end Tsys contribution

- Temperature of down-converter
 - Net gain ~30 dB but amplifier gain ~100 dB
 - Now stabilized with flow control of water cooling
- Temperature of LNA and gain stage at array
 - Net gain ~65 dB but amplifier gain ~75 dB
 - Working at night helps
- T_{sys} contribution
 - Nominally 1 K but up to ~4 K under some conditions
 - Needs measuring for particular measurement conditions



Uncertainties - Example

Contributions to combined Uncertainty



2009 configuration Chippendale et al. PASA 2014

Selected results

Improved design informed by measurements

• "BETA" design and 5x4-BETA 20120408 (b) vs. 5x4-MkIIa 20120407 (r) 200 First MkII prototype 150 Tsys (K) [Measured 295/(Y-1)] 100 50 800 800 1000 1200 1400 1600 1800 Frequency (MHz)

Selected results

Resolving material and fabrication issues

 Final MkII design (aka ADE) for 40 element prototype



Summary

- Aperture measurement set up has grown incrementally based on immediate needs
- Developing uncertainty analysis for current mode of operation
- Future
 - Side by side comparisons of chequerboard with Vivaldi arrays for SKA
 - Measurements at ASKAP site: MRO (lower RFI important for lower frequencies)



Selected References on the Parkes Facility

- 12m dish installed for testing PAFs
 - O'Sullivan, J. D.; Cooray, F.; Granet, C.; Gough, R.; Hay, S.; Hayman, D. B.; Kesteven, M.; Kot, J.; Grancea, A. & Shaw, R.
 Phased Array Feed Development for the Australian SKA Pathfinder URSI General Assembly, 2008
- Aperture array tests
 - Chippendale, A.; O'Sullivan, J.; Reynolds, J.; Gough, R.; Hayman, D. & Hay, S. Phased Array Feed Testing for Astronomy with ASKAP IEEE Int. Symp. on Phased Array Systems and Technology, 2010, 648-652
 - Chippendale, A.; OSullivan, J.; Reynolds, J.; Gough, R.; Hayman, D.; Hay, S.; Shaw, R. & Qiao, R.-Y.
 Chequerboard Phased Array Feed Testing for ASKAP
 Int. Workshop on Phased Array Antenna Systems for Radio Astronomy, 2010
 - Chippendale, A. P.; Hayman, D. B. & Hay, S. G. (ArXiv now or PASA any day now) Measuring Noise Temperatures of Phased-Array Antennas for Astronomy at CSIRO *Publications of the Astronomical Society of Australia*, **2014**
- Hayman et al. EuCAP 2014 summary of dish and aperture testing



ASKAP latest news – brief ad break

http://www.atnf.csiro.au/projects/askap/news.html

- BETA (6 antenna array) operational
 - First 6 antenna image
 - First 15-baseline BETA observation achieved
 - BETA still learning how to use PAFs in interferometer + debugging
 - Hotan et al. 'close' to publication in PASA
- ADE
 - RFoF design
 - Final chequerboard design details confirmed by prototype late 2013
 - First PAF being tested at Marsfield







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