The CSIRO Astronomy and Space Science Phased Array Feed Development Program

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CSIRO – Technologies for Radio Astronomy and The SKA PAF AIP

26 August 2016

Outline

- Current CSIRO PAF Development
  - ASKAP
  - Parkes 64m – Bonn PAF (MPIfR)
  - Rocket PAF
- CSIRO PAF Development – The Future
- SKA PAF Development – SKA Survey
- PAF – Dish Consortium Engagement
- PAF Advanced Instrumentation Program (AIP)
- SKA Observatory Development Program (ODP)
- Questions for the Future

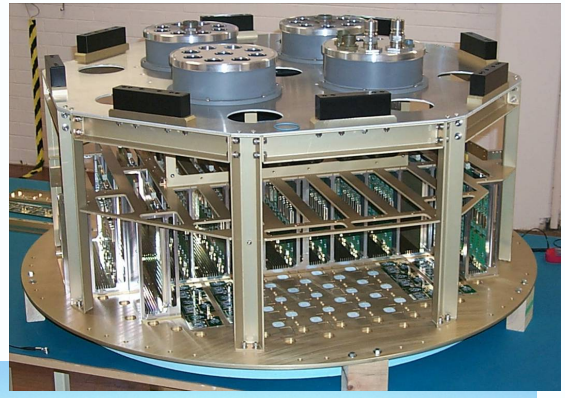
ASKAP – Australian SKA Pathfinder

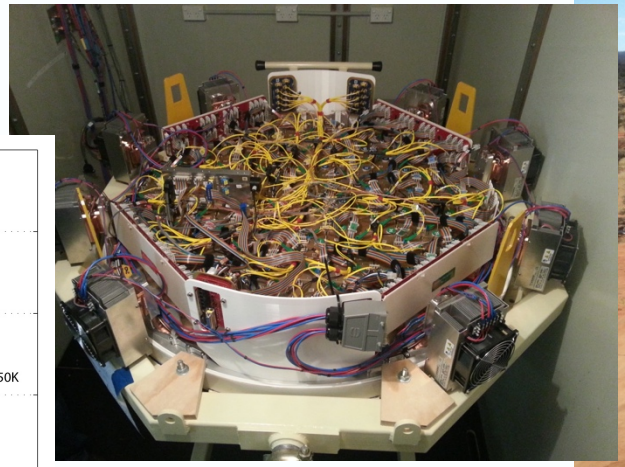
A Wide Field-of-View Radio Telescope

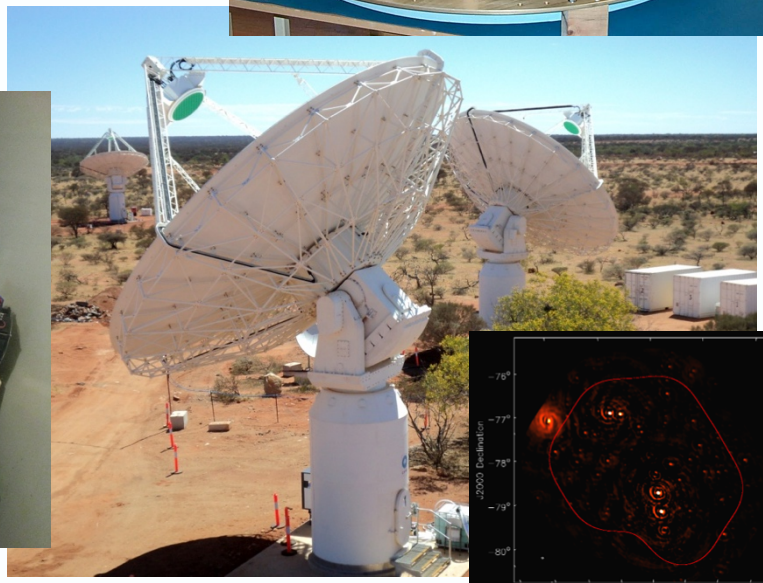
Number of dishes	36
Dish diameter	12 m
Max baseline	6km
Resolution	10” (6km array), 30” (2km core)
Sensitivity	70 m^2/K
Field of View	30 deg^2
Speed	$1.5x10^5$ $m^4/K^2 \cdot deg^2$
Observing frequency	700 – 1800 MHz
Processed Bandwidth	300 MHz
Spectral Channels	16,000
Phased Array Feeds	188 elements (94 dual polarisation)

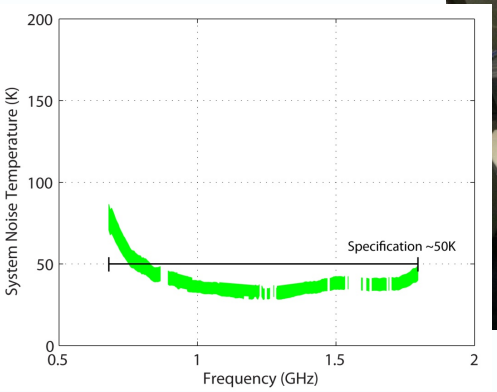
ASKAP – Australian SKA Pathfinder

- Boolardy Engineering Test Array (BETA)
  - Decommissioned February 2016
  - 6 antennas fitted with Mk. I Chequerboard PAFs
  - Conversion and baseband sampling at antenna
- ASKAP Design Enhancement (ADE)
  - 12 antennas currently operational
  - Mk. II Chequerboard PAFs
  - Direct sampling at central site



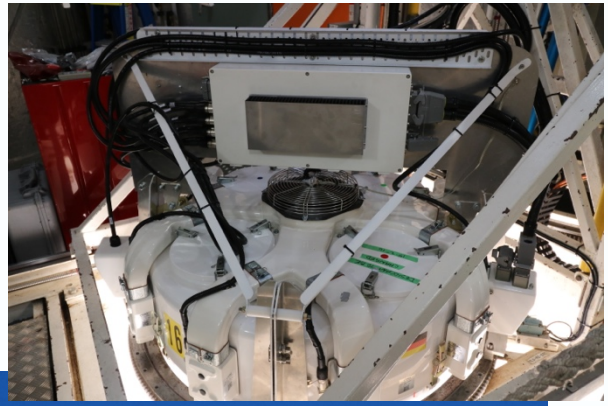


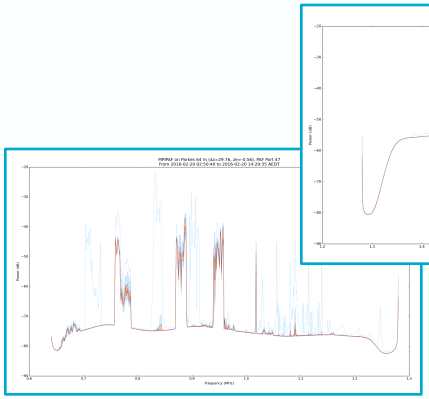


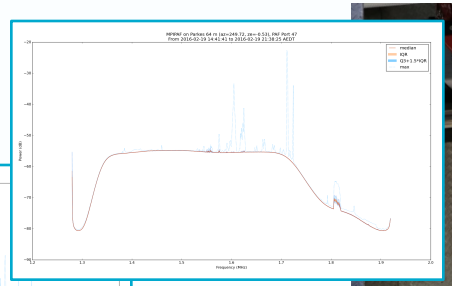


Parkes 64m – Bonn PAF (MPI)

- ASKAP PAF (Mk. II) built by CSIRO for MPIfR
  - ASKAP Digitiser and Beamformer
  - GPU Correlator
  - Modified RF signal chain – Additional filters (RFI)
- Commissioning on Parkes 64m antenna
  - Replaces Parkes multibeam receiver (13 beam)
  - Installed – February 2016
  - Commissioning and software development
  - Removal – September/October 2016



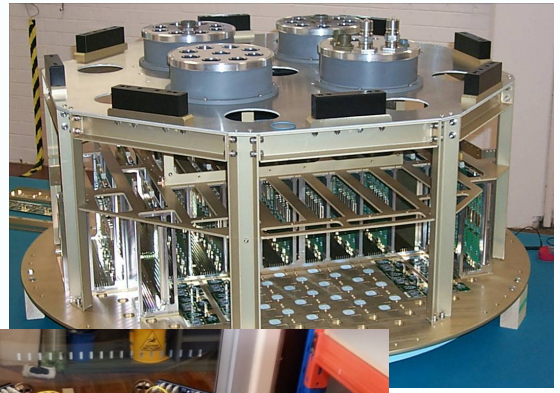


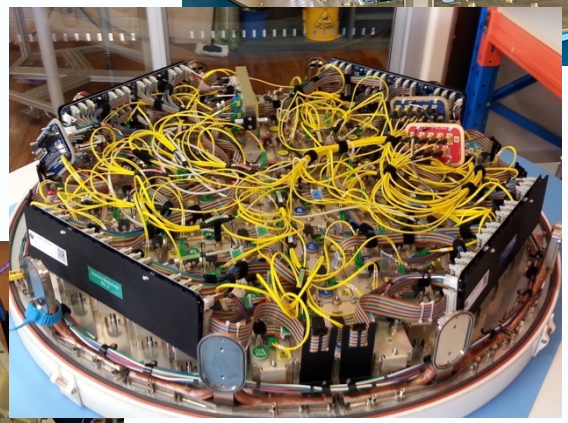


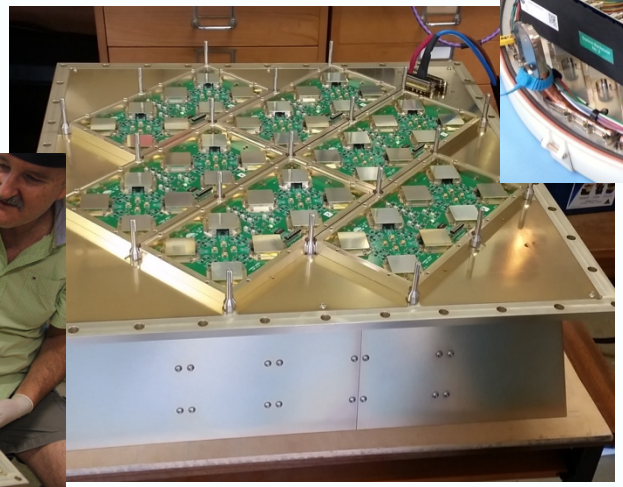
Rocket Array – CSIRO

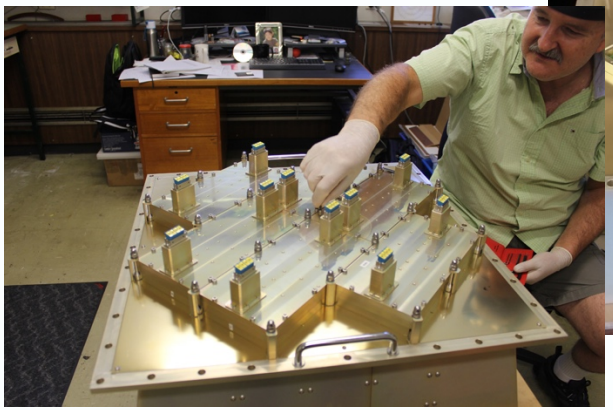
Originated in CSIRO SKA PAF Program

- Initially focussed on 650 – 1670 MHz
- Common RF signal chain (SKA Bands 1, 2, 3)
- Reduced system temperature (T_{LNA})
- Concept demonstrator – Signal distribution
- Ongoing evolution of ASKAP feed package (Mk. II → Mk. III → Mk. IV)



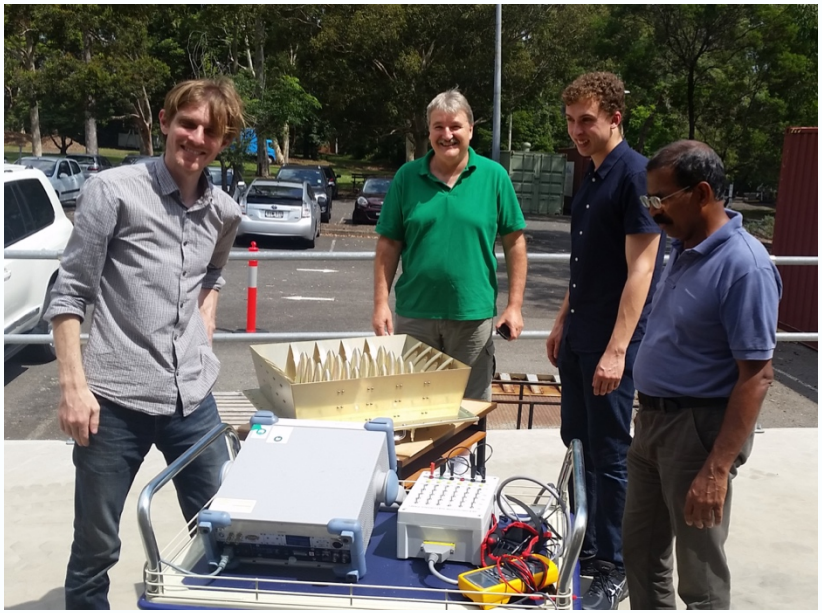


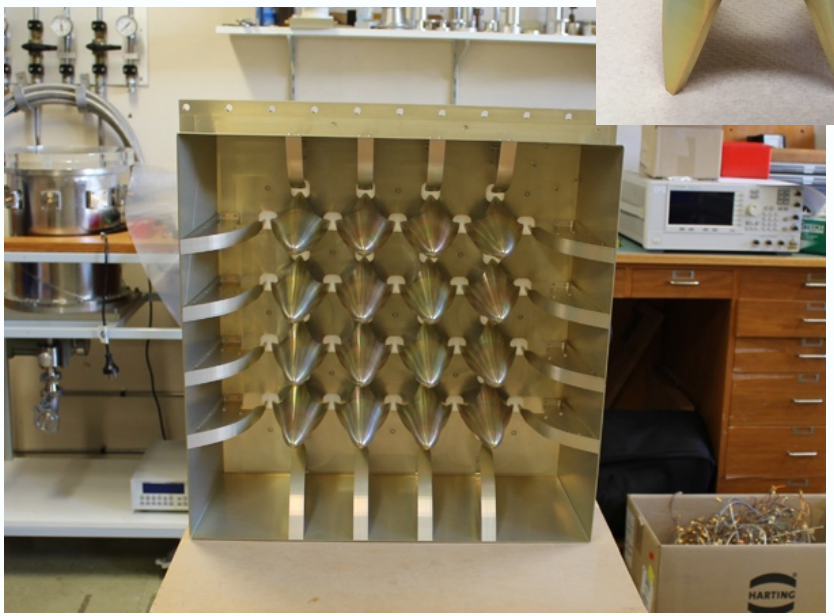




Element and LNA Design

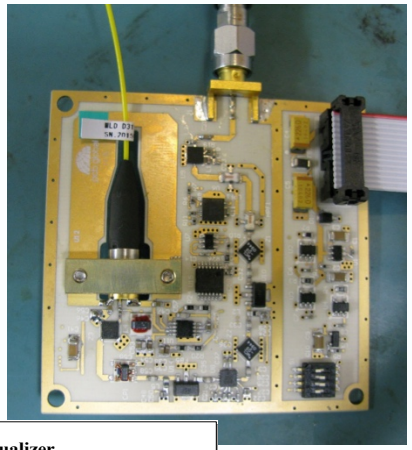
- Element based on a conical solid of revolution
- Edge elements designed to reduce the effect of the edge discontinuity
- Feed line loss minimised
- Balanced LNA – Differential impedance 180Ω
- Commercial HEMT LNA – TriQuint TQP3M939 & TQP3M9040
- 5 x 4 array constructed as proof-of-concept

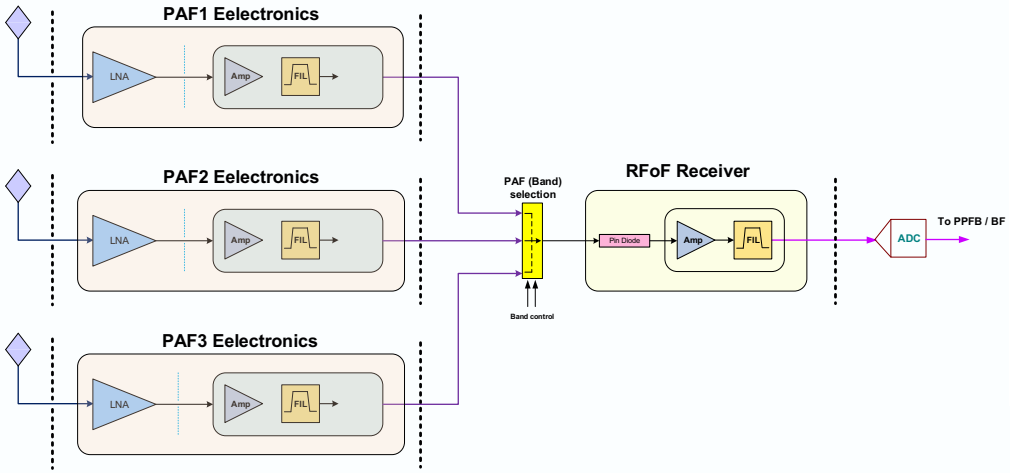




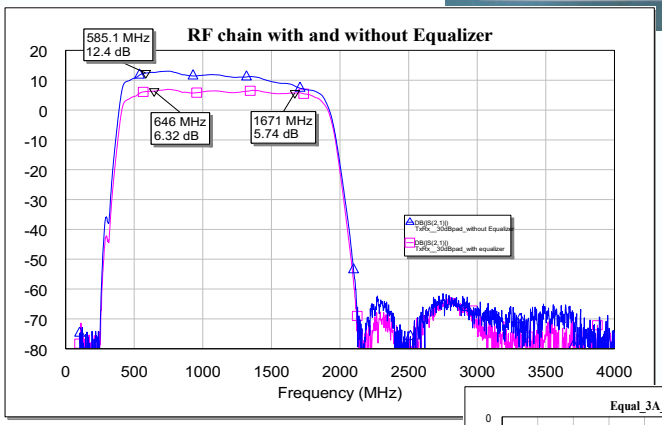
RF Signal Chain

- Leverage off other developments – SKA
- Common RF system architecture – SKA bands (1, 2, 3)
  - RF over Fibre (RFoF) for signal transport (ASKAP)
  - Integrated 8 channel assembly completed and tested
  - Allows direct interfacing with ASKAP digital backend

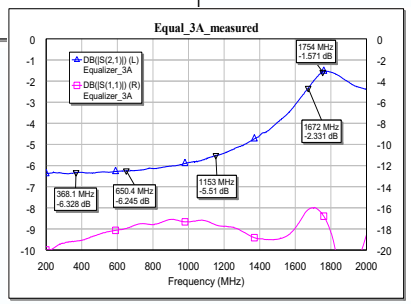




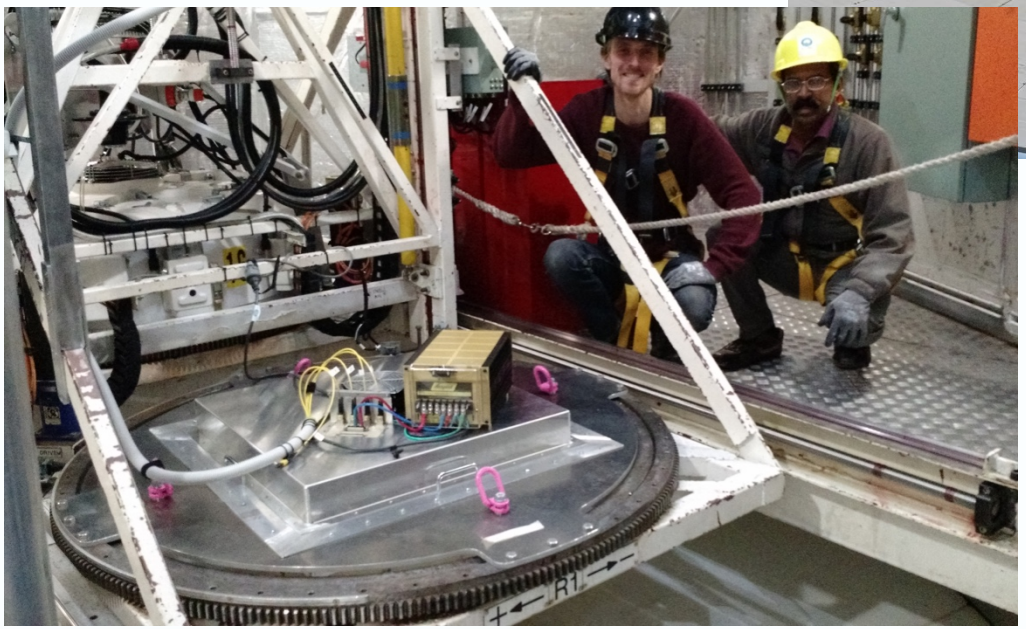
Simplified System Block Diagram
(Y. Chung 2015)

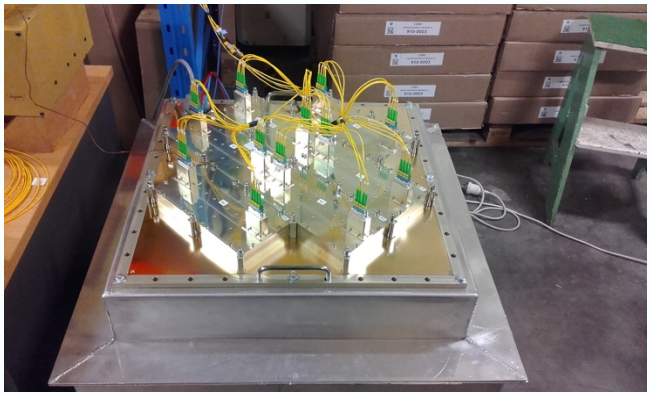


Prototype RF Signal Chain Gain



Array Testing - Parkes





CSIRO PAF Development – The Future

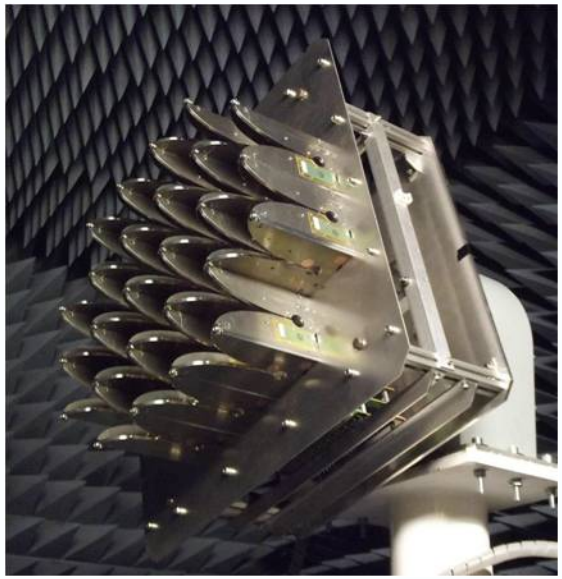
- Enhance existing Australia Telescope National Facility (ATNF) Instruments
- Collaboration and engagement with radio astronomy PAF community
- GPU based correlator development – MPIfR PAF
- Reduction in PAF Tsys achieved incorporated into ASKAP
- Incorporate development from other projects
  - Next generation beamformer
  - High speed digitisation
- Continue rocket PAF development
- Cryogenically cooled PAF for Parkes
  - Rocket array element geometry
  - RFI/EMI considerations
  - Sampling at the focus
- Participate in SKA PAF AIP

SKA PAF Development – SKA Survey

CSIRO PAF Design

- Chequerboard array
- Australian SKA Pathfinder (ASKAP) Mk. II
- RF over Fibre signal transport
- 650 – 1670MHz band (SKA - Band 2)

Credit: A. Chippendale, CSIRO



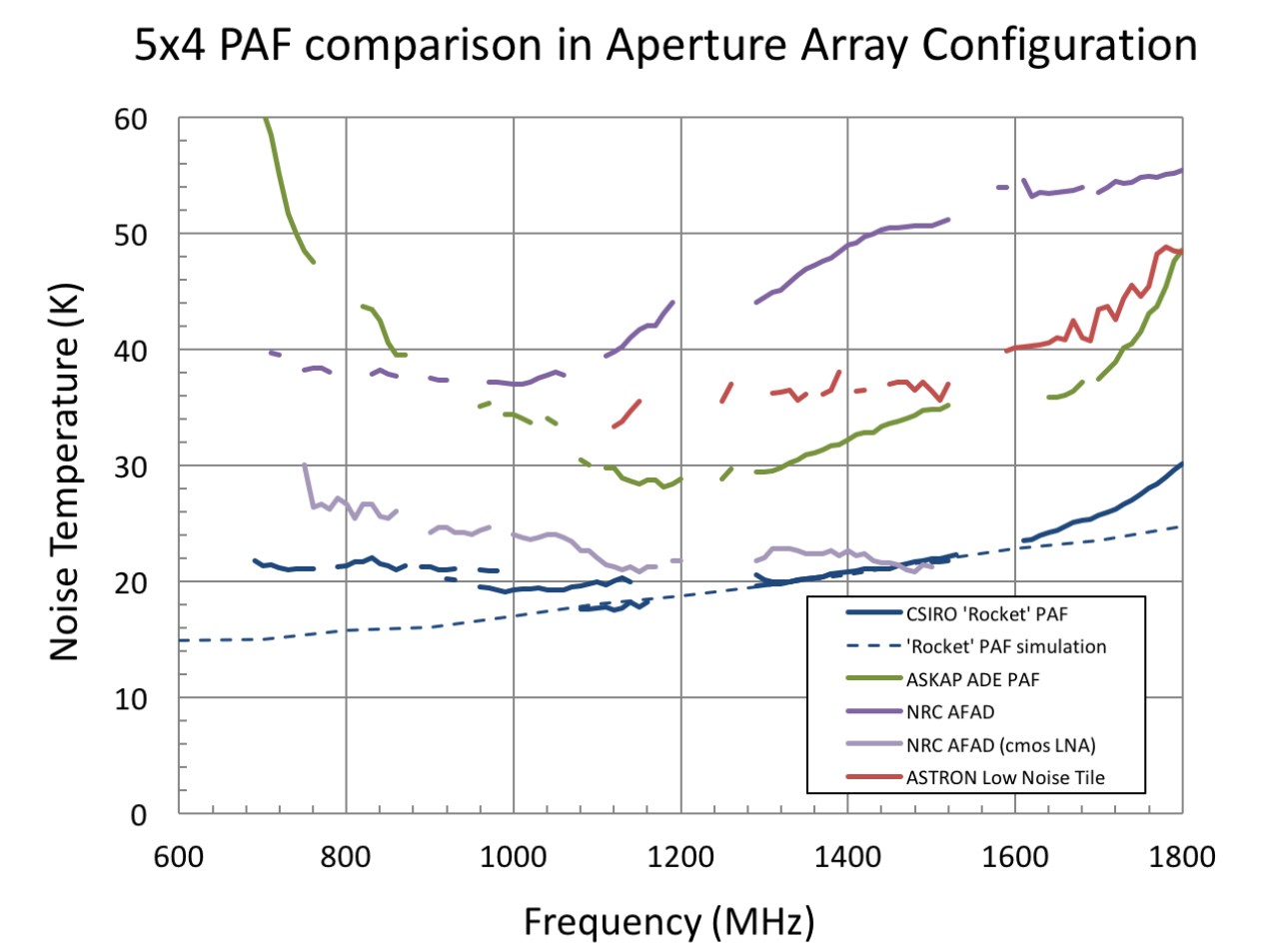
Credit: B. Veidt, NRC Canada

NRC PAF Design

- Thick Vivaldi Array
- Advanced Focal Array Demonstrator (AFAD)
- Cryogenic cooling (CryoPAF)
- 1.5 – 4.0Hz band (SKA - Band 3)

SKA Measurement Program

Performance Comparison



- Measurements “calibrated’ using ASKAP (Mk. II) reference array.
- Gaps in the measurements are caused by RFI.

PAF – Dish Consortium Engagement

- SKA Dish common optical configuration defined and dish design well developed (SKA SA, EMSS, NRC, CSIRO).
  - 15m Offset Gregorian
  - 5m sub-reflector (oversized)
  - Shaped reflector with 58°openning angle
- Ensure PAFs are not built out in SKA1_MID antenna design
  - SKA Feed Indexer design and structure interfaces
  - SKA_Survey Band 2 PAF replaces – SKA SPF Band 1
  - SKA_Survey Band 3 PAF (CryoPAF) replaces – SKA SPF Band 3, 4, 5.
- Basic system architecture defined
- Draft PAF ICD under development – Compatibility with SKA_Mid antennas

SKA PAF Advanced Instrumentation Program

- SKA Organisation agreed to set up a PAF AIP
  - Initial AIP Plan to SKA Board – November 2016
  - AIP runs for the remainder of SKA Preconstruction – Late 2018
  - System Requirements Review (SRR) and Conceptual Design Review (CoDR)
  - Precursor to PAF development program during SKA Construction (ODP)
- PAF AIP Consortium "founding" members
  - CSIRO – Australia (Lead)
  - NRC – Canada
  - ASTRON – The Netherlands
  - INAF – Italy
  - JBCO – UK
- Additional members
  - JLRAT – China
  - MPIfR – Germany

SKA Observatory Development Program

- Role of the ODP – To ensure ongoing instrumentation development
  - Concept agreed but shape of program yet to be defined
  - Cover ALL areas of development – PAF, WBSPF, AAMID, Software, …
  - Managed centrally by SKA Organisation
  - Funding model not decided (Fully funded or co-funded)
- ODP Proposals put to SKA Organisation on possible ODP Programs
- General agreement that PAFs are one of the key future technologies for radio astronomy and should be part of the ODP
- Key role of AIP program(s) is to do the ground work for the ODP

Questions for the Future

Radio Astronomy in General

- Which niche/niches do PAFs fill in radio astronomy?
  What science will PAFs do better than anything else?
  Remember – Scientists can be an impatient bunch; although they can see the potential; they will not wait forever – Promising early science results
- What is the role of PAFs in the SKA?

Key Areas of Technical Development

- Understanding on-dish performance
- Beamforming – Algorithm, calibration, RFI mitigation, de-rotation
- Improving sensitivity – Room temperature, cooled and cryogenic
- Bandwidth – Observed and processed
- Manufacturability and cost – Appropriate for the application

We acknowledge the Wajarri Yamatji people as the traditional owners of the Murchison Radio Observatory site.

CSIRO Astronomy and Space Science

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