Australian SKA – Progress & Directions

Peter Hall
Berkeley, July 2001

http://www.atnf.csiro.au/SKA
Formation of Australian SKA Consortium
- Executive Committee, Science & Engineering Working Groups now functional
- First symposium held Feb. 2001

Major National Research Facilities (MNRF) bid
- Submitted May 2001; outcome known August 2001
- Contained proposals for 2 major SKA demonstrators

Technical Work
- Significant results in antenna and interference mitigation projects

Site Survey
- First field work completed in Western Australia

Collaborations
- Industry and international SKA joint work increasing

Outreach
- Professional and community
SKA Outreach

- **Professional**
  - Institution of Engineers national congress
  - ‘Engineering World’ article
  - ITEE Society mailout
  - Spectrum management & community issues
    » Introducing Radio Quiet Zone concept

- **Government**
  - Federal parliamentary briefing
  - South Australian Govt. briefing
  - Continuing Western Australian interaction
  - Emerging New South Wales interest

- **General**
  - Radio, TV, print material
    » Site tests
    » Prototype Luneburg Lens
  - Local & indigenous community contact
Australian SKA: Some Pictorial Philosophy

- Widely separated multi-beaming
- Wide field-of-view
- Active interference mitigation
- Broadband
CSIRO SKA Program – Highlights

- **Antennas**
  - Luneburg Lens EM design & analysis – encouraging first results
  - Russian prototype Luneburg Lens
  - Materials science: Artificial dielectrics & manufacturing
    » Powders and wires
  - Phased array collaboration (ASTRON, industry….)

- **Site tests & data visualization**
  - Initial Western Australia field work
  - Characterize sites AND contribute to international site selection process

- **Interference mitigation**
  - Strengths in post-correlation IM
  - Extending to simultaneous multiple satellite sources (IRIDIUM, GLONASS)
  - ATCA operational IM goals

N → Poster N & coffee
Luneburg Lenses for SKA

SKA Telescope Fly-Through

CSIRO ATNF

Commonwealth Scientific & Industrial Research Organisation
Australia Telescope National Facility

Ben Simons, Sydney VisLab
www.vislab.usyd.edu.au
Konkur Luneburg Lens

- Obtained with PRAO collaboration
- Two initial uses:
  - Verify EM design & analysis
  - Int Mit reference antenna
- Currently under test by CSIRO

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Diameter</td>
<td>2r = 0.9 m</td>
</tr>
<tr>
<td>Operating frequency range</td>
<td>To 12 GHz</td>
</tr>
<tr>
<td>Gain (12 GHz)</td>
<td>39 ± 0.5 dB</td>
</tr>
<tr>
<td>Aperture efficiency</td>
<td>&gt; 50%</td>
</tr>
<tr>
<td>Sidelobe level (standard horn feed)</td>
<td>&lt; -17 dB</td>
</tr>
<tr>
<td>Focal distance</td>
<td>1.5r</td>
</tr>
<tr>
<td>Mass</td>
<td>90 kg</td>
</tr>
<tr>
<td>Operating temperature range</td>
<td>-50 to +50 °C</td>
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(Patented construction process)
Konkur Lens: First Results

Directivity ~ 39.3 dBi
Raw aperture eff ~ 67%
- with 0.5 dB dielectric loss ~ 57%

Amplitude
(Ref centre meridian plane)

12 GHz Tests; TV Feed
Pattern cuts for Luneburg lens in 0 deg plane

Far-field Beam

Directivity (dB)

Theta (deg)

2D Beam
(Co-polar)
Industry Link: Advanced Nano Technologies

- Collaboration between Advanced Powder Technology (Aust) and Samsung Corning (Korea)
- Make particles smaller than thickness of DNA string
- Unique chemical, mechanical, optical, magnetic properties
- Great potential in artificial dielectrics
Industry Link: CEA Technologies

- Canberra based
- 150 employees, $20M turnover
- Modular S and X-band radars sold internationally
- Interested in becoming involved in SKA prototyping
Practical Interference Mitigation

Before

ATCA, 1500 MHz, Terrestrial Data Link Interference

After

Post-Correlation Interference Mitigation
Site Tests – First WA RFI Survey

- CSIRO & WA Govt
  - Private contractor
- 27 March – 17 April 2001
- “First look” study
  - Representative RFI at one site
  - Highlight practical challenges
  - Compare with spectrum database
- Analysis continuing – reports this week
Australian SKA Demonstrators

- Explore new territory
  - Concentrators, signal processing.…

- Money amounts are small ( ~ $US 10M)
  - Careful selection of concepts
    » Best short-term astronomy ≠ best SKA demo

- Cover “big” and “smart”
  - Address hard radio science issues AND
  - Focus on scaling and cost issues relevant to SKA

- Integrate with existing telescopes
  - Extends host’s capabilities
  - Allows detailed assessment of concept

- Contribute to 2005 concept assessment
MNRF Bid – The Money Trail

MNRF Bid ($US29M)

- Gemini ($18M)
- SKA ($11M)
- Sydney U. ($0.9M)
- CSIRO ($8M)
- Swinburne U. ($1.25M)

Figures Include 50% Matching Funds
SKA Demonstrators: What We Propose

- **AT Compact Array demonstrator** ($US 6M)
  - New 2 GHz F/X correlator
    - Main short-term “astronomical” deliverable
    - Complements recent mm-wave ATCA upgrade
  - 2 x mini SKA stations
    - Final number and form TBD
      - Lenses or phased arrays prime contenders
  - 4 m Luneburg Lens
    - Multi-beaming IM reference antenna using AD

- **Molonglo cylindrical reflector demonstrator** ($US 0.9M)
  - Multibeamering and advanced DSP

- **SKA enabling technology** ($US 1.5M)
  - Active focal plane/surface arrays, highly-integrated receivers

- **System simulations & software correlators** ($US 1.25M)
ATCA Demonstrator

6 x 22m antenna AT Compact Array

Interference mitigation reference antenna (4m)

F/X correlator (2 GHz bandwidth)

Real-time imager

Off-line data handling

MUX

DMUX

SKA mini-stations (~15m dish equivalent)

Wavelength division multiplexing
**ATCA Demonstrator – Design Decisions**

- **Form of station**
  - Concentrator (lens) vs phased array

- **Number & layout of stations**
  - Balance ATCA gains vs breadth of SKA demonstrator
    - Calibration issues crucial (min size, ability to adequately test homogeneous elements….)
      - Potentially powerful ‘holography’ modes

- **Nature of interconnection**
  - Fibre interconnect – analog or digital?
  - DWDM demonstrator

- **RF issues**
  - Should demonstrate highly integrated receiving systems
  - New photonic sampling scheme
Photonic PAM System

A Sub-Array Incorporating Impulse Sampling and Photonic A/D Conversion

BASE STATION

High repetition rate, low jitter pulse source locked to station reference clock

Multiwavelength Optical Pulse Source

Detectors and LPFs

Wavelength-Division Demultiplexer

A/D

DSP

Downconversion Fringe Rotation Correlation etc

\( \lambda_1, \lambda_2, \lambda_3, \ldots, \lambda_N \)

\( \lambda \)-coded samples separated by filter and digitised in parallel

To K Antennas

From K Antennas

Antenna K

Antenna 1

Antenna 2

Electro-optic Modulator

Short optical pulses sample RF at antenna

A Sub-Array Incorporating Impulse Sampling and Photonic A/D Conversion
Molonglo Demonstrator

- 18,000 sq m cylindrical paraboloid
- **Currently:**
  - 843 MHz operation
  - Analog beamforming
- **Proposed:**
  - 300-1420 MHz coverage
  - Multi-beam line feeds
  - Digital beam formation
  - Versatile FX correlator
- **New observing modes, new science**
Australian SKA Directions

- **Demonstrator design & construction**
  - Selection of demonstrator concepts by Dec 2002

- **More site studies work**
  - Extension to other states

- **More R&D in additional key technical areas**
  - Phased array concept
  - Highly-integrated RF systems
  - Photonics
    - Transport, connectivity, RFI filtering
    - High speed analog – digital conversion
  - Configurations and system simulation...need to un-stall

- **Engagement of wider astronomy community**
  - e.g. making the Gemini link real

- **Expansion of industry and international SKA links**
  - Artificial dielectrics → prototype Luneburg Lenses
  - Phased array prototypes, integrated receivers, signal processing...