Performance of the SKA1 system baseline design

Attila Popping
Phase I SKA

• SKA1-low
  • ~50-350 MHz
  • highly redshifted HI

• SKA1-mid (single pixel)
  • 64 MeerKAT dishes + 190 SKA1 dishes
  • ~350-3050 MHz

• SKA1-survey (PAF)
  • 36 ASKAP dishes + 60 SKA1 dishes
  • ~650-1670 MHz
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HI science
The performance of the SKA is tested and compared with other telescopes using simulated models

**Telescopes:**
VLA, ASKAP, MeerKAT, SKA1-survey, SKA1-mid

**Declinations:**
0, -30, -60 degrees

**Weighting:**
Uniform -> Natural (robust -2,-1,0,1,2)

**Hour angle range:**
snapshot, 12 hour synthesis

**Frequency:**
1 GHz, 50 khz bandwidth
Telescope parameters are extracted from SKA1 baseline design document.

<table>
<thead>
<tr>
<th></th>
<th>VLA</th>
<th>ASKAP</th>
<th>MeerKAT</th>
<th>SKA1-survey</th>
<th>SKA1-mid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeff/Tsys</td>
<td>265</td>
<td>65</td>
<td>321</td>
<td>391</td>
<td>1630</td>
</tr>
<tr>
<td>Receptor Size</td>
<td>25</td>
<td>12</td>
<td>13.5</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Tsys</td>
<td>25</td>
<td>50</td>
<td>20</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>efficiency</td>
<td>0.5</td>
<td>0.8</td>
<td>0.7</td>
<td>0.7</td>
<td>0.78</td>
</tr>
</tbody>
</table>

- Visibility and image data is generated.
- In the imaging step a cutoff has been applied to use uv-points within a length $q=(u^2+v^2)^{1/2}$.
- Telescope performance is compared for baselines of over 100 km.
- Typically $q$ values align with baselines of VLA in A,B,C,D config.
Performance parameters

1. RMS: 1 sigma noise value in image maps ($2048^2$ pixels)
2. Beam size: the size of the synthesized beam, $FWHM \ b_{maj} \ & \ b_{min}$
3. HI column density: the 1 sigma brightness sensitivity
4. Survey Speed: FoV / $\text{rms}^2$
5. PSFRMS: The standard deviation of the occupancy of uv-points in uv-cells

$$PSFRMS = \sqrt{\sum_{i,j} n_{ij}^2 / N_{uv}}$$

6. UVGAP: fraction between the gap between two baselines and the baseline length

$$uvgap = \frac{1}{q_{max}} \sum_{k=1}^{n} \partial q_k \times (q_k - q_{k-1}), \text{ with } q_0 = 0 \text{ and } q_n = q_{max}$$
Noise maps for SKA1-survey (q < 3.4 km) natural (left) and uniform (right)
SKA I - mid

Configuration

UV distribution

Beam PSF

Baseline distribution

UVGAP

Declination: -30
Frequency: 1000.0
Bandwidth: 0.05
HA min: -6
HA max: 6
Robust: -1
UVrange: 3400

Bmin: 11.78
Bmaj: 12.009
rms: 5.597e-05
NHI: 2.66867924502e+19
PSFRMS: 0.00738119047159
UVGAP (med): 0.00351693820765
UVGAP (mean): 0.00337028089293
SKA I-mid; Dec = 0

Configuration

UV distribution

Beam PSF

Baseline distribution

UVGAP

mid

Declination: 0
Frequency: 1000.0
Bandwidth: 0.05
HA min: -6
HA max: 6
Robust: -2
UVrange: 64000

Bmin: 0.954
Bmaj: 1.85
rms: 7.747e-05
NHI: 2.9607355058e+21
PSFRMS: 0.00637070226228
UVGAP (med): 0.0135395161424
UVGAP (mean): 0.00813686091525
Uniform

Declination: -30
Observation: 12h synthesis

Frequency: 1.0 GHz
Bandwidth: 0.05 MHz
Robust: -2
robust = 0

Declination: -30
Observation: 12h synthesis
Frequency: 1.0 GHz
Bandwidth: 0.05 MHz
Robust: 0
Natural

Declination: -30
Observation: 12h synthesis

Frequency: 1.0 GHz
Bandwidth: 0.05 MHz
Robust: 2
2nd generation configurations

Declination: -30
Observation: snapshot

Frequency: 1.0 GHz
Bandwidth: 0.05 MHz
Robust: -2
Survey speed of SKA-survey is two times better, however at 1.67 GHz ... at lower (more interesting) frequencies SKA-mid takes over at ~1.16 GHz
When changing the Fiducial frequency of the PAFS, the survey speed of SKA-survey improves significantly
The problem is complex and there is no single best solution

What is the best performance parameter, are there others?

1. What is the HI science you are interested in?
2. What are the requirements (redshift, resolution, sensitivity, position etc.)?
3. Is this possible with the SKA?
4. If yes/no would you change the baseline design?
5. Are there aspects in the design that are not so useful?

All performance plots:
https://dl.dropboxusercontent.com/u/108468270/performance_plots.tar

Specific scenarios can be calculated (relatively) quickly

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