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IMPROVING HARTRAO PEFORMANCE AT K-BAND

ABSTRACT

A first K-band (24 GHz) celestial reference frame (CRF) of more than 900 sources covering the full sky has been constructed using over 0.6 million observations from more than 70 observing sessions from the VLBA and HartRAO-Hobart. In the north, the VLBA is able to observe declinations of +90 to -40 deg. In the south, the HartRAO-Hobart baseline is currently the only baseline regularly observing the southern sky at K-band for CRF development, covering declinations from -90 to +0 deg. Southern K-band CRF observations will benefit most from improving the baseline sensitivity and increasing the data recording rate. The baseline sensitivity has been greatly improved by the inclusion of the Tidbinbilla 70-m antenna in a first successful HartRAO-Tidbinbilla K-band session at the beginning of 2019. Digital back-end enhancements should allow for recording at a data rate of 4 Gbps in the south in the near future. One of the highest priorities for the HartRAO 26-m antenna is to update the current pointing model. Further envisaged improvements for the HartRAO 26-m antenna that should improve K-band sensitivity in the south include an upgrade to the sub-reflector to allow for active-focussing, the replacement of ageing and failing encoders and re-alignment of surface panels. The additional baselines that may be provided by future HartRAO-Hobart-Tidbinbilla sessions, should allow for isolating pointing issues to a particular antenna.

K-BAND CRF

- 900+ Sources covering full sky - using 0.6 million+ observations - from 70+ VLBA and HartRAO-Hobart sessions
- Weak in far south - only HartRAO-Hobart baseline - declinations from -90 to +0 degrees
- Need to increase sensitivity at K-band for CRF development

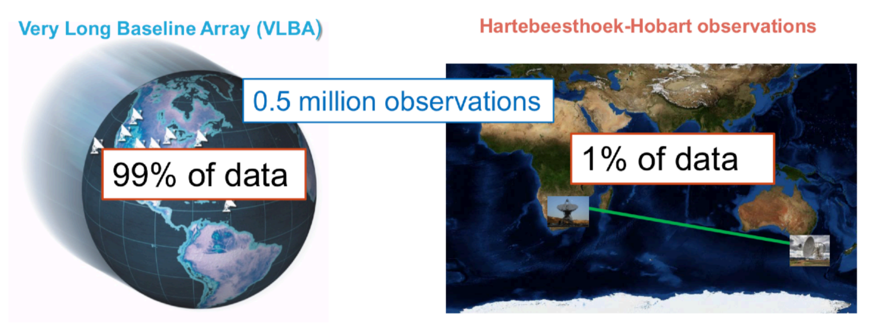

Figure 1: HartRAO-Hobart is the only baseline observing the southern sky at K-band for CRF development. Credit: P. Charlot, 2018, Ecole d'été du GRGS, Oléron, 3-7 septembre.2018.

IMPROVING K-BAND CRF IN SOUTH

- Most improvement from:
  - improving baseline sensitivity
  - increasing data recording rate
- Improved baseline sensitivity:
  - Tidbinbilla 70-m antenna included in first HartRAO-Tidbinbilla K-band session (KN1901 13 January 2019)
- Digital back-end enhancements:
  - Mark6 VLBI data recorder
  - forthcoming doubling of recording rate from 2 to 4 Gbps

Figure 2: Mark6 recorder under test at HartRAO.

IMPROVING K-BAND AT HARTRAO

1. Replace faulty bearing:
   - Faulty bearing on west end of Declination shaft of equatorially mounted HartRAO 26m
   - Bearing sliding axially along shaft by ± 10 mm as gravitational load varies
   - Replacement bearing on order

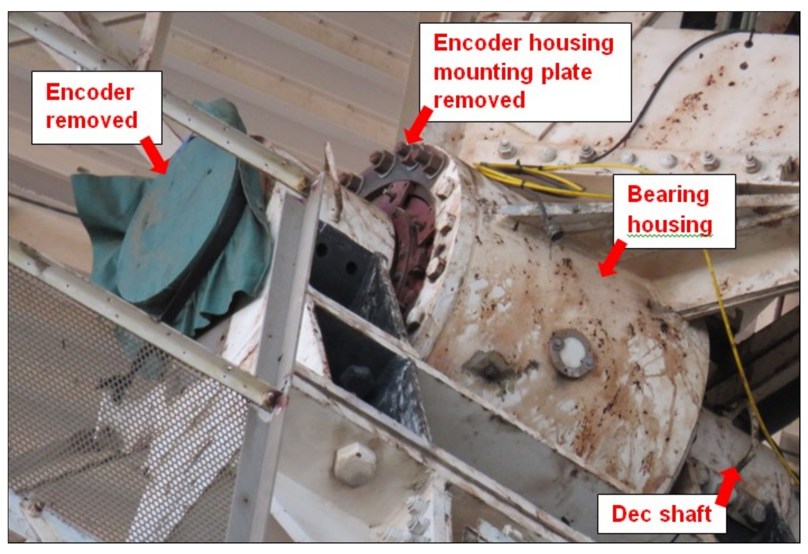

Figure 3: HartRAO 26m west end of Dec shaft with encoder removed. Credit: J. Grobler.

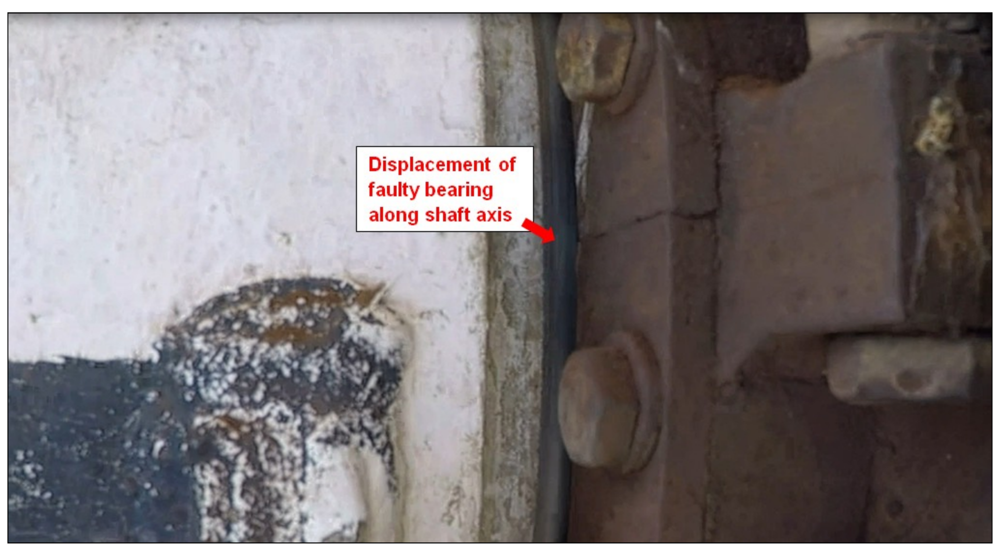

Figure 4: Bearing at west end of Dec shaft shows displacement of ±10 mm. Credit: P. Mey.

2. Replace ageing and failing encoders:
   - Current 19-bit encoders on Dec and polar shafts:
     - failing, misreading intermittently
     - insufficient resolution to reach K-band pointing tolerance
   - New higher resolution 26-bit encoders to be installed after bearing replacement
   - Able to access 23 bits:
     - interfacing only has 24-bit data bus architecture
     - 1 bit required for data validity
     - pointing resolution of 0.15 arcsec (vs. 5 arcsec of old 19-bit encoders)
   - Interface cards to access up to 24 bits have been built and are being tested
   - Minor software changes required

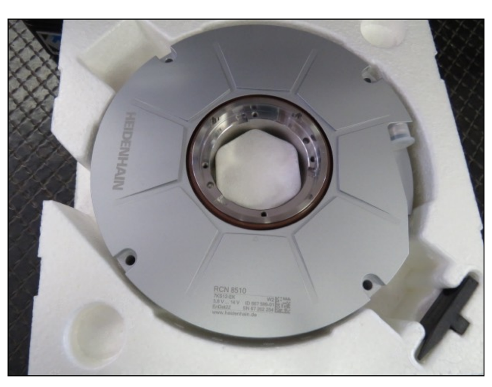

Figure 5: New HEIDENHAIN 26-bit absolute angle encoder. Credit: P. Mey

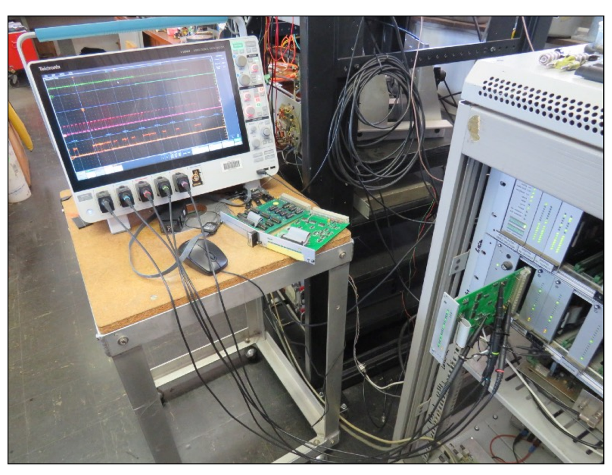

Figure 6: Encoder interface card under test. Credit: S. Blose.

3. Upgrade sub-reflector:
   - Sub-reflector control system has been upgraded
   - Tilt: upgraded to 16-bit angle encoder - measures actual angle through which sub-reflector tilts - more reliable positioning
   - Focus: hardware upgrades completed - 25-bit linear encoder installed - direct readout of focus position - improved repeatability
   - Sub-reflector position not optimised for 1.3 cm - original positions just reproduced - software to optimise in place - require campaign for optimisation
   - Active control of tilt - only if significant deflection of sub-reflector (motion relative to main reflector and its focus) detected
   - Active control of focus - displacement of sub-reflector might benefit from active focussing - software would require significant revision - only usable with on-axis 1.3 cm feed - different pointing model when active - difficult to determine suitable focus model
   - Only one 22 GHz optimisation curve analysed thus far - focus close to optimal - create pipeline for further analysis

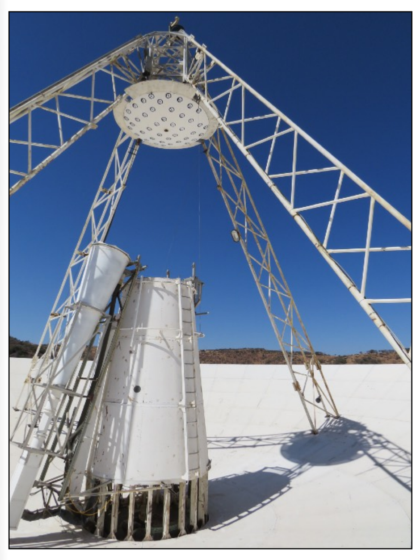

Figure 7: HartRAO 26m sub-reflector and feed horn.

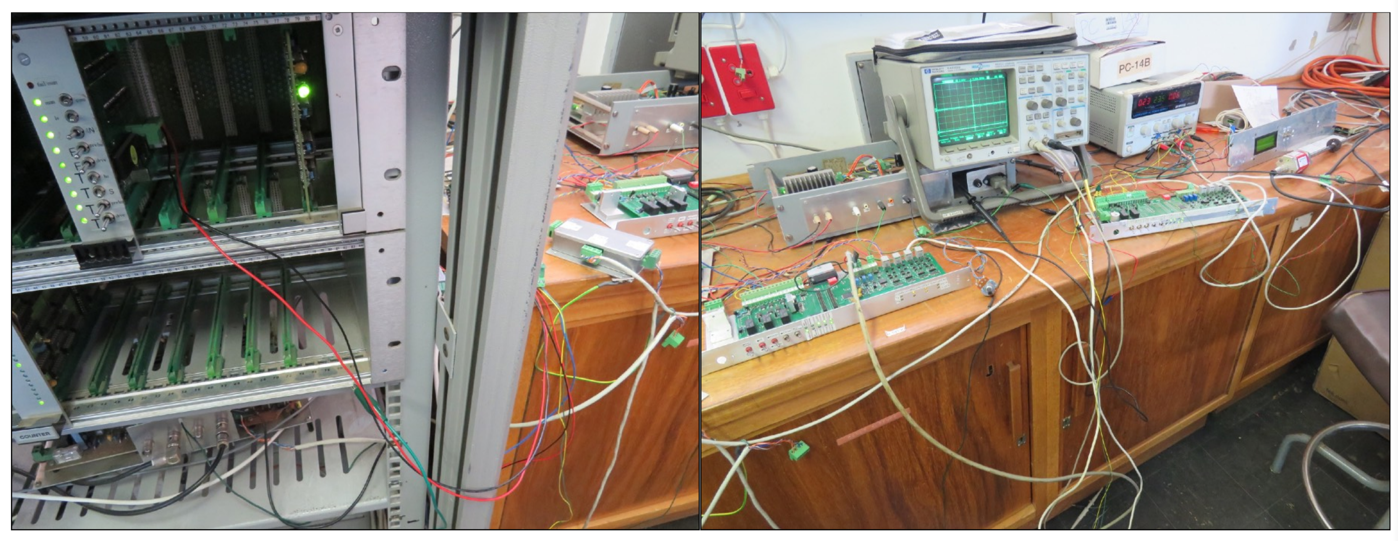

Figure 8: HartRAO 26m sub-reflector control system test setup in Electronics Workshop. Credit: S. Blose.

4. Update current pointing model:
   - Spot calibrator measurements - pointing off by up to quarter of a HPBW at K-band
   - Pointing model to be updated once bearing, encoders have been replaced
   - Additional baselines provided by inclusion of Tidbinbilla in HartRAO-Hobart-Tidbinbilla sessions - may isolate pointing issues to particular antenna

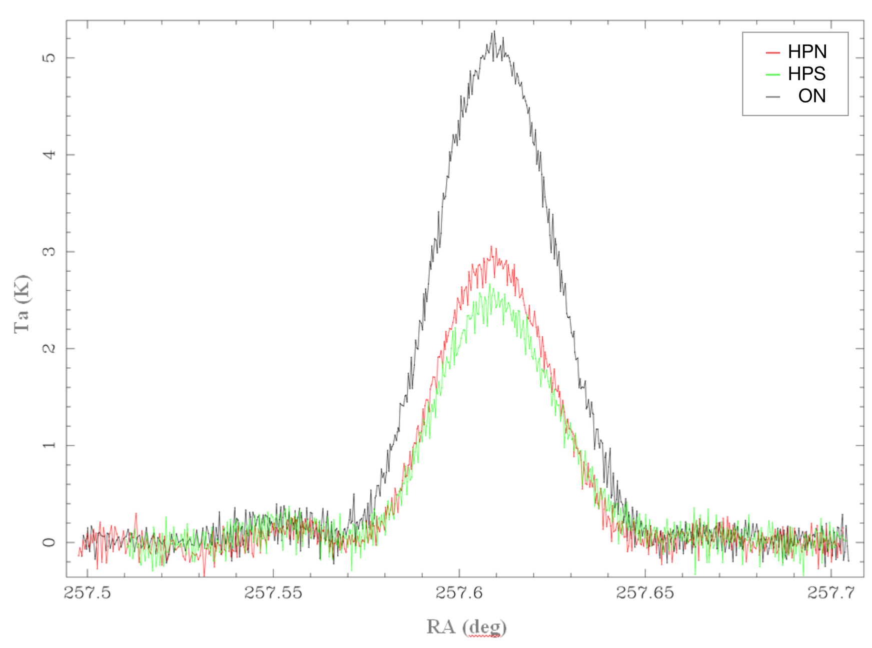

Figure 9: Jupiter triple drift scan observed at 22 GHz LCP with the HartRAO 26m on the 15th of June 2019 showing plots for observations at Half Power North, South and ON positions. Credit: A. de Witt.

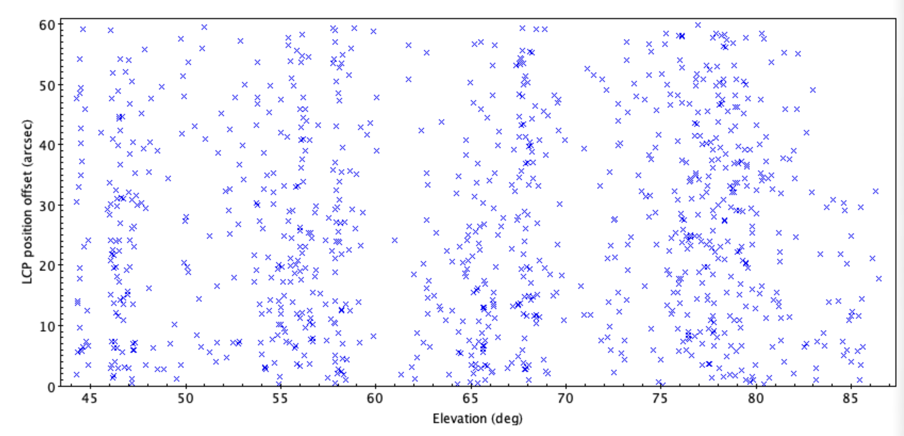

Figure 10: Pointing offset vs Elevation for Jupiter 22 GHz LCP observations from 2015-2019. Credit: A. de Witt.

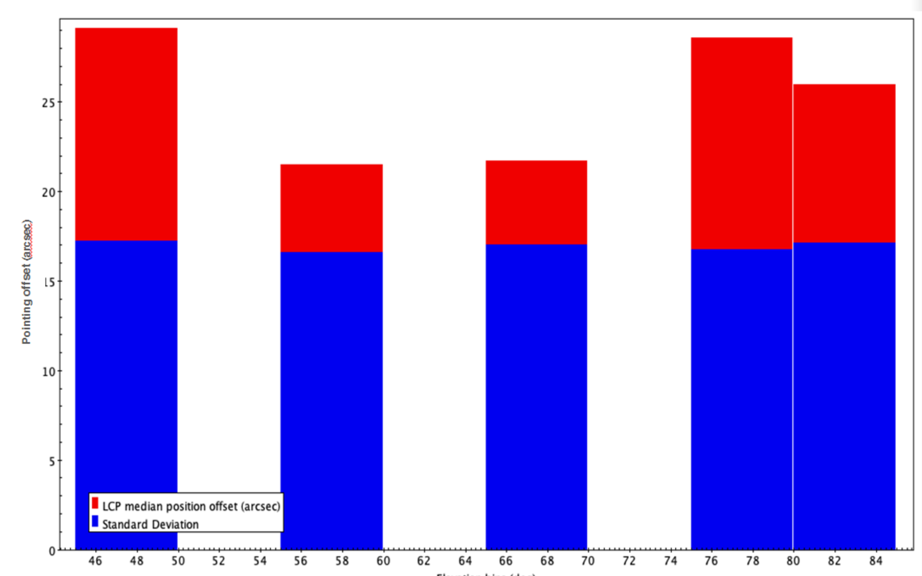

Figure 11: Pointing offset median and standard deviation values for binned Jupiter observations at 22 GHz LCP from 2015-2019. Credit: A. de Witt.

FURTHER INVESTIGATION

- Possible re-alignment of surface panels - conduct holography tests to determine whether panels misaligned - re-align if necessary
- Determine gravitational and thermal deformation of antenna structure, dish - local survey, terrestrial laser scanner?, temperature sensors
- Investigate possible deflection of sub-reflector, monitor distance between sub-reflector and base of feedhorn

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