HartRAO Site Tie Measurements: VLBI and Ground Survey

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Abstract A first short baseline VLBI experiment between the Hartebeesthoek Radio Astronomy Observatory's (HartRAO) 26 m legacy and co-located 15 m radio telescopes has been conducted. The local automated site tie system at HartRAO is currently being implemented and tested. The methodology of the two approaches to local tie measurement, VLBI and ground survey, as well as results from the first short baseline experiment are presented here.

Keywords VLBI · ITRF · Local tie · Short baseline

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1 Introduction

If the Global Geodetic Observing System (GGOS) requirement of ± 1 mm accuracy (Beutler et al., 2009) is to be met for global baselines, it must be possible to at least reach this goal for the short baseline of ~113 m between the HartRAO 26 m legacy antenna and the 15 m co-located antenna (see Figure 1). Short baseline experiments allow for discovering and investigating instrumental effects and antenna structure as the antennas share a common location position, atmosphere, local geophysics and clock. Short baseline experiments also allow for determining the local tie between the telescopes. A first such short baseline experiment between the HartRAO 26 m and 15 m antennas has been conducted.

Fig. 1: Short baseline of ~113 m between the HartRAO 26 m antenna (left) and the HartRAO 15 m antenna (right), with the Leica MS50 Multistation in the foreground.

The local automated site tie system at HartRAO is currently under test. Measurements to various on-site GNSS reference stations, the NASA and Roscosmos SLRs as well as to various reference piers will be performed on a regular basis towards fully automating the system. The HartRAO 26 m, 15 m and VGOS radio telescopes will form part of these local tie measurements in due course. Measurements of VLBI reference points, antenna axis offsets (AO) and station coordinates obtained by conventional survey with the total station, will be used to complement the VLBI determined values.

2 Short baseline experiment

A first short baseline session, SBL500, was observed on the 11th of May 2018 with the HartRAO 26 m and 15 m antennas. It consisted of a 4-hour session conducted from 22:00 UT on the 11th of May until 02:00 UT on the 12th of May, well away from sunset and sunrise hours to ensure temperature stability. It was not possible to run the antennas off the same clock for this first short baseline experiment, yet. The SBL500 session was scheduled with the Vienna VLBI and Satellite software (VieVS Böhm et al., 2018) to observe ICRF-2 defining sources at X-band at 2 Gbps, covering the full range of azimuth (for east and north baseline components), elevation (separating the vertical from the troposphere) and cable wrap.

The SBL500 session was subsequently correlated at the Vienna correlator with the Distributed FX-architecture (DiFX) software VLBI correlation package, using a spectral resolution of 0.2 MHz and applying local oscillator (LO) frequency offsets of 9999.9 Hz to HARTRAO. Fringe-fitting and post-processing were also performed at the Vienna correlator making use of the Haystack Observatory Postprocessing System (HOPS) software package. The SBL500 correlator output was made available as vgosDB files. The SBL500 session was analysed with VieVS. Earth Orientation Parameters (EOPs) and coordinates of sources with the no-net-rotation (NNR) condition were not estimated. Thirty-eight other parameters were estimated as follows:

- troposphere zenith wet delay as piecewise linear offsets (PLO) every 60 minutes with loose constraints (6 parameters per station, 12 parameters in total)
- tropospheric gradients as PLO every 360 minutes with loose constraints (3 parameters per station per gradient, 12 parameters in total)
- clock PLO every 60 minutes with loose constraints, one rate and one quadratic term per clock (6 parameters for PLO and 2 for rate and quadratic term, 8 parameters in total)
- station coordinates as one offset, datum definition via no-net-rotation/no-net-translation (NNR/NNT) condition (1 parameter per station per coordinate, 6 parameters in total)

Table 1: Comparison of VieVS estimated values for baseline components and length in SBL500 and corresponding values measured during the 2014 local tie survey (Phogat et al., 2018).

Baseline component	2014 Local tie survey measurement (m)	VieVS estimation for SBL500 (m)
X	-48.0326 ± 0.0029	-48.0353 ± 0.0017
Y	102.2991 ± 0.0032	102.2991 ± 0.0021
Z	-4.1238 ± 0.0073	-4.1286 ± 0.0014
Length	113.0895 ± 0.0187	113.0908 ± 0.0020

Results for baseline components and baseline length from the VieVS VLBI analysis of SBL500 and corresponding results from IGN measurements as determined during the February 2014 local co-location survey (Muller and Poyard, 2015) are compared in Table 1. The results obtained from VLBI analysis differ at the millimetre-level from the local tie survey results.

3 Local tie ground survey

A local automated site tie system for continuous monitoring of vector ties is being implemented. The planned measurement system is to consist of the one Leica MS50 Multistation mounted on a permanent reference pier (currently under test, see Figure 1) as well as an additional Leica MS50 Multistation to be installed on the roof of the Control room. Measurements are to be made to the prisms installed on the antennas and reference network first. The planned reference network is to consist of the on-site HRAO (IGS station), ESA, DLR and Russian GNSS to tie the measurement system in with GNSS observations to link it to the ITRF (see Figure 2).

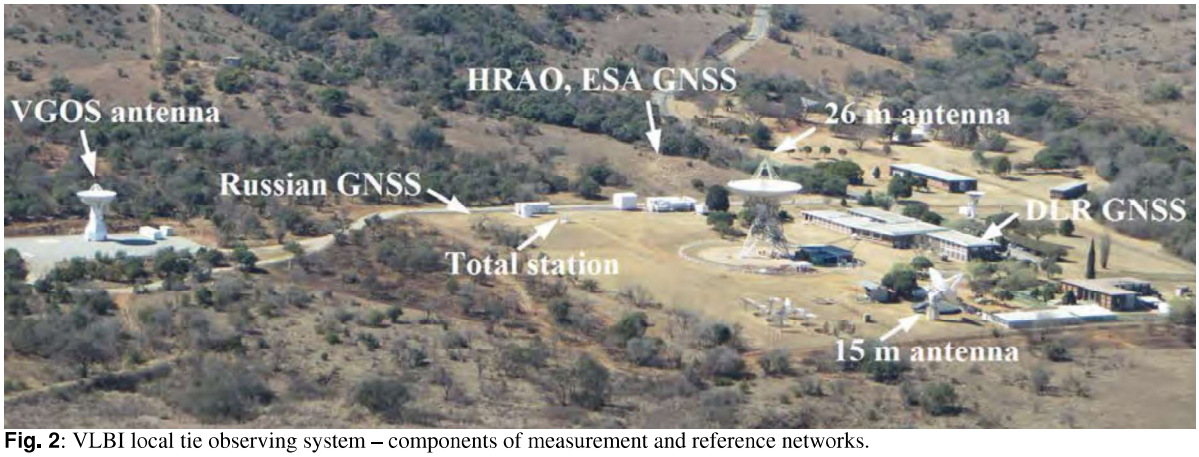

Fig. 2: VLBI local tie observing system – components of measurement and reference networks.

Fig. 3: Targets, consisting of a combination of Leica prisms and custom-made adapters.

Fig. 4: Prism combination mounted at south end of 26 m polar shaft acquired by the Leica MS50 Multistation.

It is intended to mount the targets on both the 26 m and 15 m antennas on-axis where possible. Targets on the 26 m antenna are to consist of prisms mounted on each of the east and west ends of the declination shaft as well as at the south end of the polar shaft (see figures 3, 4, and 5). The north end of the polar shaft is obscured by the bearing housing, requiring the design of special adapters to mount prisms at this end. On the 15 m antenna, it is possible to mount a prism at the west end of the elevation shaft. The east end of the elevation shaft is obscured by the elevation cable wrap. Again, either special adapters will have to be designed to mount the prisms, or prisms will have to be mounted off-axis at this end (see Figure 6). Similarly for the 15 m's azimuth axis, which is not accessible for the placement of on-axis prisms. Any existing targets on the antenna's structure will also be employed. Targets will be measured by the two total stations, simultaneously, for various positions of the primary and secondary axes respectively.

For antennas with intersecting rotation axes, it is relatively straightforward to determine the VLBI reference point. However, the rotation axes of the HartRAO 26 m polar-mount and 15 m azimuth-elevation (az-el) mount do not intersect but an axis offset (AO) exists for each of the antennas. For the 26 m antenna, the VLBI reference point is represented by the intersection of the fixed Hour Angle (HA) axis with the perpendicular plane containing the moving Declination (DEC) axis. For the 15 m antenna, the VLBI reference point is represented by the intersection of the fixed azimuth axis with the perpendicular plane containing the moving elevation axis.

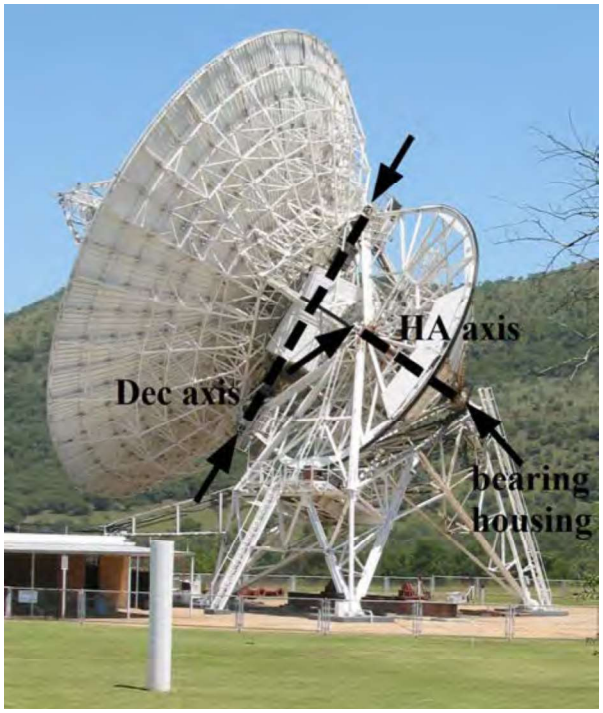

Fig. 5: HartRAO 26 m polar mount antenna – rotation axes and on-axis prism mounting points on Dec shaft (top and bottom arrows) and at south end of polar shaft (arrow in middle). The north end of the polar shaft is obscured by the bearing housing (arrow on right).

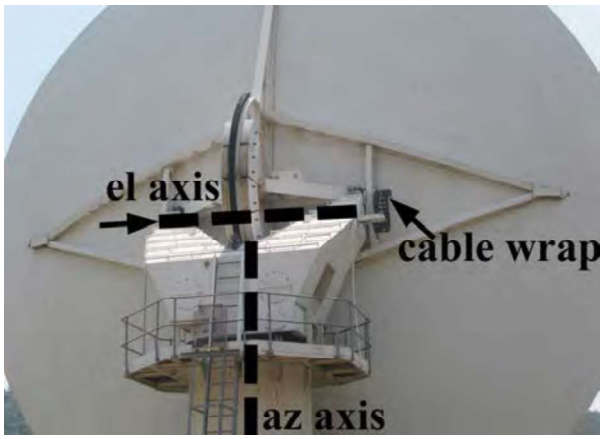

Fig. 6: HartRAO 15 m az-el mount – rotation axes and on-axis prism mounting point at west end of elevation shaft (arrow on left). The east end of the elevation shaft is obscured by the cable wrap (arrow on right).

For both the HartRAO 26 m and 15 m antennas, indirect measurement of the VLBI reference point is therefore required. In order to accomplish this indirect measurement, the intention is to, firstly, mount prisms with their optical reference points coincident with the rotation axis and then, secondly, mount prisms off-axis. The antenna is subsequently moved about one of the rotation axes with the other axis being held fixed in a specific position, for several different positions. Targets will then trace an arc in a circular plane normal to the axis being measured. The axis intersects the plane in the centre of the circle. The method suggested by Combrinck and Merry (1997) for finding the axis intersection and centre of the circle by making use of the intersection of co-planar lines, will be followed. Furthermore, comparing the results for on-axis and off-axis placement of prisms will allow for determining whether the on-axis prism is a valid and accurate measurement point for future use.

4 Outlook

A local tie survey, including all geodetic techniques on site, is currently in the planning stages. In addition to the daily measurement of various targets in the measurement and reference network by the automated total station, it is envisaged that the local tie and short baseline sessions will be conducted on a monthly basis. During the short baseline sessions, the 26 m and 15 m antennas will have to be run off the same clock. Possible variations of the baseline length will be investigated and an error budget will be drawn up for the short baseline ties. Once the VGOS telescope has been furnished with receivers, it will be included in the short baseline sessions.

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