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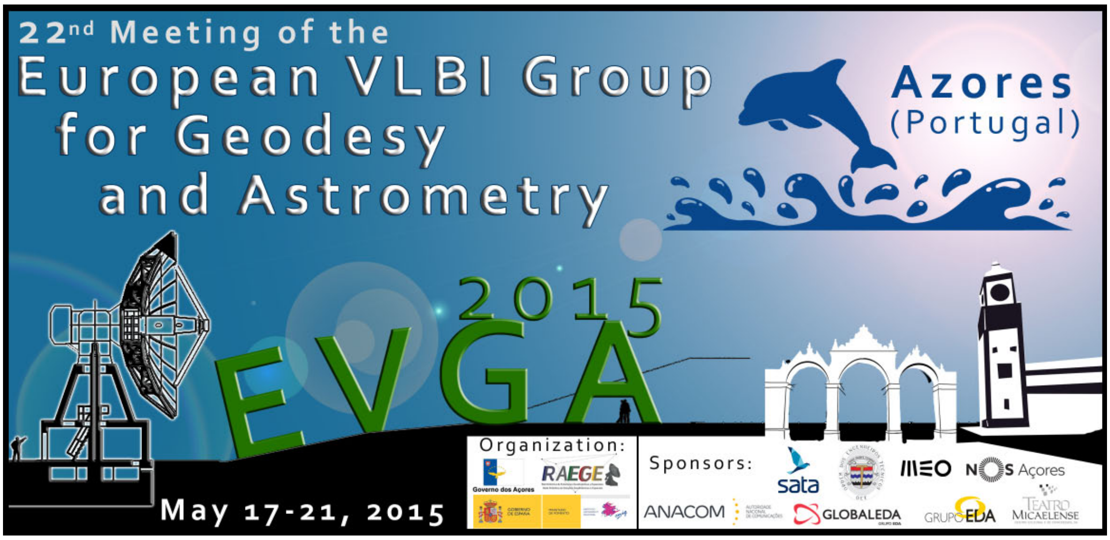


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# Determining HartRAO antenna parameters with VieVS

M. Nickola, A. de Witt, H. Krásná, W. L. Combrinck, J. Böhm

**Abstract** Geodetic VLBI sessions are analysed using the Vienna VLBI Software (VieVS) to estimate the antenna axis offsets (AOs) of both the Hartebeesthoek Radio Astronomy Observatory's (HartRAO) 26m and 15m radio telescopes and also to determine the local tie between the telescopes. Possible seasonal variations in AO as well as baseline length between the 26m and 15m are investigated.

**Keywords** axis offset, local tie, HartRAO

## 1 Introduction

The HartRAO 26m and 15m radio telescopes regularly participate in astrometric and geodetic VLBI sessions. The HartRAO 26m radio telescope suffered a critical bearing failure in 2008 and returned to operations in 2010 after repair. The 15m was built as SKA prototype during 2007 and converted to an operational geodetic VLBI antenna during 2012. It officially joined geodetic VLBI operations in 2013.

In 2014, antenna axis offset (AO) values of both the 26m and 15m were estimated using the Vienna VLBI Software (VieVS) (Böhm et al. (2012)) from geodetic VLBI sessions before and after bearing repair Krásná et al. (2014). A discrepancy was found to exist between the VieVS estimated AO values for the 26m before and after bearing repair and values previously determined for before bearing repair by other methods, such as ground surveys (which are taken to be the more accurate), as well as from analysis with other VLBI analysis software packages.

Additional geodetic VLBI sessions are analysed using VieVS to estimate the AO of both the 26m and 15m antennas, to investigate possible seasonal variations in AO as well as to determine the local tie between the two telescopes.

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## 2 HartRAO 26m and 15m radio telescopes

The HartRAO 26m is an equatorially mounted Cassegrain radio telescope built by Blaw Knox in 1961. The VLBI reference point is the intersection of the fixed Hour Angle (HA) axis with the perpendicular plane containing the moving Declination (Dec) axis (see Fig. 1 and Fig. 2). It serves as the reference point for the co-location of the Satellite Laser Ranging (SLR) and Global Navigation Satellite System (GNSS) stations on-site and as reference datum for South Africa's surveying system. On the 3rd of October 2008, the 26m suffered a critical failure of its south polar bearing. On the 11th of August 2010, the first post repair geodetic VLBI session was run. Post-repair position time series solutions indicated no noticeable shift in position.

The HartRAO 15m is an alt-az radio telescope built as SKA prototype during 2007. The VLBI reference point is the intersection of the fixed azimuth axis with the perpendicular plane containing the moving elevation axis (see Fig. 3 and Fig. 4). The 15m was con-

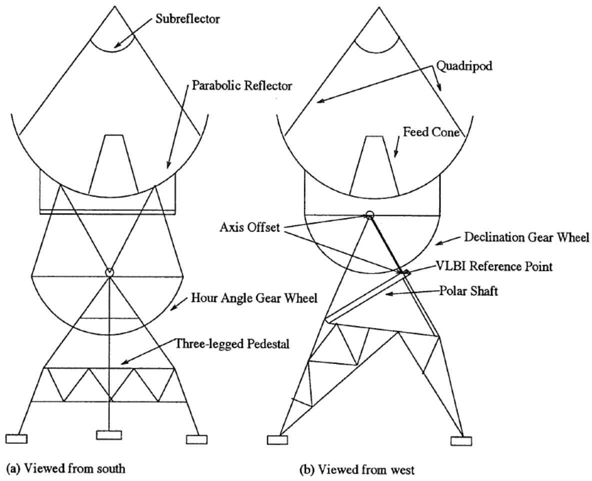


**Fig. 1** Main structural components of HartRAO 26m radio telescope (Combrinck and Merry, 1997).

**Fig. 2** Ludwig Combrinck surveying the 26m's polar shaft during bearing repair (Credit: Mike Gaylard).

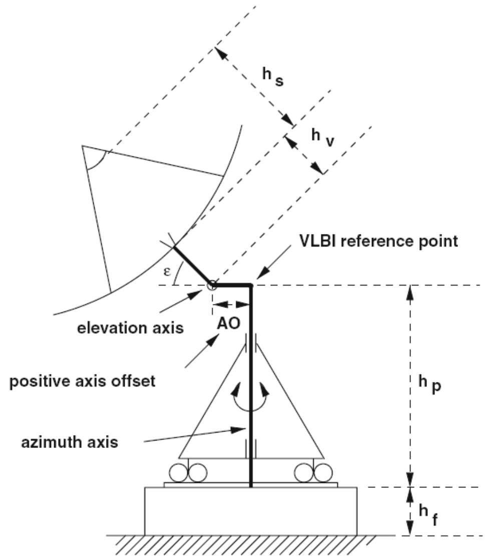


**Fig. 3** Alt-azimuth telescope mount with positive axis offset (Nothnagel, 2008).

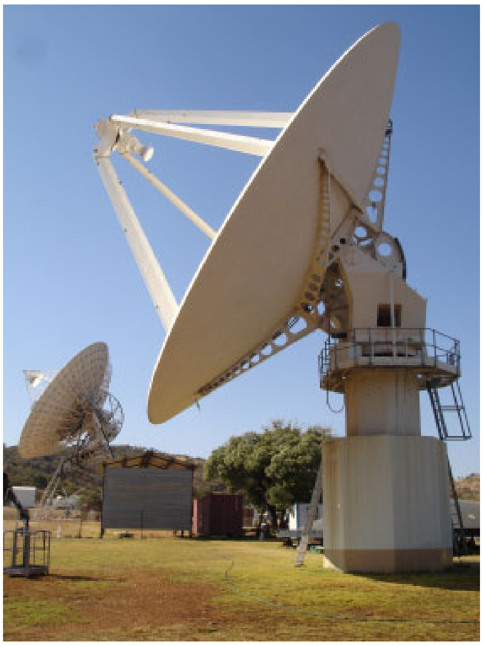

**Fig. 4** HartRAO 15m telescope mount with offset elevation axis (Credit: Mike Gaylard).

verted to an operational geodetic VLBI antenna during 2012. On 11 October 2012, the first geodetic session was run as part of the 15m's commissioning. Regular geodetic VLBI sessions have since been off-loaded to the quick-slewing, all-sky seeing 15m.

## 3 Axis offset comparison

When a telescope's rotation axes do not intersect, an antenna axis offset (AO) exists. The VLBI reference point is then the point represented by the intersection of the fixed axis with the perpendicular plane containing the moving axis. An antenna axis offset (AO) affects the geometrical and troposherical components of the delay model. The accuracy with which the AO is determined therefore influences the accuracy of VLBI results (Combrinck and Merry, 1997).

Antenna axis offset (AO) values for the 26m as determined by ground survey and estimated by VLBI solution are displayed in Tab. 1. AO values before bearing repair, obtained by using either method, are given in the top section of the table, while the middle section provides the VieVS estimates obtained by Krásná et al. (2014) for before and after bearing repair as well as from the start of the 26m's operation in 1986 until the end of 2013. The value obtained in the current study, using VieVS to estimate the AO after antenna repair until the end of November 2014, are given in the bottom section of the table. This value of (6707.9 ± 0.7 mm) agrees within the formal error with the estimate of (6707.3 ± 0.8 mm) by Krásná et al. (2014). Both VieVS estimates of AO after bearing repair differ considerably from the IVS recommended value, taken from ground survey before the bearing repair, of 6695.3 mm.

**Table 1** HartRAO 26m antenna axis offset determined by independent techniques (a priori value = 6695.3 mm).

| Method | Determined by | Value (mm) |
|---|---|---|
| Standard value | JPL (1961) | 6706 |
| Conventional survey | Newling (1993) | 6695 ± 3 |
| VLBI solution | Ma (1995) | 6693.6 ± 2.5 |
| VLBI solution | Eubanks (1995) | 6692.5 ± 1.5 |
| HartRAO GPS | Combrinck (1995) | 6695.6 ± 2.3 |
| VLBI solution | Ma (1996) | 6688.8 ± 1.8 |
| Local tie survey | Michel et al. (2005) | 6695 ± 2.5 |
| VieVS solutions: | Krásná et al. (2014) | |
| Before repair | | 6699.2 ± 0.5 |
| (1986-2008.8) | | |
| After repair | | 6707.3 ± 0.8 |
| (2010.8-2014.0) | | |
| 1986-2014.0 | | 6707.1 ± 0.5 |
| VieVS solution: | Current study | |
| After repair | | 6707.9 ± 0.7 |
| (2010.8-2014.11) | | |
| (180 sessions) | | |

Antenna axis offset (AO) values for the 15m as determined by ground survey and estimated by VLBI solution are displayed in Tab. 2. Both the value for the AO from Dan MacMillan's VLBI solution of 2014 of (1494.1 ± 2.6 mm) and the VieVS estimate of (1495.0 ± 2.6 mm) obtained byKrásná et al. (2014) for the period covering the start of the 15m's operation until the end of 2013, agree within the formal error with the AO value obtained by a preliminary GPS survey by Attie Combrinck in 2007 of 1495 mm (the IVS recommended value). The value obtained in the current study, using VieVS to estimate the AO for the period from start of operations until the end of November 2014, of (1499.8 ± 1.1 mm) differs by 4.8 mm from the IVS recommended value.

**Table 2** HartRAO 15m antenna axis offset determined by independent techniques (a priori value = 1495.0 mm).

| Method | Determined by | Value (mm) |
|---|---|---|
| GPS survey | Combrink (2007) | 1495 |
| VLBI solution | GSFC, Gordon | |
| (from 1st IVS sessions) | and Bolotin (2012) | 1464 |
| VLBI solution | MacMillan (2014) | 1494.1 ± 2.6 |
| VieVS solution | Krásná et al. (2014) | 1495.0 ±3.4 |
| (2012.10-2014.0) | | |
| VieVS solution | Current study | 1499.8 ±1.1 |
| (2012.10-2014.11) | | |
| (134 sessions) | | |

## 4 Seasonal variation in 26m and 15m AO

Sessions after bearing repair until the end of November 2014 for the 26m, and sessions for the entire period of the 15m's operation until the end of November 2014, were divided into seasonal groupings as well as into two six monthly periods to investigate the possibility of seasonal variations in antenna axis offset (AO).

The differences in AO for the 26m and 15m between their respective a priori AO values and the VieVS estimated values for the particular season are displayed in Tab. 3. For both the 26m and 15m, the smallest deviation is for sessions taking place during the autumn months (MarAprMay), while the largest deviation is for sessions taking place during the summer months (DecJanFeb).

The differences in AO for the 26m and 15m between their respective a priori AO values and the VieVS estimated values for the particular six monthly period are displayed in Tab. 4. For both the 26m and 15m, the smaller deviation is for sessions taking place during the autumn and winter months (Mar-Aug), while the larger deviation is for sessions taking place during the spring and summer months (Sep-Feb).

**Table 3** HartRAO 26m and 15m difference in antenna axis offset between a priori value and VieVS estimated value for specified months/seasons a priori values - 26m = 6695.3 mm; 15m = 1495.0 mm).

| Month/Season | 26m dAO (mm) | 15m dAO (mm) |
|---|---|---|
| DecJanFeb (Summer) | 17.30 ± 1.67 (46 sessions) | 7.09 ± 2.12 (42 sessions) |
| MarAprMay (Autumn) | 5.77 ± 1.97 (31 sessions) | 1.41 ± 2.22 (27 sessions) |
| JunJulAug (Winter) | 13.25 ± 1.56 (44 sessions) | 6.67 ± 2.37 (27 sessions) |
| SepOctNov (Spring) | 12.03 ± 1.06 (59 sessions) | 6.02 ± 2.47 (38 sessions) |

**Table 4** HartRAO 26m and 15m difference in antenna axis offset between a priori value and VieVS estimated value for specified six monthly period a (a priori values - 26m = 6695.3 mm; 15m = 1495.0 mm).

| Month/Season | 26m dAO (mm) | 15m dAO (mm) |
|---|---|---|
| Sep - Feb (Spring and Summer) | 13.14 ± 0.91 (105 sessions) | 7.11 ± 3.78 (80 sessions) |
| Mar - Aug (Autumn and Winter) | 9.75 ± 1.23 (75 sessions) | 3.74 ± 1.64 (54 sessions) |

## 5 Baseline between 26m and 15m

The baseline length between the 26m and 15m radio telescopes was estimated with VieVS for sessions in which both the telescopes participated from the start of the 15m's operation until the end of November 2014 in order to determine the local tie between the two telescopes. Values for baseline length as estimated with VieVS for eleven dual sessions taking place during 2013 and 2014 are displayed in Fig. 5. An average value of 113.0924 m agrees within the formal error with the a priori value of 113.0953 m. It was intended to compare the estimated values with the value obtained by a co-location survey, which took place at HartRAO during March 2014, but the survey results are not available yet.

Baseline lengths according to the BKG Combination Centre between the 26m and 15m for five dual sessions during 2013 and 2014 are displayed in Fig. 6. The average value of 113.0924 m obtained with VieVS compares within the formal error with the average value of 113.0938 m obtained from the five BKG baseline lengths.

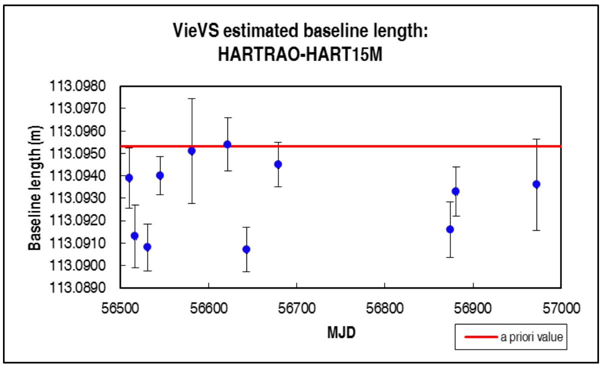


**Fig. 5** Baseline lengths between 26m and 15m for 11 dual sessions during 2013 and 2014 estimated using VieVS (a priori = 113.0953 m).

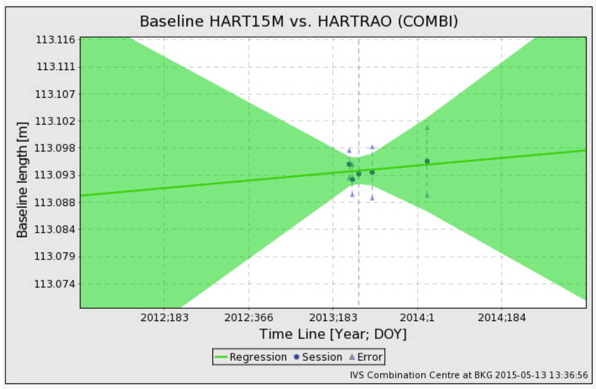


**Fig. 6** Baseline lengths between 26m and 15m for 5 dual sessions during 2013 and 2014 according to BKG Combination Centre IVS.

## 6 Conclusions

The difference in AO value for the 26m between the local survey value before bearing repair and the VieVS estimated value after bearing repair may be ascribed to a change in station position due to the bearing failure and replacement, propagating into the axis offset estimation (Krásná et al., 2014). We are awaiting values from a local site tie, which was performed during the early part of 2014, for comparison. The local site tie value for the 15m's AO will also be compared with the VieVS estimated and IVS recommended values.

Regarding possible seasonal variations in the AO - as a construction value, the AO value is supposed to remain constant over the entire year. If seasonal variations seem to occur, seasonal mismodelled and unmodelled effects, such as troposphere delay and atmosphere and hydrology loading, are possibly propagating into the AO estimates in the VLBI analysis. Seasonal variations in antenna axis offset values will be further investigated as additional sessions become available. For the 26m, sessions from before the bearing repair could also be included in the analysis.

The baseline length between the 26m and 15m estimated with VieVS will also be compared with the value obtained by the 2014 local tie survey. As indicated by Plank (2014), by comparing these values, instrumental or systematic effects causing variation in the VLBI reference points may be revealed thus. Possible seasonal variations in baseline length will be investigated as more dual sessions become available for analysis.

During 2016, an automated total station for continuous monitoring of vector ties will become operational at HartRAO. This will will contribute significantly to improving the local ties between the various techniques on site.

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