19th Working Meeting …

The 2008 Local-tie Determination at the Onsala Space Observatory

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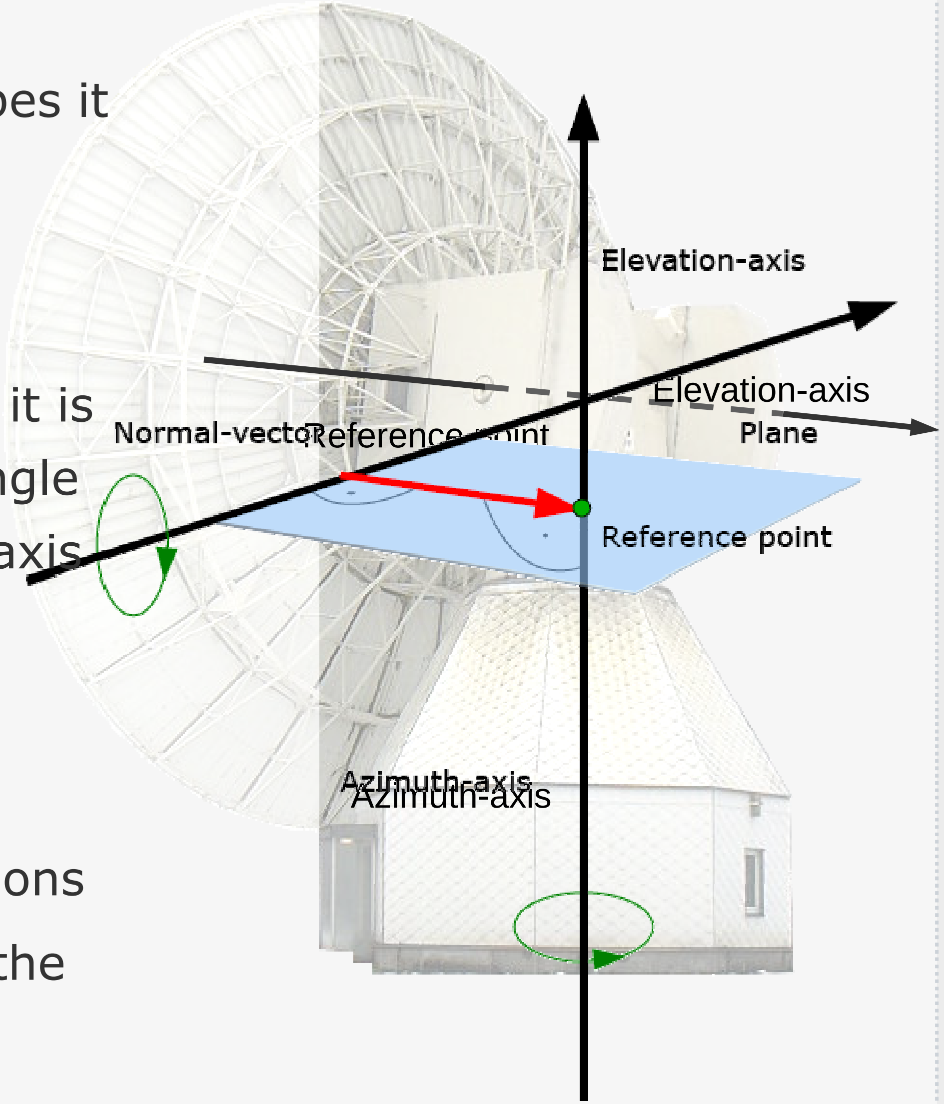
IVS reference point

Definition

- For azimuth/elevation telescopes it is defined as the intersection between the azimuth- and elevation-axis
- If these axes do not intersect, it is the intersection of the right-angle projection from the elevation-axis onto the azimuth-axis



Properties

- Usually not a material point
- Invariant w.r.t. VLBI observations
- Usually not accessible (inside the telescope)

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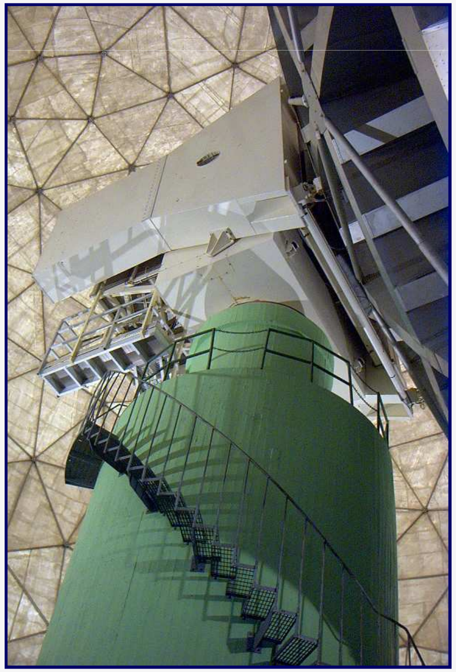
IVS reference point

Requirements

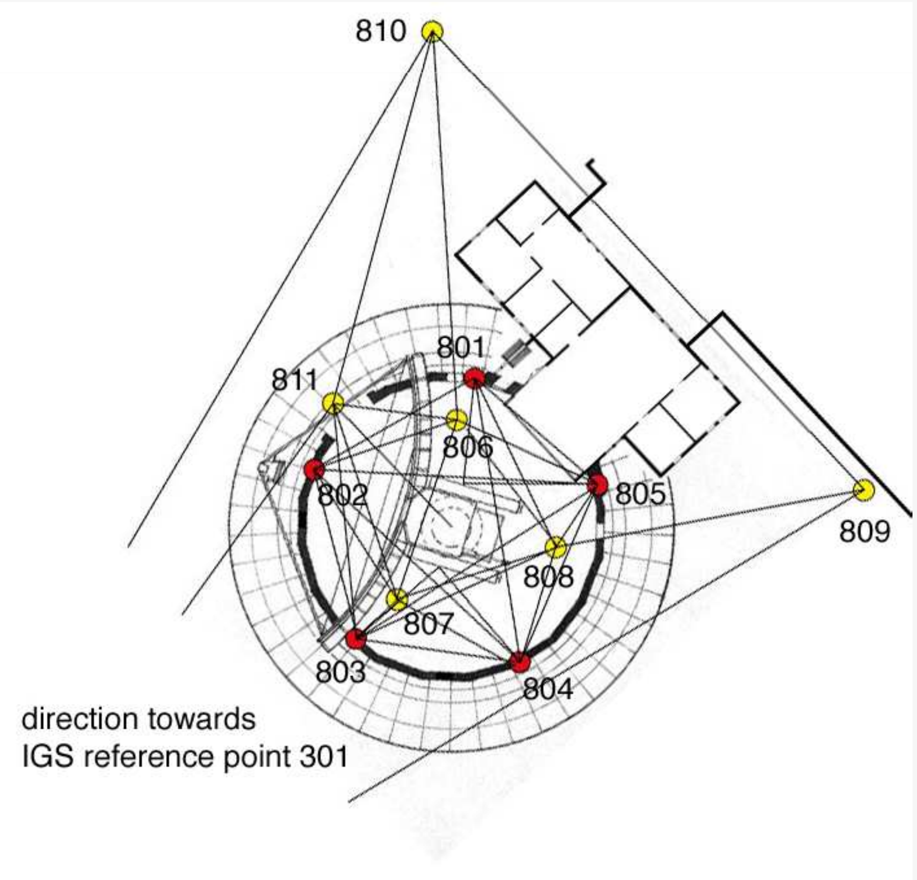
- VLBI2010 [Niell et al., 2004]
  - The accuracy requirement for the reference point is less that 1mm
  - Regular precise surveys of the local-ties to reference points of other space geodetic techniques are necessary
  - The full variance-covariance-information is necessary
- GGOS [Plag & Pearlman, 2008]
  - Continuous terrestrial monitoring of local-ties at co-location stations is desirable
  - Aim: 0.1mm-accuracy
- In general
  - Desirable to reduce the station downtime during local surveys

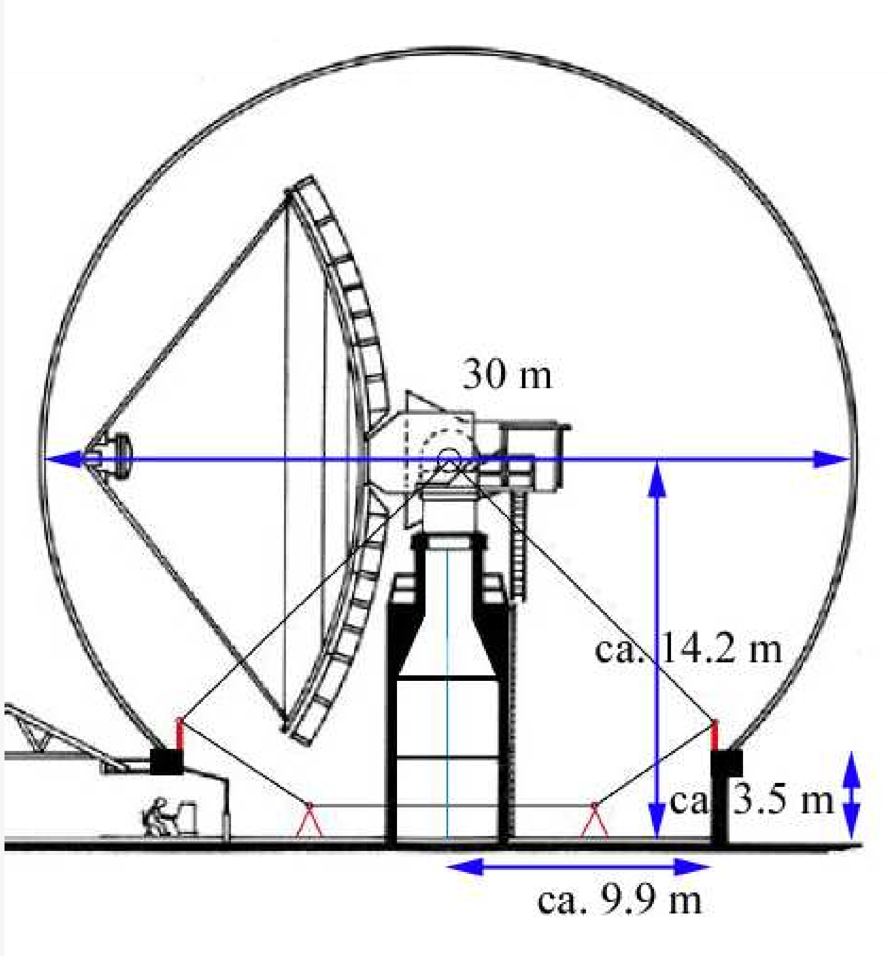
Survey situation at Onsala

- Innovative approach to observe the local site network with a laser tracker
- Spatial restrictions inside the radome
  - Elevation-axis height: ca 14.2m
  - Distance between the azimuth-axis and the observing pillars: ca 7m
- Measurement equipment
  - Laser tracker ±45° zenith-angle
  - CCR max. acceptance angle ±30°
- Special adapters for both the tracker and the targets are necessary
- A special observation strategy needs to be developed



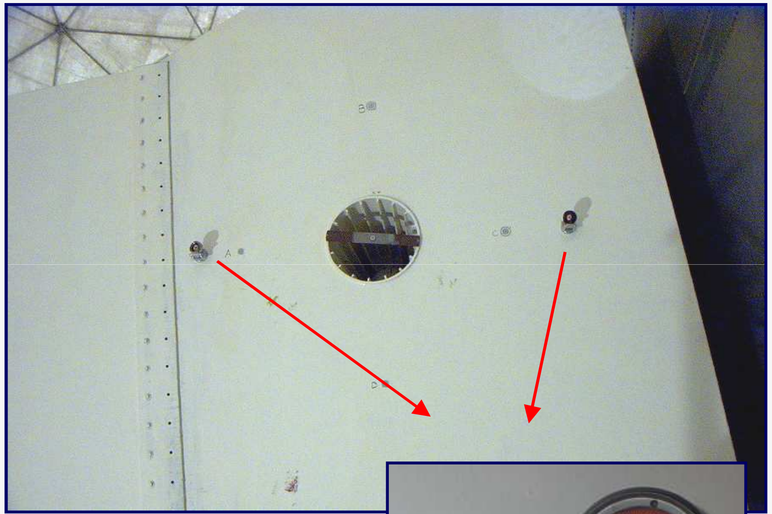
Local survey network at the 20m radio telescope





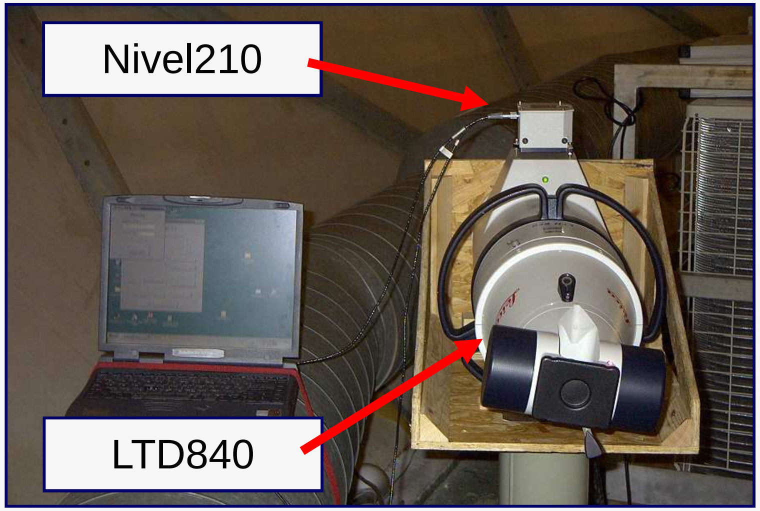
Local site network

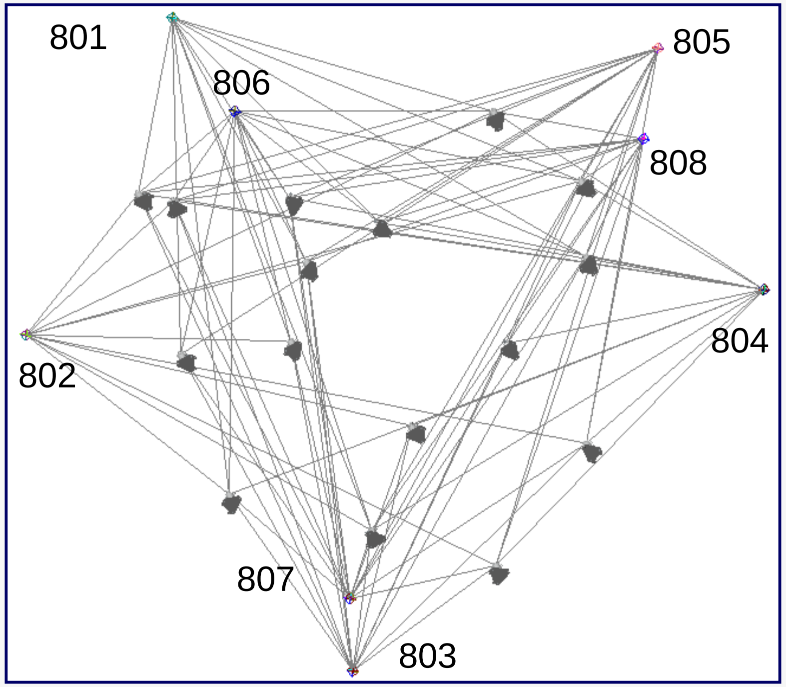
- CCR-0.5″ on the steel bolts in the concrete ground of the radome
- CCR-1.5″ with adapter at the pillars
- Cat-Eyes at the movable elevation cabin (acceptance angle ±60°)



Laser tracker LTD840

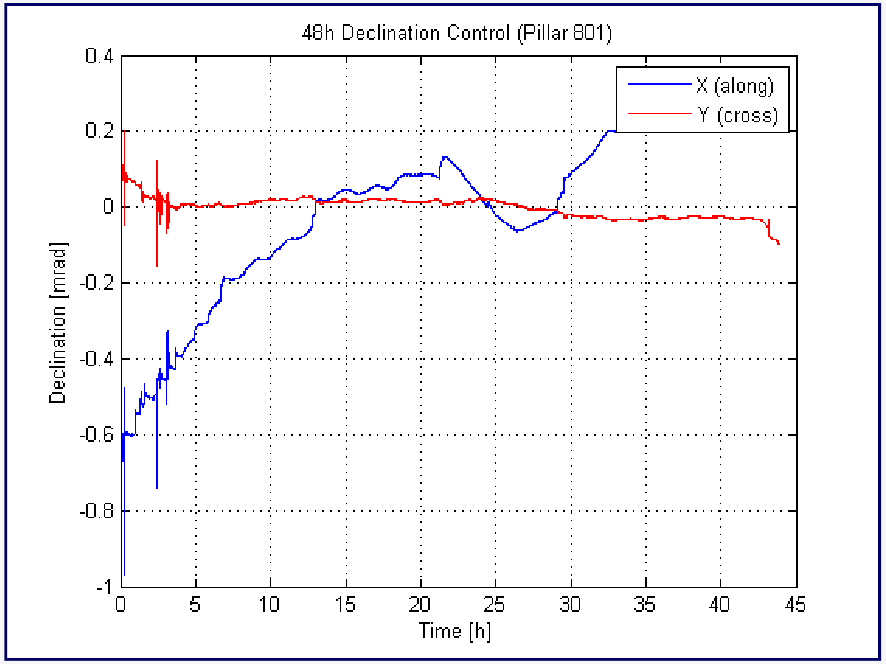
- Accuracy of a coordinate for a non-moving target 10ppm (2σ)
- Adapter to mount the instrument horizontally on the pillars
  → Expanding the measurement range
- Declination control with a precision level Nivel210
- 0.1mrad = 0.1mm/m
- Fast survey possible

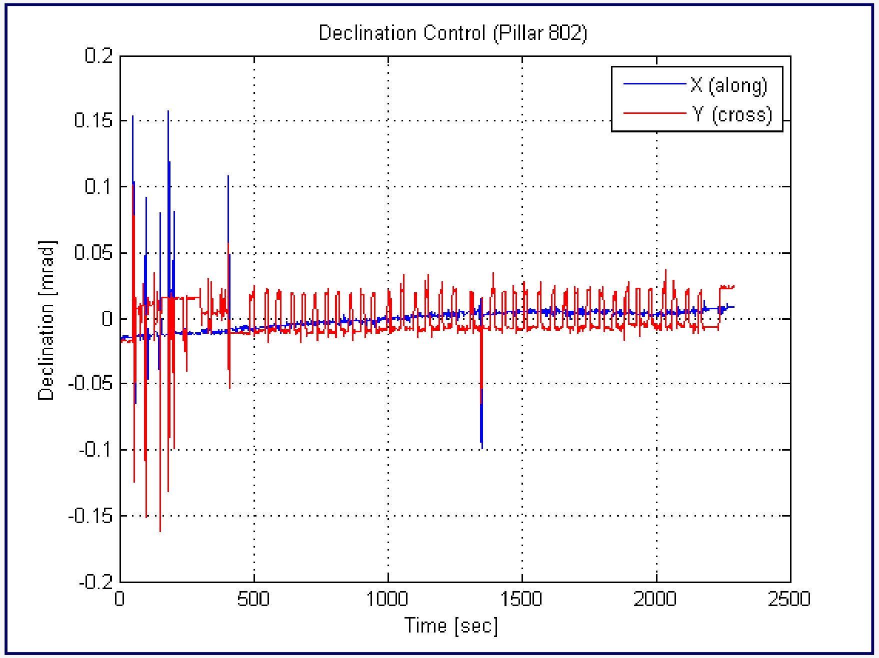




Declination control result

- 48h long-term measurement shows a large declination along the instrument axis (blue line)
  → Reducing the observation time to compensate the declination





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Network adjustment

- Measuring a traverse in the local network
- Free 3D-network adjustment
  → full variance-covariance-information
- True cartesian local system (!) (unaffected by plumb line in the local gravity field)
- IGS reference point determination during the local survey and adjustment process
  → direct measurement possible

	IGS	1 σ
X [m]	12.75551	0.00021
Y [m]	23.39043	0.00025
Z [m]	9.06529	0.00027

IVS reference point determination

Mathematical model

- Transformation between the ground-fixed observation system and the telescope system

$$\boldsymbol{P}_{Obs} = \boldsymbol{P}_R + \boldsymbol{R}_x(\beta) \cdot \boldsymbol{R}_y(\alpha) \cdot \boldsymbol{R}_z(\mathrm{A} + O_\mathrm{A}) \cdot \boldsymbol{R}_y(\gamma) \cdot \left(\boldsymbol{Ecc} + \boldsymbol{R}_x(\mathrm{E} + O_\mathrm{E}) \cdot \boldsymbol{P}_{Tel}\right)$$

Parameters

- $\boldsymbol{P}_{Obs}$ … 3D point (observation system)
- A, E … azimuth- and elevation-angles
- $\boldsymbol{P}_R$ … antenna reference point
- ***Ecc*** … eccentricity distance between the telescope-axes
- γ … non-orthogonality
- α, β … inclination
- O_A, O_E … orientation-angles
- $\boldsymbol{P}_{Tel}$ … 3D point (telescope system)

Least-squares-adjustment

- Combining the Levenberg-Marquardt-Algorithms with the Gauß-Helmert-Model to provide reliable values

$$F\left(\hat{\boldsymbol{L}},\hat{\boldsymbol{X}}\right)=F\left(\boldsymbol{L}+\boldsymbol{v},\boldsymbol{X}_0+\boldsymbol{x}\right)=\underbrace{F\left(\boldsymbol{L},\boldsymbol{X}_0\right)}_{\boldsymbol{w}}+\underbrace{\frac{\partial F\left(\boldsymbol{L},\boldsymbol{X}_0\right)}{\partial \boldsymbol{L}}}_{\boldsymbol{B}}\cdot\underbrace{\left(\hat{\boldsymbol{L}}-\boldsymbol{L}\right)}_{\boldsymbol{v}}+\underbrace{\frac{\partial F\left(\boldsymbol{L},\boldsymbol{X}_0\right)}{\partial \boldsymbol{X}_0}}_{\boldsymbol{A}}\cdot\underbrace{\left(\hat{\boldsymbol{X}}-\boldsymbol{X}_0\right)}_{\boldsymbol{x}}=0$$

↓

$$\boldsymbol{v}_w=\boldsymbol{B}\boldsymbol{v}=-\boldsymbol{A}\boldsymbol{x}-\boldsymbol{w}$$

↓

$$\boldsymbol{P}_{ww}=\left[\boldsymbol{B}\boldsymbol{Q}_{LL}\boldsymbol{B}^T\right]^{-1}$$

↓

$$(\boldsymbol{A}^T\boldsymbol{P}_{ww}\boldsymbol{A}+\mu\boldsymbol{I})\boldsymbol{x}=-\boldsymbol{A}^T\boldsymbol{P}_{ww}\boldsymbol{w}$$

	IVS	1 σ
X [m]	90.1232	0.00010
Y [m]	35.9497	0.00010
Z [m]	22.7595	0.00008
e [m]	-0.0062	0.00006

Model expansion

$$\begin{bmatrix} \begin{bmatrix} \boldsymbol{B}_{IVS} & 0 & \boldsymbol{Q}_{L_{IVS}L_{IVS}} & \boldsymbol{Q}_{L_{IVS}L_{IGS}} & \boldsymbol{B}_{IVS}^T & 0 \\ 0 & \boldsymbol{B}_{IGS} & \boldsymbol{Q}_{L_{IGS}L_{IVS}} & \boldsymbol{Q}_{L_{IGS}L_{IGS}} & 0 & \boldsymbol{B}_{IGS}^T \end{bmatrix} & \begin{bmatrix} \boldsymbol{A}_{IVS} & 0 \\ 0 & \boldsymbol{A}_{IGS} \end{bmatrix} \\ \begin{bmatrix} \boldsymbol{A}_{IVS}^T & 0 \\ 0 & \boldsymbol{A}_{IGS}^T \end{bmatrix} & 0 \end{bmatrix} \cdot \begin{bmatrix} \boldsymbol{k} \\ \boldsymbol{x}_{IVS} \\ \boldsymbol{x}_{IGS} \end{bmatrix} = \begin{bmatrix} -\boldsymbol{w}_{IVS} \\ -\boldsymbol{w}_{IGS} \\ 0 \end{bmatrix}$$

- Estimate local-tie with full variance-covariance-matrix

$$d_{IVS,IGS} = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2} = 79.5678\text{m} \qquad \hat{\sigma}_{d_{IVS,IGS}} = \sqrt{\boldsymbol{A} \cdot \hat{\boldsymbol{C}}_{IVS,IGS} \cdot \boldsymbol{A}^T} = 0.00024\text{m}$$

$$\hat{\boldsymbol{C}}_{IVS,IGS} = 1.0e^{-9} \cdot \begin{bmatrix} 6.00 & 0.23 & 8.60 & -44.22 & 3.00 & -58.42 \\ & 0.19 & 0.31 & -1.66 & -0.87 & -3.00 \\ & & 13.19 & -64.09 & 4.06 & -85.05 \\ & & & 335.30 & -24.94 & 437.95 \\ & & & & 18.19 & -22.40 \\ & & & & & 614.00 \end{bmatrix}$$

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Datum independent comparison between 2002 – 2008

- Distance between both reference points
- Telescope axes offset

Distance IVS-IGS		
2002 [m]	79.5685	0.0002
2008 [m]	79.5678	0.0002
Difference [m]	-0.0007	
Axes offset		
2002 [m]	-0.0060	0.0004
2008 [m]	-0.0062	0.0001
Difference [m]	0.0002	

- Very good agreement
- Suggesting a stable local-tie vector at the Onsala Space Observatory

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Conclusions

General

- The application of a laser tracker for local-tie surveys allows to derive the results in a true cartesian local system
- The results in the cartesian local system can be easily related to global cartesian system (e.g. GNSS, SLR)
- High accuracy for the results can be achieved
- The complete covariance information can be determined
- The survey work can be performed quickly, thus the station downtime is short

For the Onsala Space Observatory

- Stable local-tie (2002–2008)
- Complete covariance information available for ITRF calculations
- The axes offset of 6mm confirmed