VieVS User-Workshop 2018

Introduction to VLBI - A Vienna Perspective

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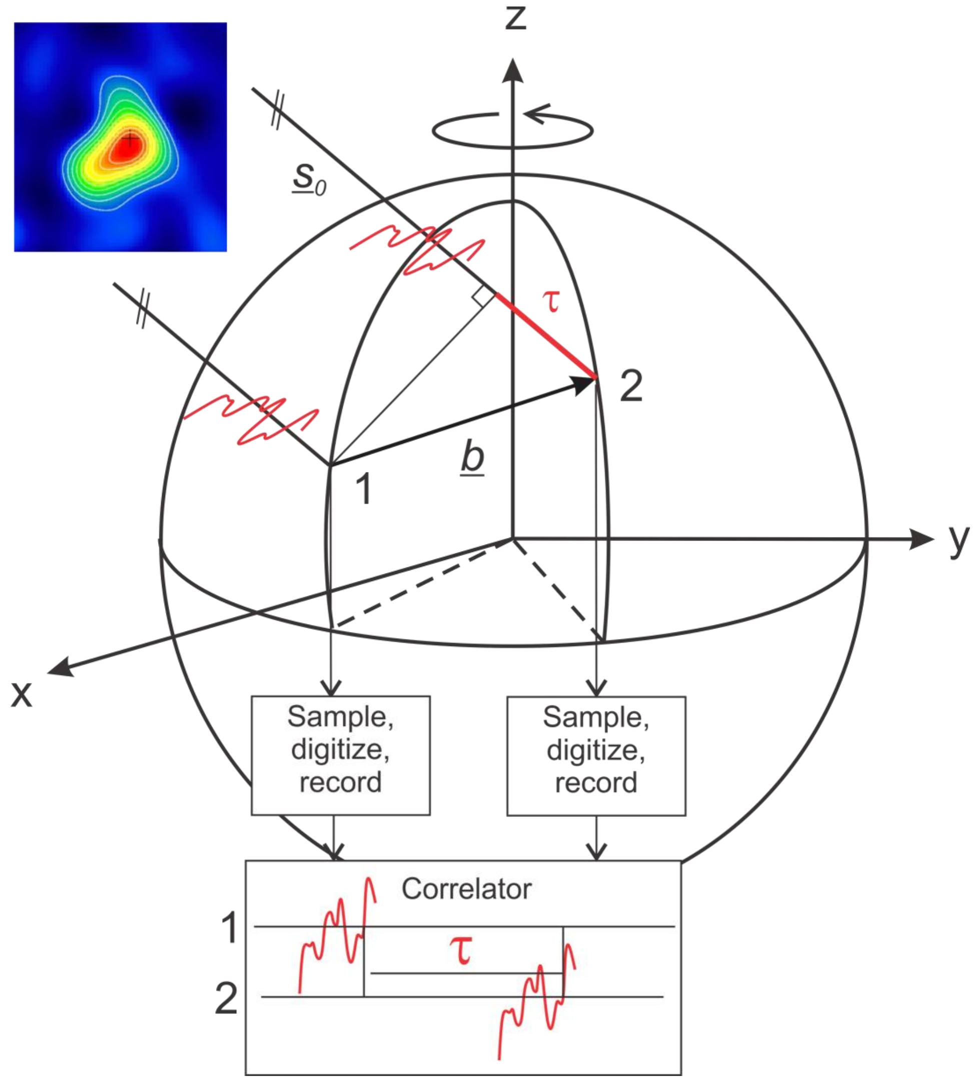
VLBI – How does it work?



$$\tau = -\frac{\underline{b} \cdot \underline{s}_0}{c} = t_2 - t_1$$

- Terrestrial Reference Frame (via baselines)
- Celestial Reference Frame (via source positions)
- Earth orientation parameters (EOP)
- ...

VLBI - Work flow

- Scheduling
- Observation and file transfer
- Correlation and fringe-fitting
- Ambiguity resolution and ionosphere calibration
- Reduction of observations (o-c) and partials
- Parameter estimation (least squares)
  - Single session solutions
- Global solutions

VieVS
Vienna VLBI and Satellite Software

Scheduling

- At any instant, different subsets of antennas will be observing different sources
- Different integration and slewing times need to be considered
- Various optimisation criteria
- Generation of vex/skd files

Scheduling

- Most geodetic schedules are generated with SKED (Vandenberg 1999)
- VieVS (Sun et al. 2014) has been successfully used, in particular for AUA sessions
  - It is equipped now with a satellite scheduling tool (Hellerschmied 2018)
- We are moving to VieSched++ (Schartner 2018)

VieSched++
Vienna VLBI and Satellite Software

Observations

- Stations take the vex/skd files and drudge them
- Observational data are available in mark4 format
- E-transferred with Jive5ab, e.g., to VSC-3

Hobart

Correlation and fringe-fitting

- Done on the Vienna Scientific Cluster VSC-3(4) (Gruber 2018)
- DifX for correlation
- HOPS/fourfit and PIMA for fringe-fitting
- Output are vgosDB files

VIENNA SCIENTIFIC CLUSTER

Ambiguity resolution and ionosphere calibration

- Due to bandwidth synthesis, ambiguities might be present in the observations and have to be removed
- Ionosphere calibration based on two frequencies (X and S)
- Currently done with Solve, but we are working on a VieVS tool

Reduction of observations and partials

- Determination of reduced observed delays (c) following the IERS and IVS Conventions
- A priori station and source coordinates
  - e.g., from ITRF2014 and ICRF3
  - Corrections to station coordinates
    - Solid Earth tides
    - Ocean tidal loading
    - Atmosphere loading
    - Thermal deformation, etc.

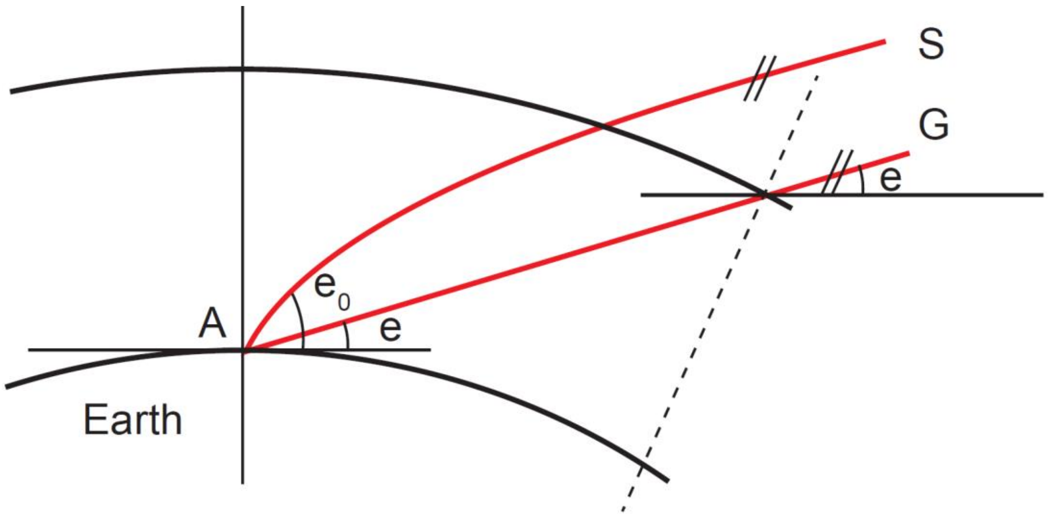
Reduction of observations and partials

- A priori EOP
  - e.g., IERS 14 C04 or Finals (with predictions)
  - Celestial Pole Offsets, polar motion, UT1-UTC
  - Corrections to daily Earth Rotation Parameters (ERP)
    - Ocean tides, etc
- Relativistic modelling
  - Following IAU Resolutions and IERS Conventions (Consensus model by Eubanks, 1991)

Reduction of observations and partials

- Troposphere delays
- Zenith delay times mapping function

$$\Delta L(e) = \Delta L_h^z \cdot mf_h(e) + \Delta L_w^z \cdot mf_w(e)$$



Reduction of observations and partials

- Troposphere delays
- Gradients

$$\Delta L(a,e) = \Delta L_0(e) + mf_h(e) \cdot \cot(e) \cdot [G_n \cos(a) + G_e \sin(a)]$$

Parameter estimation

- Least squares methods minimize the squared sum of weighted residuals
  - Classical Gauß-Markov model
  - Kalman Filter
  - Collocation

Single session solution

- Observations equations (real and pseudo observations = constraints)

$$A \cdot dx = l + v \quad \text{or} \quad \begin{bmatrix} A_{ro} \\ A_{po} \end{bmatrix} \cdot dx = \begin{bmatrix} l_{ro} \\ l_{po} \end{bmatrix} + \begin{bmatrix} v_{ro} \\ v_{po} \end{bmatrix}$$

- Weight matrix

$$P = \begin{bmatrix} P_{ro} & 0 \\ 0 & P_{po} \end{bmatrix}$$

Single session solution

- Auxiliary parameters
  - Clocks (quadratic functions plus piecewise linear offsets; reference clock)
  - Zenith wet delays and gradients
- Clock breaks
- First and main solution
- Piecewise linear offsets at e.g. integer hours
  - Allows combination with other space geodetic techniques at normal equation level
- Results as SINEX file

Global solution

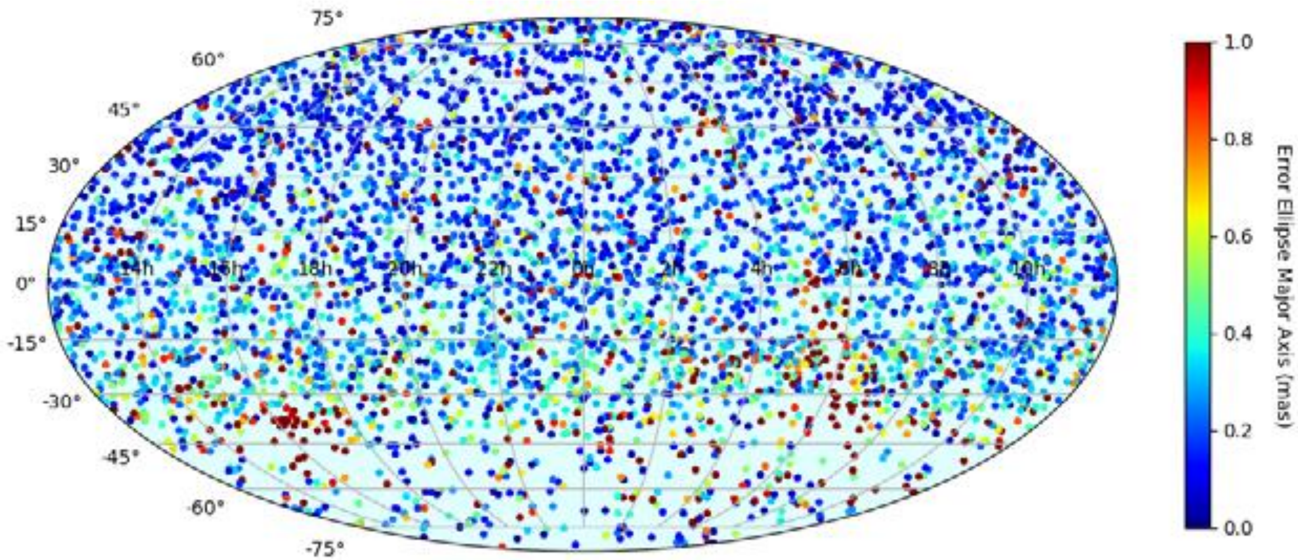
- Global VLBI solutions from a (large) number of single solutions
  - E.g., for station and source coordinates
- Often, auxiliary parameters and EOP are reduced (= implicitly estimated)

Global solution

- Conditions to prevent N matrix from being singular
- Free networks need a datum
  - Rank deficiency is six (scale is defined by observations)
- NNR/NNT usually applied on a priori TRF
  - in case of longer time spans also NNR-rate/NNT-rate
- Episodic changes need to be considered (instrumental changes, Earthquakes)

VieVS VLBI Products

- Contribution to ITRF2014
- Contribution to ICRF3
- Ongoing: submission of EOP to IVS/IERS
  - Sorting out (final issues)
- Many scientific investigations



Future VLBI activities in Vienna

- Become operational IVS Analysis Center with BEV contributing to ITRF, ICRF, and EOP
- Take on more work load from the IVS in terms of correlation (on VSC-4) and scheduling
- Set up complete data flow with VieVS
  – Do ambiguity resolution and ionosphere calibration

UTAS

BEV - Bundesamt für Eich- und Vermessungswesen

Future VLBI activities in Vienna

- Look into fringe-fitting in VieVS
- Do VGOS scheduling, correlation, fringe-fitting and analysis

FWF

Future VLBI activities in Vienna

- Continue VLBI observations to satellites and spacecraft and other artificial objects in space
- Kalman Filter or Square Root Information Filter
- Imaging (via PIMA by Hana?)