Scheduling of VLBI satellite observations for an improved ITRF

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1. Introduction

Observations of satellites with Very Long Baseline Interferometry (VLBI) radio telescopes offer a variety of new possibilities and promote the integration of different geodetic techniques, which is one of the main purposes of GGOS, the Global Geodetic Observing System of the IAG. Promising applications can be found e.g. in the field of inter-technique frame ties, having the potential to improve future realizations of the International Terrestrial Reference Frame (ITRF). Several test observations (Tornatore et al. 2014) and studies (Plank et al. 2014) have been carried out in recent years. With the standard scheduling and observing software not being prepared for this so far, such observations were complicated for careful manual interaction to the standard interchange files. The newly developed satellite scheduling module of the Vienna VLBI Software (VieVS; Böhm et al. 2012) for the planning of satellite observations with VLBI antennas offers a solution to this.

2. VieVS satellite scheduling module

This new VieVS extension provides the possibility to schedule satellites as targets for VLBI observations. The results are schedule files in the VEX data format, which can be used to control the VLBI antennas and the station equipment in order to carry out actual satellite observation experiments. The existing schedule module VIE_SCHED (Sun et al. 2014) was extended to integrate the new satellite scheduling functions to the VieVS package. The integration into the graphical user interface (GUI) of VieVS provides an easy and comfortable handling.

3. Workflow

After preparing the required input data and defining the general observation setup in the GUI (3.1.), the software calculates the available observation times for each selected satellite and provides this information to the user (3.2.). After assembling the observation schedule via a user interface, the corresponding schedule files are generated (3.3.).

3.1. Scheduling parameters & data input

➔ User sets parameter in GUI:
- a. Station network
- b. Observation time
- c. Satellites
- d. Output options
- e. Restrictive parameters
  - Cut-off elevation
  - Min. sun distance

➔ Input data are loaded by VieVS.

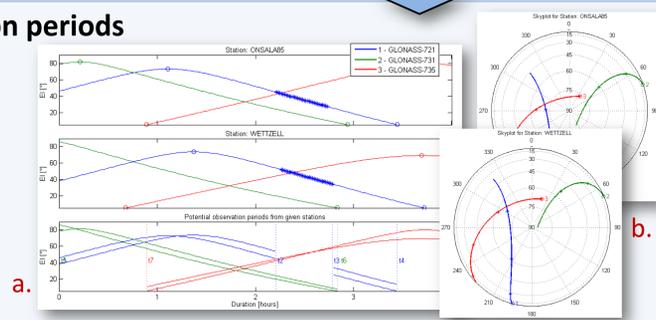Config. files
Catalog files
TLE files
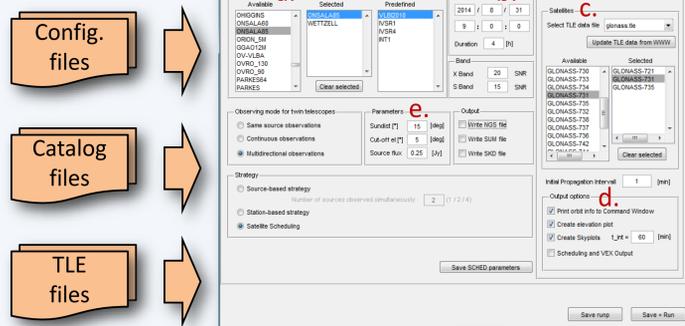
3.2. Calculation of available observation periods

➔ VieVS calculates the available observation periods of all selected satellites for the defined observation constellation.
➔ Information on satellite overpasses is provided to the user by:
- a. Elevation plot
- b. Skyplots per station

3.3. Compilation of the observation schedule & generation of VEX files

➔ The user defines any number of consecutive satellite scans by selecting the satellite and the corresponding observation period via the user interface.
➔ After preparing the complete observation schedule, VEX files are generated.

VEX files

User interface

References

Böhm et al. (2012), The New Vienna VLBI Software, Proceedings of the 2009 IAG Symposium, Buenos Aires, Argentina, 31 August 2009 - 4 September 2009, Series: International Association of Geodesy Symposia, Vol. 136, Kenyon S, Pacino MC, and Marti U (eds.), ISBN 978-3-642-20337-4, pp. 1007-1012.
Hellerschmied et al. (2014), Observing Satellites with VLBI Radio Antennas - Practical Realization at Wettzell, Proc. IVS 2014 General Meeting, Shanghai, pp. 441-445.
Hoots & Röhrich (1988), Spacetrack Report No. 3 – Models for Propagation of NORAD Elemets Sets, Office of Astrodyn., Aerospace Defense Center, Peterson.
Sun et al. (2014), New VLBI2010 scheduling strategies and implications on the terrestrial reference frames, J Geod, 88: 449-461, DOI: 10.1007/s00190-014-0697-9.
Plank et al. (2014), Precise station positions from VLBI observations to satellites: a simulation study, J Geod, 88: 659-673 , DOI: 10.1007/s00190-014-0712-1.
Tornatore et al. (2014), Direct VLBI Observations of Global Navigation Satellite System Signals, Proc. IAG General Assembly, Melbourne - 2011, pp. 247-252.

4. Program details

4.1. Required input data

➔ NORAD Two Line Element (TLE) datasets
- Used for satellite orbit determination by dedicated analytical models (Hoots & Röhrich 1988)
- Widely available online on a daily basis; update function provided in the VieVS GUI

➔ Catalog files
- Provide the required station data (antenna and receiver properties, coordinates, etc.)

➔ Configuration files
- Define the setup of receiver/station equipment used for the scheduled observations

4.2. Implementation of satellite tracking using VEX files (1.5b1)

➔ "Stepwise" satellite tracking approach:
- Satellite orbits are converted to a series of distinct topocentric equatorial positions (topocentric right ascension & declination)
- Antenna is repositioned in a defined time interval (e.g. 15 sec) to track the satellite during signal acquisition
- Feasible for standard VLBI radio antennas, e.g. of the IVS network
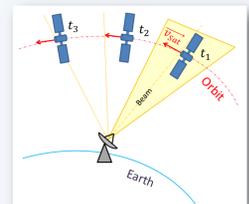
Tracking principle

4.3. Conditions for a valid satellite scan

➔ VieVS checks the following main conditions in order to decide if a satellite is observable:

1. Satellite visible from all participating stations?
2. Distance between sun and satellite above threshold?
3. Antenna slew speeds large enough to keep track?
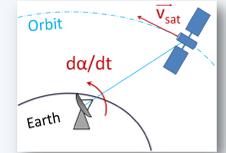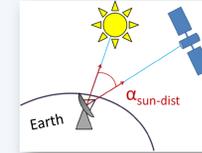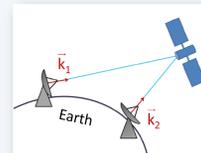
5. Satellite observation experiments: Onsala – Wettzell

Observations

During several experiments planned with VieVS (Hellerschmied et al. 2014) the new satellite scheduling capabilities could be tested.

- Baseline: Wettzell – Onsala
- Observation of several GLONASS satellites (L1-band)
- Four sessions with one hour duration each
  - 16th January 2014:   G140116a, G140116b
  - 21st January 2014:   G140121a, G140121b
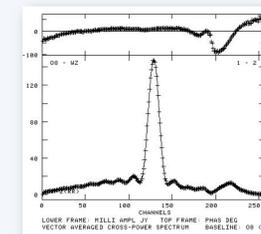
25 m antenna L-band receiver
20 m antenna L1 GNSS receiver

Station network

Results

- Preliminary data analysis by R. Haas
- Correlation of the acquired data with the DiFX software

Correlation result for GLONASS-732. Data acquired during the G140121a session.

➔ Continuous phases and strong amplitudes were found for all observed satellites!

6. Summary & Outlook

➔ The **VieVS satellite scheduling module** provides a flexible tool for planning VLBI satellite observations and for generating the required control files in the VEX format.
- ✓ Qualified for any orbit types (LEO, MEO, etc.) and various station networks (observation restrictions occur due to frequency band limitations of the participating VLBI antennas)
- ! No scheduling optimization so far
- ! An upgrade providing the possibility to create combined schedules, including observations to satellites and quasars in one session, is currently in development and will be available soon.

➔ **Satellite tracking based on VieVS schedule files** in the current data format (VEX 1.5b1) is implemented using the described stepwise tracking approach.
- ! The proposed VEX 2.0 format will support the definition of satellite orbits directly in terms of TLE data, which will provide further tracking possibilities in the future.

➔ Several **successful satellite observation experiments** carried out in January 2014 on the baseline Wettzell – Onsala showed the viability of the new satellite scheduling module.

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