Scheduling VLBI satellite observations with VieVS

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VLBI satellite observations

- Motivation for VLBI satellite observations
  - Establish inter-technique ties in space
  - Improve ITRF realization
  - etc. ...

- Previous direct satellite observations with VLBI antennas
  - e.g. Tornatore (2010a/b, 2014)
  - G130126 Experiment (Haas, 2014)

⇒ Problem: Available Scheduling Programs (SKED, SCHED, VIE_SCHED) do not support satellites as radio sources routinely

⇒ Idea: Upgrade VieVS with a tool for scheduling VLBI satellite observations
VieVS satellite scheduling - Overview

Vie_SCHED GUI updated with the new satellite scheduling module.

Catalog files

Config. files

TLE data

VEX files
Input data

• NORAD Two Line Element (TLE) data:
  – Datasets for precise satellite orbit determination by dedicated analytical models (SGP; Hoots & Röhrich, 1988)
  – Widely available, e.g. at www.celestrak.com

• Catalog files:
  – SKED catalog files (Vandenberg, 1997)
  – VEX catalog files

• Configuration files
  – To define setup of receiver/station equipment used for actual satellite observations

TLE example for GLONASS-717 (NORAD ID: 29671)
Find available observation periods

- Conditions for a valid satellite scan:
  - Satellite visibility
  - Sun distance
  - Antenna Slew rates

Available observation times for the station network
Satellite overpass information

Configuration:
3 GLONASS satellites
Wettzell, Onsala
31 Aug. 2014
9:00 – 13:00 UTC

Helps the scheduler to select satellites/observation times
Scheduler interface

- In the MATLAB Command Window
- User input:
  1. Experiment name
  2. Select Satellite
  3. Observation period \((t_{\text{start}}, t_{\text{stop}})\)

- By repeating the steps 2 and 3 an arbitrary number of consecutive scans can be scheduled.

- Schedule files (VEX) are generated after user input is finished.
Generation of VEX files

- Schedule file format: VEX 1.5b1 *(Whitney et al., 2002)*

- “Stepwise” satellite tracking approach can be implemented directly with these VEX files
  - Satellite positions are defined similar to quasars
  - Satellite orbit are converted to series of distinct topocentric Ra/Dec positions
  - Antenna is repositioned in a defined time interval (e.g. 15 sec) to follow the satellite

- “Cross-eyed” schedule *(Duev et al, 2012)*
  - Satellites orbit in the Earth’s near field
  - Topocentric view directions differ between sites
  - Separate pointing data (topo. Ra/Dec) has to be calculated for each station
Satellite observation experiments

- Scheduled with VieVS
- Baseline Wtz – O85

Onsala, Sweden:
- Responsible: R. Haas
- 25 m antenna, L-band feed

Wettzell, Germany
- Responsible: A. Neidhardt
- 20 m antenna, S/X-band feed
- New L1-band GNSS receiver (Kodet et al., 2014)

- Four sessions, each with 1h duration
  - 16th January 2014: G140116a, G140116b
  - 21st January 2014: G140121a, G140121b

GLONASS satellites
- L1 signals (1602.56-1615.5 MHz)
Observation results

- Correlations with DiFX software correlator (*Deller et al.*, 2007)
  - Preliminary data analysis by Rüdiger Haas
  - 0.25 sec integration time
  - Fringe fitted with the Astronomical Image Processing System software (*AIPS, 2014*)

→ Continuous phases and strong amplitudes were found for all satellites.

IF spectrum of GLONASS-732. Data acquired during the G140121a session.

Fringe plots for GLONASS-732. Data acquired during the G140121a session.
Summary

• The **VieVS satellite scheduling module** provides a flexible tool for scheduling real VLBI satellite observations and for generating VEX files.
  – For any satellites (LEO, MEO, etc.) and various station networks.
  – No scheduling optimization so far.
  – No combination with classical observations to quasars yet.

• **Stepwise satellite tracking** based on VEX files generated with VieVS is feasible for all VLBI stations without modifications in the Field System.

• **First satellite experiments** scheduled with VieVS were successfully carried out in January 2014 on the baseline Wettzell – Onsala.
Outlook

- **VieVS** - Flexible tool for scheduling real VLBI satellite observations and generating VEX files.
  - Additional experiments
  - Larger station networks

**Possible observation scenario:**
2014-04-01
12:00 – 16:00 UT
- ONSALA
- MEDICINA
- WETTZELL
- ZELENCHUKSKAYA
- SVETLOE
Glonass-724/736/743
Questions?

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References:

- WHITNEY A. et al. (2002). *VEX File Definition/Example, Rev. 1.5b1*. http://www.vlbi.org/vex/docs/vex