Satellite Scheduling with VieSched++

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Introduction

- scheduling observations to quasars is an integral part of VLBI but also satellite scheduling is an important topic
- observations to satellites enable interesting scientific applications
- variety of new possibilities
  - improvement of geodetic products, in terms of ITRF
  - provide geodetic space ties for connecting reference frames
  - tracking of satellite and space probes
- so far, the scheduling module of the Vienna VLBI and Satellite Scheduling Software (**VieVS**) was used to generate schedules
  - supports observations to quasars and satellites
  - successful experiments were carried out
  - but this software has its downsides
    - not very flexible
    - poor scan selection for quasar observations
    - bad performance
    - no support of VGOS observing modes
- therefore a new scheduling software **VieSched++** was developed
  - comparison showed that **VieSched++** outperform the previous version in **VieVS** in terms of quality and performance
  - **VieSched++** replaces scheduling module in **VieVS**
  - **open task:** implement satellite scheduling in **VieSched++**

Satellite scheduling in VieVS scheduler

- developer: *Andreas Hellerschmied*
- **VieVS** scheduling module was upgraded with a satellite scheduling tool written in Matlab
- integration into the Graphical User Interface in **VieVS** allows user-friendly handling
- interactive and automatic scheduling mode
- auxiliary output files
- 47 VLBI experiments were observed between 2014 and 2016

Observed satellite missions

- GLONASS
- GPS
- Galileo
- BeiDou
- APOD

VieSched++

- developer: *Matthias Schartner*
- new, modern scheduling software written in C++
- new features
  - recursive scan selection
  - station-, source- and baseline dependent parameters
  - automated iterative source selection
  - multi-scheduling approach

Schedules created with VieSched++

- AUA (035, 037, 040, 041, 044, 047)
- INT3 (021, 028, 035, 042, 049, 056, 063, 077, 084…)
- AUM (001 - 010)
- T2 (129, 130, 131)
- EURR&D (09)
- EUR (149)
- OHG (117, 118)
- EINT (001 - 012)

Satellite scheduling in VieSched++

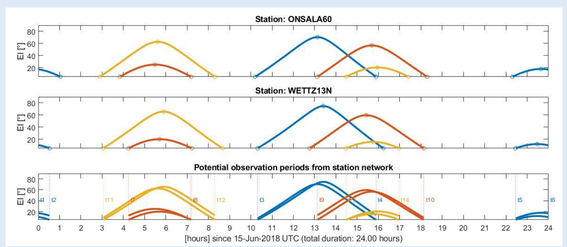
- developer: *Helene Wolf*
- written in C++
- still in development
- implemented features
  - ☑ read Two-Line-Element (TLE) data
  - ☑ read station parameters (from catalog files)
  - ☑ calculation of satellite orbit
  - ☑ checking visibility from all stations
  - ☑ calculation of possible observation periods for each satellite
- missing features
  - ☒ consideration of antenna slew limits
  - ☒ integration in GUI
  - ☒ semi-automatic mode
  - ☒ station based VEX-file generation

Satellite Scheduling

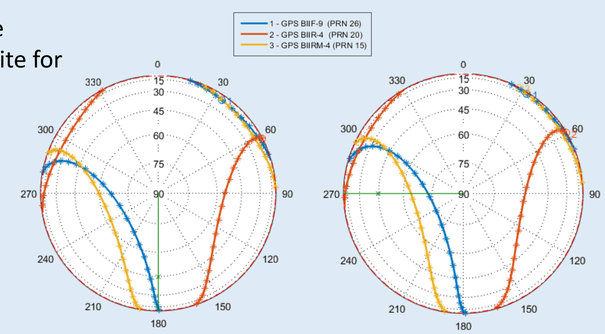
VieVS scheduling module

- module to generate VLBI schedules with possibility to schedule satellite observations
- satellite observation can be chosen in Graphical User Interface
  - select satellites
  - define observation times
- calculation of available observation periods for selected satellites
  - orbit calculations based on Two-Line-Element (TLE) data
  - internal checks (visibility from stations, antenna slew rates)
- interactive mode
  - scheduler works interactively
  - operator can choose the best target, a visible quasar or satellite and add it to the schedule
  - scheduler works for a single telescope, e.g. tracking tests
- automatic mode
  - integration of satellite scans into a geodetic schedule
  - optimisation of sky coverage and slew time at each site for quasar and satellite scans
  - user defines blocks in a defined time duration for a preselected list of satellite and quasar targets
- generation of station based VEX file
- auxiliary output
  - sky plot, showing tracks of satellites
  - visibility (satellite elevation at stations versus time)

satellite elevation at stations versus time



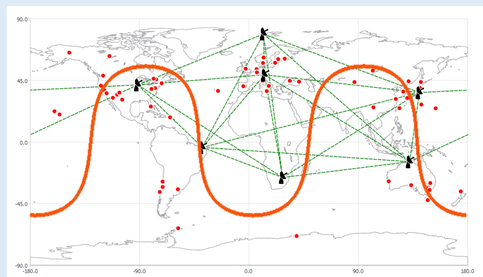
skyplot showing tracks of satellites at Onsala and Wettzell



Outlook: satellite scheduling feature in VieSched++

- integration in Graphical User Interface
  - option to integrate satellite observation in the schedule
  - satellite based parameters
    - minimum number of stations per scan
    - minimum scan length
    - minimum elevation…
- calculation of available observation periods for selected satellites
  - using C++ SGP4 Satellite Library
  - satellite orbit calculations are based on the Two-Line-Element (TLE) data
  - display satellite track on world map and on azimuth elevation plots per station
- implementation as semi-automatic mode
  - interactive mode
    - user loads satellites which should be observed
    - automatic generation of list with all possible observing periods for each selected satellites based on station network and satellite parameters
    - user can manually select satellite scans
    - these scans are added as fixed scans to the schedule
  - automatic mode
    - calculation of possible scans to quasars between satellite observations (recursively)
    - around satellite observation schedule is filled with observations to quasars
- generation of station based VEX-file
- VEX2 output (when available)

outlook: display track of satellite on world map



outlook: sky coverage and tracks of satellites at Onsala and Wettzell