

Vienna VLBI Software: Current Release and Plans for the Future

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Abstract The Vienna VLBI Software (VieVS) is a geodetic VLBI data analysis software written in Matlab. It has been developed and maintained at the Department of Geodesy and Geoinformation of the Vienna University of Technology since 2008. Recent improvements and extensions include a source structure simulator, additional estimable parameters in the global solution such as harmonic station position variations, and tools to observe satellites with VLBI radio telescopes and to analyze these observations. A highlight each year is the VieVS User Workshop which is held in September at TU Vienna. The VieVS Web site can be accessed at <http://vievs.geo.tuwien.ac.at/>.

Keywords VLBI analysis software

1 Introduction

The Vienna VLBI Software (VieVS) is VLBI data analysis software written in Matlab (Böhm et al., 2012 [1]). VieVS has been developed and maintained by the research group *Höhere Geodäsie* (Higher Geodesy) at the Department of Geodesy and Geoinformation of the Vienna University of Technology (TU Vienna) since 2008. Important contributions from other groups have been made by the Shanghai Astronomical Observatory (scheduling), Hacettepe University (least squares

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adjustment), and the University of Tasmania (source structure simulation and other features).

The current version, VieVS 2.1, was released in August 2013. The next version, VieVS 2.2, will be freely available to registered users in the middle of 2014. These registrations allow us to provide information to the users in the case of new releases or bugs in the software.

VieVS has been written in Matlab, which is commercial software and rather expensive. Nonetheless, we decided to use Matlab, because the source code is compact and easy to understand and to modify, and because Matlab provides many built-in functions to write concise code. Furthermore, Matlab provides tools to set up a Graphical User Interface (GUI). Since our students at TU Vienna are familiar with Matlab, it is rather easy for them to write bachelor or diploma theses with VieVS by developing small add-ons to the software. The disadvantages are that Matlab is costly and slower compared to other programming languages; however, a global solution with all geodetic VLBI sessions can be run in one or two days on a standard PC, which is fast enough for most of our purposes.

2 Structure of VieVS

VieVS consists of several modules which are connected in one common GUI (see Figure 1). Typically, the modules VIE_INIT, VIE_MOD, and VIE_LSM are run to analyze a single VLBI session. Additionally, VIE_SCHED can be used to schedule a VLBI session with the classical station-based approach and with the newly developed source-based approach (Sun et al., 2014 [8]). If required, these schedules can

then be supplemented with simulated observations based on thermal noise as well as correlated clock and troposphere noise (Pany et al., 2011 [4]). The simulation of source structure effects (Shabala et al., 2014 [9]) will be available with the simulator in the new release.

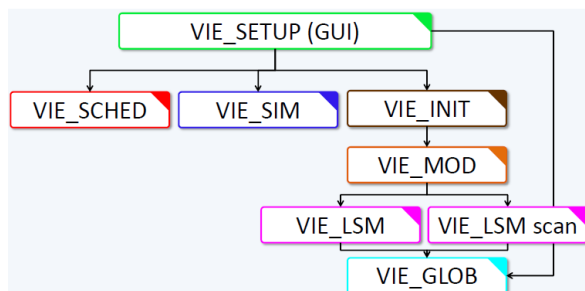


Fig. 1 Structure of VieVS: All modules are connected and can be accessed by a common GUI. Additionally, the modules can also be run in batch mode.

The module VIE_GLOB can be used to stack normal equations from single sessions to run a global VLBI solution (Krásná et al., 2014 [3]) to, e.g., determine global terrestrial and celestial reference frames. Alternatively to starting the jobs with the GUI, it is also possible to run VieVS in batch mode, i.e., without graphical user interface. This is particularly well suited to run longer jobs on a server remotely or to perform automatic processing.

VieVS is capable of following the Conventions of the International Earth Rotation and Reference Systems Service (IERS; Petit and Luzum, 2010 [5]). More specifically, VieVS applies the concept of piecewise linear offsets to nearly all parameters (Böhm et al., 2012 [1]). In terms of Earth orientation parameters, this is in agreement with the goals of the Global Geodetic Observing System (GGOS), but it is not in full agreement with other solutions by Analysis Centers of the International VLBI Service for Geodesy and Astrometry (IVS). However, ways have been found to include solutions with VieVS in the VLBI combination for the International Terrestrial Reference Frame 2013 (ITRF2013) (Thomas Artz, Andreas Iddink, and Sabine Bachmann, personal communication).

3 AUST Campaigns

The scheduling module VIE_SCHED in VieVS has been successfully applied for scheduling VLBI sessions with the telescopes in Australia (Hobart, Katherine, and Yarragadee), in South Africa (Hartebeesthoek), and New Zealand (Warkworth) (see Figure 2). The overall plan for those sessions is accessible at: <http://auscope.phys.utas.edu.au/opswiki/doku.php>.

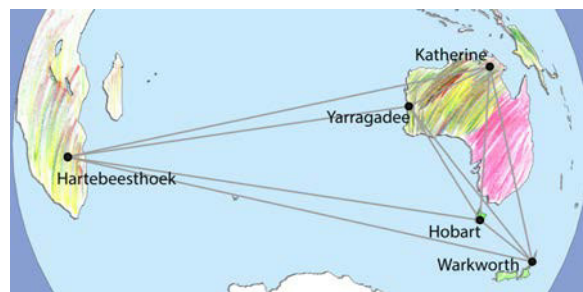


Fig. 2 Stations participating in the 15-day continuous AUST campaign (provided by Sarah and Jim Lovell).

In particular, the AUSTRAL sessions since July 2013 have been scheduled in geodetic and astrometric mode, and a continuous AUST campaign was designed for 15 days from 28 November to 15 December 2013. This continuous campaign will demonstrate the capabilities of the telescopes in the South, and it will serve to investigate source structure effects on geodetic parameters. In particular, alternate observations of 8 and 7 days with *good* structure index ($SI < 2.5$) and *bad* sources ($SI > 2.5$), respectively, have been carried out to demonstrate the impact of source structure on geodetic results. The schedules are repeated every sidereal day in order not to mitigate systematic effects by observing sources at different angles on different days.

In Figures 3 and 4, we illustrate the simulated effects (mean values and mean formal uncertainties) on the estimates of right ascension of the sources and of x -components of station coordinates. It should be clearly stated that we have used 30 sessions with structure indices 1 and 4, respectively, instead of 8 and 7 sessions with structure indices < 2.5 and > 2.5 , respectively, and we find a clear mitigation of mean values and mean formal uncertainties if *good* sources are observed. As soon as the real observations become available, we will analyze them. However, we are aware that with the real observations, the effects will not be as obvious.

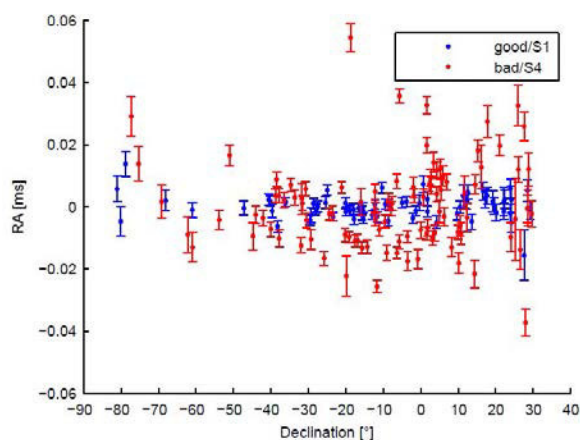


Fig. 3 Mean values of the estimates of right ascension and mean formal uncertainties (error bars) from 30 simulated sessions. In the case of good sources, the structure indices are assumed to be 1. The bad sources were simulated with a structure index of 4.

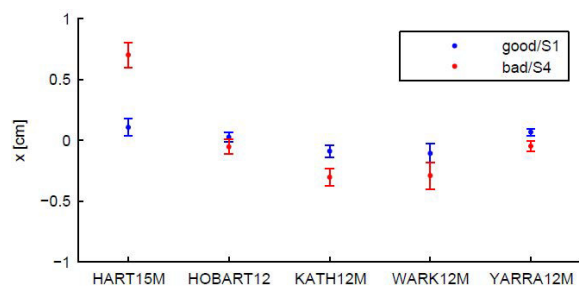


Fig. 4 Mean values of the estimates of X-components in station coordinates and mean formal uncertainties (error bars) from 30 simulated sessions. In the case of good sources, the structure indices are assumed to be 1. The bad sources were simulated with a structure index of 4.

4 New Features and Ongoing Developments

New features to become available with the new release VieVS 2.2 comprise the source structure simulator (Shabala et al., 2014 [9]), updates to the scheduling module VIE_SCHED such as the tag-along mode, and the ability to estimate axis offsets and harmonic station position variations in the global solution.

Ongoing activities are related to the observation of satellites with VLBI radio telescopes. Hellerschmied et al. (2014 [2]) developed a Satellite Scheduling Module in VieVS, providing the possibility to plan satellite observations flexibly for arbitrary station networks and satellite constellations. With the schedule files issued

in VEX format, it is possible to carry out actual satellite observations. These schedules have been successfully applied to observe GLONASS satellites on the baseline Wettzell–Onsala in January 2014. Plank et al. (2014a [6], 2014b [7]) have analyzed simulated observations to satellites with an internal version of VieVS and found that the frame ties between the dynamical frame realized by satellites and the celestial reference frame benefits greatly from a combined estimation of tropospheric parameters from both quasar and satellite observations.

5 Future Plans

A major restructuring of VieVS will be required by a rigorous change to the new VGOS databases which are provided as netCDF files. On the other hand, the new format will ease the exchangeability of data between different software packages.

Furthermore, we are considering replacing the Matlab-based GUI by graphical user interfaces built with Qt. By doing so, we could remove the dependency on the commercial software Matlab, because VieVS in batch mode could also be run with Octave, a free Matlab alternative. First steps towards that goal have already been taken.

Other main VieVS activities in the future will be related to observing satellites with VLBI radio telescopes, tropospheric delay modeling with ray-traced delays, scheduling legacy antennas together with new VGOS telescopes, geophysical and astronomical parameter estimation (e.g., galactic rotation), contributions to ICRF3, and filter solutions for the analysis of observations.

6 VieVS User Workshops

There has already been a series of four VieVS User Workshops at TU Vienna. The 5th User Workshop will be held from 17 to 19 September 2014, and everybody is welcome to attend. More information about the VieVS User Workshops can be found at <http://vievs.geo.tuwien.ac.at/>.

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