The 5th IVS General Meeting Proceedings, 2008, p.11–19

VLBI2010 Antenna Slew Rate Study

Bill Petrachenko [1], *Johannes Boehm* [2], *Daniel MacMillan* [3], *Arthur Niell* [4], *Andrea Pany* [2], *Anthony Searle* [1], *Joerg Wresnik* [2]

[1] *Geodetic Survey Division, Natural Resources Canada*

[2] *Institute of Geodesy and Geophysics/University of Technology, Vienna*

[3] *NVI, Inc./NASA Goddard Space Flight Center, USA*

[4] *MIT Haystack Observatory, USA*

Contact author: Bill Petrachenko, *e-mail:* `Bill.Petrachenko@nrc.gc.ca`

Abstract.
A relationship is developed between VLBI antenna slew parameters (rate and acceleration) and station position accuracy. The relationship supports the specification of antenna slew parameters for the next generation VLBI2010 system.

1. Introduction

The following three sections describe respectively the method used in the study, results, and conclusions.

Note: Source-switching interval refers to the time between the start of one scan and the start of the next (including both on-source time and slew time between sources); and, the term scan refers to the effect of a group of antennas simultaneously observing the same source.

2. Method

The analysis is carried out in three steps: 1) VLBI schedules are generated, each with a different uniform source-switching interval; 2) A relationship is developed between source-switching interval and position accuracy using schedules from step 1 and Monte Carlo simulators; 3) A relationship is developed between slew parameters and position accuracy using the results of step 2 and software that was developed to relate slew parameters to source-switching interval.

2.1. Schedule Generation

Four 24 h schedules were generated, each with a different uniform source-switching interval, e.g. 15, 30, 45 and 60 s, using a well-distributed global network of 16 stations and a list of 230 compact sources suggested for geodetic use by Leonid Petrov. In the scheduling software, scans are scheduled in pairs with sources as close to 180 degrees apart as possible; an attempt is made to approach uniform spatial coverage over the celestial sphere by selecting the next source to be the one that is furthest from its nearest neighbor (of the eleven most recently observed source pairs), i.e. filling the largest hole in the current source distribution; and, an attempt is made to observe each source roughly an equal number of times over the course of each 24 h session. In practice, schedules are generated scan-by-scan with each candidate source being assigned a score and the highest scoring source being selected for the next scan.

Since the uniform sky algorithm typically generates long inter-scan slews, scans were reordered in groups of five to minimize slew time. Also, since it was hypothesized that one antenna often has a disproportionately long slew time to undo the azimuth cable wrap, the last antenna to arrive on source for each scan pair was always dropped.

2.2. Monte Carlo Simulators

Monte Carlo simulators were developed [1] previously for other VLBI2010 studies. Simulated input data include the effects of reference clock drift (modelled as a random walk plus integrated random walk with ASD 1.e-14 @ 50 m), atmosphere instability (modelled as a moving turbulent screen with latitude dependent parameters from high resolution radiosonde data) and delay measurement error (modelled as a Gaussian random variable with sigma 4 ps). Output statistics are based on a sample of 25. The figure of merit for a run is the median 3D rms position error, which is taken as a proxy for station position accuracy.

Three simulators have been developed, one at GSFC based on Solve (least squares), one at TU Wien based on OCCAM (Kalman filter), and one at TU Wien based on precise point positioning (PPP) (Kalman filter). Although the last is not entirely realistic for VLBI, it is useful for assessing new analysis strategies.

2.3. Slew Parameters

A second simulator was developed to relate input slew parameters to source-switching interval. In it, source-switching interval is broken down into two components, on-source time and slew time.

On-source time is based on SEFD's of 2450 (assuming D = 12 m, eff = 0.5 and Tsys = 50 K), a data rate of 8 Gbps per band (assuming BW = 1 GHz, dual polarizations, and 2-bit Nyquist sampling), a correlated flux for the scheduled source based on the weaker of the S and X tabulated fluxes at 13000

Km, and a minimum SNR of 10, which is the minimum required to ensure successful application of the broadband delay technique.

Slew time is based on antenna mount type, number of antennas at a site, and slew parameters. Two mount types were considered. Both were of the azimuth/elevation (az/el) type with azimuth range -270 to +270 degrees. The elevation range of one mount was 5 to 90 degrees (standard) and the other was 5 to 175 degrees (over-the-top). Both the case of a single antenna at a site and a pair of antennas at a site were handled.

Using this software and input slew parameters, an average source-switching interval was calculated for a schedule and then, through trial and error, families of slew parameters were determined that achieve a specified source-switching interval (and hence a specified position accuracy).

3. Results

The Monte Carlo simulators were each run using schedules with 15, 30, 45 and 60 s source-switching interval. The results are summarized in figure 1. Although, as expected, the PPP solution is somewhat optimistic since it doesn't require separation of atmospheres between stations, some of its better performance is also due to the use of elevation dependent weighting and spherical harmonics in the analysis. As expected, the Solve and OCCAM results are fairly close. Based on the OCCAM result, rms position errors of 1, 1.25, 1.5 and 1.75 mm were associated with switching intervals of 24, 37, 50 and 63 s respectively in the remainder of the study.

Using the OCCAM switching results, the slew parameter simulator, and a fixed slew acceleration in both axes of 3 deg/s/s, it was possible to find families of azimuth and elevation slew rates that achieve the switching rates of 24, 37, 50 and 63 s corresponding to position errors of 1.00, 1.25, 1.50 and 1.75 mm respectively. See figure 2.

In a similar way, families of azimuth slew rate and acceleration were developed corresponding to the position errors of 1.00, 1.25, 1.50 and 1.75 mm repectively. Acceleration was assumed to be the same in both axes. See figure 3.

4. Conclusions

Within the limitations of the Monte Carlo simulators, the following antenna configurations and slew parameters (e.g. azimuth slew rate (deg/s), elevation slew rate (deg/s), and acceleration for both axes (deg/s/s)) can be expected to achieve the VLBI2010 station position accuracy goal of 1 mm:

- A single antenna with standard mount and slew parameters of 12, 4, and 3 (or for 1.25 mm accuracy, slew parameters of 6, 2, and 2).
- A single antenna with over-the-top mount and slew parameters of 9, 9, and 2 (or for 1.25 mm accuracy, slew parameters of 4.5, 4.5, and 1).

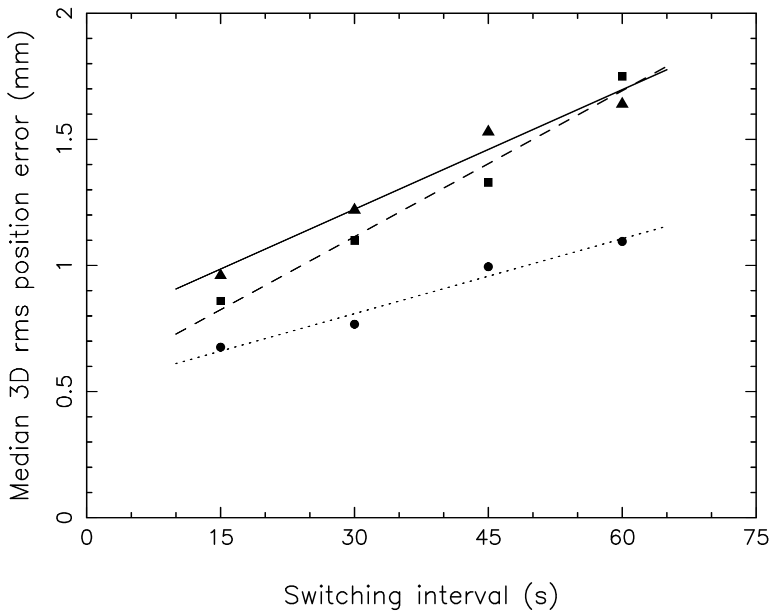

Figure 1. Median 3D rms position error vs Switching interval. The solid line and triangles are for the Solve Monte Carlo simulation; the dashed line and squares are for the OCCAM simulation; and the dotted line and circles are for the PPP simulation

- A pair of antennas with standard mounts and slew parameters of 5, 1.7, and 1.
- A pair of antennas with over-the-top mounts and slew parameters of 3.5, 3.5 and 0.4.

5. Acknowledgements

Andrea Pany is a recipient of a DOC-fFORTE fellowship of the Austrian Academy of Sciences.

References

[1] Behrend, D. et al., Recent Progress in the VLBI2010 Development, Accepted for publication in: Proceedings of the XXIV IUGG General Assembly, Perugia, Italy, July 2-13, 2007

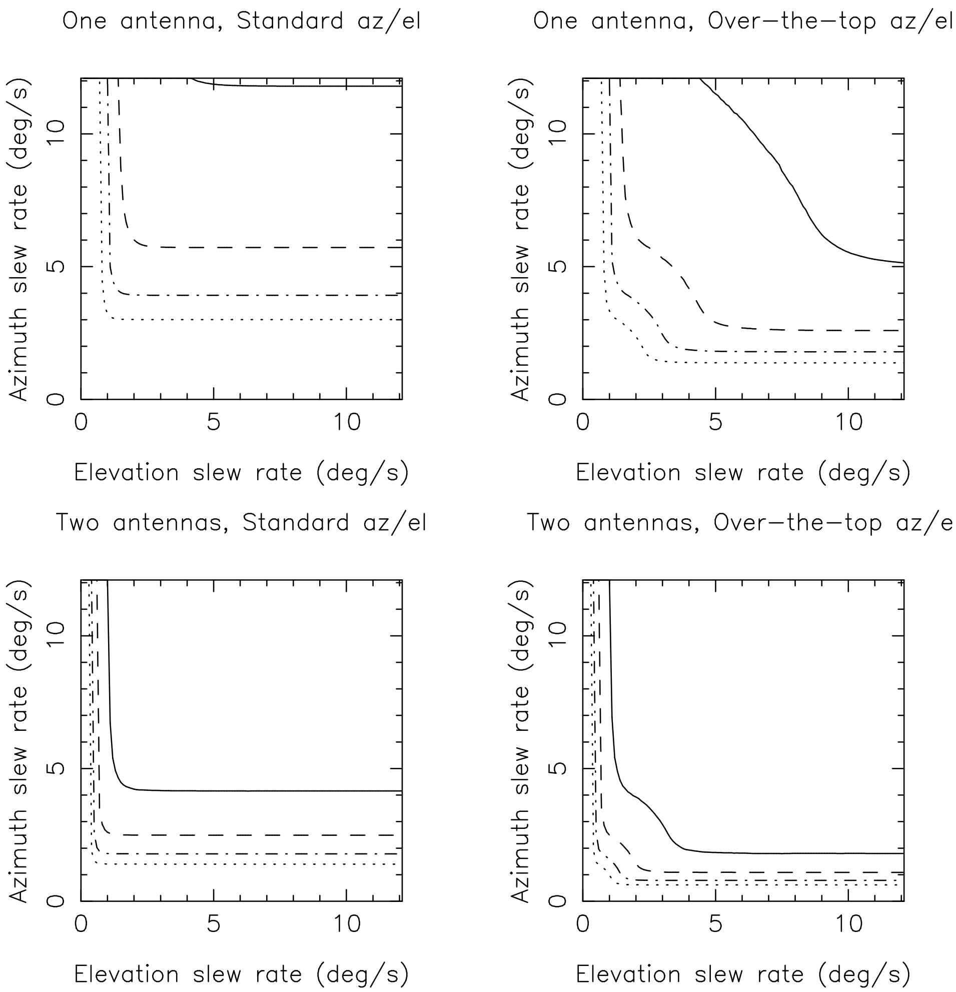

Figure 2. Azimuth vs elevation slew rate to achieve 3D rms position errors (as predicted by the OCCAM Monte Carlo simulator using an optimized uniform sky schedule). The solid line is for 1 mm position error; the dashed line 1.25 mm; the dashed-dotted line 1.50 mm; and the dotted line 1.75 mm. In all cases, 3 deg/s/s slew acceleration is assumed for both axes. All slew rate combinations above and to the right of a line achieve the level of performance of that line.

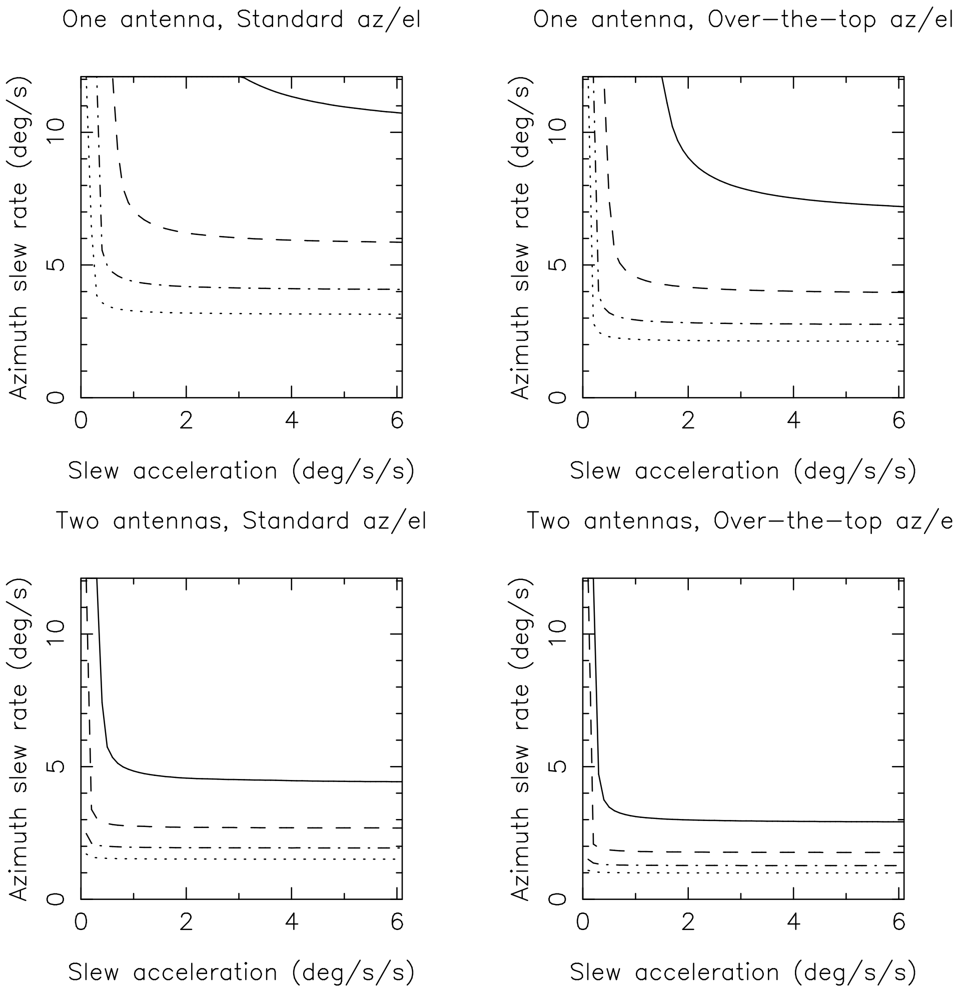

Figure 3. Azimuth slew rate vs acceleration to achieve 3D rms position errors (as predicted by the OCCAM Monte Carlo simulator using an optimized uniform sky schedule). The solid line is for 1 mm position error; the dashed line 1.25 mm; the dashed-dotted line 1.50 mm; and the dotted line 1.75 mm. Elevation slew rates are set to 0.33 of the azimuth slew rate for the standard mount and equal to the azimuth slew rate for the over-the-top mount. All azimuth slew rate and acceleration combinations above and to the right of a line achieve the level of performance of the line.