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“VLBI2010 Antenna Slew Rate Considerations”

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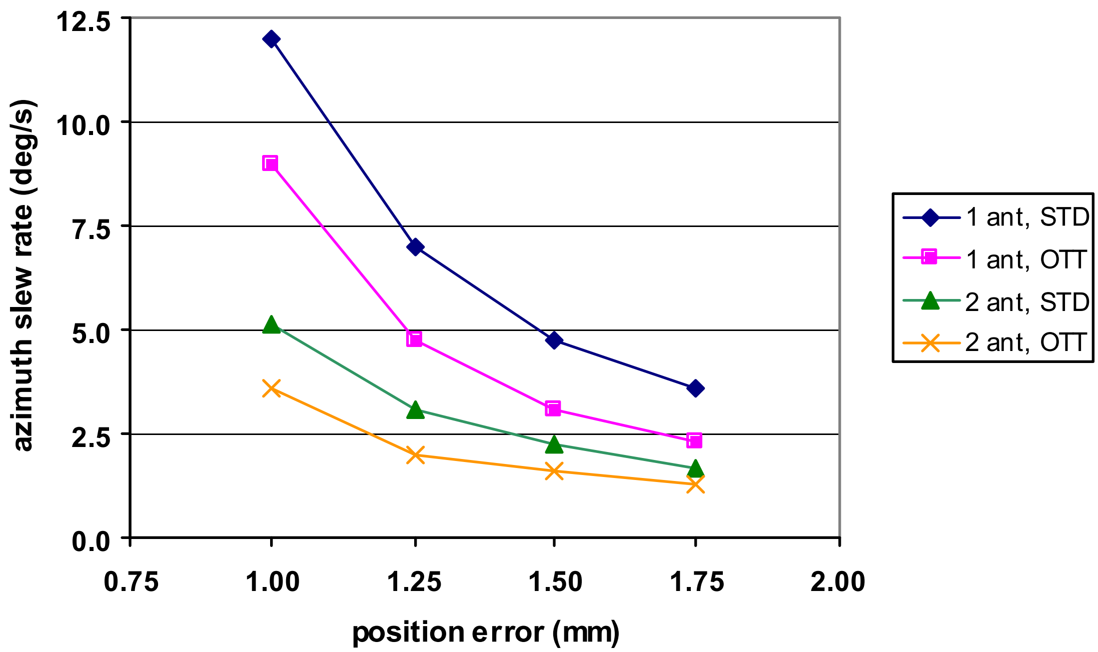
1. Introduction

One of the strategies to reduce position error suggested in the IVS WG3 final report was to dramatically increase the number of observations per session. This option was studied [1] using the VLBI2010 Monte Carlo simulators, which showed, within the limitations of the simulators, that this strategy does in fact produce large gains for reducing position error. In this memo, the implications of that study for antenna slew rate parameters are summarized and a VLBI2010 antenna slew rate recommendation is proposed. The referenced study was carried out in two steps. First, Monte Carlo simulators were use to determine the relationship between position error and source switching interval. Second, families of slew parameters (azimuth slew rate, elevation slew rate, and slew acceleration (same for both axes)) were determined to achieve specified source switching intervals. As it turned out, the resulting families of curves had well defined knees (changes of direction) so it was possible to determine single optimum sets of slew parameters for each specified switching interval. In general, small gains in one parameter can still be achieved, but at a fairly steep increase of another parameter. Finally, by combining the two steps, it was possible to relate the slew parameters to position error. The cases of either one or two antennas at a site along with two mount types were considered. The two mount types considered are a standard (STD) azimuth/elevation drive with elevation range 5 to 90 deg, and an over-the-top (OTT) azimuth/elevation drive with elevation range 5 to 175 deg. The results are summarized in Figure 1.

Figure 1. Position error vs azimuth slew rate. The cases of either one or two antennas at a site are considered, along with two mount types: either a standard (STD) azimuth/elevation mount with elevation range 5 to 90 deg, or an over-the-top (OTT) version with elevation range 5 to 175 deg. For the STD mounts, optimum elevation slew rate was shown to be about one third of the azimuth slew rate, while for the OTT mounts, optimum ratio was approximately 1:1. In all but two cases, slew accelerations no greater than 1 deg/s/s were required, with a number of cases being much lower. The two exceptions were “1 ant, STD” at 1 mm position error, which required 3 deg/s/s, and “1 ant, OTT” also at 1 mm position error, which required 2 deg/s/s.



2. Discussion and Condusions

There are a few obvious comments that can be made about Figure 1:

- Increasing slew rate (to achieve a higher observation rate) is an effective means of reducing position error, although with diminishing returns.
- Based directly on the results of the Monte Carlo simulators, it appears that a target of 1 mm position error is achievable with buildable antenna drive systems. In reality though, the simulators are expected to be optimistic. As a result, performance will almost certainly need to be derated.
- The slew requirements for 2-antenna sites are more than a factor of two lower than for 1-antenna sites.
- A second requirement for VLBI2010 antennas is that they be affordable. This is in the interest of improving network size and geometry. However, affordability is in opposition to the high cost of the antenna drive systems with high slew rates required to achieve the VLBI2010 1 mm performance target, especially with 1-antenna sites. A compromise is required between cost and performance, which may best be served using a 2-antenna site. [The most affordable (capital cost) 12 m class Ka-band antenna currently known is the one manufactured by Patriot Antenna Systems. Its slew parameters are 5/1.25/1.3 (azimuth slew rate (deg/s) / elevation slew rate (deg/s) / slew acceleration (deg/s/s)).]
- Compared to STD mounts, slew rate requirements for OTT mounts are about 25% lower in azimuth and 100% higher in elevation. When this is coupled with the fact that OTT mounts are non-standard and more expensive, there is little to recommend their use. [A similar conclusion can probably be reached for X-Y mounts, although this has not been tested. Also, given the ease of coordinate conversion with modern

computers, there is little to recommend the use of equatorial mounts besides the fact that they have no parallactic angle rotation, which eases interpretation of data from the linearly polarized broadband feeds.]

3. VLBI2010 antenna slew parameter recommendation.

Articulating an antenna slew parameter recommendation for VLBI2010 has proven difficult due to its dependence on a wide variety of factors such as scheduling strategy, analysis strategy, network size, axis configuration, slew limits, ratio of azimuth to elevation slew rate, slew acceleration, integration time (which is itself dependent on the distribution of source fluxes, data rates, antenna sefd's, SNR targets, burst mode operation, etc), and perhaps others. In addition, since real systems are not available to test performance at high observation densities, our knowledge of VLBI2010 performance comes entirely from Monte Carlo simulators. These simulators are far from perfect: e.g. they do not include any degradation due to systematic errors, there remain concerns about atmosphere models, and it remains to be seen whether the broadband delay technique required to achieve 4 ps delay precision at modest SNR (~10 per band) can be made to work operationally. The simulator results for CONT05 do, however, agree acceptably well with results from real data.

All the same, an antenna slew rate recommendation is required immediately so that VLBI2010 antenna acquisition can begin as soon as possible. I would like to make the following suggestions:

- We accept that the best VLBI2010 performance estimates at the moment are those based on the Monte Carlo simulators, scheduling strategies, analysis strategies, sensitivities, etc that have been used in this study.
- Based on these results, we aim for slew parameters that achieve the VLBI2010 performance target of 1 mm for position.
- We provide specifications for standard azimuth/elevation drives with 540 deg azimuth range and ~90 deg elevation range since this is by far the most likely mount configuration.
- We recommend a phased introduction of a 2-antenna site with the second antenna introduced several years after the first and provide the slew specs in the form of a plot. In the first phase when only one of the two antennas is installed, performance will be degraded from 1 mm to 1.5 mm. For the phased introduction though, there is an expectation that contingency will be made on site for a second antenna.

A draft of the VLBI2010 slew rate recommendation is presented below in Figure 2.

4. References

1. Petrachenko, Bill, Johannes Boehm, Daniel MacMillan, Arthur Niell, Andrea Pany, Anthony Searle, Joerg Wresnik, "VLBI2010 Antenna Slew Rate Study", The 5th IVS General Meeting Proceedings, March 3-6, 2008, St. Petersburg.

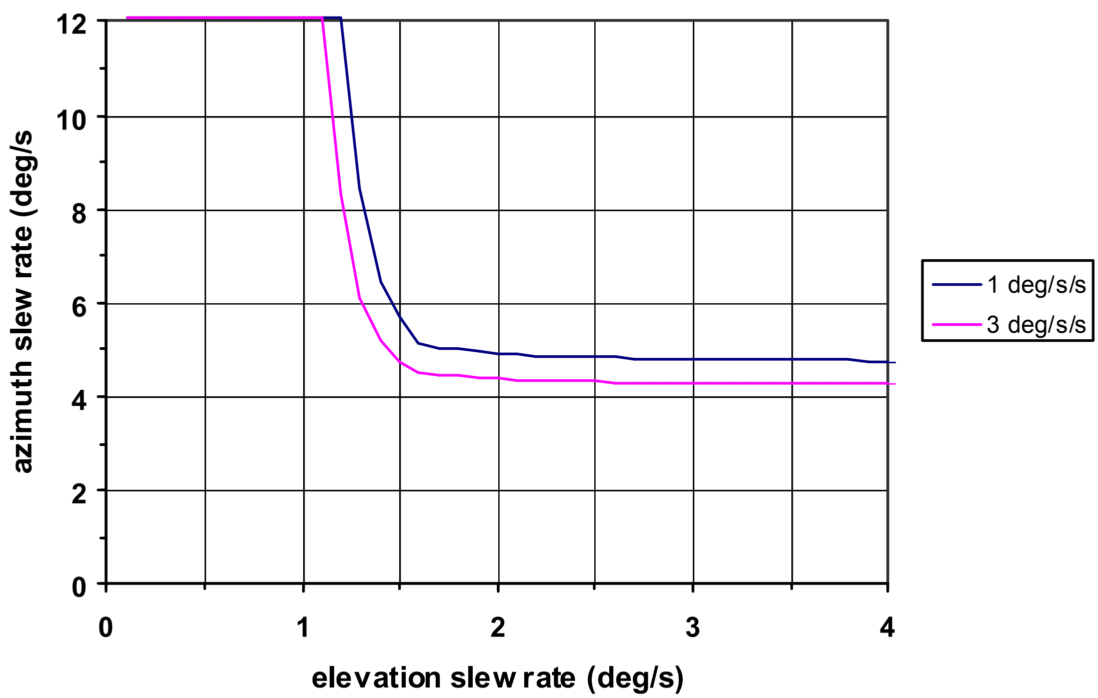


Figure 2. VLBI2010 minimum slew rate recommendation for a 2-antenna site assuming standard az/el mounts and slew accelerations per axis of 1 deg/s/s (top curve) and 3 deg/s/s (bottom curve). Although all slew rates above and to the right of the curves are acceptable, higher slew rates are preferred. Note that this recommendation is for each antenna of a 2-antenna site. If a single antenna is constructed with these slew specifications, it is expected that contingency be made on site for the phased introduction of a second antenna. This will be required to approach the position error of 1 mm. Degradation for a single antenna with these slew parameters is expected to be about 50%. To approach 1 mm position error with a single antenna will require at least: azimuth slew rate=12 deg/s, elevation slew rate=4 deg/s, slew accelerations=3 deg/s/s.]