VGOS MEMO #058

Enhancing WESTFORD to comply with VGOS slew-rate requirements

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1. Introduction

The precision of the measurements of the shape and orientation of the Earth obtained from the observations by VGOS (the VLBI Geodetic Observing System) depends on how rapidly the atmosphere above each antenna of the VGOS network can be sampled in all directions: the better the coverage, the better the removal of the adverse effect of the atmosphere. A thorough study of the desired characteristics of the system (the VLBI2010 Progress Report (Petrachenko et al 2009)) concluded that the antennas should have a speed (slew rate) of at least 12°/second in azimuth and 5°/second in elevation. These rates are achieved by the operational antennas of the VGOS network, but the two prototype antennas, WESTFORD and GGAO12M, which are active and important components of the current network, are considerably slower, having maximum rates of less than 5°/second in azimuth and less than about 3°/second in elevation. While the speed of the GGAO12M antenna cannot be increased, the WESTFORD antenna is amenable to changes in its servo system that would enable movement at VGOS rates. An important question is, what improvement in the number of VGOS measurements might be achieved by such an upgrade?

2. Simulations for an enhanced WESTFORD

Currently a VGOS session consists of observations over a 24-hour period. The sequence of the observations at each antenna is provided by a scheduling program which attempts to maximize the number of scans per hour while optimizing the distribution over the sky of the observed extragalactic radio sources that provide the signals. The primary measure of antenna performance for a geodetic schedule is the number of scans per hour acquired. This is limited by a few factors, including a) the minimum acceptable signal-to-noise ratio (SNR), b) the slew rates of the antenna, c) the minimum length of time that each radio source is observed (MinScan), and d) a parameter that gives the minimum time between observations of the same source (MinBetween). The last parameter is used to improve the distribution of the observations among the sources.

The best approach for evaluating the performance of the WESTFORD antenna without the limitation imposed by other antennas would be to generate a schedule for a single antenna; however, a second antenna is required (i.e., a baseline) to calculate the scan length to achieve the minimum SNR. To accomplish this, a fictitious antenna was added at the location of WESTFORD with the same characteristics (sensitivity, slew rates, and cable wrap limitation). Simulated schedules using these two antennas forming a zero baseline were then generated. Schedules were generated both with the current slew rates of WESTFORD and with VGOS slew rates. The MinScan was either 30 seconds, as used for the current operational VGOS sessions, or 7 seconds, as tested and proposed for future operational sessions. The MinBetween parameter was set to either 15 minutes or 10 minutes. Although both values are smaller than the 20 minutes used for the VO and VR scheduling, the values were necessary to ensure that a source was available to be scheduled after all of the other potential sources had been used. Results for these single-antenna simulations as well as for a full VGOS network are presented below.

3. WESTFORD results from single-antenna simulations

The results for WESTFORD for the single antenna tests are given in Table 1. Line 1 corresponds to the current operational VGOS parameters (the "VO" sessions). Line 5 is what might be achieved with the proposed scheduling parameter changes and with an enhanced WESTFORD able to achieve slew rates that are VGOS compliant.

	Slew rates (az/el; °/sec)	MinScan (sec)	MinBetween (min)	# scans	# scans/hour
1	current (3.3/2)	30	15	1229	**51**
2	VGOS (12/6)	30	15	1271	53
3	current (3.3/2)	7	15	1637	68
4	current (3.3/2)	7	10	1781	74
5	VGOS (12/6)	7	10	2322	**97**

Table 1. The number of scans in 24 hours and the number of scans per hour for WESTFORD as a single antenna in a geodetic schedule.

These results indicate that, in this idealized scenario, an approximately 50% improvement could be made for WESTFORD by changes in the scheduling parameters, and almost a doubling of the number of scans per hour could be made by also increasing the slew rates of the antenna.

4. WESTFORD results from a VGOS session

One would expect the results to change when additional antennas are included in a schedule, primarily because an antenna will at various times during a session have to wait for one or more of the other antennas to reach a source. To obtain a more realistic evaluation of this, the antenna configuration for the nine-station session VO2272 (2022/09/22) was used. (This session was chosen for convenience but one would expect consistent results when using other operational VO sessions.) The antennas of VO2272 were GGAO12M, ISHIOKA, KOKEE12M, MACGO12M, ONSA13NE, ONSA13SW, RAEGYEB, WESTFORD, and WETTZ13S. Three schedules were generated: 1) using the original parameters for VO2272; 2) using the slew rates from VO2272 for all antennas but MinScan of 7 s and MinBetween of 10 min; and 3) VGOS slew rates for all antennas and the MinScan and MinBetween of 2). The results for WESTFORD are given in Table 2.

	Slew rates (az/el; °/sec)	MinScan (sec)	MinBetween (min)	# scans	# scans/hour
1	current (3.3/2)	30	20	879	**37**
2	current (3.3/2)	7	10	1196	50
3	VGOS (12/6)	7	10	1574	**66**

Table 2. The number of scans in 24 hours and the number of scans per hour for WESTFORD as calculated using (line 1) the scheduling parameters for vo2272, (line 2)

the same slew rates as for line 2 but the R&D scan parameters, and (line 3) VGOS slew rates for all antennas and the R&D scan parameters.

In this more realistic example, the fractional increases in the total number of scans (and scans per hour) relative to the basic schedule are approximately 35% and 80% for the two modifications simulated (i.e., shorter scans and VGOS slew rates for WESTFORD). What is significant for the improvement due to the slew rate increase, though, is that all antennas in the network obtain a similar increase (results not shown), so the total number of observations for the session increases by 30% just due to the investment at one site, if all the other antennas are VGOS-compliant.

5. Sky coverage

A visual comparison of the azimuth and elevation coverage for the single-antenna schedules for the current slew rates and scan length (line 1 of Table 1) with the az-el coverage for the VGOS slew rates and 7 second minimum scan is shown it Figure 1. The much greater density of observations that can be obtained from the shorter scans and higher slew rates (right plot) is evident.

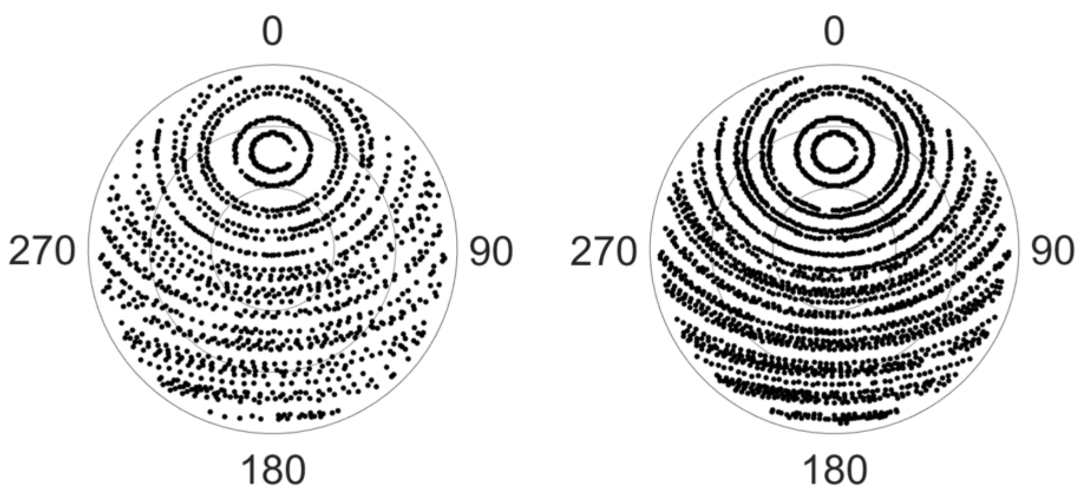

Figure 1. Positions on the sky in azimuth and elevation polar plot for WESTFORD for the parameters in Table 1 line 1 (left) and line 5 (right). Each point corresponds to one scan. Elevation is measured from zenith (center of figure) to 0° at circumference. Azimuth goes from North (0°) towards East (90°), as though the antenna were being viewed from directly above. Each of the quasi-circular tracks corresponds to successive observations of a source.

6. Summary

Two types of VGOS schedules were used to investigate the improvement in sky coverage that might be attained for an enhanced WESTFORD antenna capable of the recommended VGOS slew rates. First, in order to evaluate what the maximum improvement might be, a 24-hr session was scheduled with a second identical antenna at the same location as WESTFORD so there would not be any limitation due to the characteristics of another antenna, for example slew rate or azimuth wrap, in going from one source to another. Second, the parameters of a previously observed VGOS 'VO' session were used but the schedule was generated (using *autosked*) with WESTFORD having VGOS slew rates. Both examples showed a significant increase in the number of observations in a 24-hr session, as follows:

- An increase of up to about 90% in the number of scans in a session is achieved for WESTFORD in zero-baseline mode by reducing the minimum scan length from 30 seconds, as observed in the current operational VGOS sessions, to 7 seconds, as observed in the VGOS R&D sessions, and by increasing the slew rates for WESTFORD to the VGOS standard (Table 1).
- An increase of up to about 80% in the number of scans in a session is achieved for WESTFORD in a realistic VO schedule for the same changes (Table 2).
- For the VO-based schedule, increasing the slew rates for WESTFORD to the VGOS standard accounts for approximately 30% of the improvement in the total number of observations for that antenna, but, interestingly, this is accompanied by a 30% increase in the total number for all antennas (Table 2).

Perhaps most importantly, the enhancement of WESTFORD benefits the entire VGOS network if all other antennas are also VGOS compliant.

7. Recommendation

It is recommended that a study of an enhanced WESTFORD antenna be performed for the electro-mechanical feasibility of increasing to the slew rates to those that are VGOS compliant.

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References

Petrachenko, B., A. Niell, D. Behrend, B. Corey, J. Bohm, P. Charlot, A. Collioud, J. Gipson, R. Haas, T. Hobiger, Y. Koyama, D. MacMillan, T. Nilsson, A. Pany, G. Tuccari, A. Whitney, and J. Wresnik (2009), Design aspects of the VLBI2010 system. progress report of the vlbi2010 committee, Tech. Rep. NASA/TM-2009-214180, NASA Technical Memorandum (https://ivscc.gsfc.nasa.gov/publications/misc/TM-2009-214180.pdf).