VLASS Project Memo # 8

Scheduling Block Overheads

Amy E Kimball (NRAO)

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1. Introduction

This memo describes observing overheads for the VLA Sky Survey. The types of overhead incurred for VLASS scheduling blocks (SBs) are explained, and examples for specific types of VLASS SBs are presented, based on observations obtained and lessons learned during the VLASS Pilot.

The goal for VLASS is to reach an overall overhead percentage of no more than 19%. For the purposes of the survey and this memo, "overhead" comprises any and all time during a VLASS observation that is not spent on scanning the sky "on-source" in OTF mode. The overhead values are calculated based on the number of phase-centers in OTF scans; each phase-center equates to 0.9 seconds of on-source time. The overhead percentage refers to the total overhead time in an SB compared to the total "on-source" time during an SB. For example: a half-hour SB with 20 min of on-source OTF scanning and 10 min of overhead would have an overhead percentage of 50% (as opposed to 33.3%).

2. Types of Overhead

We consider the following categories of overhead, explained in further detail below:

1. Initial slew / Setup scans
2. Flux calibrator scan(s) (including slew time to source)
3. Phase calibration scans (including slew time to source)
4. Extra leakage calibrator scan(s) (including slew time to source)
5. Dummy time in OTF scans

Details on types of overhead with numbers corresponding to the above list:

0. Every scan must be evenly divisible by the VLASS integration time of 0.45 seconds. After accounting for slew time, each scan's duration is increased (if necessary) to

accommodate this requirement. Those extra fractional seconds are incorporated into the overheads for each scan category.

1. Initial slew / Setup scans: The setup scans (e.g., for setting the attenuators) are folded into the first long slew. The total duration is set by the longest possible slew time assuming the antennas would start at the far end of the opposite antenna wrap. The duration of the scans is at least one minute shorter than the longest possible slew time; the final minute (plus any extra time if the initial slew would require > 9 minutes to reach the source) is folded into the first non-setup scan to allow for at least one additional minute devoted to the first calibrator scan duration.

2. Flux calibrator scan(s): The majority of Pilot SBs used the flux calibrator as the setup source and first observed calibrator. Thus no "extra" slewing time was needed after the setup scans, so the majority of Pilot SBs have three minutes of overhead for the flux calibrator. The rare SB which observed the flux calibrator last have two minutes on this calibrator plus the required slew time.

3. Phase calibration scan(s): The minimum on-source time per scan for a phase calibrator scan is 30 seconds. Slew time between the OTF rows and the phase calibrator is folded into this overhead category. Note that SBs which start on the flux calibrator will have extra slew time to the phase calibrator near the beginning of the SB. SBs which end on the flux calibrator will have less slew time to the phase calibrator; the slew time instead will be folded into the flux calibrator overhead for the final slew from phase calibrator to flux calibrator at the end of the SB.

4. Extra leakage calibration scan(s): To ensure enough parallactic angle range for leakage calibration, a "CalPolLeak" scan is included before and after each tile (8x10 contiguous region) or mini-tile (4x10 contiguous region). Larger tiles (as opposed to mini-tiles) can be observed over a 4 hour period (typically one full SB) and the phase calibrator is used as the leakage calibrator. Because the phase calibrator brackets the OTF scans, no extra leakage calibration scan is needed in such a case. However, the smaller mini-tiles are observed over a 2-hour period (typically half of one SB), which is not enough time to achieve sufficient parallactic angle coverage. Therefore, SBs that cover multiple mini-tiles (with different phase calibrators for each) incorporate at least one "extra" leakage calibrator scan at either the beginning or end of the SB. The scan duration is 30 seconds plus the required slew time.

5. OTF dummy time: This overhead category refers to all of the time spent in an OTF scan that does equate to "on-source" time. The on-source time is 0.9 seconds per phase-center in an OTF scan. "Dummy" time incorporates slew time to the first OTF row in a loop, slew time between OTF rows, telescope settling time, and "back-up" time (an extra one or more phase-centers at the start of the scan, which allow the antennas to reach scanning speed).

Table 1 *Example SB Overheads*

SB type	OTF time	Setup/slew	Flux	Phase	+Leakage	Dummy	Total
Full 8×10:	SBs with "standard" 8×10 full tile(s) at $+51° < \delta < +59°$						
One tile	12150.0s	480.15	193.05	883.35	0.00	754.65	2311.20
(4 hours)		4.0%	1.6%	7.3%	0.0%	6.2%	19.02%
Two tiles	24300.0s	480.15	195.75	1533.60	256.50	1446.30	3912.30
(8 hours)		2.0%	0.8%	6.0%	1.1%	6.1%	16.10%
Near zenith:	Mini-tiles at $+29.5° < \delta < +33.5°$ with an alternative leakage calibrator						
2 minis	12610.8s	480.15	209.70	832.05	454.95	768.15	2745.00
(4 hours)		3.8%	1.7%	6.6%	3.6%	6.1%	21.77%
Near zenith:	Mini-tiles at $+29.5° < \delta < +33.5°$						
2 mini-tiles	12610.8s	480.15	180.90	1048.50	300.60	787.50	2797.65
(4 hours)		3.8%	1.4%	8.3%	2.4%	6.2%	22.18%
3 mini-tiles	18916.2s	480.15	213.30	1435.05	298.35	1132.20	3559.05
(6 hours)		2.5%	1.1%	7.6%	1.6%	6.0%	18.81%
4 mini-tiles	25221.6s	480.15	195.30	1910.25	263.70	1532.70	4382.10
(8 hours)		1.9%	0.8%	7.6%	1.0%	6.1%	17.37%

OTF time and overheads are given in seconds; percentages are shown underneath.

3. Example scheduling blocks

Table 1 shows example overheads for SBs created using the Pilot scheduling procedure (see VLASS Memo # 004). We demonstrate for a variety of SBs with different structure and length, including a "standard" 4-hour SB with one 8×10 tile, an 8-hour SB with two 8×10 tiles, and several SBs made of two or more 4×10 "mini-tiles." The SBs with the 8×10 tiles are for observations at declinations of approximately +55°. The SBs with the 4×10 mini-tiles are for declinations of approximately +31.5°; these mini-tiles transit close to the zenith and thus should be observed as mini-tiles allowing flexibility to avoid high-elevation observing. These SBs are typical of the worst overhead percentages we expect to accrue. One of these is a 4-hour SB with an alternative leakage calibrator (i.e., a leakage calibrator that is not used as a phase calibrator). The other examples demonstrate a 4-hour, 6-hour, and 8-hour SB comprising 2, 3, or 4 mini-tiles respectively.

Multiple tiles combined in one SB will be separated in the sky such that they are observed (one after another) at similar hour angle. Thus, the two 8×10 tiles are spaced by roughly 4 LST-hours, whereas the 4×10 tiles are each spaced by roughly 2 LST-hours. We emphasize that the actual survey tiles will vary in size due to the curvature of the celestial sphere (see VLASS Memo # 007). However, as the tiles are designed to have similar shape on average to those presented here, these examples represent the overhead percentages we expect to achieve in the full survey. We note that there will certainly be variations in slew time owing to distance of tiles from the flux calibrator and distance to the phase calibrators.

4. Conclusions

The example SBs demonstrate the following points with regard to overhead time.

- The initial setup/slew time is (nearly always!) a flat overhead of 8 minutes, meaning that its overhead percentage decreases linearly as SB length increases.
- The time to observe the flux calibrator is three minutes plus some (varying) slew time, so this overhead percentage decreases linearly as SB length increases.
- The phase calibration percentage ranges from 6% to $\gtrsim$ 8%. The value is fairly constant because the time required for phase calibration varies approximately with the on-source (total OTF) time. The overhead percentages are higher for the high-elevation tiles because these require extra slew time in addition to extra calibration scans when switching from one tile to another.
- For the 4-hour SB that uses an alternative leakage calibrator, three "extra" scans are required, incurring new overhead of $> 1\%$ per scan. The phase calibration overhead for this SB is lower than for the 4-hour SB with a single 8×10 tile; it is likely because the slew time from the flux calibrator is absorbed into the leakage overhead in this instance of the alternative leakage calibrator.
- The "dummy" percentage is always $\approx$ 6% as there is a constant overhead incurred for each OTF scan. The slight variation is due to slew time from the phase calibrator at the beginning of each scanning loop.
- The best instance of overhead is incurred for the 8-hour SB that covers two 8×10 tiles. This SB has two phase calibrators, thus requiring only one "switch" between phase calibrators.
- The worse instance of overhead is for the 4-hour SB with two mini-tiles that transit at the zenith, with one of the two phase calibrators as the leakage calibrator. This requires observing the leakage calibrator one time at high elevation ($\sim 70°$), where slew times tend to be long. For the longer multiple-mini-tile SBs, the leakage calibrator can be observed on both sides of transit, while avoiding to observe it in the middle of the SB when it is at high elevation.
- Whenever possible, the smaller 4×10 tiles should always be combined into SBs of 6 or 8 hours in order to minimize overhead. Much of the sky will have to be observed in these smaller tiles: very low declinations that are only above the horizon for a short period of time; declinations close to the Clark Belt, where high hour angles have a better chance of avoiding the satellite belt; and the declinations that transit above 80° elevation.

Revision History

Revision	Date	Author(s)	Description
1.0	2017-03-02	Amy Kimball	Original