CONT17 From a VieVS Perspective

J. Böhm, M. Schartner

Abstract CONT17 is a special VLBI campaign of the International VLBI Service for Geodesy and Astrometry in November and December 2017 with three independent networks. Two legacy networks with 14 stations each are observing at S- and X-band for 15 days, while a network with six stations is observing in the new VGOS broadband mode. We investigate the CONT17 schedules with the new scheduling software VieSched++ to provide feedback on the legacy and VGOS schedules. Finally, we generate a schedule for mixed-mode observations which could be observed with the CONT17 stations.

Keywords Scheduling · VGOS · Mixed-mode

1 Introduction

Two legacy networks observed at S/X band from 28 November until 12 December 2017 and one VGOS network did broadband observing over five days from 4 to 8 December 2017. The plan for the CONT17 campaign was to *acquire state-of-the-art VLBI data to demonstrate the highest accuracy of which the legacy S/X VLBI system is capable, to investigate possible network biases, and to demonstrate some of the VGOS capabilities limited by the size and geometry of the available VGOS network and observation period.*

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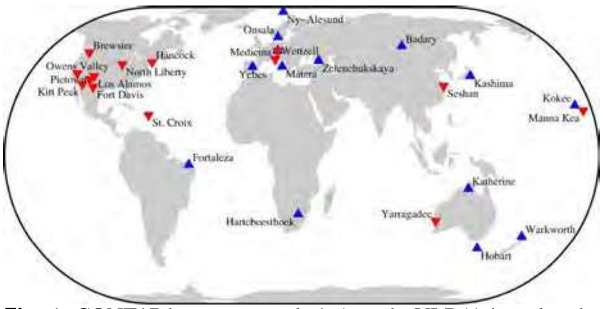

Fig. 1: CONT17 legacy network A (mostly VLBA) in red and network B in blue. The figure is taken from https://ivscc.gsfc.nasa.gov/program/cont17/ .

Fig. 2: VGOS station network during CONT17. ONSA13NE has been verifying the VGOS chain at the time of CONT17 and is not used here. The figure is taken from https://ivscc.gsfc.nasa.gov/program/cont17/ .

The legacy A network with 14 stations (mostly VLBA, correlated in Socorro) observed at a data rate of 256 Mbit/s and the legacy B network, also with 14 stations (correlated in Bonn), used a data rate of 512 Mbit/s (see Fig. 1). On the other hand, the VGOS network with six stations (see Fig. 2) observed at 8 Gbit/s and the baseband data were correlated at MIT Haystack Observatory.

In this report, we focus on the schedules of the CONT17 sessions which have been generated with *sked* (Gipson, 2010). Here, we use VieSched++ (Schartner and Böhm, 2019) to check whether there are improvements possible with those geodetic schedules. To assess both types of schedules, the simulation tool of the Vienna VLBI and Satellite Software (VieVS) (Pany et al., 2011; Böhm et al., 2018) has been applied with a refractive index structure constant of $1.8 \cdot 10^{-7} m^{-1/3}$ and a constant scale height of 2 km for all stations (Nilsson et al., 2007), a clock variation corresponding to an Allan Standard Deviation of 10^{-14} at 50 minutes (Herring et al., 1990), and a white noise per baseline observation of 30 picoseconds. The Monte-Carlo simulation is always based on 500 runs.

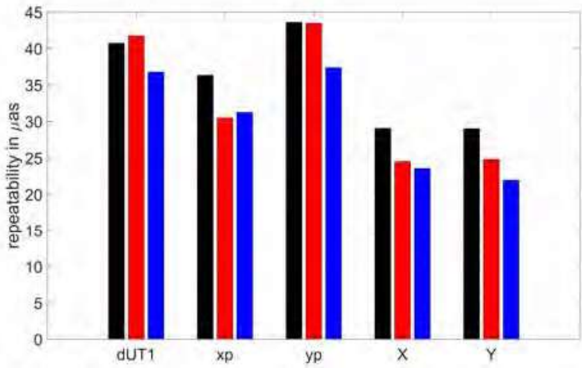

Fig. 3: Simulated repeatabilities in microarcseconds for the Earth orientation parameters for the schedules listed in Table 2. The black bars correspond to the actually observed schedules, the red and blue bars to the schedules generated with VieSched++ with the same and the extended source lists, respectively.

2 Schedules for the legacy B network

The multi-scheduling mode of VieSched++ is used to generate more than 1000 schedules with different weight factors, such as different weights for sky-coverage or the number of observations, for the first day of CONT17 and the legacy B network. Out of those schedules, 150 have been further tested with Monte-Carlo simulations as described in Section 1. Finally, we focus here on two schedules, namely v483 based on the same list of 100 sources as used by *sked* and v036 using an extended list of 300 good sources. Table 1 summarizes the number of observations and scans for the schedules.

Table 1: Characteristics of the schedules for the legacy B network. The first line corresponds to the actually observed schedule, the other two lines correspond to variants generated with VieSched++ with different source lists.

	# obs	# scans
C1701	13499	1499
v483	14921	1278
v036	15094	1478

Figure 3 depicts the repeatabilities of Earth orientation parameters as derived with Monte-Carlo simulations. In general, there is an improvement with the schedules generated with VieSched++, which is even more pronounced when using an extended source list for scheduling. In terms of station position repeatabilities, the improvement for the new schedules is not significant (not shown here).

3 Schedules for the VGOS network

We also scheduled one day of the VGOS network with the following stations participating as core stations: GGAO12M, WESTFORD, KOKEE12M, RAEGYEB. Other stations (ISHIOKA, ONSA13NE, ONSA13SW, WETTZ13S) were added in tag-along mode as was done for the actual schedule with *sked*. In accordance with the observed schedules, we used fixed values of 30 seconds for the scan times and the same down-times of the antennas. However, for the VGOS schedules generated with *sked*, a minimum slew time of 30 seconds was obviously set, too. While we understand the minimum scan lengths due to unknown fluxes at all frequencies, we do not follow the 30 seconds minimum slew times because the purpose is not clear and there is no possibility to apply that constraint in VieSched++.

Finally, two schedules are presented here: v066 with the same source list as used by *sked*, and v058 with an extended list of good sources (more than 250 mJy). The increase in number of observations and scans with about 60 % is substantial. This effect is mainly due to the minimum slew times applied with *sked* but other differences like the varied application of sub-netting plays an important role, too. Monte-

Table 2: Characteristics of the schedules for the VGOS network. The first line corresponds to the actually observed schedule with minimum slew times of 30 seconds, the other two lines correspond to variants with different source lists and without minimum slew times.

	# obs	# scans
17DEC03VS	12985	1180
v066	21041	1948
v058	21061	1985

Carlo simulations have not been carried out for these schedules.

4 Schedules for mixed-mode observations

We also generate schedules for mixed-mode observations for CONT17 as they could have been observed. In the following, we assume that the legacy A network is observing with data rates of 128 Mbit/s at X- and S-band and that the legacy B network is observing at 192 Mbit/s and 320 Mbit/s, respectively. Furthermore, we assume that the channels observed by the legacy B network comprise all channels observed by the legacy A network. Finally, we assume that the VGOS network is observing with a data rate of 2048 Mbit/s at S- and X-band, again including all channels observed by both legacy networks (cf. Fig. 3). Here, all integration times have been calculated based on the channels, and no special factor has been applied when observing with legacy S/X stations (circular polarized receivers) and VGOS stations (linear polarized) together.

Figure 4 depicts how many scans were observed with how many stations. It is evident that there is a high number of scans with many stations participating, i.e., the networks are very well connected. The schedule presented here includes 2016 scans and 126592 observations at an average idle time of 2.4 %.

Table 3: Number of baselines possible with a mixed-mode scenario.

band	data rate	# baselines	baselines
S	128 Mbit/s	399	A-A, A-B, A-V
S	192 Mbit/s	203	B-B, B-V
S	2048 Mbit/s	28	V-V
X	128 Mbit/s	399	A-A, A-B, A-V
X	320 Mbit/s	203	B-B, B-V
X	2048 Mbit/s	28	V-V

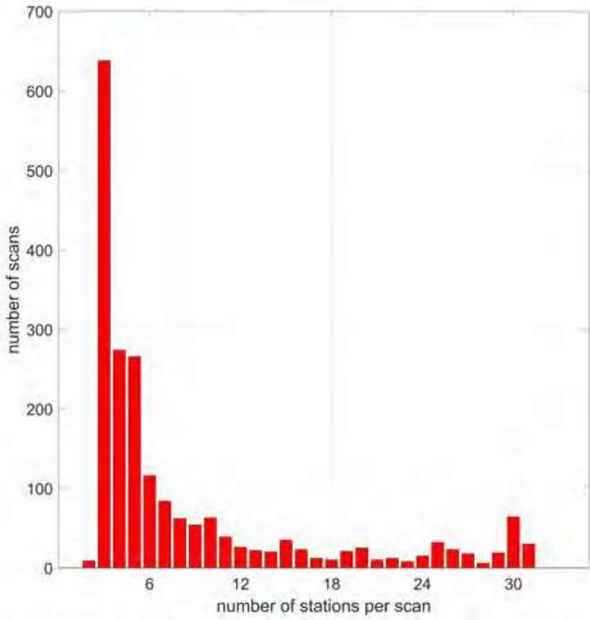

Fig. 4: Number of scans versus number of stations participating in the scans. For example, there are 638 scans with three stations and 64 scans with 30 stations.

5 Conclusions and outlook

We used the scheduling software VieSched++ (Schartner and Böhm, 2019) to assess the schedules generated with *sked* for CONT17. We could confirm that the schedules for the legacy networks are well optimized and only smaller improvements are possible with VieSched++.

The situation is different for the VGOS schedules, which could be greatly improved. It is not clear why the VGOS schedules do have constraints of minimum 30 seconds for scan and slew times. In particular, the slewing time can be well derived from the antenna specifications. Also a more sophisticated use of subnetting could improve the performance of the schedules.

It was also possible to generate a schedule in a mixed-mode scenario, which connects all networks, legacy and VGOS, in one schedule. This approach might be a useful scenario for a CONT2020 campaign.

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References

Böhm J, Böhm S, Boisits J, et al. (2018) Vienna VLBI and Satellite Software (VieVS) for Geodesy and Astrometry. *PASP*, 130, 044503, doi:10.1088/1538-3873/aaa22b

Gipson J (2010) An Introduction to Sked. In: D. Behrend, K. D. Baver (eds.): *IVS 2010 General Meeting Proceedings*, NASA/CP-2010-215864, 77–84

Herring T, Davis J, Shapiro I (1990) Geodesy by radio interferometry: The application of Kalman Filtering to the analysis of very long baseline interferometry data. *J Geophys Res*, 95, 12561–12581, doi:10.1029/JB095iB08p12561

Nilsson T, Haas R, Elgered G (2007) Simulations of atmospheric path delays using turbulence models. *Proc. 18th EVGA Working Meeting*, 175–180

Nothnagel A, Artz T, Behrend D, et al. (2017) International VLBI Service for Geodesy and Astrometry. *J Geod*, 91, 711–721, doi:10.1007/s00190-016-0950-5

Pany A, Böhm J, MacMillan D, et al. (2011) Monte Carlo simulations of the impact of troposphere, clock and measurement errors on the repeatability of VLBI positions. *J Geod*, 85, 39–50, doi:10.1007/s00190-010-0415-1

Schartner M, Böhm J (2019) VieSched++: A New VLBI Scheduling Software for Geodesy and Astrometry. *PASP*, 131, 084501, doi:10.1088/1538-3873/ab1820