VLBI2010 Monte Carlo simulations at IGG Vienna

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Abstract

The main goal of VLBI2010 is to design a new Very Long Baseline Interferometry (VLBI) system that will provide baseline length repeatabilities of less than 1mm for the longest baselines in the network. To support the design of a new geodetic VLBI system, VLBI2010, simulations are being carried out at the Institute of Geodesy and Geophysics (IGG), Vienna. The main part of these simulations is a Monte Carlo simulator which produces artificial group delays by modeling the stochastic processes caused by station clocks, wet zenith delays and additional system errors. The limiting factor of the VLBI system is the influence of the wet zenith delay. Therefore, turbulence models using wind speed and wind direction information from numerical weather models are used in the Monte Carlo Simulator to simulate realistic wet zenith delays. The clocks are simulated with a random walk plus integrated random walk. The Monte Carlo simulator is implemented in a modified version of the VLBI analysis software package OCCAM. Because of limitations due to the huge number of observations in the OCCAM Gauß-Markov algorithm, the Kalman Filter approach of OCCAM was applied. Baseline length repeatabilities and rms values of station position residuals are compared for schedules with antennas of different slew speeds (from 1.5 °/sec to 12°/sec in azimuth and 0.7 °/sec to 3.1 °/sec in elevation). The investigation shows that there is hardly any improvement with antennas faster than 6°/sec in azimuth and 2.1°/sec in elevation. Different scheduling strategies, such as those achieving uniform sky coverage, are also tested.

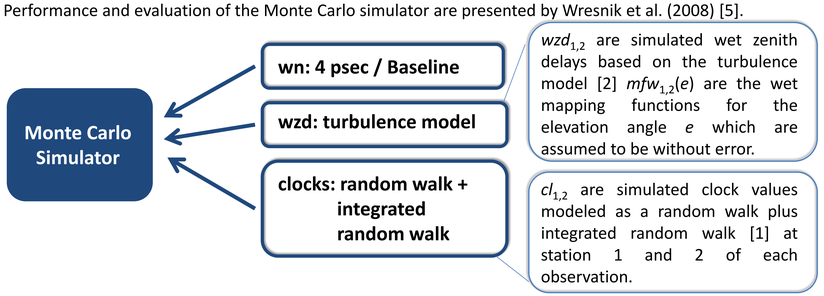
2. Monte Carlo Simulation

A sequence of software programs is used for the simulations. After scheduling the observations with SKED [4] they are transformed to the NGS format and then used as input to the VLBI analysis software package OCCAM [3], which was adapted for our simulations.

The main part of the simulation studies is a so-called Monte Carlo simulator which creates the artificial observations based on realistic properties of the wet zenith delays and clocks. The observed group delay minus computed group delay (*o-c*) can be described as follows:

$$o-c=\left(wzd_2\cdot mfw_2(e_2)+cl_2\right)-\left(wzd_1\cdot mfw_1(e_1)+cl_1\right)+wn_{bsl}$$

The Monte Carlo simulator, implemented in OCCAM, imports wet zenith delay values from the turbulence model, creates clock values for each station and epoch, and adds white noise for each observation. Performance and evaluation of the Monte Carlo simulator are presented by Wresnik et al. (2008) [5].



3. Evaluation with CONT05 real data

wn: observation error of real data
wzd: turbulence model Vienna
clocks: ASD $1\cdot10^{-14}$@50 min

Fig. 1: Station map with 11 VLBI sites for the continuous VLBI campaign CONT05 in September 2005.

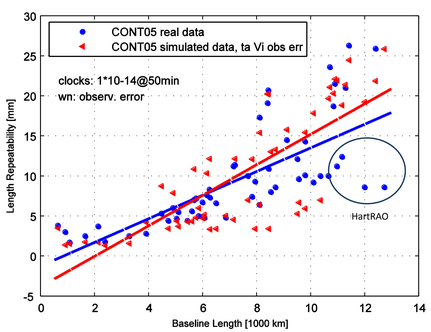


Fig. 2: Baseline length repeatabilities of the VLBI CONT05 sessions (filled circles) and the Monte Carlo simulation (filled triangles). There is good agreement, especially for baselines shorter than 6000 km. The simulated baselines including HartRAO were degraded because the Cn values for the turbulence model are determined from radiosonde data at Miami (USA) in March 2005.

4. Slew speed test

scheduled with SKED (Vandnberg 1999)
by John Gipson, NASA/GSFC, Greenbelt, USA
100 of 230 radio sources

wn: 4psec
wzd: turbulence model Vienna
clocks: ASD $1\cdot10^{-14}$@50 min

slew speed az [°/sec]	el [°/sec]	avg obs/h/st	min obs/h/st	max obs/h/st	nr. of obs.	median 3D station position [mm]
1.5	0.7	47	39	55	59392	2.15
3.0	0.7	61	46	76	83149	1.71
4.5	2.1	101	76	121	134134	1.14
6.0	2.1	120	89	144	159088	1.20
12.0	3.5	131	96	155	173831	1.05

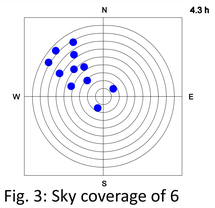


Fig. 3: Sky coverage of 6 minutes at station FORTALEZA

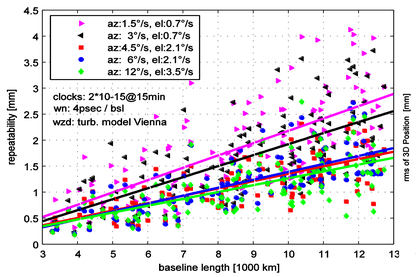


Fig. 4: Baseline length repeatabilities for different slew speeds.

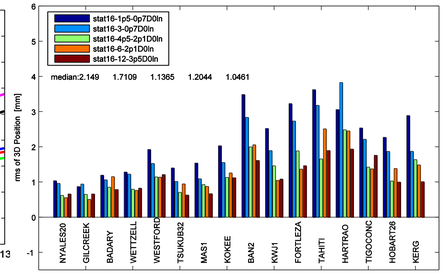


Fig. 5: Simulated rms values of the 3D station positions for all 16 stations for different slew speeds (station order: North-South).

5. Uniform sky

scheduled by Tony Searle
Natural Resources Canada (NRC)
230 radio sources

wn: 4psec
wzd: turbulence model Vienna
clocks: ASD $1\cdot10^{-14}$@50 min

Station	switching intervall [sec]	uniform sky [min]	slew speed az [°/sec]	slew speed el [°/sec]	nr. of obs	median 3D station position [mm]
16	120	12	2.1	0.6	34 806	3.29
16	60	12	4.8	1.1	69 708	1.52
16	45	9	7.3	1.8	93 231	1.29
16	30	6	12 (*)	3.2	139 564	1.01
16	15	3	32(**)	8	278 830	0.88

acceleration: 1.3 °/sec²
** 3 °/sec²*
*** 8 °/sec²*

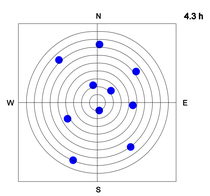


Fig. 6: Sky coverage of 6 minutes at station FORTALEZA for uniform sky coverage.

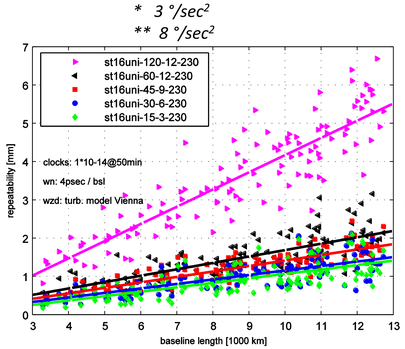


Fig. 7: Baseline length repeatabilities for different uniform sky coverage.

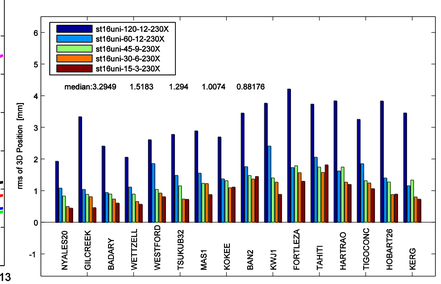


Fig. 8: Simulated rms values of the 3D station positions for all 16 stations for different uniform sky coverage (station order: North-South).

6. Different number of stations

scheduled by Tony Searle
Natural Resources Canada (NRC)
230 radio sources

wn: 4psec
wzd: turbulence model Vienna
clocks: ASD $1\cdot10^{-14}$@50 min

Station	switching intervall [sec]	uniform sky [min]	nr. of obs	median 3D station position [mm]
16	45	9	93 231	1.29
24	45	9	216 322	1.21
32	45	9	393 686	1.29

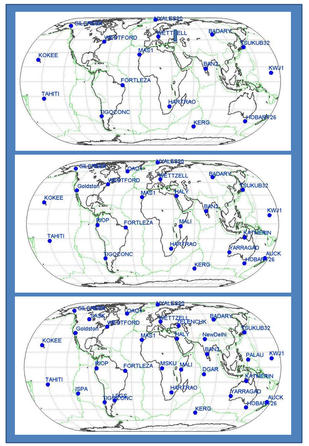


Fig. 9: VLBI2010 test networks with real and simulated stations.

dUT1

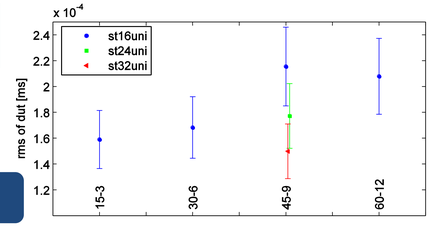


Fig.10: rms values of dut1 for different uniform sky schedules with 16 (blue), 24 (green) and 32 (red) stations.

EOPs are determined for all 16 station schedules with different switching time of 15, 30, 45 and 60 sec, and uniform sky coverage over 3, 6, 9 and 12 min. (see x-axe Fig.10). For the 24 and 32 station network, EOPs are estimated for the 45 sec switching time and 9 min. uniform sky coverage. The change of the accuracy of the estimation of the EOPs, using dUT1 as an example, can be seen with respect to the change of the scheduling strategies or change of the network size. The different network sizes have to be applied for all other scheduling strategies, which will be done in the near future.

Conclusions

- the slew speed test shows that the estimated baseline length repeatabilities (Fig. 4) are improved considerably for antennas with slew speeds up to 4.5°/sec in azimuth and 2.1°/sec in elevation
- the uniform sky schedules show a significant improvement of baseline length repeatabilities (Fig. 7) for schedules with 120 sec switching intervals down to 60 sec switching intervals. For shorter switching intervals the improvement is still linear but the rate is smaller.
- the median value of the rms of 3D station position (Fig. 8) for uniform sky schedules with 15 sec switching intervals is at the 1 mm level, which is the defined goal of the VLBI2010 committee

Next steps

- as the number of observations only increase by 9% by changing the slew speed in azimuth from 6 to 12 °/sec more investigations on scheduling (e.g. reducing the idle time of the antennas) is needed to profit from very fast moving antennas
- the improvement of EOP determination has to be proved for other switching intervals (Fig. 10)

References

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