Degradation of the KOKEE12M cablecal – 2019 April 01 to September 16

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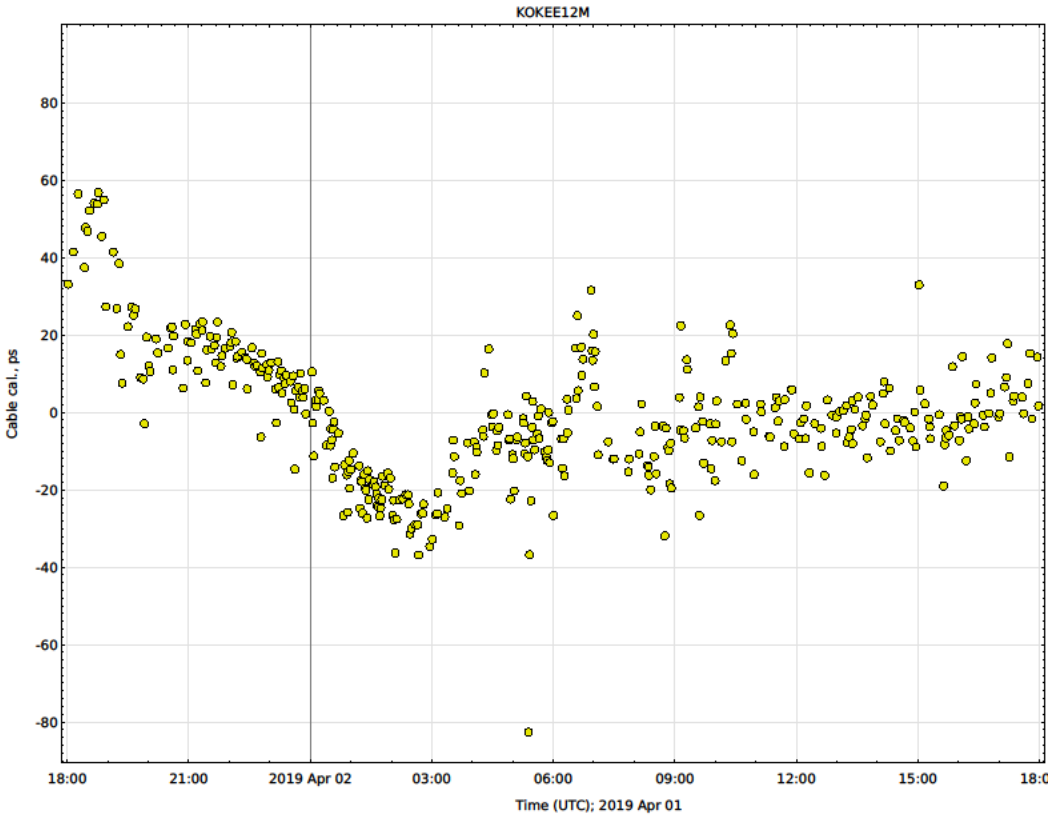
1. Introduction

A proxy measurement for the cable calibration system is derived from the phase calibrator tones. The peak-to-peak scatter for the KOKEE12M proxy cablecal increased from ~25 ps or less over a few hours in 19APR01VG (vt9091; S3688) to ~100 ps in 19SEP16VG (vt9259; S3702), indicating that the cable carrying the 5 MHz reference frequency to the phase calibrator generator had degraded over that period. This memo documents the change and demonstrates that application of the cablecal delay as measured by the proxy reduces the post-fit delay residuals for the K2 baselines in the geodetic solutions, as intended.

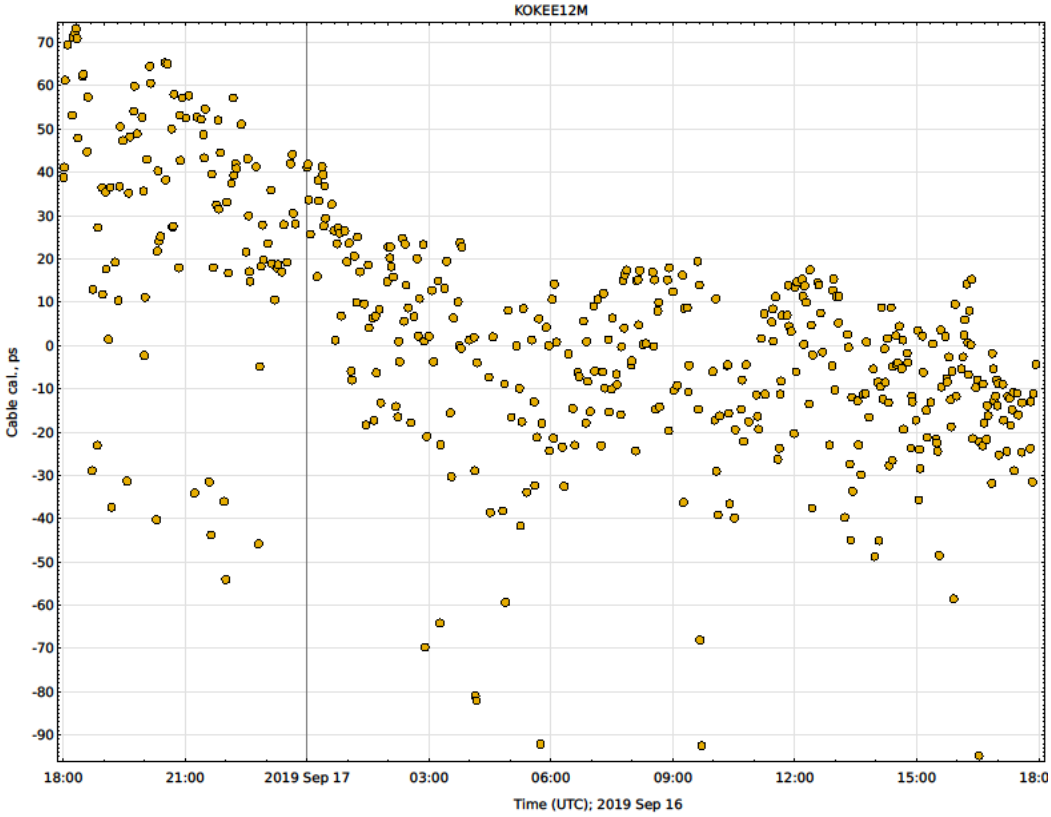
2. Analysis

The positions of KOKEE12M (K2), GGAO12M (Gs), RAEGYEB (Yj), and Wettzell-S (Ws) were estimated relative to WESTFORD (Wf) both with and without the K2 proxy cablecal (pcmtcc).
Solutions were made for two sets of clock/ZWD/atm-gradients: 1h/1h/6h and 20m/15m/3h.
The solutions used to compare the change in WRMS post-fit delay residuals are NOT re-weighted.
The proxy cablecal values for K2 for the two sessions are shown in the following figures.

19APR01VG (y-scale: -90 to +90 ps)



19SEP16VG (y-scale: -95 to +75 ps)



3. Results – summary (see Appendix 1 for values)

Post-fit delay residuals (pfdrs)

1. The WRMS of the pfdrs was larger on the K2 baselines when the proxy cablecal (pcmtcc) was not applied (by 2-4 ps on WRMS values of 29-45 ps for 1h1h6h solutions, and by ~2 ps out of 17-23 ps for 20m15m3h solutions). This implies that the pcmtcc is doing what it is supposed to.
2. The WRMS of the pfdrs for the non-K2 baselines changed by less than 1 ps when the K2 pcmtcc was not applied.

<u>19APR01VG (vt9091; S3688)</u> (see Appendix 2 for examples of commands for extraction of values)

1. ENUs agree to better than 1 mm for all antennas (including K2) with and without pcmtcc and for both 1h/1h/6h and 20m/15m/3h clocks/ZWD/atmgrad
2. WRMS pfdr's differ by less than 1 ps for K2 with pcmtcc and K2 with no pcmtcc

<u>19SEP16VG (vt9259; S3702)</u>

Station coordinates:

1. When the K2 proxy cablecal was removed:
   a. E, N, and U for the non-K2 antennas did not change by more than 1 mm when the cablecal was changed for K2 for either the 1h/1h/6h or 20m/15m/3h solutions;
   b. E, N, and U for K2 all changed by approximately 7 mm when going from 'with' to 'without' K2 proxy cablecal for both 1h/1h/6h and 20m/15m/3h un-reweighted solutions, even though for the sane cablecal configuration the 1h/1h/6h and 20m/15m/3h solutions differed by 15/6/9

mm in ENU. In other words, using or not using the K2 cablecal resulted in a change in position for K2 of approximately 7 mm in each component.

(For better evaluation of the effect of the cablecal on position, the solutions should be re-weighted. In an earlier memo I showed that, for CONT17, there is much better consistency among re-weighted solutions. The point of this memo is only to demonstrate the degradation of the cable.)

4. Conclusions

1. It is likely that the 5 MHz reference cable on KOKEE12M is deteriorating in a manner similar to the degradation seen in the past for GGAO12M such that the delays become antenna-orientation dependent.
2. The cables should be replaced as soon as possible.

Appendix 1. Results (for documentation purpose only)

19SEP16VG (vt9259; S3702)
Gs/Wf/K2/Ws/Yj aen-vmlinux GUI
1h/1h/6h for clk/ZWD/grad

19SEP16VG_GsWfWsYjK2_ENU_1h1h6h.SFF:

GGAO12M 7622	U Comp	20.81 mm	20.806 mm	0.101 mm	2.438 mm
GGAO12M 7622	E Comp	-21.91 mm	-21.914 mm	0.026 mm	0.614 mm
GGAO12M 7622	N Comp	12.02 mm	12.022 mm	0.031 mm	0.750 mm
KOKEE12M 7623	U Comp	-39.00 mm	-38.999 mm	0.398 mm	9.575 mm
KOKEE12M 7623	E Comp	6.86 mm	6.864 mm	0.136 mm	3.268 mm
KOKEE12M 7623	N Comp	-13.76 mm	-13.755 mm	0.117 mm	2.819 mm
RAEGYEB 7389	U Comp	-21.30 mm	-21.302 mm	0.127 mm	3.061 mm
RAEGYEB 7389	E Comp	4.34 mm	4.344 mm	0.077 mm	1.861 mm
RAEGYEB 7389	N Comp	2.43 mm	2.427 mm	0.048 mm	1.144 mm
WETTZ13S 7388	U Comp	-38.87 mm	-38.870 mm	0.135 mm	3.255 mm
WETTZ13S 7388	E Comp	-63.86 mm	-63.858 mm	0.086 mm	2.078 mm
WETTZ13S 7388	N Comp	28.38 mm	28.383 mm	0.052 mm	1.241 mm

19SEP16VG_GsWfWsYjK2nocc_ENU_1h1h6h.SFF:

GGAO12M 7622	U Comp	21.45 mm	21.446 mm	0.101 mm	2.487 mm
GGAO12M 7622	E Comp	-21.87 mm	-21.867 mm	0.026 mm	0.626 mm
GGAO12M 7622	N Comp	12.02 mm	12.025 mm	0.031 mm	0.765 mm
KOKEE12M 7623	U Comp	-32.56 mm	-32.562 mm	0.398 mm	9.771 mm
KOKEE12M 7623	E Comp	12.92 mm	12.921 mm	0.136 mm	3.334 mm
KOKEE12M 7623	N Comp	-6.45 mm	-6.455 mm	0.117 mm	2.876 mm
RAEGYEB 7389	U Comp	-21.75 mm	-21.750 mm	0.127 mm	3.123 mm
RAEGYEB 7389	E Comp	4.78 mm	4.779 mm	0.077 mm	1.899 mm
RAEGYEB 7389	N Comp	2.36 mm	2.358 mm	0.048 mm	1.167 mm
WETTZ13S 7388	U Comp	-38.63 mm	-38.634 mm	0.135 mm	3.321 mm
WETTZ13S 7388	E Comp	-63.41 mm	-63.406 mm	0.086 mm	2.121 mm
WETTZ13S 7388	N Comp	28.34 mm	28.336 mm	0.052 mm	1.266 mm

19SEP16VG_GsWfWsYjK2_ENU_20m15m3h.SFF:

GGAO12M	7622	U Comp	16.27 mm	16.270 mm	0.125 mm	1.798 mm
GGAO12M	7622	E Comp	-22.50 mm	-22.495 mm	0.031 mm	0.451 mm
GGAO12M	7622	N Comp	10.23 mm	10.225 mm	0.036 mm	0.519 mm
KOKEE12M	7623	U Comp	-23.83 mm	-23.828 mm	0.592 mm	8.520 mm
KOKEE12M	7623	E Comp	12.52 mm	12.515 mm	0.187 mm	2.693 mm
KOKEE12M	7623	N Comp	-4.81 mm	-4.810 mm	0.161 mm	2.315 mm
RAEGYEB	7389	U Comp	-19.40 mm	-19.404 mm	0.165 mm	2.371 mm
RAEGYEB	7389	E Comp	4.18 mm	4.179 mm	0.104 mm	1.494 mm
RAEGYEB	7389	N Comp	1.48 mm	1.482 mm	0.064 mm	0.919 mm
WETTZ13S	7388	U Comp	-38.68 mm	-38.678 mm	0.180 mm	2.589 mm
WETTZ13S	7388	E Comp	-64.61 mm	-64.609 mm	0.115 mm	1.659 mm
WETTZ13S	7388	N Comp	28.07 mm	28.074 mm	0.070 mm	1.002 mm

19SEP16VG_GsWfWsYjK2nocc_ENU_20m15m3h.SFF:

GGAO12M	7622	U Comp	17.02 mm	17.024 mm	0.125 mm	1.842 mm
GGAO12M	7622	E Comp	-22.54 mm	-22.537 mm	0.031 mm	0.462 mm
GGAO12M	7622	N Comp	10.17 mm	10.175 mm	0.036 mm	0.532 mm
KOKEE12M	7623	U Comp	-16.27 mm	-16.266 mm	0.592 mm	8.726 mm
KOKEE12M	7623	E Comp	18.04 mm	18.040 mm	0.187 mm	2.758 mm
KOKEE12M	7623	N Comp	2.08 mm	2.078 mm	0.161 mm	2.371 mm
RAEGYEB	7389	U Comp	-19.73 mm	-19.734 mm	0.165 mm	2.429 mm
RAEGYEB	7389	E Comp	4.69 mm	4.689 mm	0.104 mm	1.531 mm
RAEGYEB	7389	N Comp	1.50 mm	1.497 mm	0.064 mm	0.941 mm
WETTZ13S	7388	U Comp	-38.68 mm	-38.681 mm	0.180 mm	2.651 mm
WETTZ13S	7388	E Comp	-64.05 mm	-64.049 mm	0.115 mm	1.699 mm
WETTZ13S	7388	N Comp	28.03 mm	28.033 mm	0.070 mm	1.026 mm

Post-fit delay residuals (W.RMS Del):

~/Reports 1106 % grep -A13 'ine Stat' 19SEP16VG_GsWfWsYj**K2**_ENU_1h1h6h.SFF

Baseline Statistics

Baseline	# W.Obs used/recov	W.RMS Del ps	N.R.D. standard	N.R.D. (15ps+i) fs/s	W.RMS Rate ps	N.R.R. fs/s	D.RW	R.RW
GGAO12M -KOKEE12M	405/ 479	28.8	21.14	2.92	717.4	0.00	0.0	0.0
GGAO12M -RAEGYEB	574/ 686	30.2	23.87	2.64	843.5	0.00	0.0	0.0
GGAO12M -WESTFORD	772/ 901	27.3	23.86	2.16	1074432849.2	0.00	0.0	0.0
GGAO12M -WETTZ13S	570/ 693	37.3	26.22	3.86	950.1	0.00	0.0	0.0
KOKEE12M-RAEGYEB	169/ 226	32.5	17.30	3.42	907.1	0.00	0.0	0.0
KOKEE12M-WESTFORD	411/ 480	28.9	18.66	2.74	2096210664.2	0.00	0.0	0.0
KOKEE12M-WETTZ13S	184/ 251	45.2	23.41	4.35	887.4	0.00	0.0	0.0
WESTFORD-RAEGYEB	528/ 635	22.0	17.78	4.71	747870233.1	0.00	0.0	0.0
WESTFORD-WETTZ13S	524/ 643	29.4	21.04	2.77	759526980.6	0.00	0.0	0.0
WETTZ13S-RAEGYEB	682/ 799	23.9	29.29	2.34	535.1	0.00	0.0	0.0

~/Reports 1107 % grep -A13 'ine Stat' 19SEP16VG_GsWfWsYj**K2nocc**_ENU_1h1h6h.SFF

Baseline Statistics

Baseline	# W.Obs used/recov	W.RMS Del ps	N.R.D. standard	N.R.D. (15ps+i) fs/s	W.RMS Rate ps	N.R.R. fs/s	D.RW	R.RW
GGAO12M -KOKEE12M	405/ 479	31.8	23.28	2.98	717.5	0.00	0.0	0.0
GGAO12M -RAEGYEB	574/ 686	30.2	23.87	2.64	842.0	0.00	0.0	0.0
GGAO12M -WESTFORD	772/ 901	27.3	23.84	2.16	1074432857.5	0.00	0.0	0.0
GGAO12M -WETTZ13S	570/ 693	37.3	26.20	3.84	950.5	0.00	0.0	0.0
KOKEE12M-RAEGYEB	169/ 226	34.9	18.59	3.58	909.8	0.00	0.0	0.0
KOKEE12M-WESTFORD	411/ 480	33.3	21.50	2.97	2096210698.1	0.00	0.0	0.0
KOKEE12M-WETTZ13S	184/ 251	48.0	24.86	4.48	871.3	0.00	0.0	0.0
WESTFORD-RAEGYEB	528/ 635	22.1	17.83	4.71	747870228.4	0.00	0.0	0.0
WESTFORD-WETTZ13S	524/ 643	29.4	21.09	2.78	759526976.6	0.00	0.0	0.0
WETTZ13S-RAEGYEB	682/ 799	23.9	29.32	2.34	535.2	0.00	0.0	0.0

Solutions were repeated with 20m/15m/3h for clk/ZWD/grad.

19SEP16VG_GsWfWsYjK2_ENU_20m15m3h.SFF:

Baseline Statistics

Baseline	# W.Obs used/recov	W.RMS Del ps	N.R.D. standard	N.R.D. (15ps+i) fs/s	W.RMS Rate ps	N.R.R. fs/s	D.RW	R.RW
GGAO12M -KOKEE12M	405/ 479	17.2	12.59	2.41	1530.0	0.00	0.0	0.0
GGAO12M -RAEGYEB	574/ 686	16.6	13.10	2.10	1926.6	0.00	0.0	0.0
GGAO12M -WESTFORD	772/ 901	17.3	15.06	1.67	1074432632.8	0.00	0.0	0.0
GGAO12M -WETTZ13S	570/ 693	19.8	13.91	3.07	2206.7	0.00	0.0	0.0
KOKEE12M-RAEGYEB	169/ 226	20.8	11.11	2.42	1811.1	0.00	0.0	0.0
KOKEE12M-WESTFORD	411/ 480	17.7	11.45	2.20	2096210782.2	0.00	0.0	0.0
KOKEE12M-WETTZ13S	184/ 251	23.4	12.14	2.42	1796.1	0.00	0.0	0.0
WESTFORD-RAEGYEB	528/ 635	14.6	11.79	4.24	747870266.0	0.00	0.0	0.0
WESTFORD-WETTZ13S	524/ 643	14.8	10.62	2.09	759526958.3	0.00	0.0	0.0
WETTZ13S-RAEGYEB	682/ 799	11.5	14.12	1.30	1218.5	0.00	0.0	0.0

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19SEP16VG_GsWfWsYjK2nocc_ENU_20m15m3h.SFF: Baseline Statistics

Baseline	# W.Obs used/recov	W.RMS Del ps	N.R.D. standard (15ps+i)	N.R.D. W.RMS Rate fs/s	N.R.R. ps	D.RW fs/s	R.RW
GGAO12M -KOKEE12M	405/ 479	19.2	14.06	2.54 1545.1	0.00	0.0	0.0
GGAO12M -RAEGYEB	574/ 686	16.7	13.16	2.10 1889.4	0.00	0.0	0.0
GGAO12M -WESTFORD	772/ 901	17.2	15.05	1.67 1074432615.8	0.00	0.0	0.0
GGAO12M -WETTZ13S	570/ 693	19.9	13.96	3.07 2204.5	0.00	0.0	0.0
KOKEE12M-RAEGYEB	169/ 226	21.7	11.58	2.51 1822.5	0.00	0.0	0.0
KOKEE12M-WESTFORD	411/ 480	19.8	12.80	2.37 2096210759.6	0.00	0.0	0.0
KOKEE12M-WETTZ13S	184/ 251	25.5	13.21	2.56 1932.0	0.00	0.0	0.0
WESTFORD-RAEGYEB	528/ 635	14.7	11.88	4.26 747870284.5	0.00	0.0	0.0
WESTFORD-WETTZ13S	524/ 643	14.9	10.66	2.12 759526974.9	0.00	0.0	0.0
WETTZ13S-RAEGYEB	682/ 799	11.5	14.16	1.30 1247.6	0.00	0.0	0.0

19APR01VG (vt9091; S3688)

Gs/Wf/K2/Ws/Yj

1h/1h/6h for clk/ZWD/grad

19APR01VG_GsWfWsYj**K2**_ENU_1h1h6h.SFF:

GGAO12M 7622	U Comp	7.00 mm	7.000 mm	0.104 mm	1.704 mm
GGAO12M 7622	E Comp	-21.79 mm	-21.791 mm	0.026 mm	0.429 mm
GGAO12M 7622	N Comp	11.28 mm	11.280 mm	0.029 mm	0.471 mm
KOKEE12M 7623	U Comp	-32.52 mm	-32.516 mm	0.409 mm	6.715 mm
KOKEE12M 7623	E Comp	12.89 mm	12.888 mm	0.156 mm	2.558 mm
KOKEE12M 7623	N Comp	6.50 mm	6.503 mm	0.125 mm	2.060 mm
RAEGYEB 7389	U Comp	-4.31 mm	-4.309 mm	0.172 mm	2.831 mm
RAEGYEB 7389	E Comp	-7.50 mm	-7.501 mm	0.082 mm	1.351 mm
RAEGYEB 7389	N Comp	3.90 mm	3.895 mm	0.048 mm	0.793 mm
WETTZ13S 7388	U Comp	-36.10 mm	-36.100 mm	0.142 mm	2.333 mm
WETTZ13S 7388	E Comp	-76.30 mm	-76.301 mm	0.089 mm	1.459 mm
WETTZ13S 7388	N Comp	29.37 mm	29.374 mm	0.050 mm	0.819 mm

19APR01VG_GsWfWsYj**K2nocc**_ENU_1h1h6h.SFF:

GGAO12M 7622	U Comp	7.18 mm	7.182 mm	0.104 mm	1.715 mm
GGAO12M 7622	E Comp	-21.84 mm	-21.836 mm	0.026 mm	0.431 mm
GGAO12M 7622	N Comp	11.27 mm	11.266 mm	0.029 mm	0.474 mm
KOKEE12M 7623	U Comp	-31.77 mm	-31.768 mm	0.409 mm	6.758 mm
KOKEE12M 7623	E Comp	13.94 mm	13.936 mm	0.156 mm	2.575 mm
KOKEE12M 7623	N Comp	6.95 mm	6.949 mm	0.125 mm	2.073 mm
RAEGYEB 7389	U Comp	-4.59 mm	-4.593 mm	0.172 mm	2.849 mm
RAEGYEB 7389	E Comp	-7.24 mm	-7.235 mm	0.082 mm	1.360 mm
RAEGYEB 7389	N Comp	3.80 mm	3.800 mm	0.048 mm	0.798 mm
WETTZ13S 7388	U Comp	-36.34 mm	-36.338 mm	0.142 mm	2.348 mm
WETTZ13S 7388	E Comp	-75.99 mm	-75.988 mm	0.089 mm	1.468 mm
WETTZ13S 7388	N Comp	29.28 mm	29.276 mm	0.050 mm	0.825 mm

Solutions were repeated with 20m/15m/3h for clk/ZWD/grad.

19APR01VG_GsWfWsYjK2_ENU_20m15m3h.SFF:

GGAO12M 7622	U Comp	7.52 mm	7.517 mm	0.132 mm	1.518 mm
GGAO12M 7622	E Comp	-21.54 mm	-21.539 mm	0.030 mm	0.349 mm
GGAO12M 7622	N Comp	11.13 mm	11.126 mm	0.035 mm	0.398 mm
KOKEE12M 7623	U Comp	-38.73 mm	-38.732 mm	0.537 mm	6.195 mm
KOKEE12M 7623	E Comp	10.83 mm	10.828 mm	0.215 mm	2.478 mm
KOKEE12M 7623	N Comp	1.04 mm	1.041 mm	0.172 mm	1.984 mm
RAEGYEB 7389	U Comp	-3.51 mm	-3.512 mm	0.227 mm	2.617 mm
RAEGYEB 7389	E Comp	-6.15 mm	-6.149 mm	0.106 mm	1.218 mm
RAEGYEB 7389	N Comp	2.37 mm	2.372 mm	0.067 mm	0.774 mm
WETTZ13S 7388	U Comp	-35.70 mm	-35.705 mm	0.205 mm	2.368 mm
WETTZ13S 7388	E Comp	-76.40 mm	-76.398 mm	0.114 mm	1.321 mm
WETTZ13S 7388	N Comp	27.22 mm	27.215 mm	0.069 mm	0.792 mm

19APR01VG_GsWfWsYjK2nocc_ENU_20m15m3h.SFF:

GGAO12M 7622	U Comp	7.68 mm	7.678 mm	0.132 mm	1.530 mm
GGAO12M 7622	E Comp	-21.60 mm	-21.603 mm	0.030 mm	0.352 mm
GGAO12M 7622	N Comp	11.12 mm	11.121 mm	0.035 mm	0.401 mm
KOKEE12M 7623	U Comp	-38.48 mm	-38.484 mm	0.537 mm	6.244 mm
KOKEE12M 7623	E Comp	11.21 mm	11.212 mm	0.215 mm	2.497 mm
KOKEE12M 7623	N Comp	1.60 mm	1.599 mm	0.172 mm	2.000 mm
RAEGYEB 7389	U Comp	-4.03 mm	-4.030 mm	0.227 mm	2.638 mm
RAEGYEB 7389	E Comp	-5.63 mm	-5.632 mm	0.106 mm	1.228 mm
RAEGYEB 7389	N Comp	2.17 mm	2.166 mm	0.067 mm	0.780 mm
WETTZ13S 7388	U Comp	-35.97 mm	-35.968 mm	0.205 mm	2.387 mm
WETTZ13S 7388	E Comp	-75.88 mm	-75.878 mm	0.114 mm	1.332 mm
WETTZ13S 7388	N Comp	27.03 mm	27.026 mm	0.069 mm	0.798 mm

Appendix 2. Command examples (for documentation purpose only)

Samples:

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1115  grep -A13 'ine Stat'  19SEP16VG_GsWfWsYjK2_ENU_20m15m3h.SFF
1116  grep -A13 'ine Stat'  19SEP16VG_GsWfWsYjK2nocc_ENU_20m15m3h.SFF
1129  grep "[E-U] Comp " 19SEP16VG_GsWfWsYjK2*_ENU_1h*.SFF|grep KOKEE
1130  grep "[E-U] Comp " 19SEP16VG_GsWfWsYjK2*_ENU_20m*.SFF|grep KOKEE
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