Summary of Data Analysis: Low-Band 1, Original Ground Plane

Raul A. Monsalve
raul.monsalve@colorado.edu

CASA, University of Colorado Boulder
SESE, Arizona State University

August 24, 2017

Here we show results for the analysis of data from the Low-Band 1, Original Ground Plane instrument.

Nominal choices and calibration settings:

1. Dates: 2015-288 to 2016-186 (later days were considered but not used due to solar effects and switch problems)
2. Sun cut: none
3. Moon cut: none
4. Receiver calibration S11 file: s11_calibration_low_band_LNA25degC_2015-09-16-12-30-29_simulator2_long.txt
5. Receiver parameter polynomial terms: Nfit=6, Wfit=5
6. Antenna S11 file: S11_blade_low_band_2015_342.txt
7. Antenna S11 modeling: 9 polynomial terms after removal of delay
8. Balun loss correction: yes
9. Ground loss correction: yes, 2.0%
10. Beam correction: no

The results are summarized in the following figures.

The first six figures provide a overview of the data. It is also shown that an adequate compromise between noise level and spectral structure is obtained for an average over the GHA range 0-16 hr.

- Figure 2: daily residuals to 7-term polynomial over 50-100 MHz, for all days considered. The GHA range is 0-24 hr.
- Figure 3: residuals for 4-hr GHA averages, to 7-term polynomial over 50-100 MHz.
- Figure 4: residuals for 4-hr GHA averages, to 6-term polynomial over 65-95 MHz.
- Figure 5: residuals for 4-hr GHA averages, to 6-term polynomial plus 21-cm signature, over 65-95 MHz. Between 0 and 12 GHA, the signature center frequency was fixed at 78.5 MHz. At 16 and 20 GHA, the frequency was fixed at 75 MHz due to the different structure in the residuals.
- Figure 6: amplitude of 21-cm signature as a function of GHA, in parallel to the total sky temperature at 78.5 MHz. Between 0 and 12 GHA, the signature center frequency was fixed at 78.5 MHz. At 16 and 20 GHA, the frequency was fixed at 75 MHz due to the different structure in the residuals.
- Figure 7: residuals for nominal average over 0-16 GHA, to 1) 6-term polynomial over 50-100 MHz; 2) 6-term polynomial over 65-95 MHz; 3) 6-term polynomial plus 21-cm signature over 65-95 MHz.

The next five figures show the residuals and 21-cm signature for the nominal data average, and compare them with those obtained for different data cuts and calibrations. All the cases correspond to data averages over GHA 0-16 hr and 65-95 MHz, modeled with a 6-term polynomial plus a 21-cm signature. In these cases, the frequency and duration of the 21-cm signature, as well as its amplitude, are found by maximizing the ratio SNR $= |a_{21}/\sigma_{21}|$.

- Figure 8: residuals and 21-cm signature for three different averages of consecutive subsets of data.
- Figure 9: residuals and 21-cm signature for four different averages: 1) daytime only ($\text{EL}_{\text{sun}} \geq 0^\circ$), 2) nightime only ($\text{EL}_{\text{sun}} < 0^\circ$), 3) Moon up only ($\text{EL}_{\text{moon}} \geq 0^\circ$), 4) Moon down only ($\text{EL}_{\text{moon}} < 0^\circ$).
- Figure 10: residuals and 21-cm signature for two alternative receiver calibrations: 1) cal2015, Nfit=7, Wfit=7, and 2) cal2017, Nfit=7, Wfit=7.
- Figure 11: residuals and 21-cm signature for five alternative antenna S11: 1) 2015-289 (2015 switch parameters), 2) 2016-177 (2015 switch parameters), 3) 2015-289 (2017 switch parameters), 4) 2015-342 (2017 switch parameters), 5) 2016-177 (2017 switch parameters)
- Figure 12: residuals and 21-cm signature for two alternative corrections: 1) applying no ground loss correction, and 2) applying beam correction, using beam file *oldniv* rotated to $\text{AZ} = -7^\circ$, and Haslam sky map scaled to 76 MHz using $\beta = -2.5$.

Finally, Table 1 compares the estimates for the different data cuts and calibration alternatives, and Figure 1 shows the values.

Table 1: Signature amplitude estimates for all the cases considered. In all cases, the GHA range is 0-16 hr. The frequency range is 65-95 MHz and, in addition to the signature, the fit model includes six polynomial terms.

Case	Description	Amplitude estimate [mK]
0	Nominal	458 ± 29
1	1st data subset	384 ± 34
2	2st data subset	493 ± 42
3	3st data subset	432 ± 39
4	Daytime only	443 ± 39
5	Nighttime only	350 ± 29
6	Moon up only	378 ± 35
7	Moon down only	346 ± 31
8	recv cal2015, Nfit=7, Wfit=7	544 ± 31
9	recv cal2017, Nfit=7, Wfit=7	433 ± 28
10	ant S11 2015-289, switch2015	446 ± 28
11	ant S11 2016-177, switch2015	436 ± 27
12	ant S11 2015-289, switch2017	450 ± 27
13	ant S11 2015-342, switch2017	463 ± 29
14	ant S11 2016-177, switch2017	439 ± 27
15	No ground loss correction	434 ± 26
16	Yes beam correction	428 ± 27

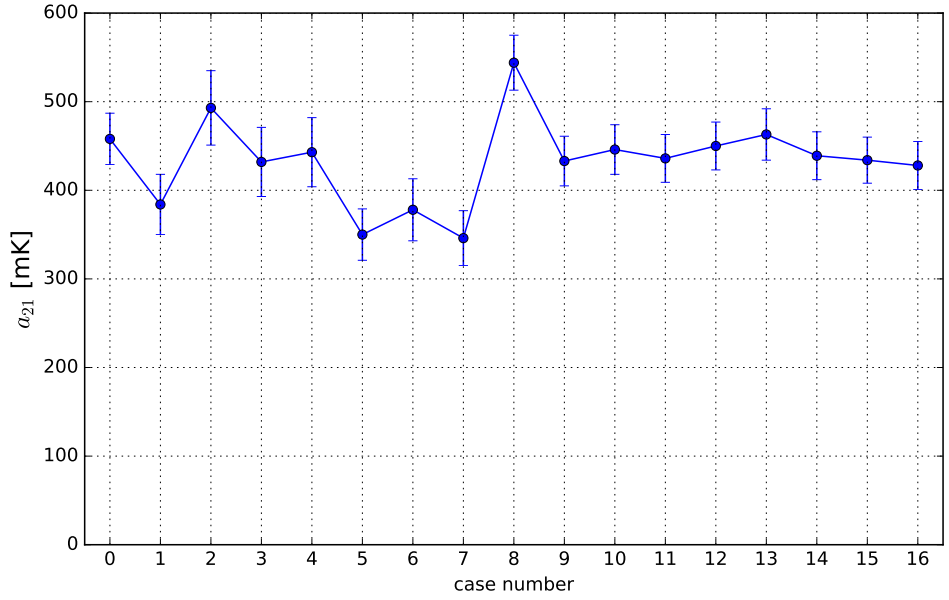

Figure 1: Signature amplitude for the conditions and cases of Table 1.

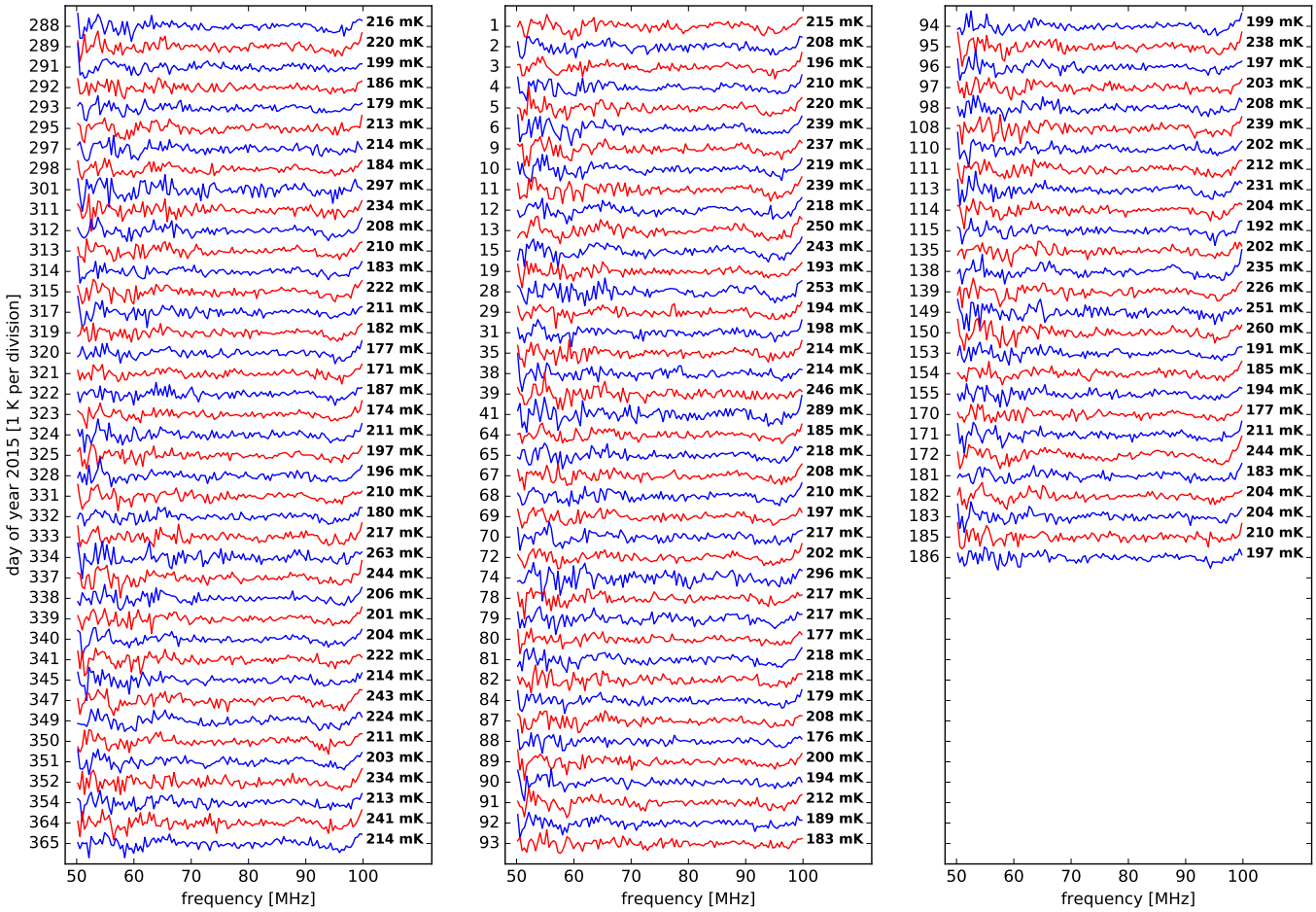

Figure 2: Daily residuals to 7-term polynomial over 50-100 MHz, for all days considered. The GHA range is 0-24 hr.

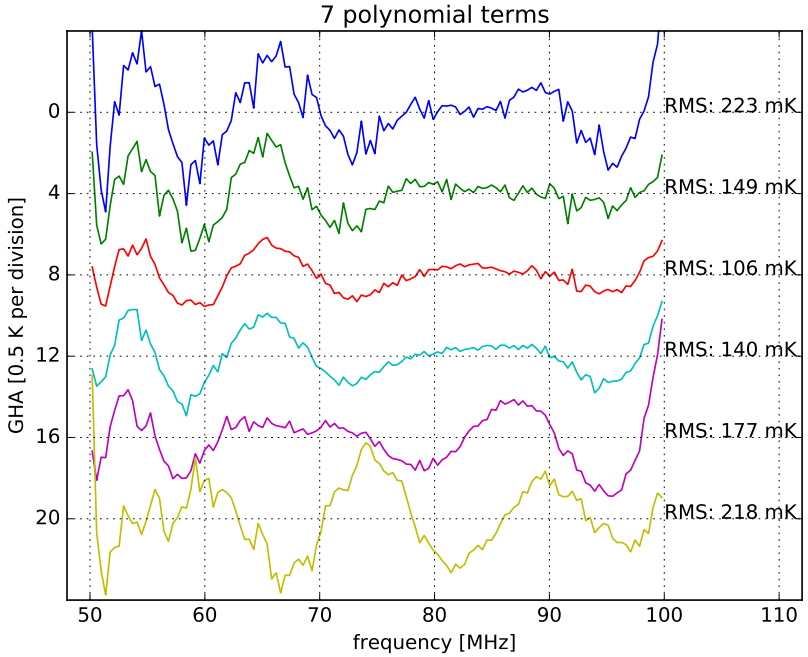

Figure 3: Residuals for 4-hr GHA averages, to 7-term polynomial over 50-100 MHz.

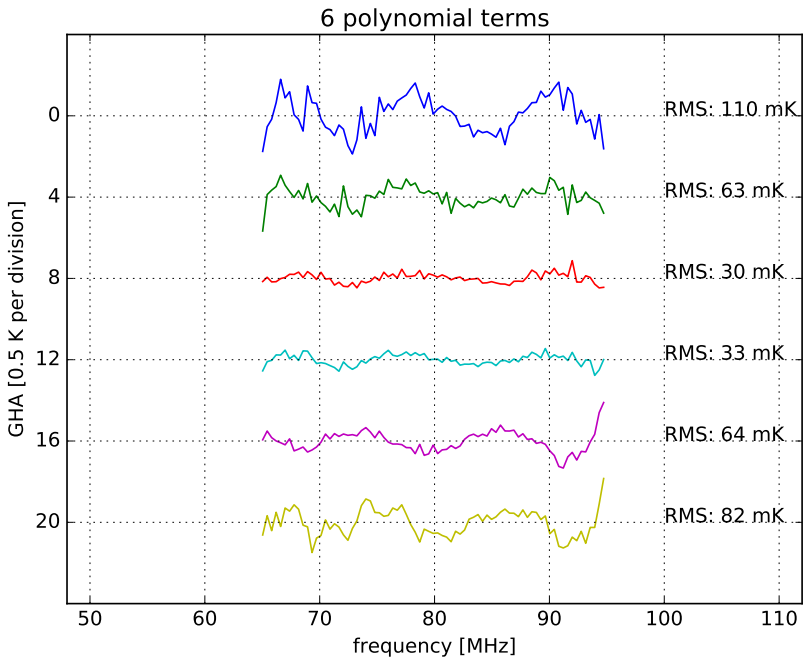

Figure 4: Residuals for 4-hr GHA averages, to 6-term polynomial over 65-95 MHz.

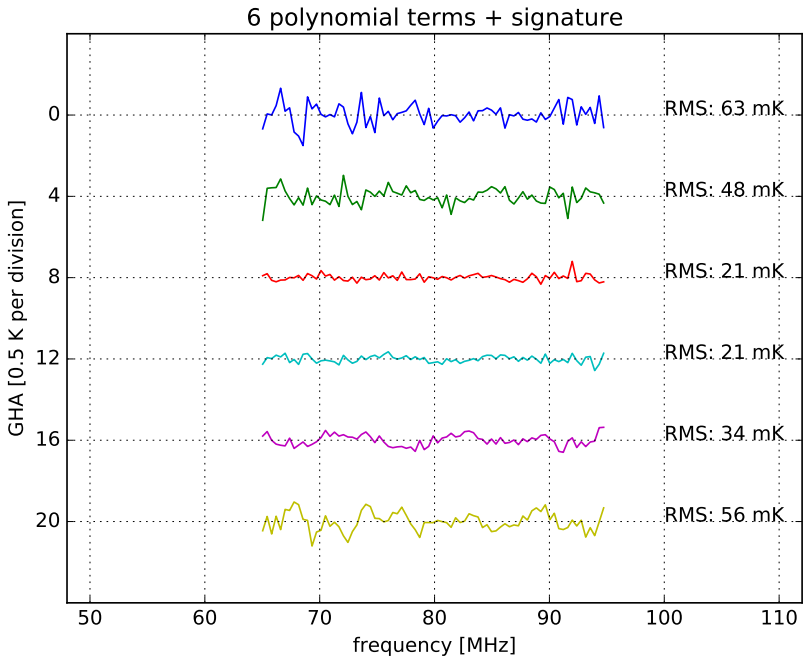

Figure 5: Residuals for 4-hr GHA averages, to 6-term polynomial plus 21-cm signature, over 65-95 MHz. Between 0 and 12 GHA, the signature center frequency was fixed at 78.5 MHz. At 16 and 20 GHA, the frequency was fixed at 75 MHz due to the different structure in the residuals.

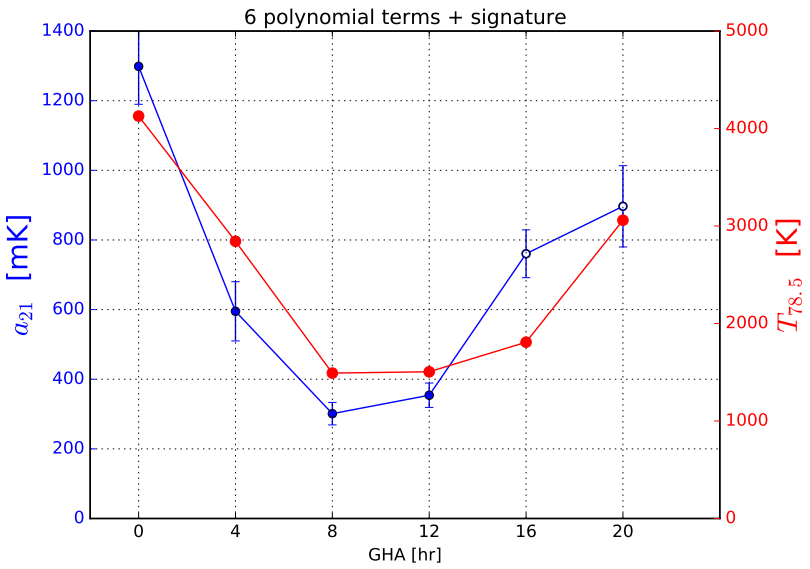

Figure 6: Amplitude of 21-cm signature as a function of GHA, in parallel to the total sky temperature at 78.5 MHz. Between 0 and 12 GHA, the signature center frequency was fixed at 78.5 MHz. At 16 and 20 GHA (circles with white filling), the frequency was fixed at 75 MHz due to the different structure in the residuals.

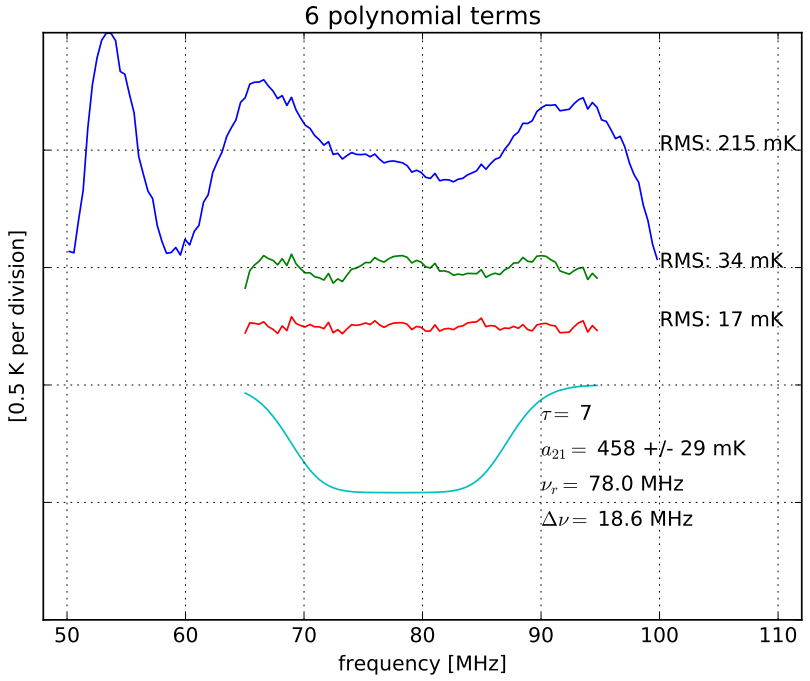

Figure 7: Residuals for nominal average over 0-16 GHA, to 1) 6-term polynomial over 50-100 MHz (blue); 2) 6-term polynomial over 65-95 MHz (green); 3) 6-term polynomial plus 21-cm signature over 65-95 MHz (red). Also shown (cyan) is the best fit 21-cm signature over 65-95 MHz.

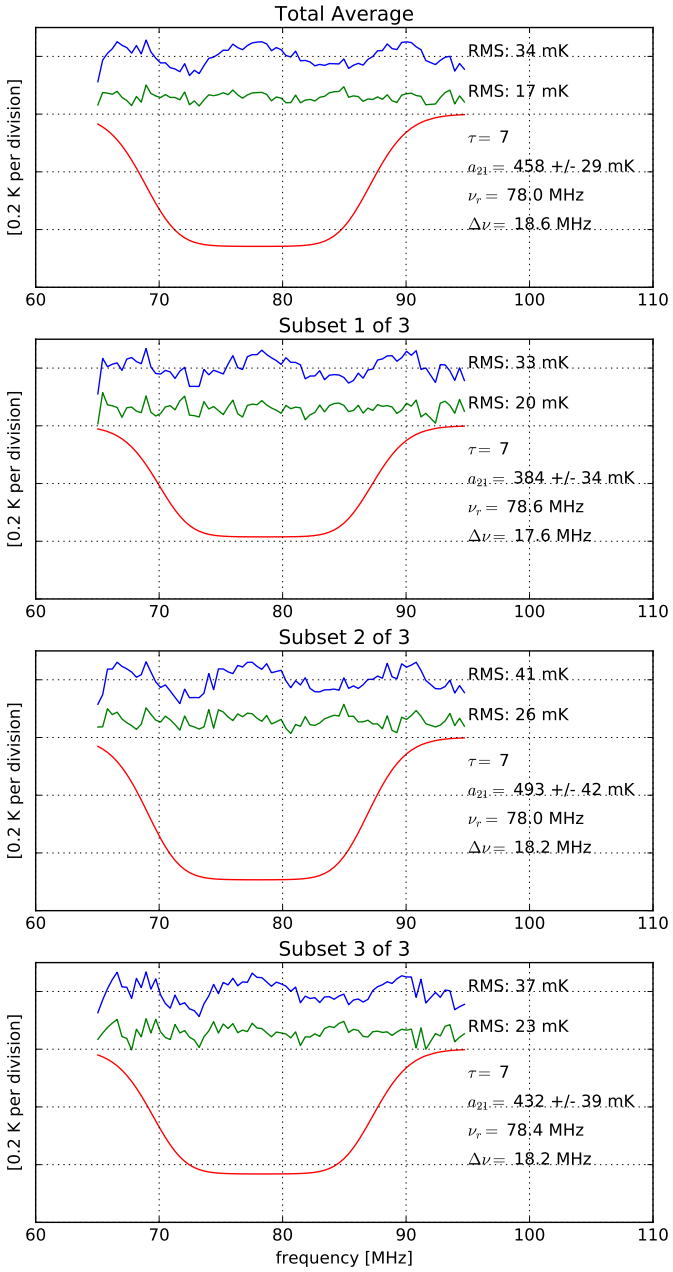

Figure 8: Residuals and 21-cm signature for three different averages of consecutive subsets of data. Each subset contains one third of the total data. Top panel is the nominal case.

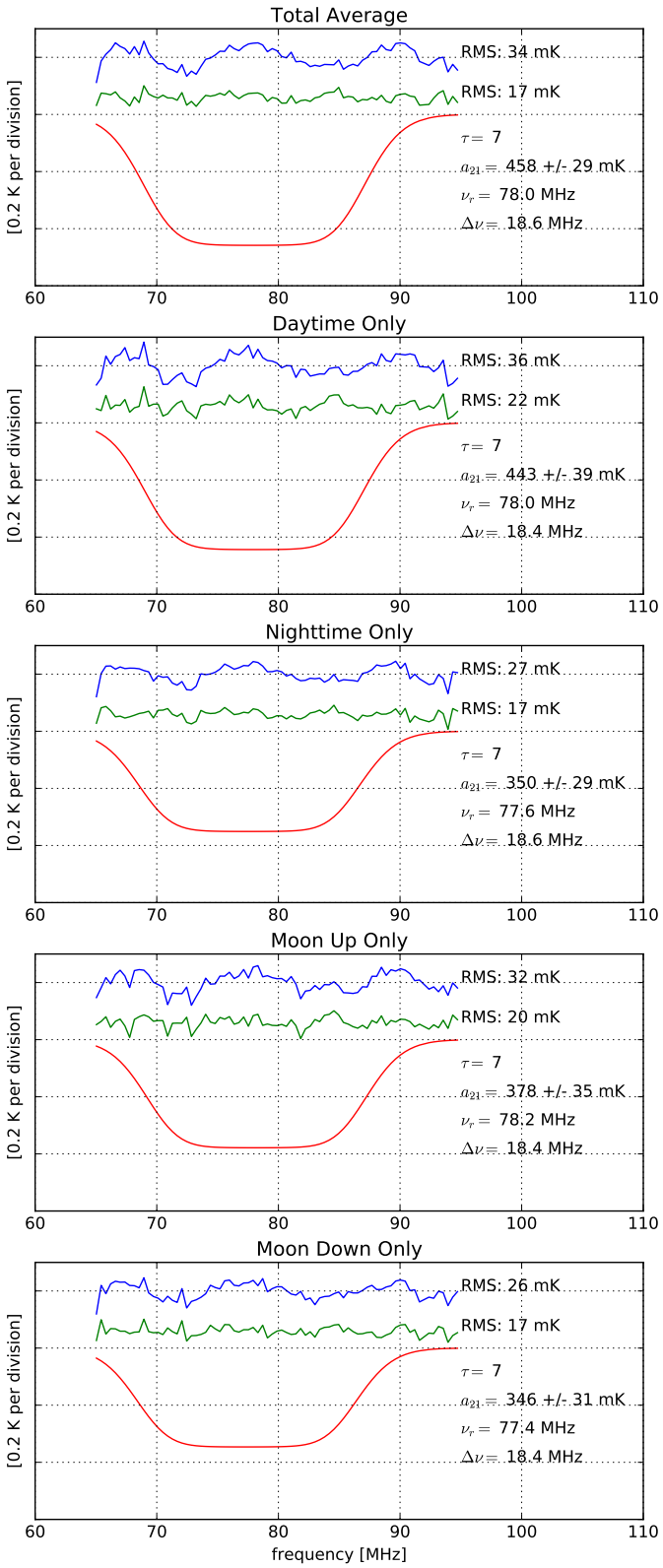

Figure 9: Residuals and 21-cm signature for four different averages: 1) daytime only ($EL_{sun} \geq 0°$), 2) nightime only ($EL_{sun} < 0°$), 3) Moon up only ($EL_{moon} \geq 0°$), 4) Moon down only ($EL_{moon} < 0°$). Top panel is the nominal case.

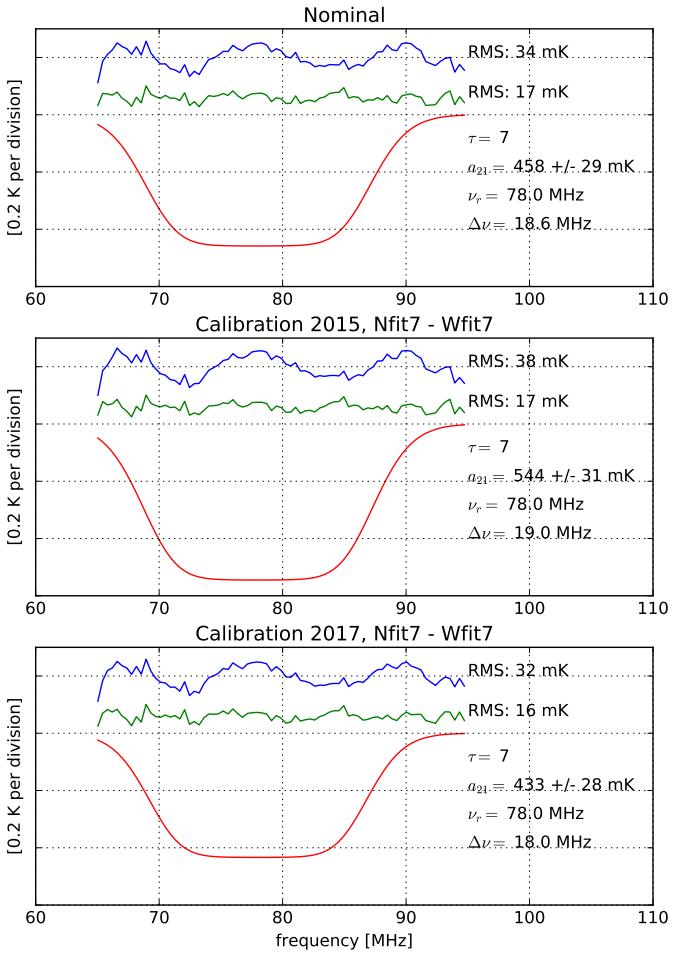

Figure 10: Residuals and 21-cm signature for two alternative receiver calibrations: 1) cal2015, Nfit=7, Wfit=7, and 2) cal2017, Nfit=7, Wfit=7. Top panel is the nominal case.

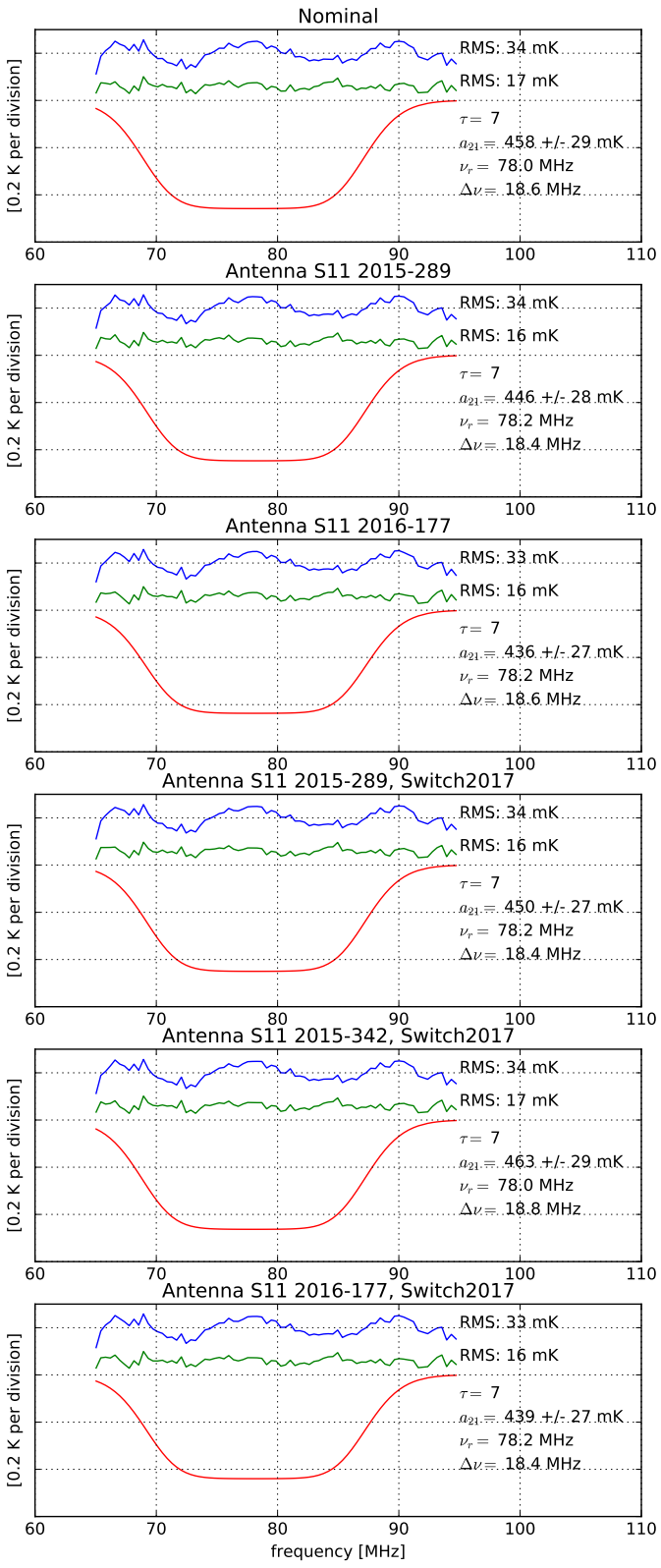

Figure 11: Residuals and 21-cm signature for five alternative antenna S11: 1) 2015-289 (2015 switch parameters), 2) 2016-177 (2015 switch parameters), 3) 2015-289 (2017 switch parameters), 4) 2015-342 (2017 switch parameters), 5) 2016-177 (2017 switch parameters). Top panel is the nominal case.

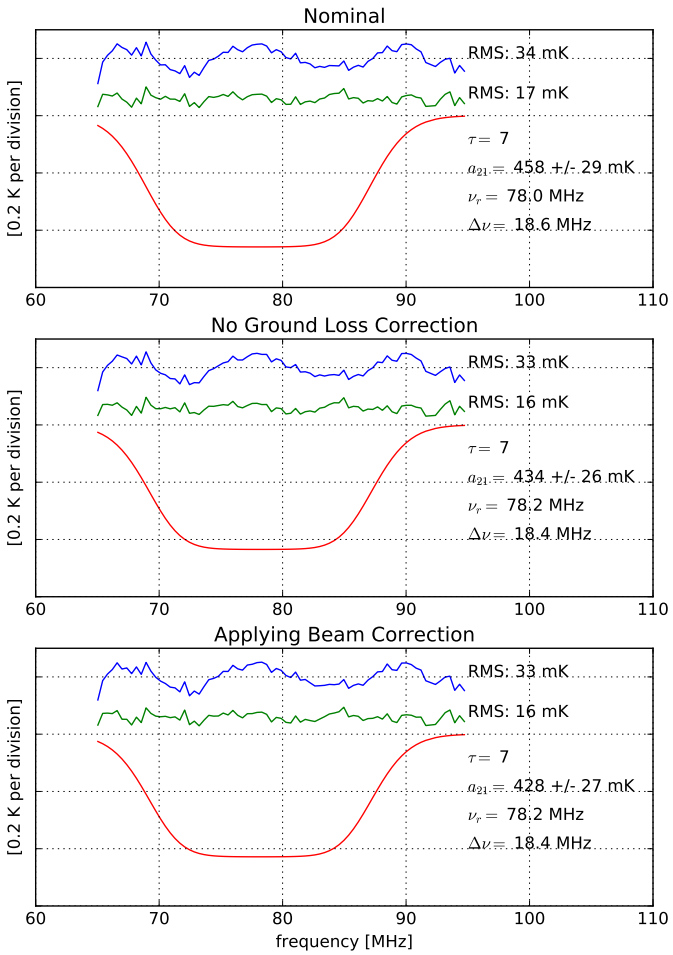

Figure 12: Residuals and 21-cm signature for two alternative corrections: 1) applying no ground loss correction, and 2) applying beam correction, using beam file *oldniv* rotated to AZ $= -7°$, and Haslam sky map scaled to 76 MHz using $\beta = -2.5$. Top panel is the nominal case.