EDGES MEMO #182

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To: EDGES Group
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Subject: EDGES-2 error budget update #2

A] Simulations

Earlier EDGES-2 error budgets are in memos 136 and 156. In this update only the largest sources of error are considered using simulations while other sources of error like comparing results of different antenna S11 measurements are obtained using actual data. Table 1 shows the results for low and high band using frequency ranges of 51-95 MHz and 102 – 190 MHz. The first column in each section is the rms residual with 1 term removed. The second column is with 5 terms removed. These terms are scale, spectral index, gamma, ionospheric absorption and ionospheric emission. All the simulations are for times of minimum signal when the Galactic center is below the horizon.

Error source magnitude	Low band (mk)		High band (mk)		Note
ANT |S11| 10^{-4}	21	1.0	9	1.3	1
ANT S11 10^{-4}	6	1.3	6	2.5	2
LNA |S11| 10^{-4}	55	3	9	1.7	
LNA S11 10^{-4}	72	6	10	3.1	
Balun and ground loss	1979	22	828	33	3
Ground loss	3031	10	57	0.2	4
S11 fit change	140	102	168	100	5
S11 measure change	349	4	99	33	6
S11 cal load offset	164	18	46	5	7

Table 1 Simulations of major sources of error.

Table notes:
1] Magnitude change is in units of S11. The value of 10^{-4} is taken as best that can be expected for a VNA. 10^{-4} corresponds to 0.005 at -15 dB and 0.03 at -30 dB. The rms values are linear so that an error of 2×10^{-4} S11 units doubles the residuals in table 1.
2] Magnitude change is in units of S11. The value of 10^{-4} change in S11 in a direction that changes the phase. 10^{-4} corresponds to 0.2 degrees at -15 dB and 1 degree at -`30 dB.
3} see memos 148 for high band at 181 for low band
4] see memos 88 and 179

5] The result of changing the number of polynomial terms in the fit to the blade antenna S11 from 7 to 9 terms.
6] The result of changing the measured S11 from day 2015_289 to 2015_342 for low band and from 2015_203 to 2015_262 for high band.
7] Simulation of the effect of not using a 33 ps offset in the model of an Agilent calibration load with 2.5 Gohms/s loss. See memos 133 and 181.

B] Tests with data

Tests were made on the low band data from 2015_286 to 2015_345 and on the high band from 2015_204 to 2015_327 using only nighttime data with the Galactic center below the horizon. The first test was made to remove the balun correction as it appears from the simulations to have a large effect on the rms fit with 5 terms removed. Removing the balun and ground correction has about the expected effect for the high band data but owing to the large rms of the low band data it is not clear if the balun correction is having the desired effect. The second test was to test the effect of changing the fitting of the S11 data. In the low band the lowest rms was obtained with a 9 term polynomial. In the high band the best fit was with a 8 term polynomial. The changes in the rms fits to the data confirm that this is a critical source of error. In both the high and low bands some smoothing of the S11 over the unsmoothed 27 term fit reduced the rms.

Test	Band	Freq. range	# terms	Initial rms (mK)	Final rms (mK)	Comments
Remove balun correction	Low	51-95	5	148	130	
Remove balun correction	Low	61-95	5	45	45	
Difference	“	51-95	5	38		Days 286-317 315-348
7 term fits to S11	“	51-95	5	235		
8 term fit to S11	“	51-95	5	163		
9 term fit to S11	“	51-95	5	148		
27 term fit to S11	“	51-95	5	148		
Remove balun correction	High	102-190	5	16	44	Difference
Difference		102-190	5	23		Days 204-267 268-327
7 term fit to S11	“	102-190	5	37		
8 term fit to S11	“	102-190	5	16		
9 term fit to S11	“	102-190	5	31		
27 term fit to S11	“	102-190	5	29		

Table 2. Tests using the high and low band data from the blade antennas. All the data was for Galactic hour angle 10±2 hours taken at night with the Sun more than 10 degrees below the horizon.

To test the consistency of the data a test was made of the difference of the first and second half of the data by date. This test shows that the low band is more consistent than the high band data. In the case of the low band the difference is flat within the expected noise whereas the high band data shows a signature which appears consistent with a change in S11 due to moisture as discussed in memo 178. An example of the effect of on days which are expected to have condensation of the antenna are shown in Figures 1 and 2.

Summary

The major sources of remaining error in the EDGES-2 system appear to be as follows:

a) A changing calibrated spectrum of the high band antenna which has the signature consistent with moisture condensation on the topcap.
b) Noise on the measured S11 which needs some degree of smoothing.
c) Large rms with 5 terms removed at the low end of the low band which is most likely due to the limited size of the ground plane.

These error sources might be modeled and reduced using Galaxy up data. Careful filtering out of days with higher rms fit is also needed to get the best results.

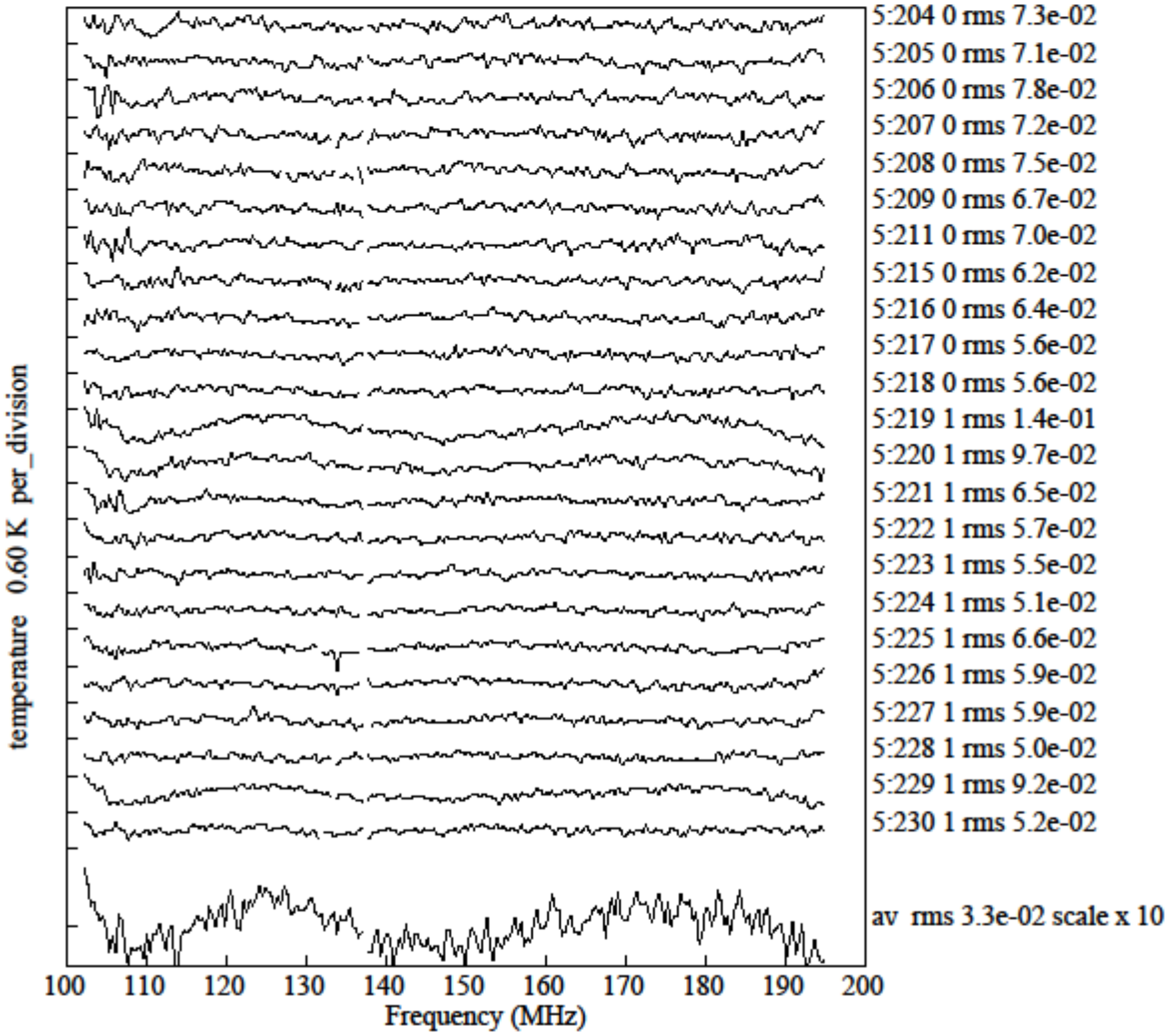

Figure 1. Average 5 terms removed of the difference between days 219_230 and days 204_218

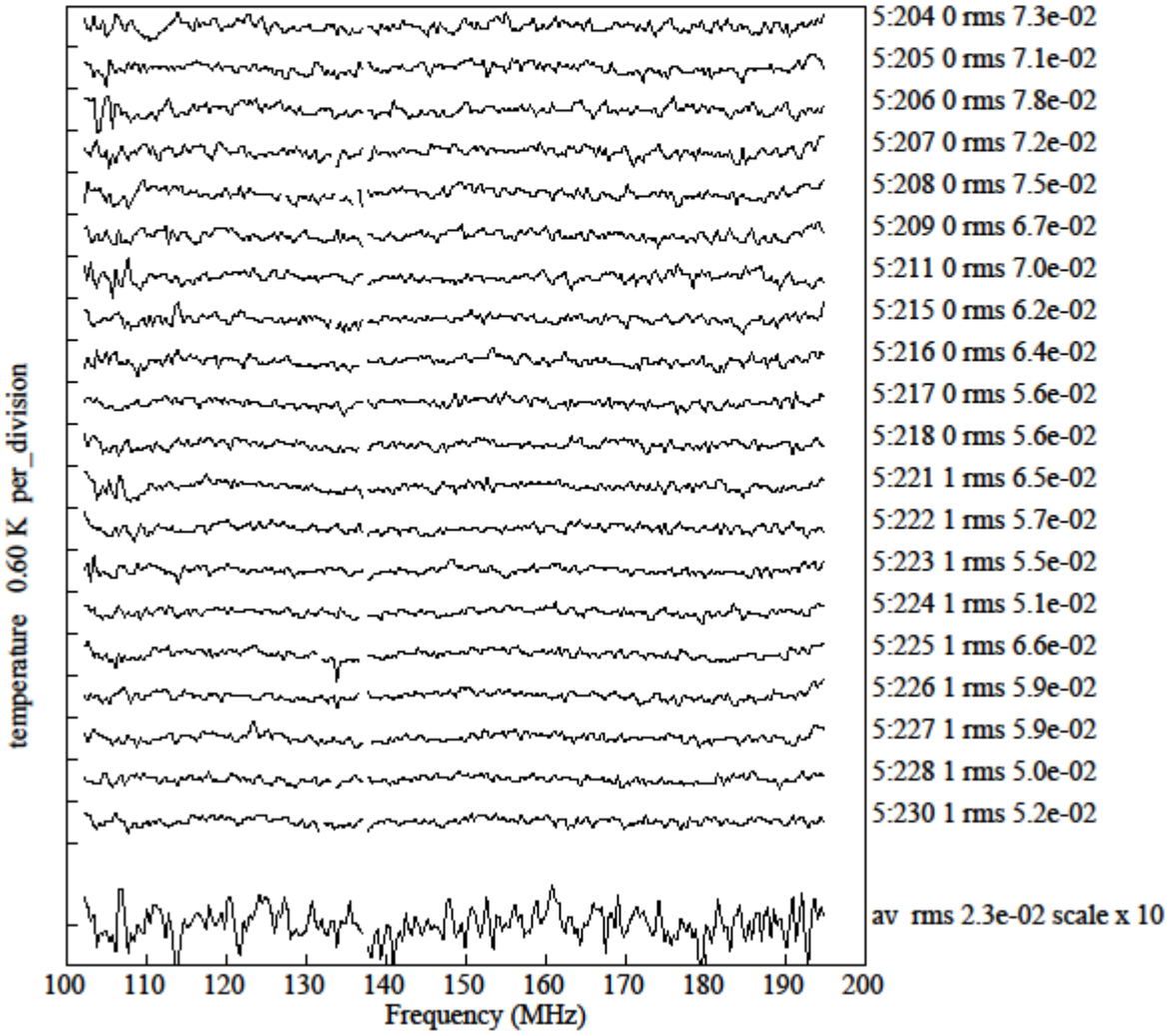

Figure 2. Average difference after removing days 219, 220 and 229. These days most likely had condensation on the antenna.