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September 16, 2014

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To: EDGES Group

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Subject: EDGES2 error budget

This memo provides the current EDGES-2 error budget. It will be updated periodically as studies of the error sources are completed.

The table of error sources lists the following:

Error source	the origin of the error
Magnitude	the full magnitude followed by
	the percentage remaining after subtraction of a model
Structure	F= fine structure, M = Medium, S= Smooth
Low Band	The effect of the error source in the low band 50-100 MHz. The bias in EoR using 8 (see memo 118) basis functions to remove error plus a basis function to model EoR of 10 MHz full width at 75 MHz and 20 MHz width at 150 MHz at low and high band respectively. The bias given in the column following the total effect of the errors source is used to quantify the effect on the EoR determination.
High Band	- 100-200 MHz. A second column following the rms is the EoR for 40 MHz width.
Note	Reference note number
Memo	relevant memo number

Error sources which reduced by more than a factor of 10 when the Galaxy up/down ratio is (see memo 145) used are: VNA S11amp, VNA S11 phase, Calibration.

Error Source	Magnitude		Structure	Low Band [mK]		High band [mK]			Note	Memo
VNA S11 amp	0.01 dB		F	125	23(7)	22	12		1, 8	134
VNA S11 phase	0.1°		F	60(20)	18(9)	10	3		10	
Antenna loss	0.004 dB	20%	S	60	0	60	0	2		98
Balun loss	0.01 dB	10%	F	60	12	60	1	8		98
Ground noise	0.4%		S	1200	0	1200	2	20	11	88
Ground plane loss	0.001 dB		S	60	0	60	0		2	
Calibration	1 K		M	3000	50(10)	600	30		5, 9	129
Ionosphere absorption	1dB@18 MHz		S	22000		1000				79
Ionosphere emission	1dB@18 MHz		S	12000		3000				101
Atmosphere absorption	0.0016 dB		S	100	0	100	0		3	106
Foreground	$\gamma = 0.1$		S	17000		3000				101
Jupiter	10^5J		F	1	0		0		4	2
Beam variation	1.5 dB		S	56000	8	10000	2		6	118
Horizon	7°		S	2000		300			7	118

Table 1. EDGES-2 Error Budget Table

Comments on Table: The largest error sources like the ionosphere are expected to be smooth and follow a power law which is well modeled by the 8 basis functions. The errors with fine frequency structure are difficult to model and when modeled tend to be correlated with an EoR signature. Not shown are the large effects on the spectrum are produced by RFI via reflections from meteors, aircraft and the moon as well as occasional strong over the horizon propagation. In addition solar emission often dominates EoR. Assumes observations are made at minimum ionosphere between midnight and sunrise and when the moon is below the horizon.

Notes:

1] The numbers in parentheses in the low band are for 10 dB attenuation between the antenna and 3-position switch.
2] For $8\lambda \times 8\lambda$ ground plane
3] Oxygen attenuation 2×10^{-4} dB/km at 100 MHz.
4] Occasional bursts from Jupiter at about 10^{5}J at 16 MHz. Expected to be very weak above 40 MHz. See Zarka 2004. Synchrotron continuum DIM from Jupiter is 5J.
5] Assumes a 1K temperature difference between the electronics during observation and during calibration. Assumes no linear correction based on temperature.
6] Assumes 10% foreground excess at zenith
7] Assumes -25 dBi horizon response
8] The width of 20 MHz for the EoR signature in the high band combined with the 8 basis functions results in value of 3.6 for the square root of the normalized covariance for an estimated 10 sigma detection of a 20 mK signal in 2 weeks of 8 hours per day. A similar result is obtained for a 100 mK signal of 10 MHz width in the low band. Doubling the width of the EoR signature increases the square root of the covariance to about 25. The covariance is normalized to a value of one for a least square solution with a basis function for the scale of a sky model with an assumed spectral index of 2.5 plus a basis function for the model of the EoR signature.
9] In order to reduce the effects of noise in the S11 parameters a series is used to smooth the S11 data and the calibration results. See memo 129.
10] The fundamental limit to VNA accuracy is thought to be set by the ADC non linearity at the level of about 3×10^{-4} which sets the accuracy to about 5×10^{-5} linear units which corresponds to 0.003 dB at a reflection coefficient of -15 dB.
11] 5.35m × 5.35m + 2m × 5m mesh on each side.