EDGES MEMO #127

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

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Telephone: 781-981-5400
Fax: 781-981-0590

To: EDGES Group

From: Alan E.E. Rogers

Subject: An examination of potential improvements

The following improvements to the EDGES instrument are examined:

1] Better LNA match

2] Larger antenna balun tubes

3] Alternate antenna panels

4] Better temperature control

These potential improvements are examined using simulation employing the 8 basis functions listed in memo 118 along with 3 additional basis functions to account for a constant magnitude and phase error in S11 as well as a basis function with the signature

$$\left(1-\left|\Gamma_a\right|^2\right)$$

Where $\left|\Gamma_a\right|$ is the magnitude of the antenna S11

Two measures of performance are examined:

1] Error in EoR signature determination for covariance matrix

2] Bias in EoR signature determination

Item 1 is expressed in 2 ways. The first is square root of the covariance normalized to one for solving for only a scale factor and the EoR signature which is assumed to be a Gaussian. The second is an estimate of the number of daily 8 hour observing sessions with 40% processing efficiency needed for a 10 sigma detection of an EoR signature of 20 mK in the high band and 100 mK in the low band.

1] An error of 0.01 dB in S11 combined with a slope of 0.006 dB across a 2:1 frequency range.

2] An error of 0.1 degrees in S11

3] 10% error in balun model

4] A change in the temperature of the electronics by 1K

Table 1 shows the results of simulations of effects of these error sources on the EoR estimate. The first 4 columns indicate the bias in EoR for the error sources 1 through 4 above. N is the number of parameters estimated. The column labeled “Err” is the normalized error from the covariance. The column labeled “days” is the estimated time for a 10 sigma detection of a EoR signature.

EoR bias (mK)				N	Err	Days	EoR (MHz)	LNA (dB)	Balun size	band
19	15	17	-52	9	2.9	8	20			H
-4	-1	-1	13	12	4.1	17	20			H
19	7	17	-35	9	2.9	8	20	-40		H
0	-1	-1	1	12	5.5	30	20	-40		H
19	15	7	-52	9	2.9	8	20		×2	H
-4	-1	-1	13	12	4.1	17	20			H
50	39	45	-133	9	7.5	40	30			H
-1	-12	-5	44	12	13.5	133	30			H
24	53	-1	98	8	2.0	10	10			L
21	5	6	52	12	2.6	18	10			L
55	10	17	-22	12	6.5	75	16			L
9	0	3	-13	12	5.7	58	16	-40		L
16	-1	5	-24	12	11.5	200	20	-40		L

Table 1. Simulations of the magnitude of systematic errors in EoR observations. Low band is 55 to 112 MHz and high band is 95 to 195 MHz. See text for a detailed description of the column.

These simulations were performed using the calibration data from EDGES2 electronics serial #2 (see memo 120) to generate a calibration data file which contains the LNA S11, calibration scale and offset, noise waves and calibration weight as described in memo 113. This calibration data file is then read along with the S11 data for the EDGES 2 antenna in a simulation program which generates the spectrum that is expected from the antenna based on a sky temperature of $300\left(f/150\right)^{-2.5}$. This spectrum along with the antenna S11 data is then fed back into the analysis program. When this spectrum and S11 data are returned without change the analysis program estimates a calibrated spectrum which agrees with the sky temperature to within a fraction of a millikelvin. The small deviations are the result of the arithmetic limits of the least squares fitting of the calibration parameters and antenna S11 data need to allow different frequency spacing for the calibration and antenna data. The results in table 1 are obtained by applying the previously listed errors to the data in the simulation programs. The effect of the change of temperature of the electronics is obtained by using the calibration data for 25 C for the simulation while the analysis program uses the calibration data obtained for 35 C. The results (in column 4) of the table are divided by 10 so that the bias in mK is per kelvin change in electronics temperature.

It is noted that of the 8 basis functions listed in memo 118 the functions 5 and 6 used for the foreground are very highly correlated with a combination of the other functions. Removing functions 5 and 6 so that the values of N in table of 9 and 12 becomes 7 and 10 makes very little difference to the bias numbers, normalized error and days. Removal of any of the other basis functions results in a significant of the EoR bias values.

From the results in Table 1 is clear that:

1] Increasing the balun tube diameter reduces the bias due to balun model error by a factor of 2.

2] A LNA with -40 dB S11 only results in a significant improvement in the low band. In the low band this improvement can also be achieved using a 10 dB attenuator.

3] Reaching a EoR width of more than 40 MHz in the high band and more than 18 MHz in the low band is problematic.

Increasing the diameter of the balun tubes from 0.5" to 1.0" for the high band is a clear improvement. It reduces the EoR bias due to a 10% error in the model by a factor of 2. While the change may require a slight retuning of the tuner on the balun simulations show the change will have little effect on the S11.

A preliminary study of alternate antenna designs show that it is unlikely a circular planar dipole will achieve a S11 below -12 dB over a 1.8:1 frequency range. The problem is this dipole has impedance around 100 ohms and in addition interacts more strongly with the ground plane than the Fourpoint so that the S11, is expected to be worse than the S11 measurements of a dipole without ground plane published by Schantz ("Planar Elliptical Element Ultra-wideband Dipole Antennas". URSI IEEE 2002).