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December 1, 2014

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To: EDGES Group

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Subject: Frequency dependence of the EDGES antenna beam

Lowering the antenna panels to reduce the flattening of the beam above 180 MHz degrades the S11 but should reduce the frequency dependence of the beam. The degraded S11 below 130 MHz might be compensated by adding wire tips to the antenna (see memo #13) or by a small increase in the diagonal length of the panels.

Lowering the antenna panels was tested using FEKO models. The following table summarizes the results. While lowering the panels does help maintain a constant gain at the zenith no improvement could be made in the residuals to a 5 term fit to effect beamshift with frequency.
The 5 fitted function were:

- Scale of spectral index of 2.5
- Spectral_index derivative
- Ionospheric absorption
- Ionospheric emission
- Constant

Lowering the panels makes it more difficult to achieve a S11 better than -15 dB over a wide frequency range. To help improve the S11 tests were made by adding wire tips to the panels, tilting the panels up and increasing the diagonal length of the panels. In all cases the residuals to a 5 parameter fit were degraded. The effect of the tilting up the panels by 15° resulted in a -9 dBi gain at the horizon and a substantial increase in residuals compared with a planar design for the period when the Galaxy is down. The optimum tuning obtained with FEKO for tip capacitance of 1.4 pf was 5.8 pf at the topcap and 3.4 *pf* for a tuner at 0.34 m above the ground plane. The table also lists the results for a theoretical thin dipole which is ½ wave long and ¼ wave above the ground plane at 150 MHz. In addition a “blade” antenna is listed. This antenna is similar to a Fourpoint with only 2 panels for a single polarization it has similar residuals but has an S11 no better than -10 dB from 100 to 190 MHz after optimization. This antenna may warrant further study.

The Fourpoint with 3 *pf* tip capacitance results in more structure in the frequency dependence of the beam even though no asymmetry was present in tip capacitance in this FEKO model. All these results assume a constant spectral index for the sky. The spectral index model used in memo #7 was tested and found to have only small changes in the rms values given in table 1.

	Residual to 5 term fit min-max (mK)			
Model	100-190 MHz		110-180 MHZ	
	8-16 GHA	20-4 GHA	8-16 GHA	20-4 GHA
Fourpoint 3*pf*	4-16	140		
Fourpoint 1.4 pf	4-10	65	1-3	18
Tilted up 15°	36-55	70		
Added Tips 0.1	2-14	160		
Reduced Height	3-12	110		
Dipole	1-3	8	1	4
Blade	4-7	70		

Table 1 rms residuals to 5 term fit for scale, spectral index, ionospheric absorption, ionospheric emission and constant. Tests assumed a NS orientation at latitude -26.7°

Additional Comments:

1] Effect of antenna orientation
NS is best. Typically other directions increase the rms in the 8-16 GHz range by a factor of 2.

2] Effect of latitude
27S is a little better than 45 N

3] Galaxy up/down method
The signal ratio "Galaxy up" to "Galaxy down" is about 3.1 at 27 S compared with only about 1.8 at 45N favoring a Southern side for this method of analysis.

4] Further optimization of the Fourpoint parameters.
Using a multidimensional search the lowest value of the rms over the full range of GHA the optimum diagonal length and height were 0.645 and 0.515 compared with the values of 0.685 and 0.520. The slight preference for lower values of diagonal is marginally significant and goes in a direction which degrades the S11.

5] Alternate measure of antenna performance
An alternate measure is to consider the detectability of a Gaussian EoR signature of half power full width of 20 MHz using a 6 function fit where the 6th function is the EoR signature expressed as an SNR determined from the ratio of the expected amplitude of 20 mK to the noise determined from

Noise = $(rms^2 + bias^2)^{1/2}$

Where rms = rms fit to 6 functions
bias = value of signature

The following results (SNR 1)are the average for short integrations taken over the GHA range of 8-16, frequency range 120-170 MHz and EoR centered at 150 MHz.

	SNR1	SNR2	SNR3
Foupoint 3 *pf*	2	5	0.7
Fourpoint 1.4 *pf*	5	15	2
Tilted up 13°	1	1	0.5
Added tips	6	10	6
Reduced height	4	10	6
Dipole	40	100	35
Blade	7	50	25

Table 2 SNR for EoR signature measurement

Similar results (SNR 2) were obtained after adding an additional function, which represents curvature in the spectral index known as "gamma," for a 7 parameter fit. Also similar results are obtained moving the EoR signature from 110 to 180 MHz in the center of 70 MHz window. Unless an antenna can be found whose beam shift is a smooth as the dipole these results suggest that beam correction based on an EM model will be needed to detect or set limits on a high band EoR signature wider than 20 MHz. There may be an advantage in averaging data and beamcorrections over 8 hours as to some extent the beam corrections average out. These results are shown in the last column are for an EoR width of 30 MHz using a frequency range of 100-190 MHz and a 7 parameter fit.