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To: EDGES Group

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Subject: Sensitivity of beam chromaticity to antenna azimuth

The antenna on its ground plane has fine structure in the beam on the scale of λ/D where D is the diameter of the ground plane which is about 8 degrees at 70 MHz for the 30x30m ground plane. The chromaticity from the convolution of the beam with the sky map can change with angle on a scale of the beam or sky map resolution whichever is the larger.

data	azimuth	freq MHz	amplitude	width	rms1 mK	rms2 mK	tau	range MHz
Low1-H2	354	78.1	0.55	18.8	85.5	19.1	7	53-99
Low1-H2	0	78.1	0.65	19.4	92.3	23.3	6	53-99
simulated	354	78.1	0.50	19.0	74.7	0.0	7	53-99
simulated	0	78.1	0.58	19.3	84.2	8.8	7	53-99

Table 1. Grid search for absorption parameters with correct antenna azimuth 384 degrees and results with azimuth 0 degrees which is 6 degrees above the true azimuth.

The rms1 is the rms residual using 5-physical terms for foreground and rms2 is the rms after adding a grid search for the best fit feature. There is a significant change of the best fit absorption amplitude of 0.1 K and 0.08 K respectively for low1 data and simulated data respectively. The data and simulations cover a range of 12 hrs GHA centered at 12 hours. This change in 6 degrees is not surprising as the Haslam sky map used in the convolution has a resolution of 5 degrees.

The azimuth offsets in table 2 show a minimum absorption amplitude at 80 degrees offset. The beam used for the data and the first set of simulations is one using FEKO with automatic meshing for the 30x30m ground plane used for the H2 data in the Nature paper. This beam shows a little asymmetry while “beam2” which used fixed meshing in FEKO shows very little difference between 0 and 180 degrees offset. The last two entries in table 2 are using the low2 antenna on an infinite PEC ground plane. In this case the chromaticity is just from the antenna. The ground plane is the critical factor in achieving low beam chromaticity. However, while a large ground plane reduces the magnitude of the lack of smoothness in the beam a sky map with sufficient resolution is needed to correct the effects of the beam chromaticity on the global 21-cm absorption.

comments	azimuth	Freq MHz	amplitude	width	rms1 mK	rms2 mK	tau	range MHz
no offset	0	78.1	0.5	19.0	74.7	0.0	7	53-99
	10	78.1	0.38	19.0	56.6	8.6	7	53-99
min amp	80	78.9	0.22	18.3	38.3	38.3	7	53-99
	90	77.7	0.37	18.7	58.7	13.6	7	53-99
	170	78.1	0.31	18.3	50.3	7.3	7	53-99
symmetry	180	77.7	0.47	18.9	71.5	5.0	7	53-99
beam2	0	78.0	0.50	19.0	74.7	0.0	7	53-99
beam2	10	78.1	0.38	18.6	60.0	9.0	7	53-99
beam2	180	78.1	0.51	19.0	75.4	0.3	7	53-99
diff	0	77.4	0.52	19.8	73.2	12.8	7	53-99
PEC	0	78.1	0.50	19.0	74.7	0	7	53-99
PEC	10	78.1	0.47	19.0	70.2	4.2	7	53-99

Table 2. Grid search for absorption parameters using simulations with larger azimuth offsets

data	azimuth	freq	amp	width	rms1	rms2	tau		map
Low1-H2	354	78.1	0.52	19.1	79.7	22.7	7	53-99	Haslam plus Guzman
Low1-H2	0	78.1	0.55	19.2	83.5	24.4	7	53-99	Haslam plus Guzman
Low1-H2	354	78.2	0.49	19.2	75.2	24.2	7	53-99	Guzman
Low2 -H2	0	78.5	0.52	19.4	76.8	25.1	7	53-99	Guzman
simulated	354	78.1	0.50	19.0	74.8	0.0	7	53-99	Haslam plus Guzman
simulated	0	78.1	0.54	19.2	79.0	5.6	7	53-99	Haslam plus Guzman
simulated	354	78.1	0.50	19.0	74.8	0.0	7	53-99	Guzman
simulated	0	78.1	0.53	19.1	78.6	6.1	7	53-99	Guzman

Table 3. Same as in table 1 using Haslam map with spectral index from comparison of Guzman 45 MHz map with 408 MHz Haslam map and Guzman 45 MHz with constant spectral index of -2.5

The change of amplitude with an azimuth change of degrees is about 0.03 K which is less than with the Haslam as expected owing to the lower angular resolution of the Guzman 45 MHz map. In tables 1 and 3 the absorption flattening parameter is added to the grid search is added but with only the exception of the Low2 data using the Haslam map with 6 degrees azimuth offset, for which tau=6 gives the best fit, a value of tau=7 results in the best fit for tau in grid steps of one.

In summary the most accurate measurement of the global 21-cm absorption needs a large ground plane to minimize the magnitude of the departures from a perfectly smooth beam and a sky map with enough resolution to be able to accurately remove departures from smooth beam via the “chromaticity correction”.