EDGES MEMO #248

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To: EDGES Group

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Subject: Comparison of beam models

The importance of the effects of the frequency dependence of the beam was recognized and studied in 2006 (see memo 7) but what not well recognized until 2014 were the effects of the ground plane and the soil on the beam. It wasn't until 2016 that the lowband ground plane was extended using a design with perforated edges to reduce the reflections from the edges. Even with the extended ground plane the beam chromaticity is a limiting factor within about 4 hours of transit of the Galactic center. So that the use of Galaxy calibration to reduce the effects of systematics is limited by the need for an accurate EM model of the beam to reduce the other systematics like those introduced by S11 and calibration errors.

Until recently EM simulations have been limited to FEKO Method of Moments (MoM) using Green's Function (GF) to model an infinite lossy dielectric under the ground plane. The values of dielectric constant and conductivity found to minimize the residuals of lowband1 data with the original ground plane are

Dielectric constant 3.5

Conductivity 2e-2 S/m

Recently Nivedita Mahesh of ASU has run "test" versions of FEKO and HFSS model for comparison with the Haystack FEKO model of the original low band ground plane. Table 1 shows a comparison of these models made by using a model to generate a spectrum with one beam model convolved with the Haslam all-sky map for a range of GHA and analyzed by another model.

Models	65-95 MHz	55-99 MHz
F vs M	15	22
F vs H	37	116
M vs H	41	128
F vs N	120	520

Table 1. Average residuals 4 polynomial terms removed in mK for full range GHA in 2 hr steps. F = ASU FEKO, M = Haystack FEKO, H = ASU HFSS, N = no beam correction.

The differences between 2 independently set-up (i.e. independent choice of meshing parameters etc.) is very small. The difference between the FEKO models and the HFSS is larger but not large enough that a comparison using lowband data can be used to determine which is more accurate. Table 2 gives the comparison using lowband1 data taken with the original square ground plane approximately 10×10 m. The same letters indicate which beam model was used for beam correction.

Models	65-95	55-99
F	132	260
M	133	277
H	151	333
N	227	613

Table 2. Average residuals with 4 polynomials removed for lowband1 data using 10×10 m ground plane.

Figures 1 and 2 show the residuals with 4 terms removed for lowband1 data from 2015_284 to 2016_250 for which the ground plane was the original size of approximately 10×10 m. Figure 1 is with FEKO beam correction and Figure 2 is with no beam correction. For comparison Figures 3 and 4 show the lowband1 residuals with the extended ground plane with and without beam correction. The residuals with the extended ground plane clearly show the large reduction of the beam effects.

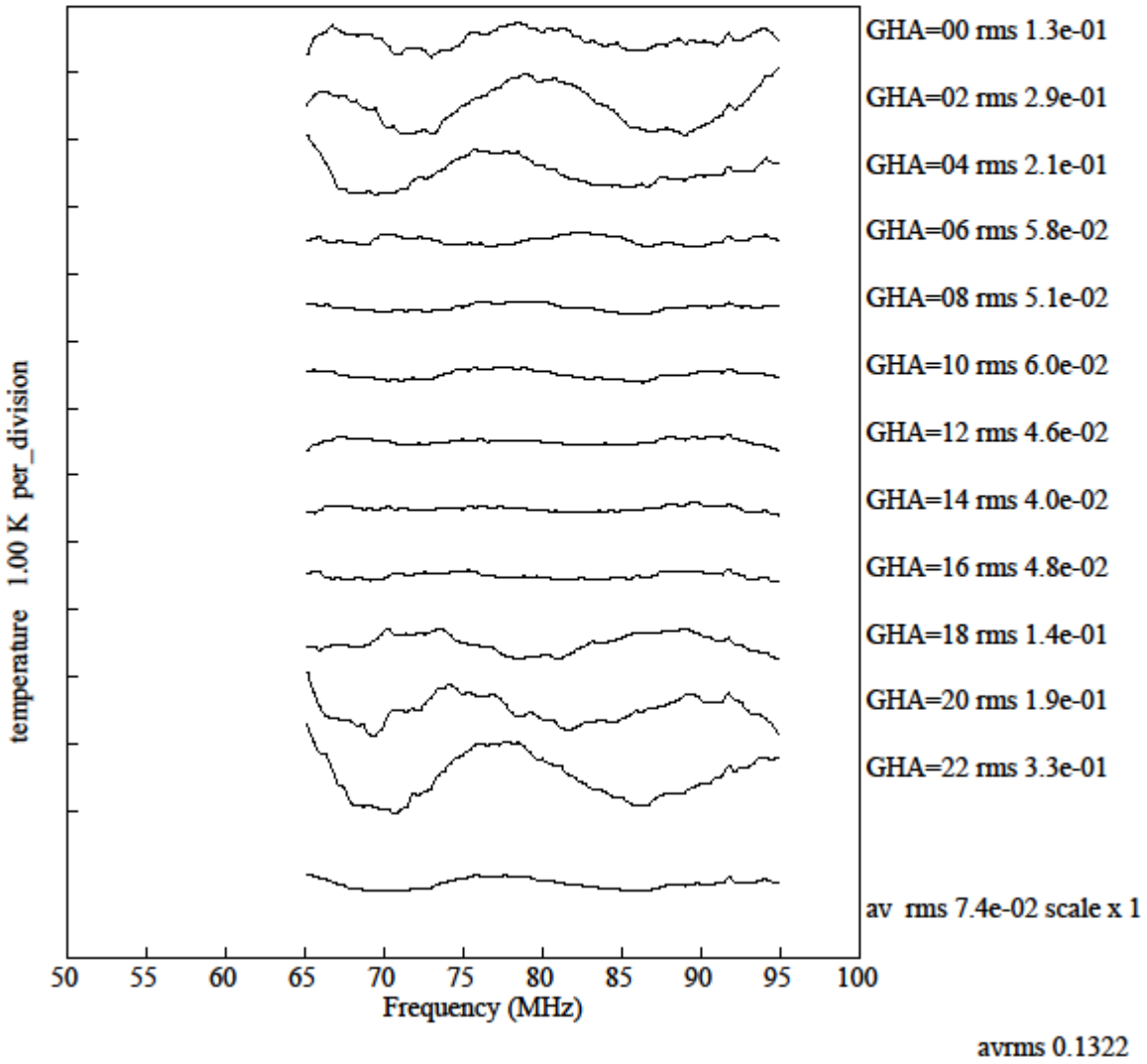

Figure 1. Residuals 4 polynomial terms removed for lowband1 data from 1015_284 to 2016_250 using FEKO model.

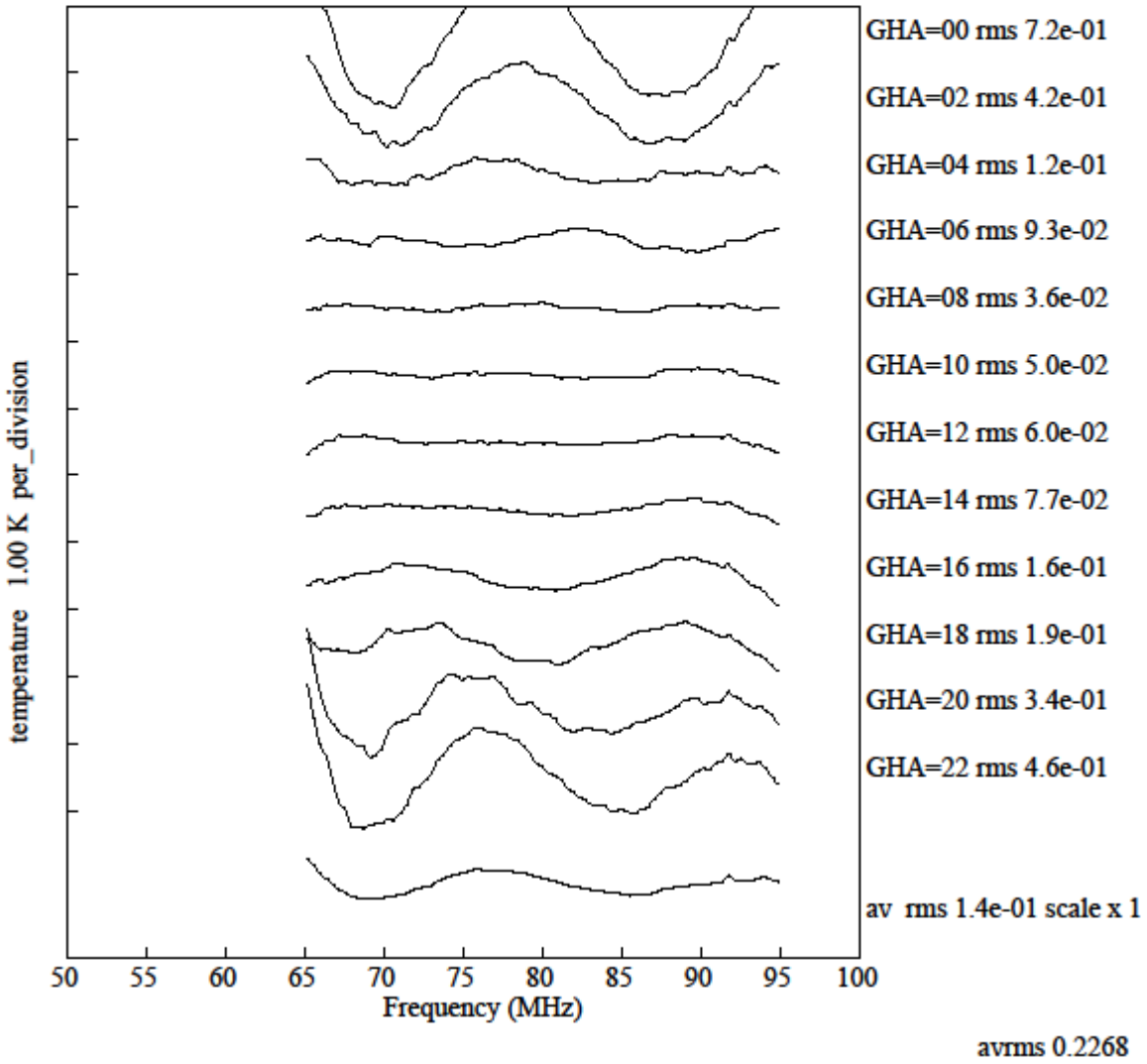

Figure 2. Without beam corrections.

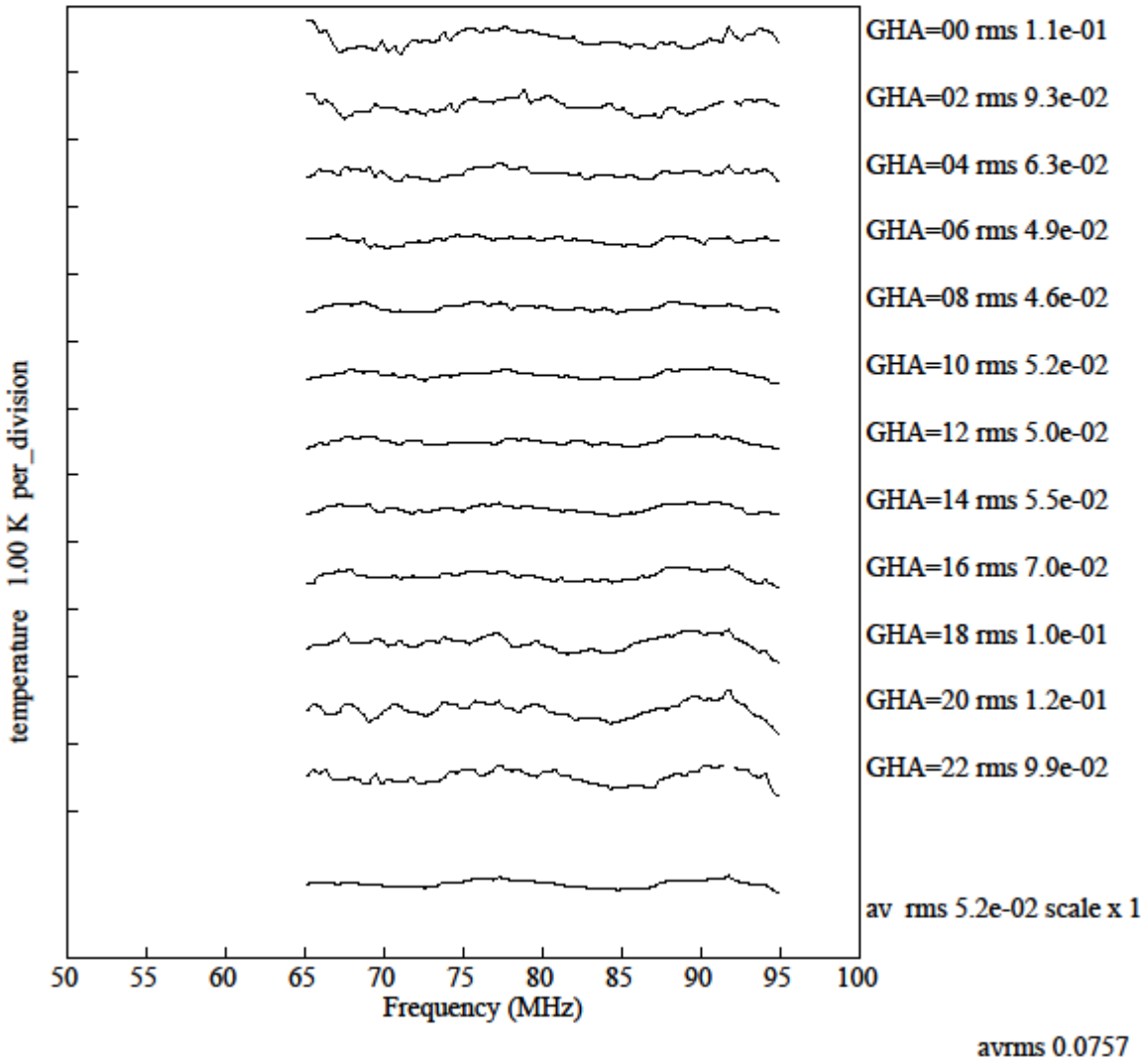

Figure 3. Residuals from lowband1 from 2016_251 to 2017_095 with 4 terms removed. Antenna on large ground plane. FEKO beam correction.

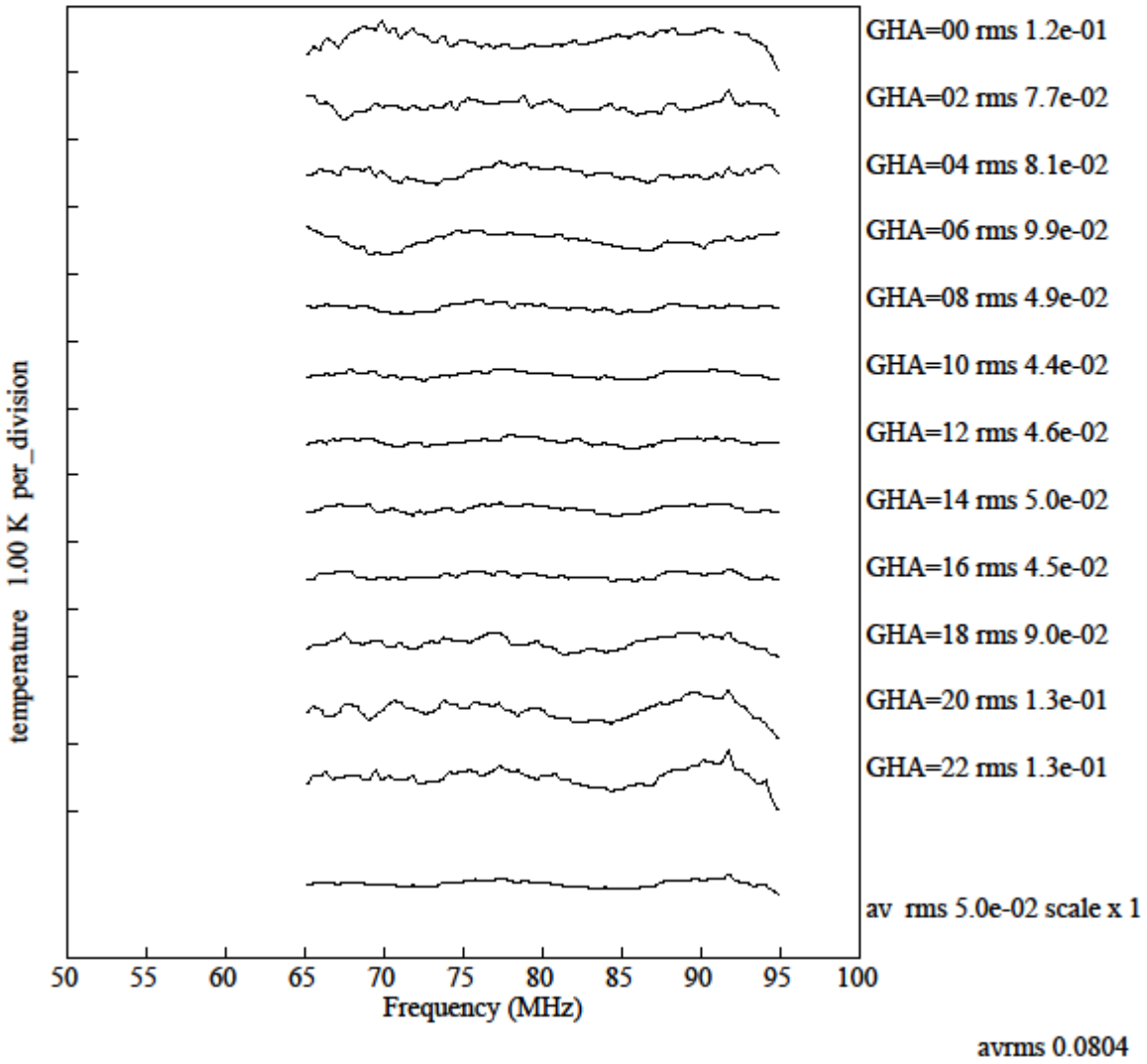

Figure 4. Lowband1 as in Figure 3 with large ground plane without beam correction.