EDGES MEMO #231

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To: EDGES Group

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Subject: Tests of the FEKO beam accuracy

Accurate beam correction is critical to EDGES. Memo #204 shows the simulated effects of beam correction using FEKO for different ground planes. Memo #206 shows the effects of ground plane model parameters. Memo 215 shows the effect of soil parameters in beam correction on the "Galaxy calibrated" low band data. While "Galaxy calibration" removes many systematic errors it doesn't remove errors in beam correct. Memo #222 shows that beam correction and balun loss has the largest effect on an absorption signature in the low band data. Memo 225 shows more simulations of changes in the model parameters of the beam correction. While the FEKO derived beam corrections lower the residuals in the calibrated spectra with physical or polynomial terms removed and reduce the change in parameters of a potential absorption signature we have no direct method of testing their accuracy.

In this memo we look more carefully at the effects of changes in the meshing used in FEKO and in addition look at the changes in beam for high and low band. Prior beam files have all been run for a frequency range of 80 to 200 MHz and these have been used to derive the beam corrections for both high and low band on the assumption that the beam only depends on the model in wavelengths.

The equivalence of an antenna beam at 80 to 200 MHz with an antenna and ground plane twice the size from 40 to 100 MHz should hold when skin effect losses are ignored. However, comparisons of the results from FEKO are found to be different. Figure 1 shows the differences in simulated data vs GHA with 4 polynomial terms removed. Figure 2 shows the differences when an infinite ground plane replaces the perforated ground plane (see memo 204) over soil with dielectric 3.5 and conductivity 2e-2.

While the differences are very small and completely negligible in the case of the infinite ground plane they are becoming significant when the Galaxy is up in the case of a real ground plane. The character of the differences suggest that they largely are due to the numerical errors in large matrix inversions etc.

Table 1 lists the rms values of the differences for 4-polynomial terms removed from 55 to 95 MHz using simulation at GHA=0 where the effects are the largest.

Change	rms (mK)
Change of frequency from high to low band	140
Change of frequency for antenna	18
Change of mesh on antenna from 0.0938 to 0.1 m	12
Change of mesh on antenna from 0.0938 to 0.08	24
Change of ground plane mesh from 0.5 to 0.4 m	40
Change of soil conductivity from 2e-2 to 1e-2	210
Change of soil dielectric from 3.5 to 4.5	96
Increase panel gap by factor of 2	15
Add rock ε =8.5 σ = 2e-2 0.2m below soil	91
Add rock ε =8.5 σ = 2e-2 0.4m below soil	54
Add rock ε =8.5 σ = 2e-2 1.0m below soil	7
Add wet soil ε = 8.5 σ = 2e-2 0.1 m thick over soil	170
Add wet soil ε = 8.5 σ = 2e-2 0.05 m thick over soil	130
Add wet soil ε = 8.5 σ = 2e-2 0.02 m thick over soil	110
Add wet soil ε = 8.5 σ = 2e-2 0.01 m thick over soil	68
Add wet soil ε = 8.5 σ = 2e-2 0.005 m thick over soil	20
Change rock at 0.2m below soil conductivity from 2e-2 to 1e-1	140

Table 1. Measure of the effect uncertainty of EM modeling accuracy and soil conditions.

In addition to showing the effect of a change in dielectric and conductivity in a single infinite layer below the ground plane the results of adding another infinite layer of finite thickness are given using multiple layer supported by FEKO. These results show that any rock under the soil which is less than 0.5m below the soil has a significant effect. In the event of rain the wet layer must be less than 1 cm thick to have a negligible effect. The reason only a very thin layer of wet soil has an effect is that it changes the propagation velocity of transmission line reflections from the edges of the ground plane.

Figure 3 shows the effect of a change in meshing as a function of Galactic Hour Angle (GHA).

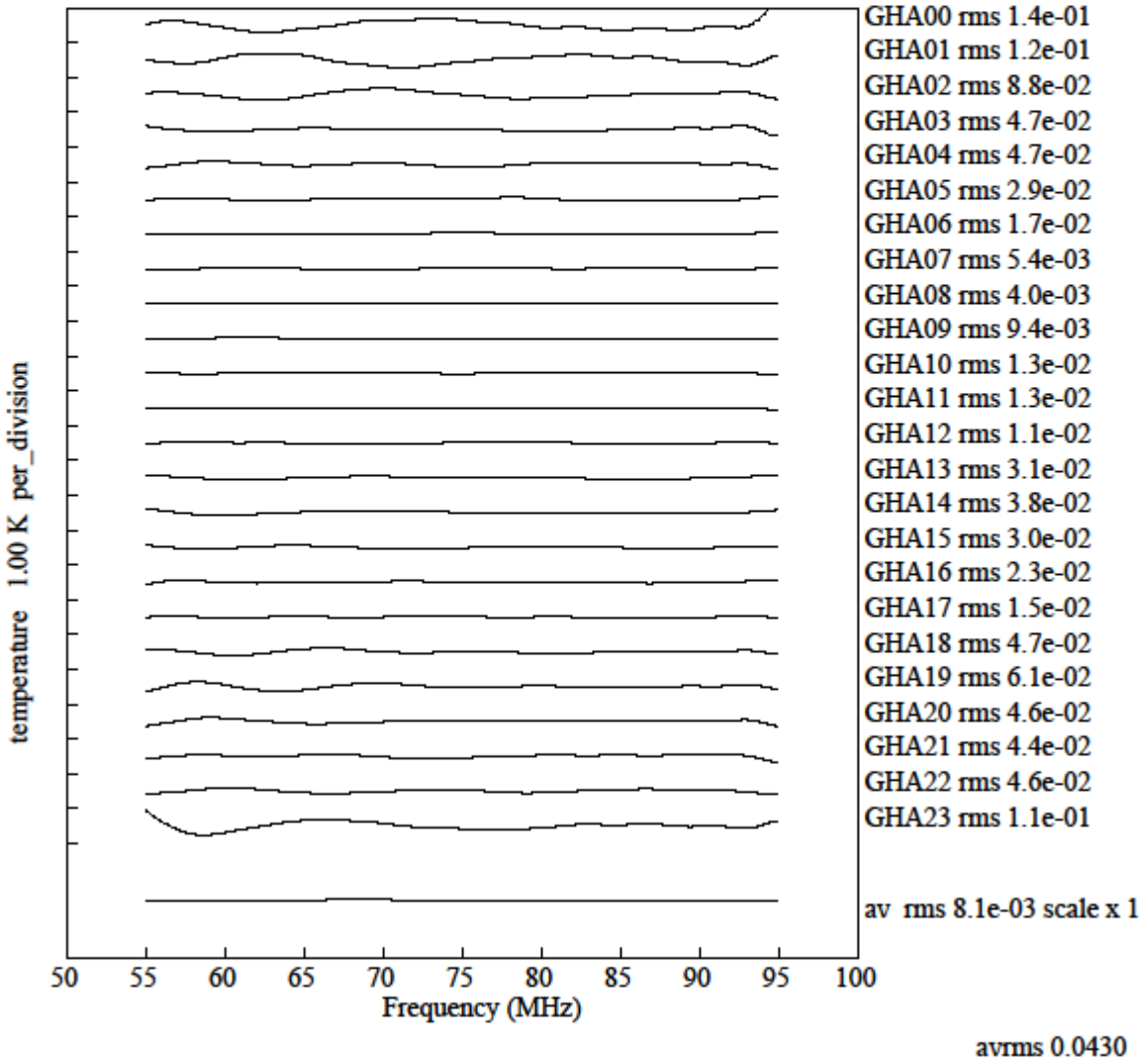

Figure 1. Differences in simulated spectra residuals with 4 polynomial terms removed.

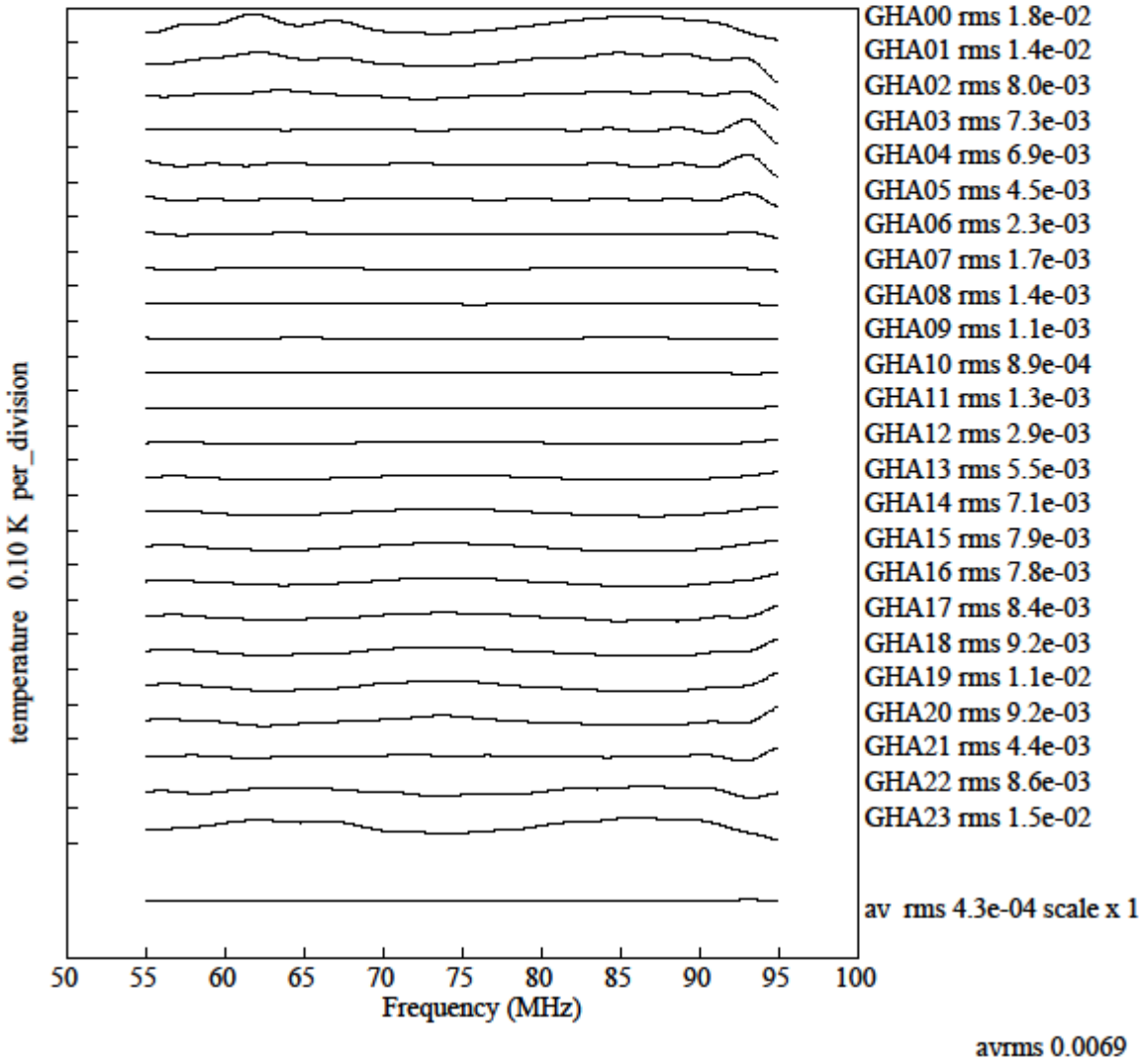

Figure 2. With infinite ground plane. Note scale change.

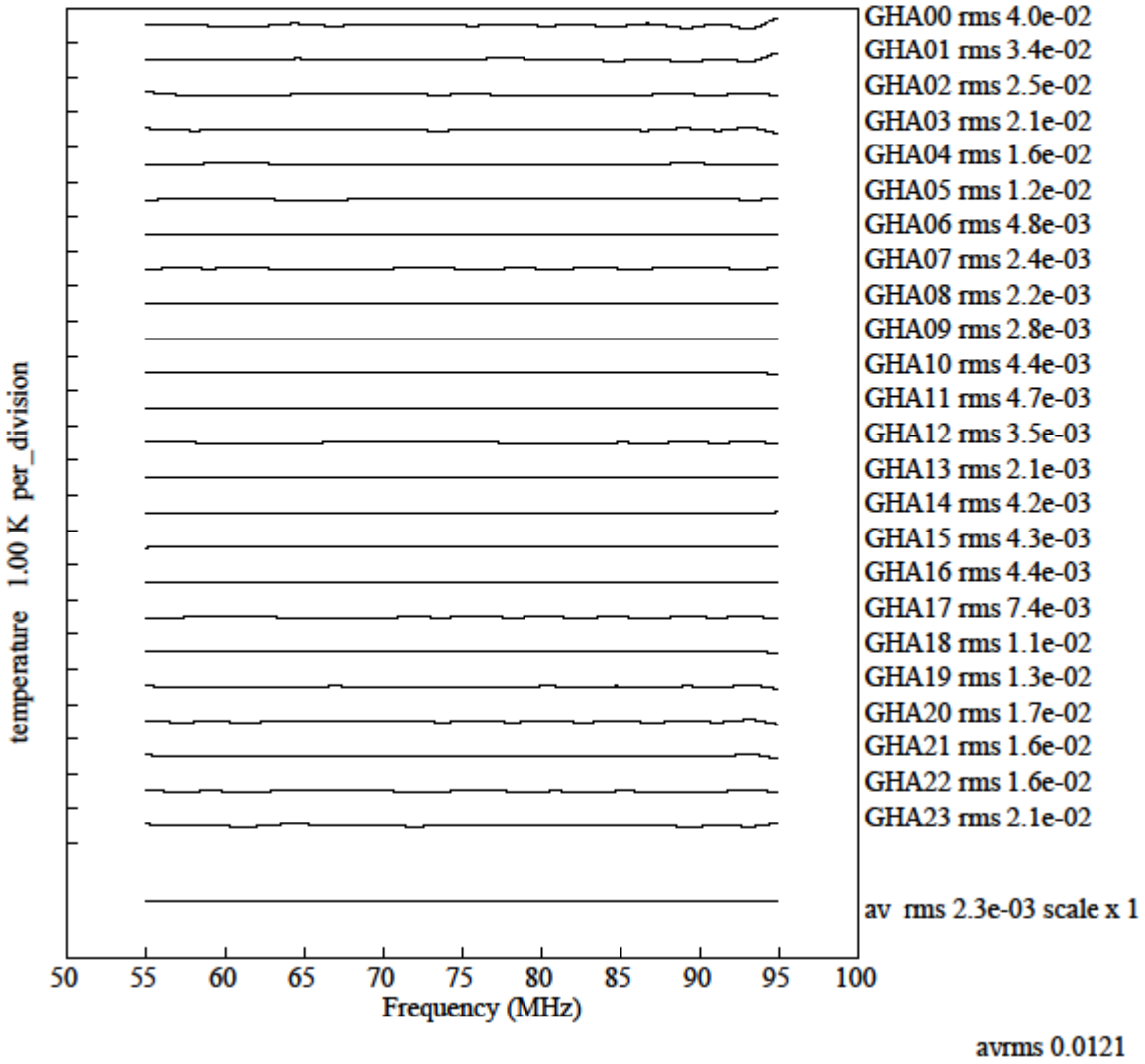

Figure 3. Effect of a change in meshing.