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To: EDGES Group

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Subject: Additional tests of sources of beam chromaticity

In memos 336 and 337 added details of the effects of baseline tilt and deviations from a flatness were studied. In this memo we check the assertion that chromaticity that changes on the scale of an hour has to arise primarily from imperfections in the ground plane or reflections from the edges of the ground plane and not from the sky. The effect of refraction by the ionosphere is checked and the effects of an air gap between the mesh and the soil as well as a layered soil is also checked.

1a] Effect of adding a strong point source to the skymap

Table 1 shows the effect of adding a point source of 40 K at galactic lat, long = 0,18h

Ground plane	av rms mK	av rms at GHA = 18h	GHA significantly effected
PEC	4	2	Maximum of 18 mK
Low2-45 4e-2 S/m	40	197	14,15, 18 above 100 mK
Low2-45 1e-3 S/m	55	197	11,12,13,14,15,16,18 above 100 mK

Table 1. Residuals for 5-physical terms removed 52 – 95 MHz as the result of added point source

The point source of 1e5 K was added to a single 0.35x0.35 deg pixel of the Haslam 408 MHz map which results in a 40 K increase EDGES low2 beam at transit. This simulation shows that when 5-terms are removed errors in the sky map only significantly affect the beam chromaticity which results from the ground plane. In each case the chromaticity without the added point source is used as the reference.

1b] Effects of refraction from the troposphere and ionosphere

Another source of beam chromaticity which changes on the scale of an hour is refraction since refraction produces fine scale structure of the beam in the sky. For a tropospheric refraction of 0.75 and 0.011 degrees at the horizon and 45 degrees respectively about 3K is added to the observed sky temperature for EDGES low2_45. This is very small and smooth and contributes less than 1 mK to the beam chromaticity for 5-physical terms removed 52 – 95 MHz. The ionosphere has a small but more significant effect. Using a refraction of one arc minute at 100 MHz, frequency dependence inversely proportional to frequency squared and zenith angle dependence from equation (6) of Sokolowski et al. 2015 about 25 K is added to the sky. Even with the frequency dependence of the refraction the average beam chromaticity is only 5.7 mK. The dependence on GHA for low2-45 is shown in Figure 1. This is increased by a factor of 10 during daytime but would still be much too small to explain the “bump” at 60 MHz” discussed in memo 336 and most of the data at GHA=21 was taken at night. Memo 118 discusses the effects the absorption and refraction of the ionosphere along with plots using the theory of Bailey (1948).

2] Sensitivity of the beam chromaticity to soil conditions.

As discussed in memos 186, 263, 265, 294, 295, 297, 336 and 337 the advantage of a large ground plane is reduced loss and beam chromaticity but the frequency dependence of the beam has a finer frequency structure as the size is increased and this fine structure becomes more significant as more terms are removed. Some way of terminating the reflections from the edges of the ground plane like putting a trench with absorber under the edges of the ground plane might be worth exploring but would be expensive.

Table 2 shows the effects of changes to the soil conductivity, dielectric and spacing between the mesh and the ground for the low2-45 ground plane using a reference of 4e-2 S/m dielectric 3.5 and zero spacing.

conductivity S/m	dielectric	spacing cm	Av rms mK	Max mK	Max GHA hrs
4e-2	3.5	5	29	128,74,54	23,0,21
4e-2	3.5	10	47	182,129,102	23,0,21
1e-3	3.5	0	53	247,142,114	0,23,21
4e-2	6.5	0	8	50,30,16	1,23,0
Infinite PEC			78	433,330,223,142,141	1,0,23,22,21

Table 2. Residuals using simulations to 5-term model removed

This shows that the mesh needs to be within about 5 cm of the soil to avoid significant additional chromaticity as raising the mesh is approximately equivalent to lowering the soil conductivity. The sensitivity to dielectric constant is relatively low. The last entry is for an infinite PEC or equivalently for the reference using the PEC as reference. A test of placing 2 mm thick and 50 cm wide carbonized fiber welding sheet under the mesh aligned with the edge to help absorb reflections produces only a few percent drop in beam chromaticity assuming a conductivity of 5e2 S/m for the sheet so this technique of trying to resistively terminate the edges of the ground plane doesn’t look promising.

A test of adding vertical sections of mesh on the edges of the ground plane which go down 20 cm into the ground made on a 8x8 m square ground plane lowered the chromaticity from 162 down to 131 mK for 5 terms 52 – 95 MHz. The results of simulations for this modified shape of an inverted cavity are given in Table 3 below:

size	side depth cm	diel	conductivity S/m	av rms mK
8x8	0	3.5	4e-2	161
8x8	10	3.5	4e-2	139
8x8	20	3.5	4e-2	131
8x8	30	3.5	4e-2	134
Inf. PEC				12
8x8	0	3.5	4e-1	65

Table 3. Performance of “inverted cavity” ground plane

There is only a 20 percent reduction in the beam chromaticity so more is gained by just increasing the size of the ground plane. Another approach like adding metal stakes into the ground at the tips of the triangular extensions might be worth study.

Vertical Soil Profiling Using a Galvanic Contact Resistivity Scanning Approach show that in most cases the conductivity is much lower for the first 10 to 20 cm especially in sandy or clay loam soil which is another factor which limits the accuracy of modeling the beam chromaticity. (see Pan et al.) A multilayer soil can be modeled by FEKO along as the layers are uniform and infinite. These effects were studied in memo 295. With soil conductivity of 4e-2 S/m and higher the effect of a layer change below 20 cm is small.

3] Check of the effect of trees or brush within 32 m of the antenna

Simulations in memos 310 and 318 show that a metal fence more than 70 m or another antenna 50 m away have a small effect but can have a large effect if close to the edges of the ground plane. A check of non conducting material like trees or brush was made with 0.5 m^2 cross section 1.5 m off the ground 32 m from the antenna results in residual 160 mK at GHA = 21 hours with 5-physical terms removed 52 - 95 MHz. The brush was modeled using a 3m long dielectric 15 cm x 15 cm cross-section with dielectric constant 10 and loss tangent 1e-1 on the west side of the antenna. The simulation was run with a PEC ground plane because soil cannot be included with a lossy dielectric above ground. The dielectric simulating the wooden brush was 1.5 m of the ground plane and appears at an elevation of 3 degrees. Figure 2 shows the simulated residuals for one hour blocks of GHA for antenna azimuth 42 degrees as in low2-45.

4] Summary

In summary the goal of achieving low residuals for one hour blocks of GHA so that an accurate absorption profile can be obtained for each one block is currently thought to be mainly limited by reflections from the edges of the ground plane and deviations of its flatness. These effects are difficult to model but should be reduced with the construction of the larger ground plane currently planned for EDGES-3 at the MRO.

References:

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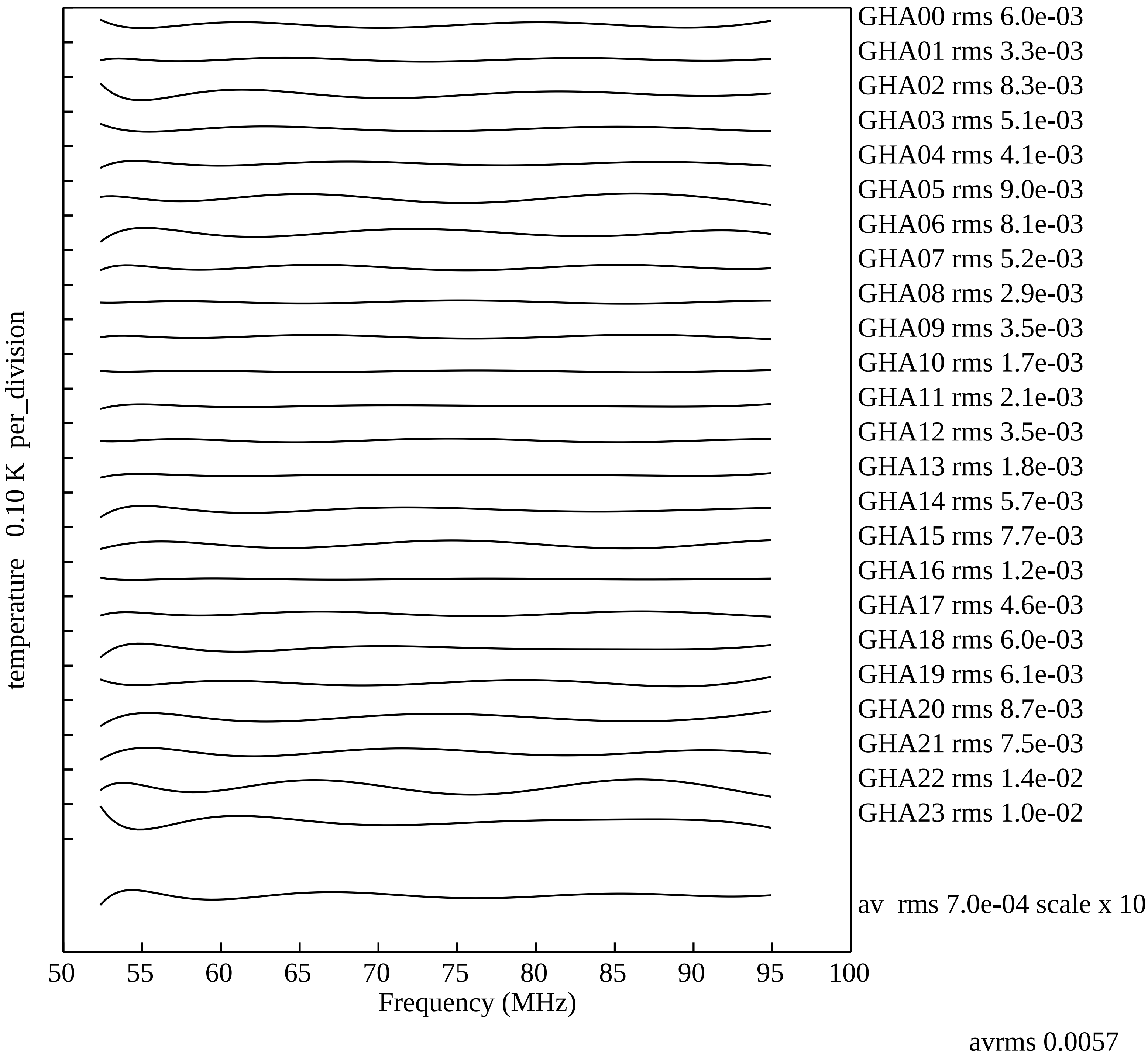
Figure titles:

Figure 1. Residuals to simulations of the effect of ionospheric refraction to low2-45 vs GHA with 5-physical terms removed. The frequency dependent refraction is taken to be 1 arc minute at 45 degrees. Note the fine scale and see the text for details.

Figure 2. Residuals to simulations of trees or brush 32 m from the antenna – see text for details.



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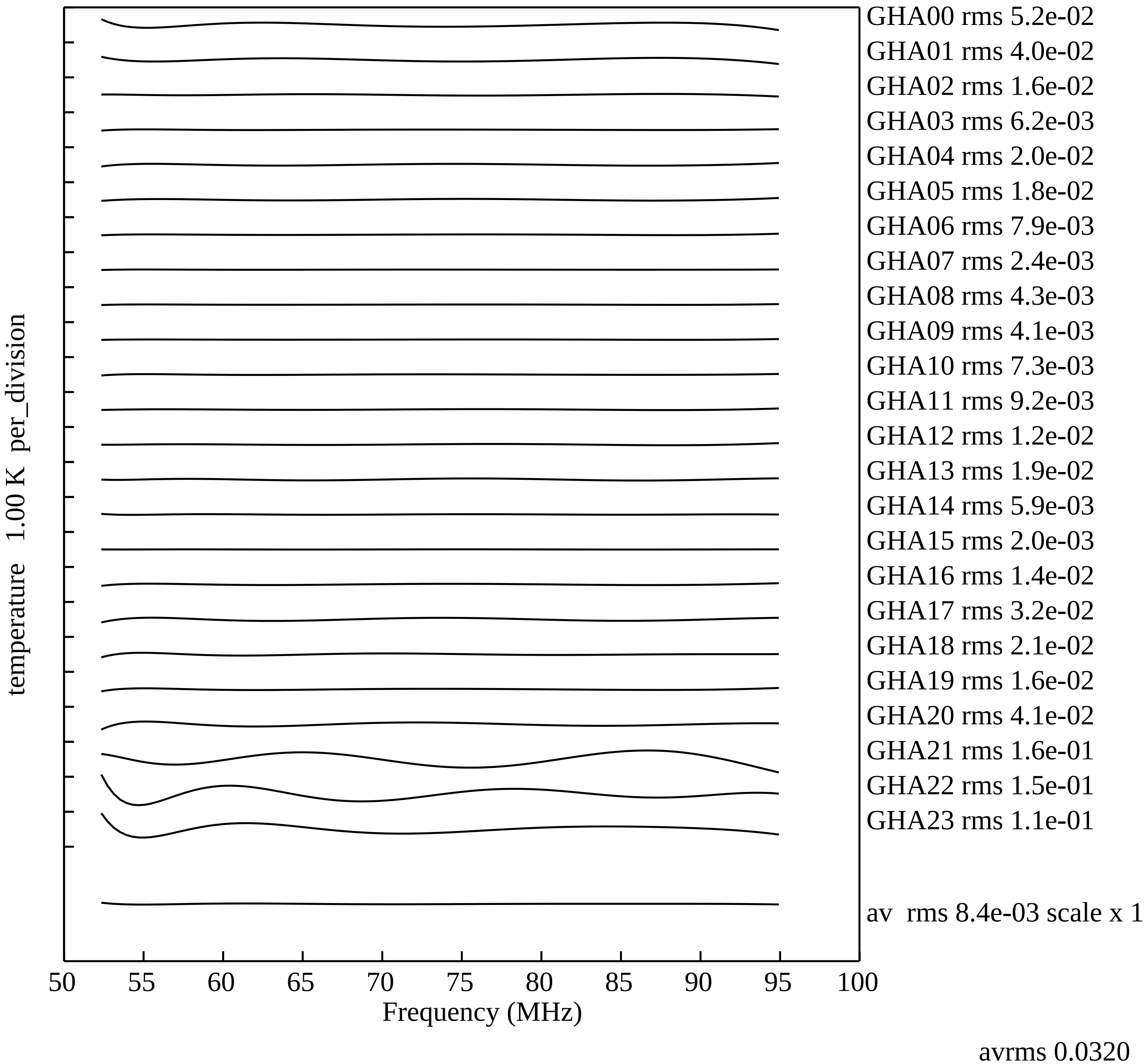

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