EDGES MEMO #340

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Subject: Simulations of reflections from objects which produce fine structure in the antenna beam

Estimates of scatter have usually been made with the assumption that objects like the edges of the ground plane produce a "ripple" with a period, p in Hz,

$$p = c / (2d) \quad (1)$$

where c = 3e8 m/s and d = distance from the antenna to the object which is reflecting or scattering some sky noise back to the antenna in meters.

This added scatter effectively acts like an "adding" interferometer so that an estimate of the period is

$$p = c / [d (1 - \cos(\mathrm{elev})\cos(\mathrm{azd})] \quad (2)$$

where the elev is the elevation of the region in the sky being scattered and the azd is the difference in azimuth between the region of the sky and the azimuth of the object as seen from the antenna. Equation 2 assumes that the scattering from the object is picked up by the antenna and adds to the antenna voltage forming an adding interferometer like those which used the scatter from the ocean into the broad beam antenna on the coast to produce a very simple interferometer in the very early days of radio astronomy.

What equation 2 shows is when a strong region of the sky, like the Galactic center, is low in the sky and is close to the direction of the scattering object the ripple period can be large. For example, the period would be 24 MHz or more for an object at 50 meters away if the Galactic center is 40 degrees in elevation and within about 10 degrees in azimuth.

Figure 1 shows an example of a simulation in which a 4x1 m metal sheet is placed 50m southeast of the antenna. As the Galactic center rises the metal sheet is close to the direction of the Galactic center and the ripple period is 20 MHz which then decreases to 6 MHz at transit and then to 3 MHz past transit in agreement with equation 2. The ripples weaken by more than the drop in total power away from transit because the 50 m baseline interferometer resolves the Galactic plane. Figure 2 shows a simulation in which the Haslam sky map is replaced by a 1e5 K point source in the single pixel at the Galactic center and 8K elsewhere to illustrate the effect of the resolution of the galactic center region in Figure 1.

This simulation demonstrates the objects within 50m can produce significant chromatic structure on the scale of 20 MHz. Simulations show that the power decreases approximately with the square of the distance, d, so that at 100 m away the effects are lowered by a factor of 4 for the same size scattering object and in addition the ripple period not only reduces by a factor of 2 but change phase rapidly with GHA so the ripples tend to average out. In addition, there is a further reduction in the effects of beam chromaticity from more distant scatterers owing to the resolution of the extended regions of the sky.

Additional simulations have been made which show the following:

1] Replacing the metal 4x1m metal sheet with a 4x1x0.1m dielectric of 10 and loss tangent 1e-1 has about the same effect. Lowering the dielectric to 3 reduces the effect by about a factor of 3 while changing the loss tangent has very little effect.

2] Changing the soil over which the scattered wave travels from the sheet to the antenna from a very low conductivity to a PEC surface has very little effect.

3] Reducing the size of the antenna all the way down to an electrically small size has very little effect.

4] Changing from a horizontal dipole to a vertical monopole increases the effect by a factor of about 2 for the same 4×1 sheet while changing the sheet to 1×4 so that it stands vertically increases the effect by about a factor of 10 for the monopole while reducing the effect by a factor of 10 for the dipole.

In summary in order to reach the low level of beam chromaticity needed to verify the 21-cm absorption for each one hour block of GHA it may be necessary to remove brush and trees out to 100 m from the antenna at least in some critical directions like to the southeast at the MRO.

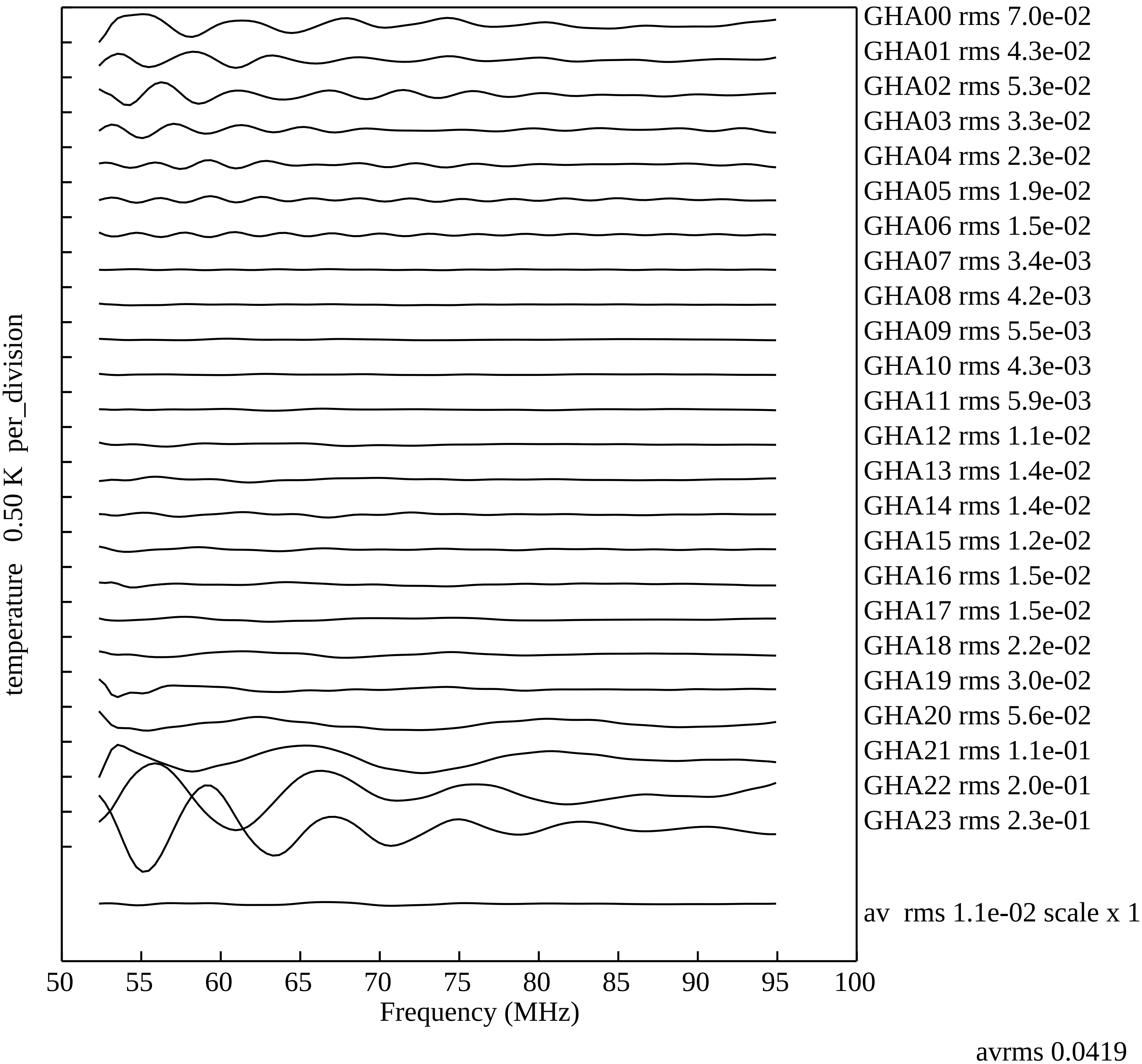

Figure 1. Simulation of the effects of a 4x1 m metal sheet 50m southeast of antenna on the residuals with 5-physical terms removed.

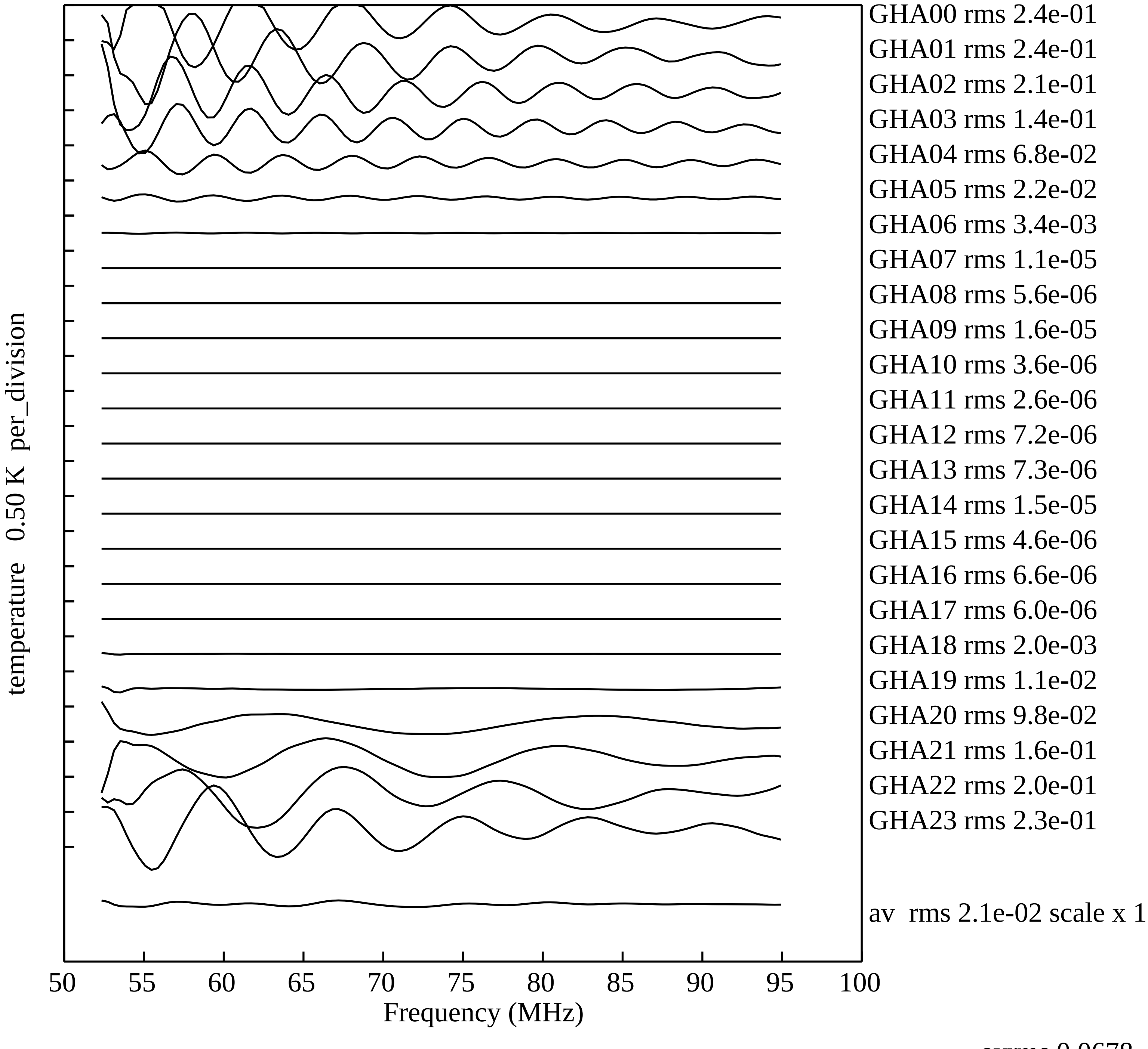

Figure 2. Simulation when Haslam map is replaced by a single point source at the Galactic center.