EDGES MEMO #390

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To: EDGES Group

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Subject: Proposed wire grid ground plane for deployment in the arctic

Potential sites for a temporary deployment in the northern hemisphere are discussed in memo 388. In each case the site would meet the requirements listed in memo 383. It would be a temporary deployment because the site would need to have someone at the site 24 hours each day to limit the encroachment of animals and because of the freezing and thawing of the ground in the arctic the ground would probably not remain flat and level from one year to the next. For a temporary deployment a simple wire grid is a good choice for which simulations have yielded low enough beam and loss chromaticity to provide a result good enough to show that the feature reported from the MRO is real or instrumental with high confidence. In order to refine the parameters of the MRO result a 48x48m welded mesh ground plane has been proposed for the MRO and is awaiting approval.

In order to get a more accurate absorption parameters obtained from the data taken at the MRO the systematics need to be further reduced. The largest source of systematics for the observation of the global 21-cm absorption is the ground plane which needs to be larger, more level and more uniform than the 30x30m ground plane at the MRO used for the EDGES-2 horizontally polarized antenna. For a vertically polarized antenna a much larger ground plane would be needed for the antenna to be more than 50m from the edges of the ground plane or lake shore. The beam and loss corrections for smaller ground planes are limited by the lack of knowledge of the ground beneath the ground plane and the scattering from objects beyond the edges of the ground plane. The most severe case is a layered ground for which the top layer has insufficient conductivity to prevent reflections from the layers below. This is the major concern for a site in the arctic and on the far side of the moon (see memo 279). For example, a circular ground plane has much higher beam chromaticity in free space than when on the ground as shown in figure 5 of memo 384 which shows chromaticities of 795 and 519 for 20m diameter circular ground planes in space and on the ground respectively compared with the 30x30m ground plane at the MRO for which the chromaticity is only 122mK.

Following an extensive set of FEKO simulations the best compromise between complexity and the expected performance is a 30x15m wire grid using 7.23 km of # 18 awg insulated copper wire meandered via 482 pegs with initial wire spacing of 6.25 cm which is increased to 12.5 cm at more than 3m from the antenna. This design is similar to, but not exactly the same, as the ground plane used in Oregon described in memo 310.

The optimum orientation of this wire grid given by the direction of the 30m long wires which are aligned the antenna electric field is an azimuth of about 340 degrees for the site in Alaska.

Table 1 below shows the beam chromaticity for 24 1 hour blocks over GHA at 69.5427 -148.5941

which is about 48 miles south of Prudhoe Bay Alaska. The antenna and ground plane is on gravel with the dielectric constant and conductivity indicated. Columns av, cen, amp, wid, rms1 and rms2 are the average beam chromaticity, the center frequency for a grid search with the Nature feature added to the sky, the amplitude, the width, the rms for a 5 physical term fit for the foreground and the rms for the fit which includes the 21-cm absorption feature parameters.

Wire grid size	eps	S/m	comments	av mK	cen MHz	amp K	wid	rms1 mK	rms2 mK
30x15m	3.5	1e-2		95	78.1	0.53	19.1	51	2
30x15m	7.5	1e-2		89	78.1	0.52	19.0	51	2
30x15m	7.5	1e-3		94	78.1	0.52	18.6	51	2
30x15m	7.5	1e-2	Wires 1 cm off ground	104	78.1	0.60	18.6	63	11
30x15m with GF loss	3.5	1e-2		93	78.1	0.54	20.1	45	7
30x15m "	7.5	1e-2		89	78.1	0.56	19.2	54	4
30x15m "	7.5	1e-3		97	78.1	0.58	18.8	60	9
30x15m "	7.5	1e-2	Wires 1 cm off ground	102	78.1	0.58	18.7	61	10
30x15m "	7.5	1e-2	Wires 1 mm off ground	96	78.1	0.53	18.3	58	6
30x15m "	7.5	1e-2	Wires 2 cm off ground	247	78.9	3.61	25.5	232	64
30x15m loss memo 277	7.5	1e-2	Wires 2 cm off ground	103	77.7	0.56	18.4	63	11
30x15m no loss	7.5	1e-2	Wires 2 cm off ground	104	78.1	0.60	18.6	64	13
30x30 perf no loss	7.5	1e-2	"	84	78.1	0.57	18.9	58	10
30x30 perf with loss	7.5	1e-2	"	316	76.6	4.78	29.2	314	67

Table 1. Beam chromaticity for 24 1 hour blocks for a site at latitude of 68 degrees.
A major concern which arises from these simulations is the sensitivity to any separation between the ground plane and the ground. While the effects of loss are exaggerated by the glitches in the FEKO GF calculations which is discussed in memo 370 these effects can only be eliminated by using the method to obtain a loss without glitches for soil with zero conductivity discussed in memo 277 and 315. Unfortunately, there is a glitch in FEKO which results in a step jump over less than a few Hz in an estimate of the loss. This jump occurs at a frequency of 62.5275 MHz for a ground plane 2 cm above the ground with dielectric 7.5 and conductivity 1e-2 S/m. Lowering the dielectric 3.5 increases the step to around 75 MHz. Increasing the height to 4 cm moves the step to about 84 MHz.

Ground plane	eps	S/m	azimuth	lat.	av	cen	amp	wid	rms1	rms2
30x15m wire grid	7.5	1e-2	340	68	89	78.1	0.56	19.2	54	4
30x15m wire grid	7.5	1e-1	340	68	63	78.1	0.51	18.9	51	2
30x30m perforated edges	7.5	1e-2	90	68	73	78.1	0.54	19.0	53	4
30x15m wire grid	7.5	1e-2	90	79	93	77.7	0.52	18.4	58	8
30x15m wire grid	7.5	1e-1	90	79	65	77.7	0.51	18.6	56	6
" change of azimuth	7.5	1e-2	340	79	89	78.5	0.33	17.5	52	34
30x30m perforated edges	7.5	1e-2	90	79	70	78.1	0.52	19.6	47	4
30x15m wires raised 2cm	7.5	1e-2	90	79	96	77.7	0.56	18.4	64	12

Table 2. Effects of a change in site latitude and ground plane azimuth

Table 2 shows the results of FEKO simulations of the EDGES-3 antenna on different ground planes at the latitude of 68 for Alaska and 79 degrees for Ny-Alesund. The best azimuth is 340 deg for latitude 68 and 90 deg for latitude 79. The change of the chromaticity with azimuth is larger for the higher latitude. The 30x30m "perforated" ground plane is the current design used at the MRO. A uniform soil/sand is assumed but with 1e-1 S/m a change below about 0.5 meters would have no effect and only a small effect at 1e-2 S/m as the 2-way attenuation is only 6 dB vs 44 dB at 50 MHz for 1e-1 S/m. A survey of potential sites in Ny-Alesund by Devin Huyghebaert and Juha Vierinen is in Memo 389. For comparison with the results of simulations in the tables 1 and 2 the 30x15m wire grid average rms in free space is 185 mK with 1.5% loss.

Obtaining a low beam and loss chromaticity is essential because obtaining an accurate beam correction requires an accurate knowledge of the details of the soil as well as an accurate sky map so that keeping the spectral effects to a minimum is essential and simulations show that 120 mK rms 5-terms removed is probably the largest that can be accommodated.

In summary combined beam and loss chromaticity should be under 120 mK averaged over all GHA 5-terms removed from 55 – 95 MHz provided the gravel or sand under the ground plane has conductivity greater than about 2e-2 S/m for which the attenuation is about 10 dB/m at 50 MHz. Tests of the loss using the method of memo 258 are free of the glitches but only provides an upper limit on the loss.

Owing to the high cost of leveled gravel in Alaska some added tests have been made to see if the size of the ground plane can be reduced. At 4x2m wire grid with gravel conductivity more than about 3e-3 S/m a small ground plane is possible even with only 0.5m of gravel before a change to a layer with high dielectric but the leveled area has to extend at least 5m beyond the edges of the ground plane so a leveled area of only about 18x18m might be an acceptable way to lower the cost of the gravel.

In summary there are 2 possible regimes for low chromaticity. One is a 30x15m as in Oregon and the other is 4x2m which is small but not so small that the loss chromaticity becomes a problem. However it is emphasized that even with the small ground plane the uniformity of the layered gravel plus soil below has to continue well beyond the edges of the ground plane for the FEKO model to be accurate as it assumes layers below which are infinite in extent. Tests in memo 358 show that even with a small ground plane the area still has to be level to within a few cm out to about 20m from the antenna implying that ideally we can still benefit from having a 40x40m flat area even if it is not all covered with a wire grid or mesh.

Figure 1 shows the results for the small and large ground plane on infinite layered ground of 0.5m gravel with dielectric 3.5 and 5e-3 S/m over dielectric 20 and 2e-2 S/m all the way down to z = minus infinity. The results are for a feature search over all GHA without beam or loss corrections since detailed layered ground parameters will not be known. While the larger wire grid ground plane has more variation of the residuals from the 5-term fits with GHA the small wire grid is assumed to be on a perfectly uniform layered ground over an area much larger than the wire grid. In practice this is unlikely to be true and the imperfections in the ground beyond the edges of the wire grid will result in more fine structure like those present in the simulation of the larger wire grid. The sensitivity to scattering from objects beyond the edges of the ground plane is set by the gain at low elevation which is about -23 dBi for both 4x2m and 30x15m ground planes at 1 degree elevation making them equally sensitive to scattering using the analytic approximations in memo 360. The low elevation gain for a vertically polarized antenna is about 10 dB higher which increases the sensitivity to scattering effects by a factor about 3 using the fractional ripple formula from equation 7 of memo 360. The average rms for the 4x2m ground plane increases to 200 mK as the gravel conductivity drops to 1e-3 S/m while the 30x15m ground plane rms only increases to 120 mK for gravel at 1e-3 S/m.

Figure 2 shows FEKO simulations of the effects of a 2.5x2.5x2.5m cubic hut 30m west of the antenna on the beam chromaticity with 5-terms removed for the 4x2m and 30x15m ground planes with layered gravel as in Figure 1. These plots which are difference between the chromaticity with the hut and the chromaticty without the hut show that the sensitivity beyond the edges of the ground plane is very close to being the same for the small and large wires grid ground planes so that the ground needs to be leveled for an area much larger than the size on the ground plane in the case of the small ground plane.

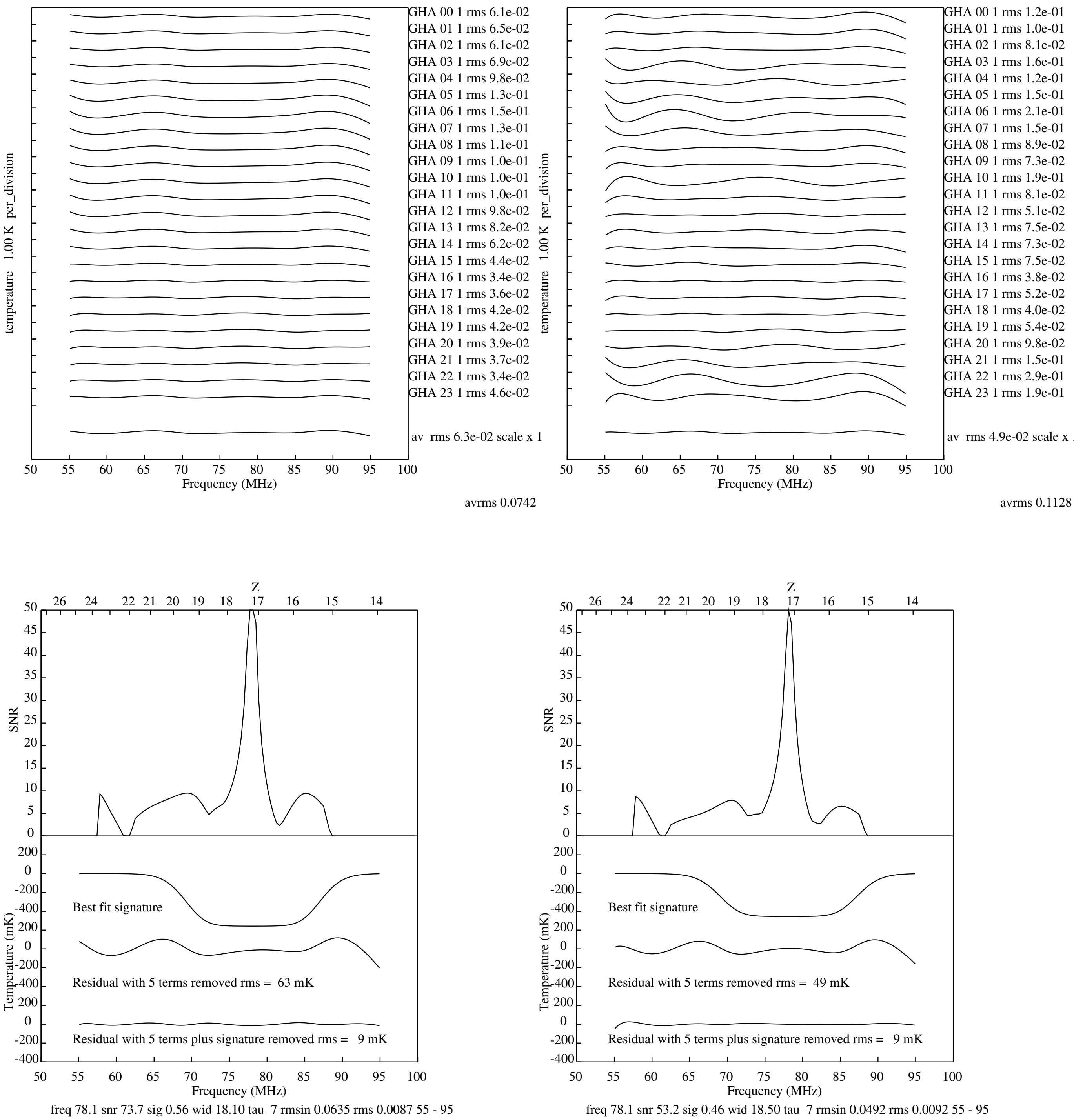

Figure 1. Plots of beam and loss chromaticity with Nature feature added to the Haslam map. 5-physical terms removed for 1 hour blocks of GHA at 68 degrees latitude along with the results of a grid searches for the best fit feature parameters with fixed tau = 7. The 4x2m wire grid of the left and the 30x15m wire grid on the right.

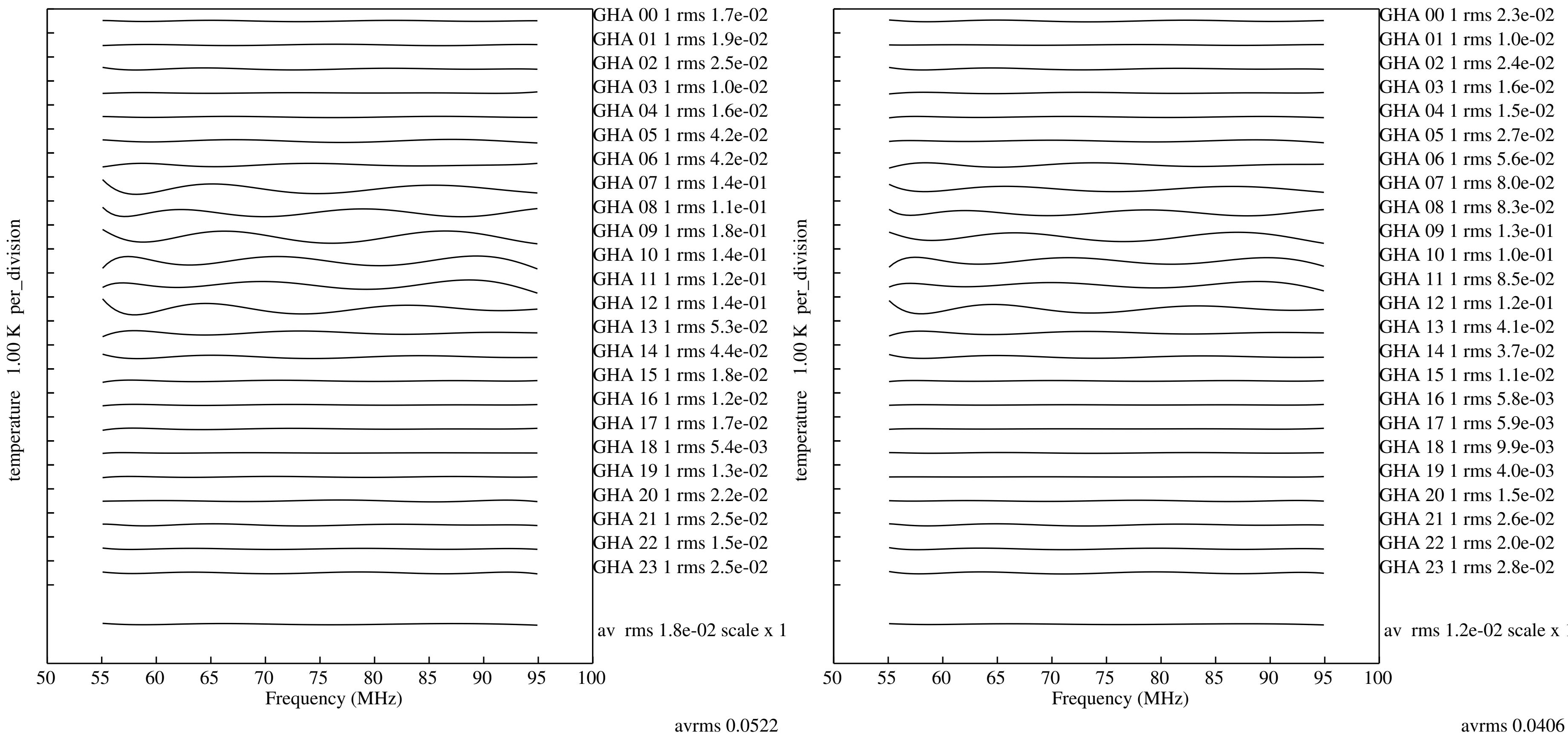

Figure 2. Plots of the effect of a 2.5x2.5x2.5m hut 30m west of the antenna on the beam chromaticity with 5-terms removed for the 4x2m on the left and the 30x15m ground plane on the right.