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To: EDGES Group

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Subject: Comparison of different EDGES antennas

The original EDGES antenna was a "Fourpoint" based on a design by Suh, IEEE VTC 2004 as discussed in memo 152. The Fourpoint was replaced by the "Blade" which is a simpler more compact planar antenna with slightly lower beam chromaticity than the Fourpoint when compared on an infinite PEC ground plane. Both have similar S11 bandwidth.

The added chromaticity due to a finite ground plane is very close to the same for these 2 designs and for both antennas the chromaticity improves and the S11 bandwidth degrades as the antenna is moved closer to the ground plane. For EDGES-3 we desire an improved chromaticity and larger S11 bandwidth but as discussed in memo 291 FEKO simulations have not yet shown that any improvement is possible although not all changes in shape etc. have been explored. However, simulations have shown that placing the antenna over uniform soil results in lower chromaticity and wider S11 bandwidth despite a drop in efficiency from over 99.5% to around 60%. What is still uncertain is whether a location with uniform soil to a sufficient depth can be found. FEKO simulations show that a soil depth of at least 10 m is needed for soil conductivity of 1e-3 S/m in order to provide sufficient attenuation of reflections from rock below.

Soil depth (m)	Soil dielectric	Soil S/m	rms (mK)
No rock	3.5	2e-2	8
5	3.5	2e-2	10
5	3.5	1e-3	300
10	3.5	2e-2	10
10	3.5	1e-3	51
20	3.5	1e-3	9

Table 1. Beam chromaticity simulations of box blade on soil with rock below at various depth. The rms is the average of 2-blocks over all GHA at lat = -27˚ for 5-terms removed from 60-100 MHz.

Table 1 shows the results of FEKO simulations of the chromaticity of the blade box antenna over soil for different conductivity and soil depth. Another potential source of frequency structure is the smoothness of the loss in soil even without reflections from the underlying rock. Figure 1 shows the loss and Figure 2 shows the residuals to a 5-term fit to effect not making a loss correction to the calibrated spectra. When a 7-term fit is made to the ground loss the rms residual to a 5-term is 28 mK for a frequency range 60-100 MHz. Figure 3 shows a simulated grid search for the Nature signature using 5-terms and uncorrected residual frequency structure in ground loss from FEKO with uniform soil.

The ground loss can be reduced by adding a small ground plane on the soil made of wires spaced 6.25 cm apart oriented in direction of the electric field

Grid size	rms to 5-terms mK	Loss at 60 MHz	Loss at 100 MHz
None	8	47%	34%
3×3 m	8	10%	6%
4×4 m	27	7%	3%
5×4m	57	4%	1%

Table 2. Effect of adding a wire grid of 3×3 m is probably be best compromise between lower loss and increased chromaticity as the grid size is increased. As discussed in memo #289 a very large grid can eventually produce both low loss and low chromaticity.

EDGES-3 will be easily deployed for nighttime observation over uniform soil as data can be retrieved and batteries changed during the day by opening the access cover on the receiver box. EDGES-3 should give better results than EDGES-2 primarily because of the elimination of the balun loss, which is a significant source of systematic error, and the reduced delay in the antenna S11 without a balun which reduces the effects of S11 phase error.

Christos Kolitsidas proposed in his thesis "Next Generation Wideband Antenna Arrays for Communications and Radio Astrophysics," KTH 2017 the possibility that a strongly coupled asymmetric dipole array (SCADA) might be a good choice for measurement of the Foreground and 21-cm line. The potential for obtaining a wider S11 bandwidth is clear and this has the potential for a more accurate determination of the Foreground. The potential for detection fo the 21-cm absorption looks more difficult as the SCADA introduces fine frequency scale structure in the S11 and beam chromaticity. The fine scale structure in chromaticity from Kolitsidas over a frequency range of 100-200 MHz is at the 20 mK level with 5-terms removed and this level would increase by a factor of 5.6 at 50-100 MHz for a spectral index of -2.5.

Simulations using an array were made using FEKO in which an array was made using dipoles and blade antennas placed 50 cm above an infinite PEC ground plane. The chromaticity, defined as the average rms fit to 5 terms in 2 hour blocks over full range of GHA at lat = -27˚ over 60-100 MHz.

Array	Spacing (m)	rms (K)	element
1×1		0.003	Blade
3×3	1.5×1.5	0.38	Blades
3×3	1.1×1.1	1.7	Blades
5×5	1.1×1.1	0.65	Blades
5×5	1.5×1.5	0.46	Dipoles
5×5	1.5×1.5	0.22	Single blade

Table 3. Chromaticity for arrays

The arrays are single polarization in 2-D and driven by a voltage source of the same amplitude and phase at each element. The height of each element above the ground plane is 50 cm which is small enough that the chromaticity of a single isolated element is under 4 mK.

The last entry in Table 3 is for the chromaticity of a single blade in the center of the array with all other blades terminated. This shows that the cross-coupling introduces significant spectral structure so that incoherent averaging of the spectra from each element of an array is likely to be degraded by cross-coupling. While the SCADA has potential it clearly needs more study and simulations of the confirmation of the absorption reported by EDGES.

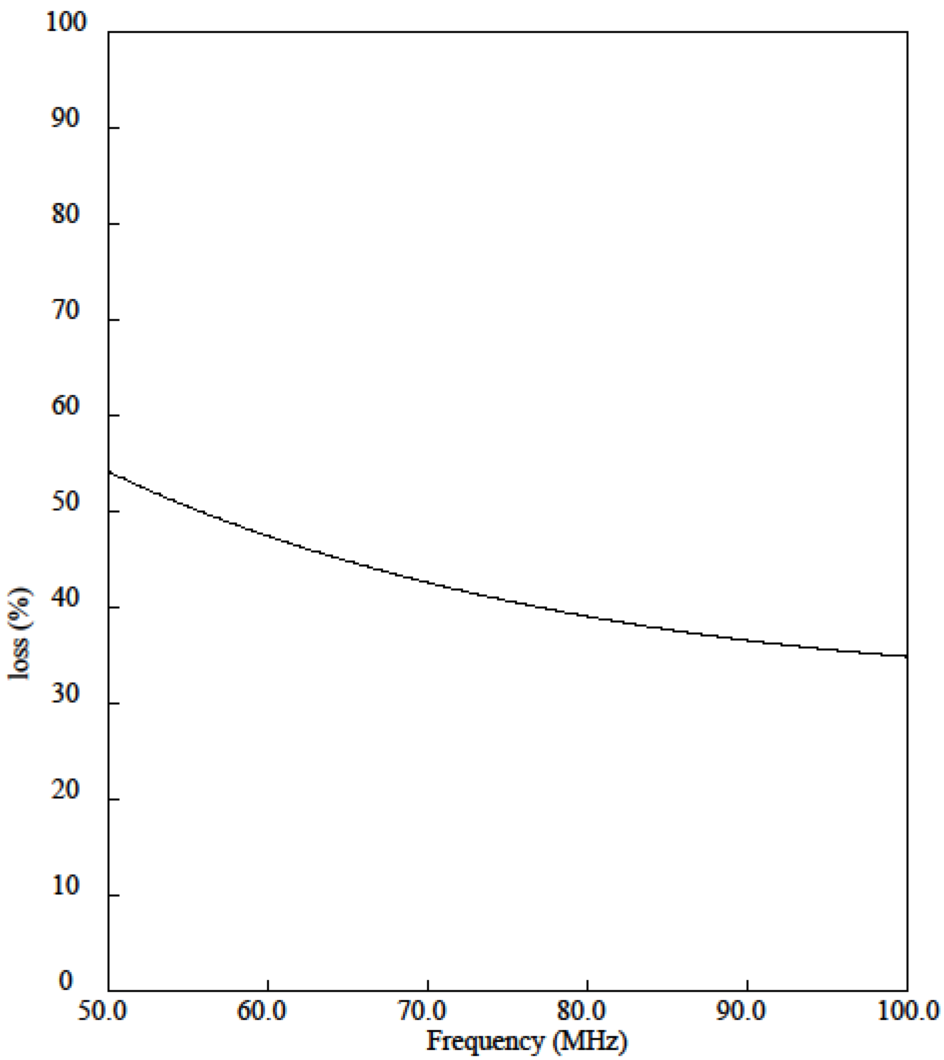

Figure 1. Loss for EDGES-3 at a height of 72 cm above uniform soil with dielectric 3.5 and conductivity 1e-2 S/m.

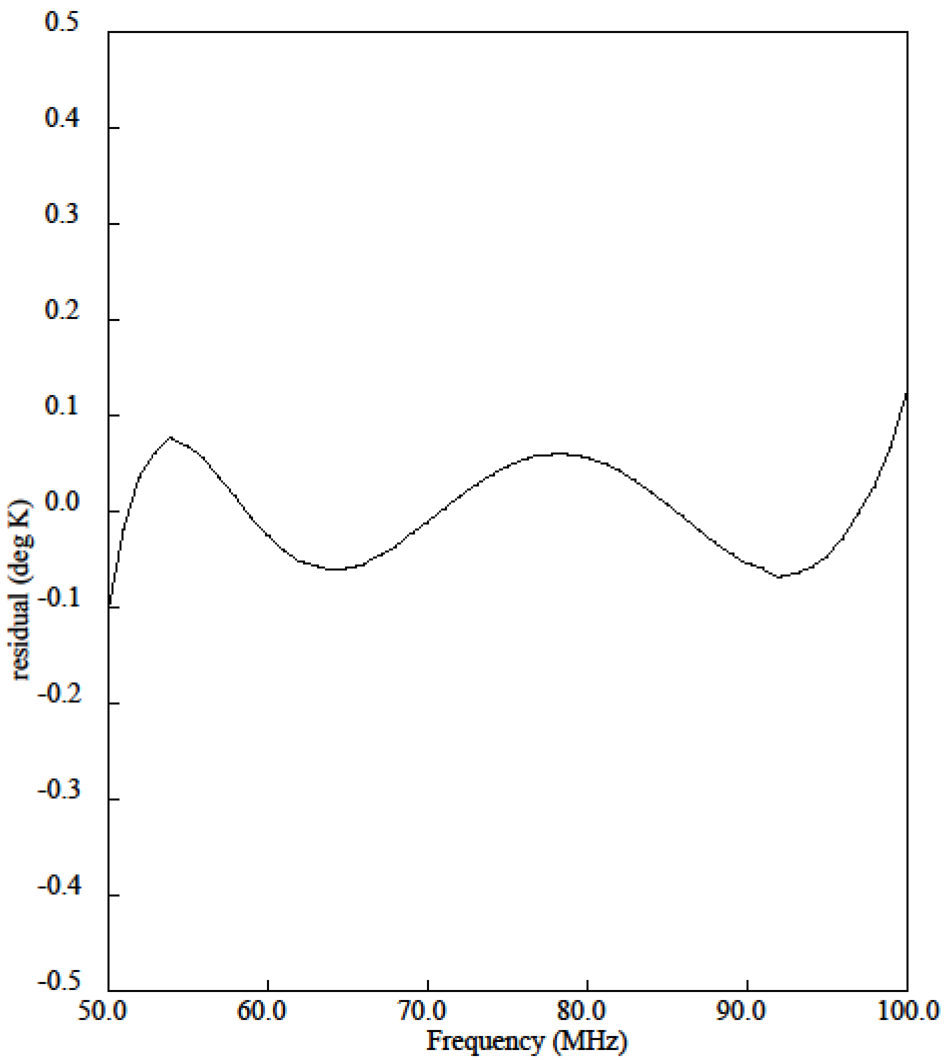

Figure 2. Residuals 5-terms from simulations of the effect of not correcting for the loss in calibrated data at GHA=12.

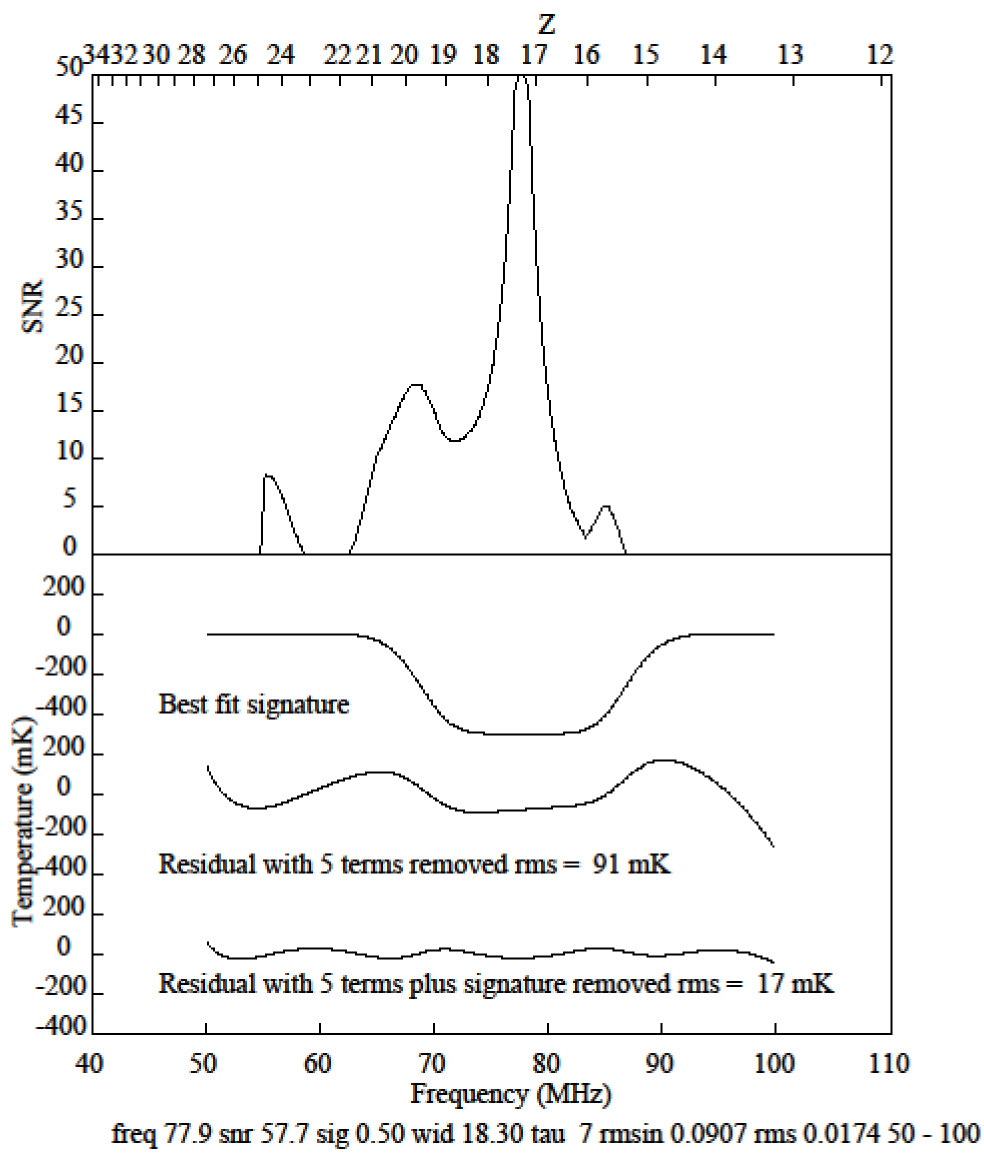

Figure 3. Simulated grid search for signature with 5-terms with uncorrected ground loss structure.