EDGES MEMO #088

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To: EDGES Group

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Subject: Effect of ground plane size on ground loss

FEKO was used to estimate the ground loss. For this estimate the EDGES antenna was placed over a finite wire grid in space and the fraction of the antenna power pattern for elevations below zero degrees was calculated. This method gives an upper limit on the loss since in practice the ground results in some reflection which reduces the amount of "back radiation" which results in picking up the ambient noise from the ground. In the case of a wet ground the Earth itself is a fairly good reflector.

Owing to the large amount of computing required for large ground planes the results are limited to a few discrete sizes and grid spacing

Ground plane extent in wavelengths	Wire spacing in wavelengths	Loss in percent
8×8	0.1	6
4×4	0.1	6
4×4	0.05	1.5
2×2	0.1	7
2×2	0.05	3
2×2	0.025	1.5
1×1	0.1	10
1×1	0.05	6.5
1×1	0.025	5.6
1×1	0.0125	5.5

An examination of the results in Table 1 shows that the loss is made up of a component which depends on the overall size and another which depends on the grid spacing. The grid spacing loss is about 6% at 0.1λ spacing and decreases by a factor of 4 (6 dB) which the grid spacing is reduced by a factor of 2 so that a spacing of 0.01 λ (or 2 cm at 150 MHz) is needed to keep this loss under 0.1% (or 300 mK). The size loss also decreases by a factor of 4 for each doubling of the size so that about 8×8λ (16×16 m at 150 MHz) is needed to get the overall loss under 0.1%.

Spectral flatness of antenna ground loss

Following early deployments with a mesh ground plane EDGE-2 high band will be deployed with a 5.3 m square solid ground plane. Figure 1 shows the ground loss pick-up vs frequency for a 2 meter from FEKO square solid ground plane assume a 300 K ground temperature. This shows that with a small ground plane there is substantial frequency structure in the ground noise pick-up. Figure 2 shows the ground noise pick-up for a 4 meter square ground plane. The larger ground plane has a factor of 4 less pick-up and less fine scale frequency structure. The broad structure can be fit with the same 5 functions used to remove ionosphere, Galaxy spectral index, beta and gamma (discussed in memo 145). For a 4mx4m ground plane solving for an EoR signature at 150 MHz in addition to the 5 functions gives

EoR width (MHz)	EoR bias (mK)	rms residual (mK)
10	0	0
20	2	0
30	16	0
40	60	1
50	166	2

Figure 3 shows the ground loss pick-up for a ground plane of 5.35mx5.35 m made by increasing the segment size for the ground plane by a factor of 2 to a value of 0.0938m in order to achieve a reasonable run time. The accuracy was judged by comparing the ground noise pick-up from a segmentation of 0.0469 m at 100, 145 and 190 MHz.

Freq MHz	0.0469	0.0938
100	4.2960K	4.3131K
145	2.5701K	2.5743K
190	2.5464K	2.5521K

The following table gives the results of fitting an EoR signature for a 5.35mx5.35m ground plane.

EoR width (MHz)	EoR bias (mK)	rms residual (mK)
10	0	0
20	2	1
30	13	2
40	50	2
50	127	2

Some of the frequency structure which is dominant in the 2mx2m ground plane is also in the larger ground planes but it is not yet clear if the FEKO results are accurate to be applied as corrections to the observed spectra. In addition the effects of the surrounding

soil are not known. In order to reduce the level of the ground noise pick-up to a level well below the level of expected EoR signature it may be necessary to extend the solid ground plane with mesh.

While the exact cause of the frequency structure is not known in detail one model which fits the bump at 130 MHz is a resonance which occurs when the ground plane size equals a wavelength. This model shows to the expected shift in frequency with ground plane size. A major concern is the structure in the ground loss for the 5.35mx5.35m ground plane is significantly larger than for a 4mx4m ground plane which if correct means we will need to extend the ground plane. However more tests are needed with alternate EM simulation software CST and NEC.

The residuals to a 5 term polynomial fit from 100 to 190 MHz 10 MHZ spacing for various sizes of solid ground plane and different FEKO mesh size are given below.

Size	mesh_size	Loss at 150 MHz (K)	residuals_to_fit_rms (milliK)
2mx2m	0.0469	17.0	142
2.4mx2.4m	0.0469	11.8	112
2.8mx2.8m	0.469	9.0	57
3.2mx3.2m	0.0469	6.5	47
3.6mx3.6m	0.0469	5.2	25
4mx4m	0.0469	4.3	11
5.35mx5.35m	0.0469	2.7	29
5.35mx5.35m	0.0938m	2.7	34
5.35mx5.35m	01876m	2.7	34
14.62mx14.62m	0.1876m	0.5	1
5.35mx5.35m[1]	0.1876m	0.5	1

[1] Adding 2mx5m sections of mesh on each side of the solid 5.35mx5.35m square
The added 2mx5m sections also reduce the EoR signature bias from 50 to 30 mK for a 40 MHz signature width.

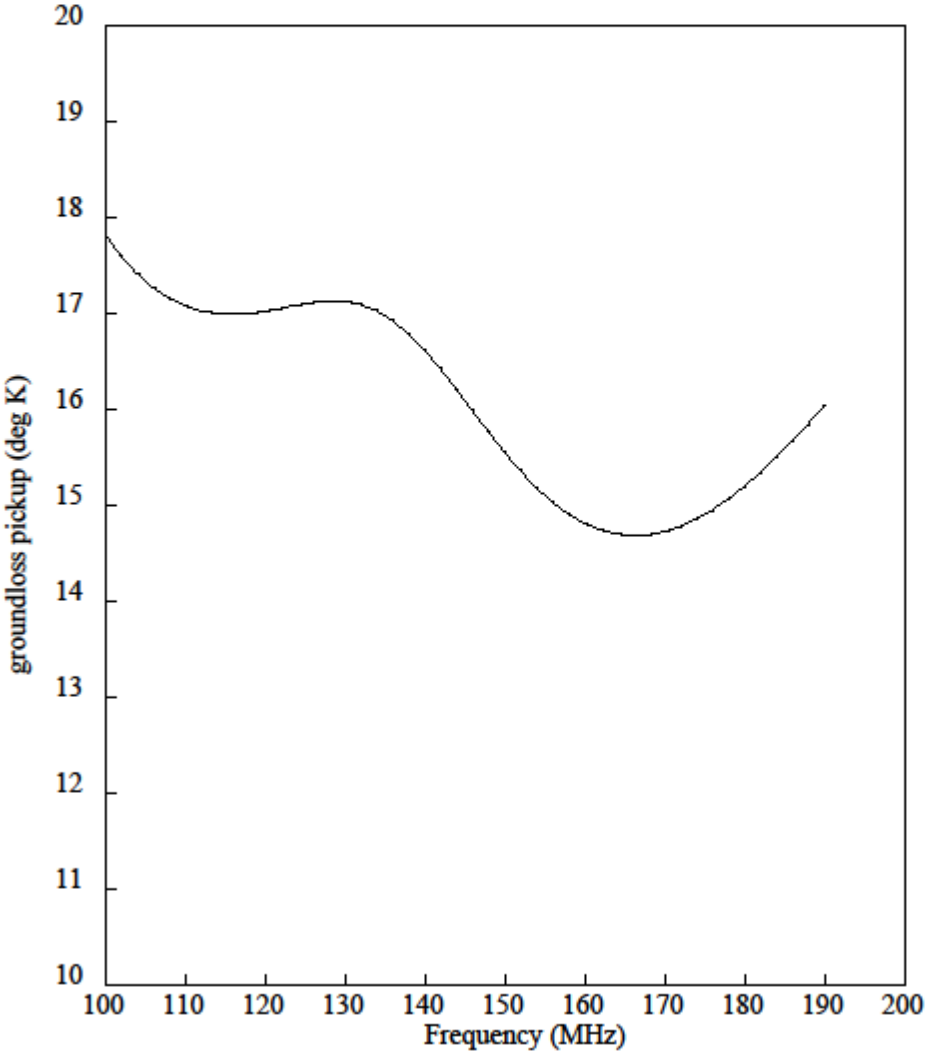

Figure 1. Frequency structure of EDGES antenna with 2mx2m solid ground plane.

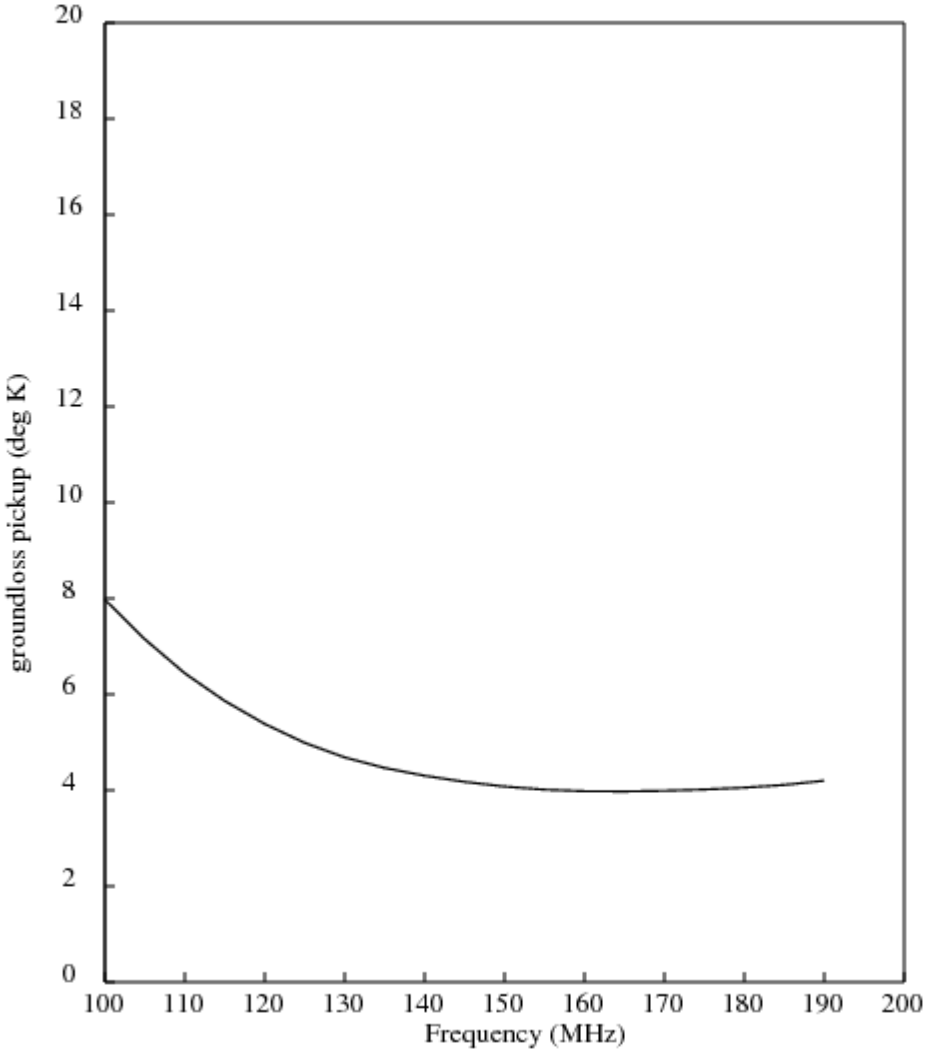

Figure 2. 4mx4m ground plane

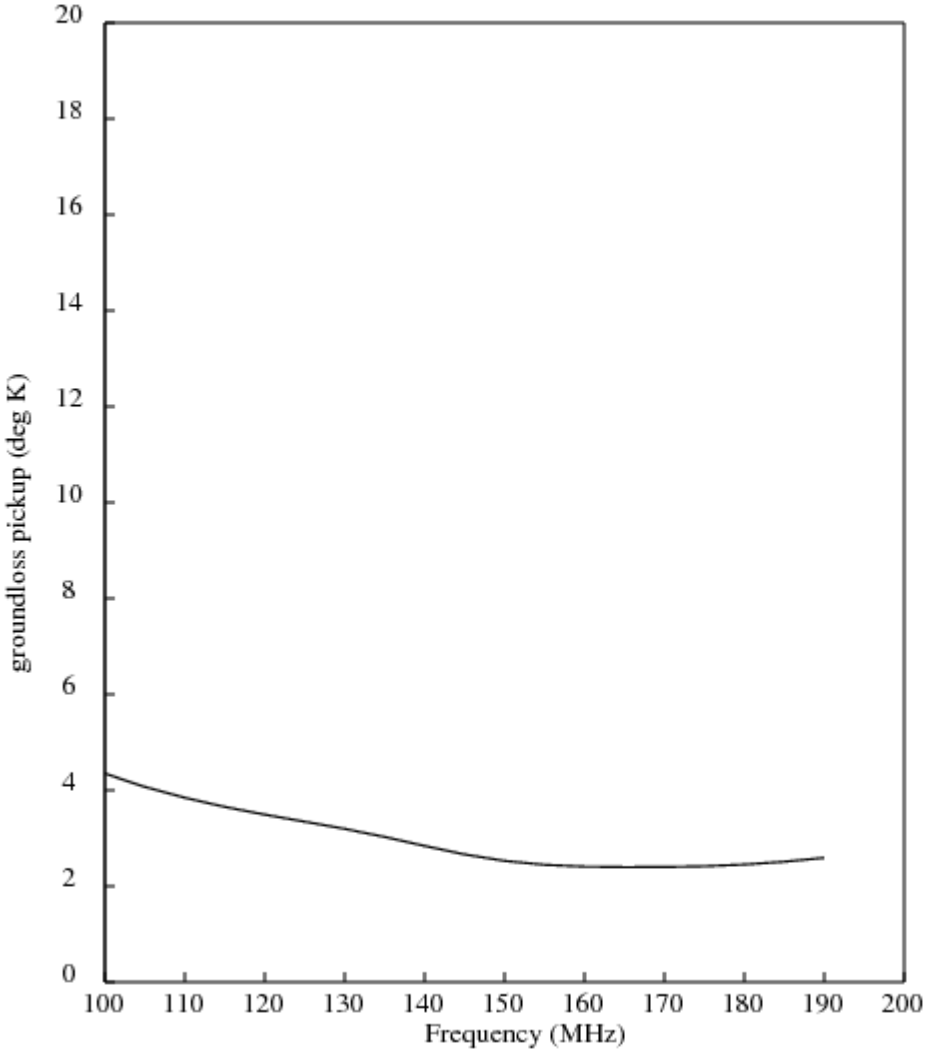

Figure 3. 5.35m x 5.35 m ground plane