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To: EDGES Group

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Subject: Effect of antenna resonances on beam pattern.

Memo #138 discussed the effects of lossy resonances on the antenna loss. These resonances produce dips in the spectrum when the sky noise temperature is higher than ambient and peaks when the sky temperature is below ambient.

In this memo the effects of resonances on the antenna beam pattern are discussed. For example the resonances in the director and reflector of a 3 element yagi have a very large effect on the beam pattern. In the case of the EDGES Fourpoint antenna the effects of irregularities in the ground plane, like those discussed in memo #138, edges of a finite ground plane and structures on the ground plane like the LNA box and any exposed cables can have an effect on the beam. The beampattern change results in spectral features which vary with the spatial structure of the foreground. The effects are largest around the transit of the Galactic center.

An estimate of the order of magnitude of the effect can be made from the antenna voltage response

$$v(f,\theta) = g_0(f,\theta) + c(f)\, g_1(f,\theta)$$

Where $g_0(f,\theta)$ is the voltage gain of the antenna as a function of frequency, f, and angle θ

$g_1(f,\theta)$ is the voltage gain function of a structure in the vicinity of the antenna.

$c(f)$ is the mutual voltage coupling

$v(f,\theta)$ is the antenna response to a unit point source at angle θ.

$$|v|^2 = |g_0|^2 + |c|^2 |g_1|^2 + 2\,\mathrm{Re}\left(g_0 c^* g_1^*\right)$$

If we assume that $|g_0|^2$ and $|g_1|^2$ are approximately one then the effect of the coupling is approximately

$$1 + 2|c|$$

So that a mutual coupling of -60 dB results in a frequency dependence of about 2×10^{-3} or 1 K out of 500 K when a strong source dominates sky noise.

FEKO simulations have been made of the “high” band EDGES antenna installed at Boolardy in November 2013. The simulations include the effects of the “top cap” on the antenna, the LNA box under the antenna and the cable from the LNA box to the back-end. [It is noted that the placement of the LNA box above the ground plane was a last minute decision based on the constraints of the installation. Earlier plans had the LNA box and cable under the ground plane.]

Qualitatively the effect of the "top cap" and LNA box are relatively smooth with frequency which peak at about ±2 hours of transit of the Galactic center. The rms residuals to a 3 parameter fit to the scale, spectral index and "gamma" of the beam effects on the sky noise spectrum derived from the FEKO simulations are given in table 1 for a frequency range of 150 to 190 MHz.

Antenna configurations	rms (K)
"basic" EDGES Fourpoint antenna	0.25
with asymmetric "top-cap"	0.27
with LNA box	1.0
with LNA box plus "top-cap"	1.2
with added cable resonance	2.5

Table 1. Effect of frequency dependence of antenna beam for various antenna configurations.

Cable resonance was simulated by placing a 0.8 m long cable near the output of the NLNA box coming out at an azimuth of 322 degrees for the geometry of the EDGES2 at the MRO at a height of 0.05 m above the ground plane. The ends of the cable are grounded through ferrite chokes with an assume impedance of 900 ohms. The ferrite chokes damp and broaden the resonance. The 408 MHz Haslam et al. map was used for the foreground sky model.