EDGES MEMO #395

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To: EDGES Group

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Subject: FEKO modeling ground loss for layered soil in the arctic

Obtaining the spectral structure of the ground loss using FEKO is limited by "glitches" as discussed in memos 239, 277, 313, 315, 308, 370, 375, 378, 384, ASU memo 150 "Calculating total gain of the antenna above the horizon" and ASU memo 153. Modeling the loss of an EDGES deployment in the arctic requires an assessment of the frequency structure which maybe introduced by the layered ground as discussed in memos 388, 390 and 393 which show that an acceptable beam chromaticity can be obtained by a 50x25m ground plane which is large enough to avoid significant sensitivity to the details of the layered soil below the ground plane. While it may be possible to apply corrections for the beam chromaticity and chromaticity of the loss of a small ground plane using the dielectric and conductivity of the layers using a soil probe it will still require accurate EM modeling using FEKO, CST or other software to be able to apply accurate beam chromaticity and loss corrections to the data.

The plots in Figure 1 show the frequency structure produced by the loss obtained using the integration over the beam above the horizon compared with unity compared with the frequency structure using the fraction the integrated beam below the horizon. The beam chromaticity shown in figure 2 of memo 393 is free of resonances so that is it fairly certain that the jump at 70 MHz is a computational "glitch" in FEKO. It should be possible to obtain "glitch free" loss for a "layered ground" using a non-conducting 50cm thick layer soil of dielectric 3.5 above a permafrost layer of dielectric 7.0 to minus infinity in free space but when this method is used FEKO reports a divide by zero error. In order to avoid the divide by zero (error #3977 reported by FEKO an error which is reported by others on the web) a conductivity of 1e-9 S/m is used for the 50cm layer of soil. Owing to the almost zero conductivity of the soil and zero conductivity of the permafrost the computed loss, which has 5 polynomial terms removed, represents an upper limit of the loss. The effect of the loss on sky noise temperature is estimated using

$$Tsky = 300(f/150)^{-2.55}(1-l) + 300l$$

where $f$ is the frequency in MHz and $l$ is the loss fraction which is about 1 percent.

The plot on the right has a rms of 66 mK which drops to 19 mK if the frequency range is restricted to 54 to 100 MHz which is low enough that frequency structure in the loss is not likely to be a major contributor to the systematics which limit the accuracy of the global 21-cm spectra. These tests used the 2022 version of FEKO which runs a little faster than the 2018 version.

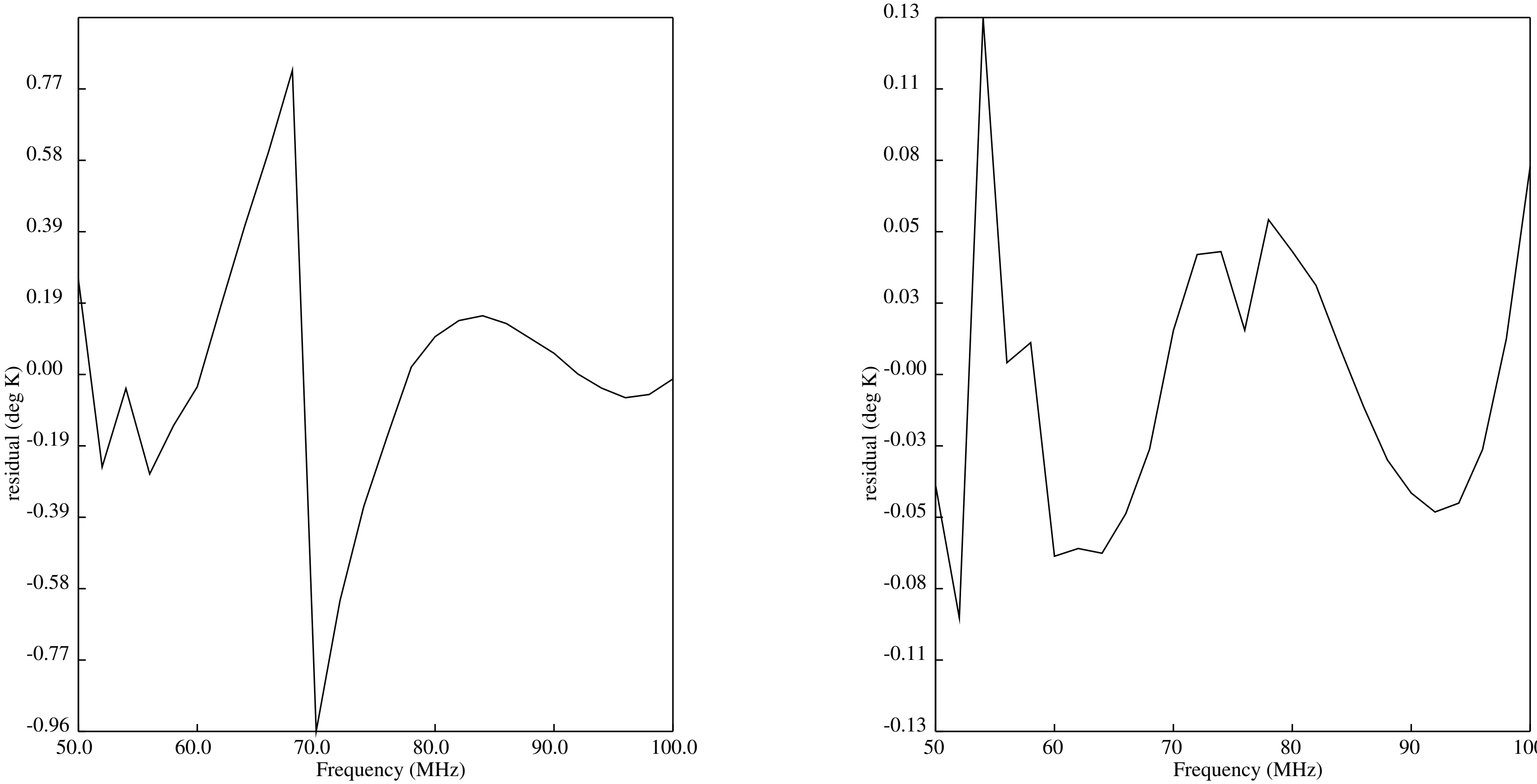


Figure 1. Effect of loss on the sky noise with 5-terms removed using the GF method for layered ground of 50cm thick soil with dielectric 3.5 conductivity 1e-6 S/m over layer of permafrost with dielectric 7 and conductivity 1e-4 S/m. The plot on the left is from the FEKO beam which is computed from the beam above the horizon using the GF method to account for the layered soil below the ground plane but has a large glitch. The plot on the right is from the FEKO calculation over all angles above and below the ground plane to obtain the loss from the fraction of the total beam power below the ground plane.  Since nonconducting layers need to be assumed for this method this loss estimate is an upper limit.