EDGES MEMO #459

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To: EDGES group

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Subject: Simulations of the sensitivity of EDGES-3 to conditions at Adak

The proposed wire grid ground plane with the dimensions used in memo 393 and antenna orientation of 240 degrees with rodent proof metal covered cables for DC power and fiber described in memo 457 is used as the reference for FEKO simulations. On the assumption that the EDGES-3 internal calibration system is accurate and the changes in S11 at night are small the main sources of instrumental error will be due to a lack of knowledge of the beam chromaticity and loss due to moisture.

Table 1 shows the results of FEKO simulations made of the beam, loss and antenna s11 using the model shown in Figure 4 of memo 457 as a reference to simulate data from 50 – 110 MHz with the 2018 EDGES 21-cm result added which is then processed with a different model with 5 loglog terms removed 58-102 MHz over 1 hour blocks of GHA at a azimuth of 240 degrees at Adak. The second entry includes the effect of the change of antenna s11. The other entries include the effects of moisture on the parts listed. The rmsin is the rms after averaging over GHA prior to fitting an absorption and rms is the rms after including the best fit absorption.

| ref. EDGES-3 on wire grid at Adak | Freq MHz | SNR | sig K | width MHz | rmsin mK | rms mK |
|---|---|---|---|---|---|---|
| EDGES-3 on PEC | 78.1 | 108 | 0.56 | 19.1 | 0.038 | 0.006 |
| EDGES-3 on PEC with s11 | 78.1 | 81 | 0.42 | 20.9 | 0.176 | 0.008 |
| 0.1 mm water on sides & connector | 77.7 | 109 | 0.58 | 19.0 | 0.039 | 0.006 |
| 0.2 mm rain water on sides | 78.1 | 107 | 0.56 | 19.1 | 0.039 | 0.006 |
| 5 cm rain water above wire grid | 77.7 | 83 | 0.73 | 19.4 | 0.049 | 0.010 |

Table 1. Results of simulated grid search for 2018 EDGES 21-cm absorption with systematics

Table 2 shows the results of the simulated grid search for 3-cases without beam correction for 1 hour blocks of nighttime data. While rain water changes the antenna s11 it actually slightly lowers the beam chromaticity.

| case | Freq MHz | SNR | sig K | width MHz | rmsin mK | rms mK |
|---|---|---|---|---|---|---|
| EDGES-3 ref. | 78.1 | 55 | 0.67 | 18.9 | 0.032 | 0.006 |
| PEC | 78.1 | 296 | 0.53 | 18.8 | 0.028 | 0.002 |
| 5 cm rain water above wire grid | 78.5 | 87 | 0.57 | 18.6 | 0.026 | 0.009 |

Table 2. Results using antenna s11 but without beam correction

Table 3 shows the result of raising the ground plane wires under the antenna. This emphasizes the need to ensure that the ground plane wires under the antenna remain in a stable location as a change in height has a large effect on the antenna s11. This can be calibrated but must remain constant to within

about 2 mm during observations. The last entry in Table 3 is for a box height change from 88 to 87.2 cm for a change of 2 mm.

| box height changed 88 to 85 cm | Freq MHz | SNR | sig K | width MHz | rmsin mK | rms mK |
|---|---|---|---|---|---|---|
| EDGES-3 2018 feature added | 90.6 | 49 | 0.51 | 19.4 | 0.083 | 0.009 |
| EDGES-3 without added feature | 69.2 | 22 | 0.37 | 11.8 | 0.066 | 0.028 |
| EDGES-3 2018 feature added 2mm | 77.4 | 75 | 0.46 | 19.9 | 0.036 | 0.007 |

Table 3. Effect of antenna s11 change with ground plane wires raised 3 cm and 2mm

The potential use of hooks on 1 inch thick wood planks instead of plastic pegs for the meandering wire grid ground plane would raise the wires off the ground by 1 inch but the weight of the wires will ensure that they will be on the ground under the antenna and on this assumption the only effect will be a change of beam chromaticity. This is found to have the very small change in the simulation results shown in table 4.

| Ground plane wire grid raised 1 inch | Freq MHz | SNR | sig K | width MHz | rmsin mK | rms mK |
|---|---|---|---|---|---|---|
| EDGES-3 2018 feature added | 77.7 | 161 | 0.53 | 19.5 | 0.037 | 0.004 |

Table 4. Effect of using 1 inch wood planks with hooks instead of plastic pegs for wire grid

A simulation of using separate cables within a metal shield as in figure 4 of memo 457 and separate cables for power and fiber shows that this choice makes very little difference on antenna s11 or beam chromaticity. The results of simulation using the FEKO model using a single cable and processing using the FEKO model for separate cables are given in table 5.

| Separate cables for power and fiber | Freq MHz | SNR | sig K | width MHz | rmsin mK | rms mK |
|---|---|---|---|---|---|---|
| EDGES-3 2018 feature added | 78.1 | 149 | 0.53 | 19.2 | 0.035 | 0.004 |

Table 5. Separate cables for power and fiber using a single cable with power as reference

Power line filtering in a box connected to the antenna is needed to obtain the >200 dB isolation needed to avoid the amplified analog signal producing feedback by coupling back into the antenna and to avoid RFI from the generator and other electronics in the building about 170 m away. The filtering used in the EDGES-3 at the WA is shown in memo 399 and the feedback tests are described in memo 425.

A FEKO simulation of the effect of a larger box for the termination of the power and fiber cables is made below. This box needs to be large enough to accommodate the filters and the bend radius of the fiber cable. The test results in table 6 show that a larger box has little effect on the beam chromaticity, loss or antenna s11. Based of tests discussed in memo 425 concern over the potential of feedback and the need to avoid a direct connection of the cable to the box without filtering. Memo 399 shows the cable filtering at the EDGES-3 in WA.

I suggest cables come into the box with insulated covers without electrical connection and then inside the box to pass a wire connected to the metal shield through a ferrite to the box ground and negative DC wire go though another ferrite connected to box ground. The positive DC go through a ferrite and Tusonix filter connected to box ground and then up the pipe into the electronics as in figure 1 of memo 399. The dimensions and detailed design of the filter box are still TBD. Table 6 below shows that the length of the box has very little effect on the antenna s11 and the beam chromaticity.

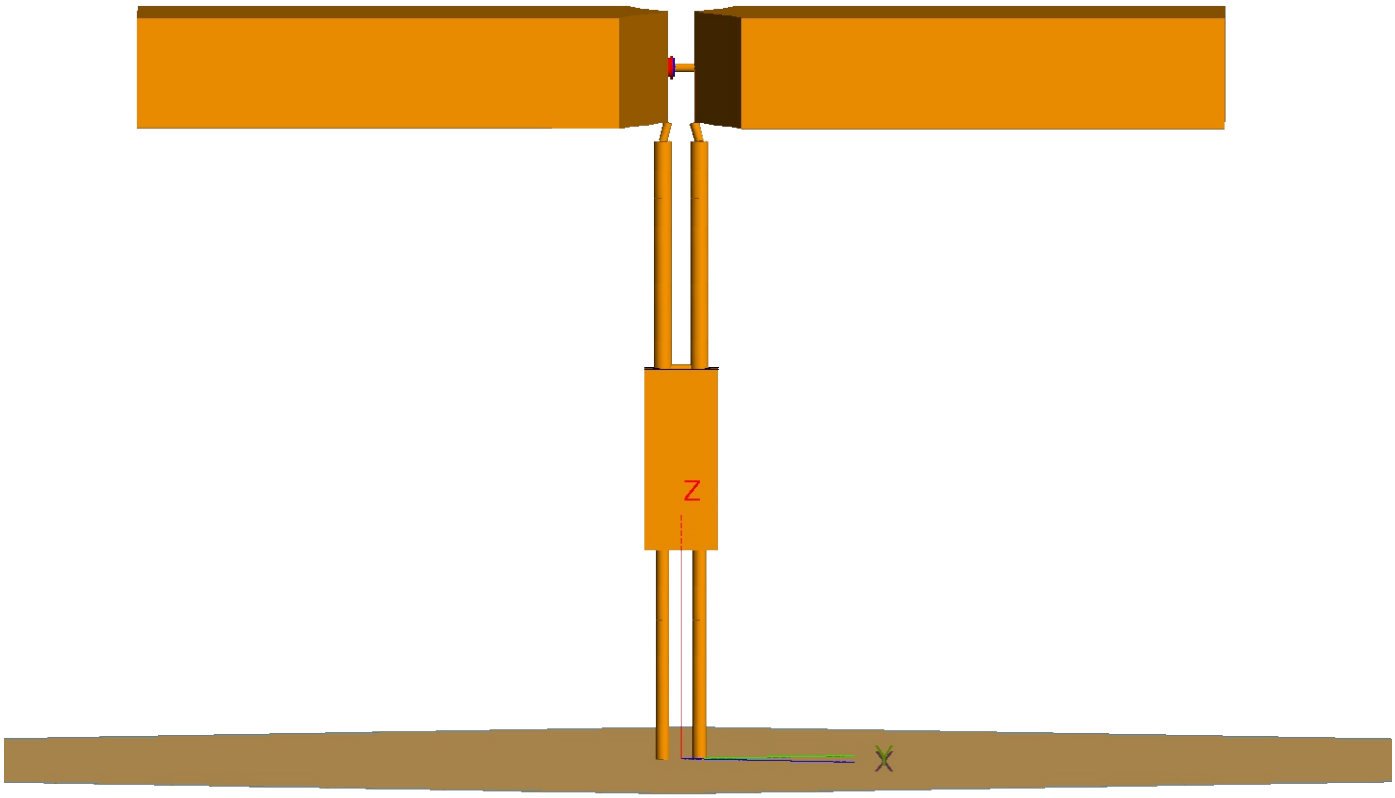
| Box for cables 4x4” square x-section | Freq MHz | SNR | sig K | width MHz | rmsin mK | rms mK |
|---|---|---|---|---|---|---|
| EDGES-3 2018 feature added 5 cm | 78.1 | 393 | 0.50 | 18.7 | 0.039 | 0.0016 |
| EDGES-3 2018 feature added 25 cm | 78.5 | 146 | 0.50 | 18.2 | 0.060 | 0.0046 |

Table 6. FEKO simulations of box height of 5 and 25 cm

The FEKO model for the box used in the simulations of the EDGES-3 antenna with the height is shown in Figure 1. The “pipes” from the ground with DC power and fiber go into the box without electrical connection and get filtered and connected to the positive DC line and fiber which go up into the electronics box in the antenna.

In summary these simulations show that the following are needed to keep changes in antenna s11 at acceptable levels during observing sessions:

1] Layers of water under 200 micron thick on the critical parts of the antenna.
2] A build up of the water above the wires under the antenna of less than 5 cm.
3] Changes in any “bumping up” of the ground plane wires above the ground below the antenna under 2 mm and “bumping up” changes a meter away would need to be under 1cm and at 5m away to be under a few cm.





| Altair Feko™ | test7<br>2024-10-08 07:40 | View direction<br>Theta = 89°<br>Phi = -44° |
|---|---|---|

Figure 1. FEKO model of filter box of 25 cm height.