EDGES MEMO #371

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October 14, 2021

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To: EDGES Group

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Subject: Simulations of effects of scattering on absorption search with antenna with small ground plane

Memo 370 uses simulations to show that the ground loss has significant spectral structure. This spectral structure can be modeled using a polynomial with more than 5 terms over a frequency range of 52 to 99 MHz. However, using more terms reduces the rms of the residuals of absorption signatures before fitting that are smooth so that it may not be possible to distinguish a signature with tau = 7 or higher from signatures with lower values of tau so that tau may need to be constrained.

Table 1 shows the results of simulation of the effects of ground loss for the lowband blade antenna on uniform soil with dielectric 3.5 and conductivity 2e-3 with and without a 2.4x2.4m square ground plane for different numbers of polynomial terms to remove the foreground and unknown ground loss.

Ground plane	# terms	center MHz	SNR	amp K	width MHz	rms1 mK	rms2 mK
none	5	78.1	60	0.47	18.8	73	13.4
none	6	78.1	60	0.44	19.2	29	5.2
2.4x2.4m	5	70.3	11	1.26	14.8	254	176
2.4x2.4m	6	82.0	22	1.34	29.9	92	41.1
2.4x2.4m	7	77.7	29	0.46	21.0	32	11.3

Table 1. Simulations of feature search with Nature feature added to sky at +78 deg latitude

The rms1 and rms2 are the rms residual for EDGES polynomial fit before and after fitting for best fit absorption with tau=7 respectively from 52 to 99 MHz. This shows that the 2.4x2.4m ground plane requires 7-terms in the absence of a model for the ground loss whereas without the ground plane the ground loss is smooth enough that 5 terms are sufficient for uniform soil. The advantage of having to use only 5-terms for the foreground and ground loss is that the residuals in the presence of the Nature feature are larger than the added ripple due to scattering. The simulations used a EDGES-3 antenna but results for the lowband, midband and MIST (from MIST memo33) blade antennas are similar.

In order to illustrate the difficulty of needing 7-terms to model the foreground and ground loss when additional systematics are present a simulation made by introducing a 500 ps error in antenna S11 as an added systematic which like scatter introduces fine scale structure. The results are given in Table 2.

case	ground plane	Nature feature	Antenna S11	rms residual mK
1	none	Not added	500ps offset	32
2	none	added	500ps offset	31
3	none	Not added	No offset	11
4	none	added	No offset	20
5	2.4x2.4m	Not added	500ps offset	77
6	2.4x2.4m	added	500ps offset	75
7	2.4x2.4	Not added	No offset	16
8	2.4x2.4	added	No offset	30

Table 2. Residuals for 7-term fit from 52 – 99 MHz and details for plots in Figure 1.

Figure 1 shows the plots of the residuals for cases 1 to 8. Note that when the Nature feature is added the residuals in cases 2 and 6 are lowered owing to the correlation introduced by the 500 ps offset to the antenna S11 whereas without the systematic the rms will increase so that the subtraction of the Nature feature if present in the sky would normally decrease the rms. If the offset is changed to minus 500ps the correlation with the systematic results in a larger than expected decrease in rms.

In summary the difficulty of a 21-system with a small ground plane on soil is that without an accurate knowledge of the soil 7-terms may be required to remove the fine frequency structure in the ground loss which makes the detection of the 21-cm absorption more sensitive to other systematics like those from scattering from an uneven ground and nearby objects.

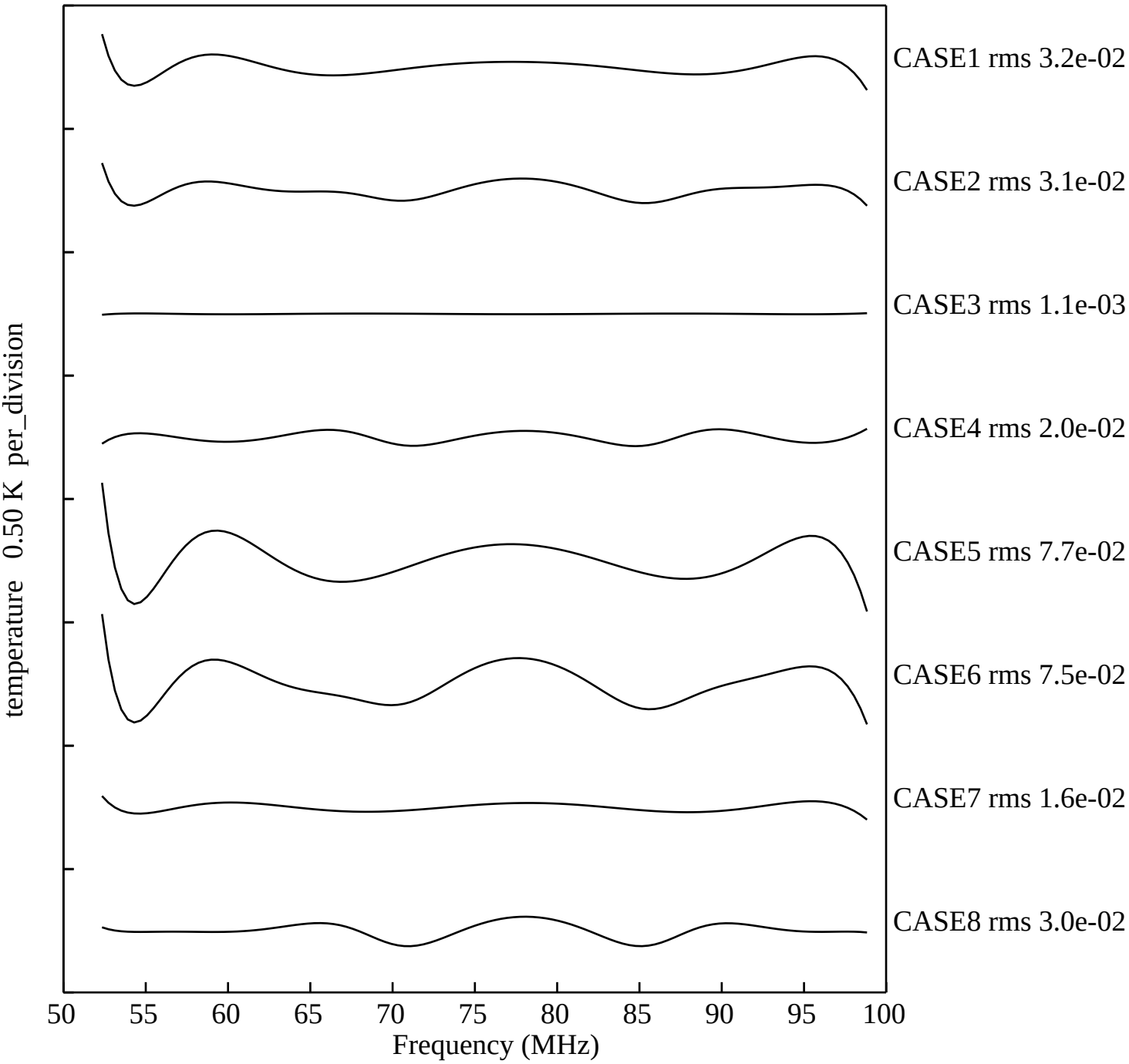

Figure 1. Plots of the residuals for the 8 cases listed in Table 2.