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To: EDGES group

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Subject: A test of the effect of feedback on the 21-cm absorption measurements of EDGES

Many tests have been made on the EDGES results which include measurements with different ground planes, different antenna orientations, different ranges of Galactic Hour Angle (GHA), with and without beam correction, loss correction and with different antennas. In this memo we look in more detail at the effect of a small fraction of the amplified sky signal at the ADC would have if it is coupled into the antenna.

The EDGES system uses a radiometer which has been accurately calibrated using spectra from hot and ambient temperature loads as well open and shorted cables along with VNA to measure reflection coefficients of the loads, antenna and the LNA. Noise waves are estimated from the spectra of the open and shorted cables. The accuracy can be be verified in the laboratory using an “artificial antenna” which is a noise source whose noise temperature has been estimated using using the noise from a high temperature thermal source generated using a tungsten filament whose is determined from its resistance as described in memo 104.

It is more difficult to verify the loss and beam chromaticity of the antenna, which includes a large ground plane so FEKO and CST modeling is needed. The accuracy of the modeling can be partially verified from the ability to obtain low residuals.

Verification of an absorption requires enough integration time and very low systematics in order to get a reliable detection of an absorption feature. Table 1 shows the contribution of a flattened absorption feature centered at 78 MHz with 19 MHz width and 500 mK depth without noise or systematics. The simulations are made for the EDGES-3 at the MRO (recently renamed the WA) with antenna azimuth of 269 degrees.

Frequency range MHz	tau	Poly type	# of terms	GHA hours	rms mK
60 - 100	7	physical	5	0	47.5
60 - 100	7	physical	5	12	45.4
58 - 104	7	physical	5	12	55.9
58 - 104	7	loglog	5	12	41.9
58 - 104	7	physical	4	12	92.6
58 - 104	7	physical	3	12	137.1
58 - 104	4	physical	5	12	47.6
58 - 104	4	physical	3	12	126.9
58 - 104	4	loglog	3	12	99.1

Table 1 Simulated rms residuals of absorption feature in the presence of zero noise and systematics

This table shows that using few terms and a wider frequency range increases the strength of the 21-cm absorption signal but this is offset by a much larger sensitivity to systematic error.

For example:

The very high sensitivity to systematic error can be tested when using only 3 physical terms. A simulation using with 3 physical terms 58 to 104 MHz and no noise at 12 hours GHA increases from 126.9 in Table 1 to 852 mK and a best fit absorption at 82.8 MHz, a depth of 2.9K and width of 25.2 MHz with rms residual of 229 mK when no beam correction is made.

Compared with a simulation using 5 physical terms the residual goes from 47.6 to 53.5 mK with change in best fit absorption from 500 to 560 mK and change in width from 19 to 19.3 MHz when no beam correction is made. These are very small changes compared with those using only 3 terms.

The possibility of feedback of the amplified sky noise at the ADC input feeding back into the antenna is a concern and it was estimated in memo 299 that feedback of the amplified signal into the antenna requires an isolation of more than 180 dB to keep the effect of coupling under 10 mK as discussed in memo 299. The possibility of feedback was checked in an indirect manner by connecting the antenna port to a probe inside the box with the electronics as shown in Figure 6 of memo 376. Some further tests are made in this memo to see if there is any evidence for feedback using simulations and tests on EDGES-3 data.

Simulations of the effects of feedback can be made by running simulations of negative antenna loss and tests on EDGES-3 data using 3 physical terms. The plot on the left in Figure 1 shows a simulation in which the feedback has been "tweaked" by using a loss of minus 20% and the frequency range "tweaked" to 58 to 98 MHz to get a result close to the EDGES 2018 result. The plot on the right in Figure 1 shows the same simulated data processed with only 3 physical terms and shows that with 3 terms the effect of the feedback is very large.

Figure 2 shows EDGES-3 data from the WA from 2023 days processed with only 3 physical terms. The result in Figure 2 is close to the EDGES 2018 result and the 3 physical terms in the best fit have values of Tsky = 2183.80 spectral index = -2.63 ionosphere absorption = 3.80%. All 3 physical terms from the observed sky noise have reasonable values which is not the case for the simulation in Figure 1 which had Tsky = 1629.00 spectral index = -2.89 and ionosphere absorption = 3%.

In summary while measurements made with an antenna probe inside the EDGES-3 show no evidence of feedback simulations show that it is possible to adjust the feedback to produce an absorption feature close to the 2018 result using 5 physical foreground terms but the use of only 3 physical terms with the same level of feedback produces a very large absorption with very large residuals which is not observed in the EDGES-3 data. In fact the use of only 3 physical terms yields an absorption in reasonable agreement with the 2018 result at least over a selected range of days with good data from the MRO but it is emphasized that using only 3 physical terms is subject to more potential error and 5 terms are normally needed to produce residuals close the the noise level without the presence of significant structure in the residuals.

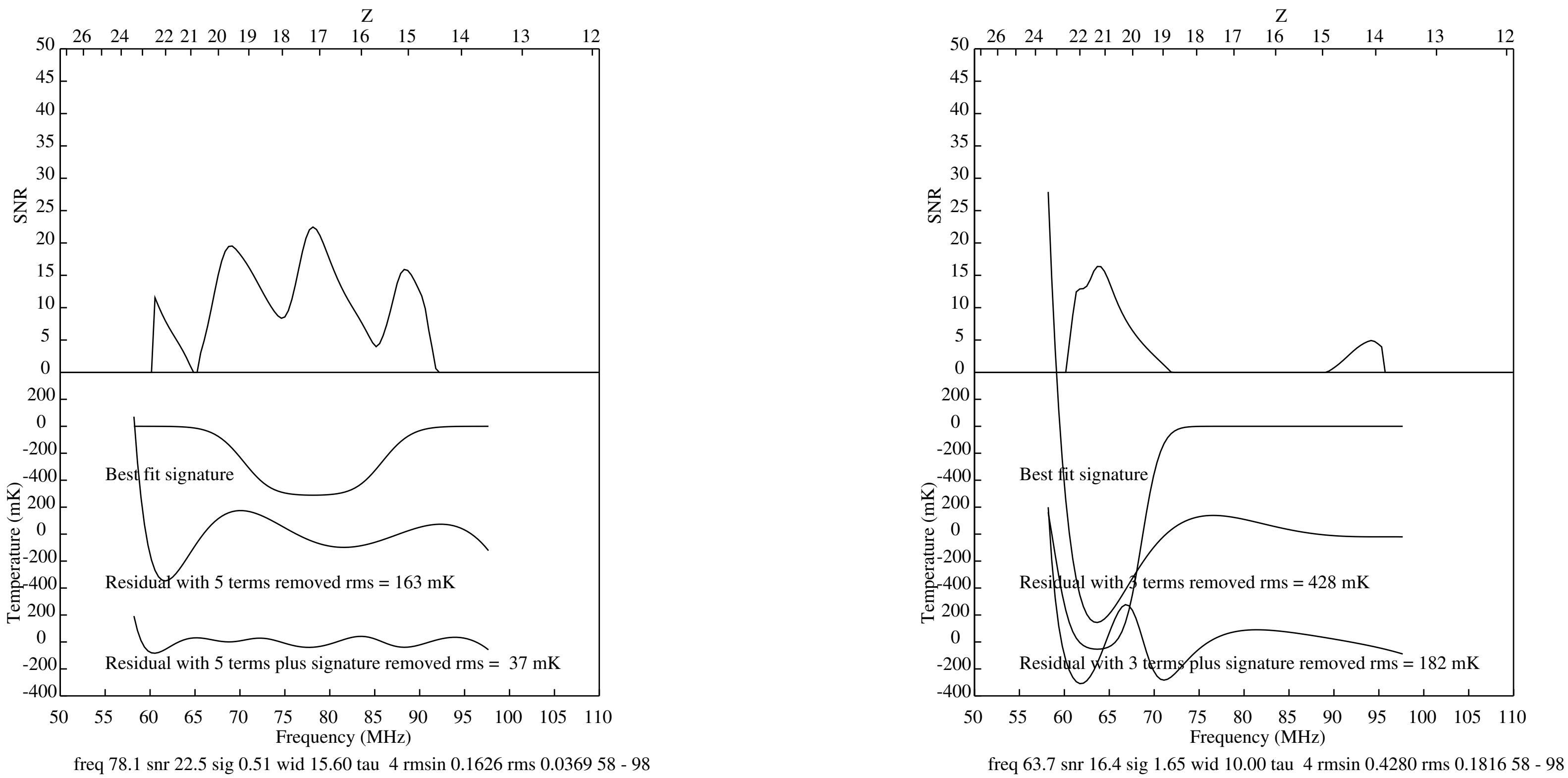

Figure 1. Simulations of feedback with 5 foreground terms on the left and with 3 terms on the right.

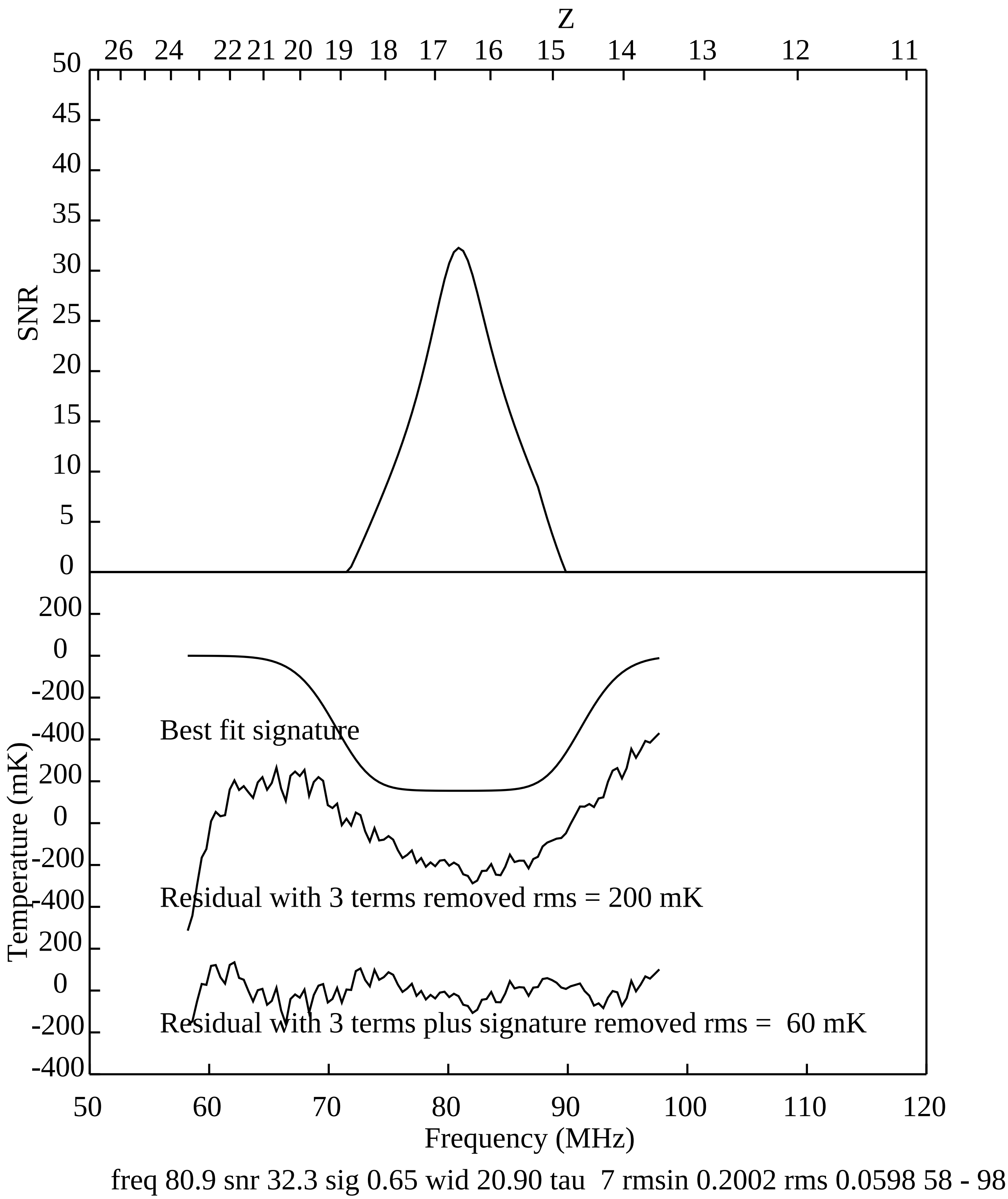

Figure 2. Absorption feature from EDGES-3 2023 day 160 to 179 using 3 physical terms.