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To: EDGES Group

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Subject: Feature at 84 MHz

An average of the low band spectra from 2015_286 to 2016_99 covering GHA 4 to 16 hrs shows a dip at 84 MHz. The rms residual to a 4-term fit from 65 to 95 MHz is 36 mK. When a Gaussian is added to physical terms of scale, spectral index, spectral curvature and ionospheric absorption the rms residual drops to 14 mK for the best fit Gaussian whose parameters are

Depth 200±50 mK

Width (FWHM) 10±2 MHz

Frequency 84±1 MHz

and the SNR is about 18. Tests to determine if instrumental effects are the source of this signal are started in memo 195. Potential candidates for an instrumental source for this signal are:

1] A “resonance” in the ground plane. Resonances have been observed in EDGES deployments. For example a “dip” was reported in memo 138. A resonance produces a dip (see memo 140) when the sky temperature is above the ambient as it is in the low band. However the effect of a resonance also produces a beam shift and consequently the effect changes with GHA.

2] A “reflection” from the electronics hut. This examined in memos 194 and 195. Like a resonance this effect will change with GHA.

3] An error in receiver calibration or antenna S11. An error in antenna S11 can be checked by comparing the “features” in the spectra at different antenna temperature levels. The ratio between GHA=0 and GHA 4 to 16 hours is about 3:1 so the “dip” should be about to 500 mK at GHA=0.

Table 1 shows the variation of the signal vs GHA with and without beam correction.

While table 1 shows some variability with GHA in the range GHA 6 to 18 a significant absorption feature is present over this range. When the Galaxy is up in the range -4 to 6 hours the rms is high with 4 terms removed. In the one case of GHA=0 there is a significant detection and it has about the same absorption depth. This lowers the probability that the absorption is due to a S11 errors as the dip would be magnified by the sky noise power ratio of about 3. However the results at GHA=0 vary so much with the beam model that it cannot be shown that the “absorption” is not due to S11 error or beam effects.

	No beam Correction		With beam correction			With beam correction 75-95 MHz	
GHA hours	Strength mK	SNR	Strength	SNR	rms mK	Strength	SNR
0					123	152	4
2					146		
4					106		
6			57	3	33		
8	143	5.3	197	11	49	144	8
10	223	15	281	22	56	252	20
12	122	6	191	11	42	230	20
14	130	3	199	14	43	238	20
16	205	3	120	3	73	177	9
18			147	3	115	251	7
20					181	329	13
22					173	317	10

Table 1. “Gaussian absorption” depth, SNR for 2 hour averages at GHA 0-22 hours. Only shows results with SNR 3 and above.

Figures 1 and 2 show the average spectrum from 67 to 99 MHz with 4-terms removed and after also fitting a Gaussian that maximizes the SNR which is about 30. In order to study the sensitivity of systematics a number of tests have been performed on the average of spectra from 2015_286 to 2016_99 covering GHA 4 to 16 hours. The results are shown in table 2. The entries in the table start with the “reference case” which is a weighted least squares fit to 4 physical terms of scale, spectral index, spectral index curvature and ionosphere absorption plus a Gaussian of full width at half power of 10 MHz centered at 84 MHz. The fit is made over a reduced bandwidth from 72 to 94 MHz. The entry “rms 1” is the rms residual of a 4 term fit and “rms 2” is the rms residual to the 5-term fit which includes the Gaussian. The reference case is for the “best calibration” and best values of ground loss and balun loss but is without any beam correction. The tests are listed in the first column. These include removing the ground loss and balun loss, adding beam correction, changing the smoothing of the antenna S11 and the day of S11 measurement. In addition a test is made of a 0.1 dB and 30 ps bias the S11 measurement. The first beam correction tests uses the beam for the blade antenna on a 9.9×9.8 m ground plane with soil dielectric 3.5 and conductivity 0.01 S/m. The second test includes a more complete model of the antenna with balun and balun shield.

Test	rms 1 mK	rms 2	Depth mK	SNR	Note
Reference	20.1	12.0	190	10.0	1
No balun corr	19.6	12.0	183	9.62	
No ground loss	21.5	12.2	209	10.85	
With beam correction	27.9	10.7	303	17.8	2
Ant. S11 +0.1 dB	20.1	12.1	188	9.8	
Ant. S11+30 ps	20.4	12.1	194	10.1	
nfit4 10-8	20.8	11.4	202	11.1	5
342-289	19.8	12.0	186	9.7	4
With beam correction	30.4	10.6	335	20.0	3
Only nighttime	24.8	13.6	242	11.25	

Table 2. Tests of sensitivity to changes in processing for 4 physical terms removed of the more limited bandwidth of 72 to 94 MHz.

Notes:

1] No beam correction
2] Beam correction using $11-3.5-1e-2$
3] Beam correction using 10gf balun 2.35
4] Antenna S11 from day 289
5] Increase smoothing of antenna S11

More tests are in progress, these include:

1] Additional modeling of the ground plane effect to extract more information on the "dip" over a larger range of GHA.
2] Verification of the S11 accuracy with laboratory measurements made with the VNA on a long cable to more accurately evaluate the level of systematics which may be due to the long cable between the electronics hut and the receiver.
3] Laboratory tests of the receiver with an artificial antenna which more closely emulates effects of the higher sky noise signal in the low band to more accurately evaluate the dynamic range of the receiver.
4] On a longer time scale increase the size of the ground plane and deploy another low band system 100 m North of the electronics hut.
5] It is emphasized that the "feature at 84 MHz" may well be instrumental and has not been shown without reasonable doubt to be from the 21-cm line.
6] An examination of local RFI. Distant RFI is eliminated as it would be very variable and strong at times and this is not observed. A comparison of averaged spectrum with moon above and below the horizon show no significant difference eliminating this source of RFI as a contribution to the feature at 84 MHz.

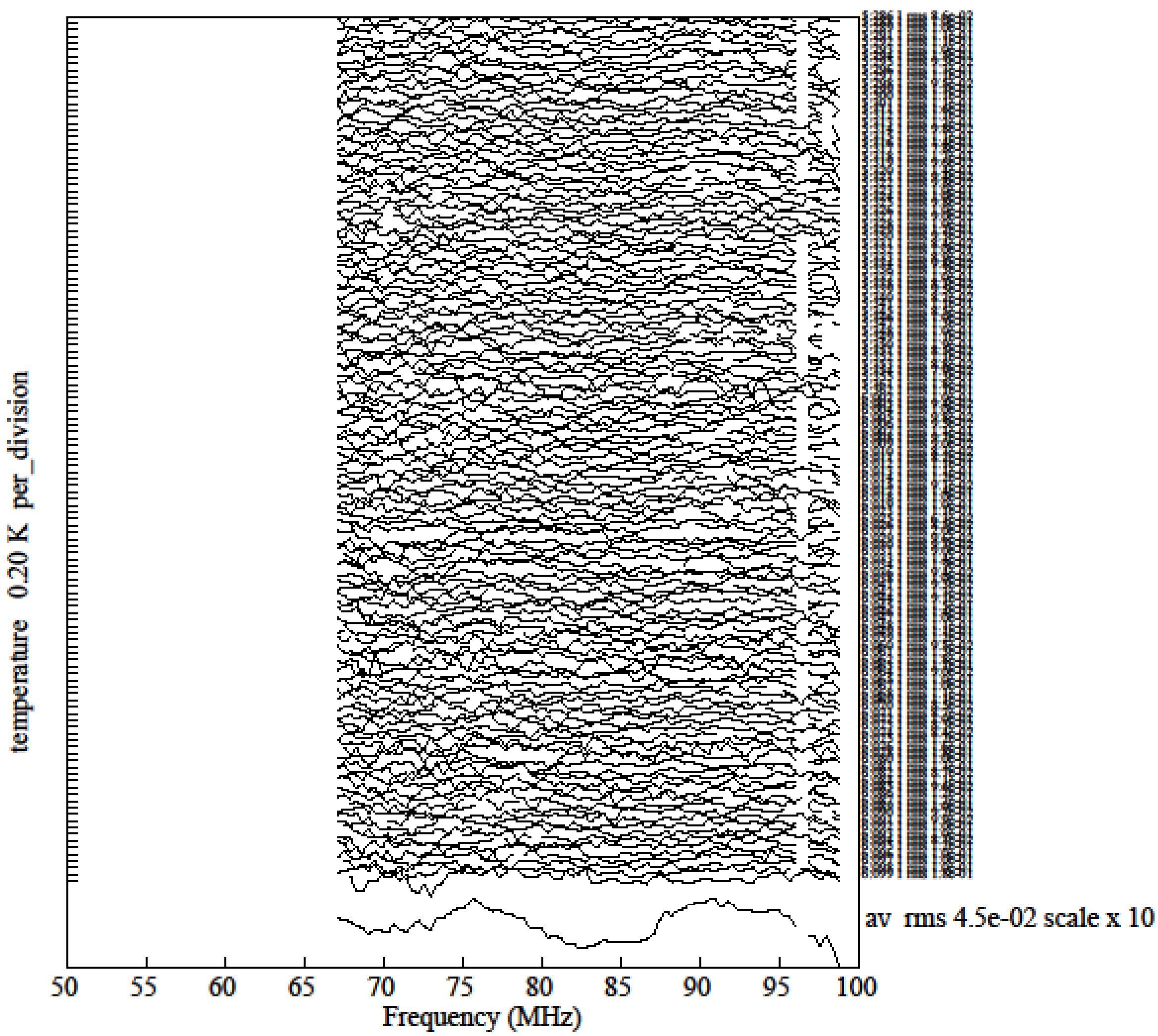

Figure 1. Spectrum averaged over GHA=4 to 16 hrs with 4-terms removed.

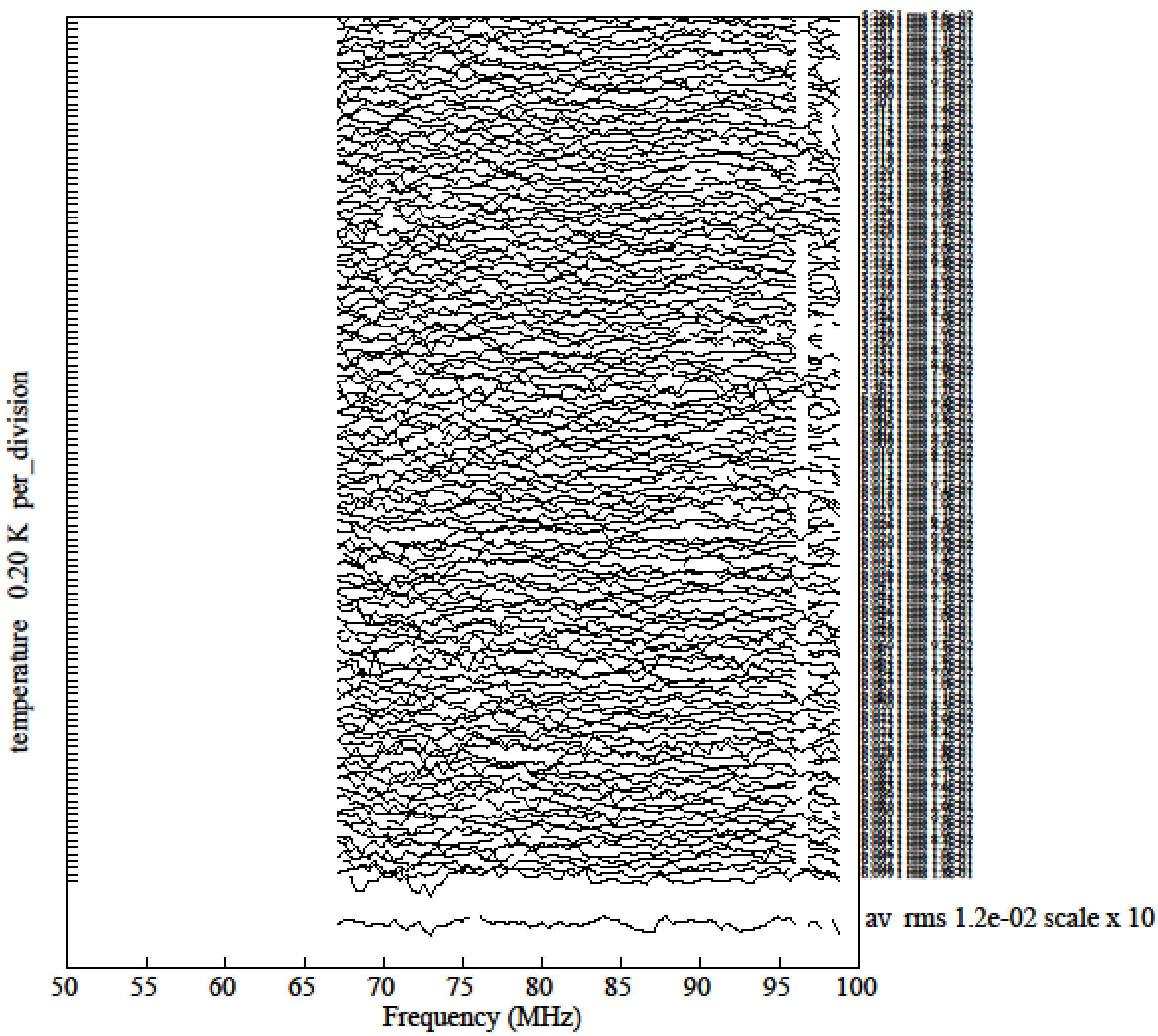

Figure 2. Spectrum average after fitting 4-terms plus an additional Gaussian centered at 84 MHz.