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To: EDGES group

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Subject: EDGES-3 simulations to assess effects calibration error using LNA circuit model

Memo 334 shows simulated data using a circuit model of the LNA with antenna s11 from a FEKO model of the EDGES-3 on an infinite metal ground plane. The c-shell script example shown below produces a plot of calibration results (comb.pdf) and 21-cm absorption plot (spez.pos) for an added feature eoramp 0.5 and beam effect at 2022:051:00:00. Many different cases can be tested by changing the arguments in the script. For example cablen -4 in simw, which provides a simulated LNA s11 without 4 inches which needs to be corrected using cablen 4 in corresy. Tests of the effects of errors in antenna s11 amplitude and phase can be made using adb and delaylna.

#!/bin/csh -f cp azelq box 1 pec.txt azelq.txt ./csv azelq.txt -mode 0 >! azelq.csv

./simw -num 1 -cabnum 2 -dlant 0.0 -dlna 0.0 -noise 0.0 -nmode 99 -mode 0 -cablen -4 -sparms 1 -Lh 0.05 -antcsv azelq.csv -lnas11amp 1 -lnas11del 2e-9 # thot=367; tcold=296 in simw.c;

./corresv s11lna.sim -cablen 4 -cabdiel 0 -cabloss 0 cp c s11lna.sim s11lna.sim

./edges3 -fstart 50 -fstop 198 -spant spant.sim -spcold spcold.sim -sphot sphot.sim -spopen.sim -spshort spshort.sim -s11ant s11ant.sim -s11hot s11hot.sim -s11cold s11cold.sim -s11lna s11lna.sim -s11open s11open.sim -s11short s11short.sim -Lh 0.05 -mfit 1 -smooth 0 -wfstart 50 -wfstop 198 -eorcen 0 -eorwid 0 -tcold 296 -thot 367 -wtmode 1 -lmode 1 -tant 296 -tcab 296 -wfit 7 -eorcen 75 -dbcorr 0.0 -delaycorr 0.0e-12 -delaylna 0e-12 -nfit4 37

gs -sDEVICE=ps2write -dNOPAUSE -dBATCH -dSAFER -sOutputFile=spe.ps spe0.pos spe1.pos spe2.pos spe3.pos spe99.pos spevna0.pos spevna1.pos spevna2.pos spevna3.pos spevna4.pos spevna5.pos spewav.pos psnup -s0.31 -12 -m50 spe.ps comb.ps ps2pdf comb.ps comb.pdf

./edges3 -fstart 50 -fstop 120 -spant spant.sim -s11ant s11ant.sim -mfit 3 -wfstart 55 -wfstop 120 -lmode -1 -tant 297 -skymode 384 -antaz 85 -wtmode 100 -nfit4 37 -smooth 0 -mdd 4 -delayant 0.0e-12 -adb 0.0 -cmb 2 -ldb 0.0 -adb 0.0 -delaylna 0.0e-12 -sim 9 -ydhms 2022:051:00:00:00 -binteg 3600 -test 9 -eoramp 0.5 -eorwid 19 -eorcen 78 -tau 7 -site 1 -fbstart 50 -fbstop 120 -bfit -12 -low 1 -aloss 0.0

./longav spe0.txt -lim 100 -nfit 5 -dmax 0.5 -fstart 55 -fstop 110 -schk 0 -rfi 0 -date -ti GHA -seor -1 -tau 7 -sig 20 -md 1 -fsmin 65 -fsmax 95 |grep rmsin

The effects of changing the offset parameters in the script are listed in the Table below. The first entry has no offsets and no beam beam effects. The last two entries show the effects of beam chromaticity and in this case the antenna spectrum is derived from the Haslam sky map whereas the other entries use simulated sky data from simw which is 300 K at 150 MHz with spectral index of -2.5 and is not a function of GHA.

In each case the 2018 21-cm result -eoramp 0.5 -eorwid 19 -eorcen 78 tau 7 has been added.

maxfreq MHz	SNR	amp	K width	MHz rms1 r	nK rms2 mK	range MHz	Offsets applied in script above
78.0	140	0.50	19.0	78	4	55-110	-skymode -384 no beam error
79.0	77	0.69	18.9	121	26	55-110	-cablen 5 inches
77.0	19	0.37	19.2	55	20	55-110	-cablen 3
78.0	19	0.32	18.7	53	20	55-110	-cabdiel 1 error in %
78.0	25	0.41	18.9	47	23	58-110	-cabdiel 1
78.0	41	0.69	19.2	106	19	55-110	-cabdiel -1
78.0	34	0.59	19.1	65	14	58-110	-cabdiel -1
78.0	105	0.47	18.9	73	5	58-110	-cabloss 50 error in %
79.0	25	0.77	19.0	137	40	55-110	-adb 0.05 error in dB
76.0	5	0.25	20.8	47	39	55-110	-adb -0.05
77.0	14	0.45	19.5	48	22	58-110	-adb -0.05
79.0	30	0.62	19.0	109	27	55-110	-delayant 300.0e-12 sec
78.0	55	0.58	19.0	91	12	55-110	-delaylna 300.0e-12
78.0	117	0.48	19.0	74	5	55-110	-1db 0.05 error in dB
78.0	136	0.51	19.0	79	4	55-110	-1db -0.05
79.0	18	0.71	20.0	120	46	55-110	-ydhms 2022:051:00:00:00
79.0	35	0.60	18.9	105	22	55-110	-ydhms 2022:051:12:00:00

Table 1. Offsets in cable path correction, antenna and LNA s11 and beam at GHA 1 and 12 hrs.

Figure 1 shows the results from the first entry in Table 1. In the cases of a significant effect the result is also shown for a reduced frequency range of 58-110 MHz.

The sensitivity to changes in the cable parameters warrants a grid search in all 3-parameters that minimize the rms residuals in the spectra of the open and shorted cables as discussed in memo 367.

Figure 2 shows that the rms residuals to the open and shorted cable spectra increase from near zero to 23 mK with a 1 percent offset in the dielectric of the cable from the VNA to the LNA.



Figure 1. Plot of simulations results from comb.pdf in script run for the first entry in Table 1



Figure 2. Plots of the cable spectra and 21-cm feature on top with cabdiel = 1 on bottom