HERA Memo 115
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Excess Corr ASU Investigations

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1 Introduction

Excess correlation has been observed in both field and laboratory tests.[cite issue] In the field the largest excesses occurred between inputs on the same snap board. Smaller excess were observed between different snaps within the same node. Bench testing with noise sources inputs at Cambridge confirmed larger than expected correlations between snap board inputs, particularly at higher frequencies. Further testing at Berkeley (HERA memo 103) confirmed this correlation with tone inputs. The correlation is observed to occur even in voltage streams captured directly after the digitizer.

This document summarizes the tests done at ASU in the second half of 2021 to investigate excess correlation seen in the load data observations for HERA. All tests in this memo were done with SNAP serial C77, connected to a 10 MHz and 1 PPS from a thunderbolt E-gps module. The module was free running and unlocked to GPS. The tests were done using the eeedb60e351bf498afcd15ed2af8a79f69760496 commit of the master branch of hera_corr_f repository, unless otherwise noted. The fft shift was set to 0xffff and the equalization coefficients were set to 400 on all inputs. Six tones were input to the six inputs used for HERA; in order of the hera_corr_f correlatior numbering: 0(N0): 163.8125 MHz, 1(E2): 201.3125 MHz, 2(N4): 140.625 MHz, 3(E6): 180.625 MHz, 4(N8): 14 MHz, 5(E10): 24 MHz, all at roughly between -5 and 0 dBm. These roughly corrospond to channels 0(N0): 671, 1(E2): 825, 2(N4): 576 , 3(E6): 740, 4(N8): 57, 5(E10): 98.

2 Tone Matricies

A few matrices were created to exemplify the correlative behavior. The row and column designation determine the input number to the snap (in order of the hera_corr_f correlatior numbering), making the diagonal axis the autocorrelations and all other correlations numbered respectively. Linear and log plots are shown, with the log plots showing vertical lines where the tones are expected to appear. They are colored by input. The Fengine used to create the matrix is labelled in the captions. Figures 1-3 show the initial matrix test for the 08-2019 and 03-2021 Fengines. The data was taken with the get_new_corr function from hera_corr_F. The 08-2019 Fengine shows some amount excess correlation on all

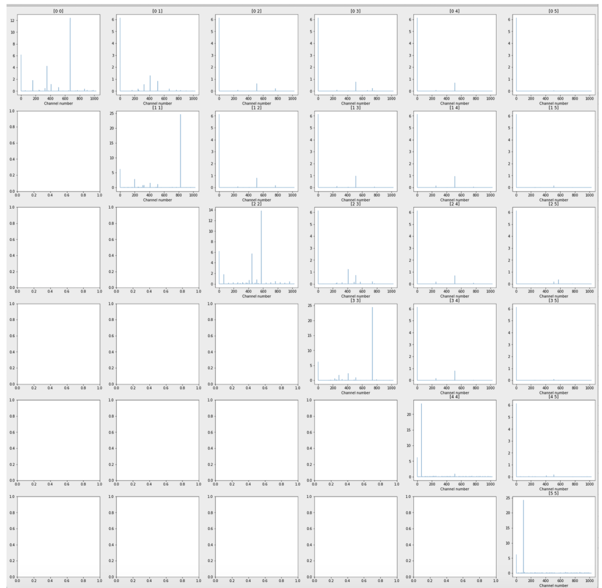

Figure 1: The correlation matrix for the 08-2019 Fengine. The row and column designation determine the input number to the snap (in order of the hera_corr_f correlatior numbering), making the diagonal axis the autocorrelations and all other correlations numbered respectively. Off diagonal correlations are expected to be close to -70 dB down if there is not excess correlation.

cross correlations, with no particular pattern. The 03-2021 Fengine shows distinctive behavior, with the tone of an input showing up on the previous input. This will henceforth be referred to as i+1 behavior.

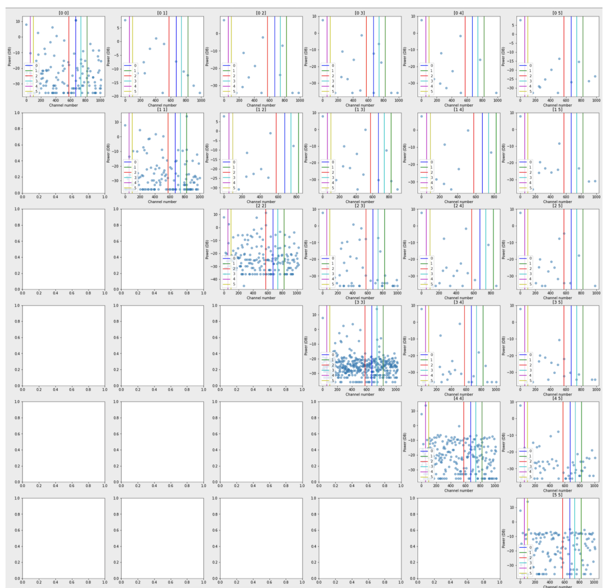

Figure 2: The correlation matrix for the 08-2019 Fengine, log scale. The row and column designation determine the input number to the snap (in order of the hera_corr_f correlatior numbering), making the diagonal axis the autocorrelations and all other correlations numbered respectively. Off diagonal correlations are expected to be close to -70 dB down if there is not excess correlation. Vertical lines indicate the expected tone locations, colored by the channel the tone is input to.

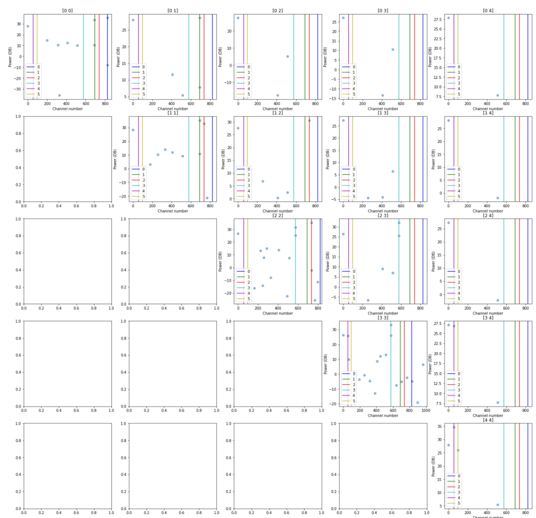

Figure 3: The correlation matrix for the 08-2019 Fengine, log scale. The row and column designation determine the input number to the snap (in order of the hera_corr_f correlatior numbering), making the diagonal axis the autocorrelations and all other correlations numbered respectively. Off diagonal correlations are expected to be close to -70 dB down if there is not excess correlation. Vertical lines indicate the expected tone locations, colored by the channel the tone is input to. Input 5 was turned off in this test.

3 ADC initialization issues

The next thing I investigated was some issues in initializing the ADCs. I noticed with the 08-2019 Fengine, it would very often initialize in a non-sensical state. The 03-2021 Fengine would do the same, but less frequently. To investigate this, I ran renitialization and data capture for input 0 20 times with both Fengines, and plotted the results in Figures 4-7. The data was taken with the get_new_corr function from hera_corr_F The tests shows that roughly 25% of initializations on the 08-2019 Fengine come up in a bad state, and 5% of the 03-2021. The two Fengines also show spectral differences, and from Jonathon Kocz the best guess for why is a change in the FFTSHIFT parameter.

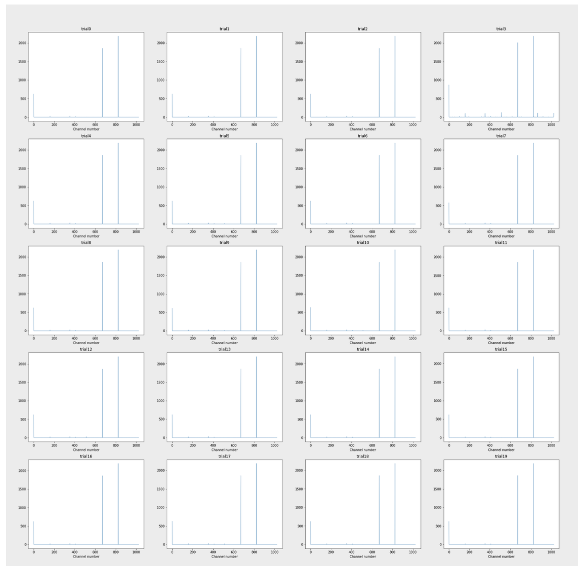

Figure 4: 20 trials of ADC initialization for the 03-2021 Fengine. On a linear scale, these look reasonable.

Figure 5: 20 trials of ADC initialization for the 08-2019 Fengine. On a linear scale, trial 5 looks like a noisy init.

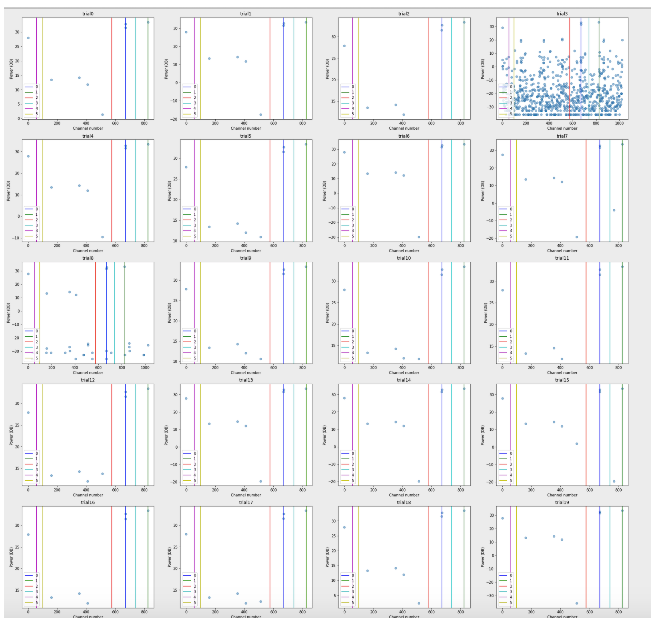

Figure 6: 20 trials of ADC initialization for the 03-2021 Fengine, on a log scale. Colored lines indicate the tones put into each channel of the SNAP. On a log scale, initialization 4 is clearly spectrally different than the rest.

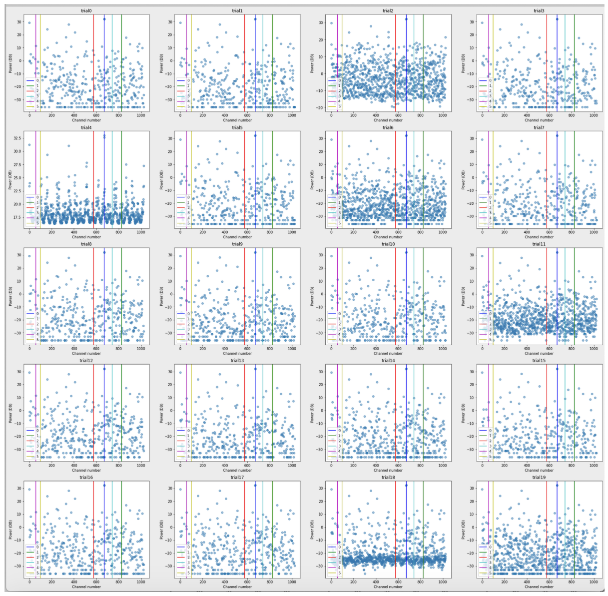

Figure 7: 20 trials of ADC initialization for the 08-2019 Fengine, on a log scale. Colored lines indicate the tones put into each channel of the SNAP. On a log scale, initializations 3, 5, 7, 12, and 19 look spectrally different than the rest.

4 Ramp tests

For the next test, we put ADC1 (controlling inputs 2 and 3) into a test mode. This test mode was in the form of a ramp. This test indicates whether the excess correlation is coming from the analog or digital portions of the SNAP board, since the ramp is an entirely digital signal. The excess correlation signal from this test with the 03-2021 Fengine clearly shows the i+1 behavior, indicating that it is a digital issue. The 08-2019 Fengine again shows a less clear pattern, but the excess correlation between inputs 2, 3, and the 4 other inputs still appears, indicating that the issue is also digital. The data was taken with the get_new_corr function from hera_corr_F.

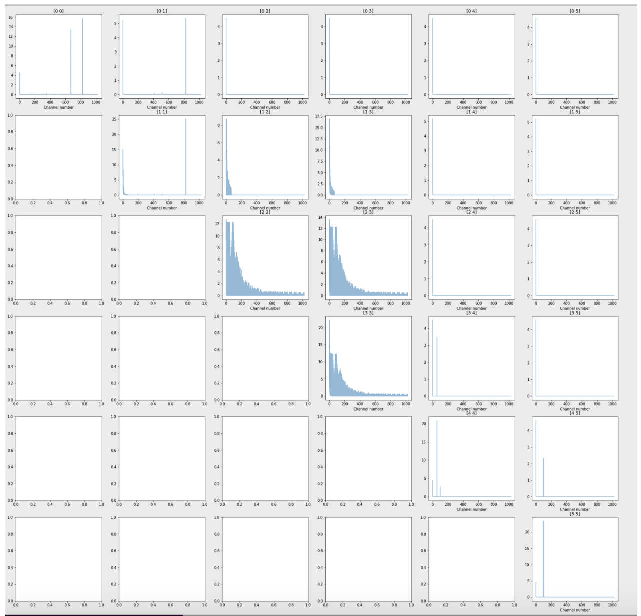

Figure 8: The ramp test matrix for the 03-2021 Fengine. The ramp from inputs 2 and 3 is clearly seen correlating with input 1 in the i+1 pattern.

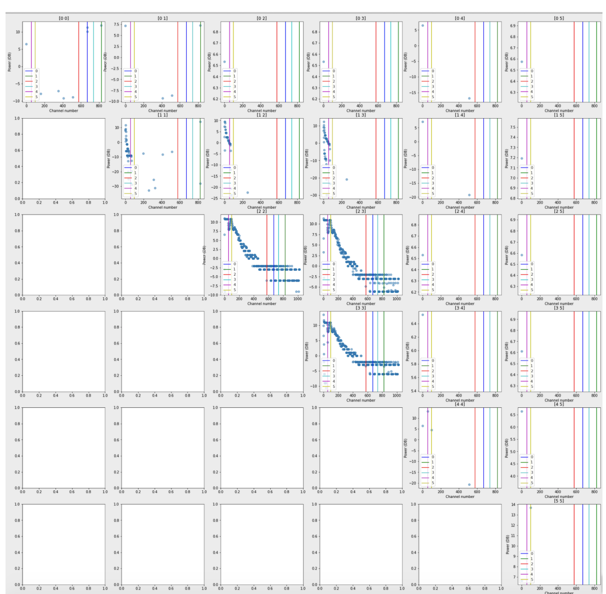

Figure 9: The ramp test matrix for the 03-2021 Fengine, log scale. The ramp from inputs 2 and 3 is clearly seen correlating with input 1 in the i+1 pattern. Colored lines indicate the tones put into each channel of the SNAP.

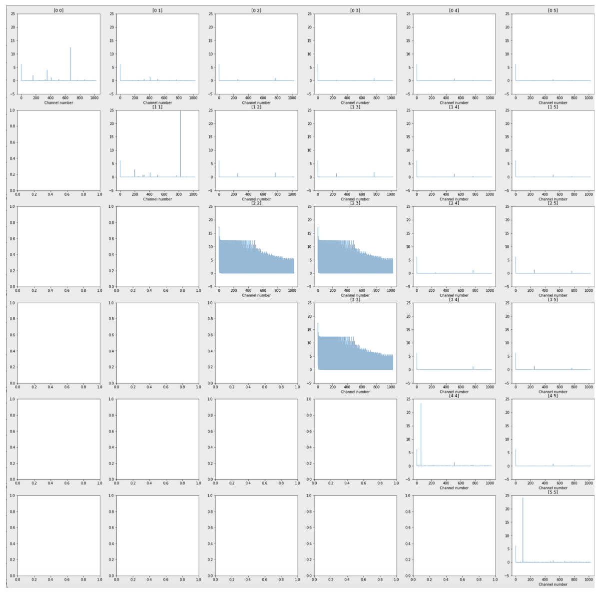

Figure 10: The ramp test matrix for the 08-2019 Fengine. On a linear scale, the excess correlation looks minimal but present.

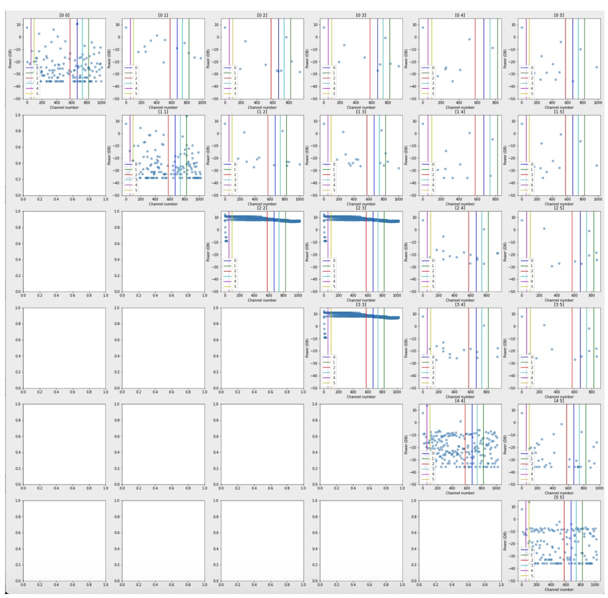

Figure 11: The ramp test correlation matrix for the 08-2019 Fengine, log scale. On a logs scale, the ramp from inputs 2 and 3 is clearly seen correlating with other inputs. Colored lines indicate the tones put into each channel of the SNAP.

5 Timestream data

All previous tests were done with the get_new_corr function from hera_corr_f, but there was interest in getting timestream data to look for streams crossing one another. One example for the 08-2019 Fengine is shown here. In the timestream data for inputs 2 and 3 it is clearly shown that the ramp is getting spurious signals.

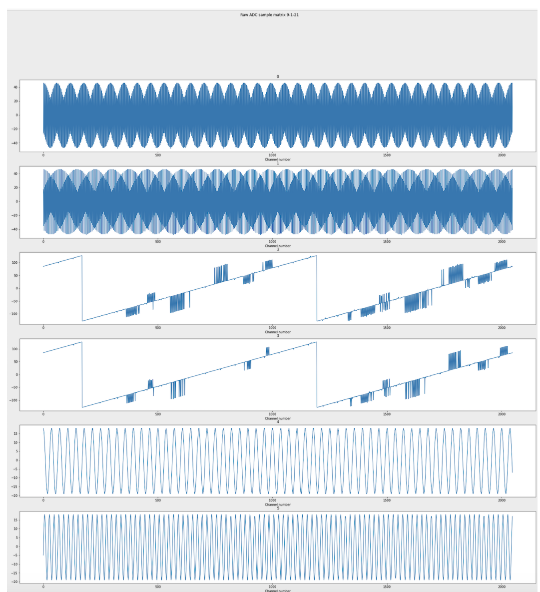

Figure 12: The timestream data for the 08-2019 Fengine. Inputs 2 and 3 are in ramp mode, and show a spurious signal. This indicates there is an issue somewhere between the actual ADC and the casper ADC yellow block, or with the readout from that block.

6 Long integration tests

To look at long term stability of the excess correlation, I ran the get_new_corr function in hera_corr_f in a loop for an hour and plotting waterfalls and power vs time for this data. The 03-2021 Fengine looks very stable over the course of an hour, with the notable exception of input 5, while the 08-2021 Fengine looks less time stable. The tones are colored by input.

Figure 13: 1 hr integration waterfalls for the 03-2021 Fengine. The i+1 behavior is clearly seen.

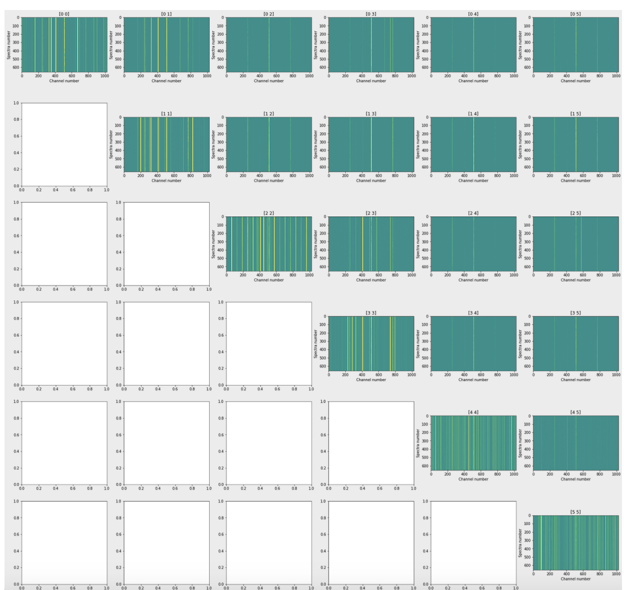

Figure 14: 1 hr integration waterfalls for the 08-2019 Fengine. Off diagonal correlation is clearly seen.

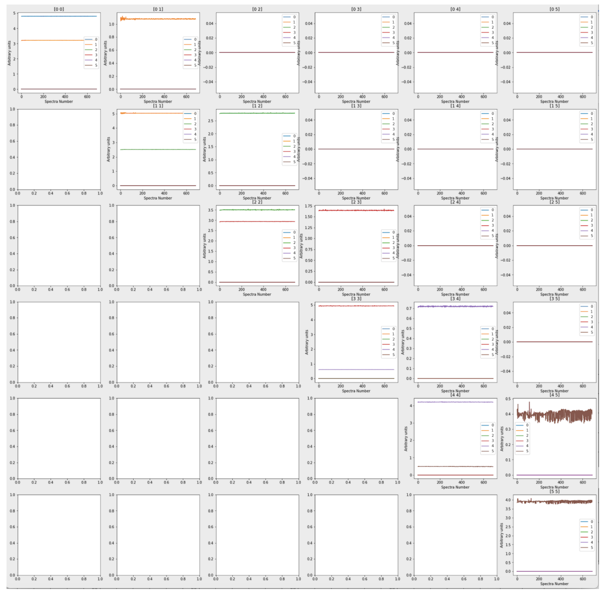

Figure 15: 1 hr integration Power vs time for the 03-2021 Fengine. The i+1 behavior is clearly seen, and things look fairly time stable. The colored lines indicate the channel that the tone is put into.

Figure 16: 1 hr integration power vs time for the 08-2019 Fengine. Off diagonal correlation is clearly seen, and things seem to vary a bit with time. The colored lines indicate the channel that the tone is put into.

7 i+1 fix

The issue causing the i+1 error in the 03-2021 Fengine was discovered and fixed. The issue was narrowed down to an incorrect delay in the first tap of the polyphase filter band, causing data to move through the PFB too quickly. Therefore, one antenna's stream was showing up in the previous antenna's data. The following plots (figures 17 and 18) show the matrix plots for the corrected Fengine, dated 10-2021. Excess correlation is still present, but at a much lower level without the i+1 correlation.

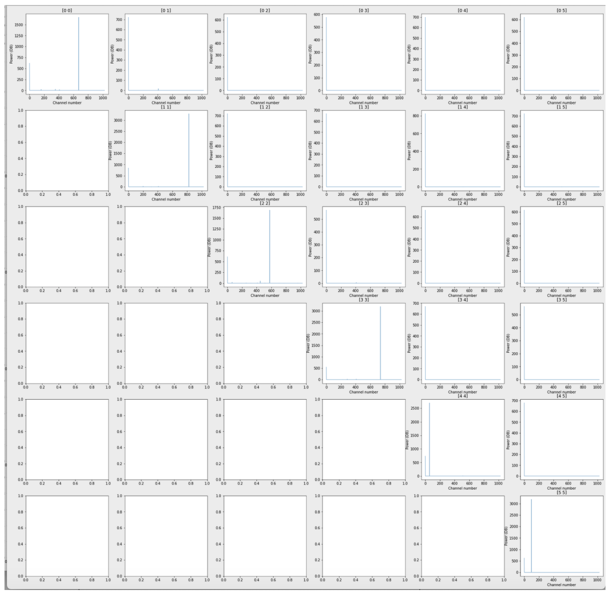

Figure 17: The tone matrix for the new 10-2021 Fengine with i+1 fix. i + 1 tone leakage is no longer evident in the auto or cross correlations.

Figure 18: The tone matrix for the new 10-2021 Fengine with i+1 fix, log scale. i+1 tone leakage is no longer evident in the auto or cross correlations. The colored vertical lines indicate where the tones will be, colored by which input they are expected to appear on.