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Excess Corr Berkeley Investigations

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1 Introduction

This memo summarizes the excess correlation investigations in the Berkeley lab. We investigate attempts to reproduce the excess correlation signal seen in the Cambridge lab, as well as further tests.

2 Setup

A SNAP board with the lid off (serial C77) was running the 2021-03-03 snap fengine firmware, connected to a 10 MHz and 1 PPS from a white rabbit module. The tests were done using the master branch of hera_corr_f repository. The fft shift was set to 0xffff and the equalization coefficients were set to 400 on all inputs.

3 Reproduction of excess correlation signal

3.1 Tests with default MUX

For the initial test to see if we could reproduce the excess correlation seen on site in the Berkeley lab, as Cambridge has already done, we started with two independent noise sources from the RAL noise generator. The spectra for the noise sources are plotted in figure 1. We drove input E2 on the SNAP with the left noise source, and input N0 with the right noise source. The MUX settings were left at the hera_corr_f defaults of (1,1,3,3). A drawing of what this MUX looks like is included in figure 2.

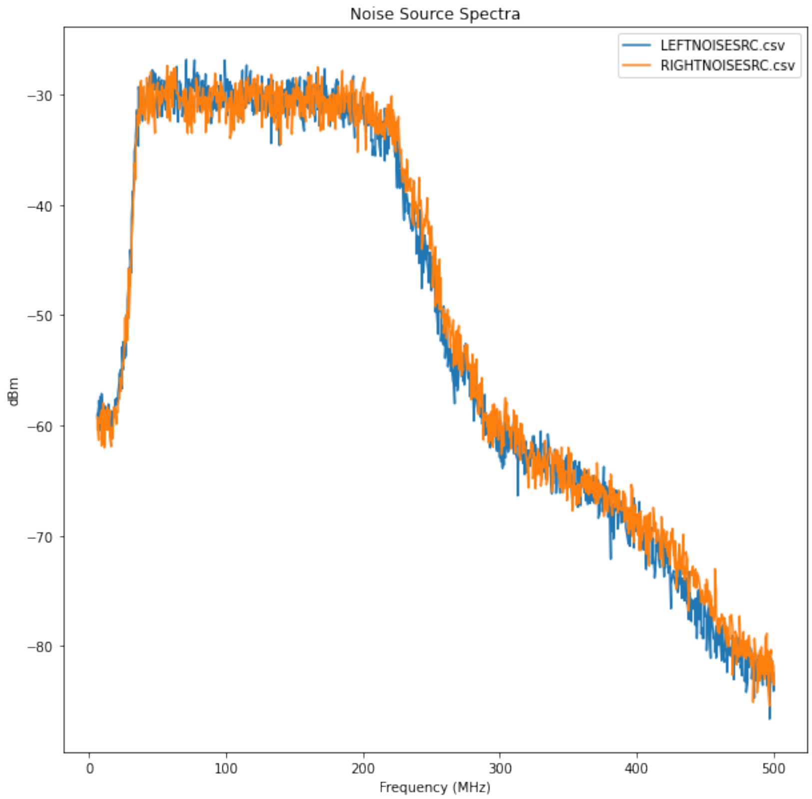

Figure 1: Spectra of the RAL noise sources. The Left and Right sources on the box are labelled LEFTNOISESRC.csv and RIGHTNOISESRC.csv, respectively

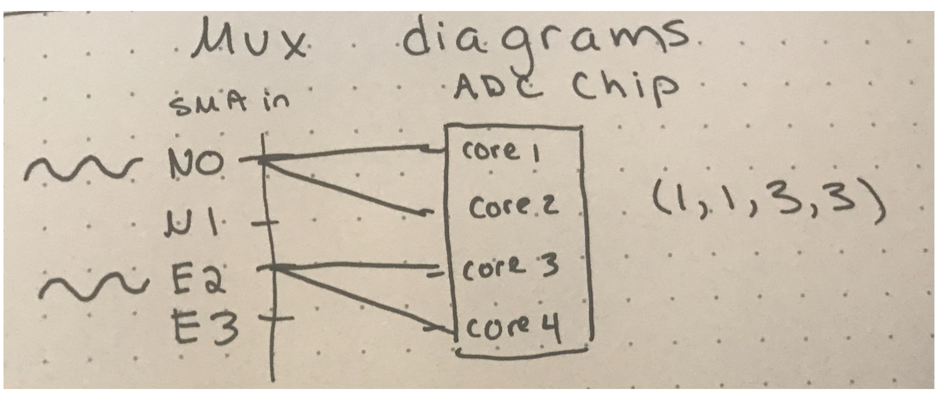

Figure 2: A diagram of the mapping of SMAs to the ADC with mux 1133 and signal on N0 and E2

The autocorrelation for input N0 is shown in figure 3. The autocorrelation for input E2 is shown in figure 4. The cross-correlation, showing the excess correlation between the two sources, is shown in 5. This is consistent with what Cambridge has been seeing.

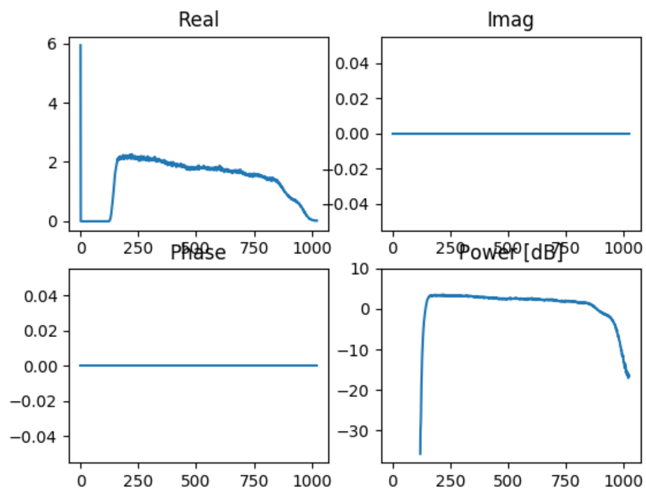

Figure 3: Autocorrelation for N0

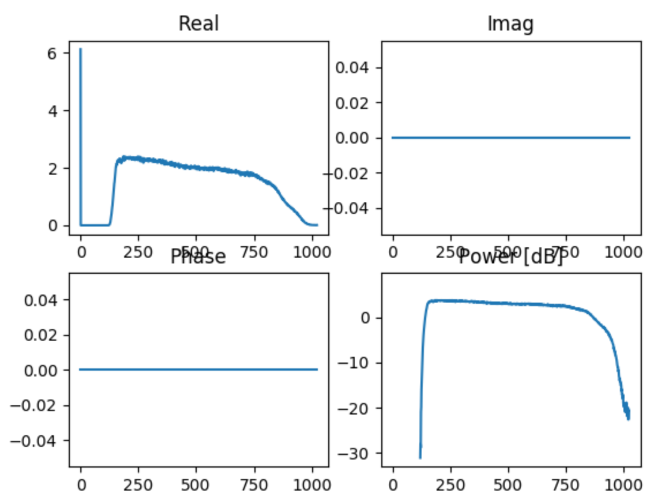

Figure 4: Autocorrelation for E2

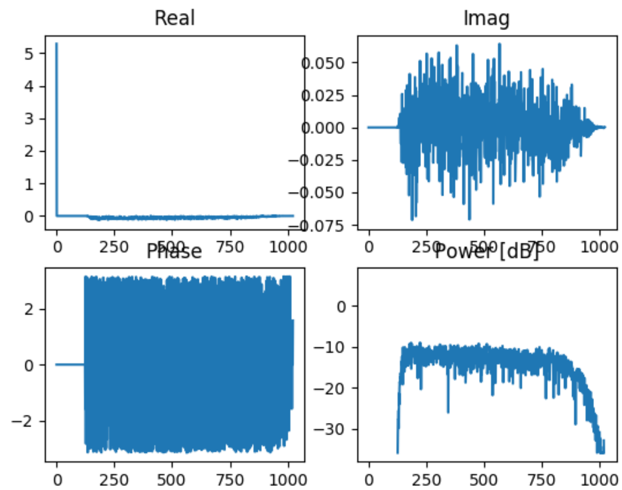

Figure 5: Crosscorrelation of N0 and E2

3.2 Test with Mux (1,1,1,1)

The next test we did was to change the MUX from the default HERA settings to 4 copies of the same SMA signal. The diagram of this MUX is shown in figure 6. This test was to show that if we drove the ADC cores with 4 copies of the same signal, we would see the expected near perfect correlation. The input tones on N0 and E2 were left the same as the previous test, however the ADC should only be seeing input N0 due to the MUX settings. E2 is driven at the SMA but disconnected to the ADC. The normal auto for N0 is shown in figure 7. The auto for the ADC input that used to be E2 but is now another copy of the signal for N0 is shown in figure 8. The cross of these two ideally identical signals is shown in figure 9. This test looks as expected.

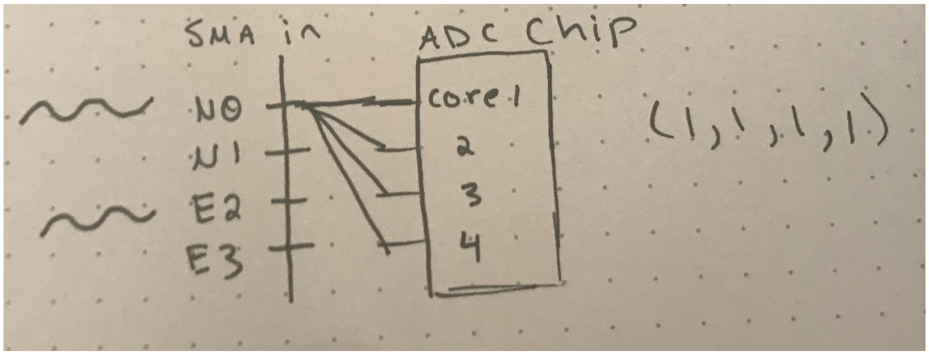

Figure 6: A diagram of the mapping of SMAs to the ADC with mux 1111 and signal on N0 and E2

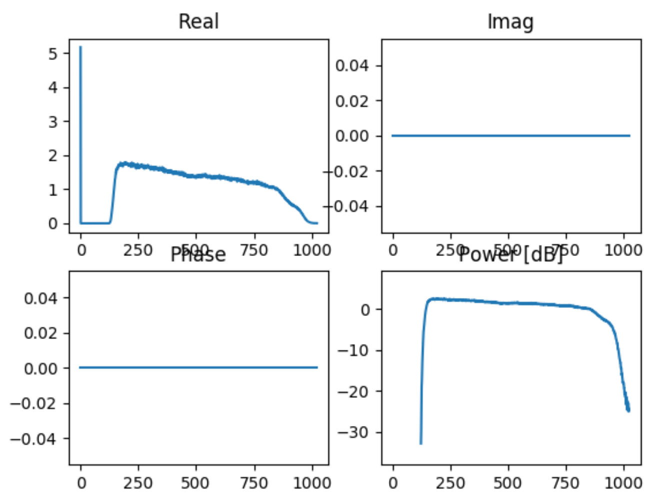

Figure 7: Autocorrelation for N0 on it's usual ADC cores

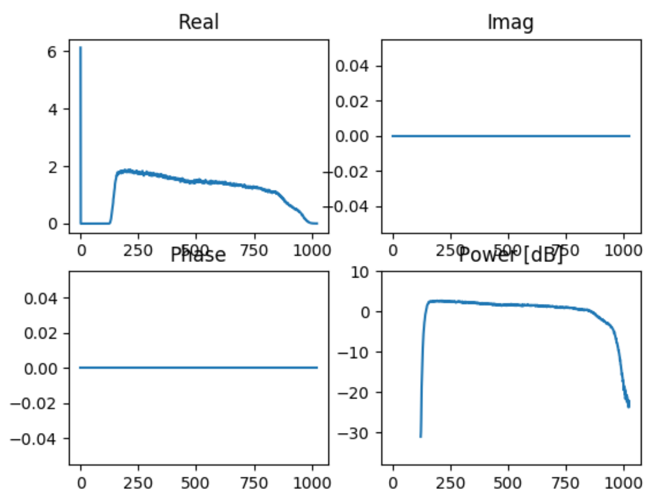

Figure 8: Autocorrelation for N0 copied to the ADC cores usually used for E2

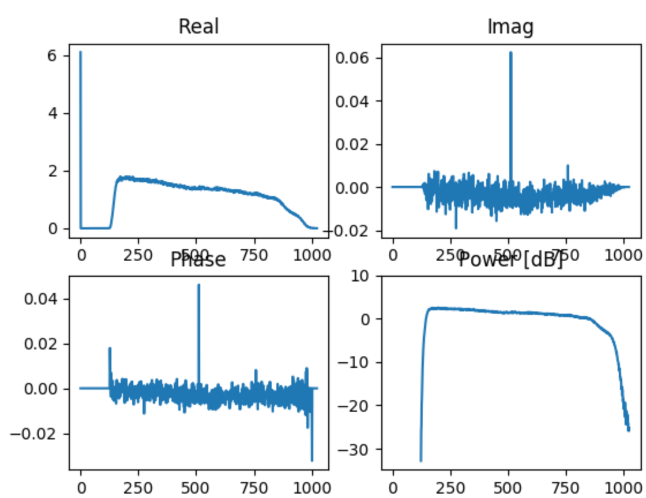

Figure 9: Cross correlation of N0 from ADC cores 1,2 and ADC cores 3,4

3.3 Test with MUX 1144

Now that we've proved we can copy a signal to all of the ADC inputs, we change our MUX to (1,1,4,4). We leave the signals on E2 and N0 unchanged at the SMA, but now we have the ADC cores driven by N0 and an unconnected input. E2 is driven at the SMA but not connected to the ADC. The diagram of this MUX is shown in figure 10. We do not see the excess correlation in this case. This test shows that driving a signal on an SMA input that is not connected to an ADC core. The auto for N0 is shown in 11. This is identical to the previous two tests. The auto for E3, which is the unconnected input corresponding to the 4 in the MUX is shown in 12, and shows no signal, as it should. The cross, showing no correlation, is shown in 13. This suggests that the issue is not dependent on the SMA inputs- driving an SMA input at E2 that is not connected to an ADC core does not show significant leakage into the driven signal on N0 or the undriven signal on E3.

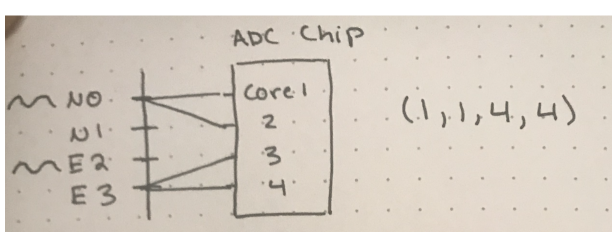

Figure 10: A diagram of the mapping of SMAs to the ADC with mux 1133 and signal on N0 and E2

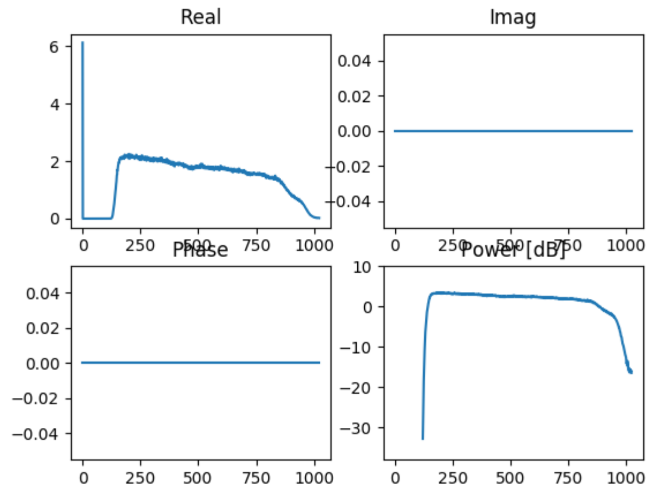

Figure 11: Autocorrelation for N0 with MUX 1144

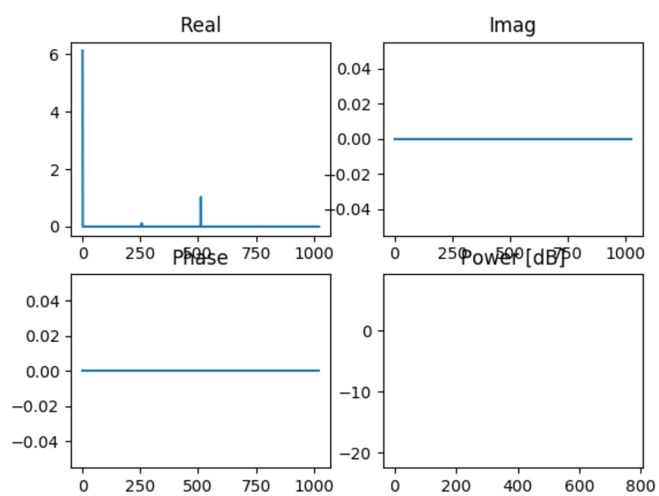

Figure 12: Autocorrelation for undriven input E3, showing no signal

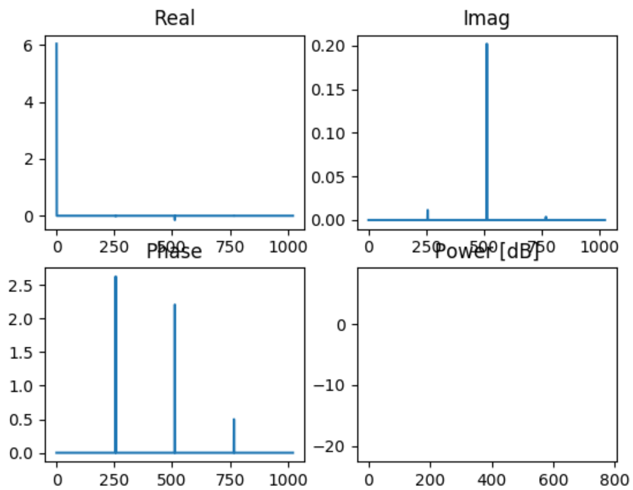

Figure 13: The cross correlation of N0 and E3, which shows no significant correlation.

3.4 Test with MUX 1133 and one undriven input

Now, we stop driving E2 and set the MUX back to default. The diagram for this test is shown in figure 14. We drive N0 with the same signal as in every other test, and put a 50 Ohm load on E2. This is the SMA equivalent of the MUX test in the previous section. The auto for the driven input N0 is shown in figure 15 and the auto for the undriven input is shown in figure 8. The cross between the N0 and E2. is We cannot see correlation on channels N0 and E2.

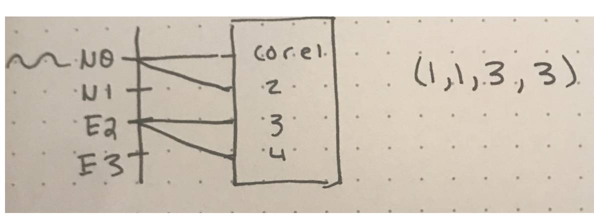

Figure 14: A diagram of the mapping of SMAs to the ADC with mux 1133 and signal on N0 and E2

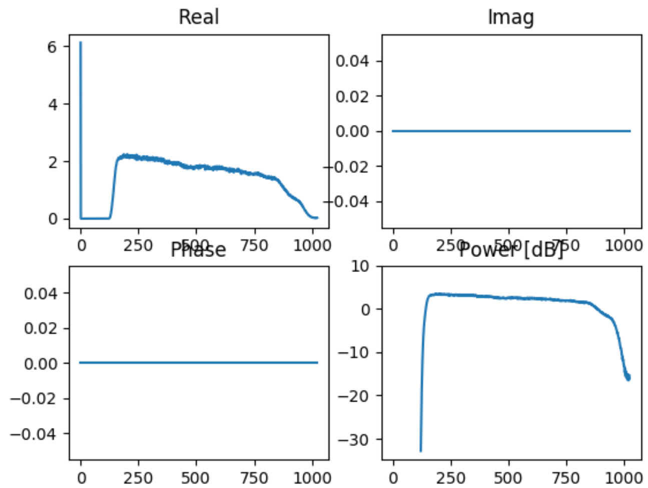

Figure 15: Autocorrelation for N0 with the input driven

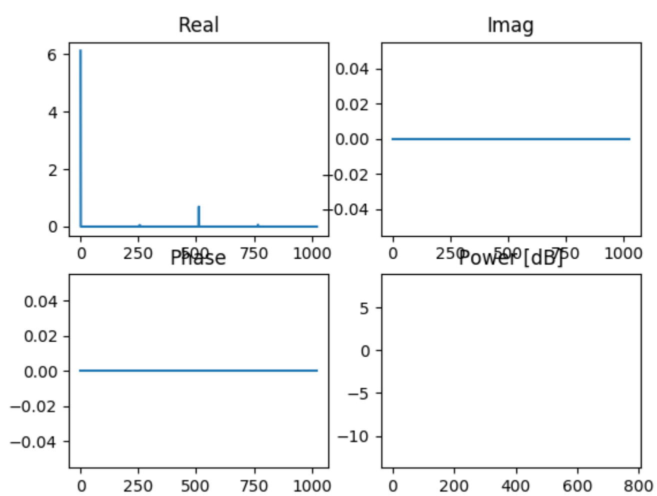

Figure 16: Autocorrelation for E2 with the input undriven

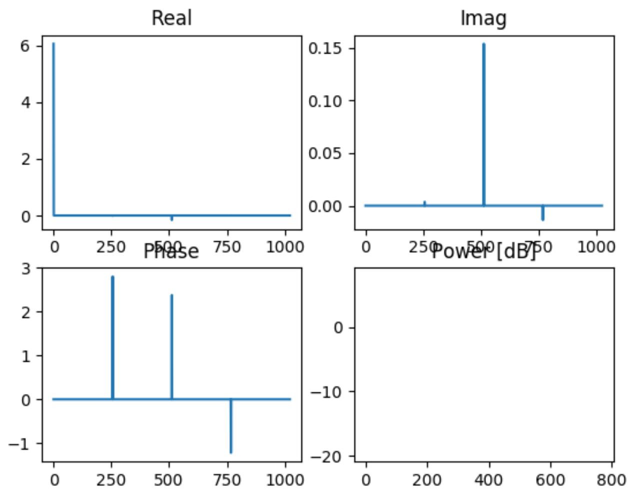

Figure 17: Crosscorrelation of driven N0 and undriven E2. No significant correlation is seen.

3.5 Excess correlation tests summary

4 Tone test investigation

This section investigates using tones to probe the excess correlation issue, rather then noise sources as the previous section.

4.1 Default tone test setup

For the first test, the MUX is set to the default 1133 and the inputs N0 and E2 are used. A tone at 66.66 MHz is on SMA E2 at 0 dBm, and a tone at 93.5 MHz is on SMA N0 at 0 dBm. The graphic of this setup is included in figure 18. The autocorrelation of N0 is shown in figure 19. We clearly see the tone at 93.5 MHz, but we also see a tone at 66.66 from E2 show up, indicating possible leakage. There is a higher frequency signal that was showing up intermittently that can be seen as well. We're not sure where this is coming from. The autocorrelation for E2 is shown in figure 24. Notably, we don't see the signal from N0 leaking into this auto. The cross correlation is shown in 25, only showing the correlation of E2 from N0 and E2 from E2. This possibly suggests that the excess correlation is caused by leakage from one channel into another, but not the reverse.

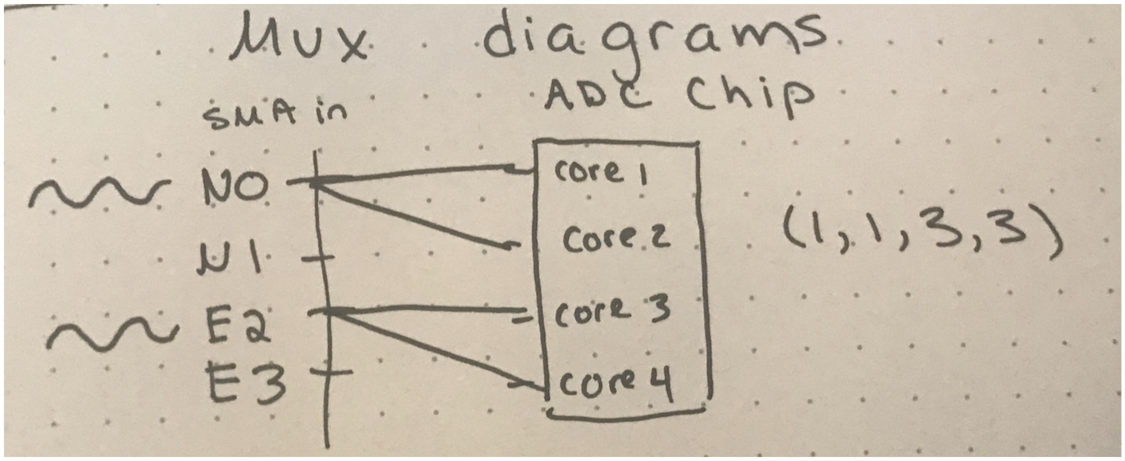

Figure 18: The default MUX for HERA with tones on N0 and E2

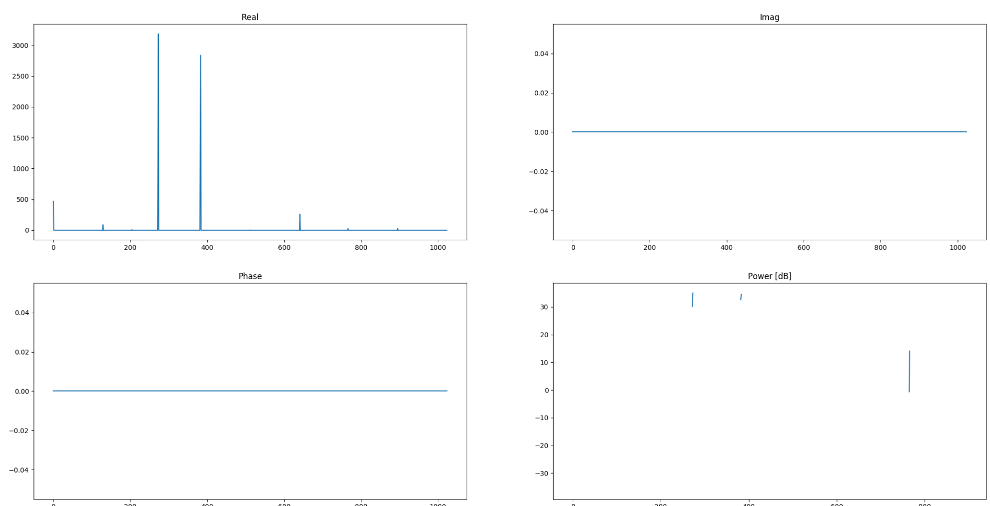

Figure 19: The autocorrelation of N0 with a tone at 93.5 MHz. The tone from E2 at 66.66 also shows up in this autocrrelation as leakage. There is another higher frequency signal of indeterminate origin.

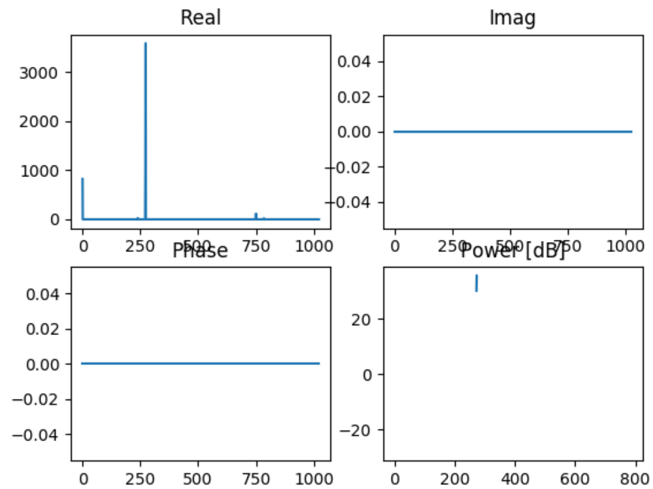

Figure 20: The autocorrelation of E2 with a tone at 66.66 MHz. The tone from N0 is not seen as leakage here.

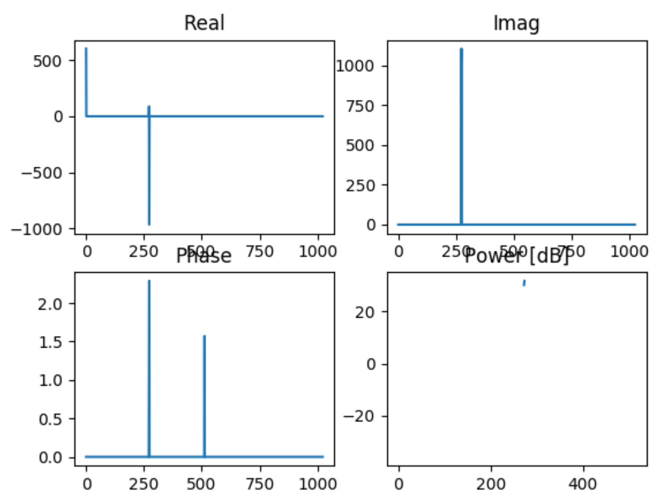

Figure 21: The cross correlation of N0 and E2, with the signal from E2 showing as correlated between the two inputs.

4.2 Tone test with swapped input

Now we switch the 93.5 MHz signal to N1 and leave the MUX the same. This means that N0 is connected to the ADC cores, but undriven, and N1 is driven but not connected to the ADC cores. E2 is connected to the ADC cores and is driven. The setup for this is shown in figure 22. We see, again, E2 leaking into N0, and the two correlating. The 66.66 MHz is seen in both. However, the signal on N1, which is not connected to the ADC cores, does not show up anywhere.

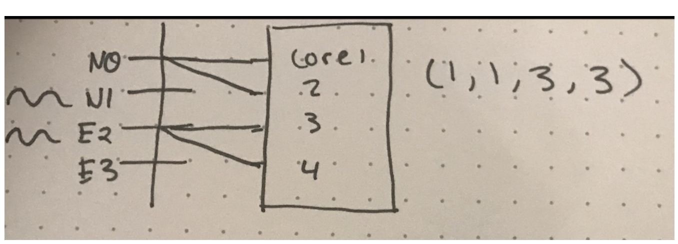

Figure 22: The setup for two tones into N1 and E2 but the MUX set to the default for HERA

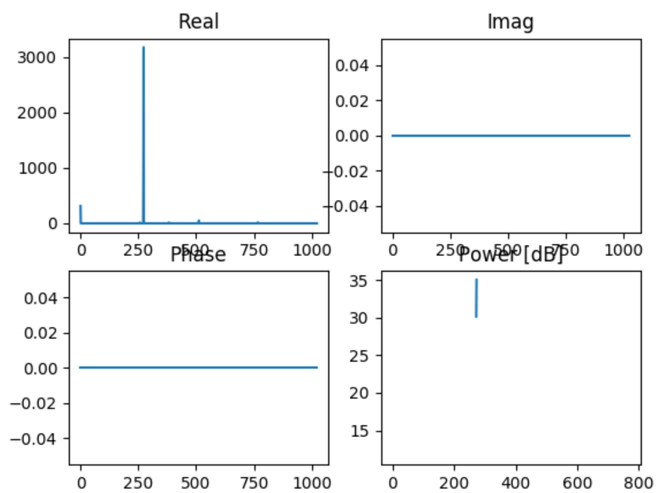

Figure 23: The autocorrelation of N0 with a tone at 66.66 MHz from E2. The tone from N1 at 93.5 MHz is not seen.

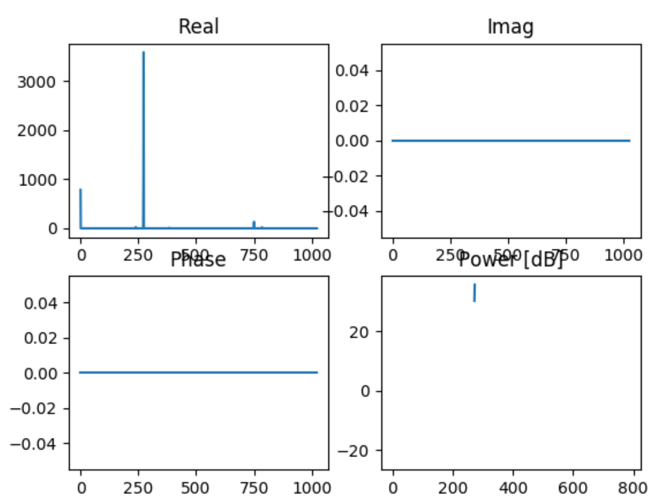

Figure 24: The autocorrelation of E2 with a tone at 66.66 MHz. The tone from N1 is not seen as leakage here.

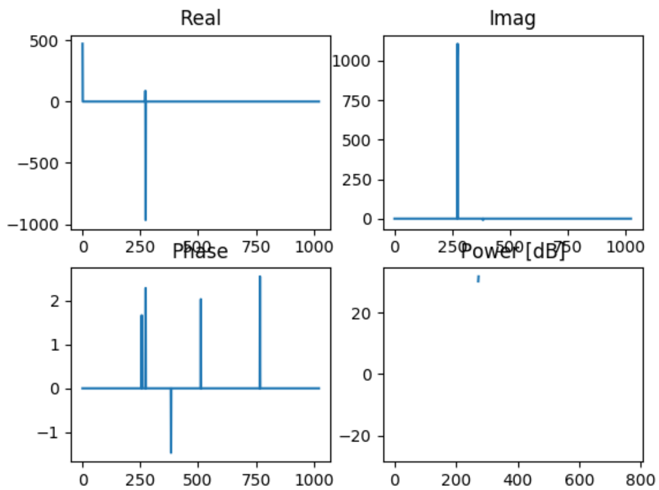

Figure 25: The cross correlation of N0 and E2, with the signal from E2 showing as correlated between the two inputs.

4.3 Change MUX to 2233

Now we leave the signals as the previous test on N1 and E2, but connect N1 instead of N0 to the ADC cores. This test appears identical to the test with N0 and N2 and MUX 1133- the SMA (N1) connected to ADC cores 1 and 2 shows leakage, while the SMA (E2) connected to ADC cores 3 and 4 shows no second tone. This suggests that the excess correlation issue may follow the ADC lanes, and not the SMA inputs.

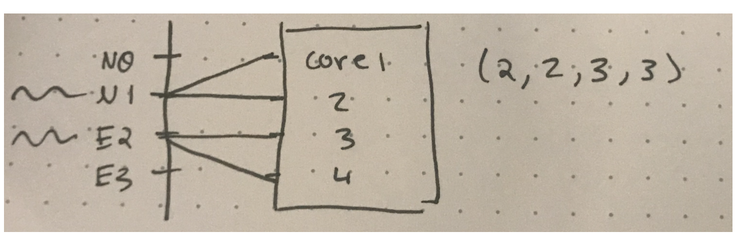

Figure 26: The diagram for a MUX of 2233 and signals on N1 and E2.

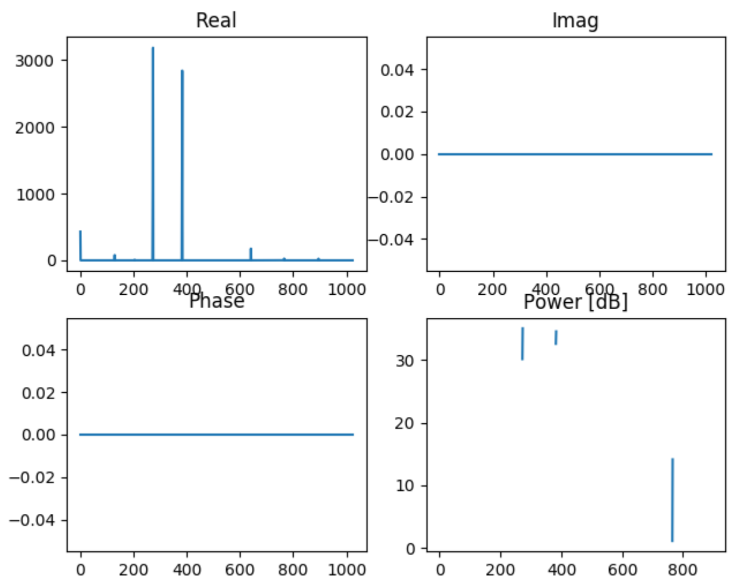

Figure 27: The autocorrelation of N1 with a tone at 93.5 MHz. The tone from E2 at 66.66 also shows up in this autocorrelation as leakage. There is another higher frequency signal of indeterminate origin.

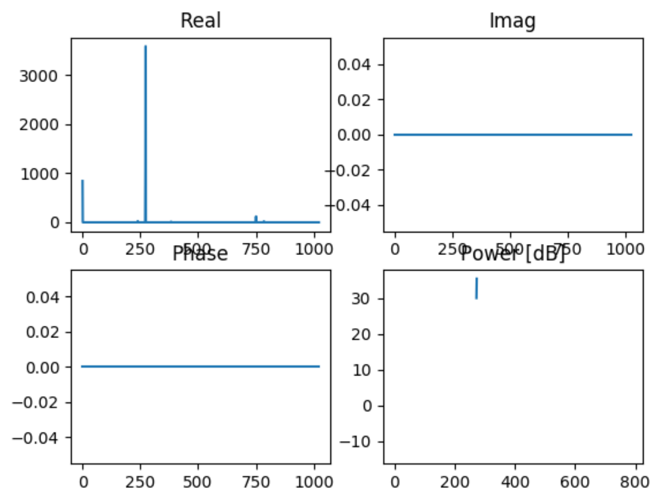

Figure 28: The autocorrelation of E2 with a tone at 66.66 MHz. The tone from N1 is not seen as leakage here.

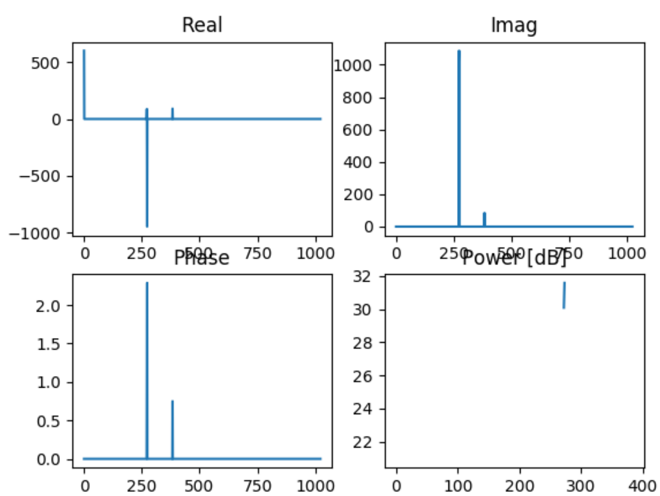

Figure 29: The cross correlation of N0 and E2, with the signal from E2 showing as correlated between the two inputs.

4.4 Change MUX to 3322

To test the theory that the leakage is following the ADC lanes, we change the MUX to 3322 and keep the signals as identical to the previous test. The diagram for this is shown in figure 30. If it is a lane dependent issue, the leakage should swap channels now to follow ADC cores 1 and 2, and this is in fact what we see. The autocorrelation of N1 in figure 31, which used to show leakage as a second signal from E2 when connected to ADC cores 1 and 2, no longer shows the leakage. It does still show the indeterminate higher frequency signal seen previous. Now, the autocorrelation of E2 in figure 32, having been connected to ADC cores 1 and 2, shows the double tones from N1 and E2. The cross correlation now shows the excess correlation showing up as the signal from N1. This suggests that the excess correlation issue might be a lane dependent issue in the ADCs. This does not neccesarily mean that ADC cores 3 and 4 are good, but that they aren't showing immediate issues in one single snapshot.

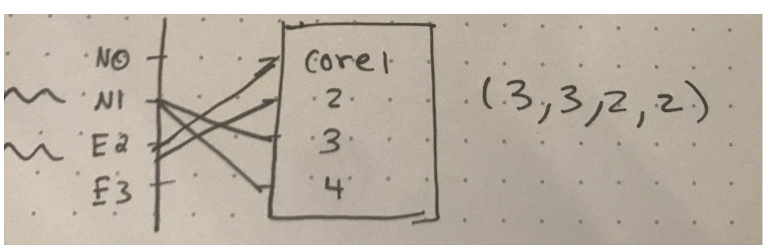

Figure 30: The diagram of the MUX set to 3322 with tones on N1 and E2

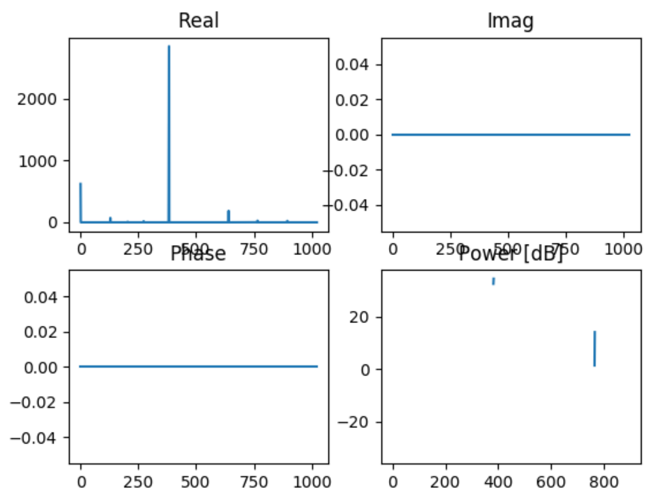

Figure 31: The autocorrelation of N1 with a tone at 93.5 MHz. There is another higher frequency signal of indeterminate origin.

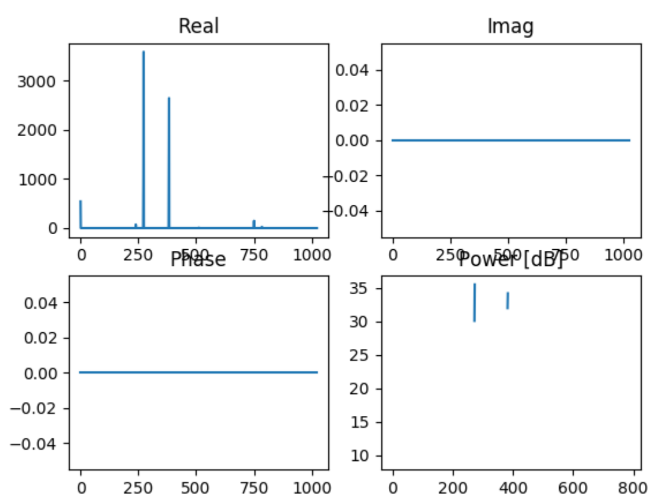

Figure 32: The autocorrelation of E2 with a tone at 66.66 MHz. The tone from N1 at 93.5 also shows up in this autocorrelation as leakage.

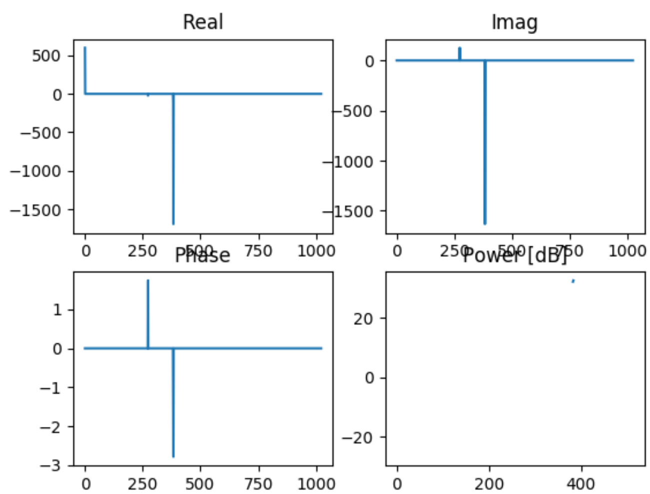

Figure 33: The cross correlation of N1 and E2, with the signal from N1 showing as correlated between the two inputs.