Noise Temperature

Collaboration Meeting 2020

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ADMX
AXION DARK MATTER EXPERIMENT

System Noise

$$\mathrm{SNRI} = \frac{G_{\mathrm{on}}}{G_{\mathrm{off}}}\frac{P_{\mathrm{off}}}{P_{\mathrm{on}}}$$ ⟶ Computed every 10 min or so
jpa_probe_snr script

$$T_{\mathrm{HFET}}/\epsilon$$ ⟶ Computed every 1-2 nibbles via a ‘hot-load’ or Y-factor measurement

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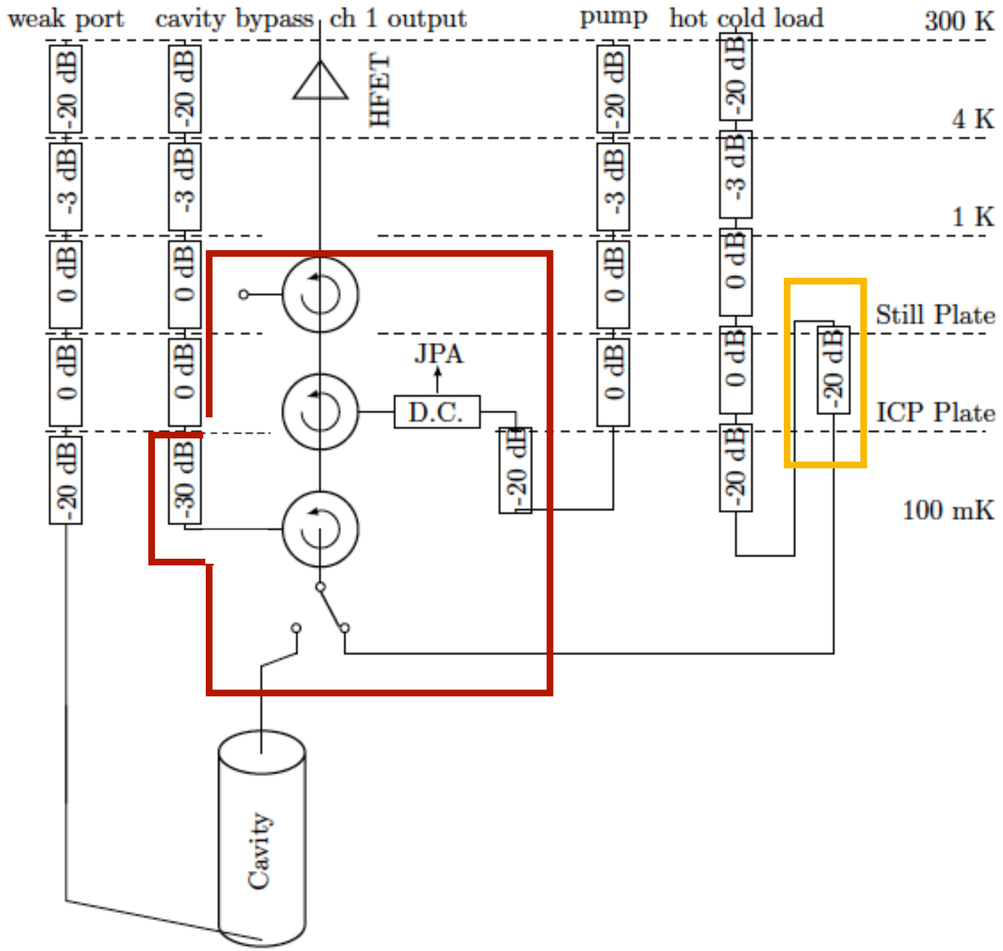
$$T_{\mathrm{sys}} = T_{\mathrm{HFET}}/\epsilon\mathrm{SNRI}$$ ⟶ Computed in analysis code by smoothing JPA SNRI over 15 min time interval

List of Hot Load Measurements

- Sept 25 (5T) https://maxwell.npl.washington.edu/elog/admx/ADMX/2364
- Oct 25 (7 T) https://maxwell.npl.washington.edu/elog/admx/ADMX/2484
- March 11 https://maxwell.npl.washington.edu/elog/admx/ADMX/2818
- May 1 https://maxwell.npl.washington.edu/elog/admx/ADMX/2982
- July 2 https://maxwell.npl.washington.edu/elog/admx/ADMX/3105
- August warm up https://maxwell.npl.washington.edu/elog/admx/ADMX/3202
- Sept 24 https://maxwell.npl.washington.edu/elog/admx/ADMX/3283
- Oct 20 attempted to do hot load with JPA on. Did not really work.

Highlighted measurements were combined into a single noise temperature measurement.

Hot Load Measurements



- Receiver chain provides means for measuring key RF parameters, such as quality factor

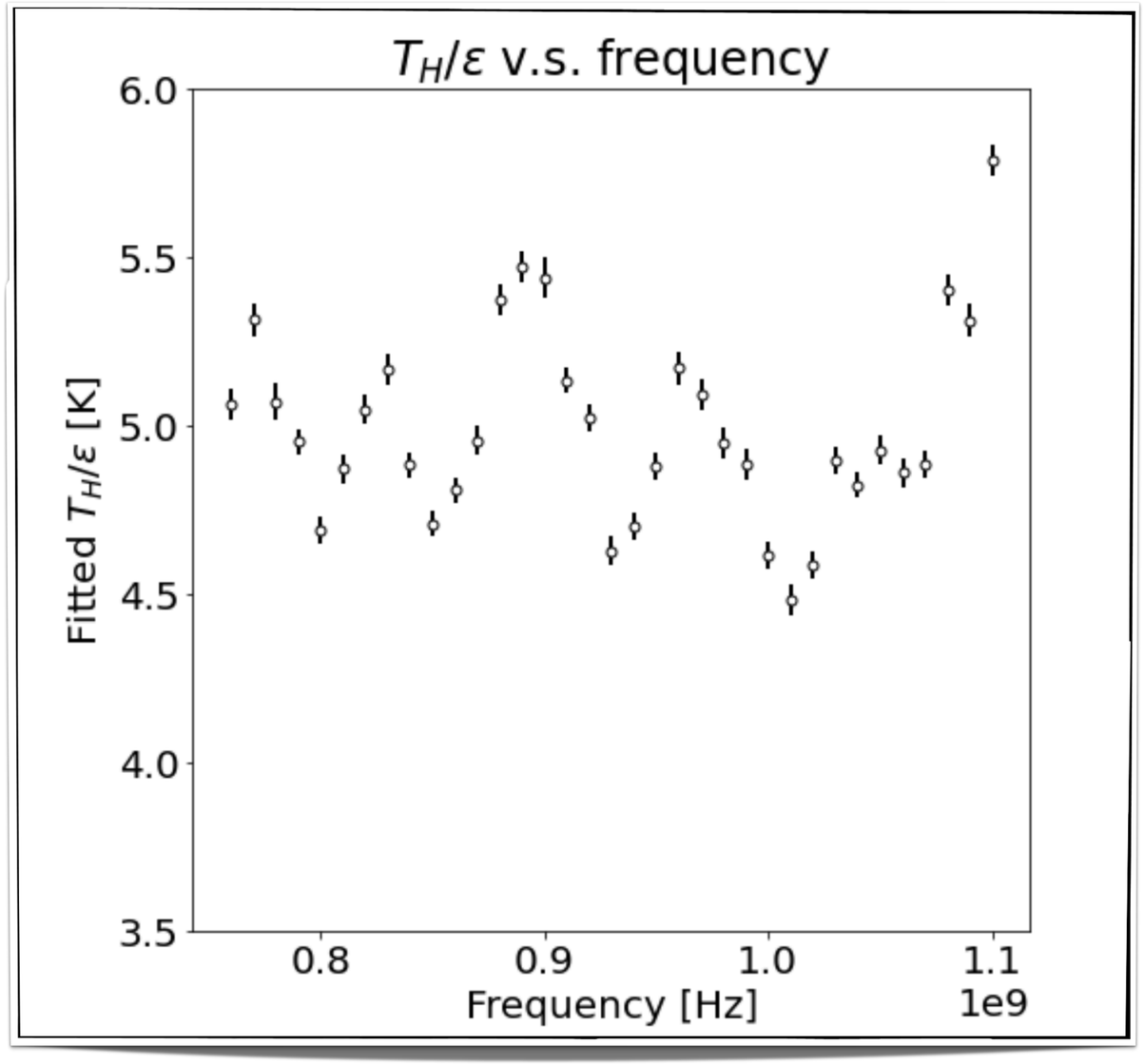
- Two types of noise measurement

- 1) Heating of the ‘hot-load’ via dc current (by design)

$$P = G_{\mathrm{HFET}} k_{\mathrm{B}} \left[T_{\mathrm{JPA}} (1 - \epsilon) + T_{\mathrm{load}} \epsilon + T_{\mathrm{HFET}} \right]$$

- 2) Heating of the quantum amplifier package via an RF switch

$$P = G_{\mathrm{HFET}} k_{\mathrm{B}} \left[T_{\mathrm{JPA}} + T_{\mathrm{HFET}} \right]$$

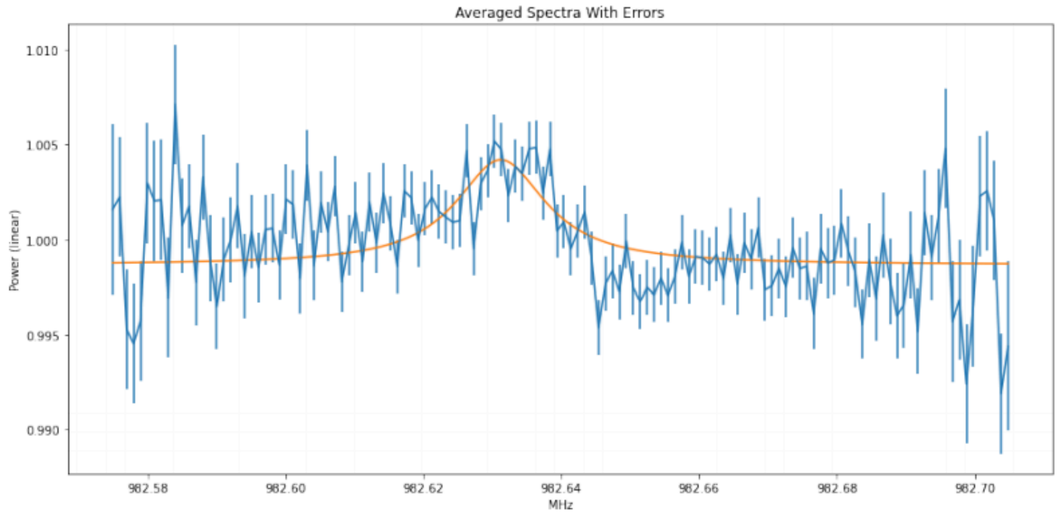


Combined HFET temperature divided by epsilon
Currently stored in new database table thfetoverepsilon_cal_data
Timestamp: 2020-08-20 14:31:43-07

There was a question of whether or not we were overestimating this variable because attenuation in the hot load line could be different from that with the cavity.
Cavity—>squidadel has superconducting line
Hot load—>squidadel does not?

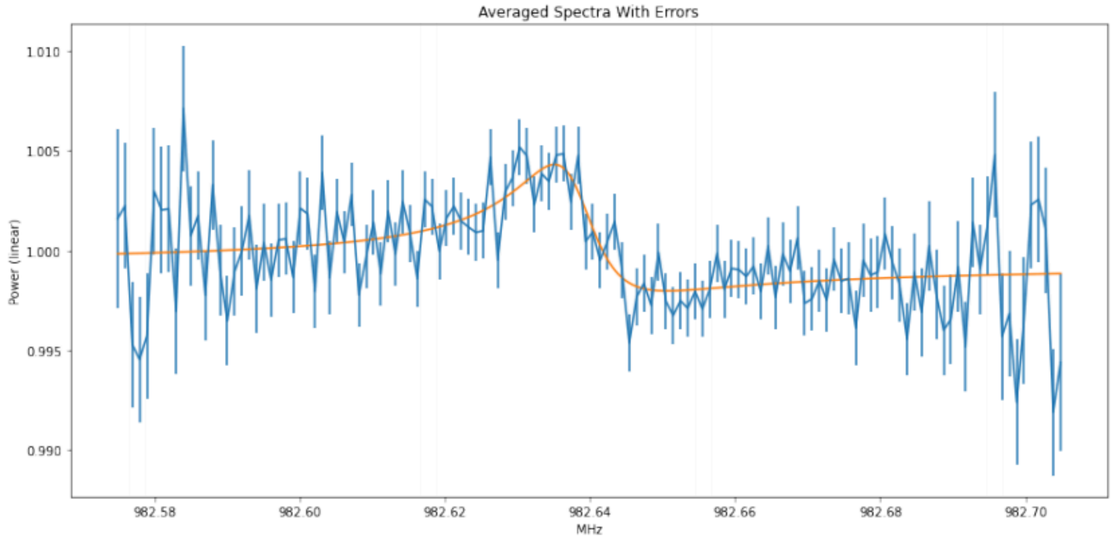
On-Off Resonance Hot Load Measurements

$$T_{\text{hfet}} = 3.28 \pm 0.35 \text{ K}$$



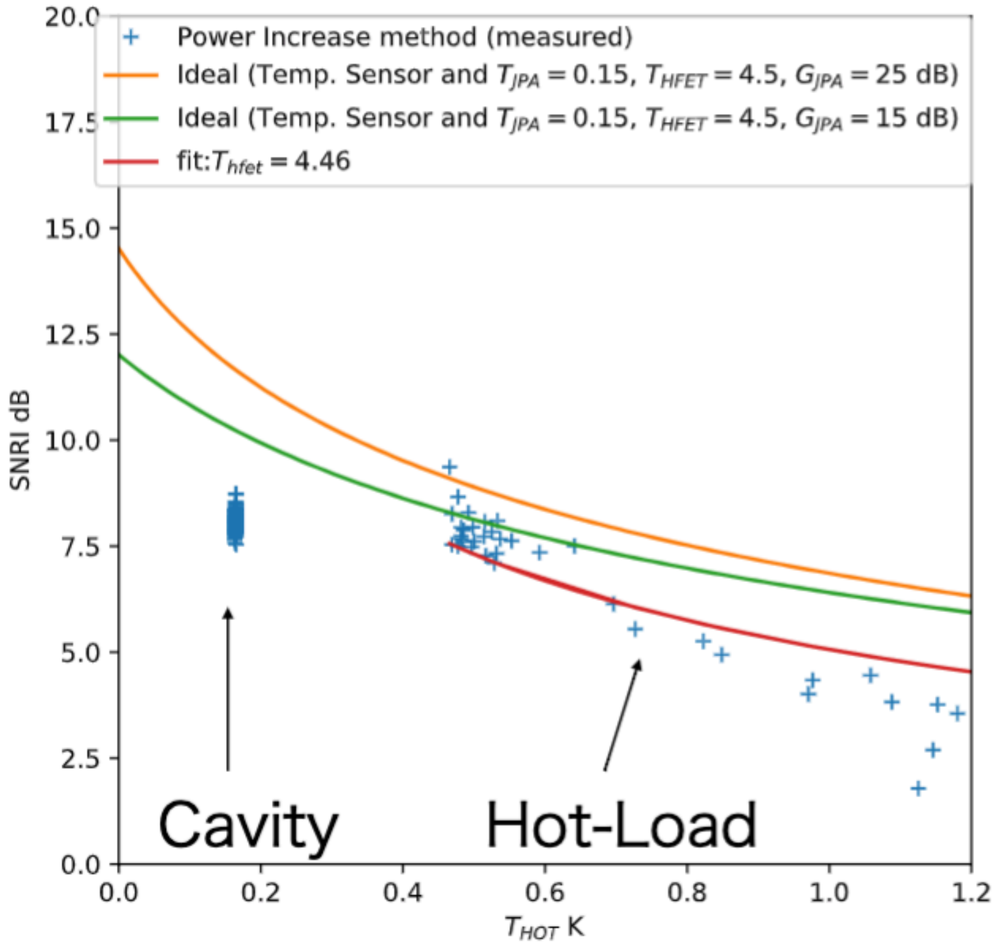
Simple model

$$T_{\text{hfet}} = 1.6 \pm \infty \text{ K}$$ (uncertainty cannot be calculated)



Fancier model which includes circulator reflection

Attempt to fit SNRI vs T_HFET



data: $\mathrm{SNRI} = \dfrac{G_{\mathrm{on}}/G_{\mathrm{off}}}{P_{\mathrm{on}}/P_{\mathrm{off}}}$

orange and green line:

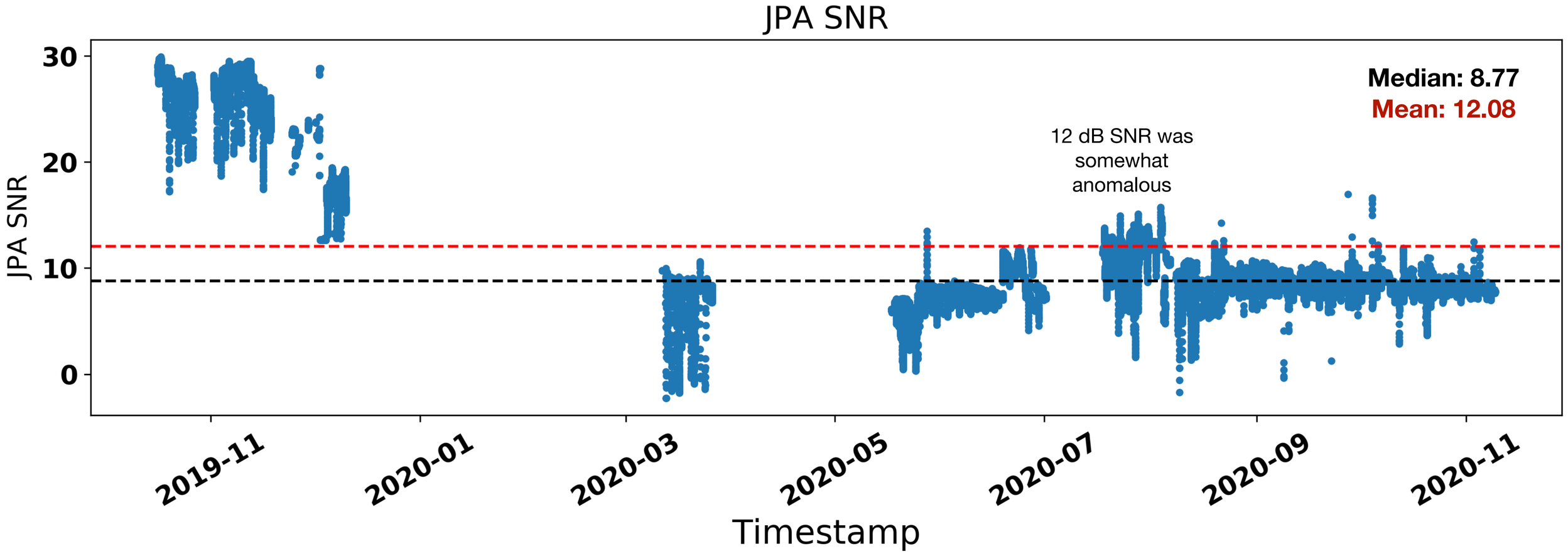
$$\mathrm{SNRI} = \frac{T_{\mathrm{JPA}} + T_{\mathrm{hot}} + T_{\mathrm{HFET}}}{T_{\mathrm{JPA}} + T_{\mathrm{hot}} + T_{\mathrm{HFET}}/G_{\mathrm{JPA}}}$$

red line:

$$\mathrm{SNRI} = \frac{2T_{\mathrm{hot}} + T_{\mathrm{HFET}}}{2T_{\mathrm{hot}} + T_{\mathrm{HFET}}/G_{\mathrm{JPA}}}$$

assuming JPA noise comes from out-of-band noise

extrapolated SNRI at cavity temperature is 11.3 dB

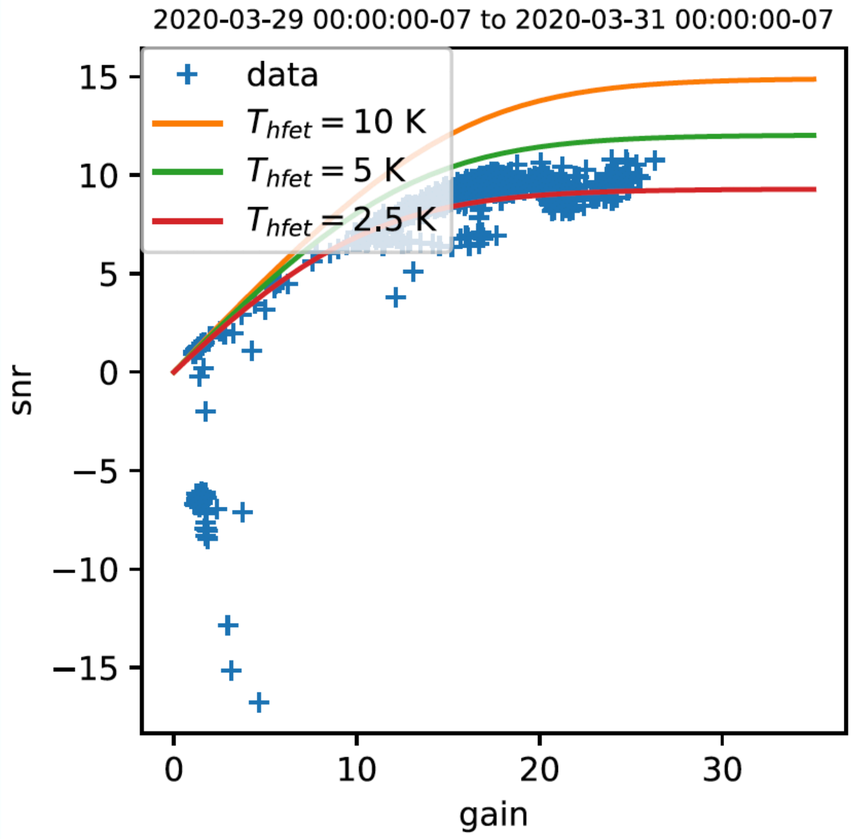

JPA SNR
Median: 8.77
Mean: 12.08
12 dB SNR was somewhat anomalous
JPA SNR
30
20
10
0
2019-11
2020-01
2020-03
2020-05
2020-07
2020-09
2020-11
Timestamp

Mystery of the low JPA SNR

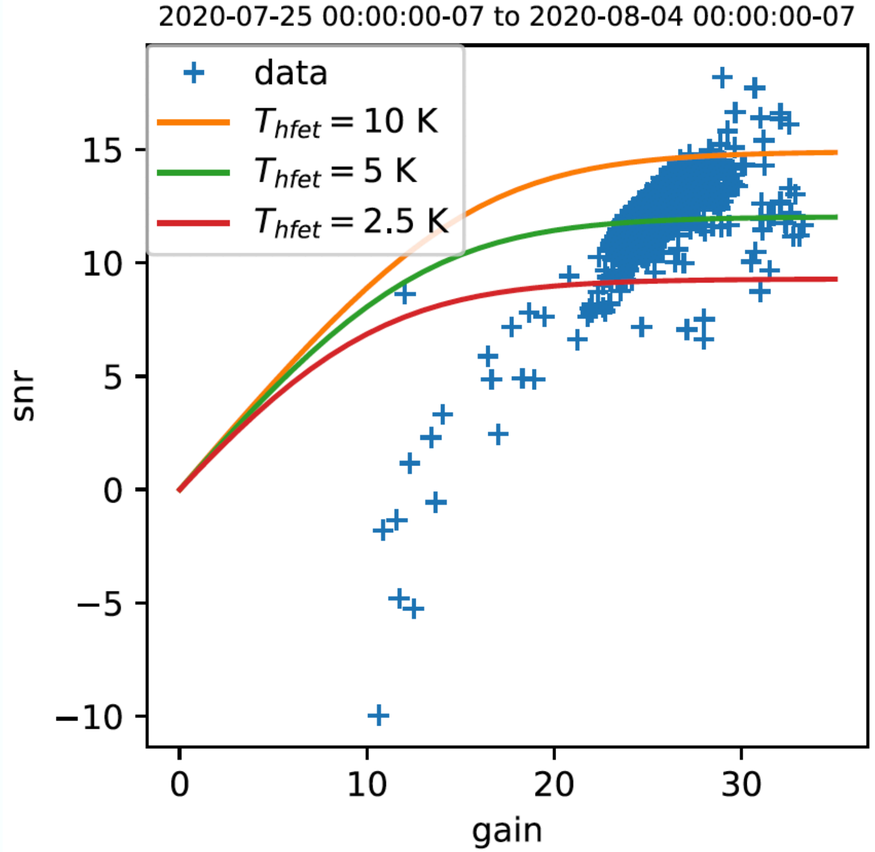
- Continuous issue of 9 dB SNR when JPA should be capable of 12 dB
- Where do we get the extra 3 dB?
- Many suggestions at scan speed meetings
- We had 12 dB for a brief time. Was it real?

Why are we suspicious of previous 12 dB SNR?

Most of time



(July 25 - Aug 4)



Many suggestions from scan speed meetings

1) Investigate if our pump power is too high ✓

2) Check pump line with scope again for noise ✓

3) Zoom into resonant phase plot and see if we can get good snri in 'good' regions ✓

4) Add filter+1kΩ resistor to current bias. ✓

5) Maybe we need to tweak the offset (475 kHz) of the pump ✓

6) Was 12 dB SNRI real?

7) Try using the other current supply ✓

Many suggestions from scan speed meetings

8) Quantify warm attenuation and check that the measured power is expected ✓

9) Use a power amplifier to deliberately inject noise and see what we learn from that ✓

10) Try changing magnetic field and making the resonant phase plot ✓

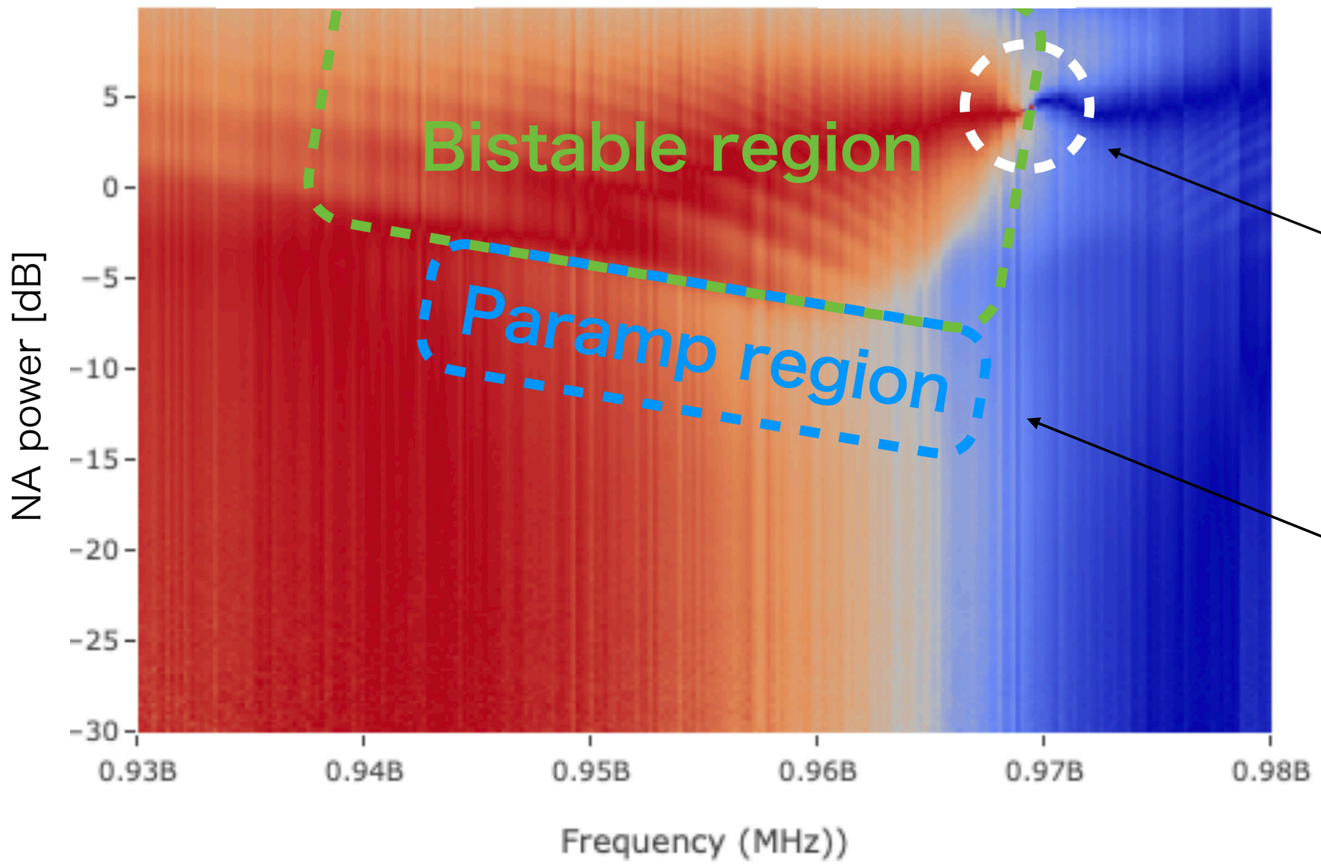
11) On the resonance scan plot, try going over to the next dip ✓

12) Maybe we are doing our rebiasing too fast and trapping flux. Perhaps rethink this. ✓

13) Hot load measurement with the JPA on ✓

14) Measure the noise spectrum with spectrum analyzer turning on each amplifier one at a time. ✓

Rakshya and Akel: Good gain should be in para-amp region



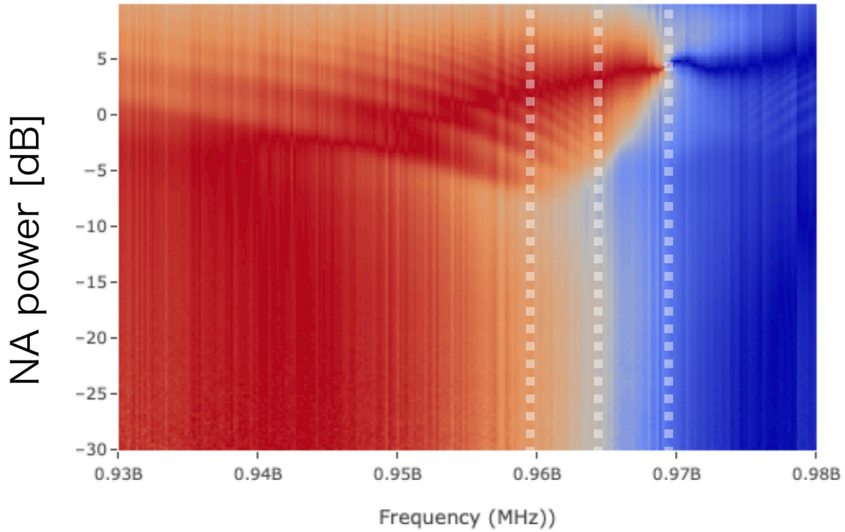
Plot courtesy of Tatsumi

Operating here

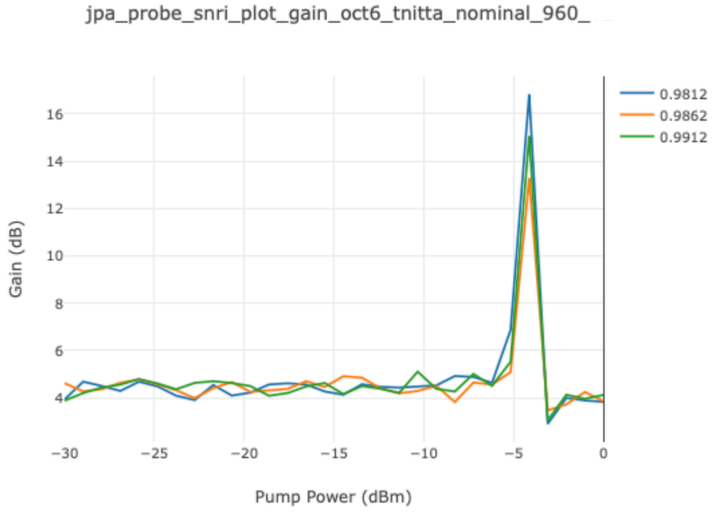
Should be operating here!

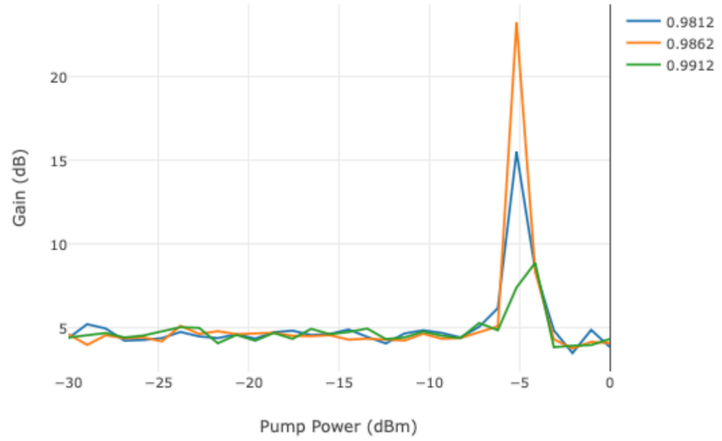
Good gain only in bi-stable region?

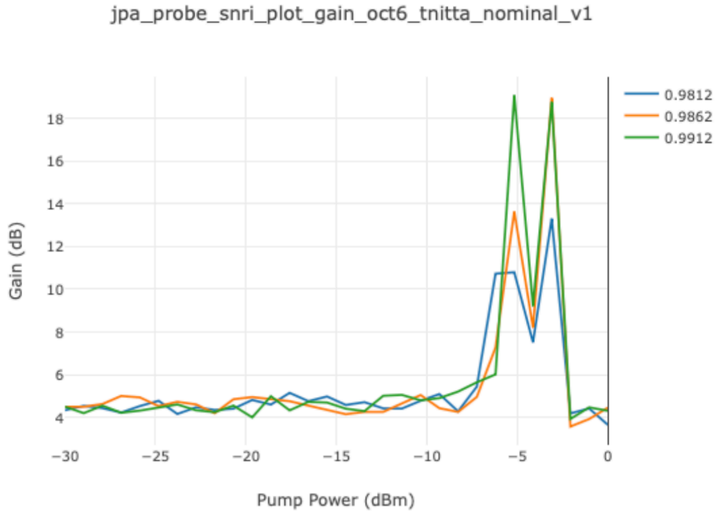
We could not find good gain in paramp region.
Only in the bistable region.



Plot courtesy of Tatsumi



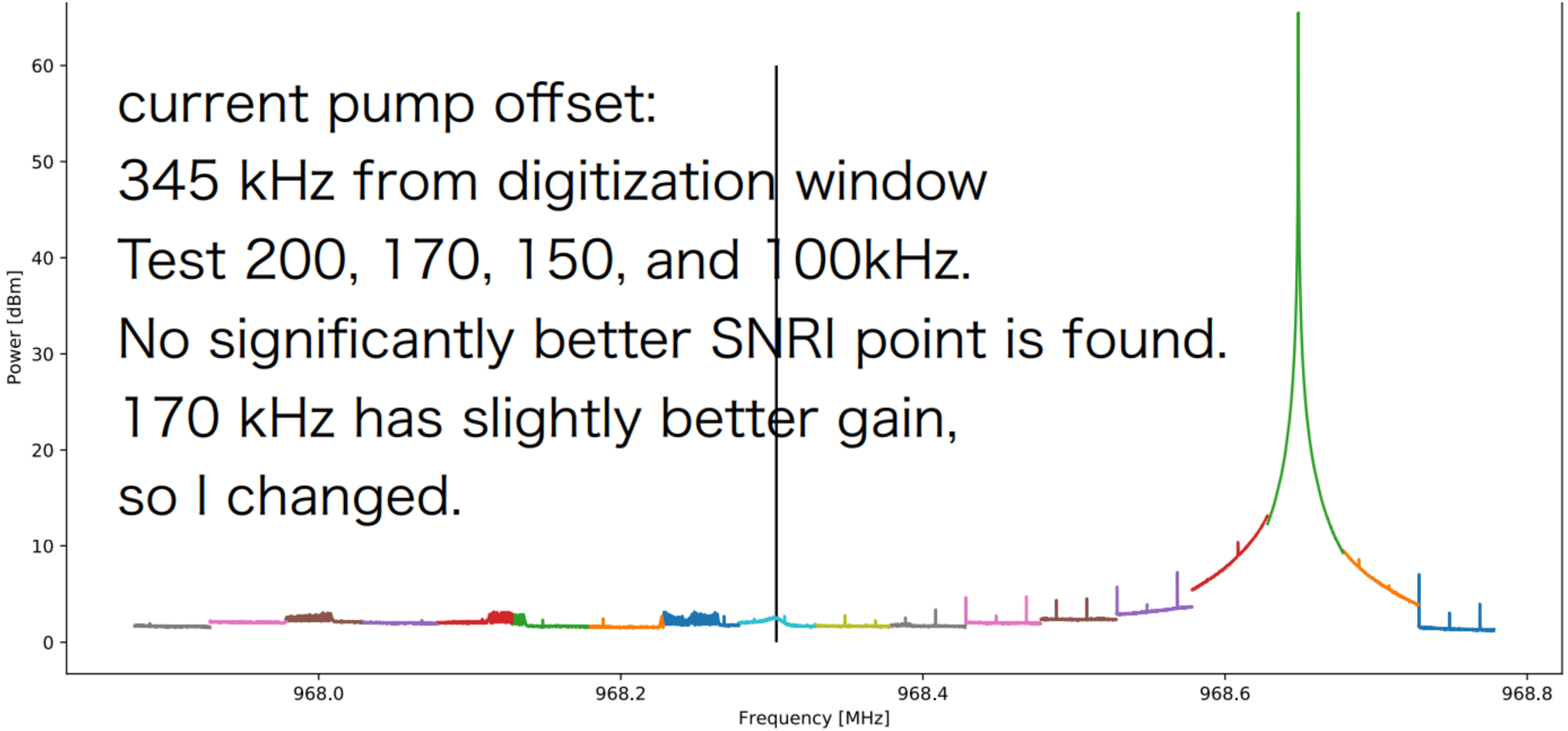




Plots courtesy of Tatsumi

Checking the pump offset

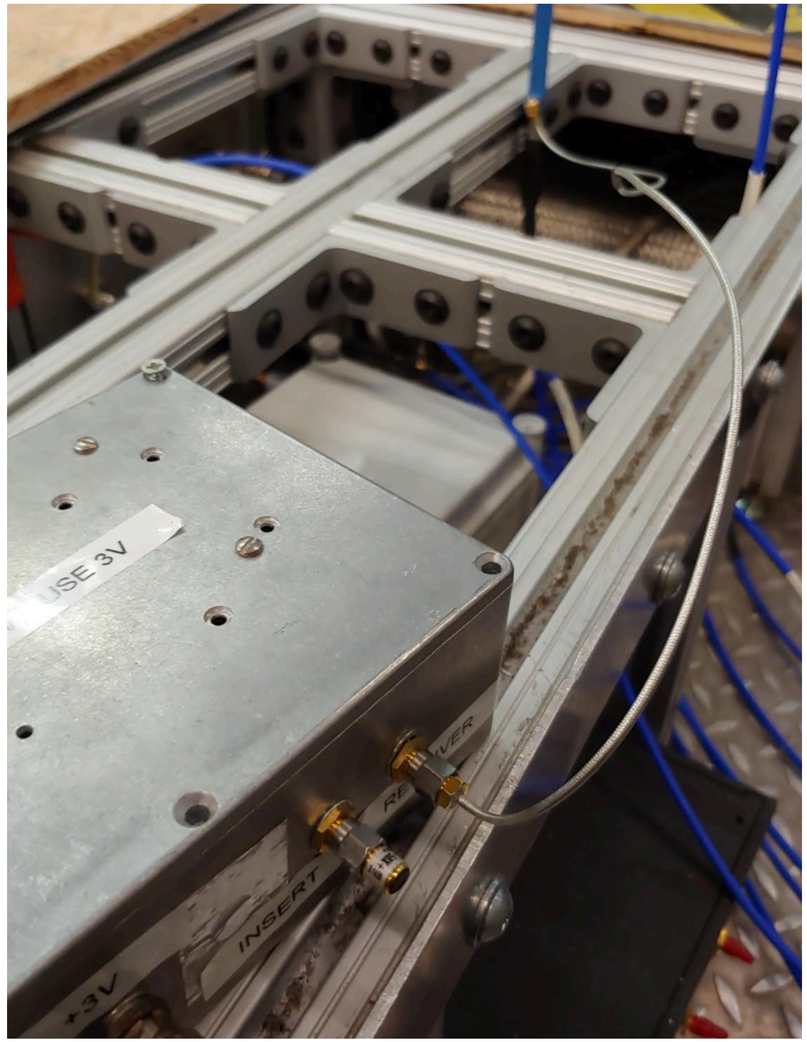
https://maxwell.npl.washington.edu/elog/admx/ADMX/3332

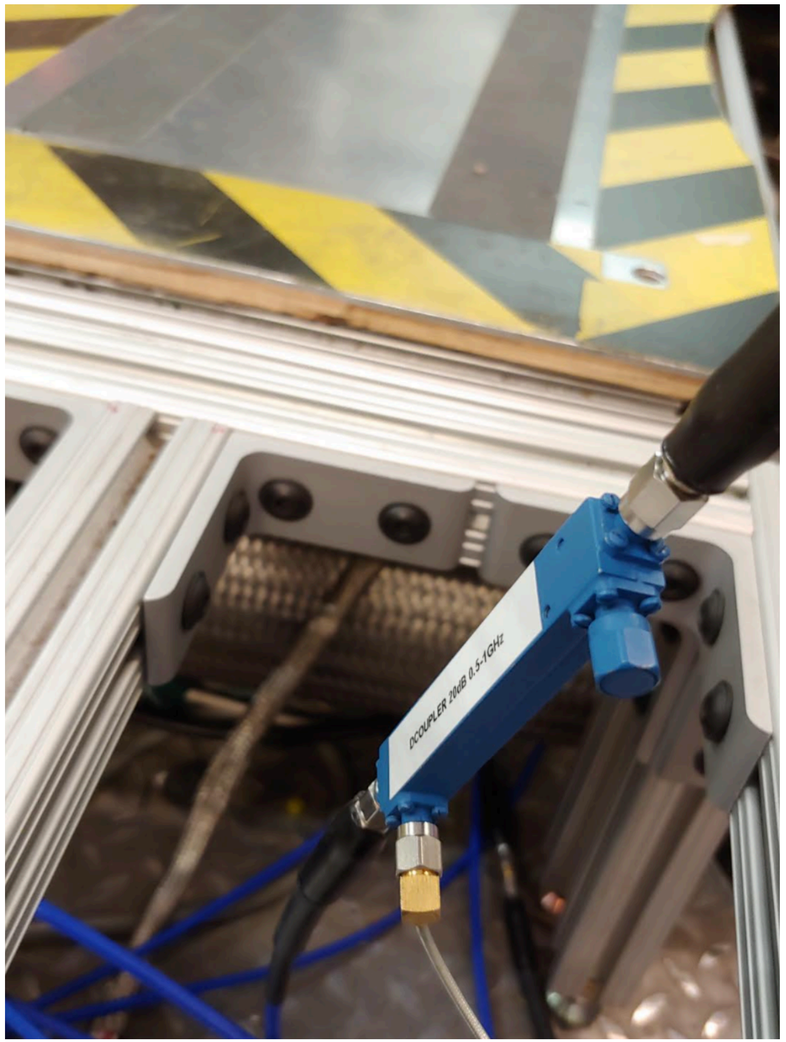


Plot courtesy of Tatsumi

Adding noise to pump line

Deliberately added noise to the pump line
https://maxwell.npl.washington.edu/elog/admx/ADMX/3333

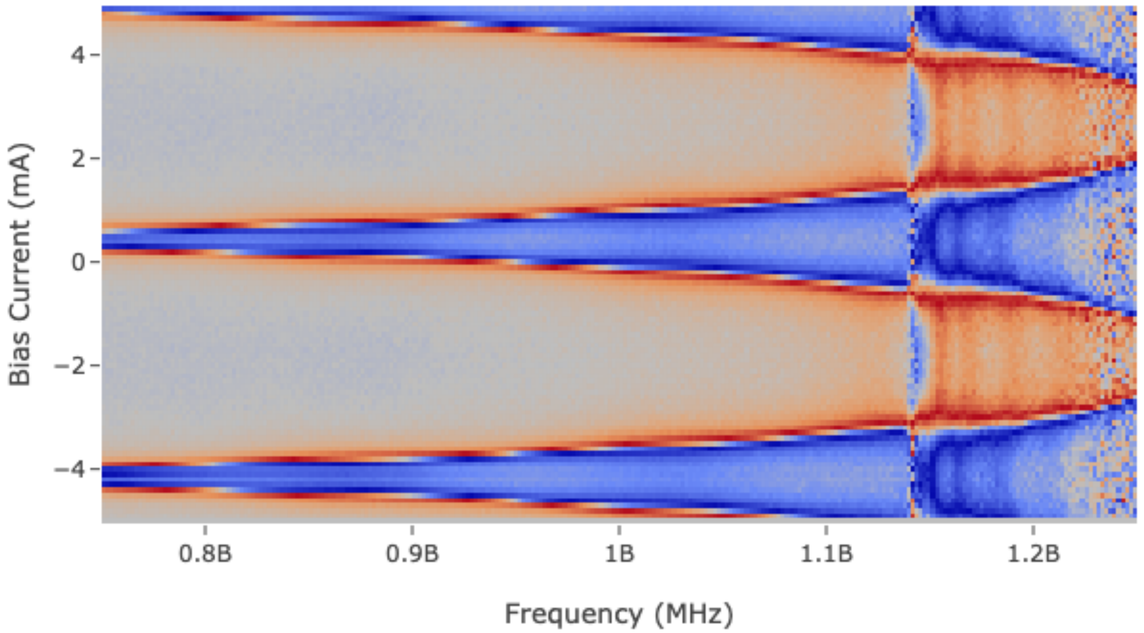




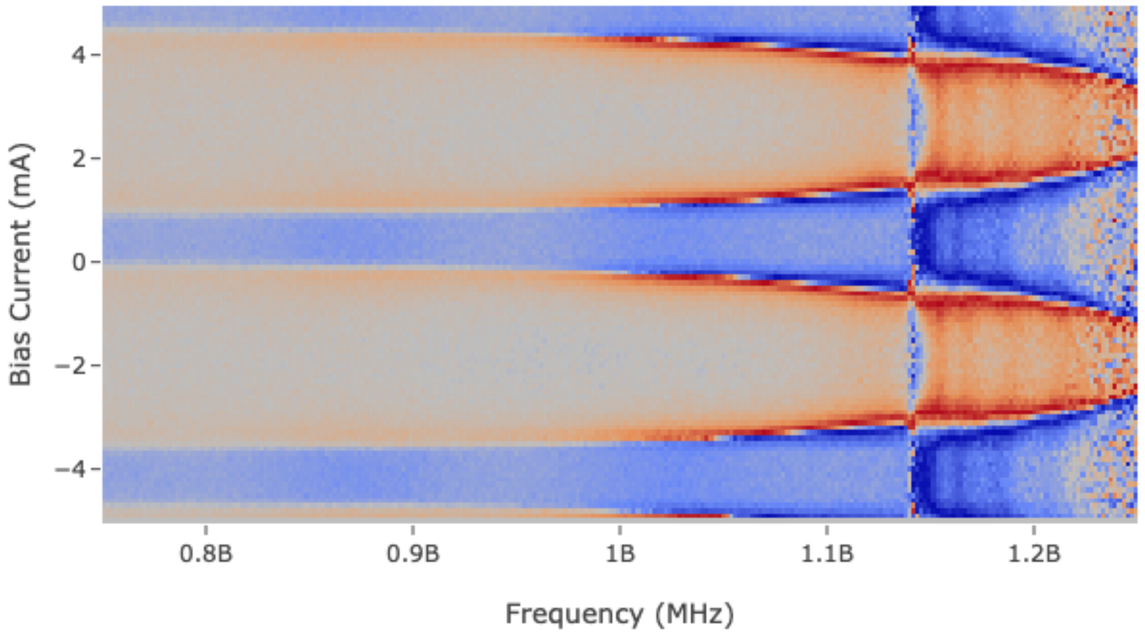
Adding noise to pump line

https://maxwell.npl.washington.edu/elog/admx/ADMX/3333

2020_10_01_tnitta_resonance_5_oldPowerSupply

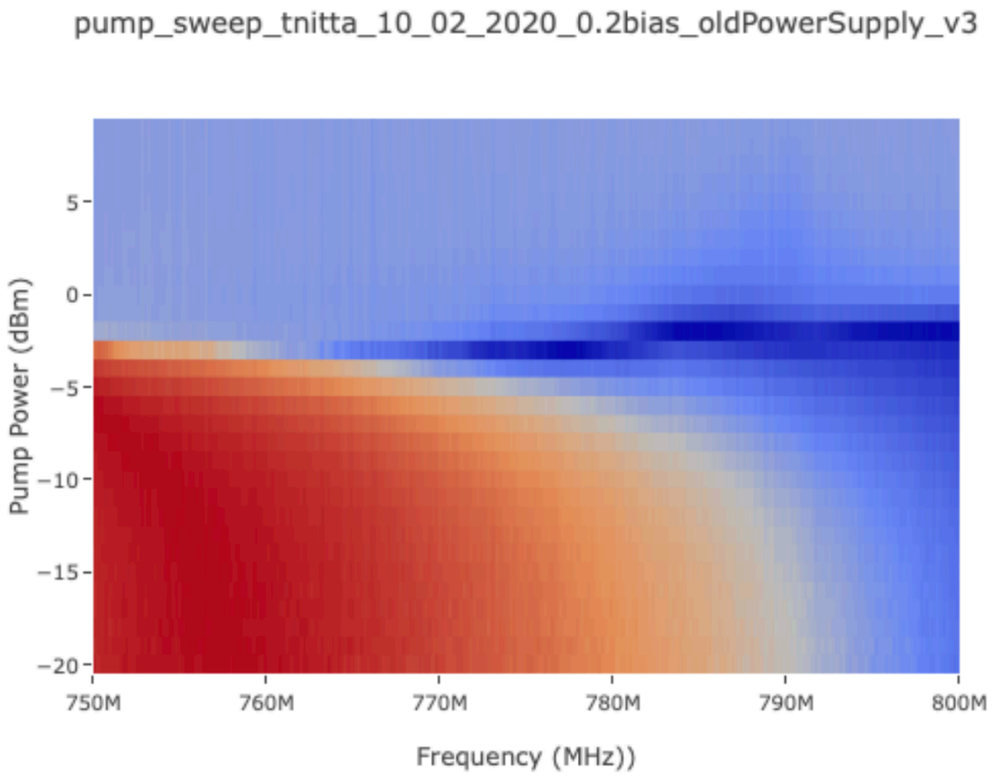


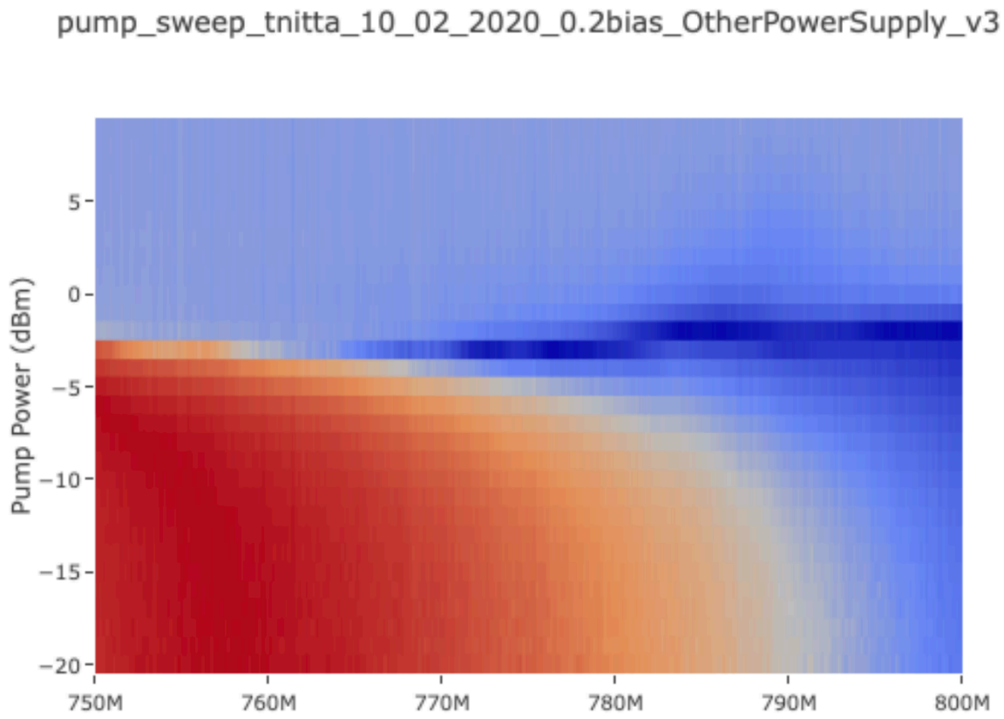
2020_10_05_tnitta_resonance_3_addNoise



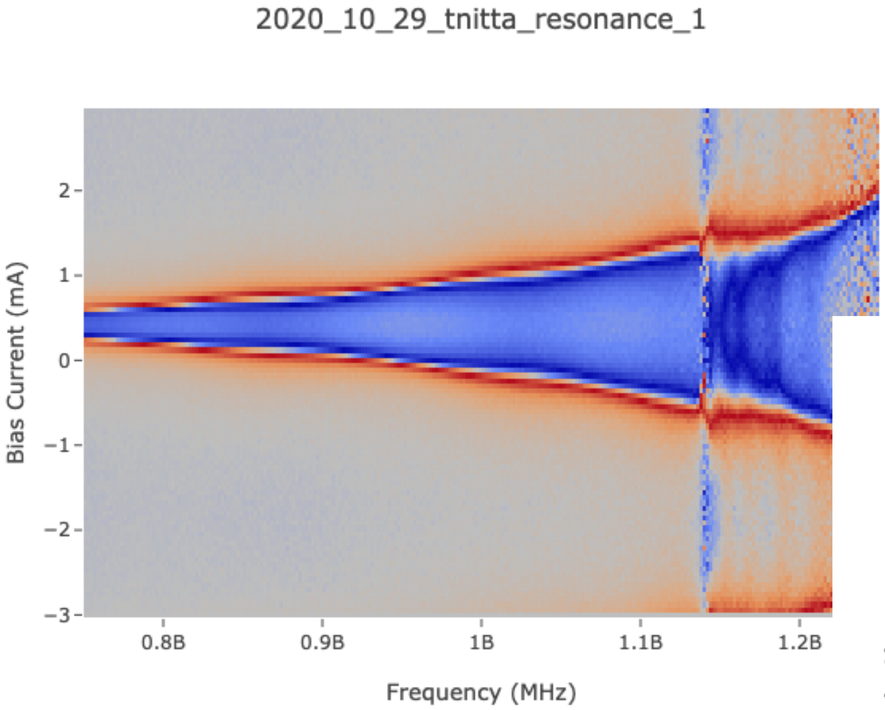
Try another current supply

https://maxwell.npl.washington.edu/elog/admx/ADMX/3326
Plots are from: https://maxwell.npl.washington.edu/elog/admx/ADMX/3327

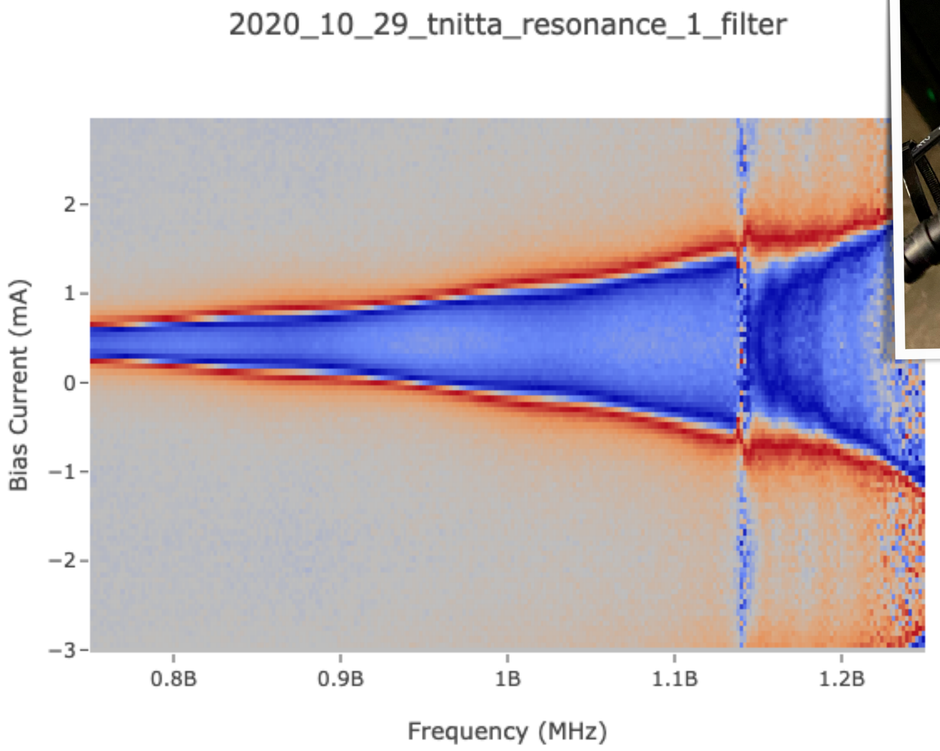




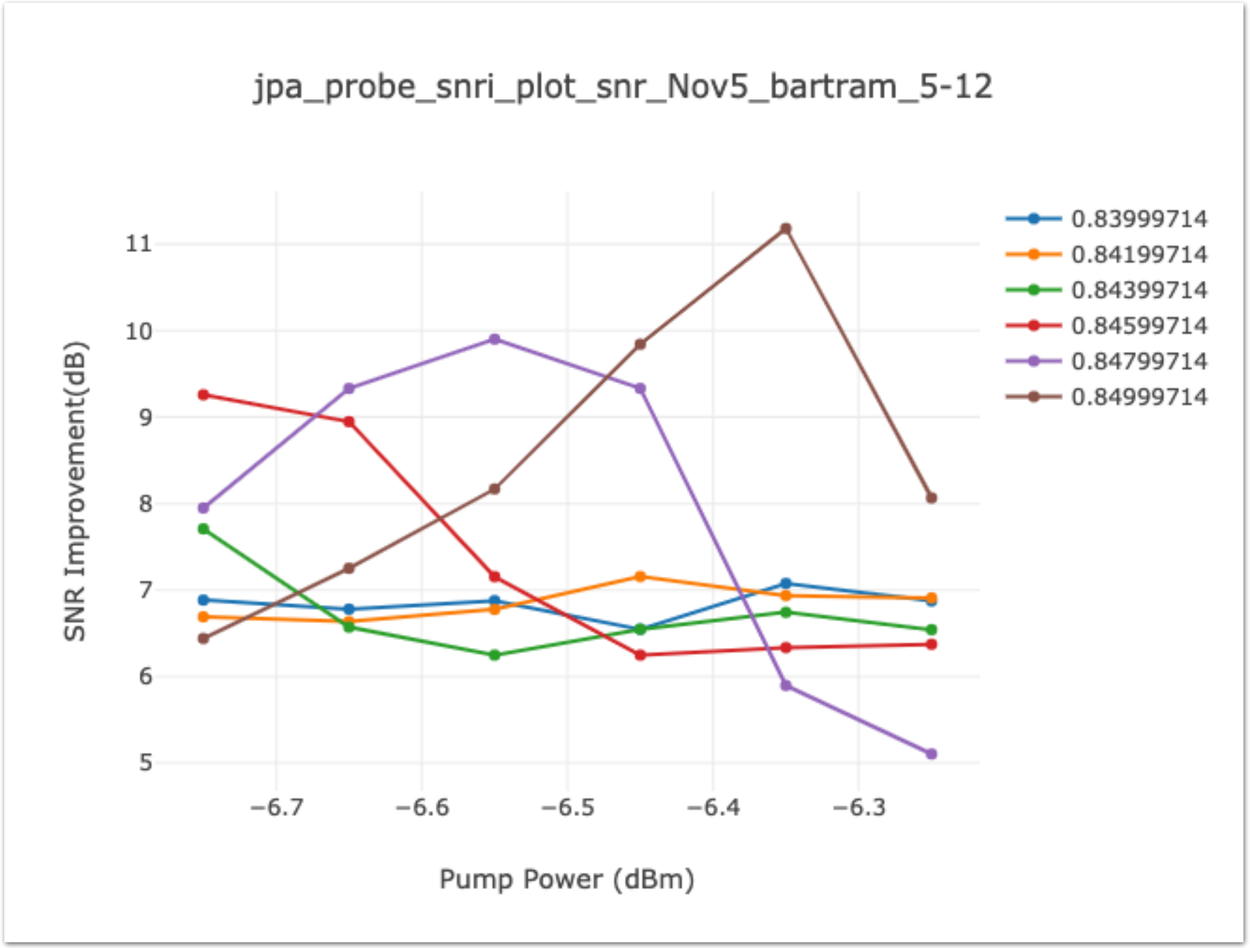
Adding filter to the current supply

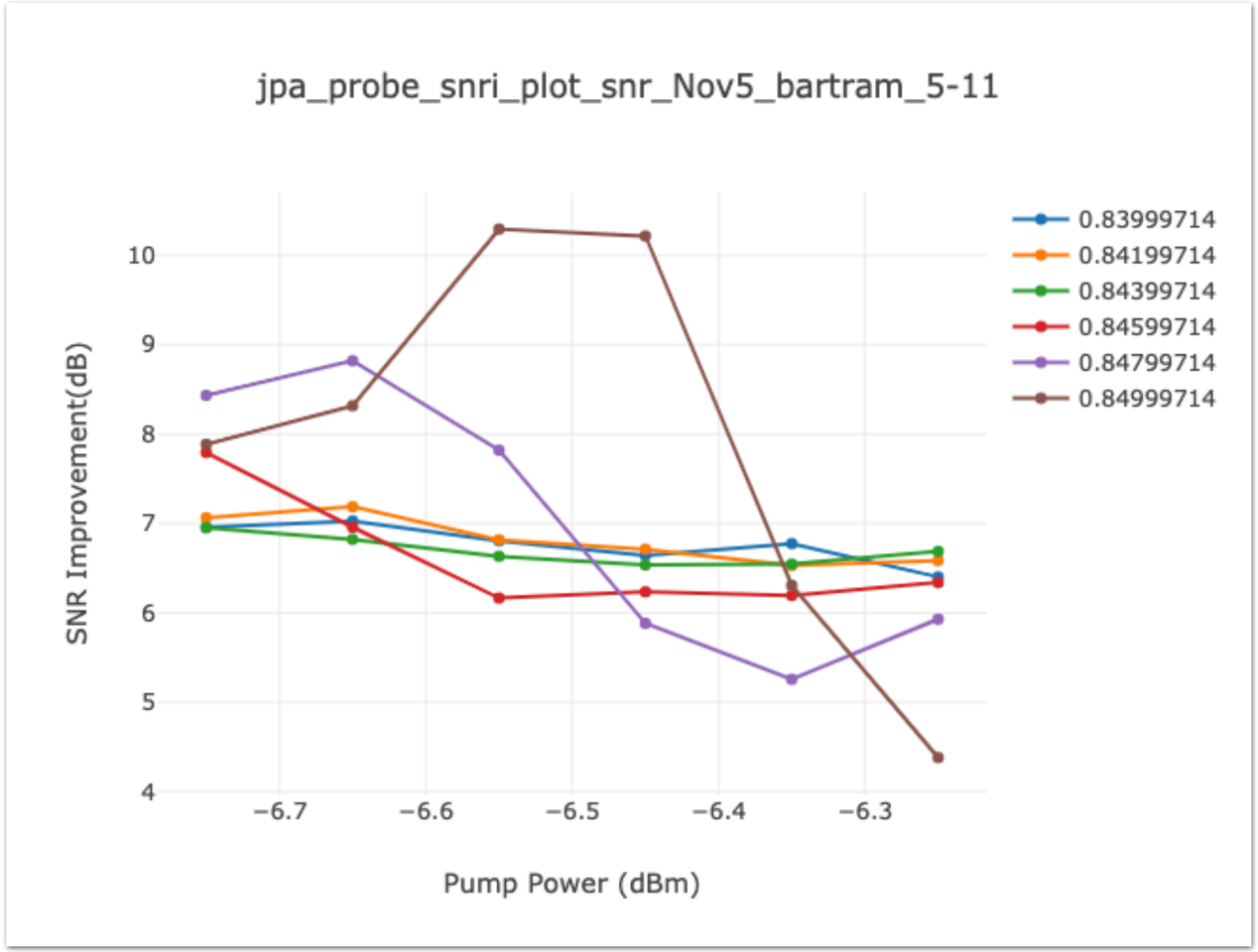


No real change was observed
Still had max of 8 dB SNRI



Tweaking the Magnetic Field

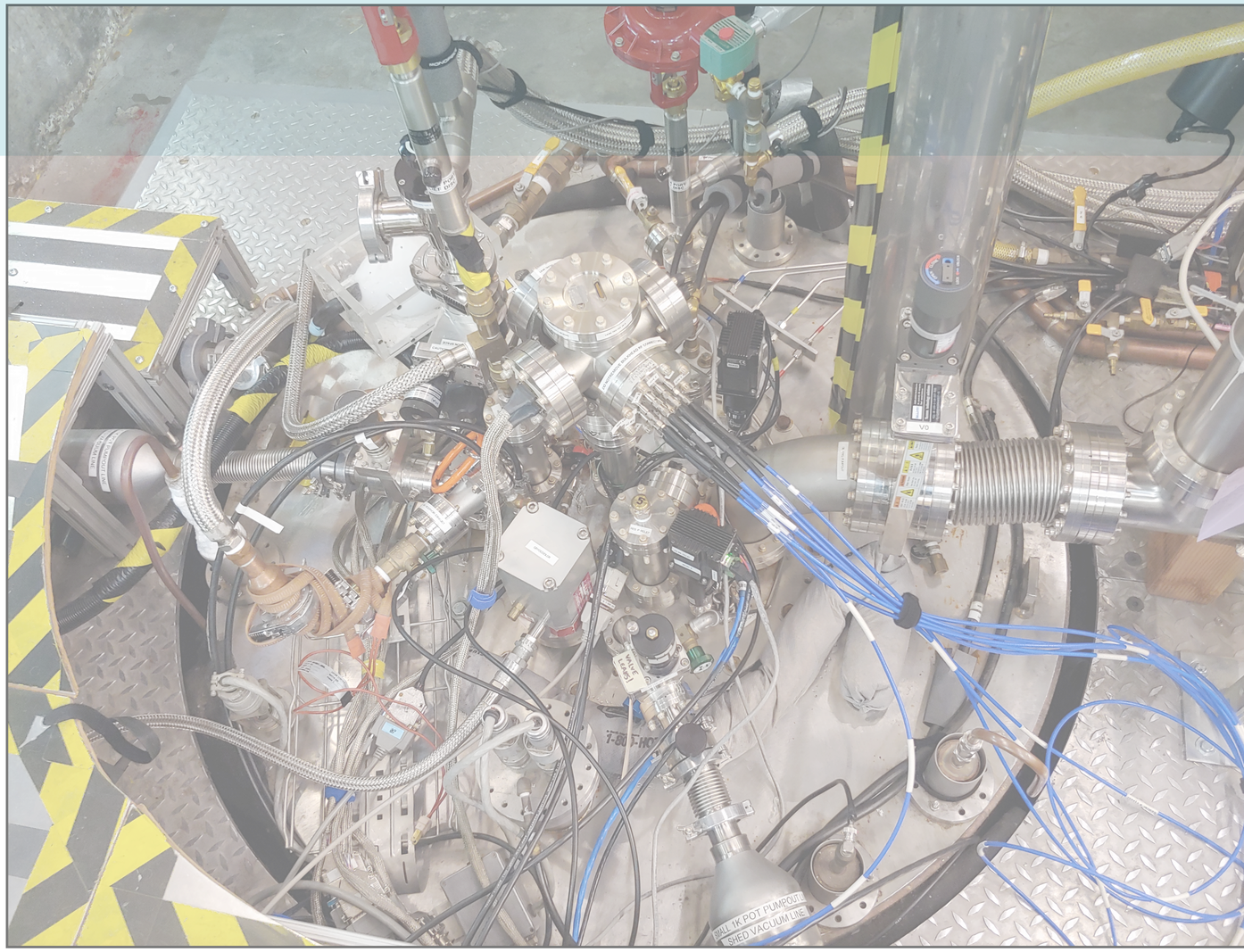




Higher SNR would appear, but was not stable enough to track.
Study points to flux trapping likely still being the issue.

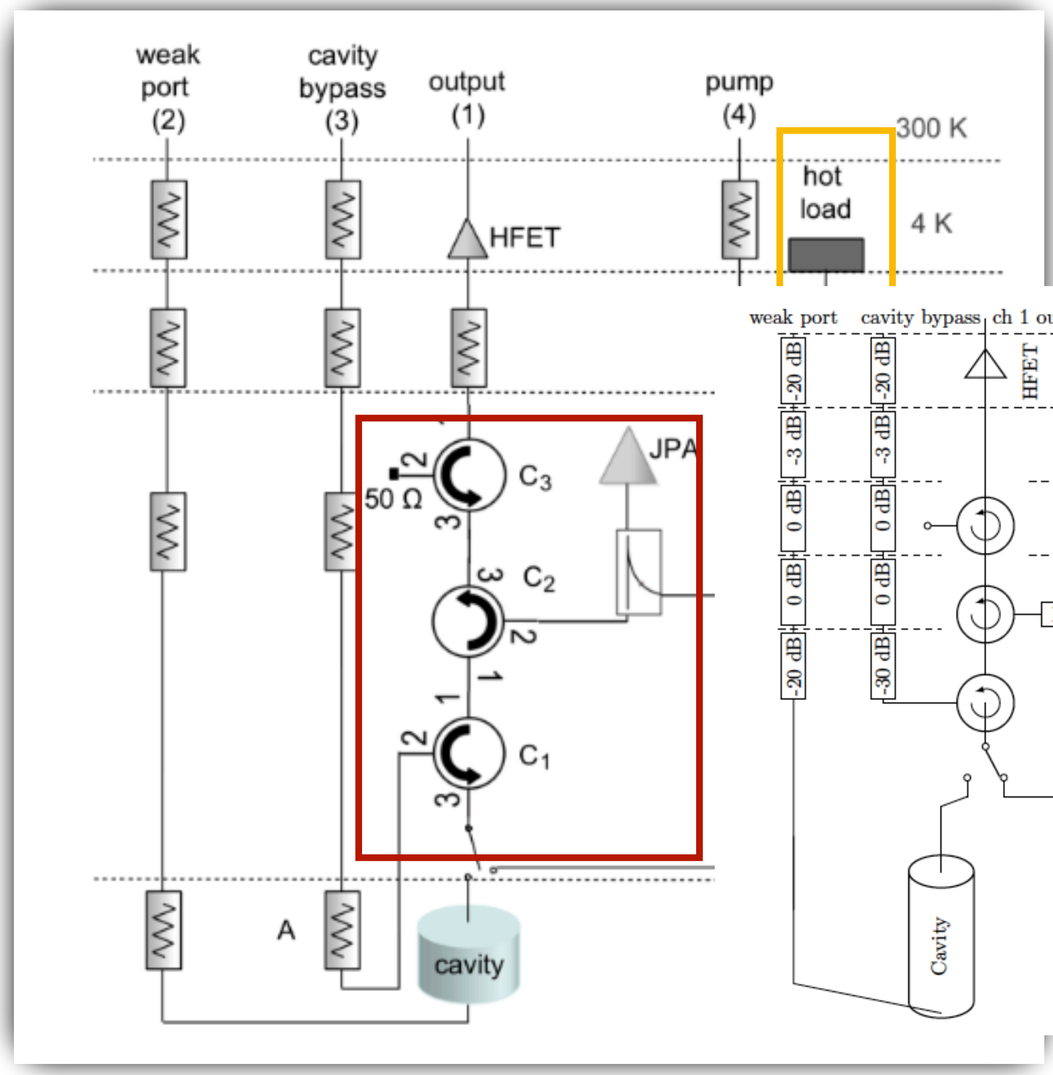
Conclusions

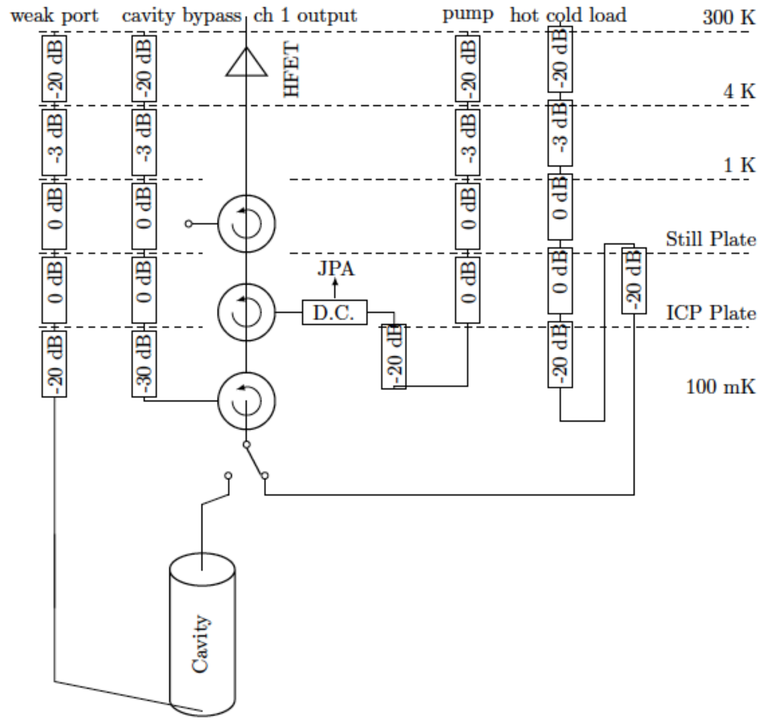
- Low SNR issue likely caused by flux trapping
- Hope is that warm-up and magnet ramp down will resolve this
- If not, plan is to extract and replace JPA and/or shielding
- New techniques to try to target the noise temperature



Any questions?

Noise Characterization





- Receiver chain provides means for measuring key RF parameters, such as quality factor

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via an