RF Leakage Studies & GPS Signal Phase Jitter Analysis

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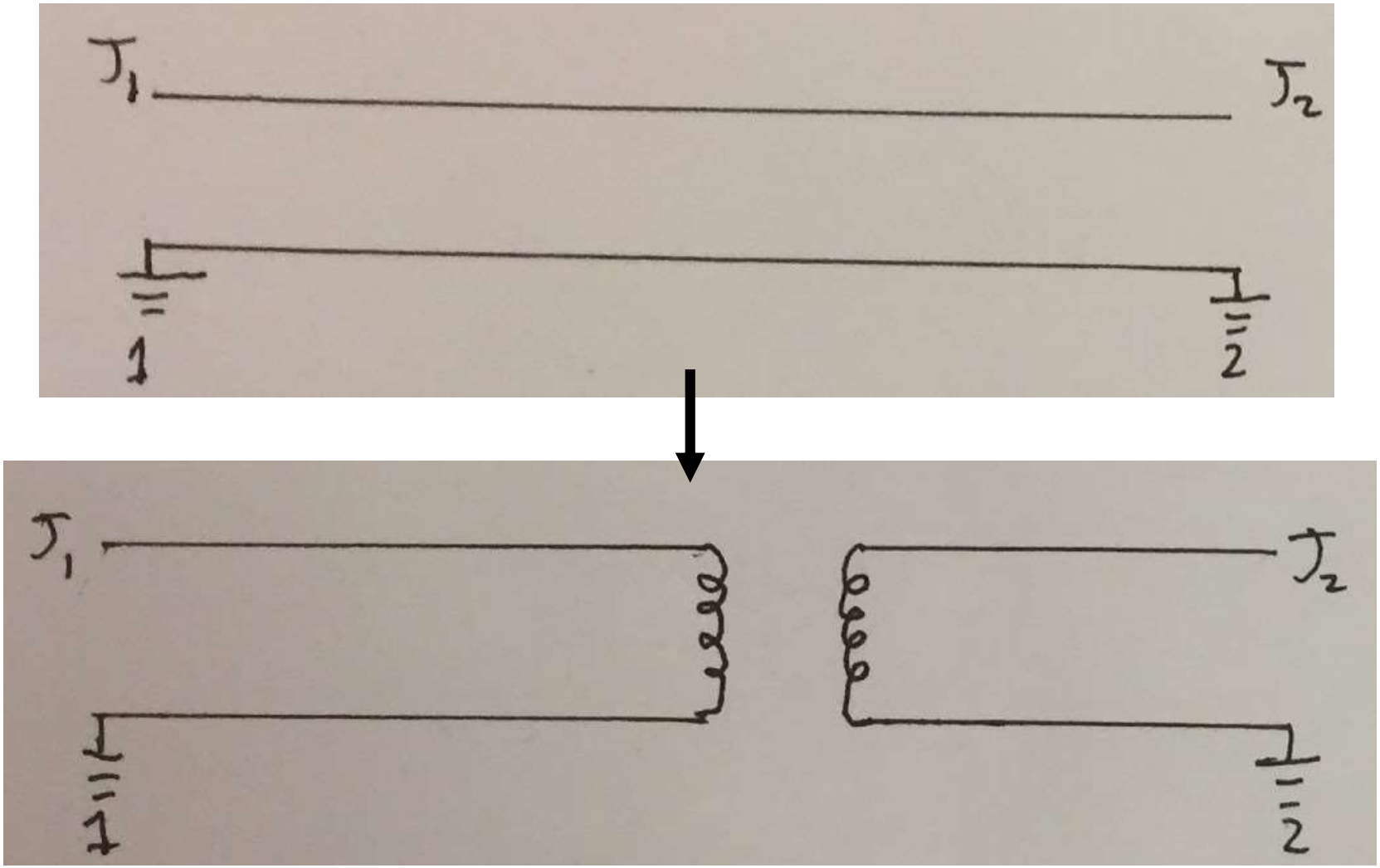
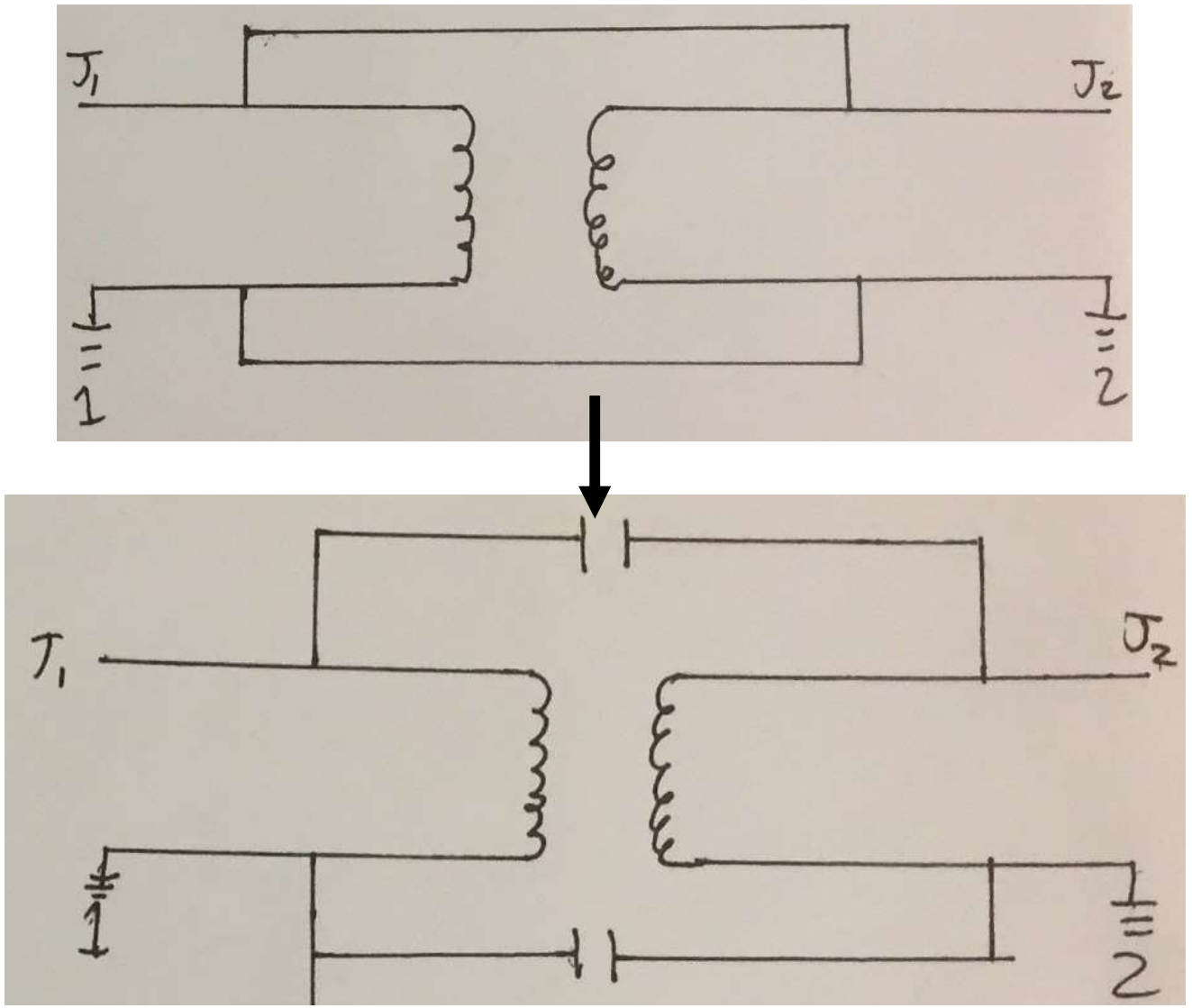
RF Signals and the IFO

- LIGO Radio Frequency (RF) roughly ranges from 100 kHz to 150 MHz
- Used to derive control and alignment signals
- RF leakage can contaminate signals in other electronic channels
- Suspected to be a source of noise and a reason behind some losses of lock
- Our culprit: DC ground isolation units (i.e. baluns)

What are our Baluns for?



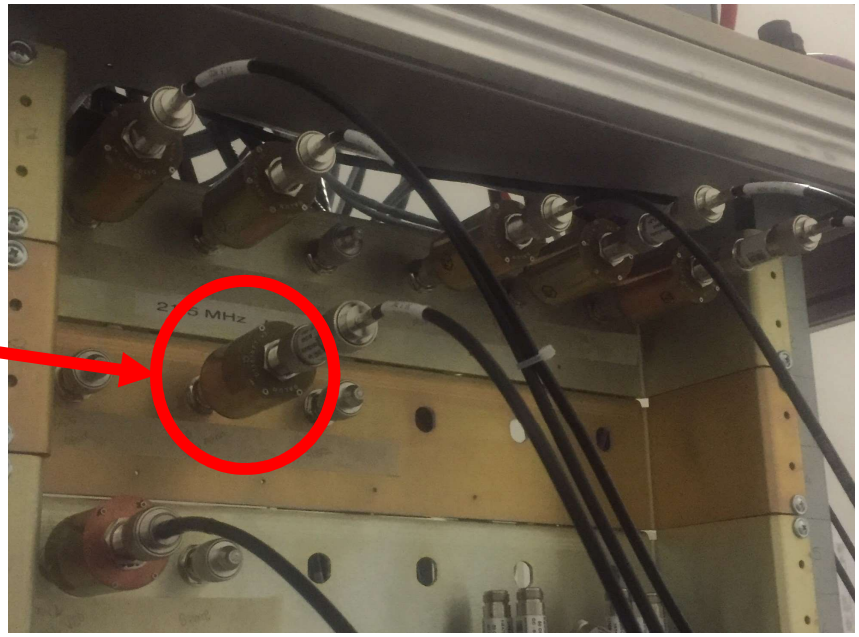
What are our Baluns for? (cont.)



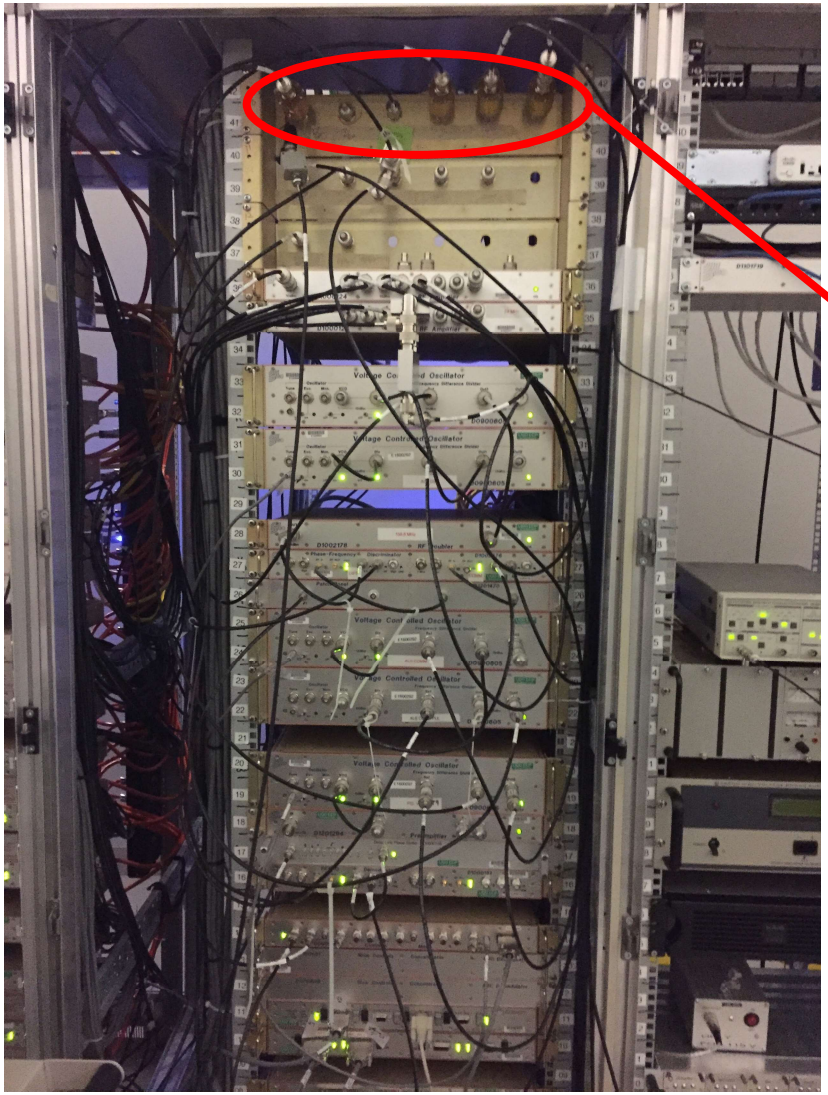
DC Ground Isolation Units ("Baluns")

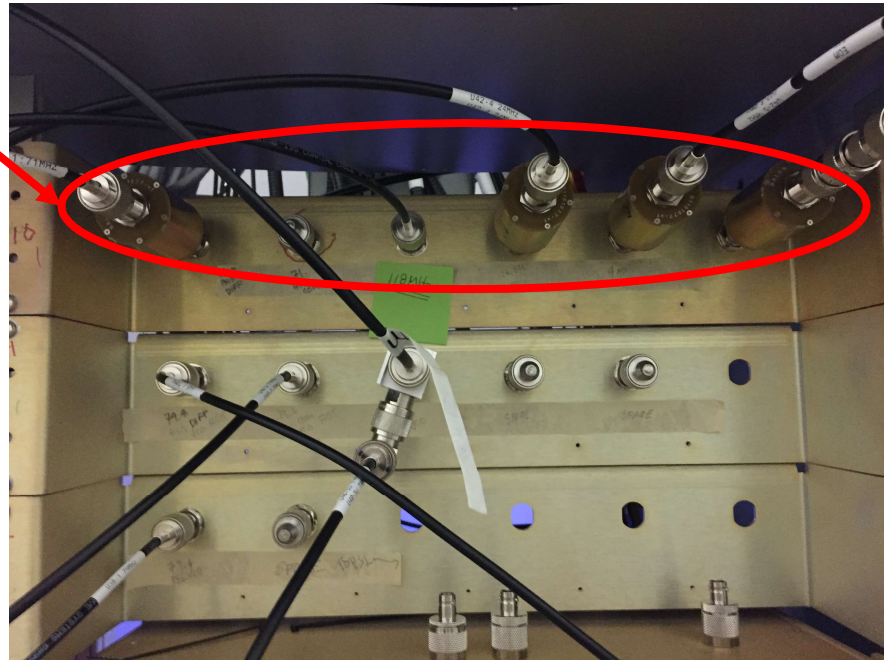
- RF leakages seen by performing spectrum analysis between cabling grounds

- Largest leakage seen with -22 dBV (~79 mV_{rms}) at 80 MHz for this balun

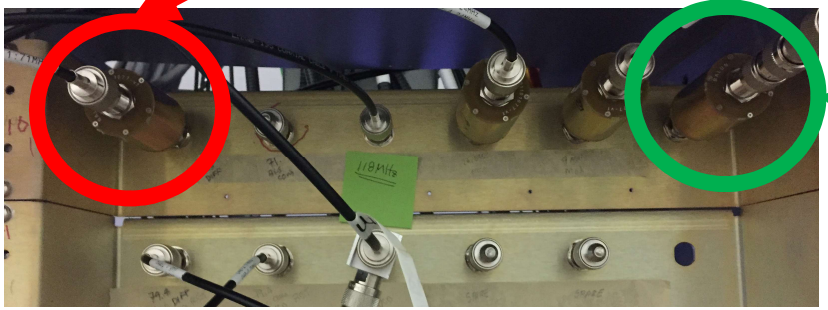


Baluns Mounted on ISC R1 rack



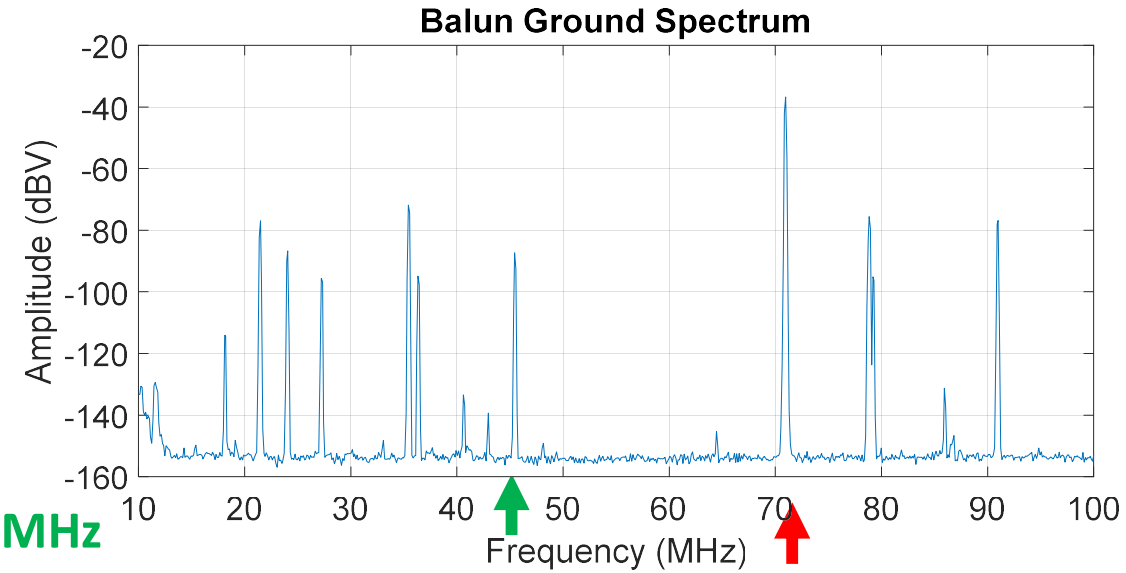


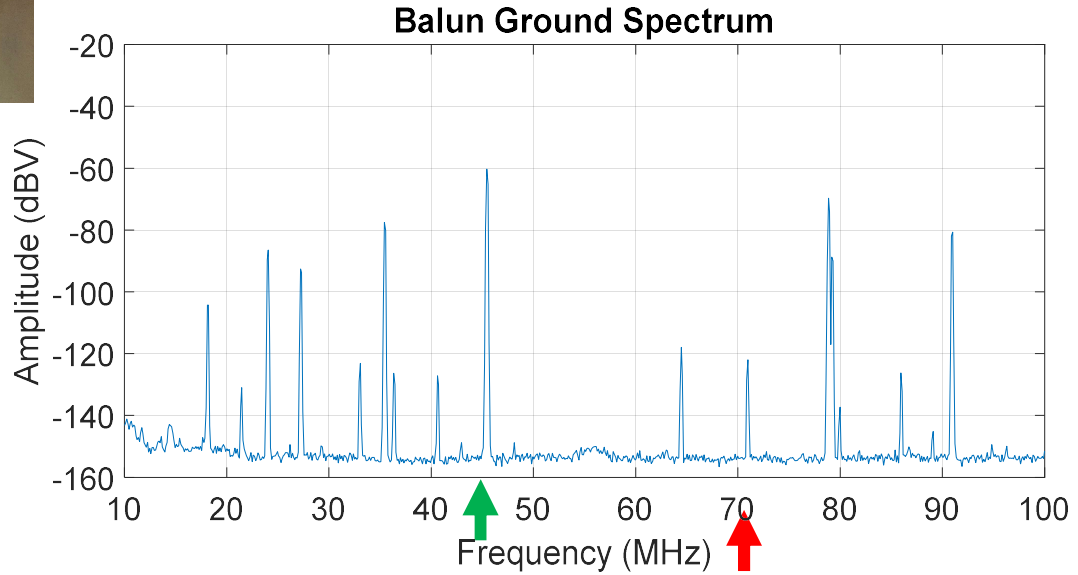
Evidence of Leakage



Carries 71 MHz

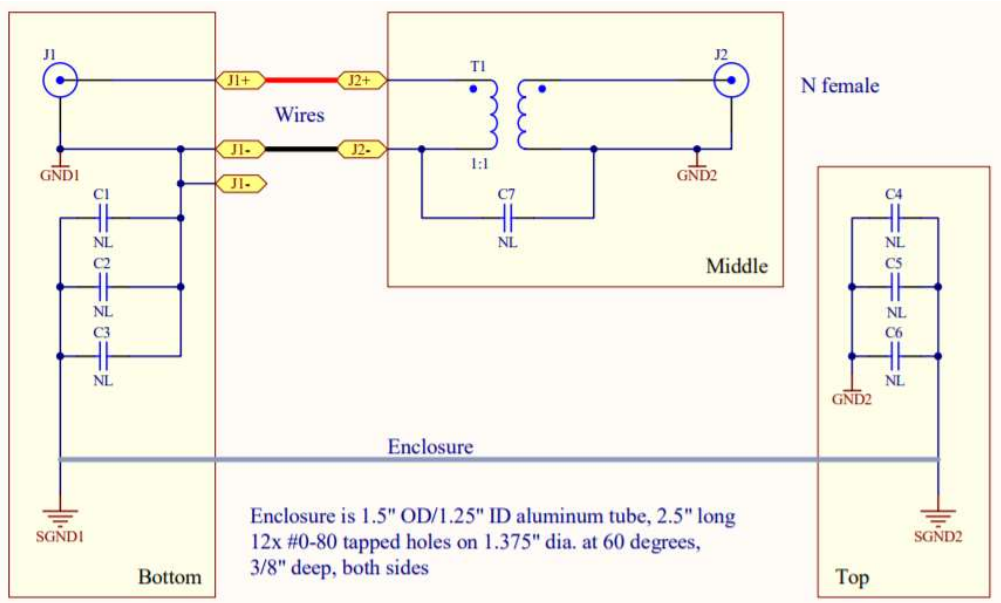
Carries 45 MHz





What Wrong with the Baluns?

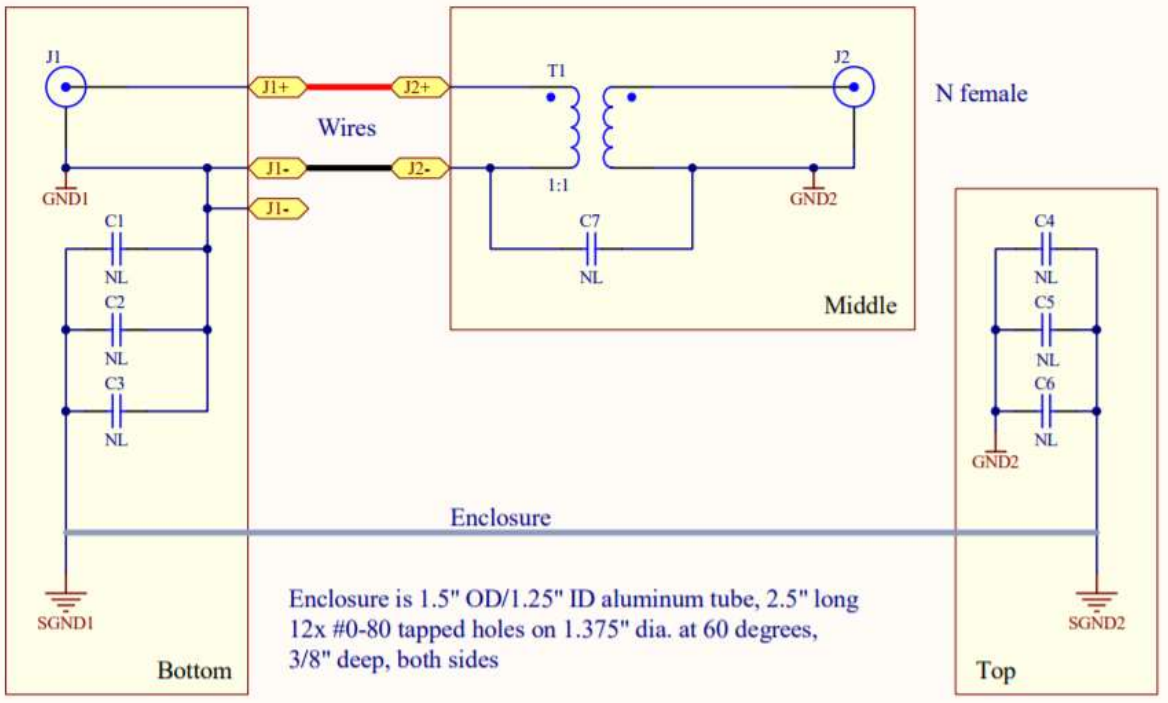
- Capacitors are high-pass filters for RF
- Impedance goes like 1/C so want high C
- Current baluns either have no capacitors or 10 nF capacitors in place



DCC: LIGO-D1101077-v2

Balun Modifications

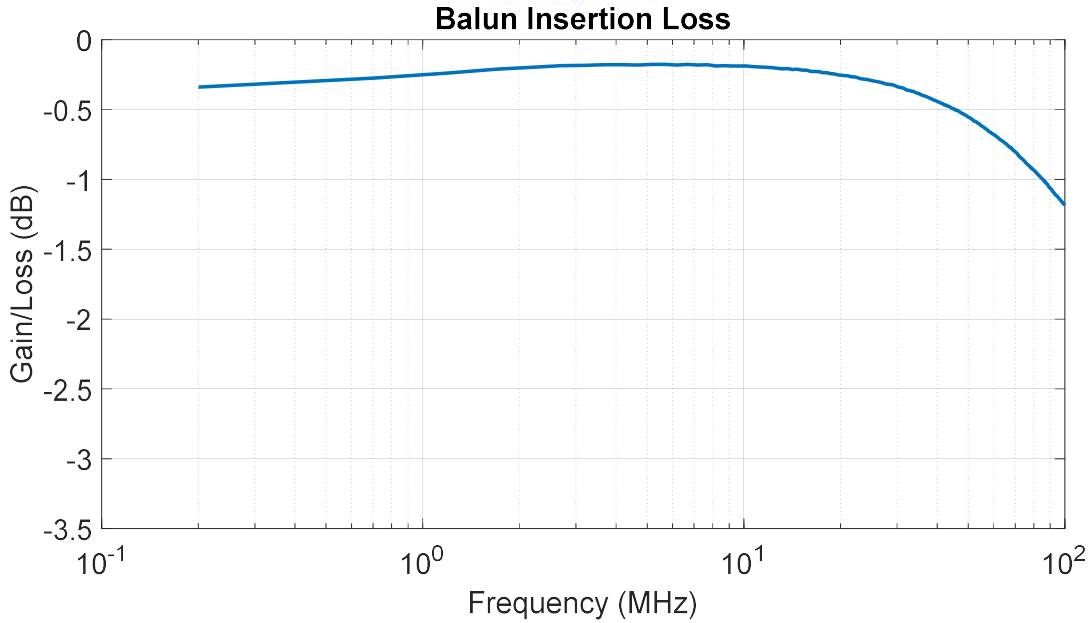
- Replace one end plate with conductor (i.e. copper)
- Load other plate with large capacitors
- Scrape off anodization on enclosure connections



Are the Baluns Still Within Spec? Insertion Loss

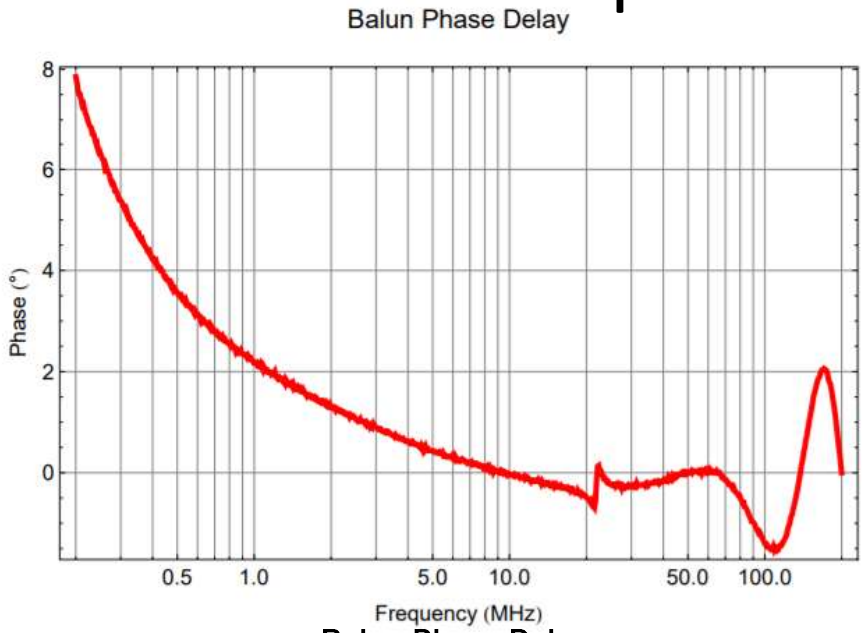
Insertion loss according to spec (LIGO-T1100369-v1)

Insertion loss measured according to testing procedures (LIGO-E1100597-v2)

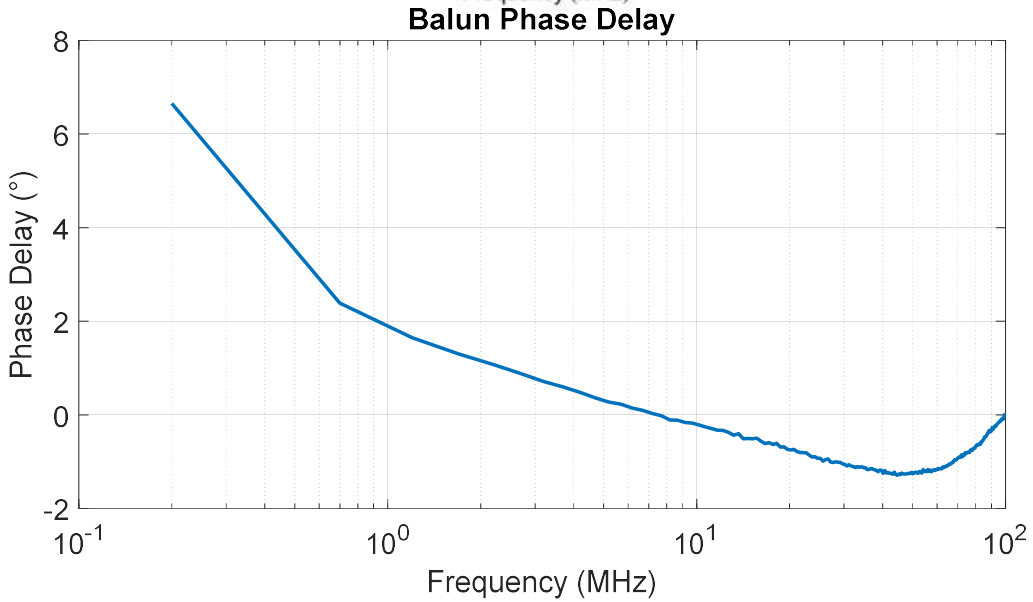


Are the Baluns Still Within Spec? Phase Delay

Phase delay according to spec (LIGO-T1100369-v1)

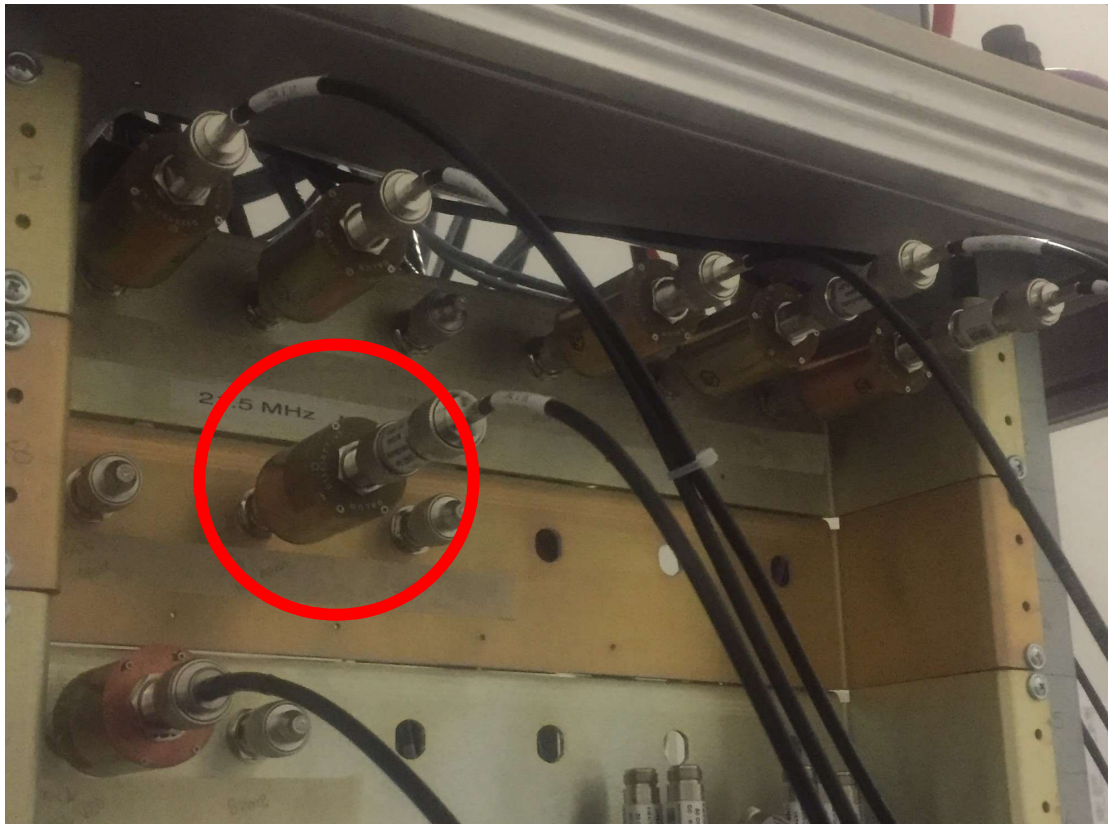


Phase delay measured according to testing procedures (LIGO-E1100597-v2)

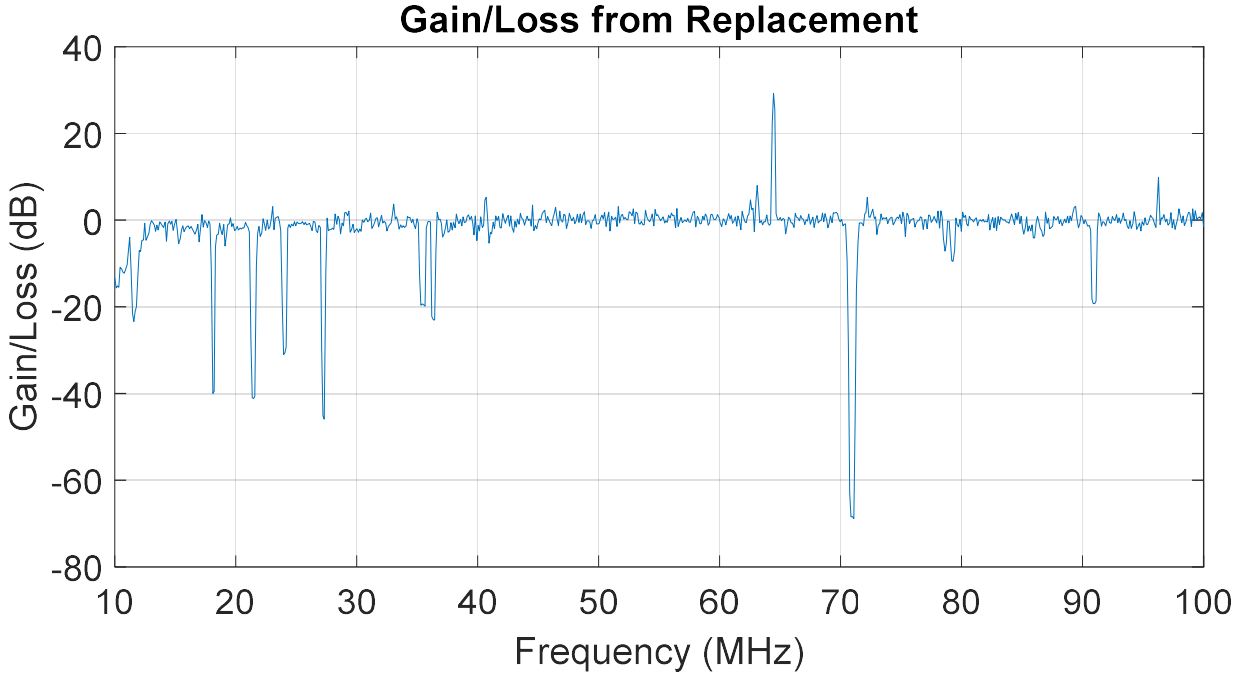


Results: Swapping out 80 MHz Balun

- Decreased leakage from -22 dBV to about -70 dBV (factor of ~250 decrease)



Results: Swapping out 71 MHz Balun



However, in the Neighboring Baluns…

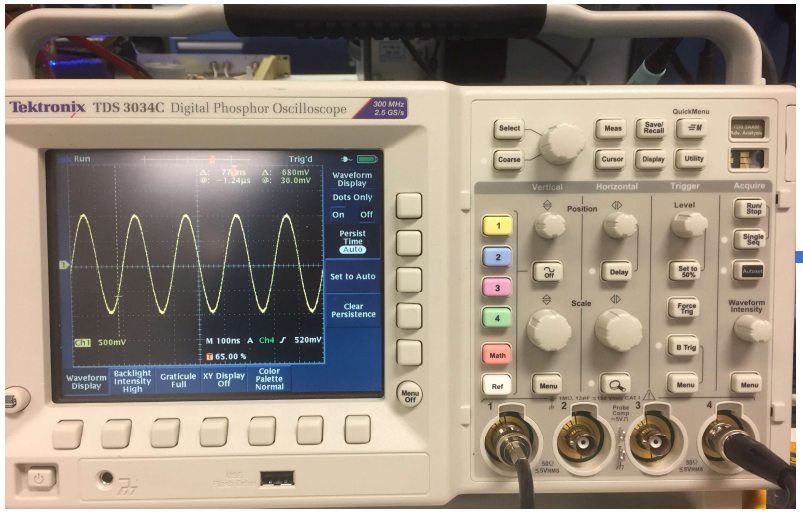
Conclusions

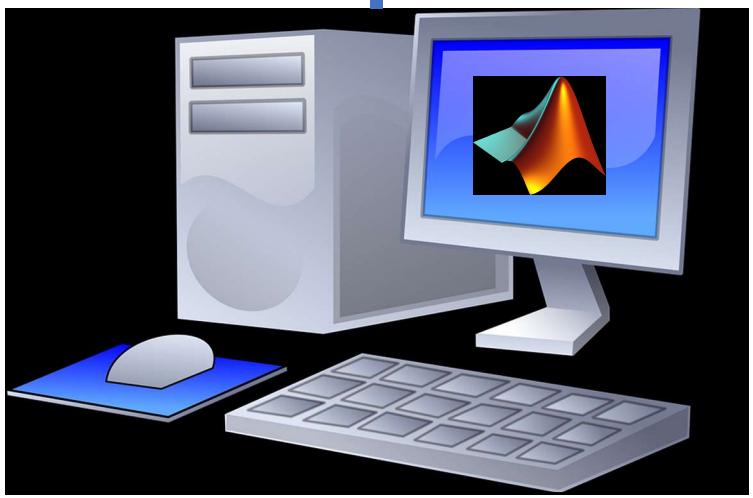
- Baluns act like an antenna
- Modifications reduce RF leakage for frequency carried
- However, unappreciated nuances in how the signals from different baluns interact with each

GPS Signal Phase Jitter

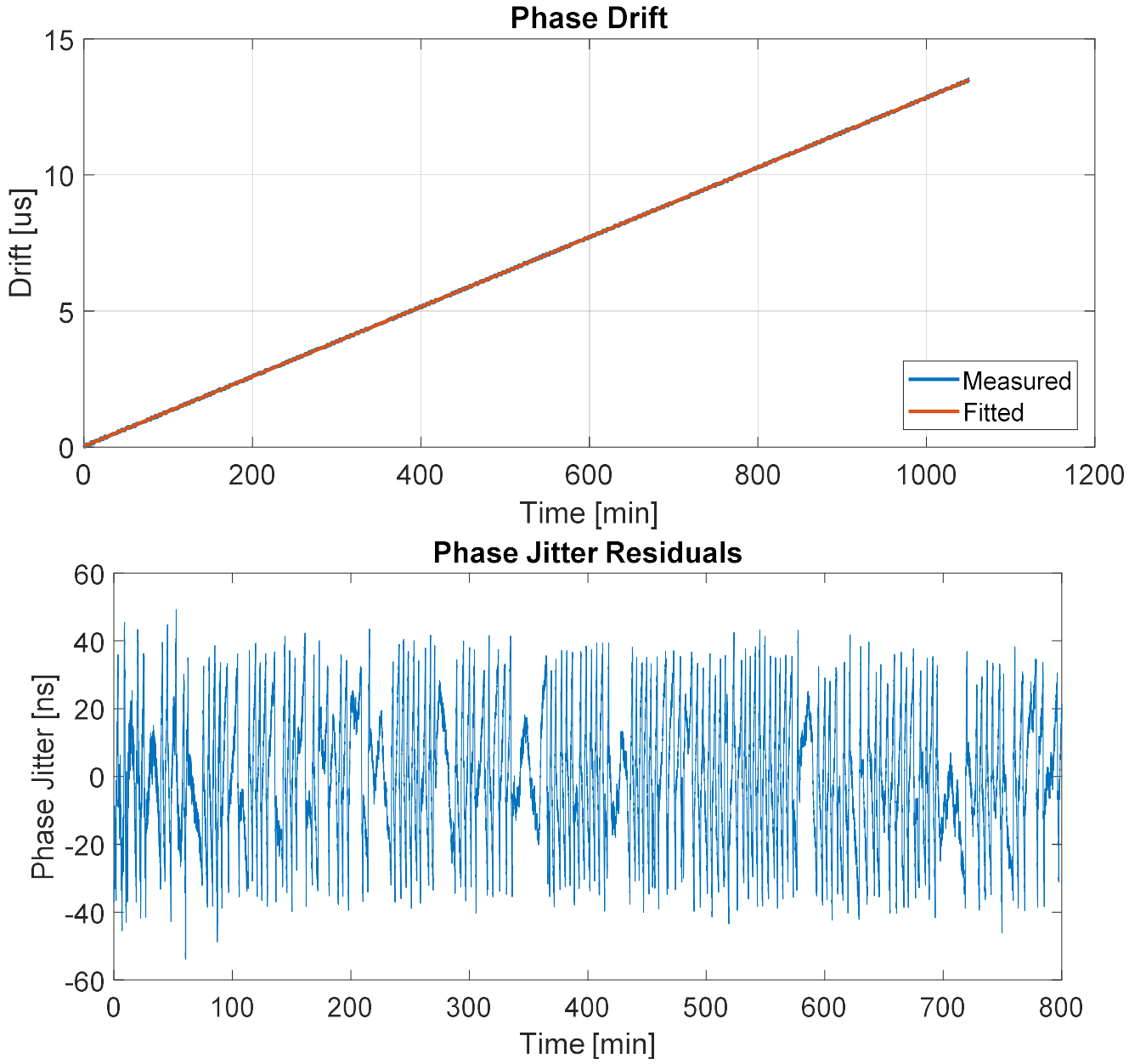
- We use GPS to discipline LHO RF sources
- 1 PPS GPS signals are observed to wander in phase against atomic clock signals
- Wandering could be a source of noise

How was Phase Jitter Measured?



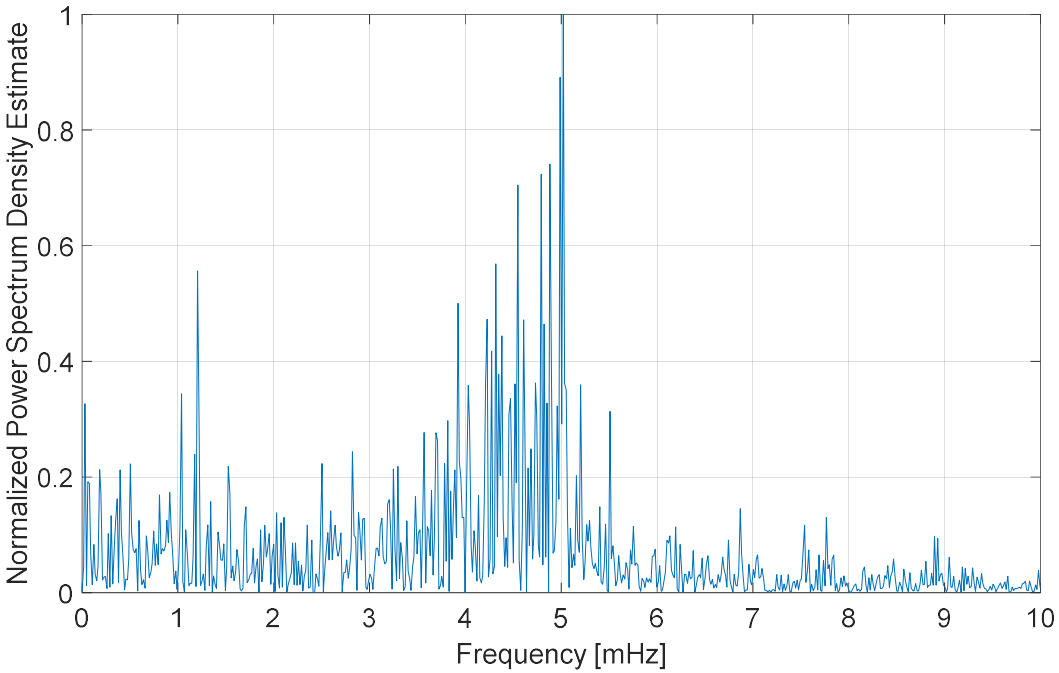


Observed Periodicity in Residuals

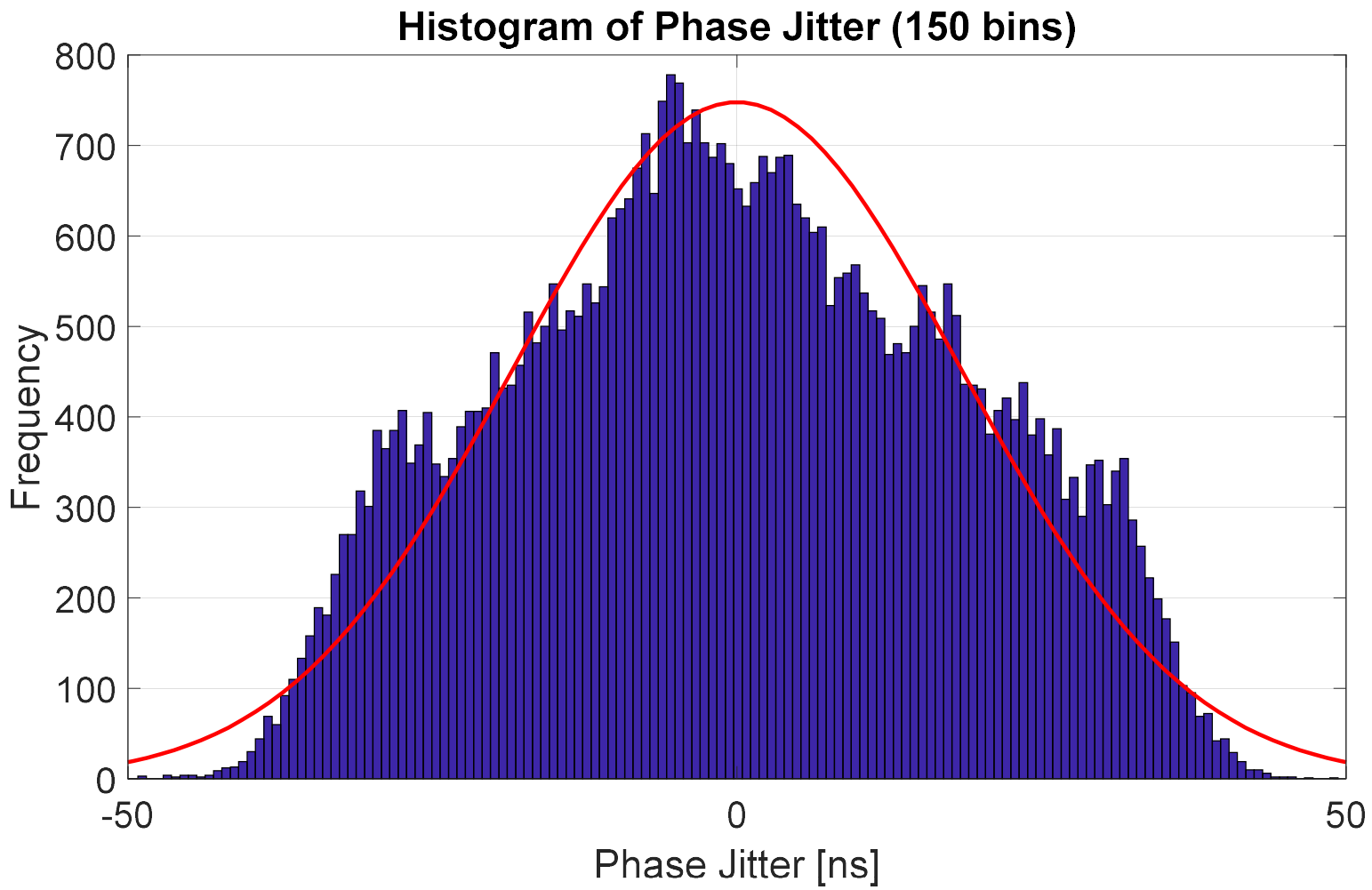


Apparent Periodicity

- Creating periodogram we find two groups of peaks with the highest of each group seen at
  - 5.02 mHz
  - 1.205 mHz



Histogram of Phase Jitter



Conclusions

- GPS phase jitters as much as ~45 ns
- Phase drift does not appear to accumulate
- Jitter appears to be pseudo-periodic
- Non-Gaussian distribution suggest deterministic aspect may be involved
- Suggest further research into understanding how this can be a source of noise

Questions?