

Characterization of microwave photonic synthesizer for future applications in radio astronomy instrumentation

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Thank you to **Jim Braatz** and all others involved in running the summer student programs at NRAO.

Jargon elimination

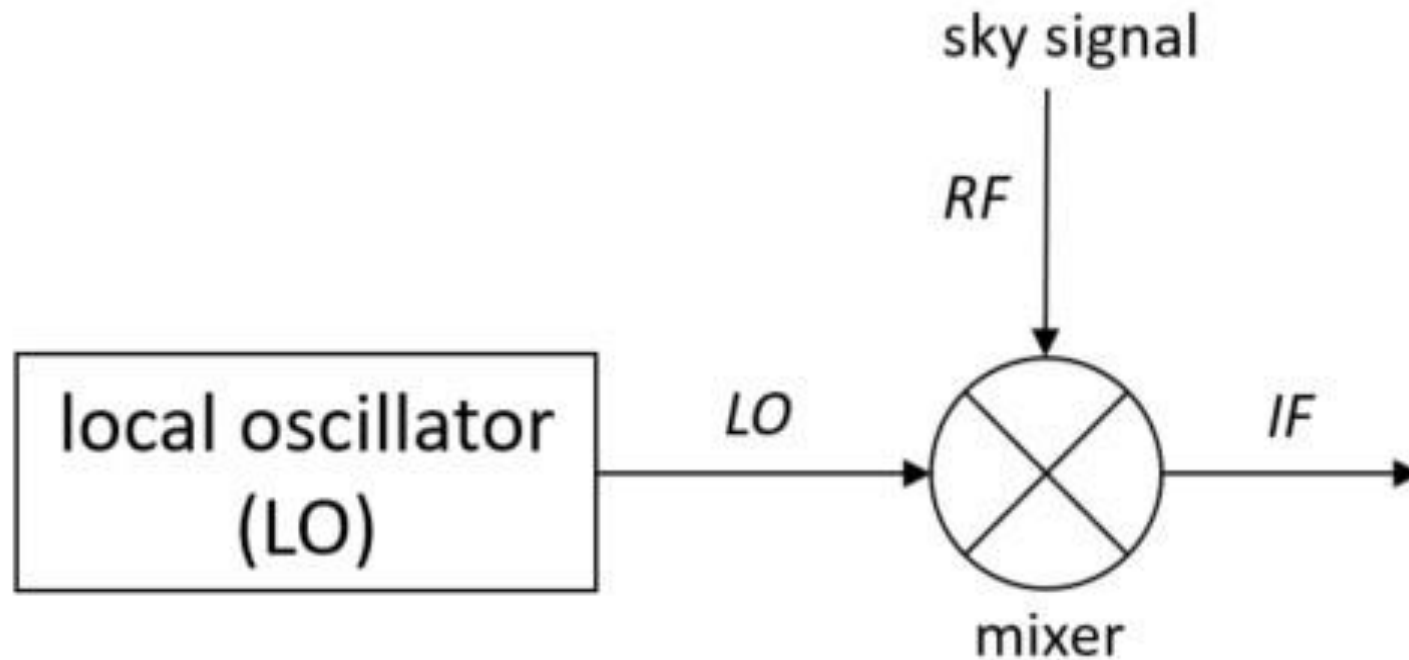
Characterization of microwave photonic synthesizer for future applications in radio astronomy instrumentation



Testing a device that generates a signal with lasers to see whether it is reliable enough to be used in future antenna designs.



Why do antennas need a signal?



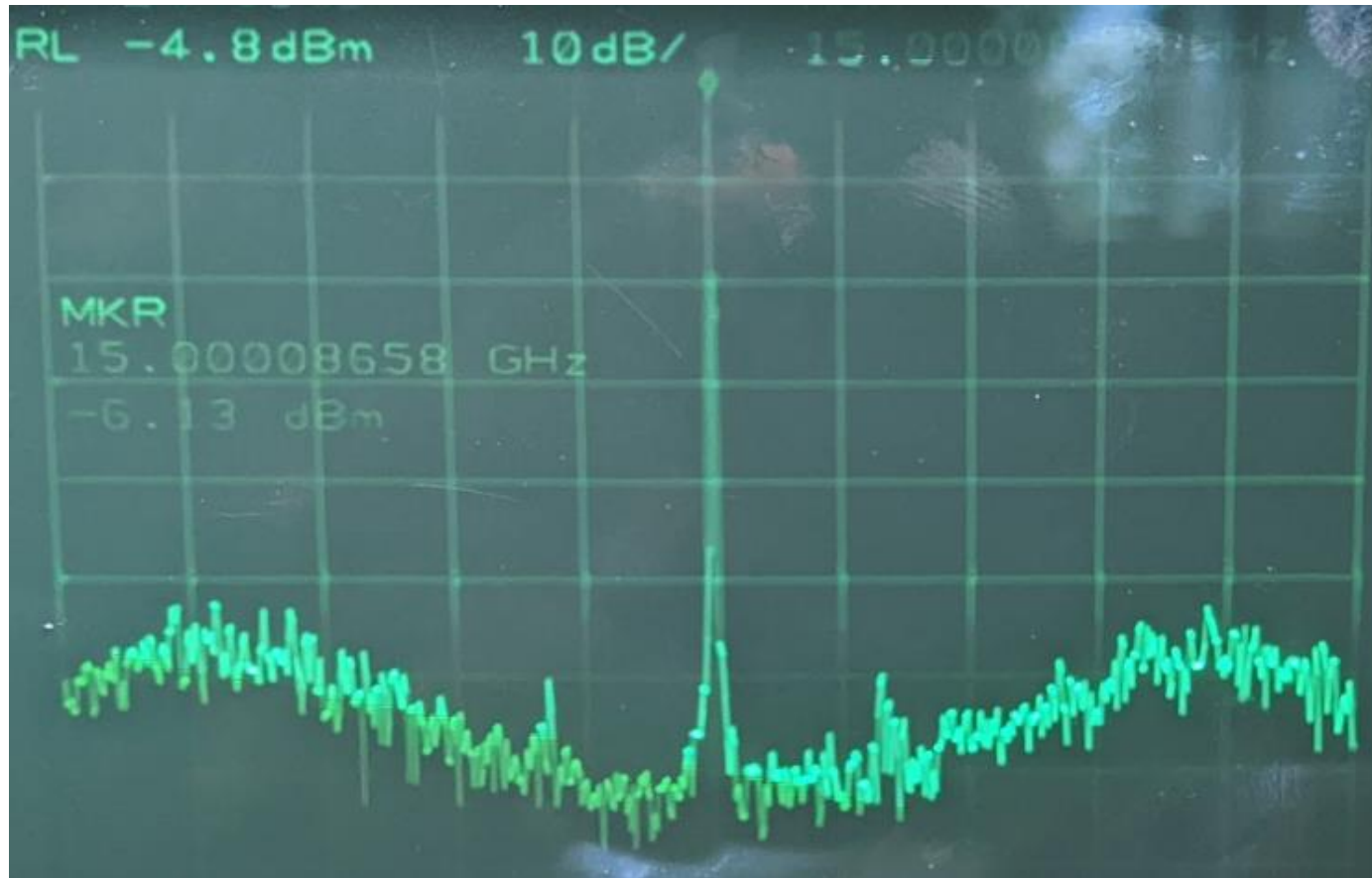
Why do antennas need a signal?



Image: ALMA observatory. <https://www.almaobservatory.org/en/about-alma/how-alma-works/technologies/interferometry/>



Wait, what kind of signal?



Needs to be...

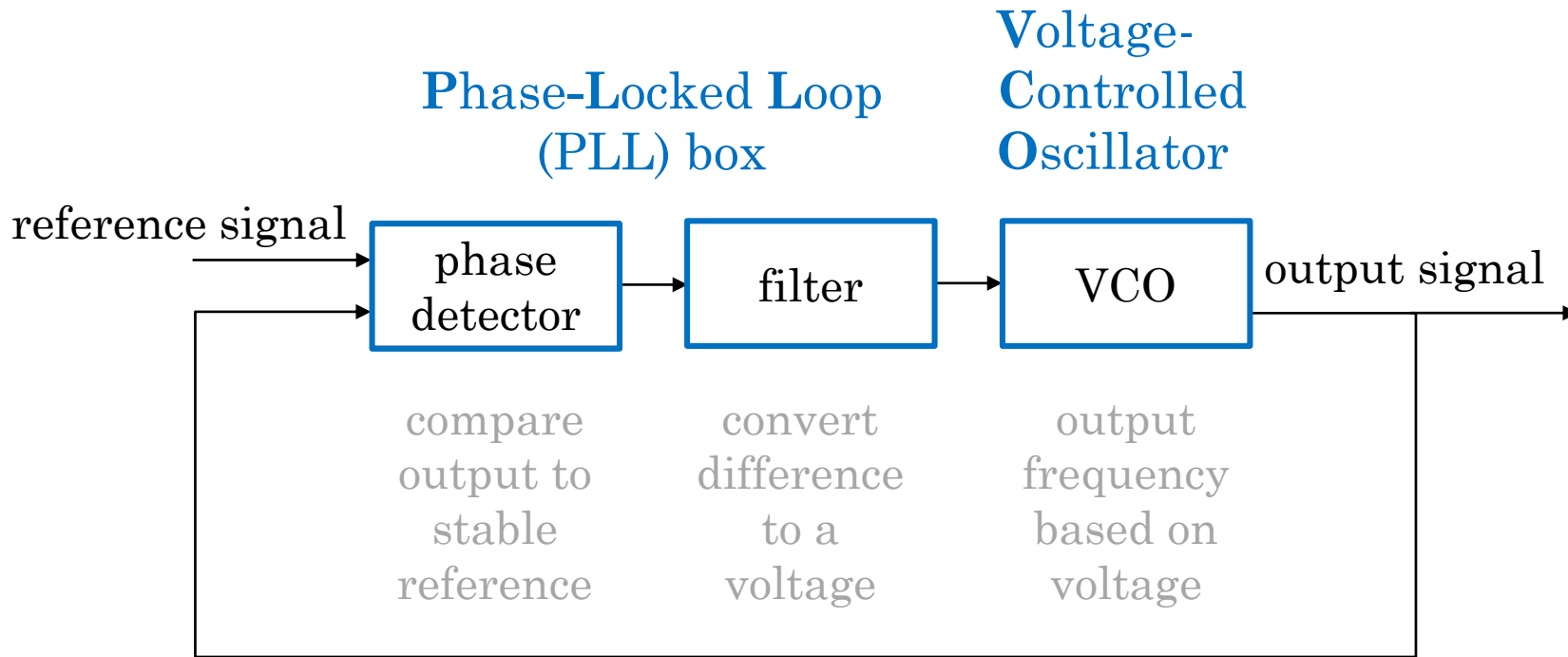
OPTICAL

LOW-NOISE

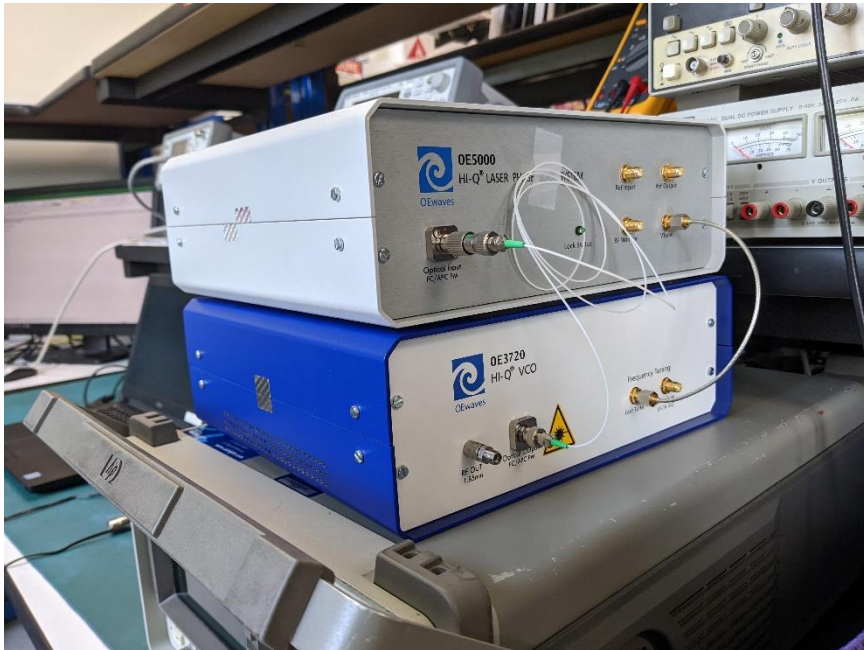
STABLE



What's a phase-locked loop?



What's a phase-locked loop?



What's the point of this project?

Implementation could decrease total size and weight, particularly at the secondary focus...

...if the system works and fulfills requirements

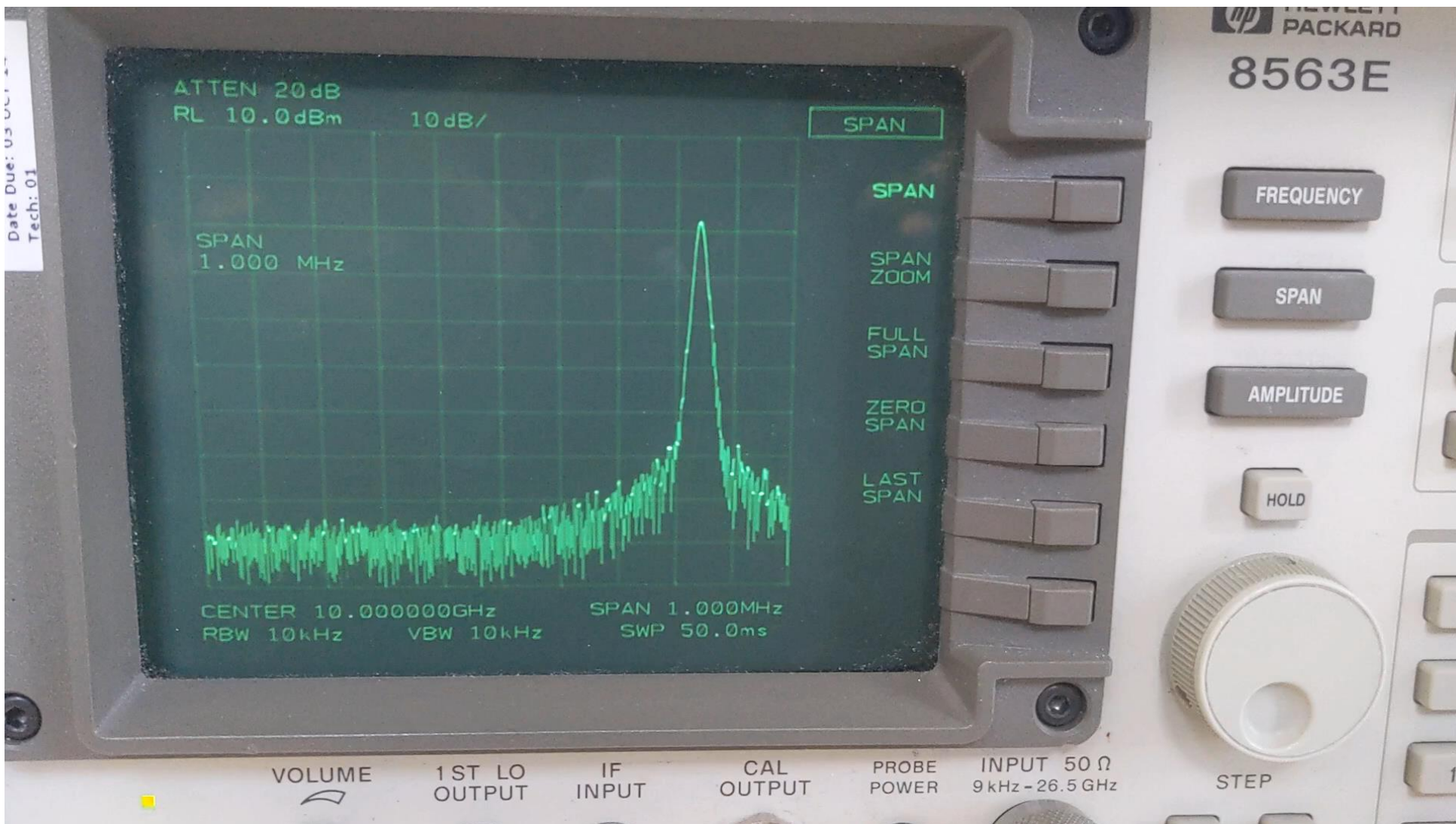
1. Make sure system functions as expected
2. Quantify signal stability
3. Compare to analogous ALMA functionality
4. Consult ngVLA specs for requirements





How does it succeed?

It does what it was designed to!





How does it succeed?

Meets or outperforms provided specifications

Output range: 0-50GHz → 0-72GHz

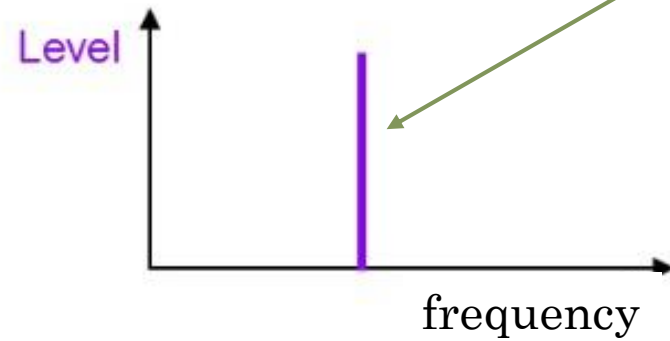
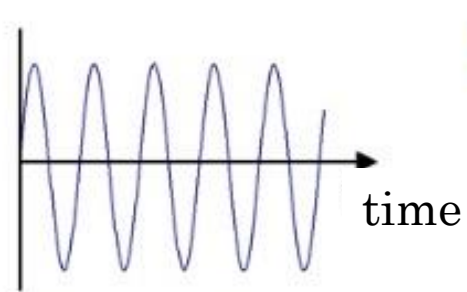
Locking range: 5-20GHz → 4-22GHz

Capture range: +/-200MHz → +/-400MHz

Loop bandwidth: 20kHz → 20kHz



Stability



JITTER

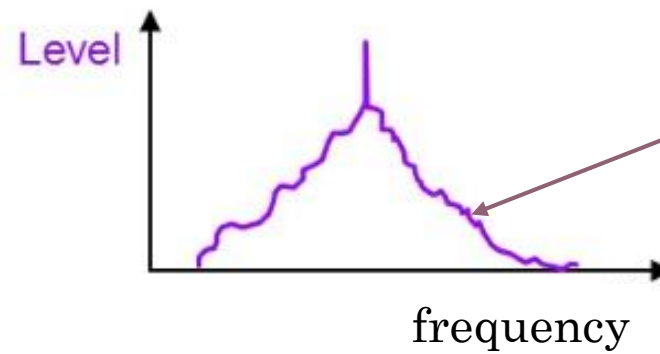
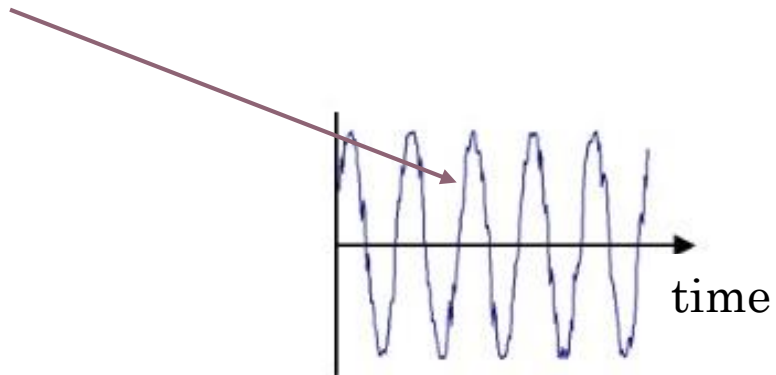
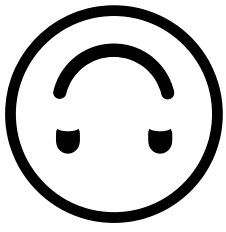
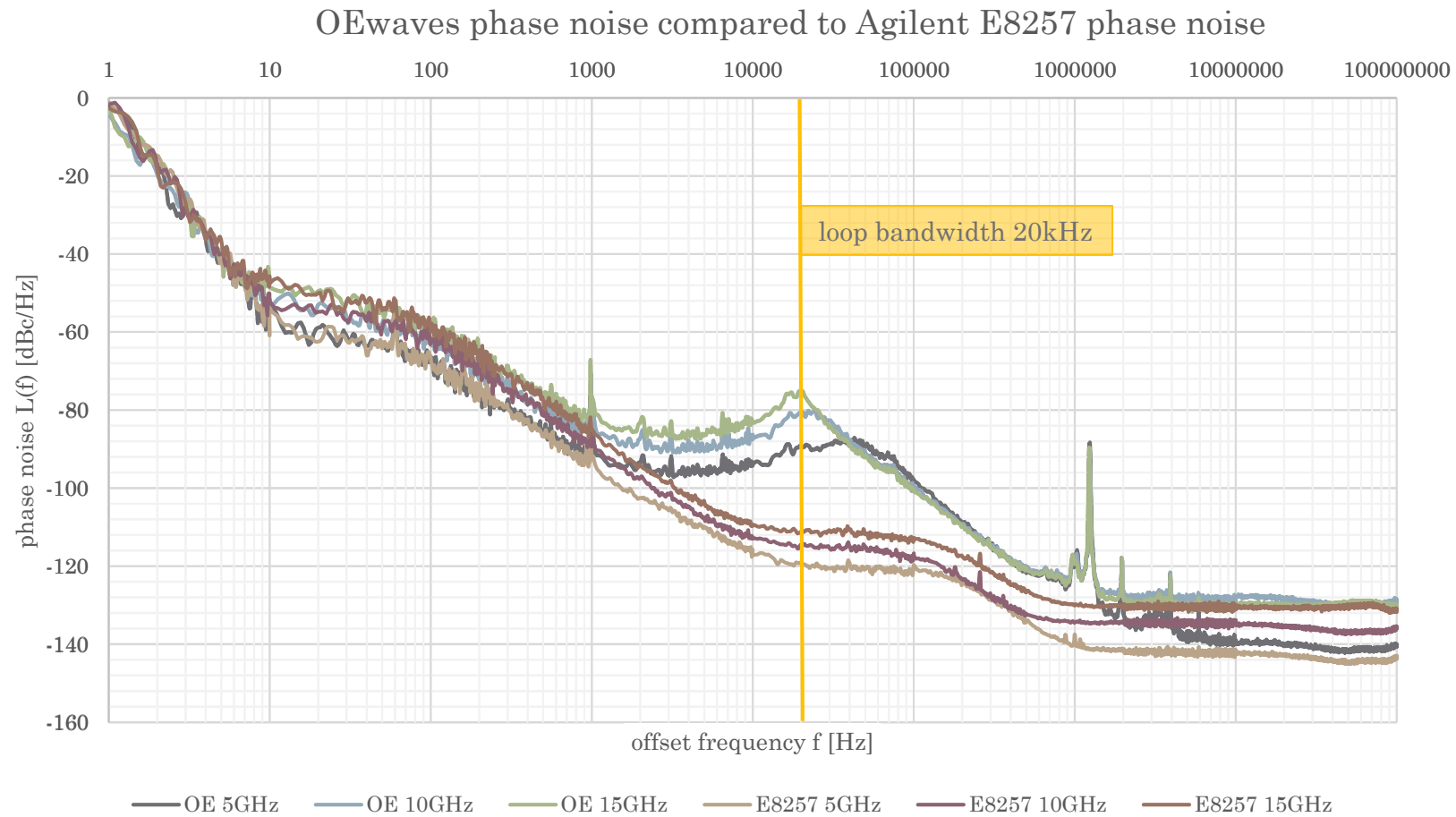


Image: Rohde & Schwarz, Mastering Phase Noise Measurements





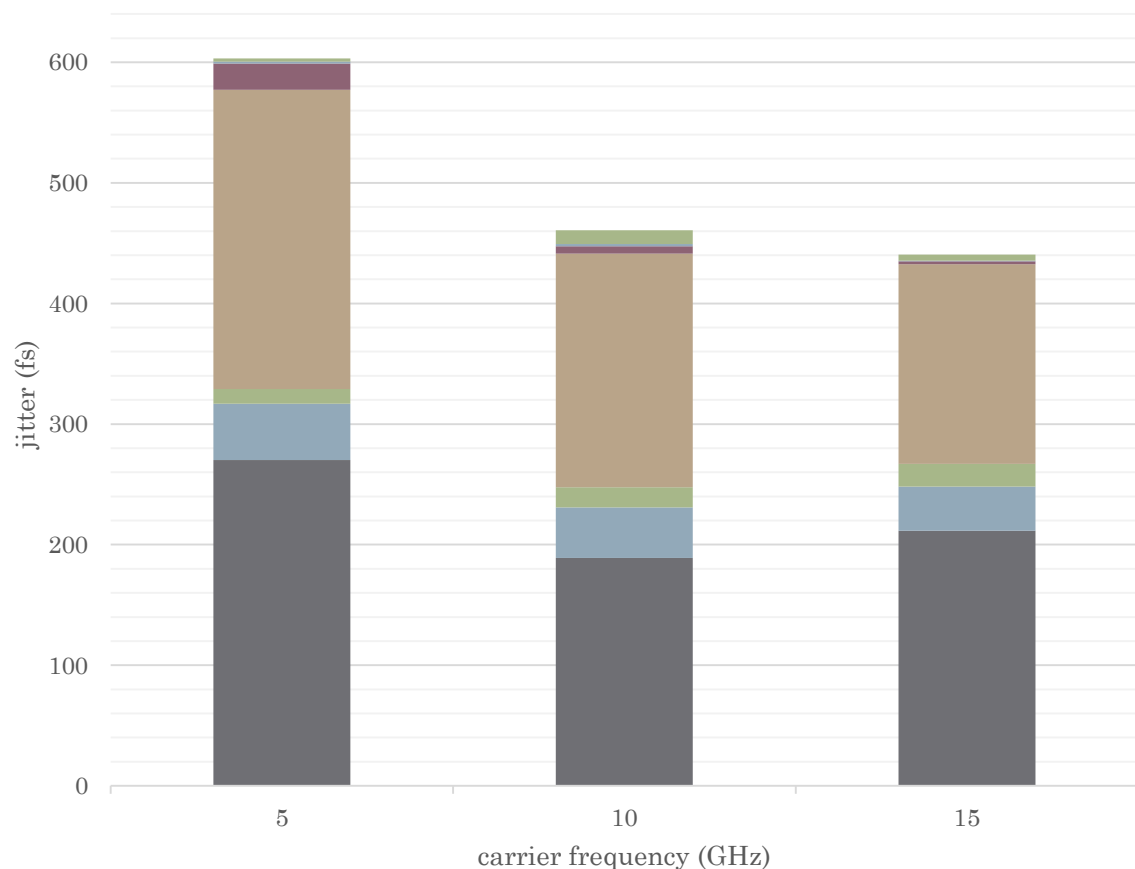
How does it NOT succeed? Phase noise



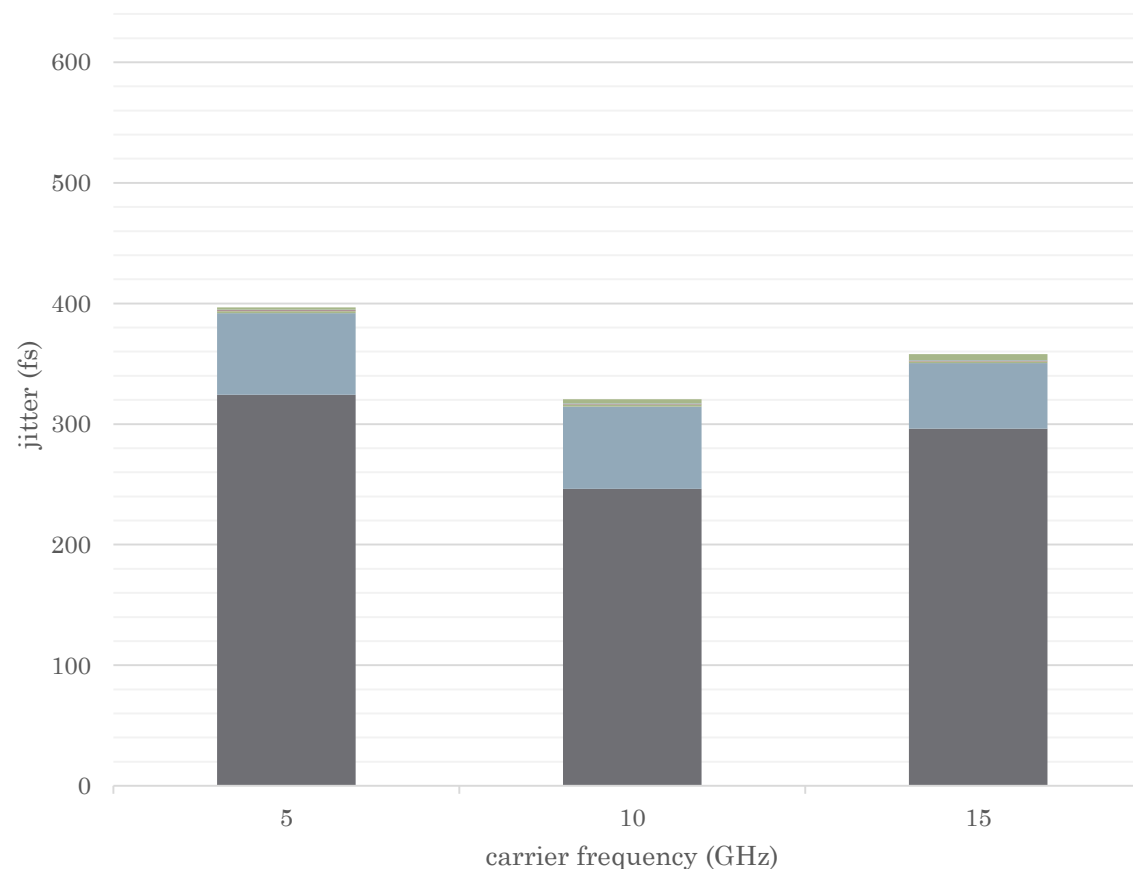


How does it NOT succeed? Timing jitter

decade-by-decade OEwaves (fs)



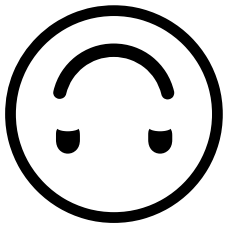
decade-by-decade Agilent E8257 (fs)



10Hz-100Hz 100Hz-1kHz 1kHz-10kHz 10kHz-100kHz
100kHz-1MHz 1MHz-10MHz 10MHz-100MHz

10Hz-100Hz 100Hz-1kHz 1kHz-10kHz 10kHz-100kHz
100kHz-1MHz 1MHz-10MHz 10MHz-100MHz





How does it NOT succeed?

Modifications
required



Conclusions

1. Make sure system functions as expected
2. Quantify signal stability
3. Compare to analogous ALMA functionality
4. Consult ngVLA specs for requirements



Conclusions

1. Functions as expected; meets provided spec
2. Poor phase noise/jitter near loop bandwidth
3. Does not perform as well as commercial synthesizer
4. Does not meet ngVLA frequency, jitter requirements

Future/ongoing work: Fine-tune components that determine loop bandwidth, hopefully reducing phase noise/jitter.
Increase maximum locking frequency. More complete testing.

With additional development to address phase noise concerns and more rigorous testing, the OEwaves laser synthesizer system is a viable option for future antenna designs.



Extra slides

In case of questions

PLL: phase detector

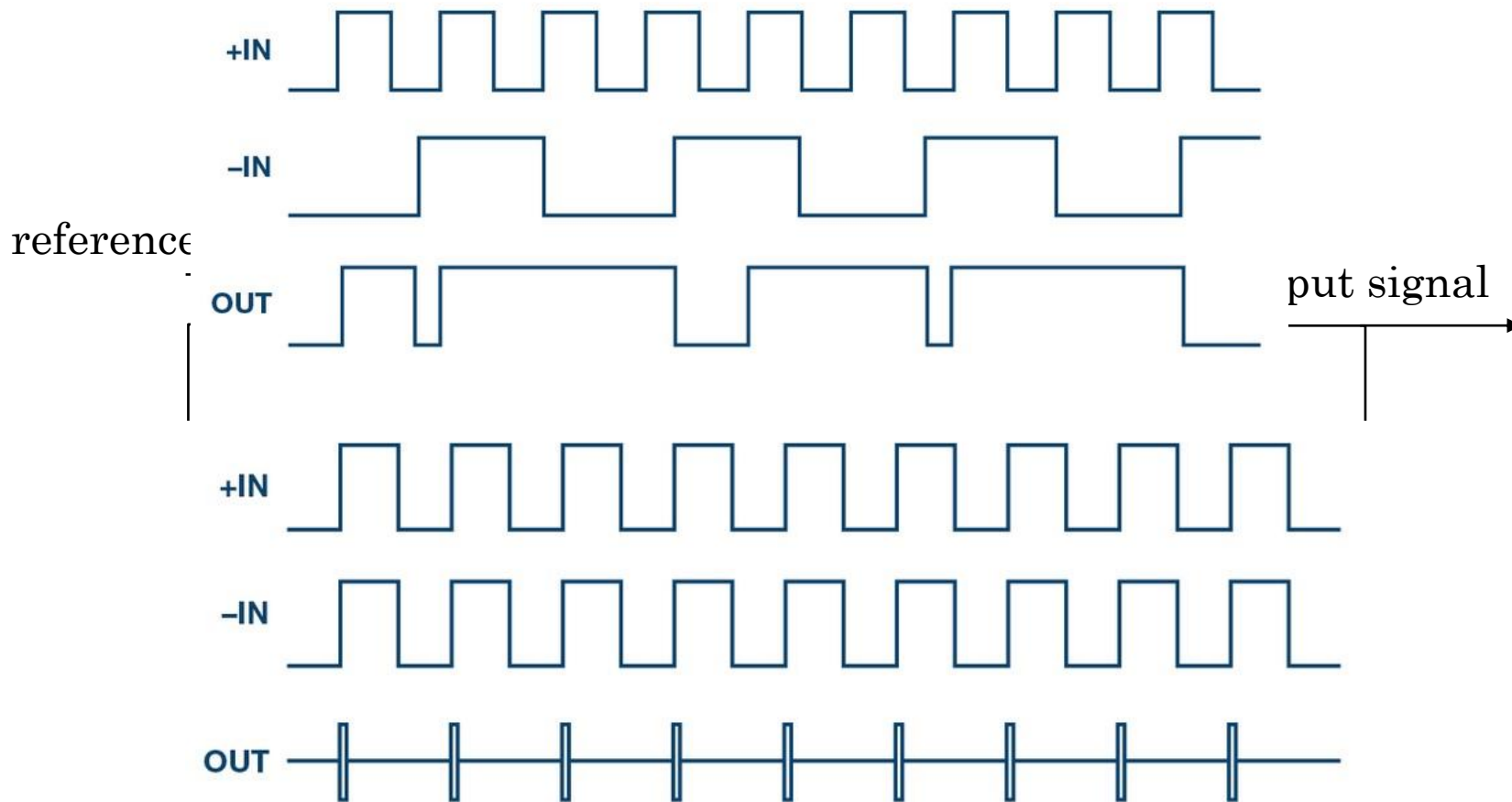
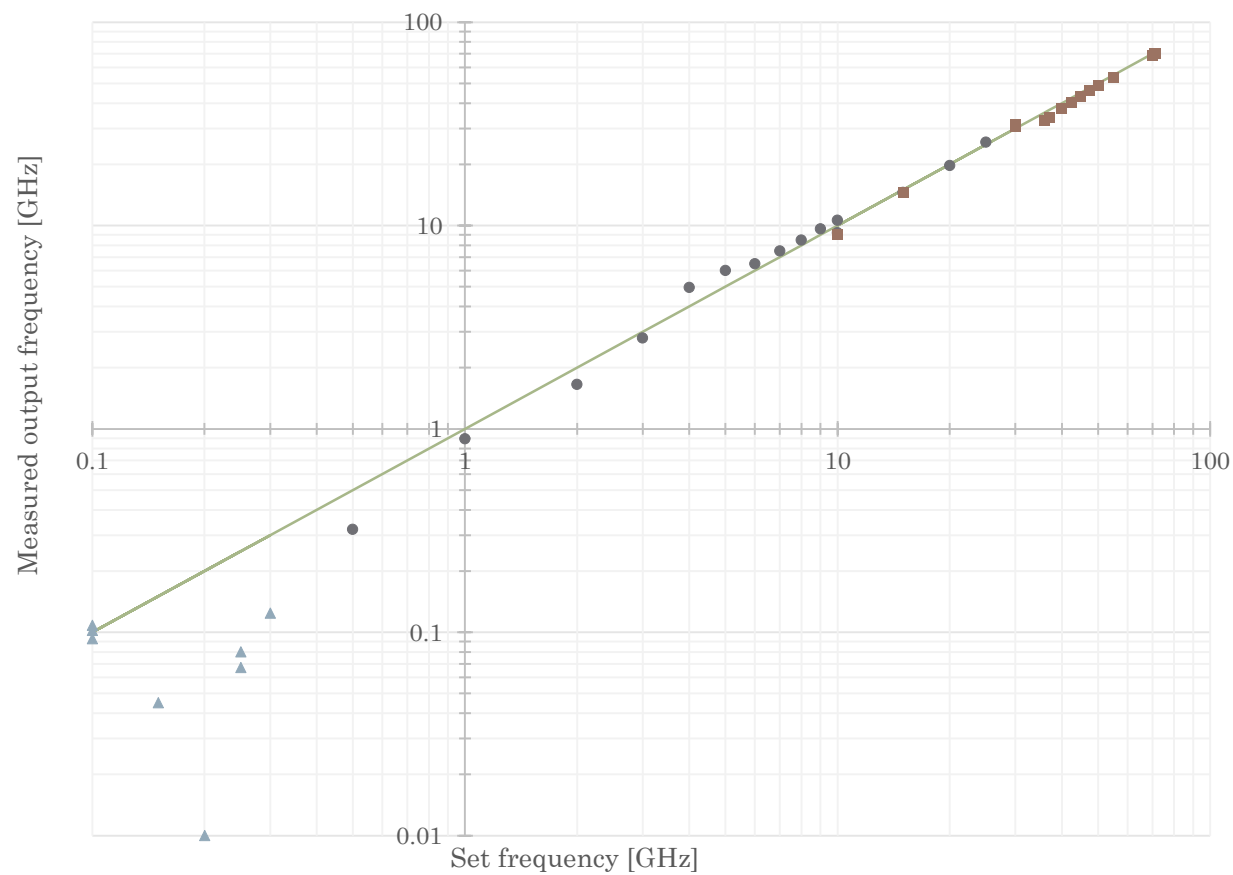


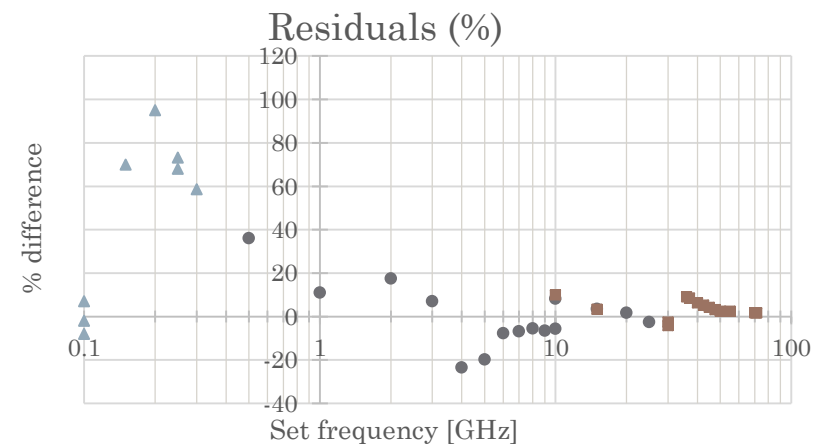
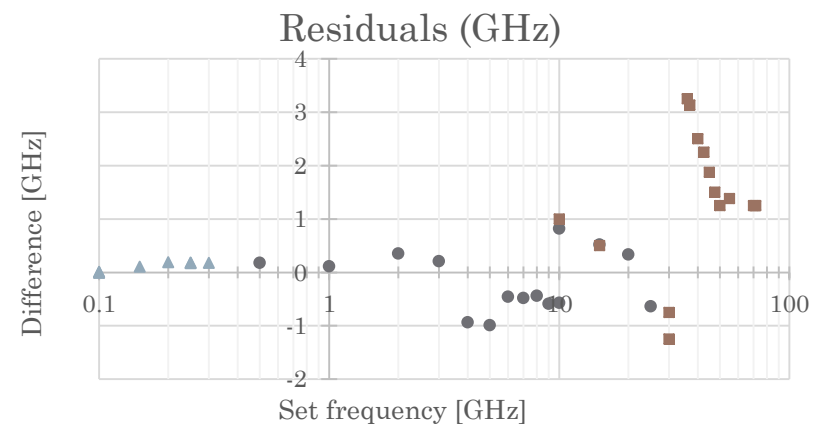
Image: Ian Collins, "Phase-Locked Loop (PLL) Fundamentals." AnalogDialogue, 2018.



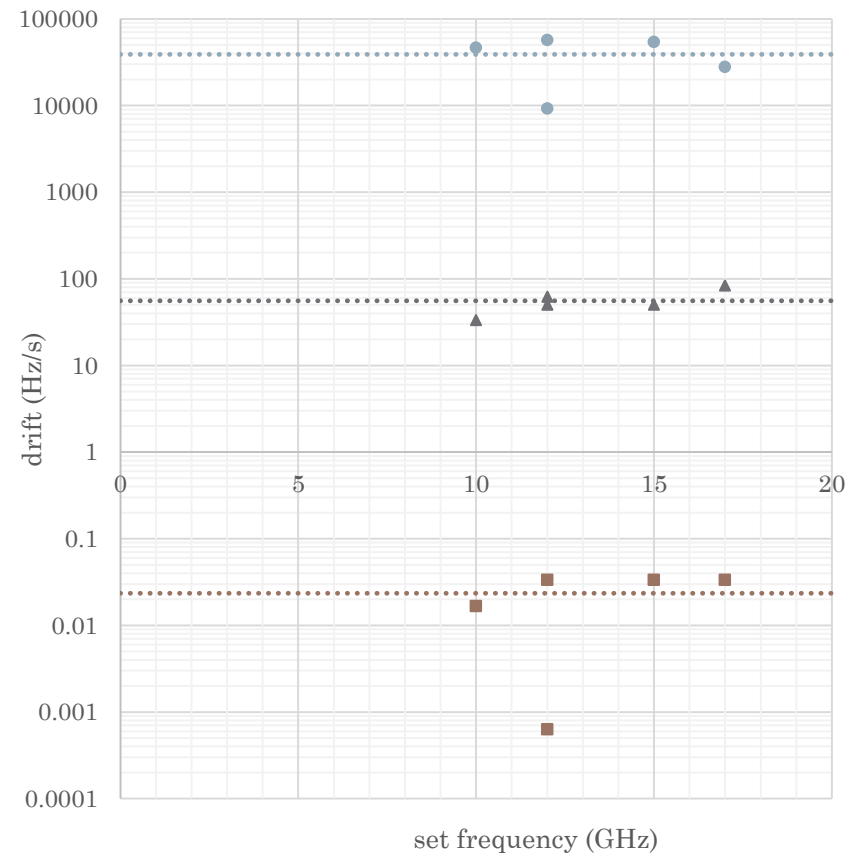
VCO output



● Spectrum analyzer ▲ frequency counter ■ optical spectrum analyzer — $y=x$



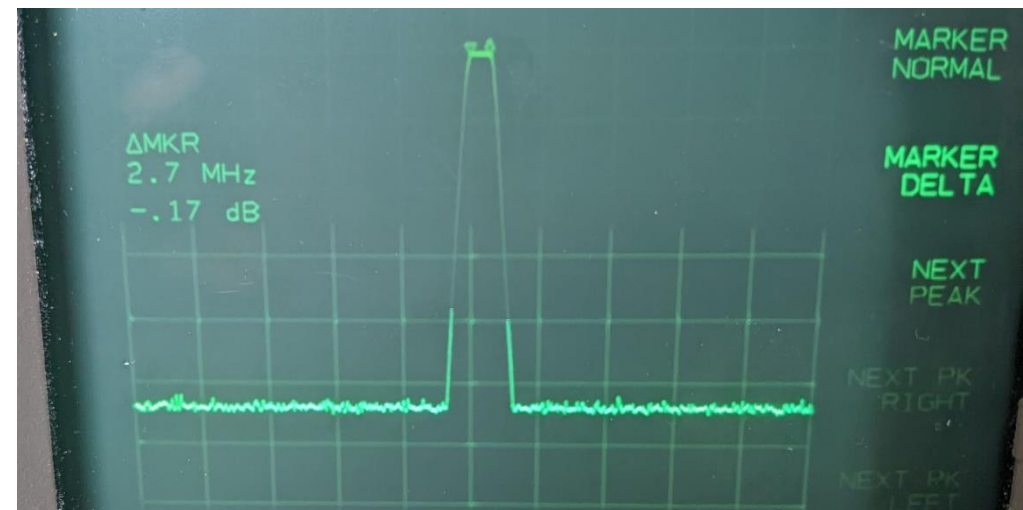
Frequency drift



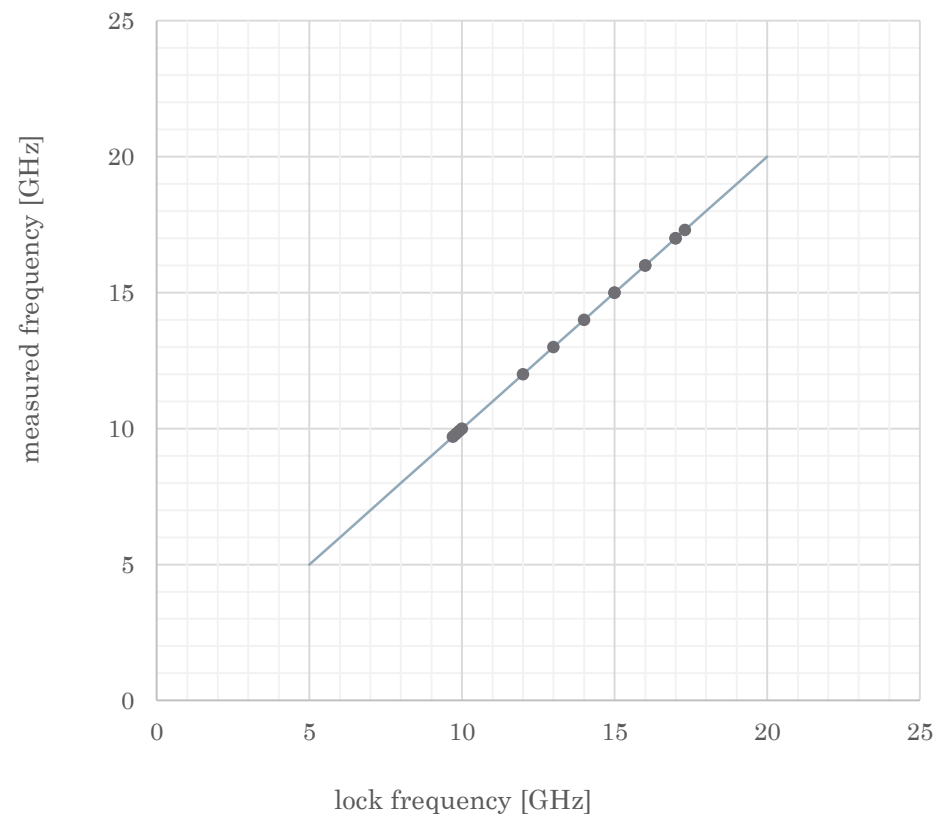
▲ locked (int ref)

● free

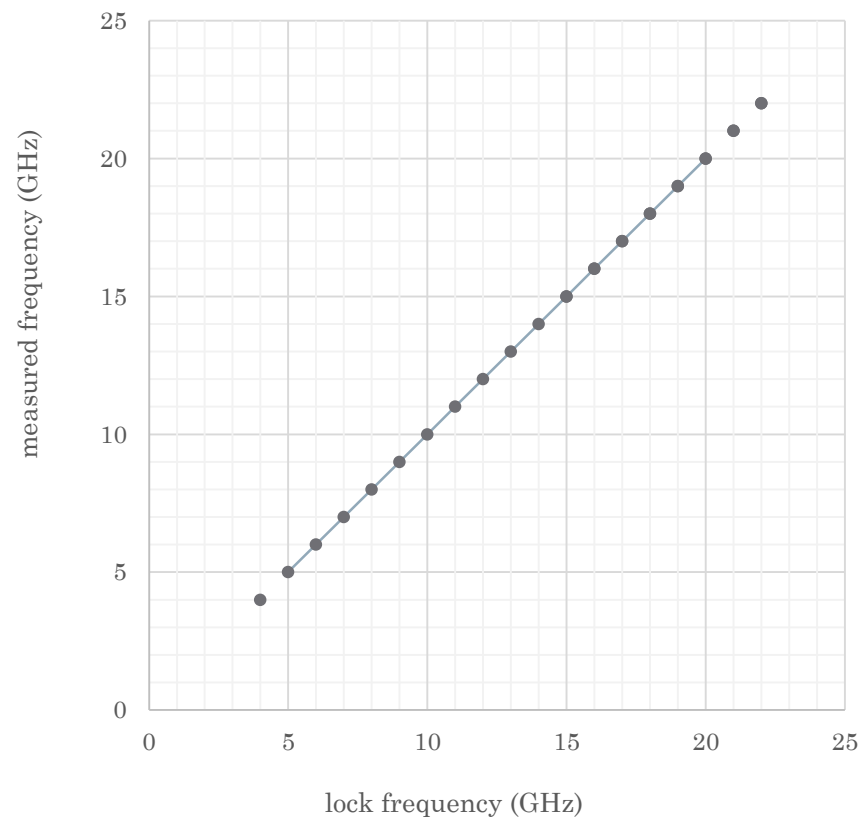
■ locked (ext ref only)



Locking range



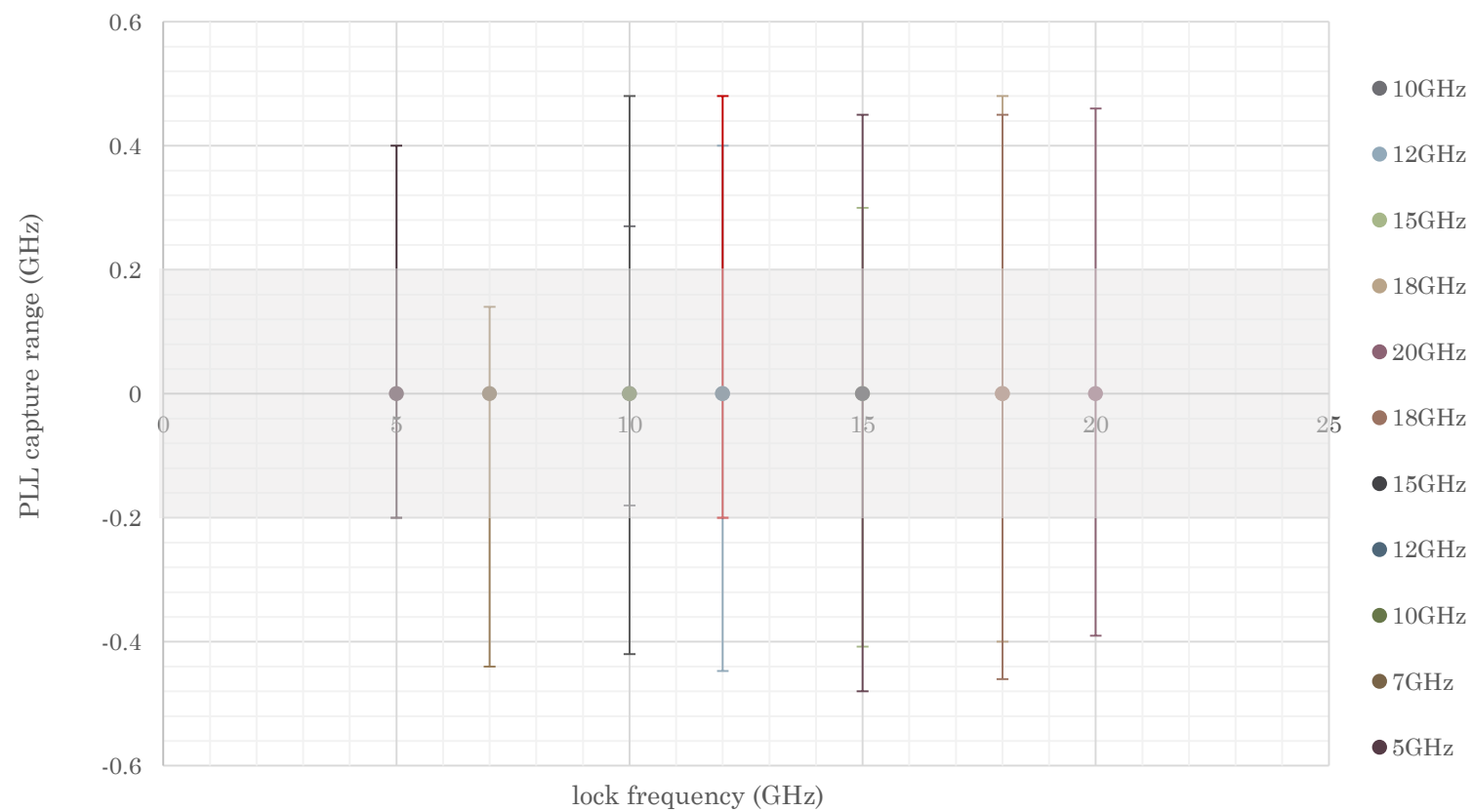
● spectrum analyzer — expected response [GHz]



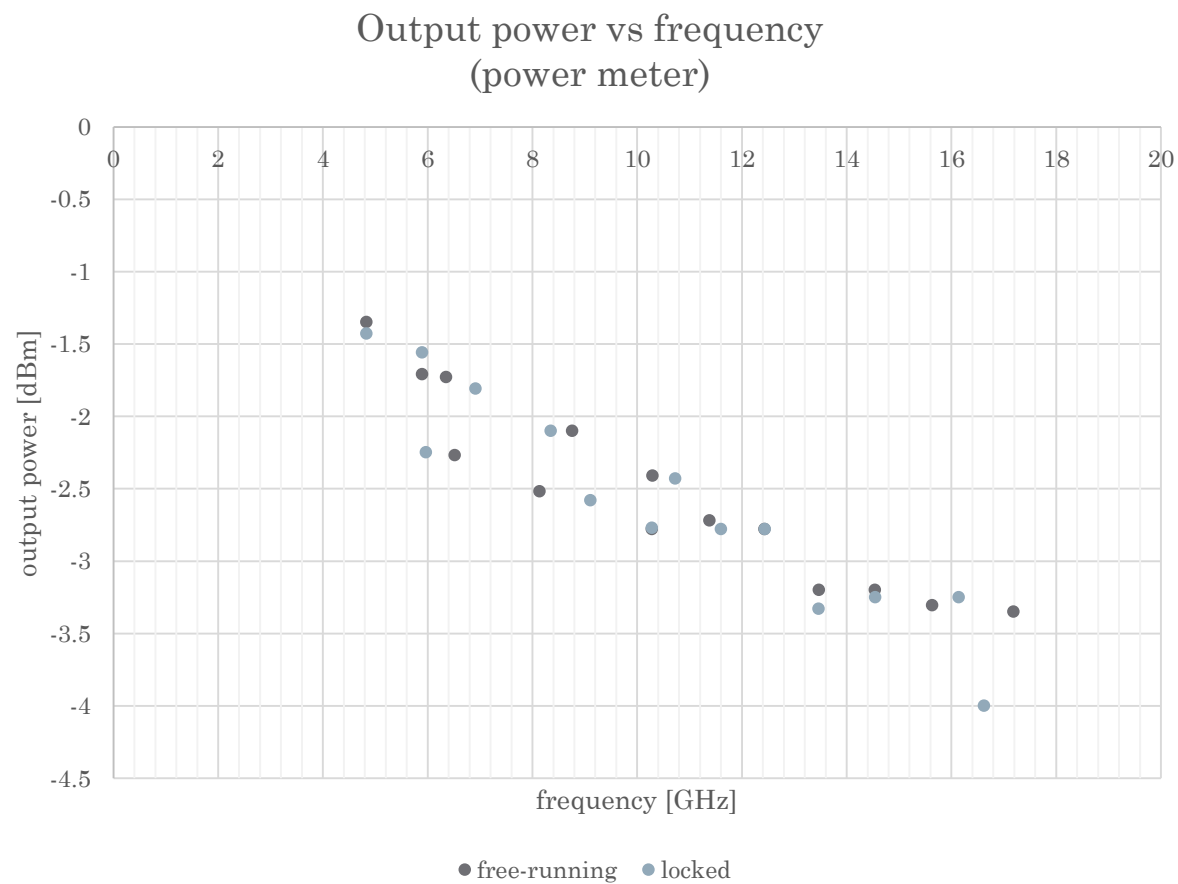
● spectrum analyzer — expected response [GHz]



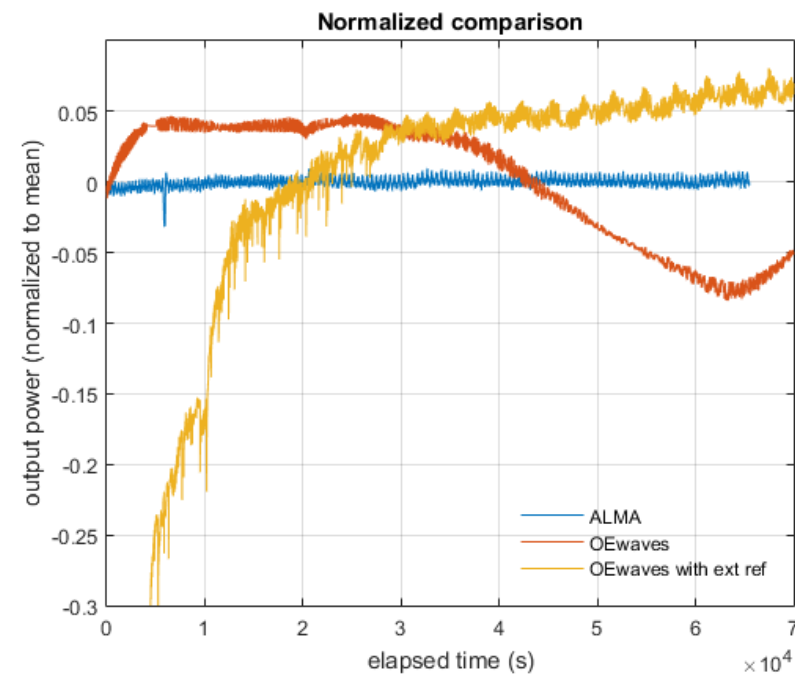
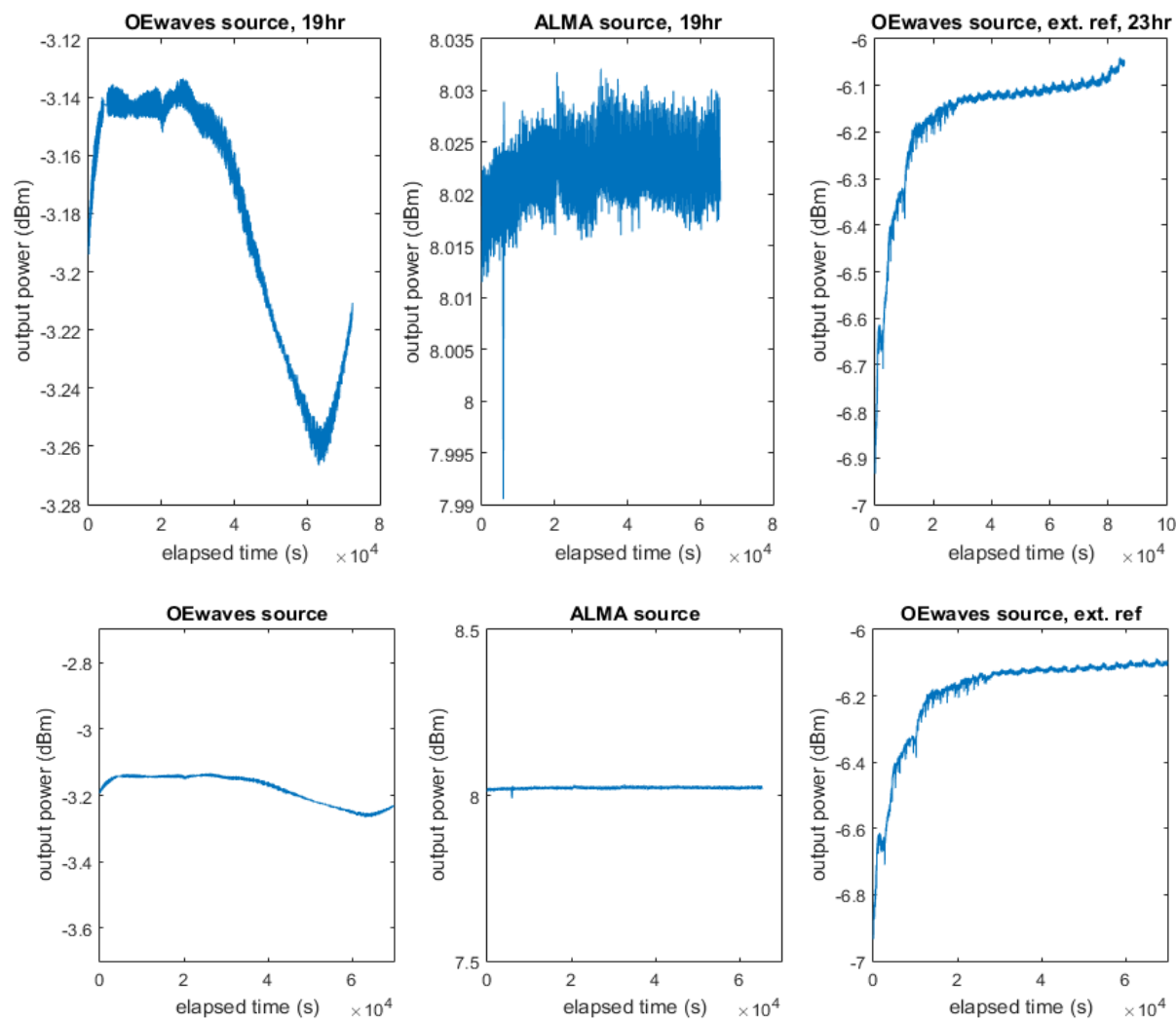
PLL capture range



Power vs frequency



Power vs time



Jitter calculations from phase noise

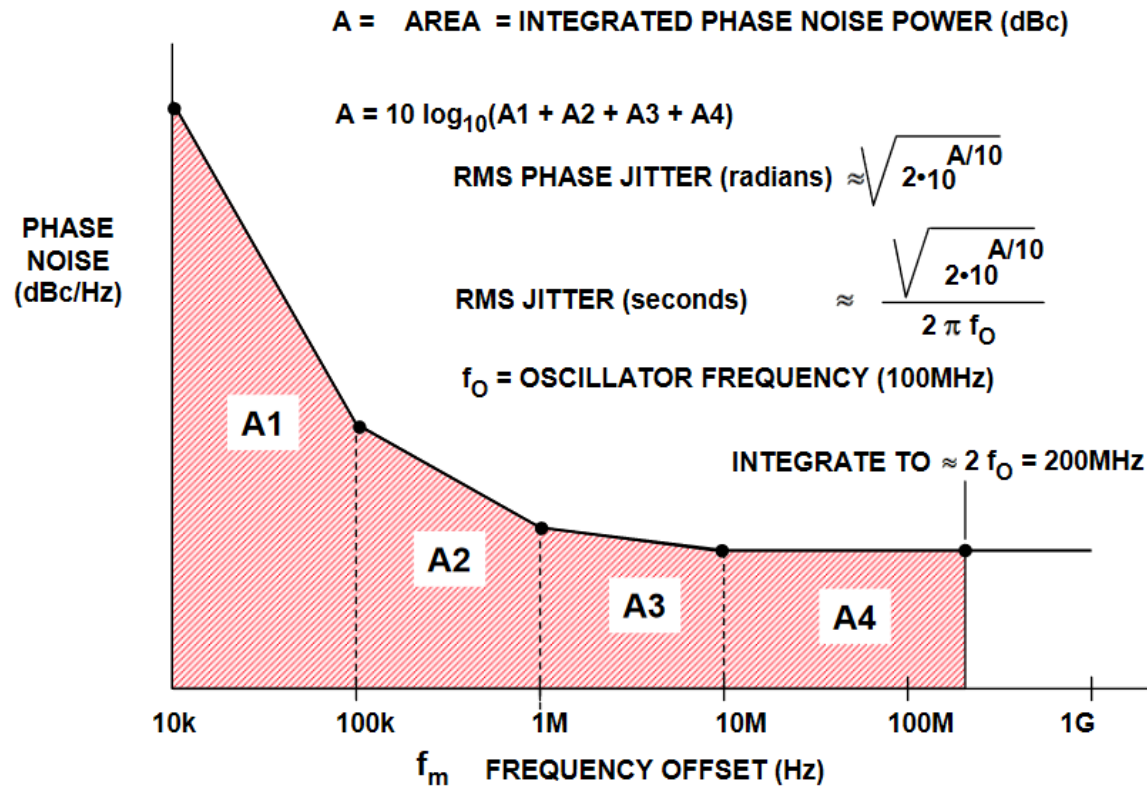


Figure 4: Calculating Jitter from Phase Noise



Phase noise to jitter calculator. RF Tools. rf-tools.com/jitter

Image: Walt Kester, "Converting Oscillator Phase Noise to Time Jitter." Analog Devices, 2008.

