UC San Diego
JACOBS SCHOOL OF ENGINEERING
Electrical and Computer Engineering

Crescendo: Towards Wideband, Real-Time, High-Fidelity Spectrum Sensing Systems

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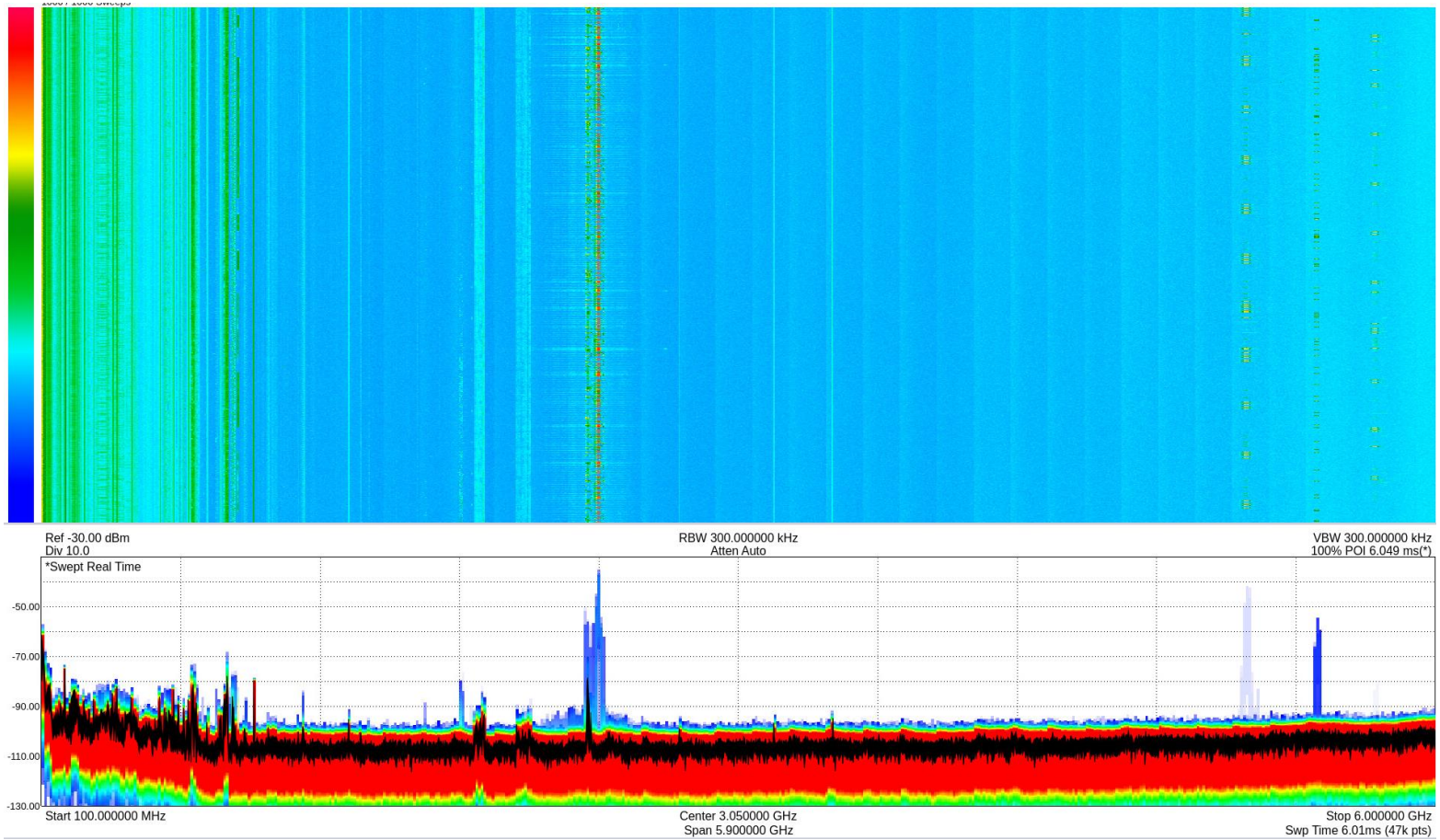
Spectrum sensing is critical for efficient use, coexistence and regulation

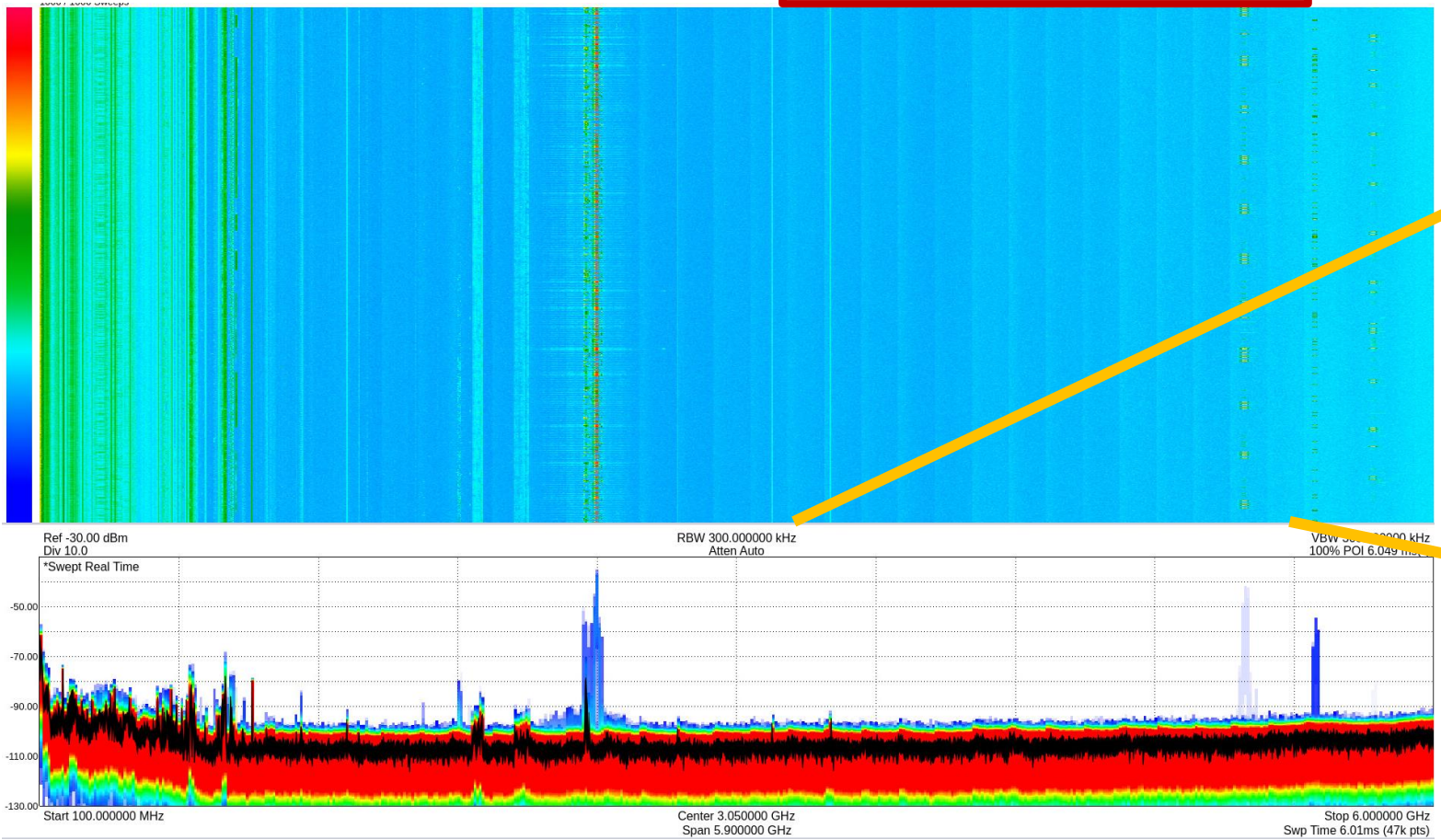
Wideband

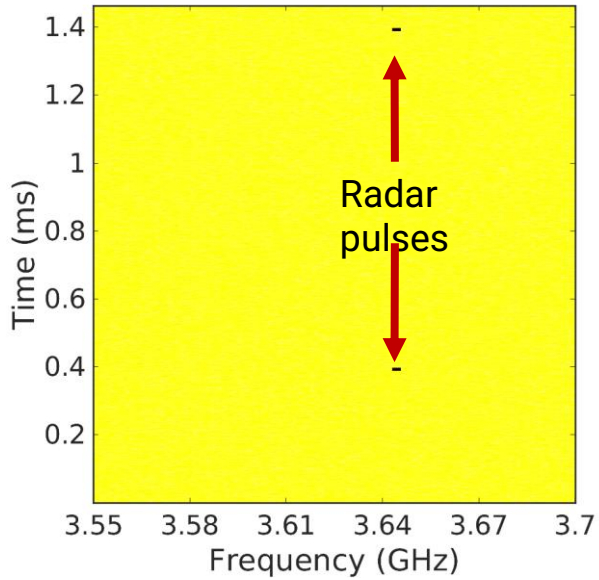


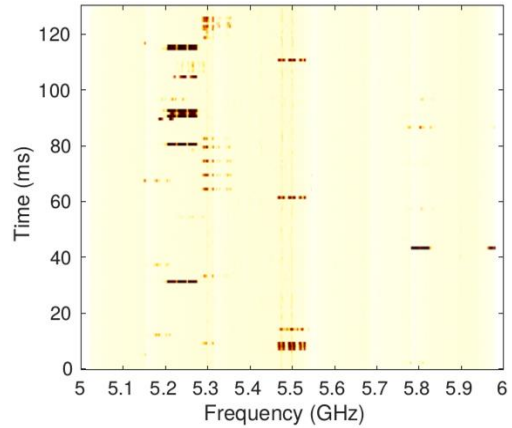
Spectrum sensing is critical for efficient use, coexistence and regulation

Wideband

Real-time (context)





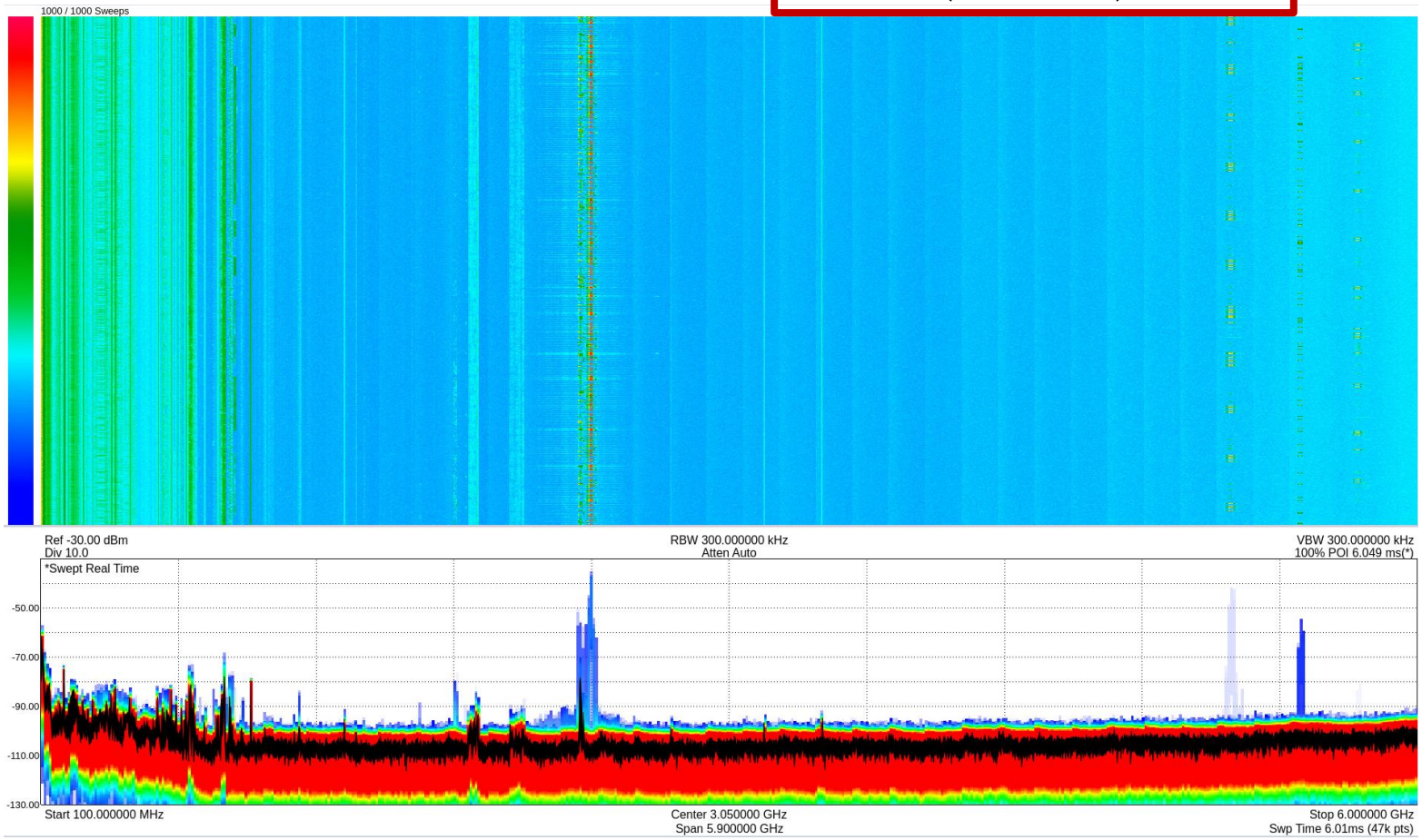


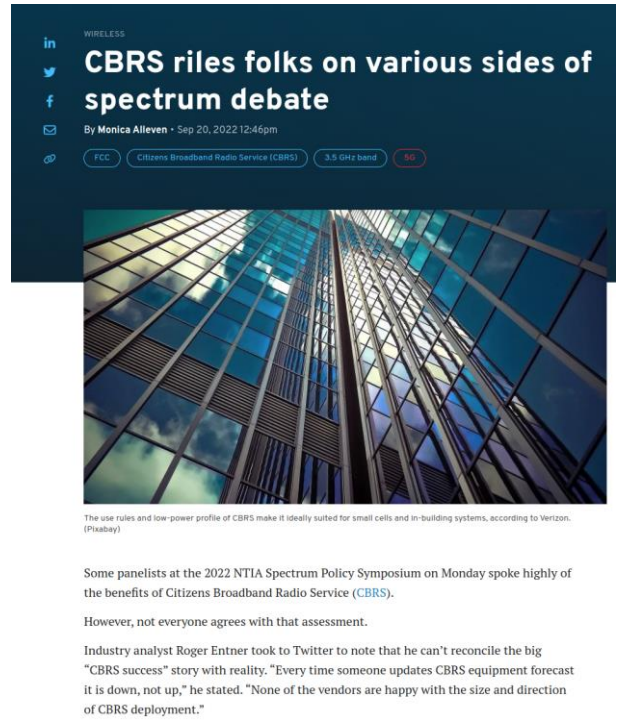
Spectrum sensing is critical for efficient use, coexistence and regulation

Wideband

Real-time (context)

Signal Fidelity





WIRELESS

CBRS riles folks on various sides of spectrum debate

By Monica Alleven • Sep 20, 2022 12:46pm

FCC | Citizens Broadband Radio Service (CBRS) | 3.5 GHz band | 5G

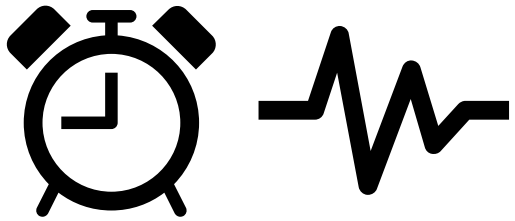
The use rules and low-power profile of CBRS make it ideally suited for small cells and in-building systems, according to Verizon. (Pixabay)

Some panelists at the 2022 NTIA Spectrum Policy Symposium on Monday spoke highly of the benefits of Citizens Broadband Radio Service (CBRS).

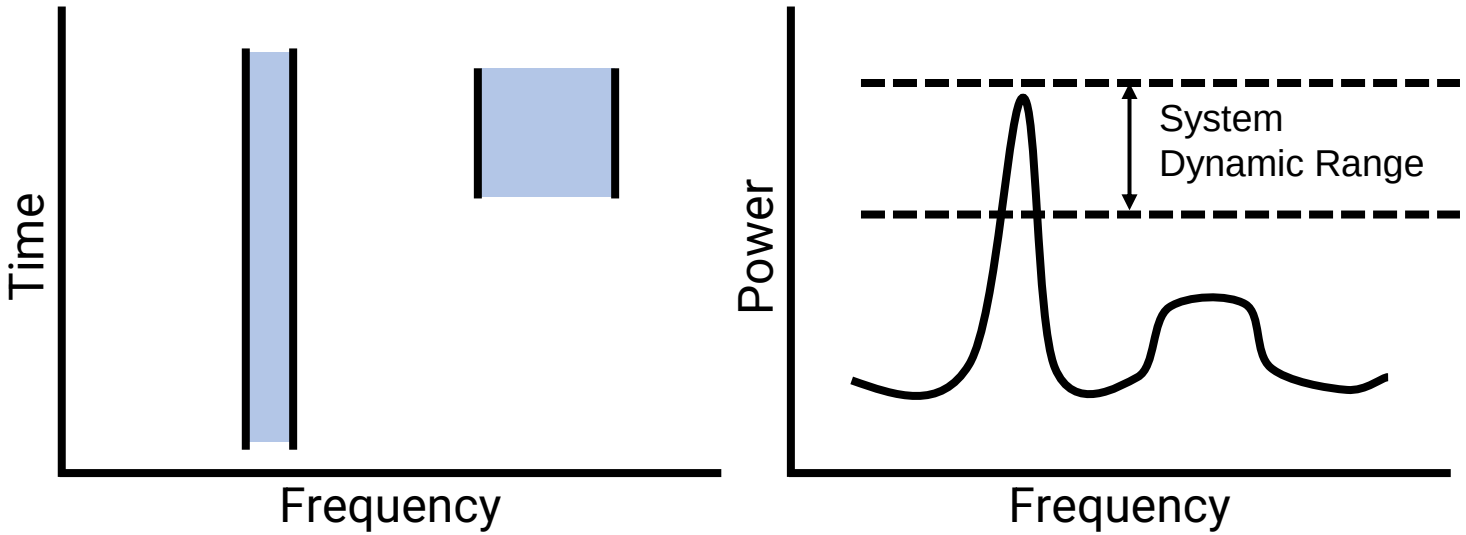
However, not everyone agrees with that assessment.

Industry analyst Roger Entner took to Twitter to note that he can't reconcile the big "CBRS success" story with reality. "Every time someone updates CBRS equipment forecast it is down, not up," he stated. "None of the vendors are happy with the size and direction of CBRS deployment."

What is signal fidelity in spectrum sensing?

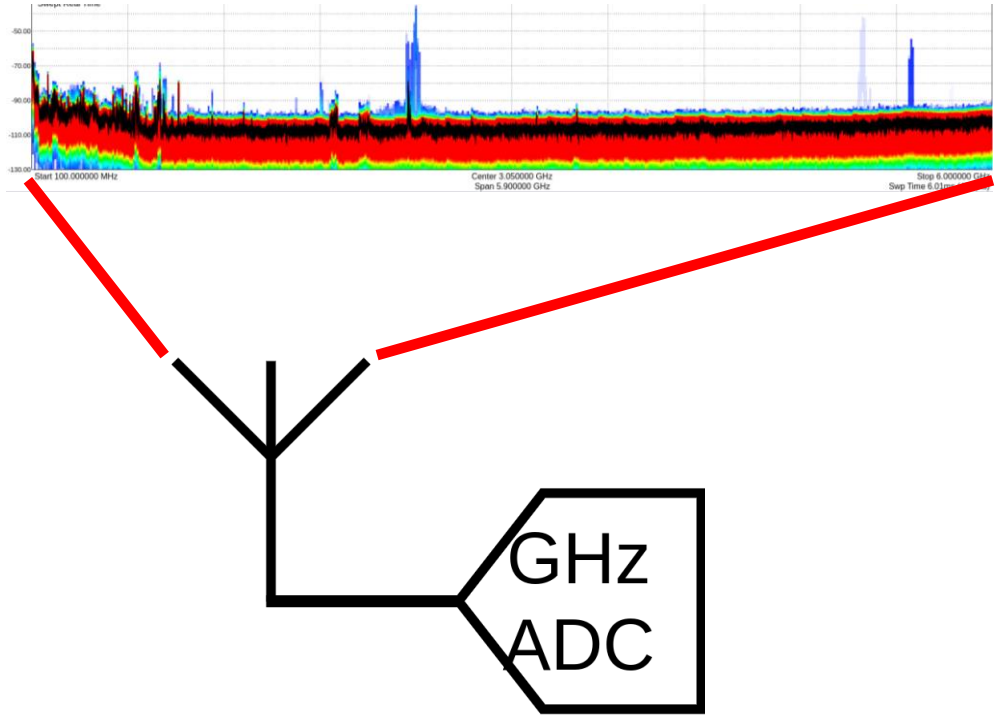


Decoding:
Frequency stability,
phase stability



Handle dynamic range

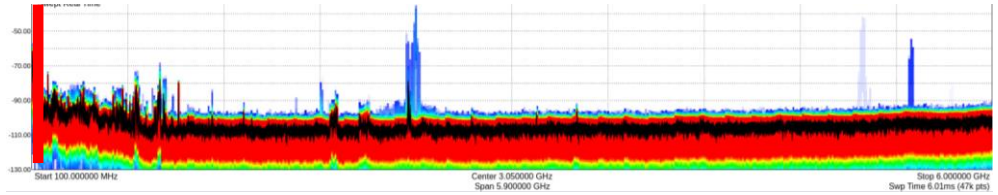
Trade-offs in existing spectrum sensors

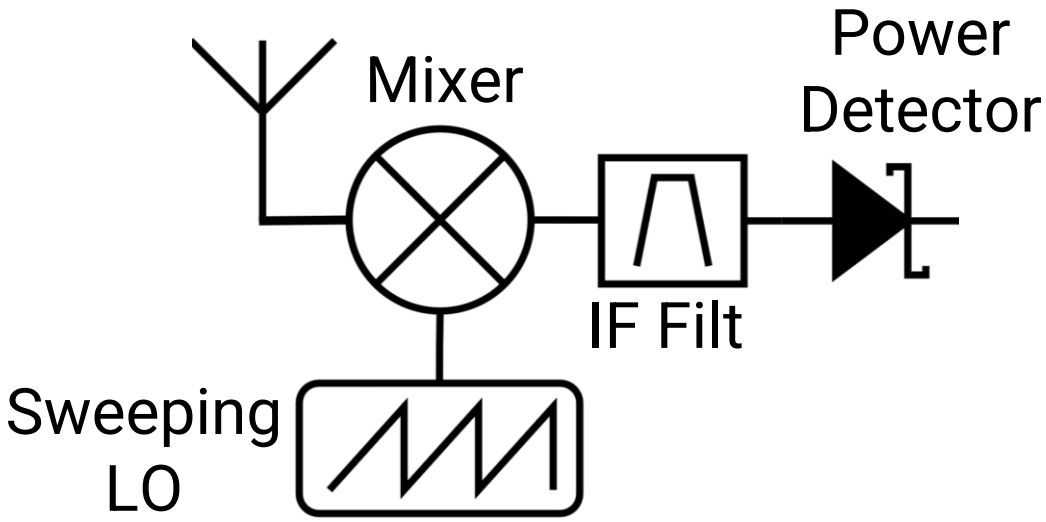


	Wideband	Real-time	Signal Fidelity
GHz ADC			

Clipping, saturation

Trade-offs in existing spectrum sensors

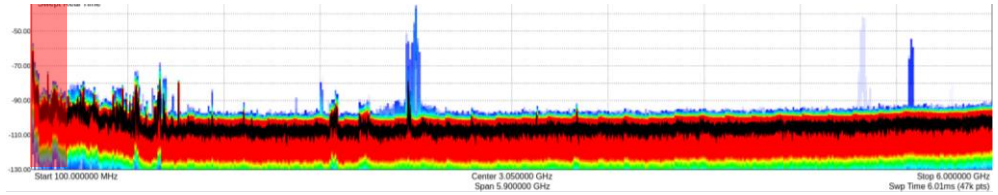


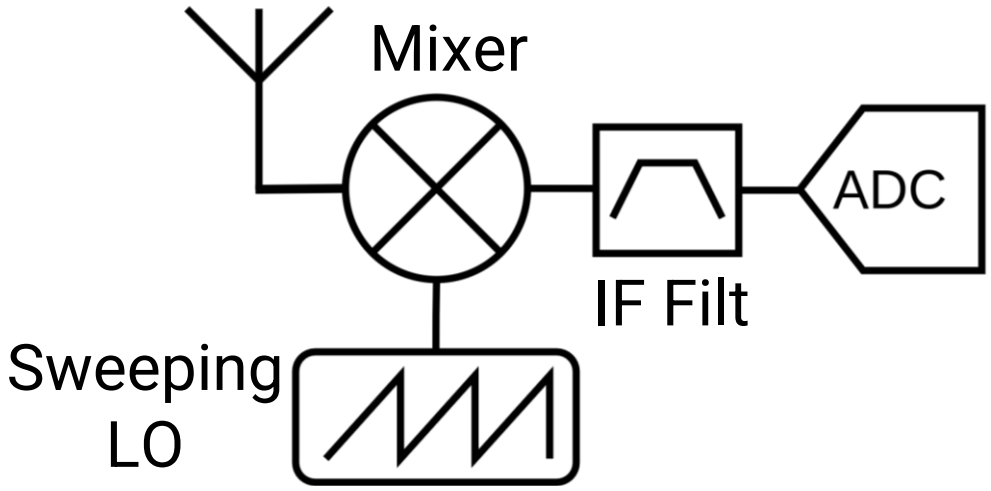


Measures only power

	Wideband	Real-time	Signal Fidelity
GHz ADC	✓	✓	✗
Spectrum Analyzer			

Trade-offs in existing spectrum sensors





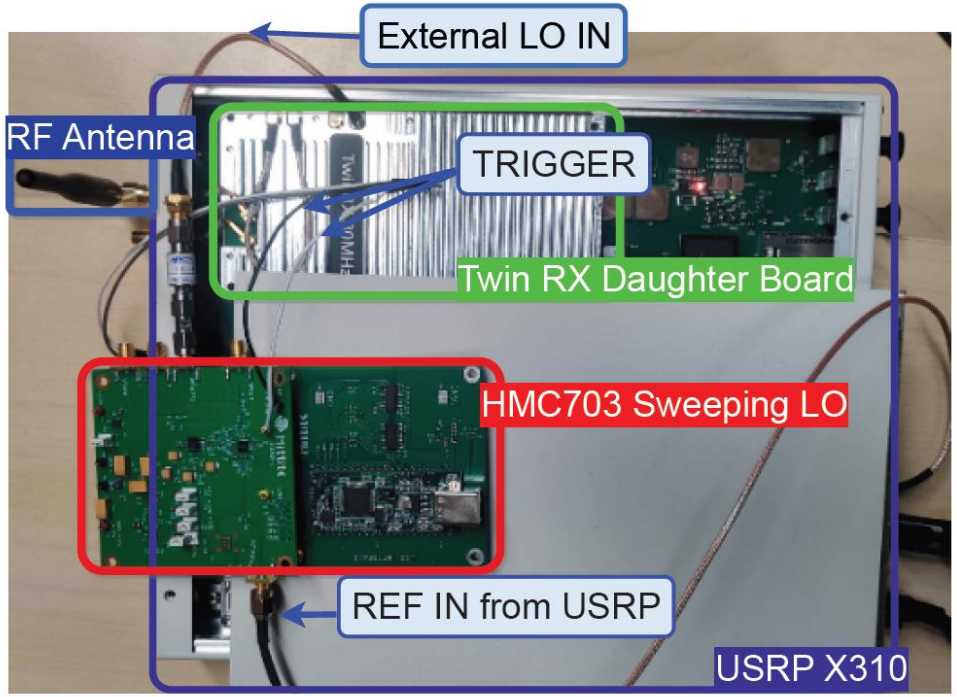
Clipping + saturation,
Open loop VCO

	Wideband	Time Resolution	Signal Fidelity
GHz ADC	✓	✓	✗
Spectrum Analyzer	✓	✗	✓
SweepSense (NSDI'19)			

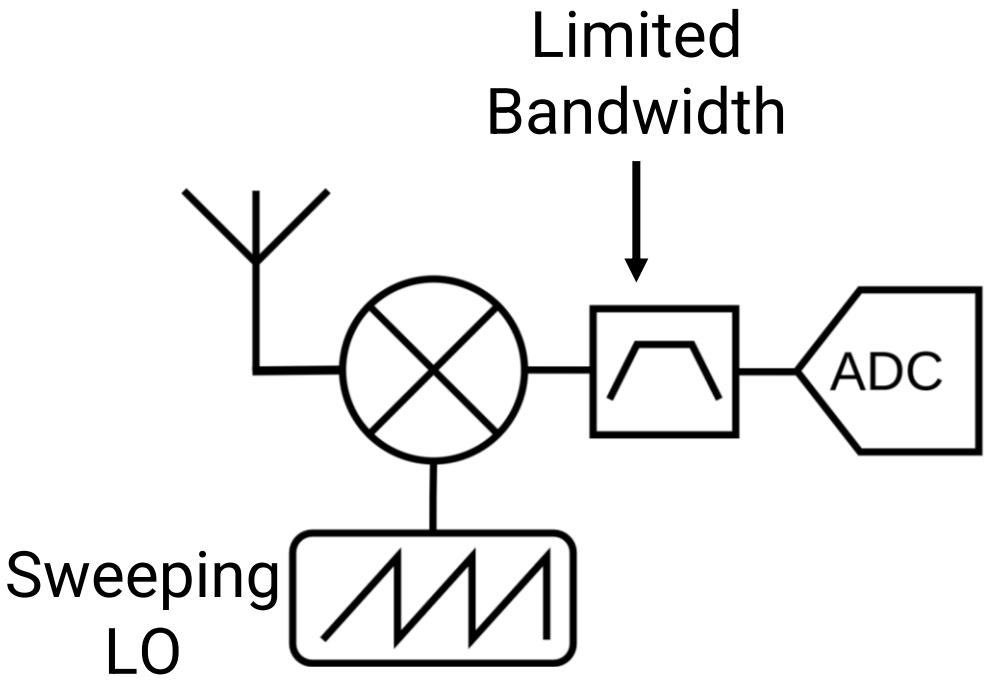
Crescendo: our contributions

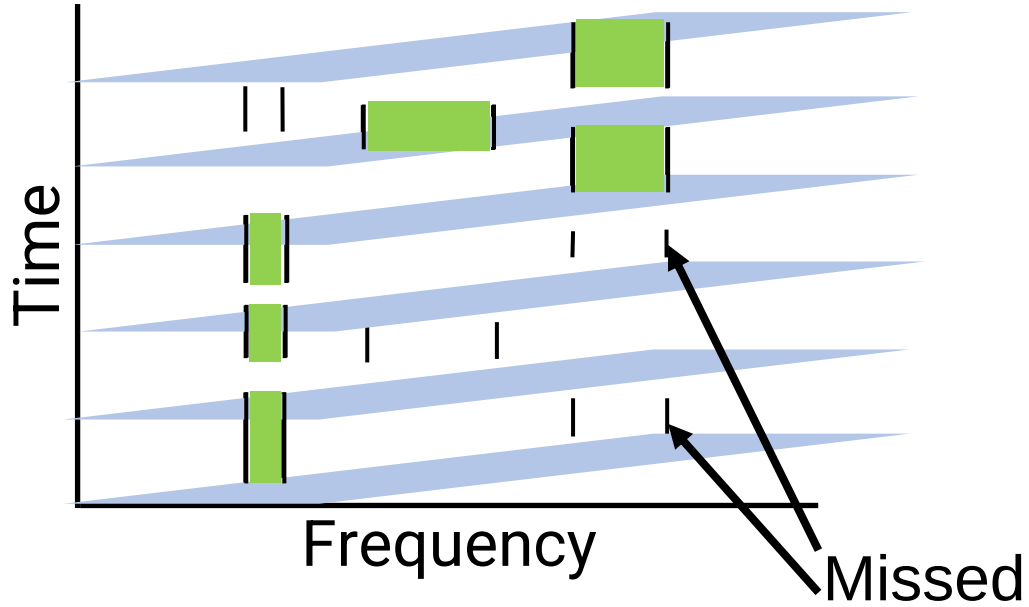
- Crescendo develops a framework to optimize sweep-sampling, while being stable
- Adaptive time-frequency dynamic range control
- Achieves
  - 100+ dB dynamic range!
  - Reliable signal decoding while sweeping

Wideband	Real-time	Signal Fidelity

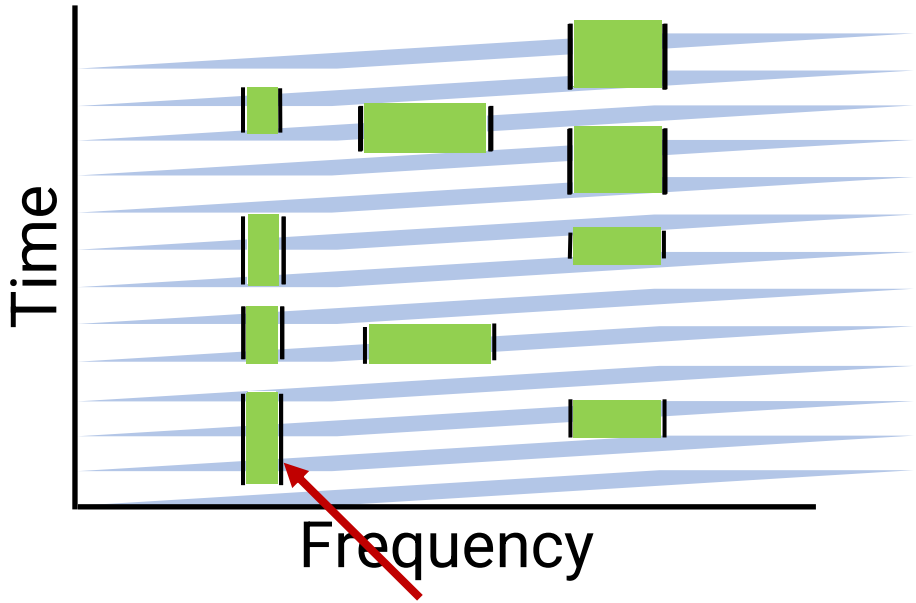


Sweep sampling misses parts of signals

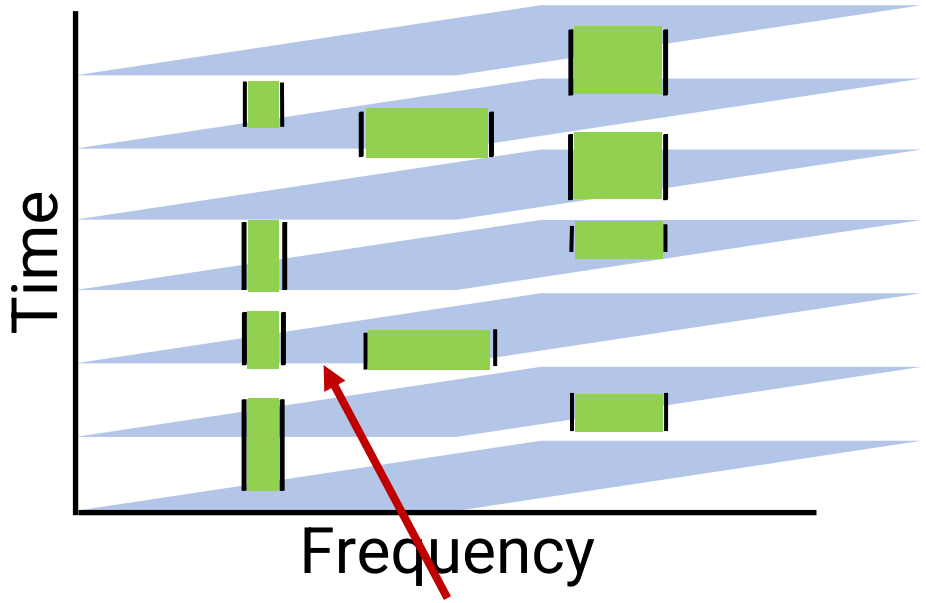




Approaches to observing more



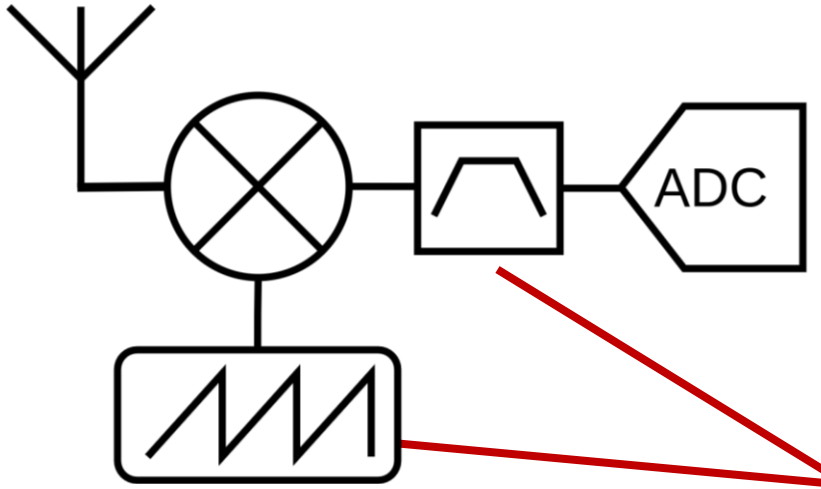
Faster sweeps -> too few samples for each transmission (samples ∝ signal bandwidth)

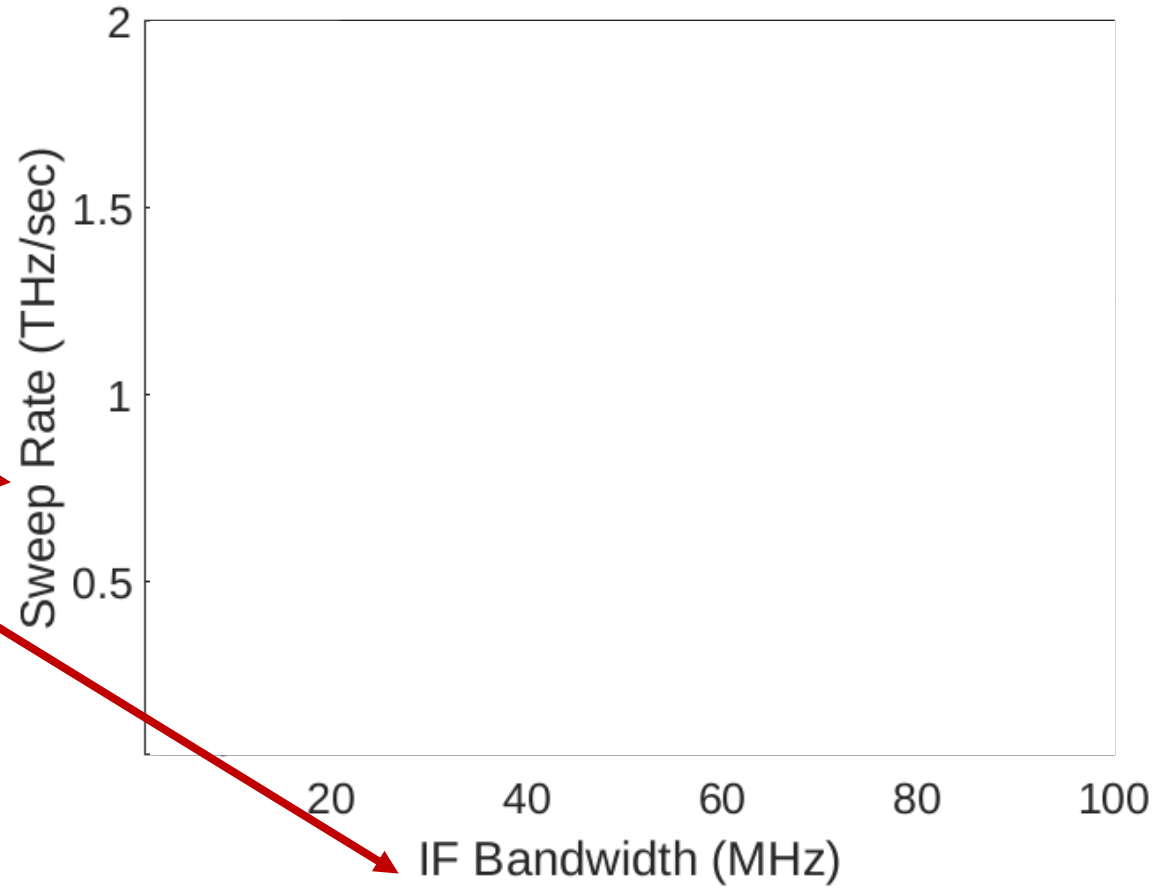


Large IF Bandwidth -> higher processing, worse dynamic range issues

Sweeping fast, or wide IF bandwidth comes with tradeoffs

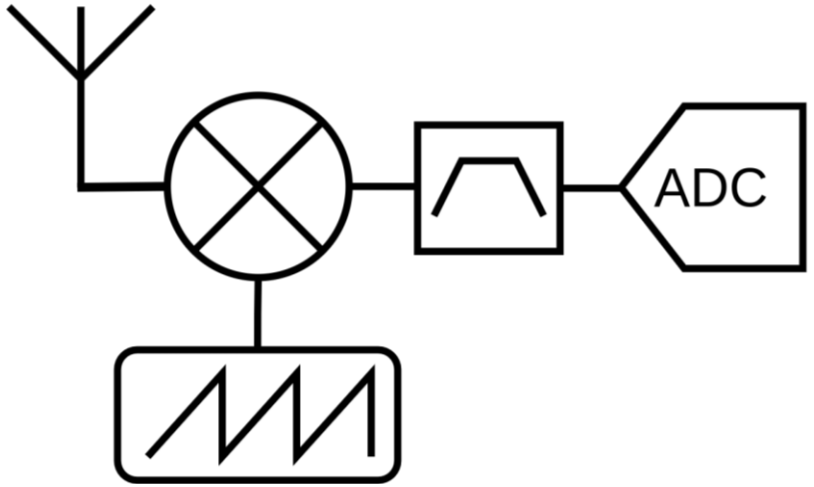
Optimizing design to handle signal dynamics

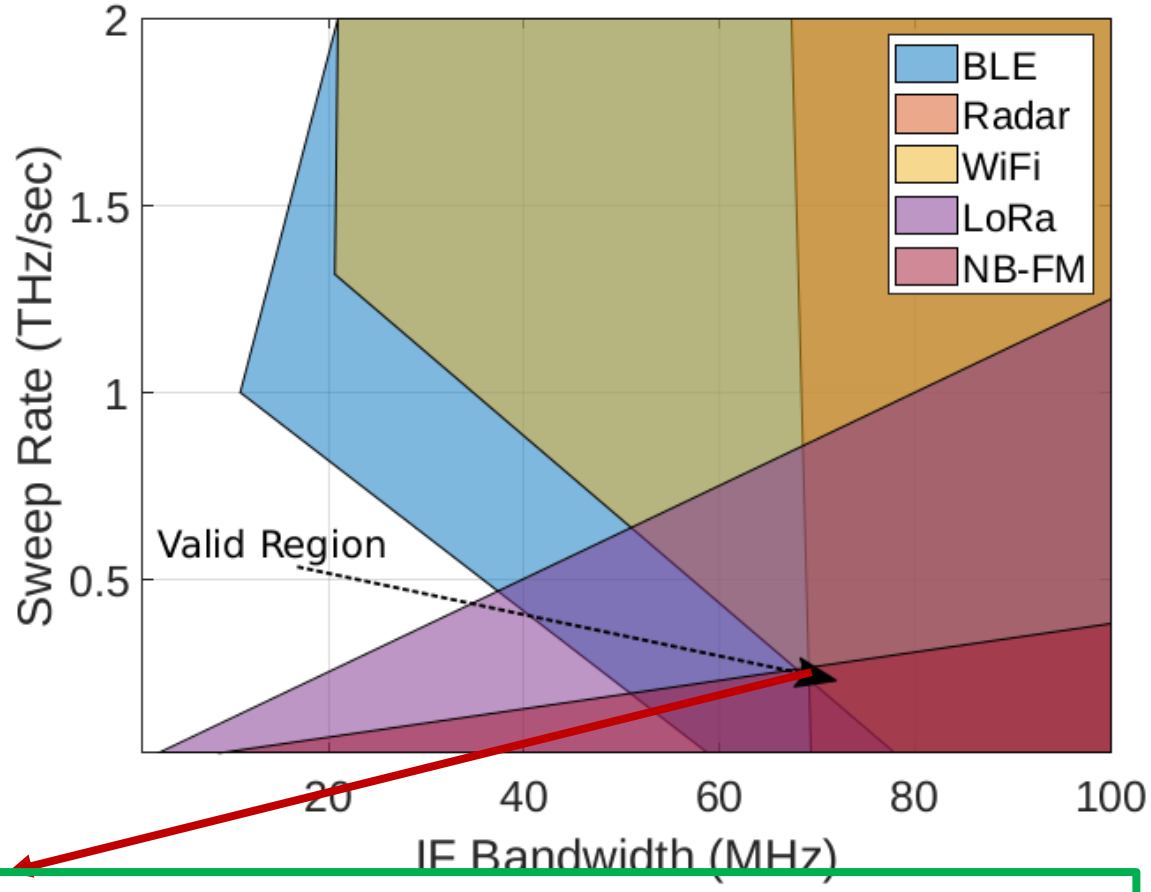




What sweep rate and IF bandwidth should we use?

Optimizing design to handle signal dynamics



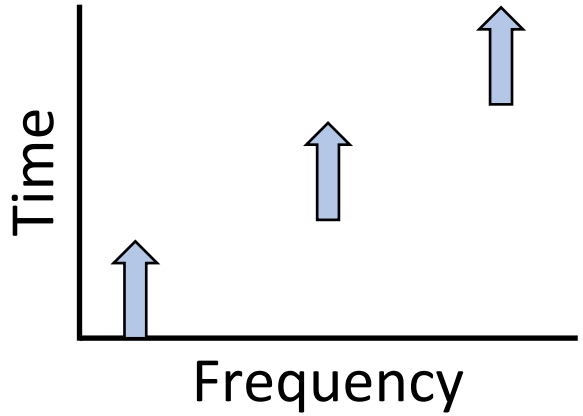


What sweep rate and IF bandwidth should we use?

> 70 MHz IF Bandwidth, < 200 GHz/sec sweep rate

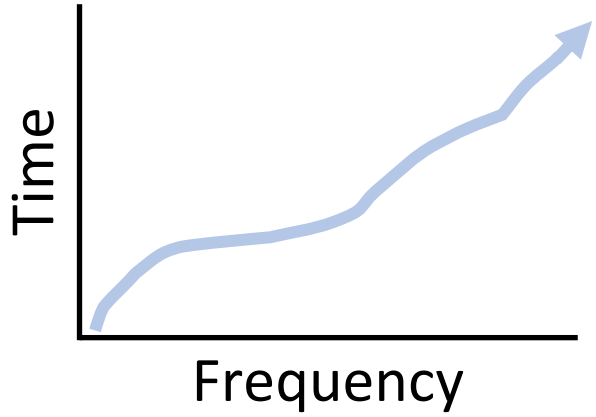
Generating stable sweeping LOs is difficult

Sequential tuning/
Frequency hopping



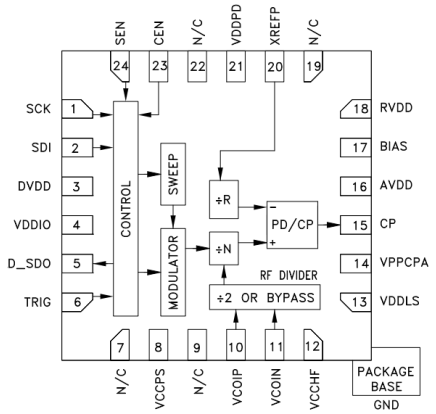
10 us per hop
High overhead!

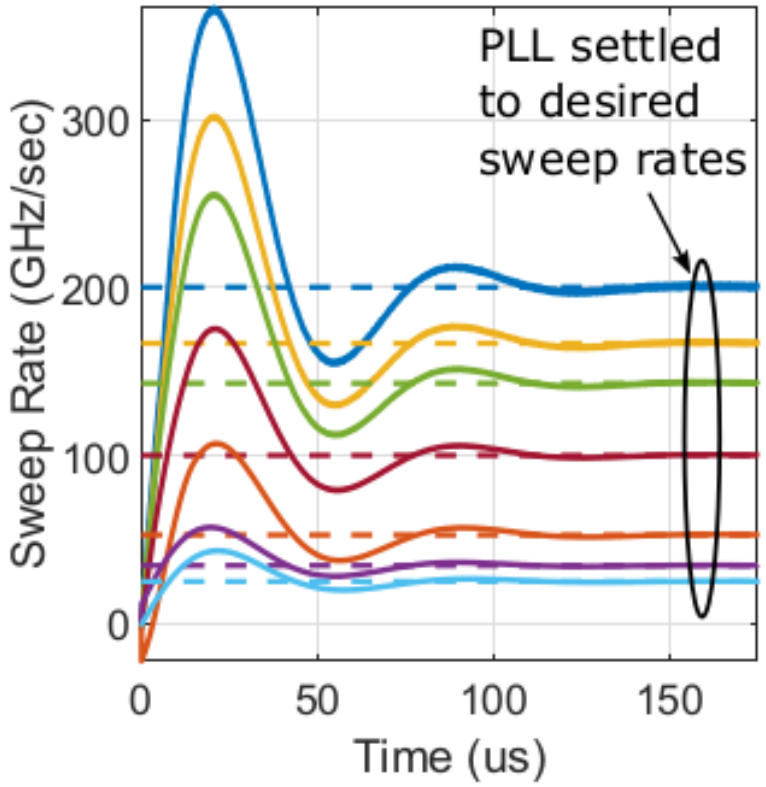
Open Loop VCO

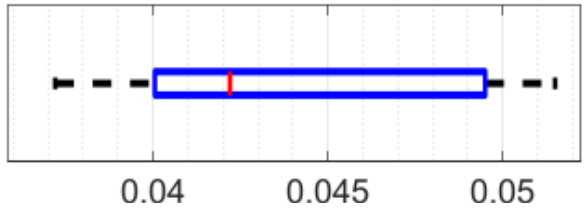


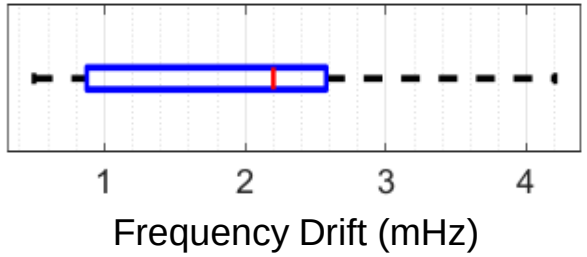
~1 MHz freq offsets
No phase stability

PLL generated sweeps are fast and stable







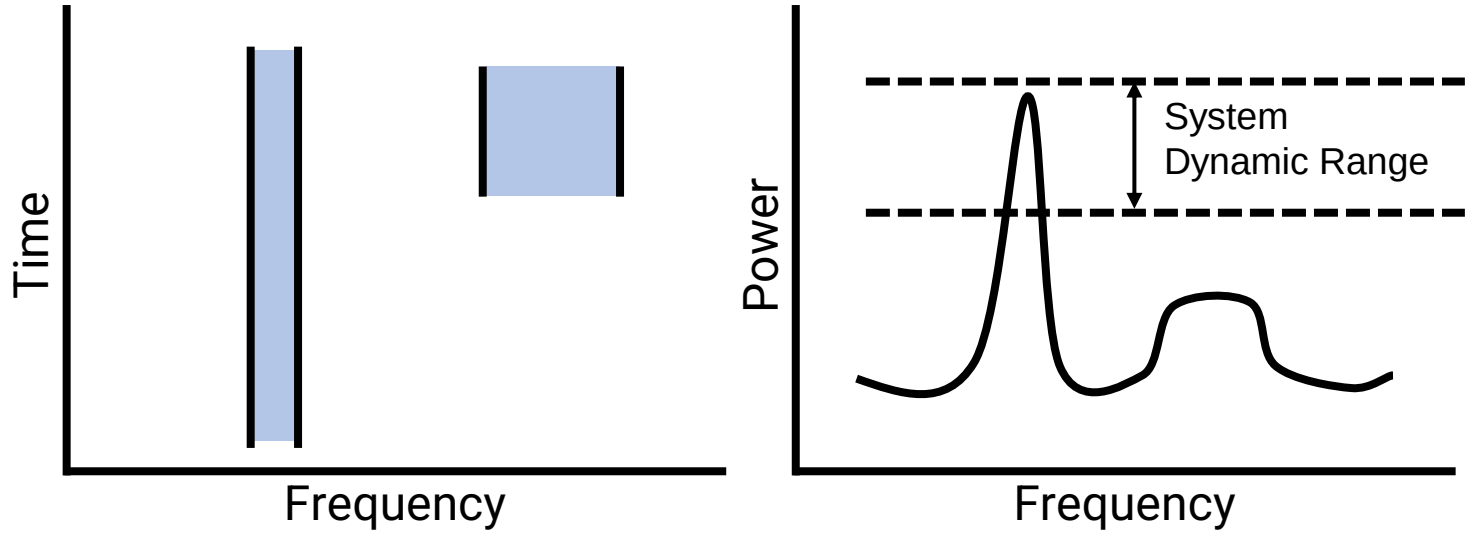


ADI HMC703 (COTS PLL)

Meets 200 GHz/sec requirement

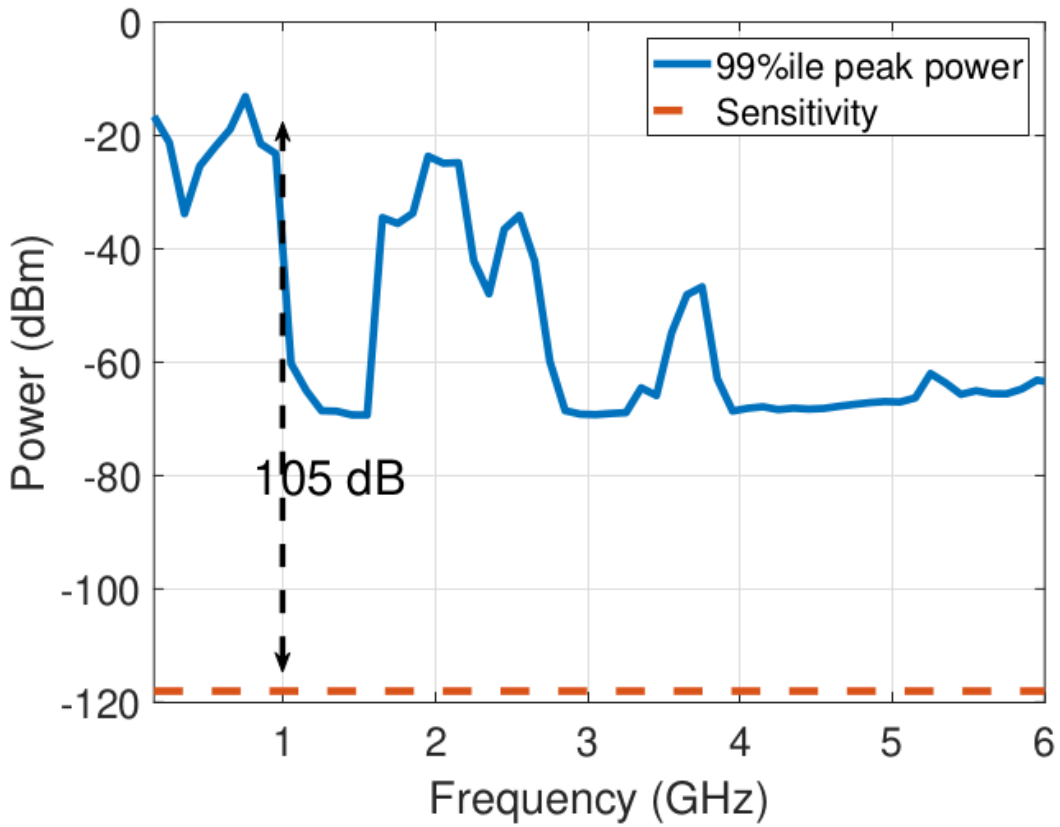
Phase/frequency stable

Delivering signal fidelity requires handling spectrum power dynamic range



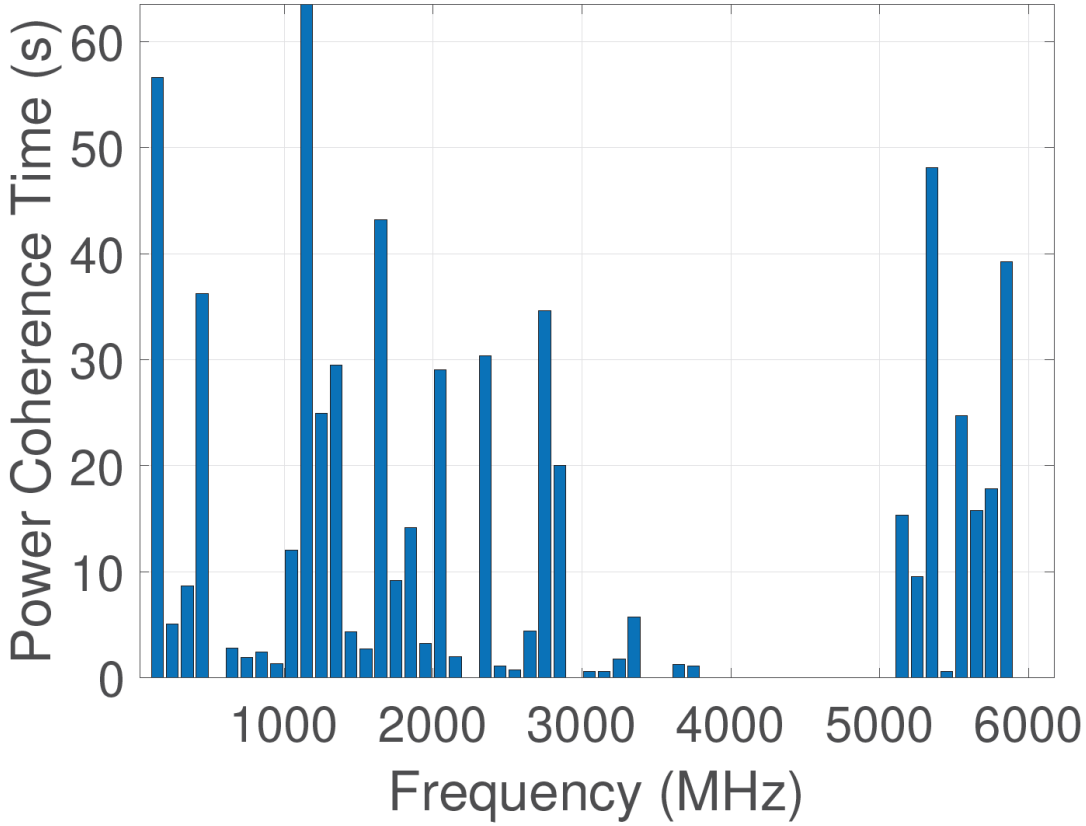
Handle dynamic range
How much?

Dynamic range requirements for wideband spectrum sensing



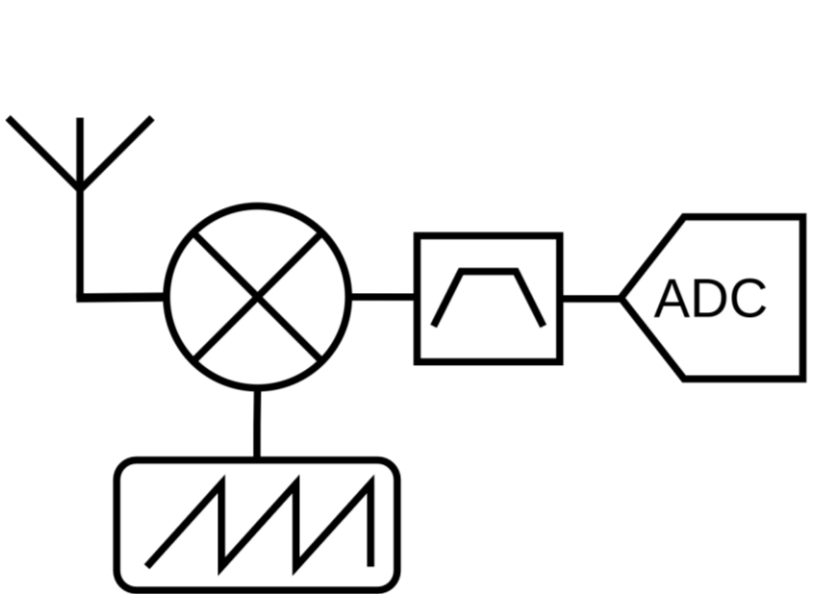
ADC SFDR: ~ 70 dB

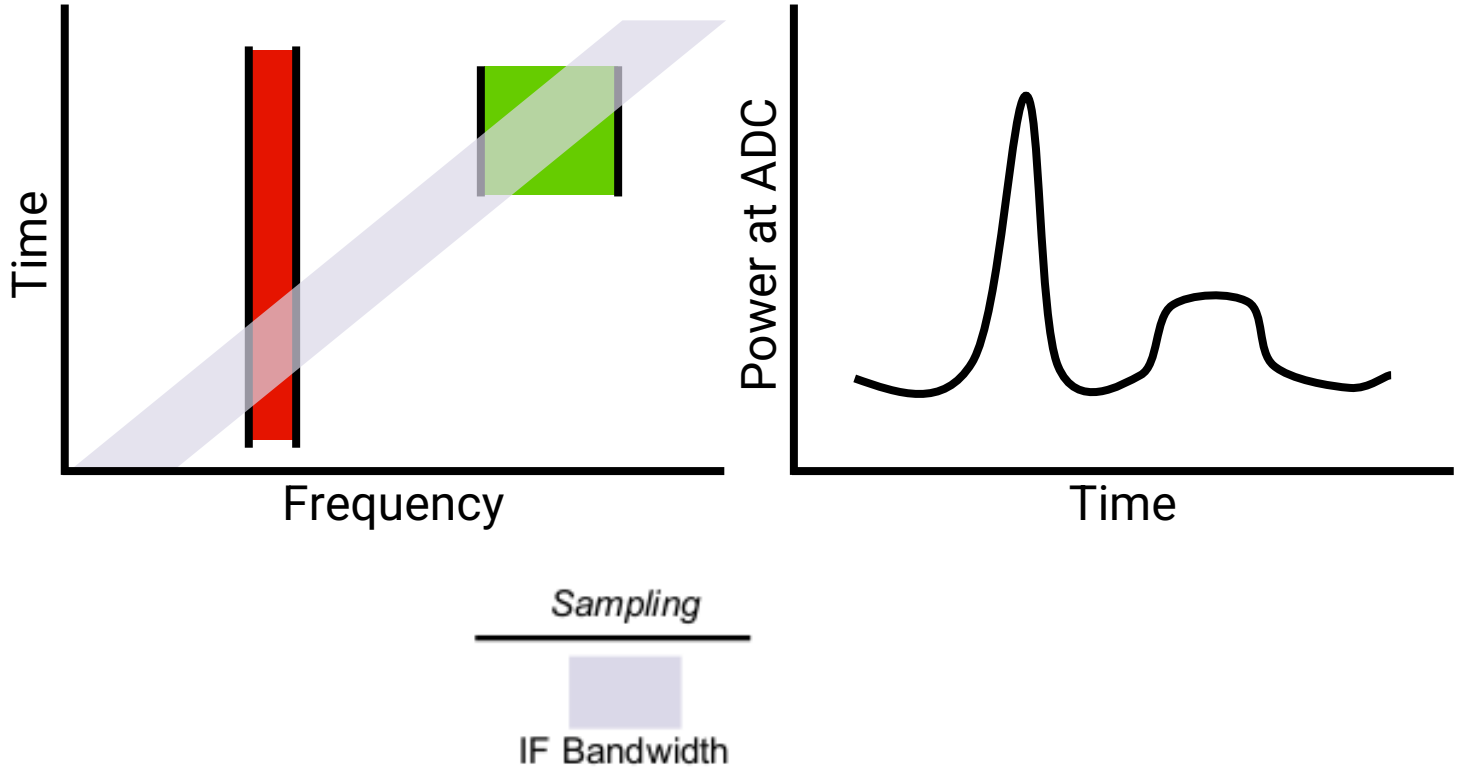
Need 1000x better



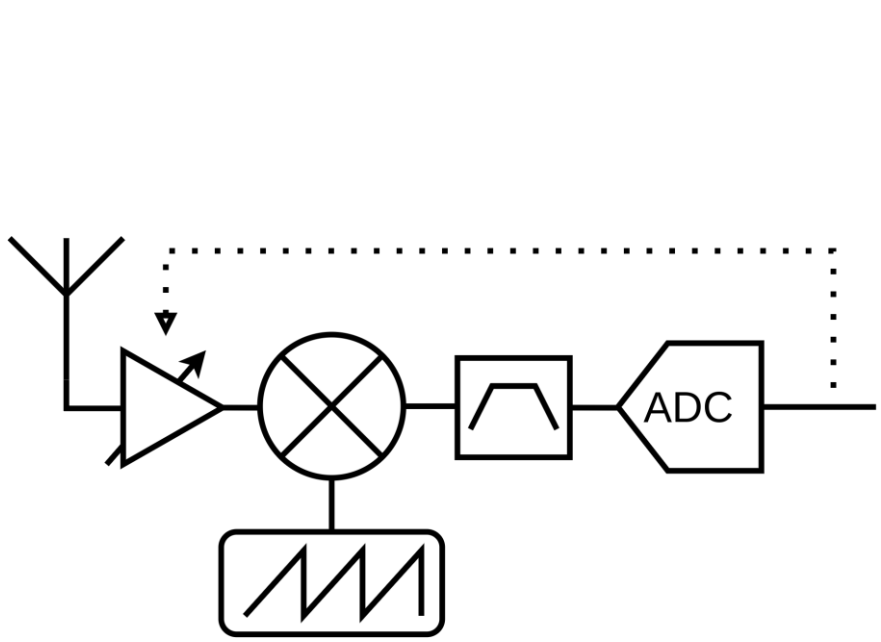
Need time-frequency adaptation

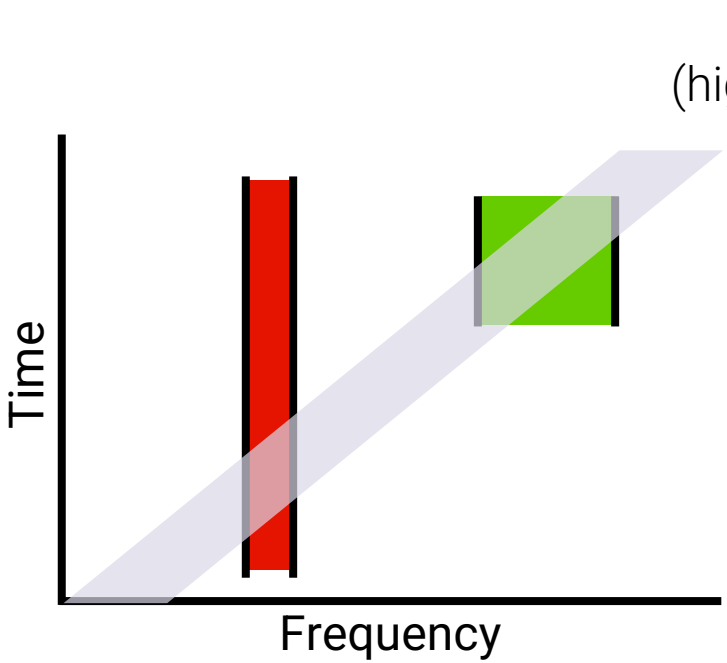
Insight: sweeping is configurable filtering

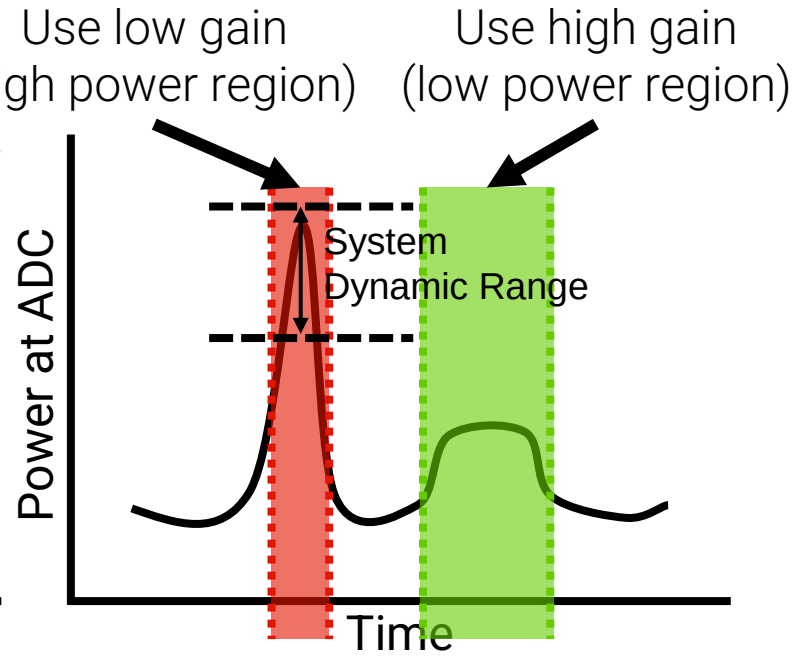




Synchronous Dynamic Gain Adaptation

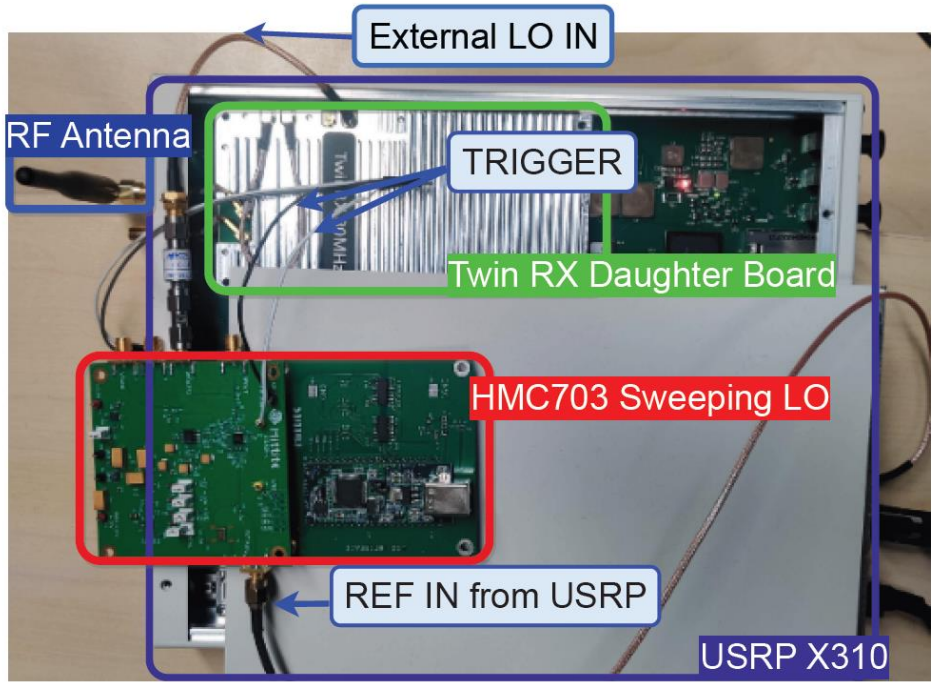




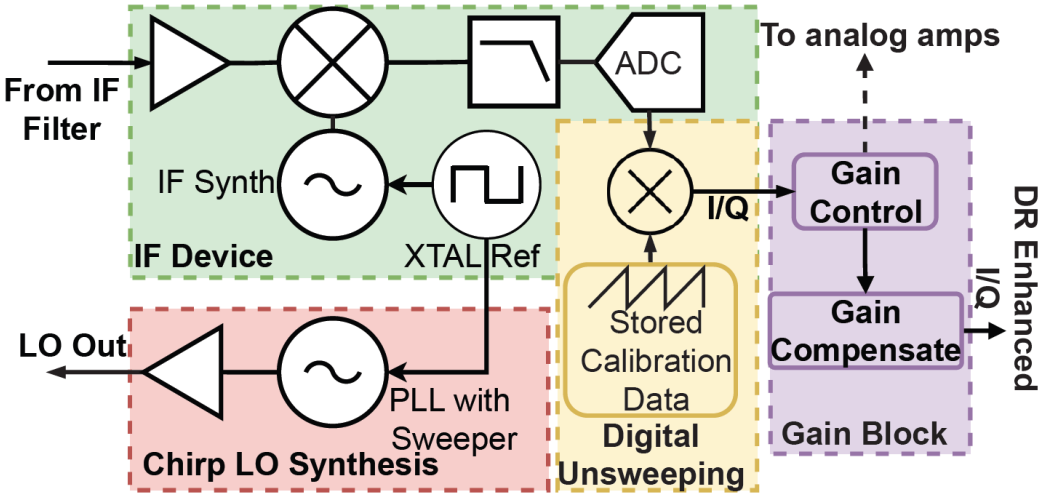


Controlling the gain while sweeping provides time-frequency dynamic range control

Putting it all together: tightly synchronized system and prototype

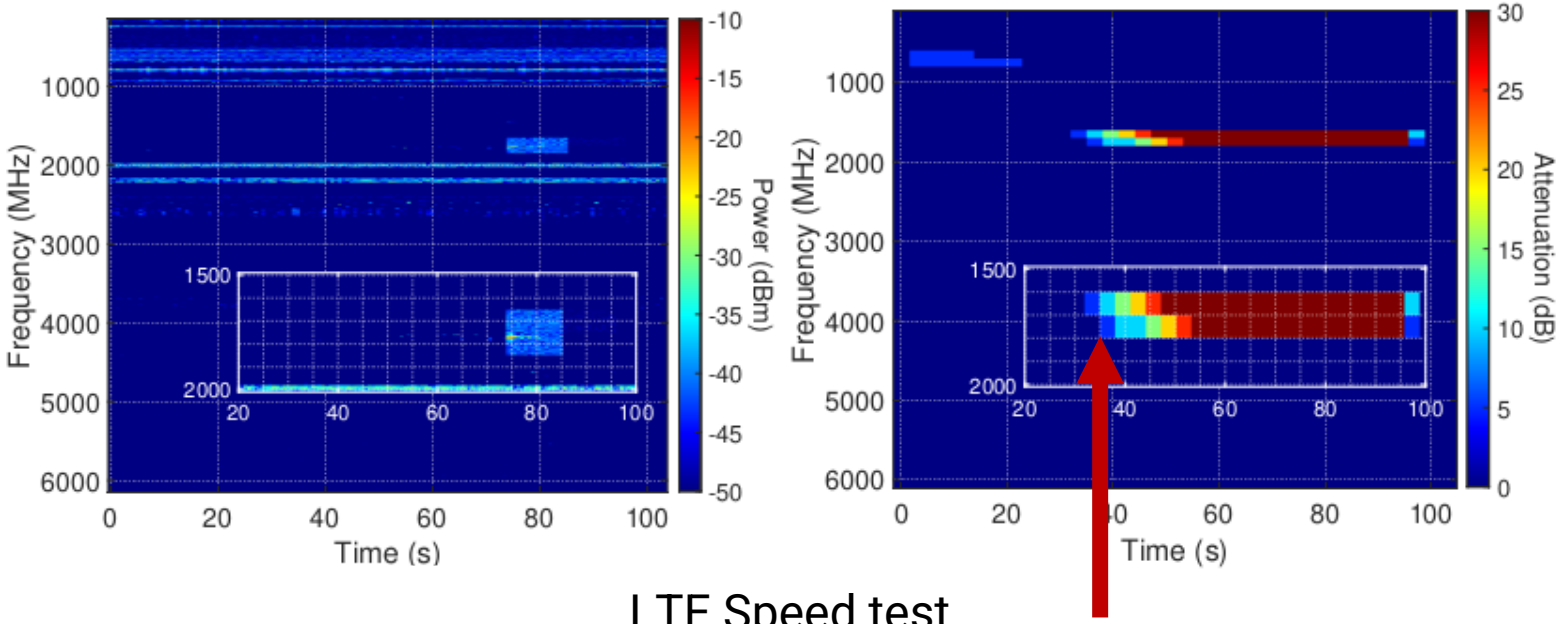


Wideband Prototype

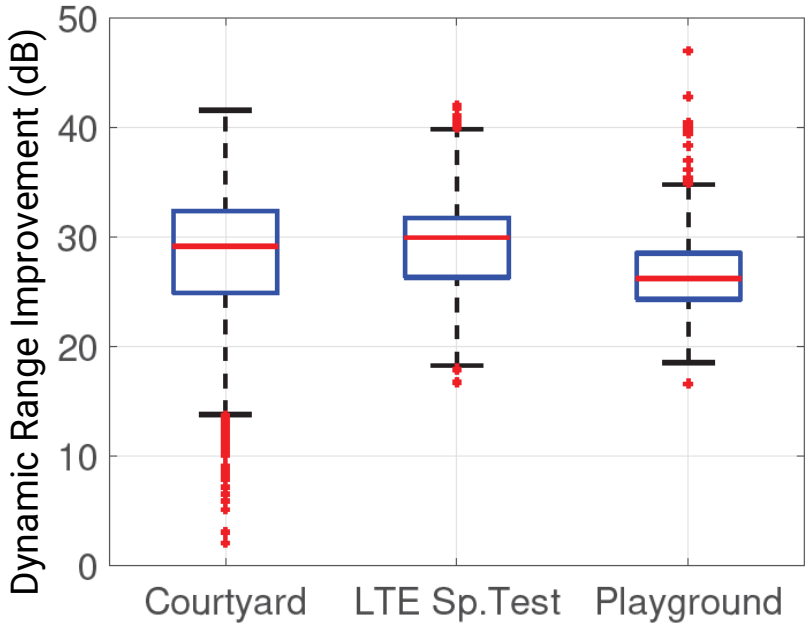


Additional considerations:
Sync, “unsweeping”, gain compensation, RF filters

Outdoor case-studies: Power handling and dynamic range improvement



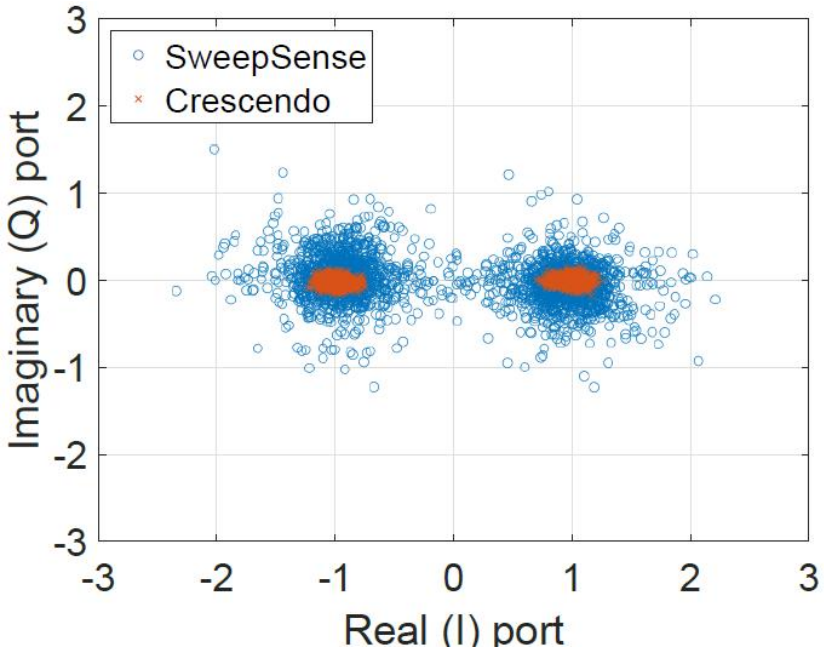
LTE Speed test

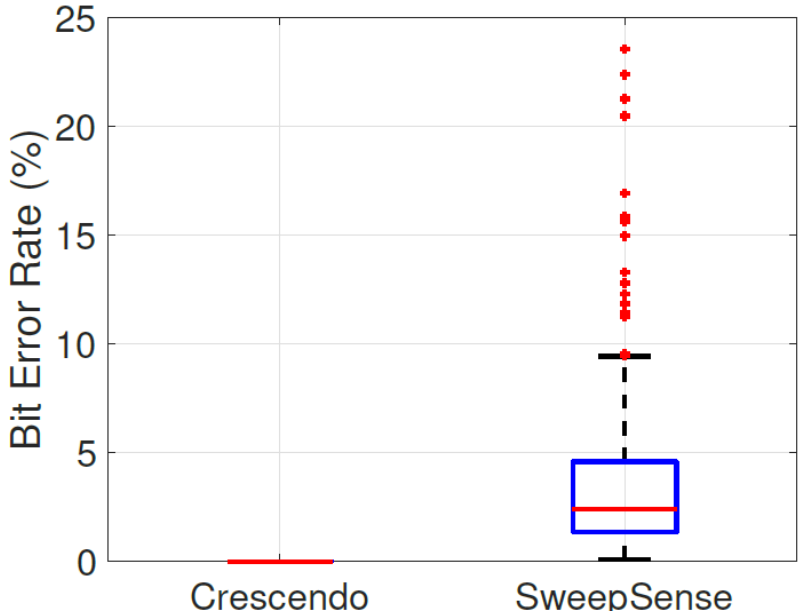


Comparison with GHz ADC baseline

Crescendo provides >30 dB dynamic range improvement

Decoding and SNR Benchmarks





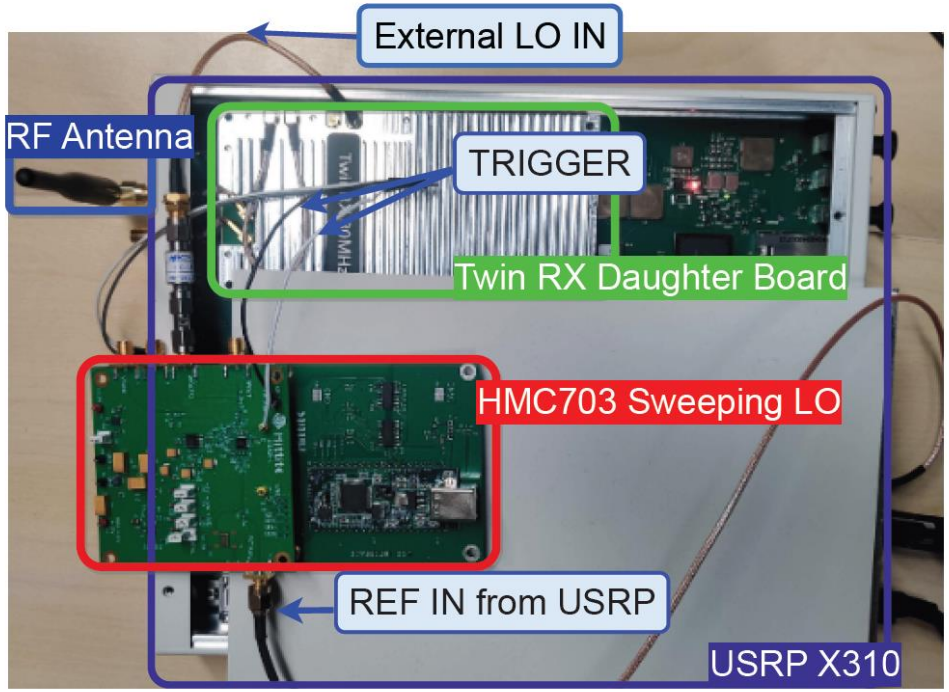
Crescendo enables decoding with 10x improvement in SNR

Crescendo -> High fidelity spectrum sensing

PLLs can create stable, wideband sweeps

Time-frequency-selective dynamic range -> SDGA

30 dB better dynamic range than baseline



Artifact

github.com/ucsdwcsng/crescendo

Questions?