Radar Waveform Pulse Analysis Measurement System for High-Power GaN Amplifiers

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Outline

- Introduction
- Transmit Receive Module Architecture
- Pulsed Waveform Analysis Measurement System
- GaN Amplifier Design and Measured Results
- Conclusion

Introduction

SweepSAR Technique

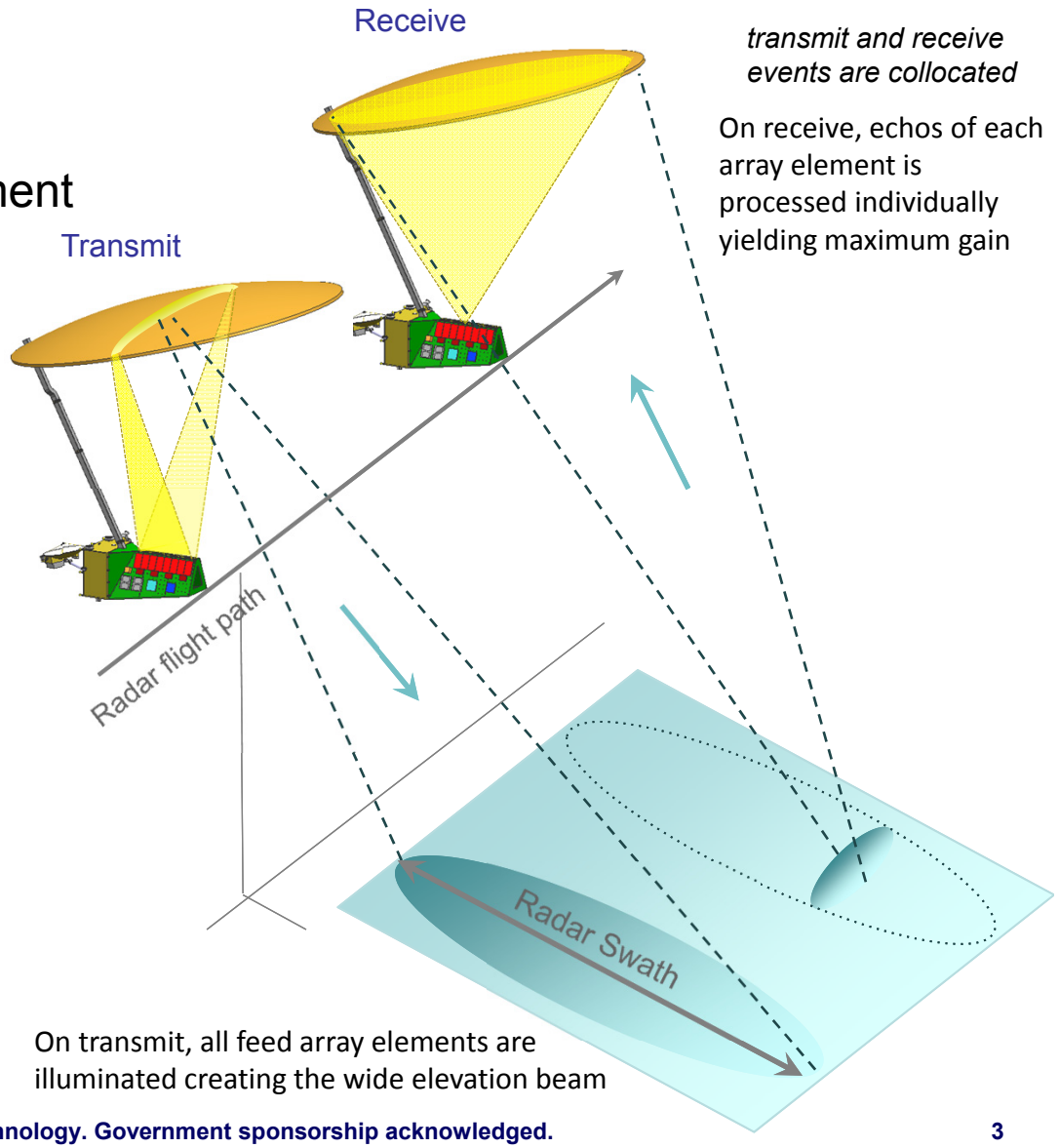
- increased swath and resolution
- TRM drives single feed array element
- digitally rcvrs + on-board cal ➔ on-orbit beamforming

Challenges:

- high rx duty cycle (near 100%)
- RF transients, calibration, or transmit events ➔ swath gaps

Goal: minimize swath gaps by reducing receiver dead-time

Need to accurately understand pulsed amplitude and phase response of TRM



transmit and receive events are collocated

On receive, echos of each array element is processed individually yielding maximum gain

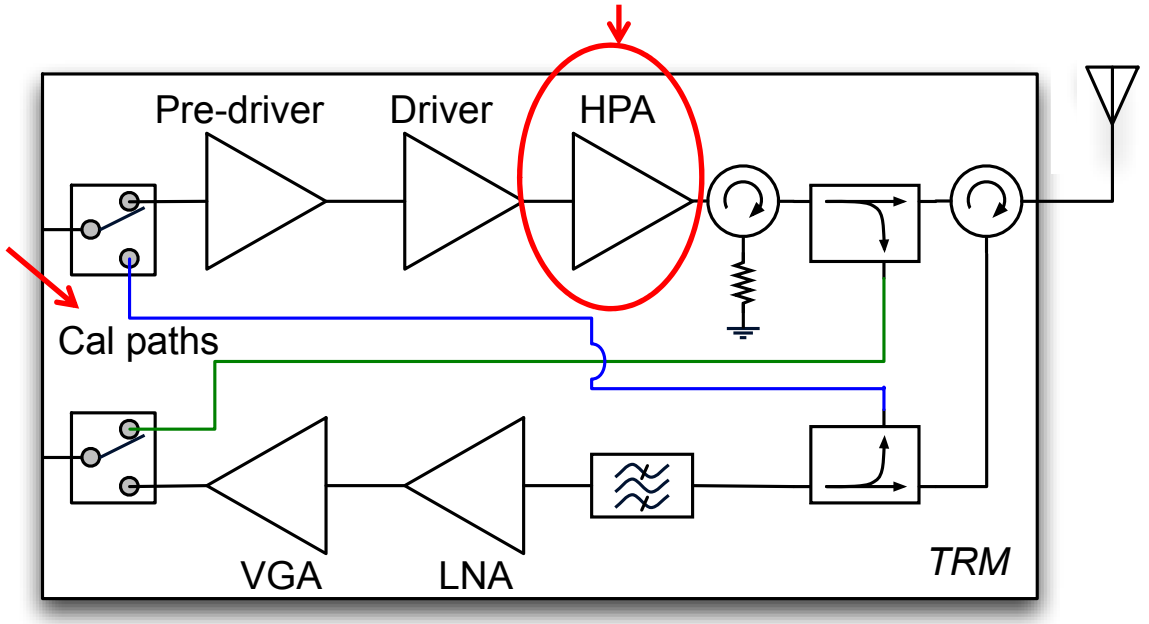
On transmit, all feed array elements are illuminated creating the wide elevation beam

TRM Architecture

Pulsed High power amplifier critical for timing

- large current and voltage transient
- non-linear operation

improved stability
➔ reduced cal time



Transmit / Receive Module (TRM) for SweepSAR instrument

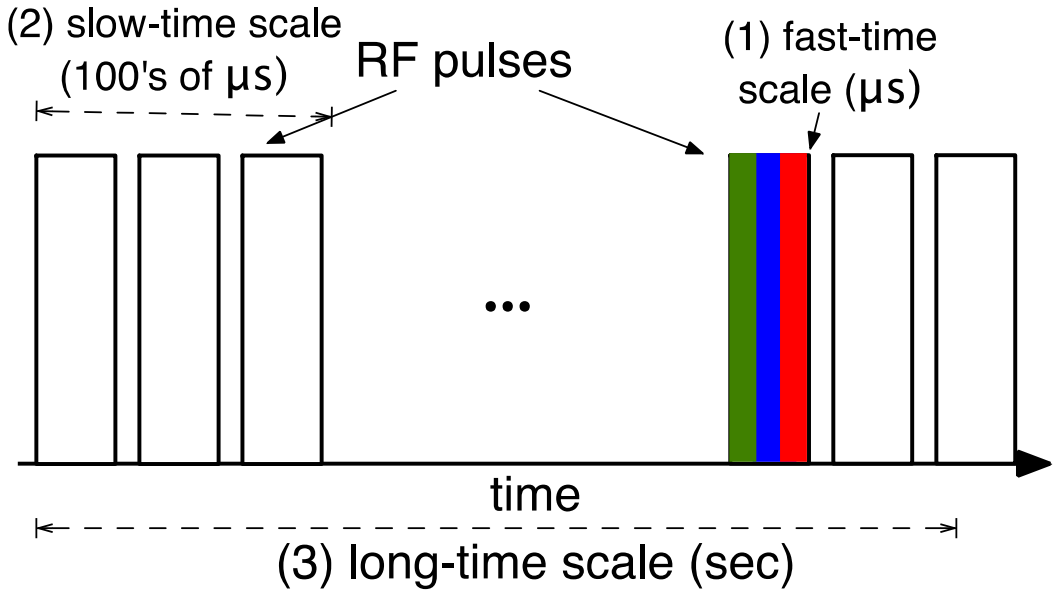
Understand effects of large-signal RF pulsing on Amplitude and Phase response of HPA

Pulsed Measurement Techniques

- **Perform I-Q demodulation in hardware**
  - high-speed
  - lack of flexibility
  - bandwidth limitations
  - difficult to process baseband or *DC* waveforms
- **Network Analyzer amplitude and phase measurement**
  - vector corrected accurate phase measurements
  - difficult to use for high power pulsed measurements
  - does not characterize response across the pulse
- **Real-time digital oscilloscope**
  - fast measurement
  - flexible setup
  - can record multiple channels
  - memory depth for capturing long traces

Pulsed Waveform characterization

- **Amplitude and Phase Response Time-scales**
  - fast-time – within a single pulse, divided into bins (μs)
  - slow-time – PRI scale in change of consecutive pulses (100 μs)
  - long-time – long-term scale (sec)



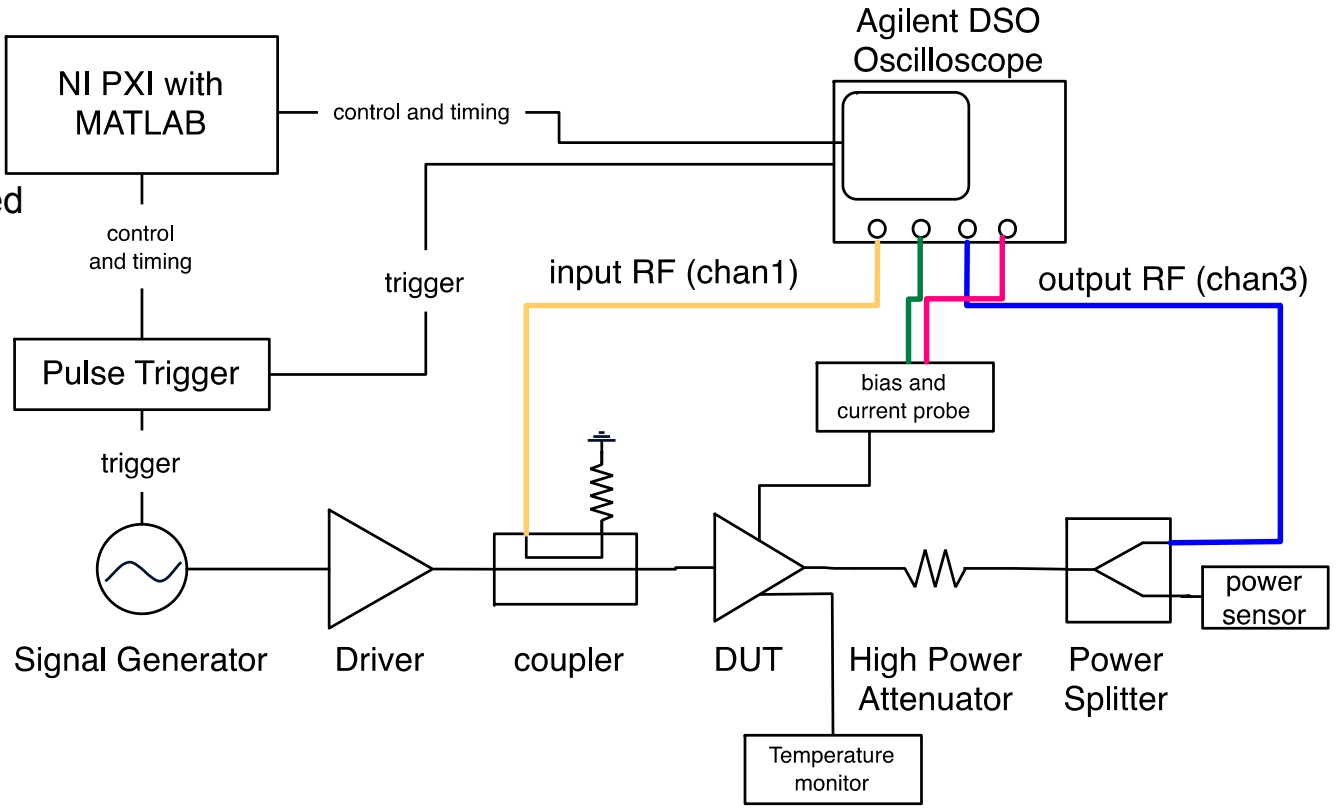
Causes of amplitude and phase variability are understood by observing the response over different time scales

Pulsed Waveform Measurement

Instrument control and data processing performed in MATLAB

DSO is used to capture input, output, current, and voltage waveforms

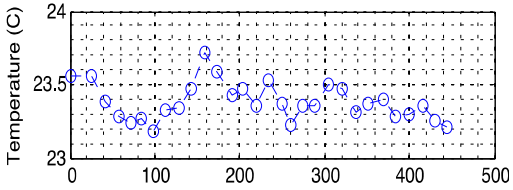
Pulses are hardware triggered to ensure sync

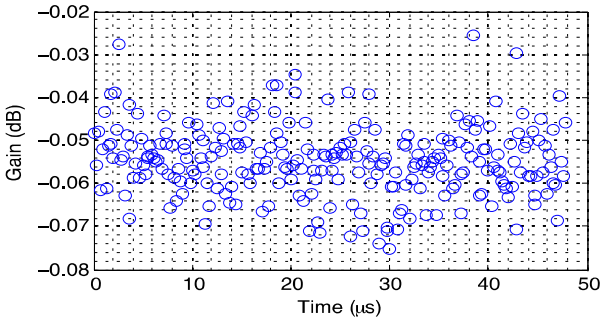


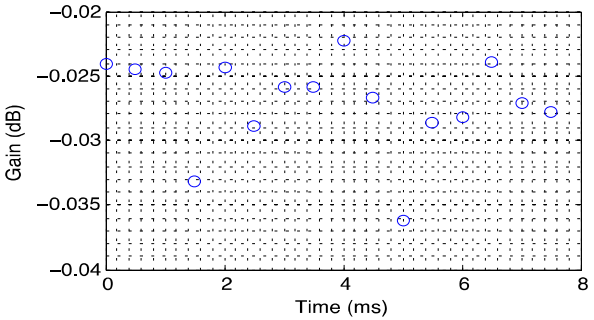
Device and ambient temperatures are also recorded

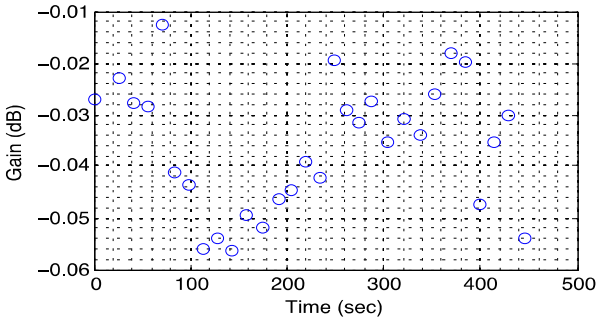
Thru verification

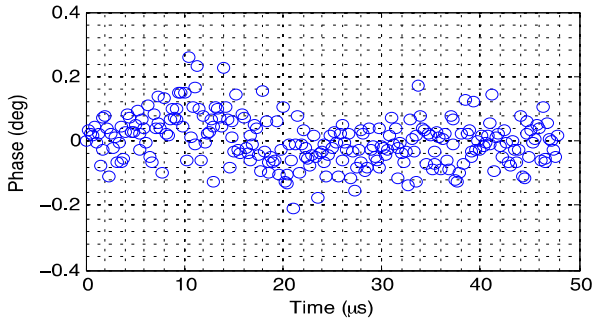
- Measured thru to verify worst case system performance
- CW pulse at 1.2 GHz , 10 GSPS, 500 kpts per acquisition
- SNR of signal does impact measurement
  - DUT with gain will have higher SNR

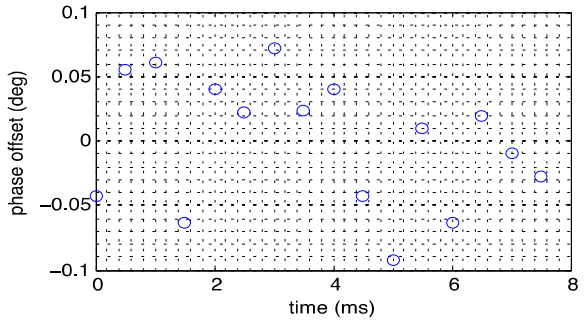


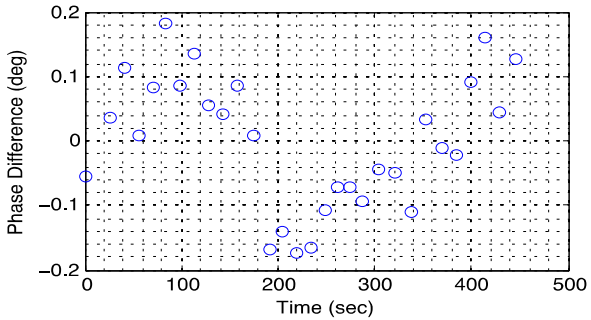










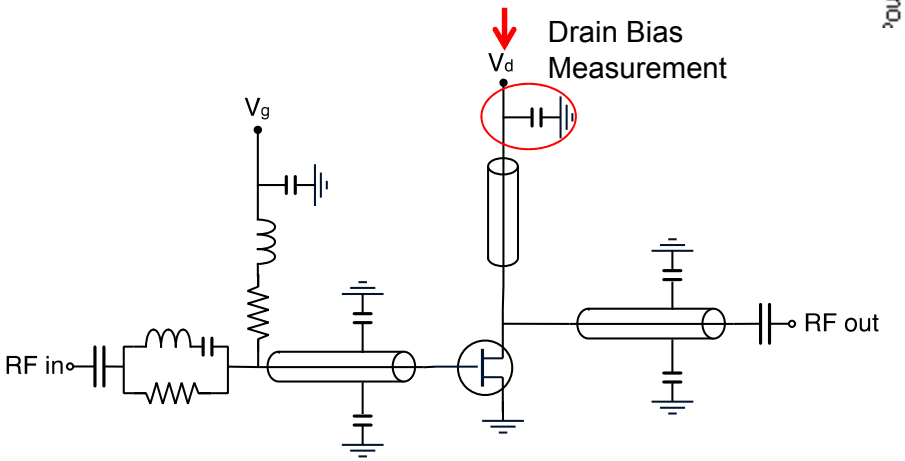


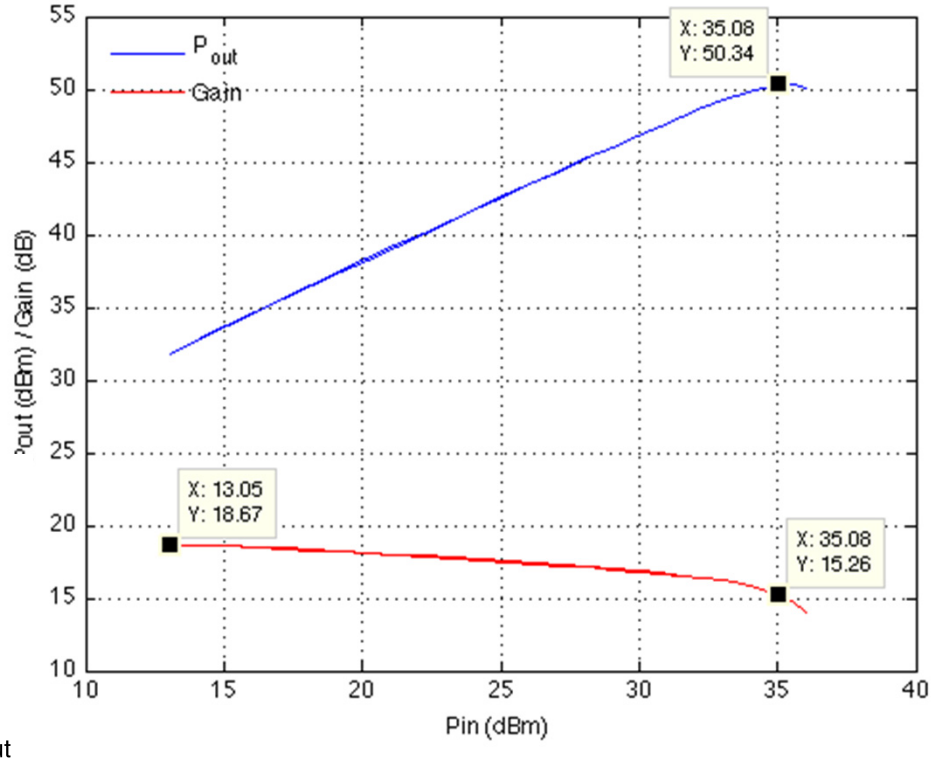
FAST **SLOW** **LONG**

Characterize < 0.1 dB change in Amp and 0.5° in phase

GaN Amplifier design

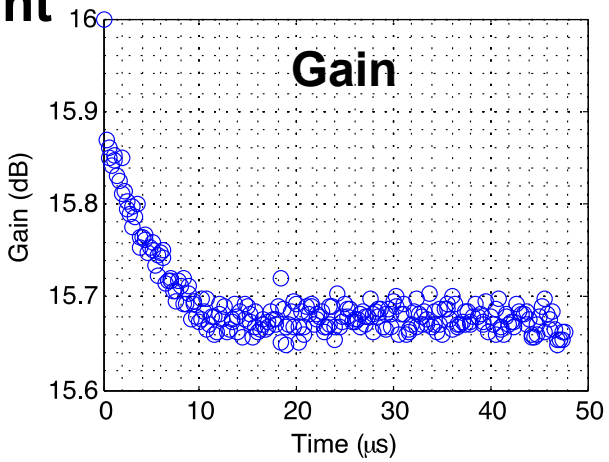
- **120 W high power amplifier using commercially available GaN HEMT**
  - R4003 substrate all internally matched
  - Vdd = 28 V, Idq = 1 A
- **Pulsed RF power sweep**
  - 1200 MHz
  - 120 W Pout, 15 dB gain
  - 10 % duty cycle
  - Pin_sat = 35 dBm





Fast-time response

- **Fast-time measurement**
  - 48 µs pulse
  - 10 % duty cycle
  - Pin = 35 dBm (Psat)
  - 5 GSPS, 1 MSa
  - 256 ‘bins’ per pulse
- **Results**
  - Δ Gain 0.2 dB
  - Δ Phase 2°
  - Droop in Vd and Id filtered by decoupling capacitor
  - Gain and Phase reach steady state in ~ 10 µs



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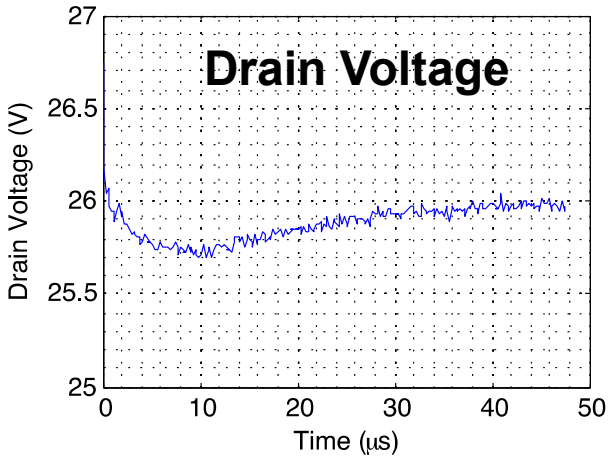

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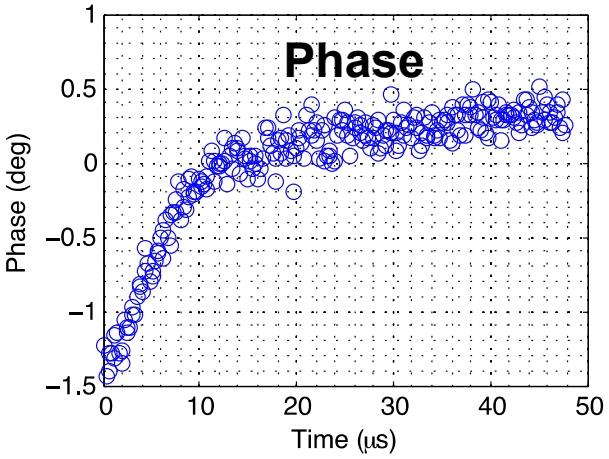

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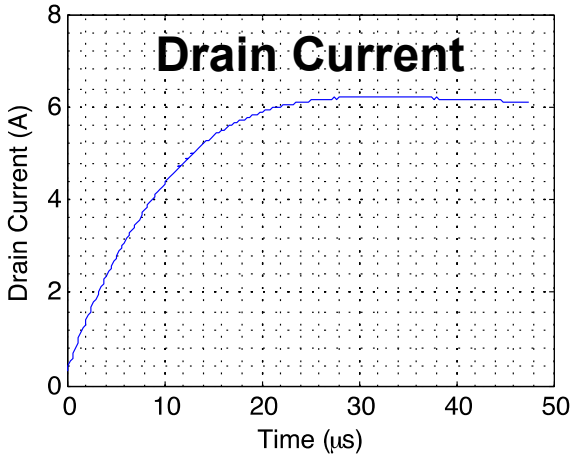
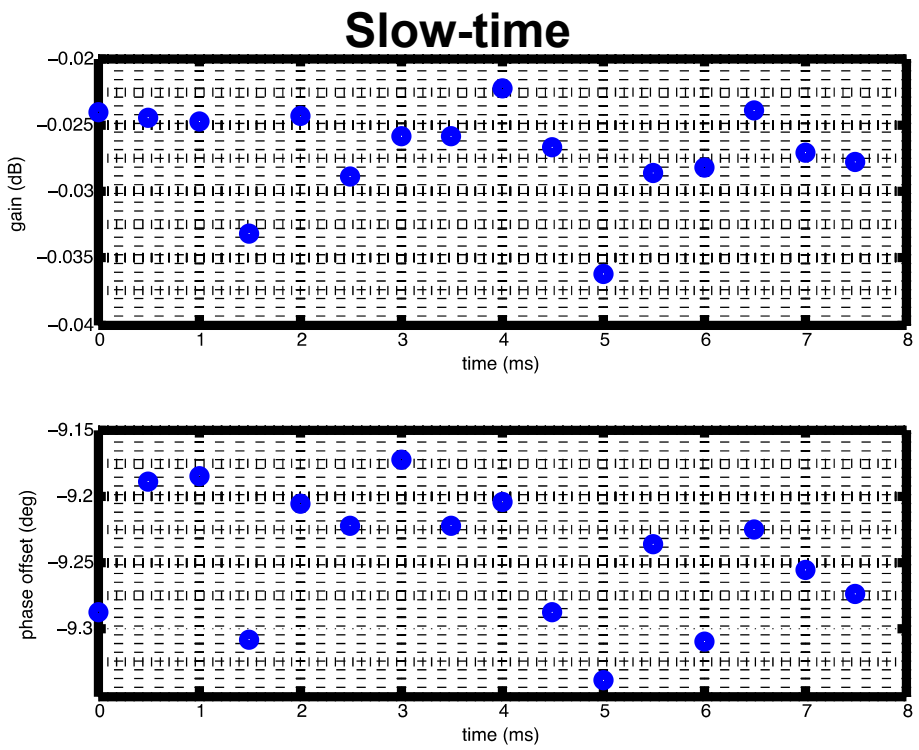
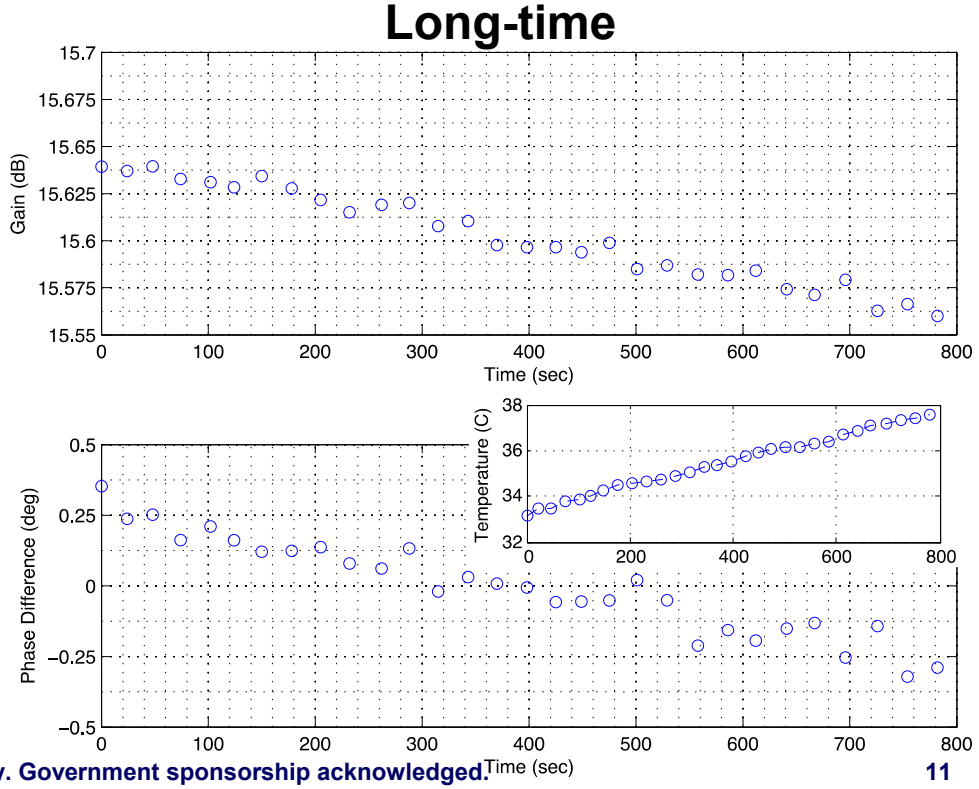


(d)

Slow and long time response

- Slow-time captures 16 pulses during a single data acquisition
  - performs fft over entire pulse to get amplitude and phase
  - gain and phase stable
- Long-time acquisition ➔ 800 sec with 16 pulses averaged per data point
  - drift correlated to device temperature change





Conclusions

- **Understanding of Amplitude and Phase stability for advanced SAR systems is critical**
- **Developed automated system to accurately measure amplitude and phase over fast, slow, and long time scales**
- **Verified measurement system performance on thru**
  - achieved < 0.1 dB accuracy in amplitude and 0.5° in phase
- **Measured performance of GaN HEMT 100 W amplifier**
  - fast-time response dominated by dynamic IV characteristics (across RF pulse)
  - slow-time response is stable (from pulse to pulse)
  - long-time response is correlated to device temperature changes
- **Future work:**
  - incorporate AWG as signal source to allow for modulated waveforms (eg chirp)
  - use differential probe to measure currents closer GaN HEMT

Amplitude and Phase measurement system can be used to accurately characterize performance over relevant time scales