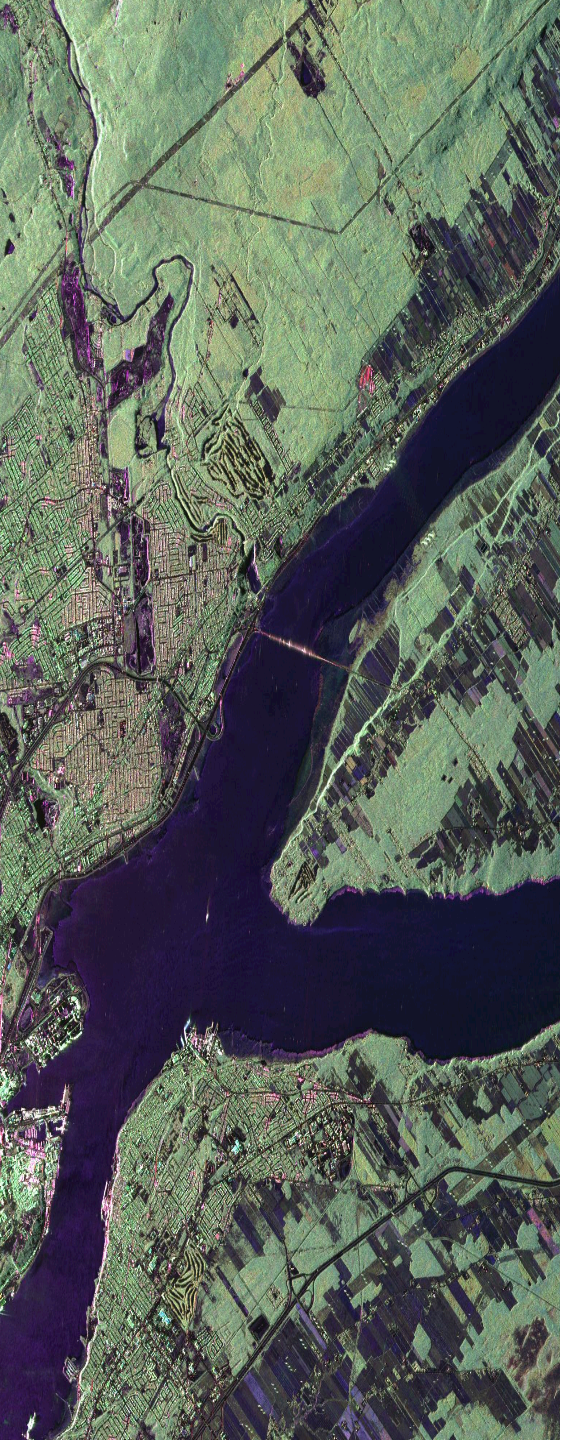

Design Of An Ultra-efficient GaN High Power Amplifier For Radar Front-ends Using Active Harmonic Load-pull

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Introduction

- Next generation synthetic aperture radar (SAR) systems:
  - multiple high-power transmit modules
  - wide-bandwidths
  - low-cost
  - SweepSAR technique
- Current technologies not suitable
  - TWTs – large and require HVPS
  - GaAs and LDMOS – difficult to meet bandwidth and efficiency
- GaN technology
  - high breakdown voltage – high output power and efficiencies
  - higher operational junction temperatures – thermal (225C)

GaN Technology allows significant performance advantages for spaced-based SAR instruments

SweepSAR Technique

SweepSAR Technique

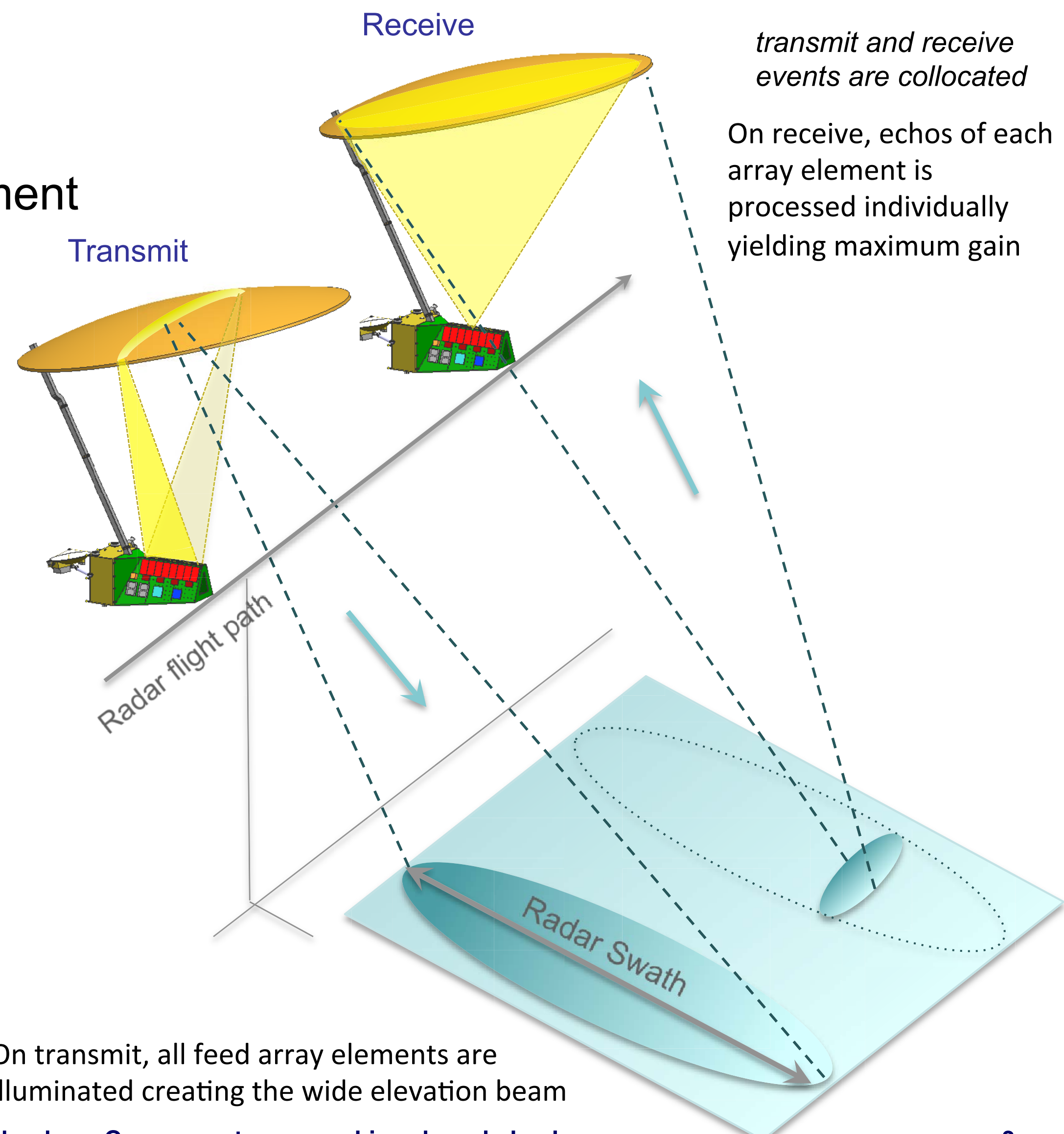
- increased swath and resolution
- TRM drives single feed array element
- digitally rcvrs + on-board cal ➔ on-orbit beamforming

Challenges:

- high rx duty cycle (near 100%)
- shorter, high peak power transmit pulse to achieve SNR

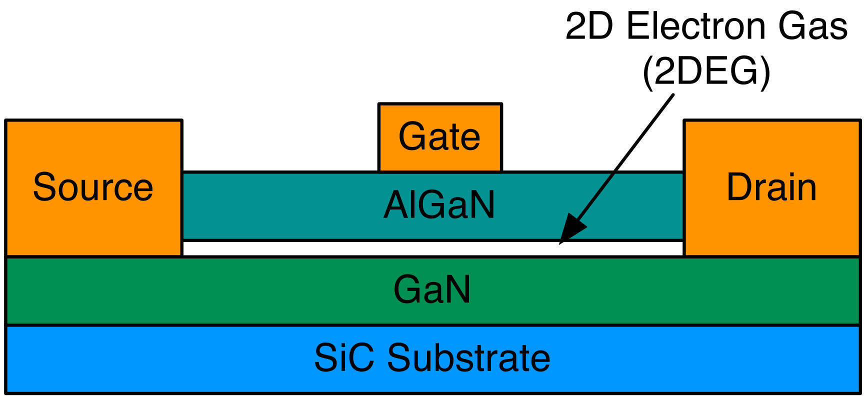
SweepSAR requires high-power and high efficiency PAs

GaN is a key enabling technology



GaN HEMT Technology

- Wide bandgap material
  - high breakdown (10 X GaAs)
  - high power density (5 X GaAs)
- Bandgap engineering with AlGaN / GaN layers
- SiC substrate – low thermal resistance
- Low parasitic capacitance – high efficiency amplifier modes
- Advanced GaN HEMTs
  - field plate to control electric field on gate



Load-pull Techniques

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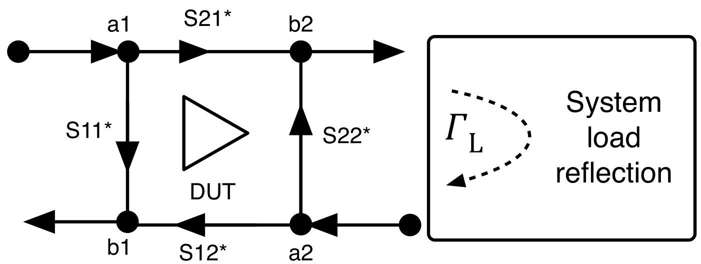
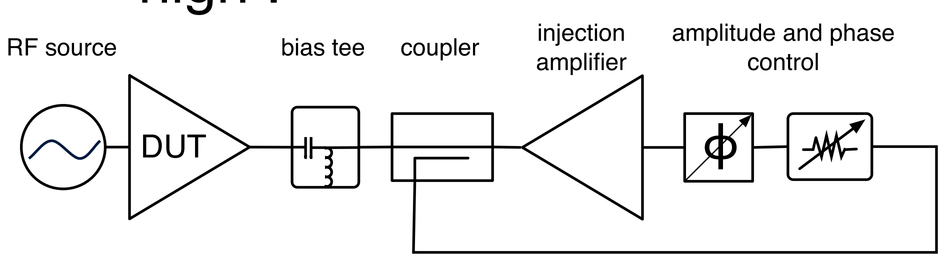
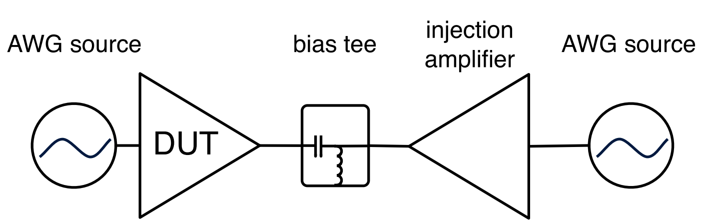
- Load-pull characterize non-linear device response
  - presents impedances to the DUT at fundamental and harmonics
- Active load-pull uses injection amplifiers to obtain Γ
  - closed loop uses signal from DUT
  - open loop uses synchronous AWG source
- Active open loop
  - complex modulated waveforms
  - harmonic control
  - high Γ





Closed loop active load pull



Open loop active load pull

Open Loop Active Load-pull

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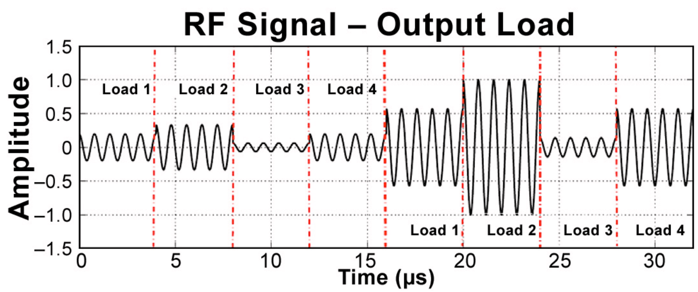
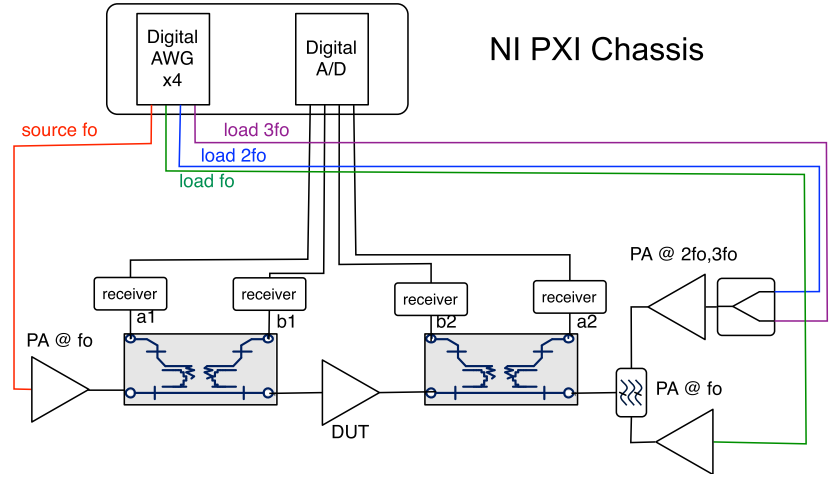
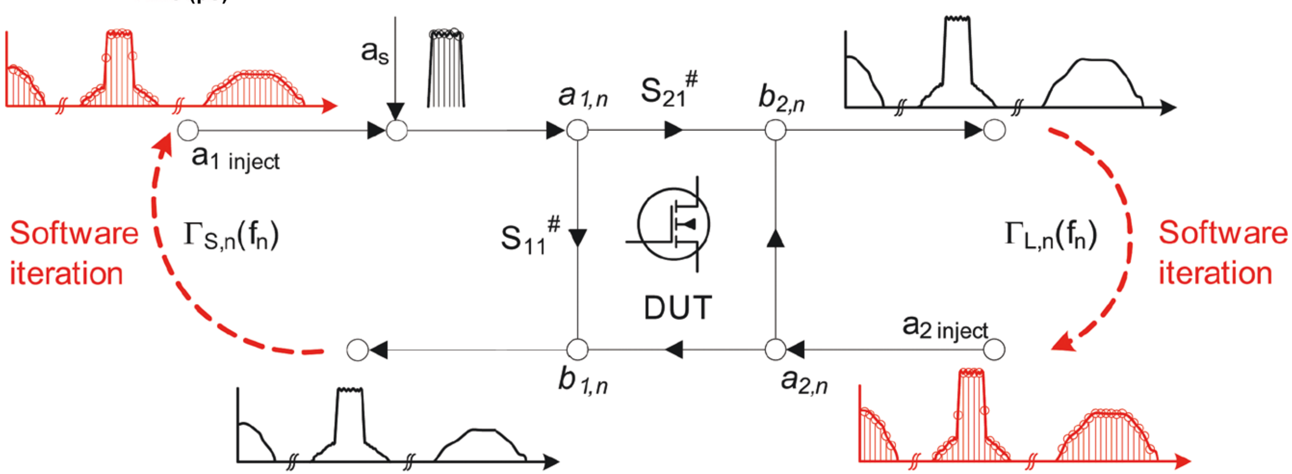
- Developed by Anteverta-mw and Maury Microwave
- 4 tuning loops – source fo, load fo, 2 fo, and 3 fo
- Measurement procedure:
  - samples *a* and *b* waves
  - iterates to achieve impedance







10W Device load-pull

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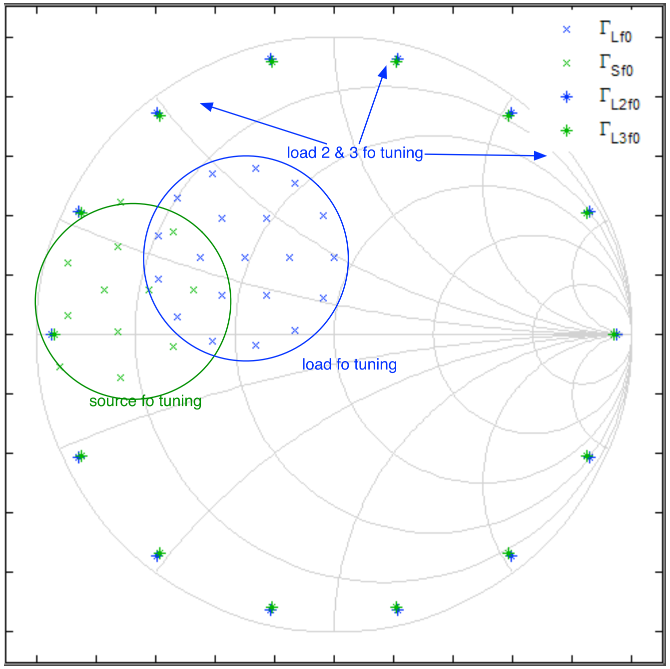
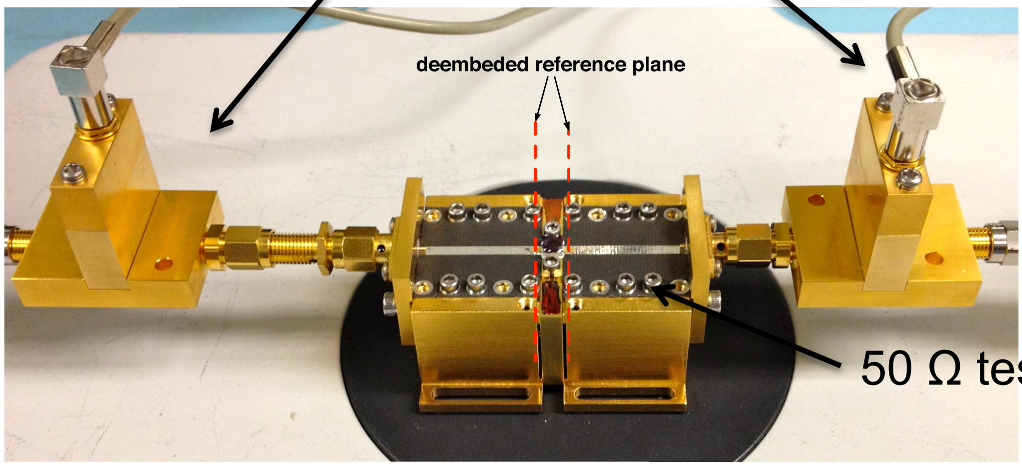
- 10 W packaged GaN HEMT
  - Vds = 28 V, Idq = 100 mA
- Device measured in 50 Ω test fixture
  - deembeded to device package
- Fundamental source and load impedances at 1.25 GHz

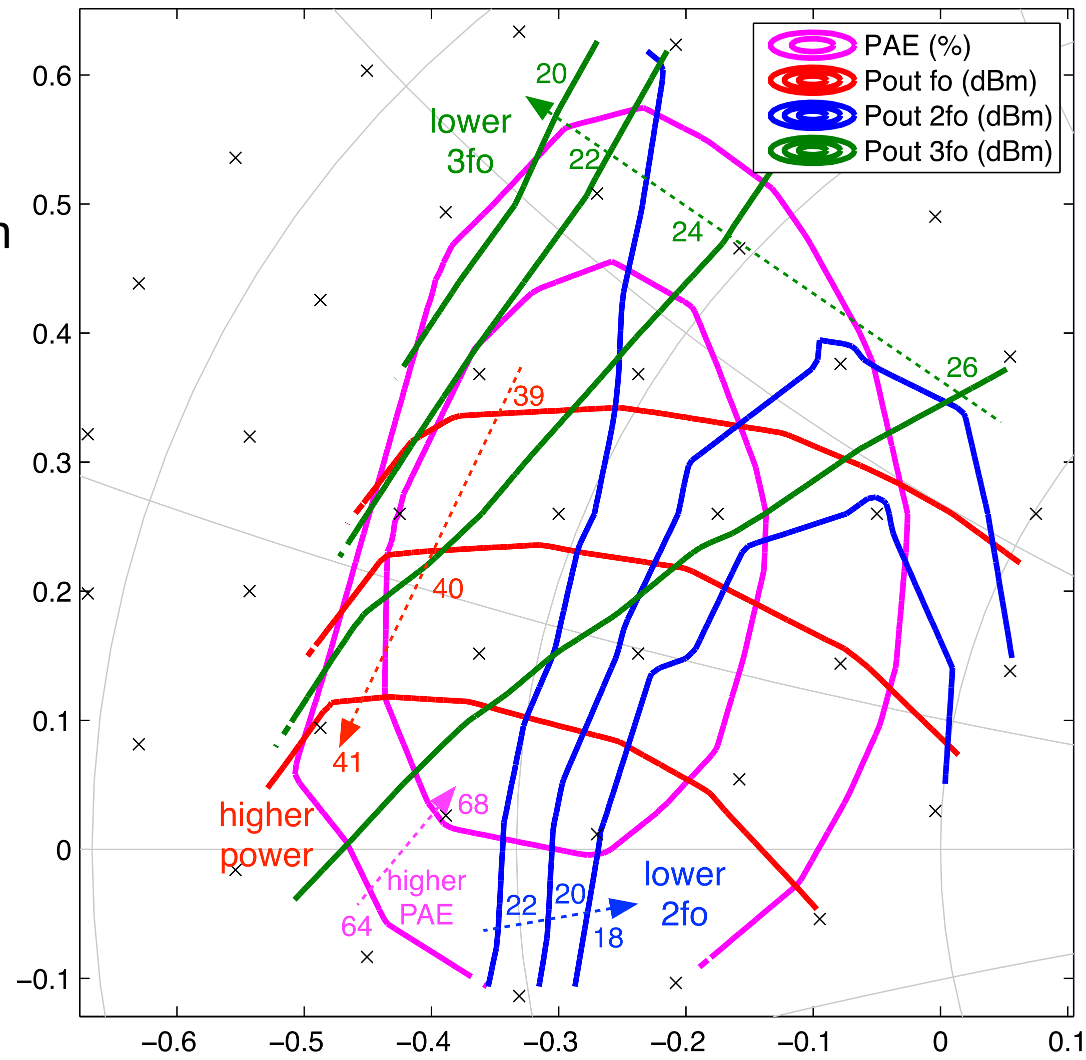


Impedance tuning



Fundamental load-pull results

- RF performance
  - > 40 dBm output power at fo
  - 68 % PAE
  - 2nd and 3rd harmonic > 20 dBm
- Even with no harmonic control efficiency is almost 70%
- Max PAE is tradeoff between fundamental power and lower harmonic powers



Harmonic control

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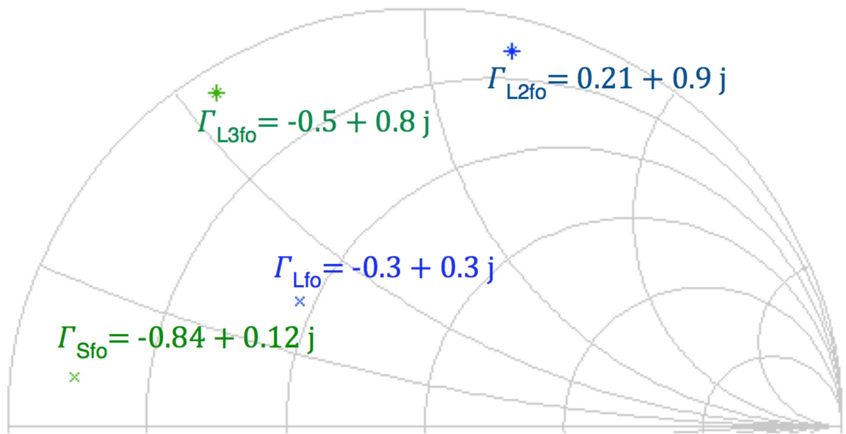
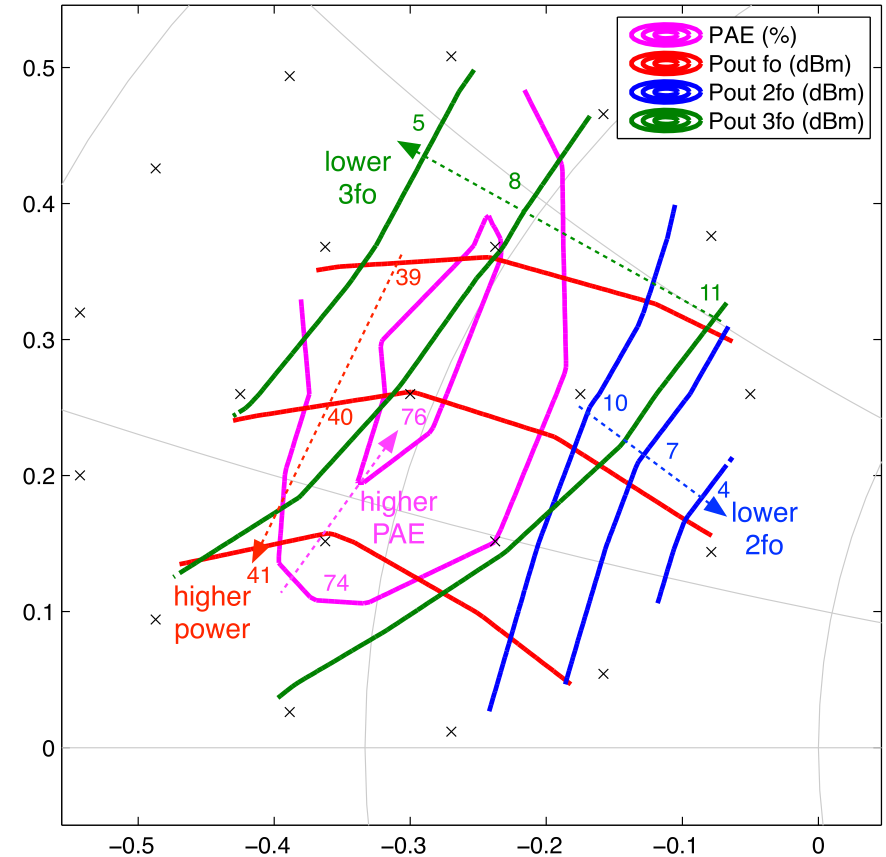
- Harmonic tuning
  - presenting the appropriately phased 2nd and 3rd harmonic impedance
  - optimizes device current and voltage waveforms
- RF performance
  - > 40 dBm output power at fo
  - 76 % efficiency
  - harmonic levels reduced to < 10 dBm

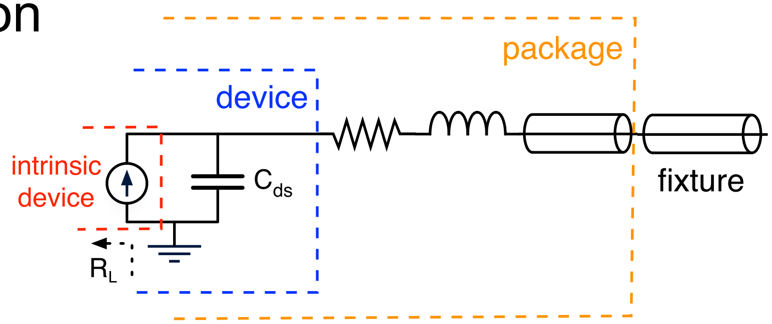


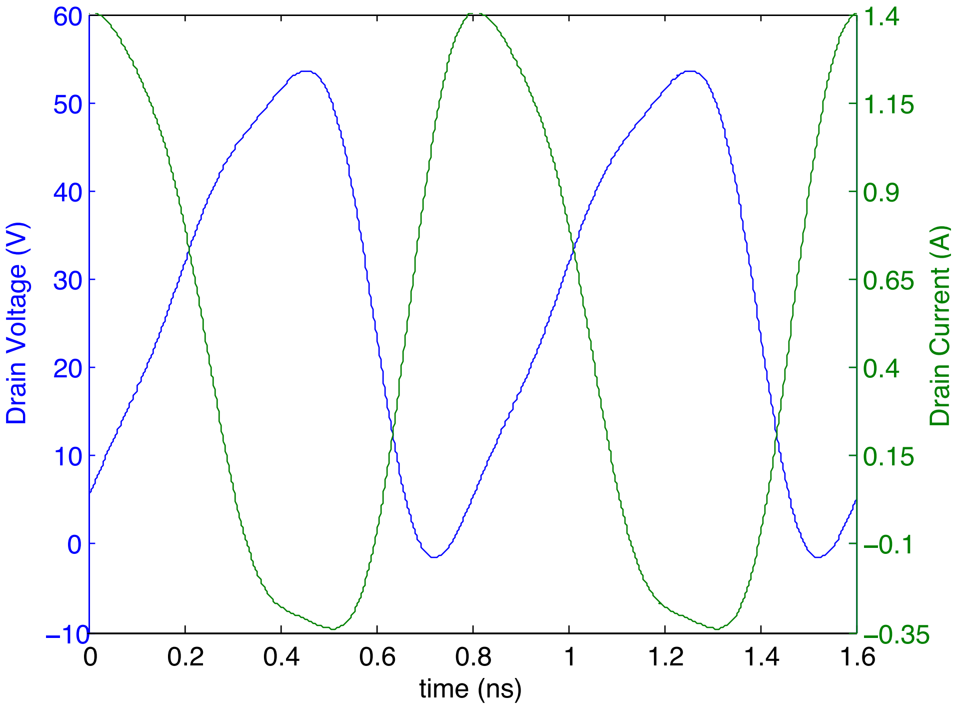
Optimized design impedances



Dynamic Voltage and Current waveforms

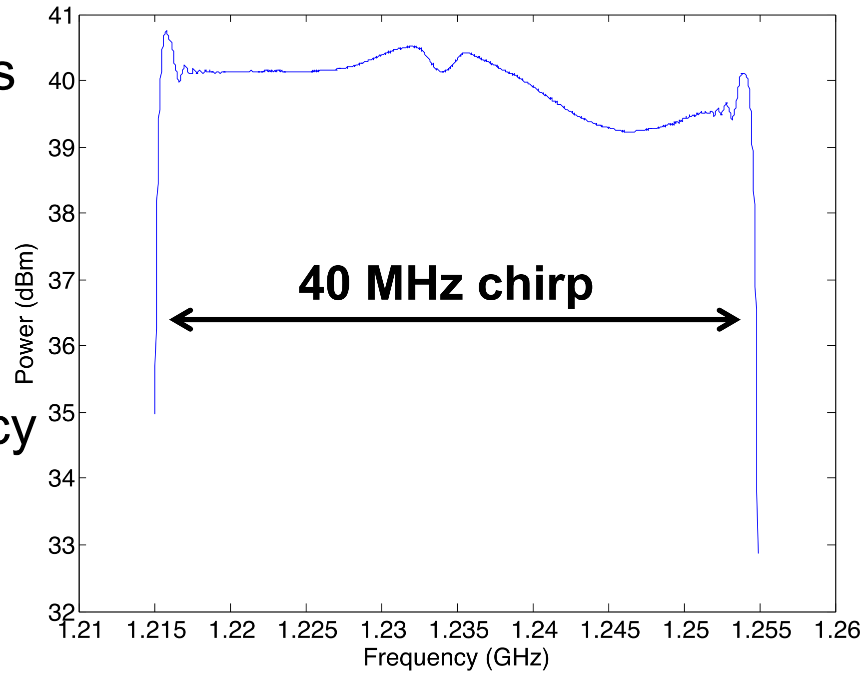
- Active load-pull system allows calculation of the dynamic voltage and current waveforms at device
- Determine optimal device load-line
- Deembed to intrinsic device plane
  - modeled package parasitics
  - internal device capacitance
- Voltage and Current peaks offset
  - not fully capturing reactive elements in deembeding
  - work with vendor to better quantify parasitics

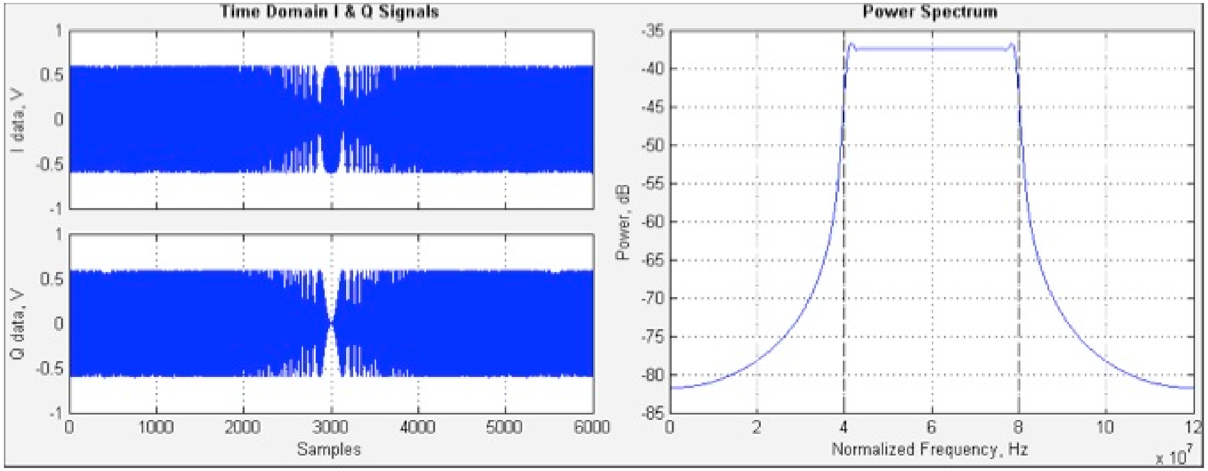




Chirp Waveform Measurements

- Load-pull modulated signals using AWGs
  - optimize for signal bandwidth
  - 40 MHz chirp centered at 1.235 GHz
- Achieve 40 dBm output with less than 1 dB variation across the band
- Can control impedances across frequency
  - simulate matching networks

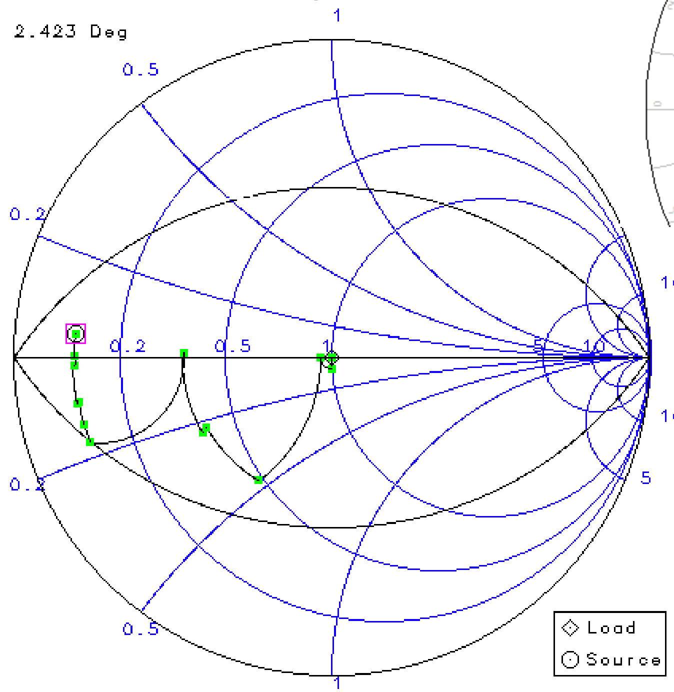




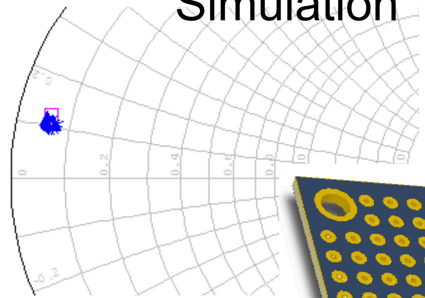
Matching network design

- Matching across harmonic impedances?
  - Stepped impedance microstrip line for fundamental
  - Shunt capacitors to tune harmonic impedances

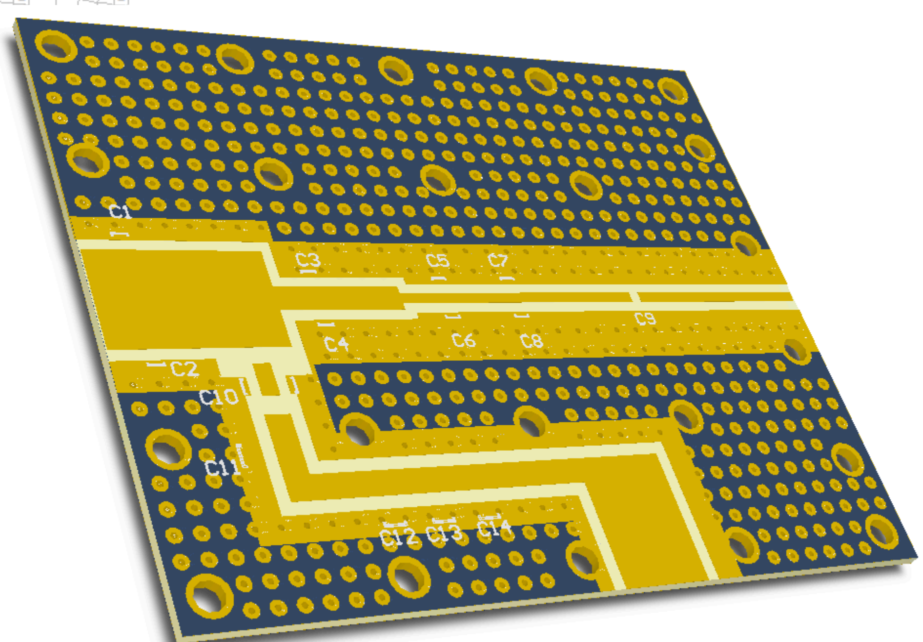
Design



Simulation



Layout / Fabrication



Conclusions

- Demonstrated use of mixed-signal active load-pull system
- Presented load-pull results of a 10W GaN HEMT amplifier
  - over 76% PAE at 40 dBm output power
  - low harmonic levels
- Active Load pull + GaN = high performance power amplifier
  - suited for demanding space applications
  - efficiency, high power density, and low harmonic levels
- Future work
  - 120 W GaN device design
  - Build input and output matching networks
  - Improve accuracy for device parasitic and packages models
  - Fully characterize device over chirp bandwidth