Digital Predistortion (DPD) Evolution for 5G and Beyond

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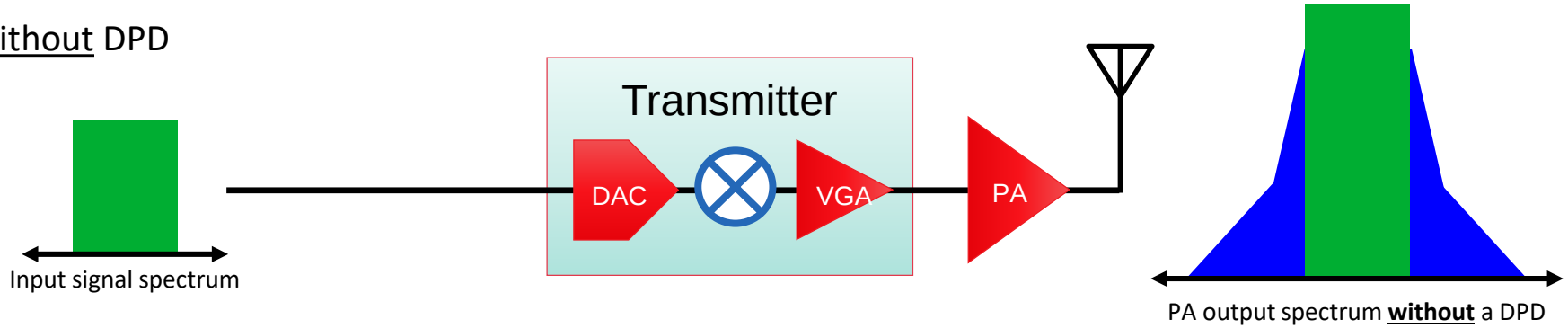
Outline

- Introduction to Digital Predistortion (DPD)
- DPD Key Performance Indicators
- 5G and Beyond Transmitters for Wireless Infrastructure
- End-to-End System Performance
- Future Trends

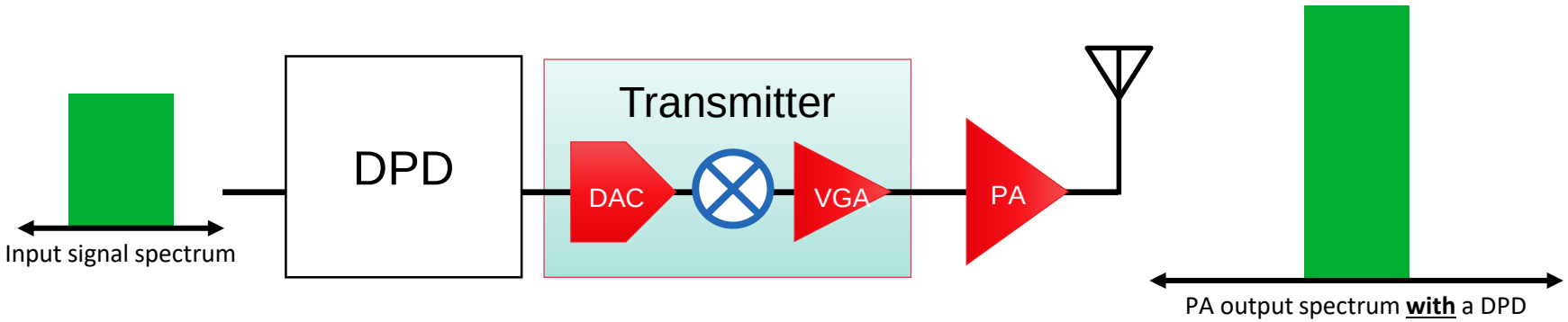
Digital Predistortion (DPD) For Transmit Chain

Without DPD



- Fails EVM spec
- Fails Spectral Emission Mask (SEM) specs
  - Fails ACLR
  - Fails OBUE (FCC requirement)

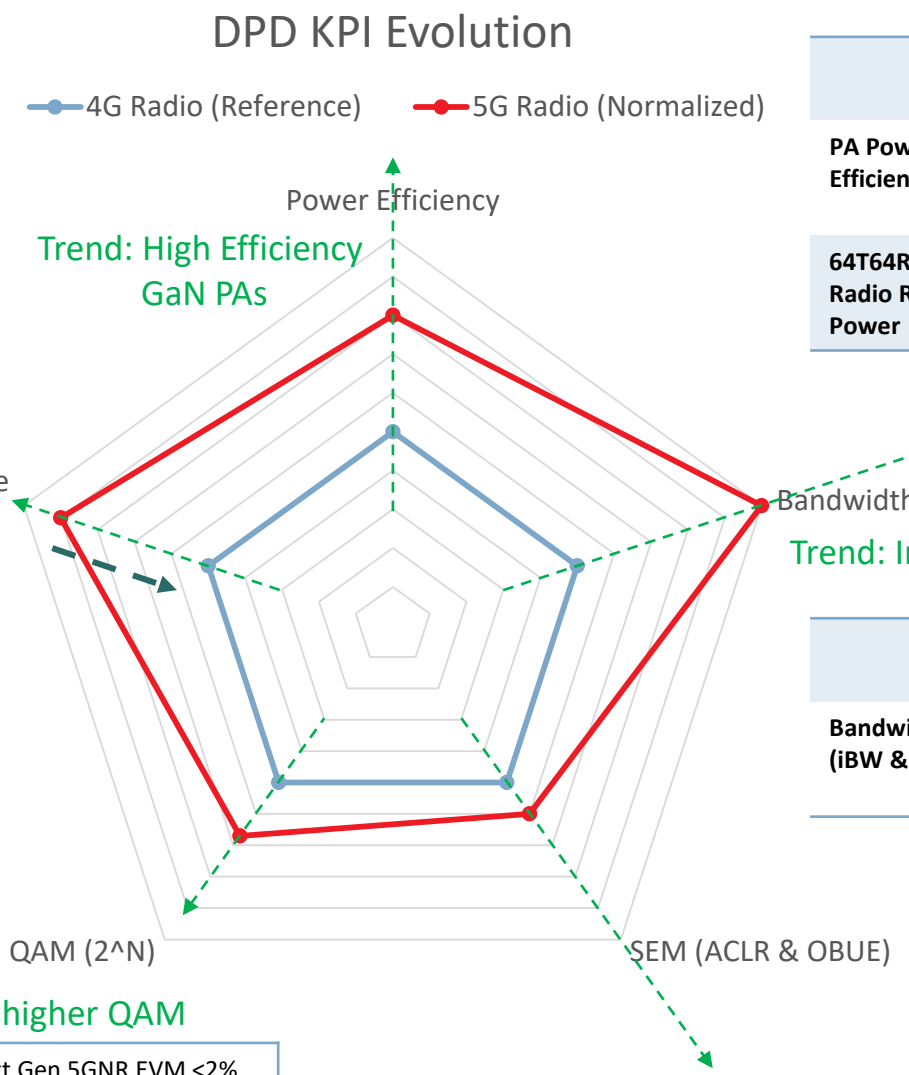
With DPD



- Meets EVM spec
- Meets SEM specs

Digital Predistortion: Key Performance Indicators (KPIs)

Without algorithmic breakthroughs, the DPD implementation size will grow exponentially, DPD algorithmic innovation keeps linear growth.



Trend: High Efficiency GaN PAs

Trend: Increase in BW

Trend: Increased Implementation Size

Desired Trend: Compact Implementation (Driving Innovation in DPD Technology)

Trend: Lower EVM due to higher QAM

LTE EVM <6% (64 QAM)	5GNR EVM <3% (256QAM)	Next Gen 5GNR EVM <2% (1024QAM)

Trend: Stricter SEM Requirements for MIMO

	With DPD (3yrs ago)	With DPD (today)	
PA Power Efficiency	$\eta = 40\%$ mMIMO PA Mid/Hi-band	$\eta > 50\%$ mMIMO PA C-band	• GaN Adoption • PA Improvements • DPD Improvements
64T64R Radio RF Power	1280W	1024W	• **250W savings** • Heat sink size reduction • Radio weight reduction

	With DPD (3yrs ago)	With DPD (today)	
Bandwidth (iBW & oBW)	100MHz	400MHz	• New available bands • PA Improvements • DPD Improvements

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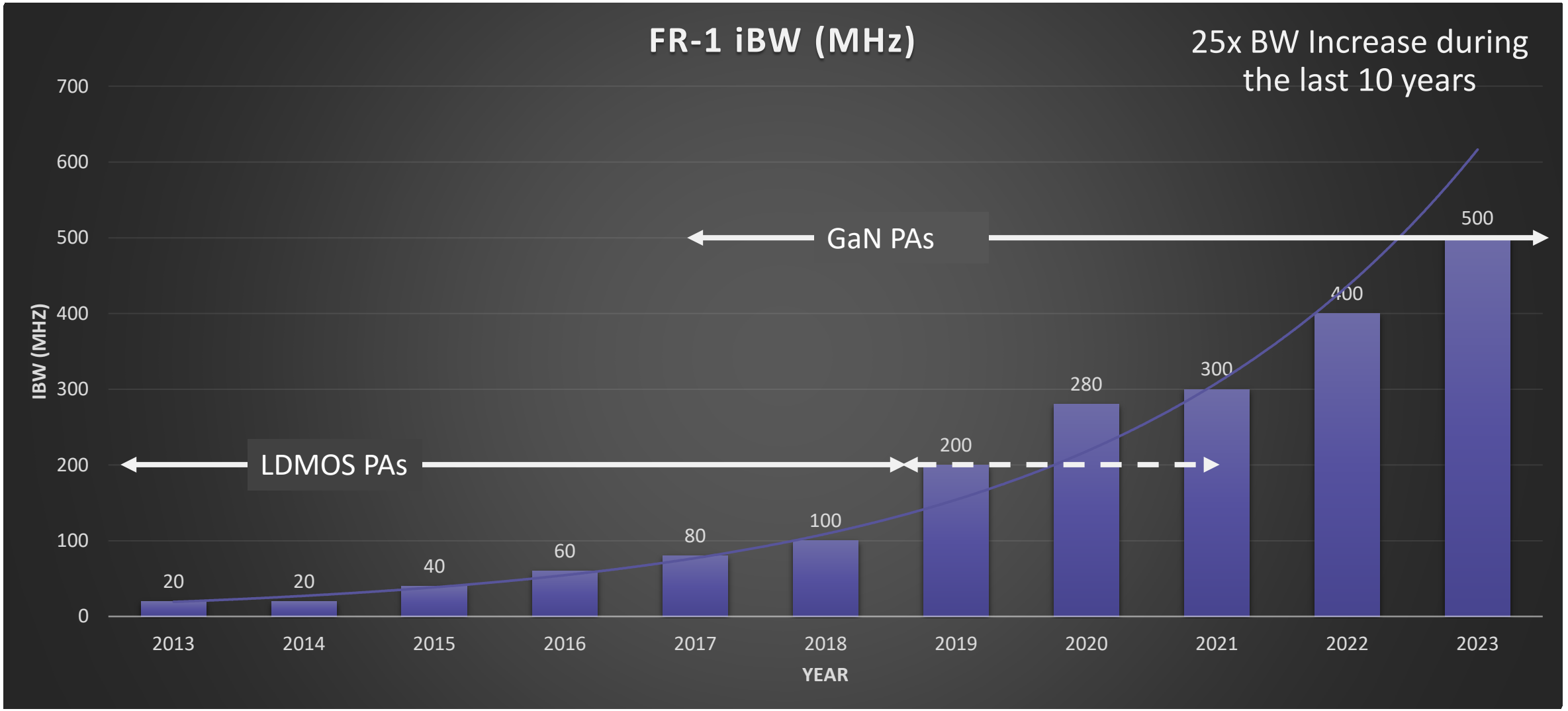
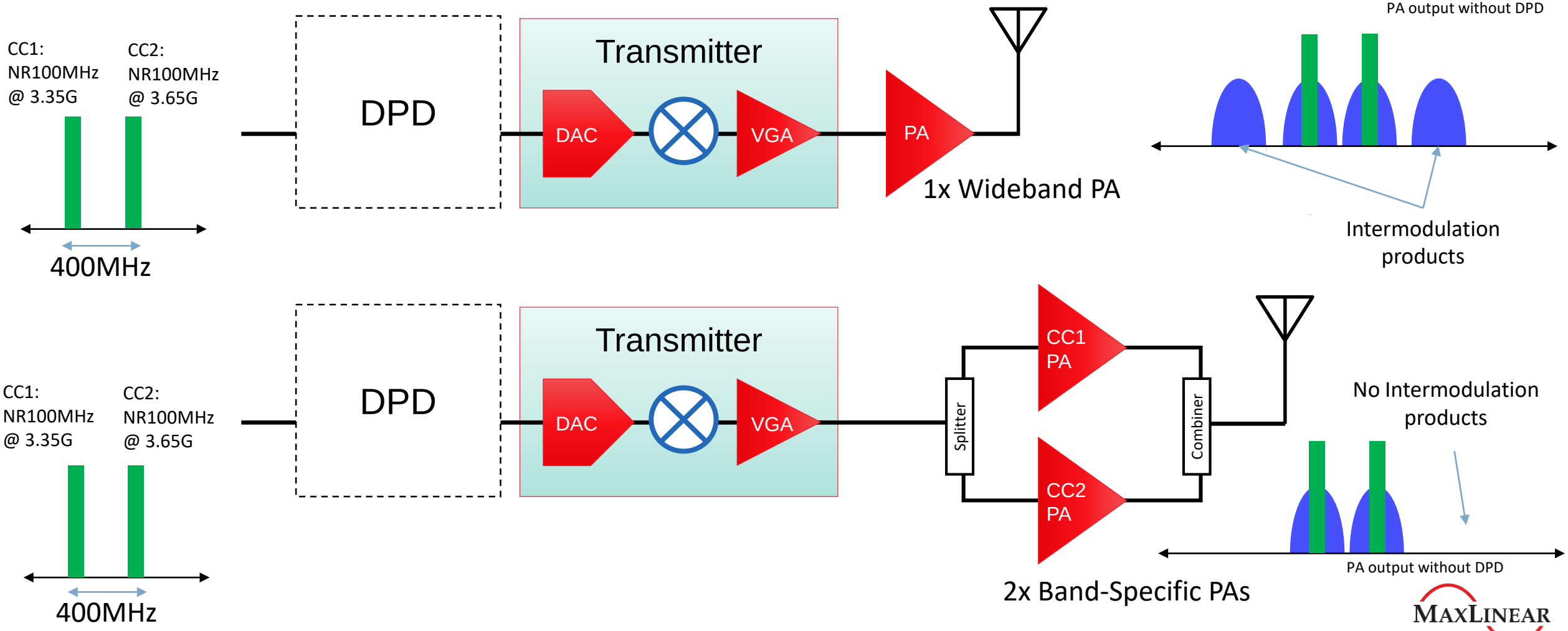
iBW Timeline



Wideband Usecases: Band N77 Example

A versatile DPD should be able to linearize both use cases



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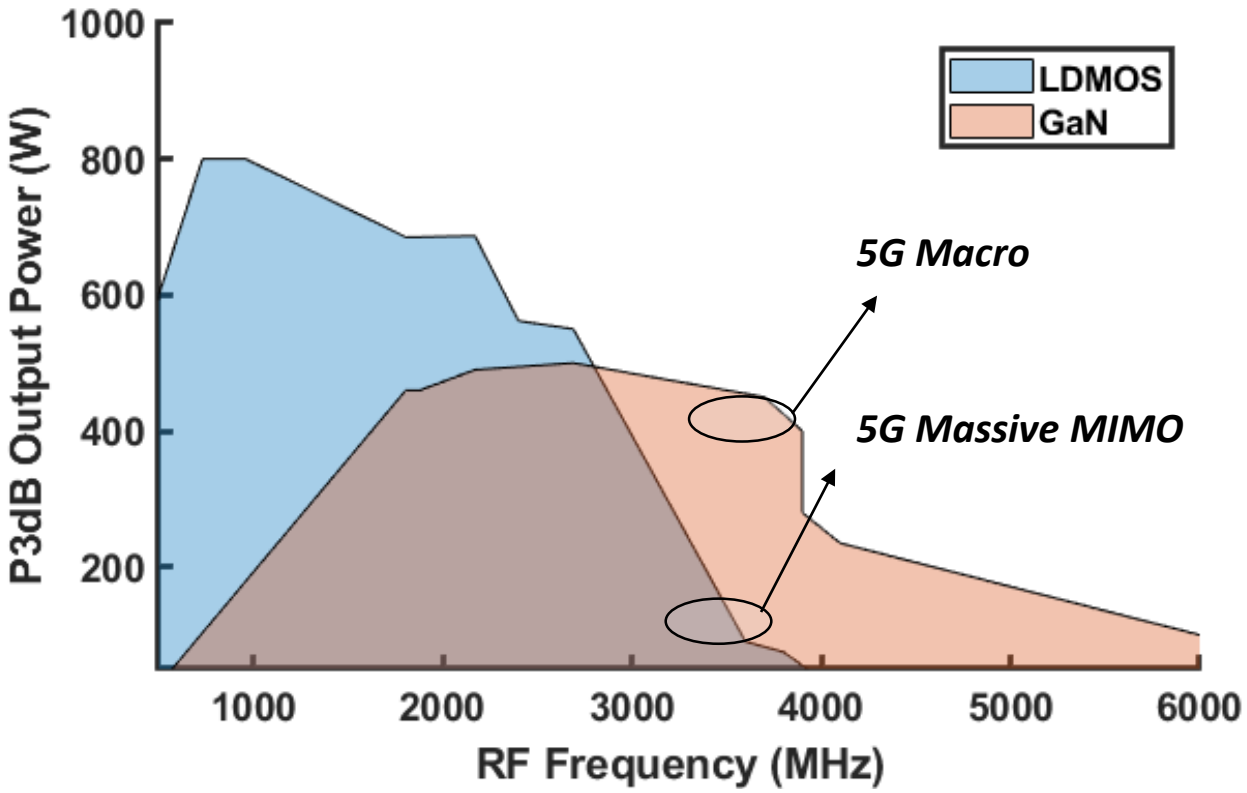
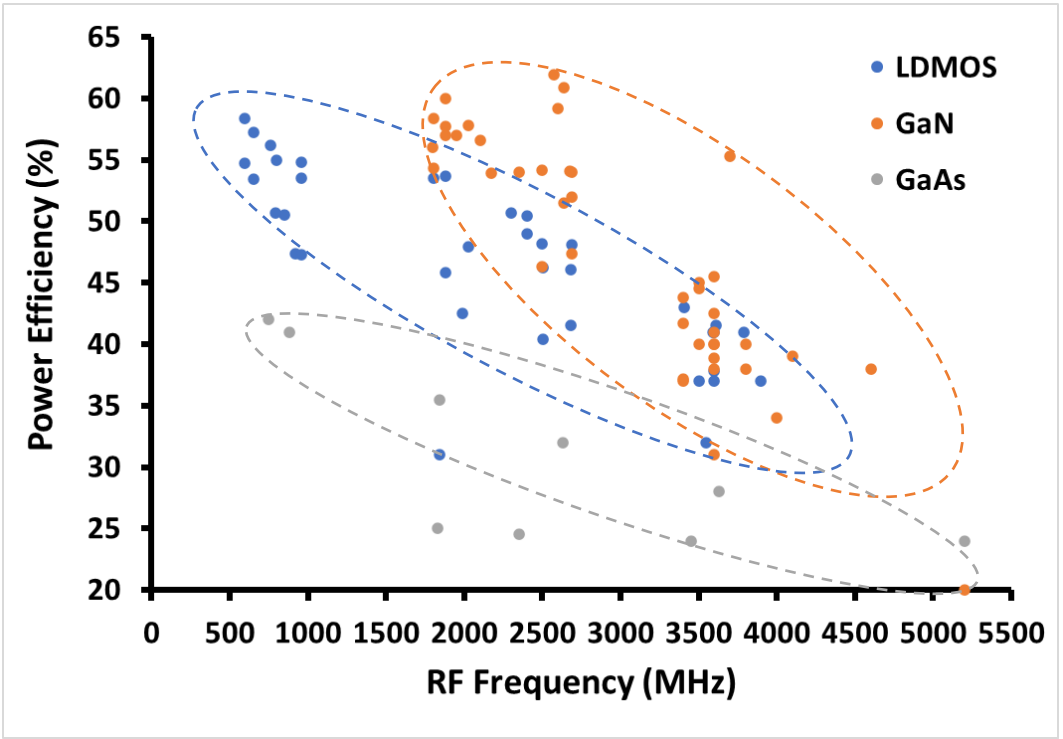
5G and Beyond Transmitters for Wireless Infrastructure

FR1 PA Technology

GaN taking over LDMOS in telecom infrastructure with a larger market share

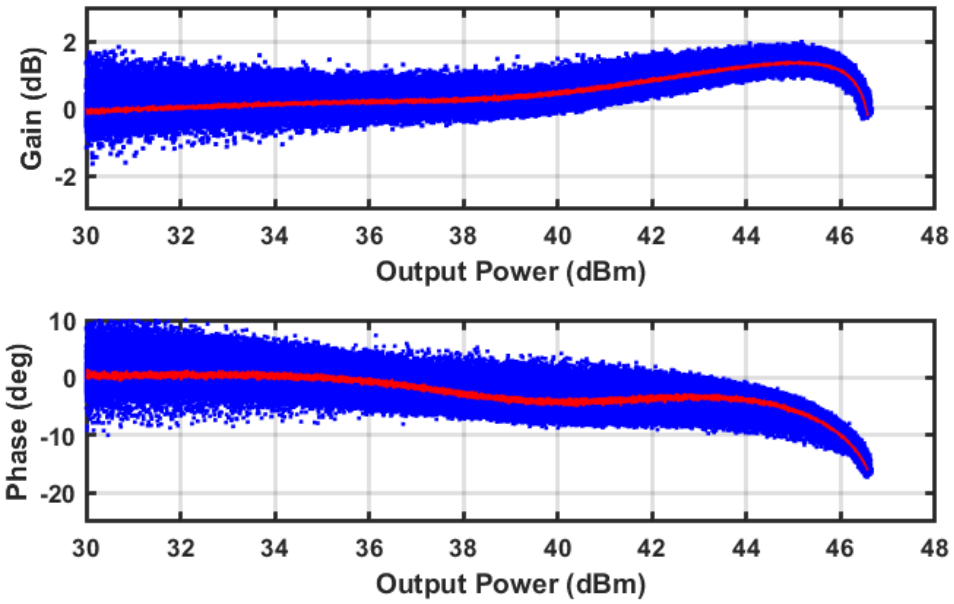




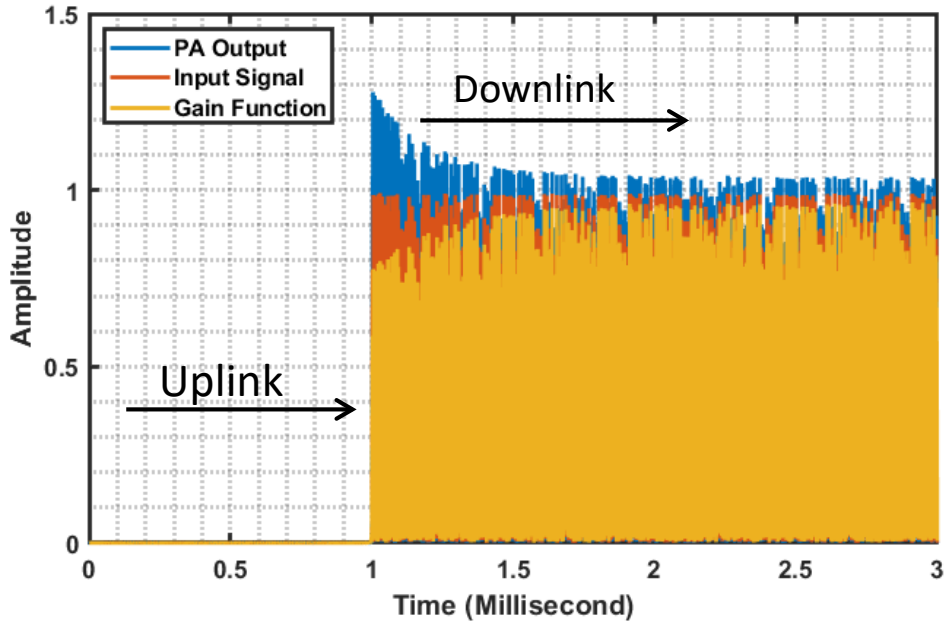
Modeling GaN PA for Higher Accuracy

- Compensation and Correction Capabilities
  - › Non-linear transformation
  - › Memory effects
  - › Non-linear dynamics

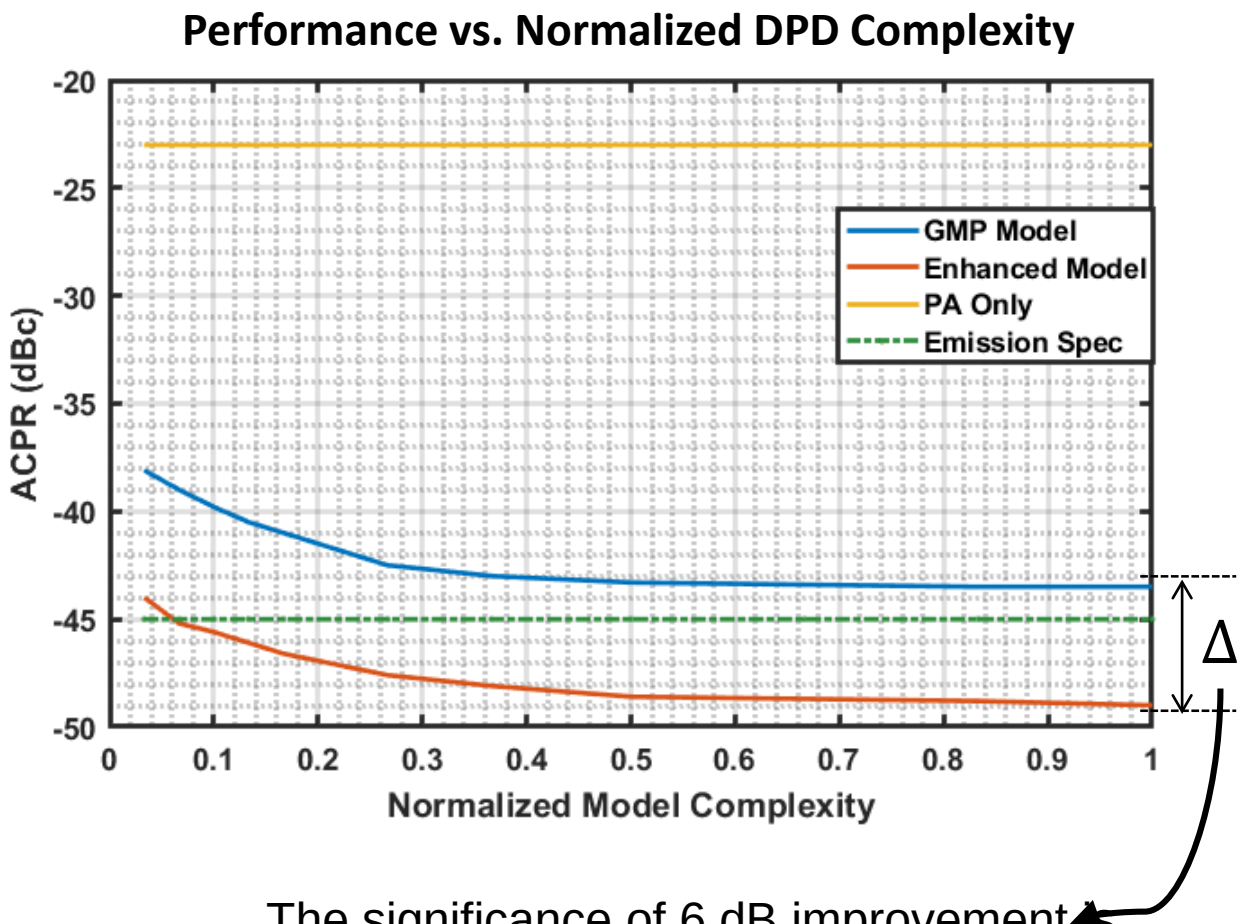
Gain and Phase vs. Output Power



Amplitude of input to PA, PA output and Gain function over Time



Overcoming DPD Performance Challenges



- GaN power devices are power-efficient but more non-linear
- Response time of drain lags gate during switching, creating undesired memory effect
- Bursty waveforms and short transition period in live traffic between base stations and mobile devices
- Rapid estimation to calculate and apply new coefficients in milliseconds
- Traditional DPD based on GMP does not represent such behavior accurately

Overcoming DPD Development Challenges

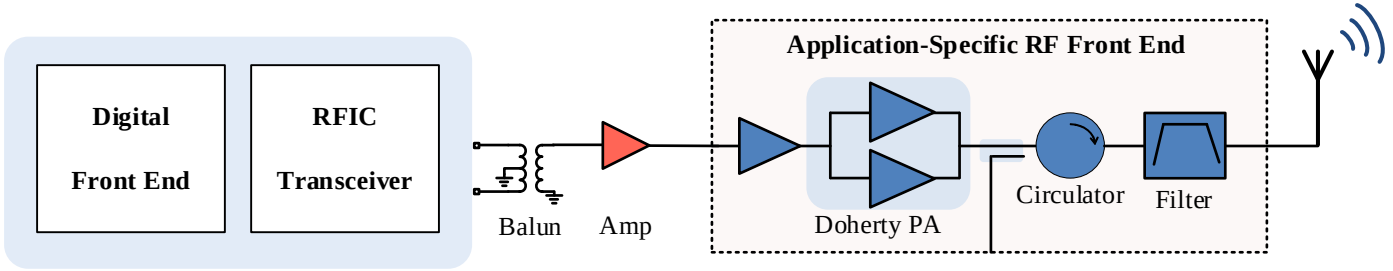
DPD Development Yesterday

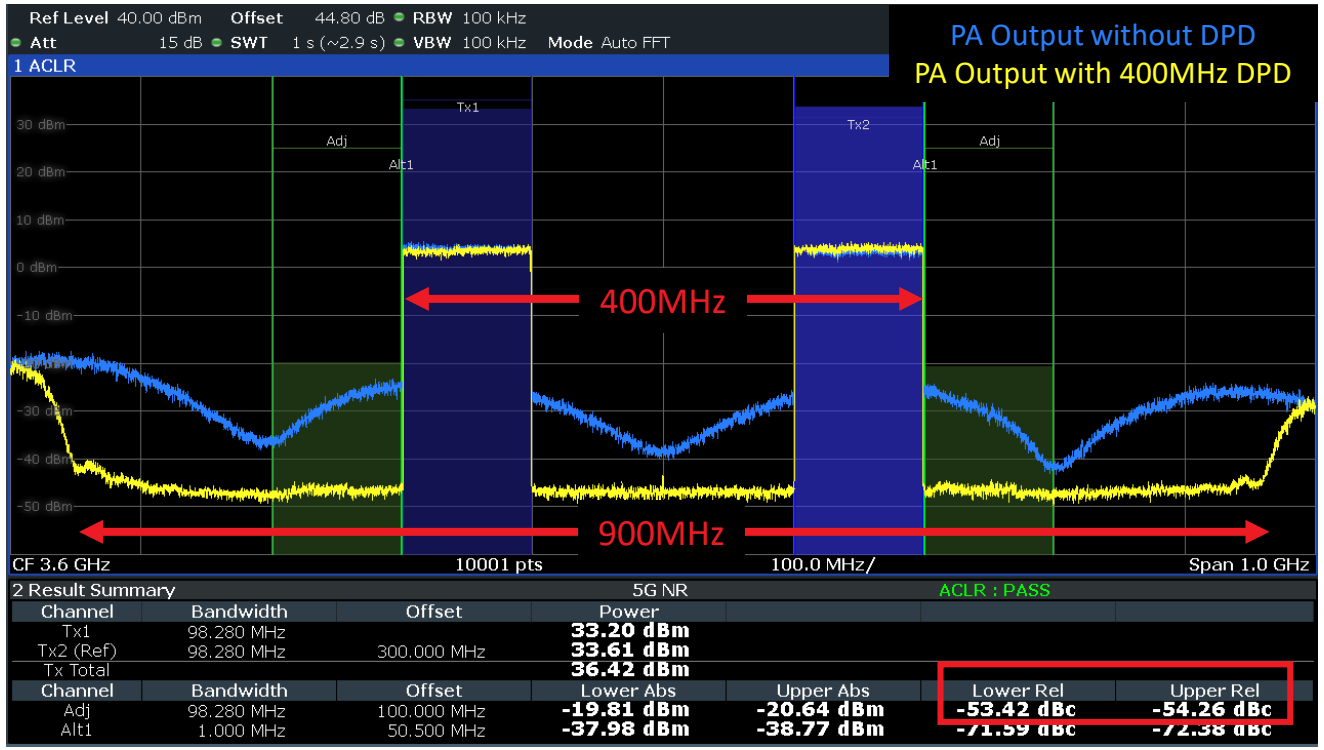
- Manual Lab Bench Design Process
  - Very Long and Iterative
  - Not Exhaustive
  - Error Prone

DPD Development Today

- Automated Process
- Powered by Machine Learning Algorithms
  - PA Characterization
  - PA Linearizer Optimization

Example 5G DPD Performance

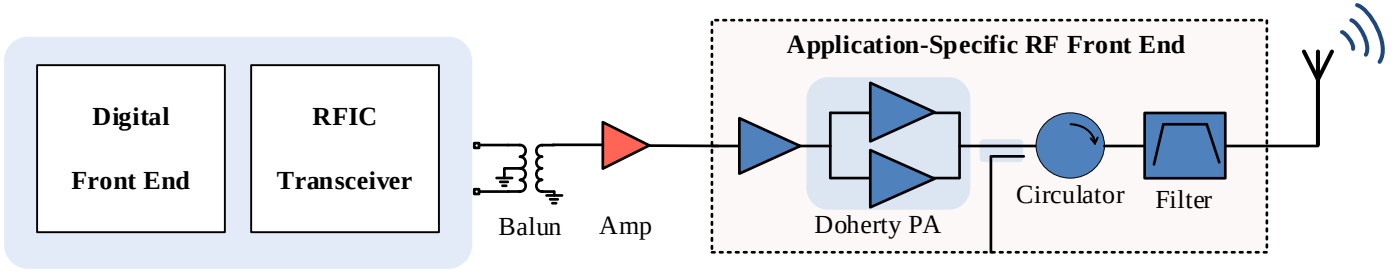




- 400MHz signal bandwidth
- 200MHz occupied bandwidth
- High TX line-up efficiency

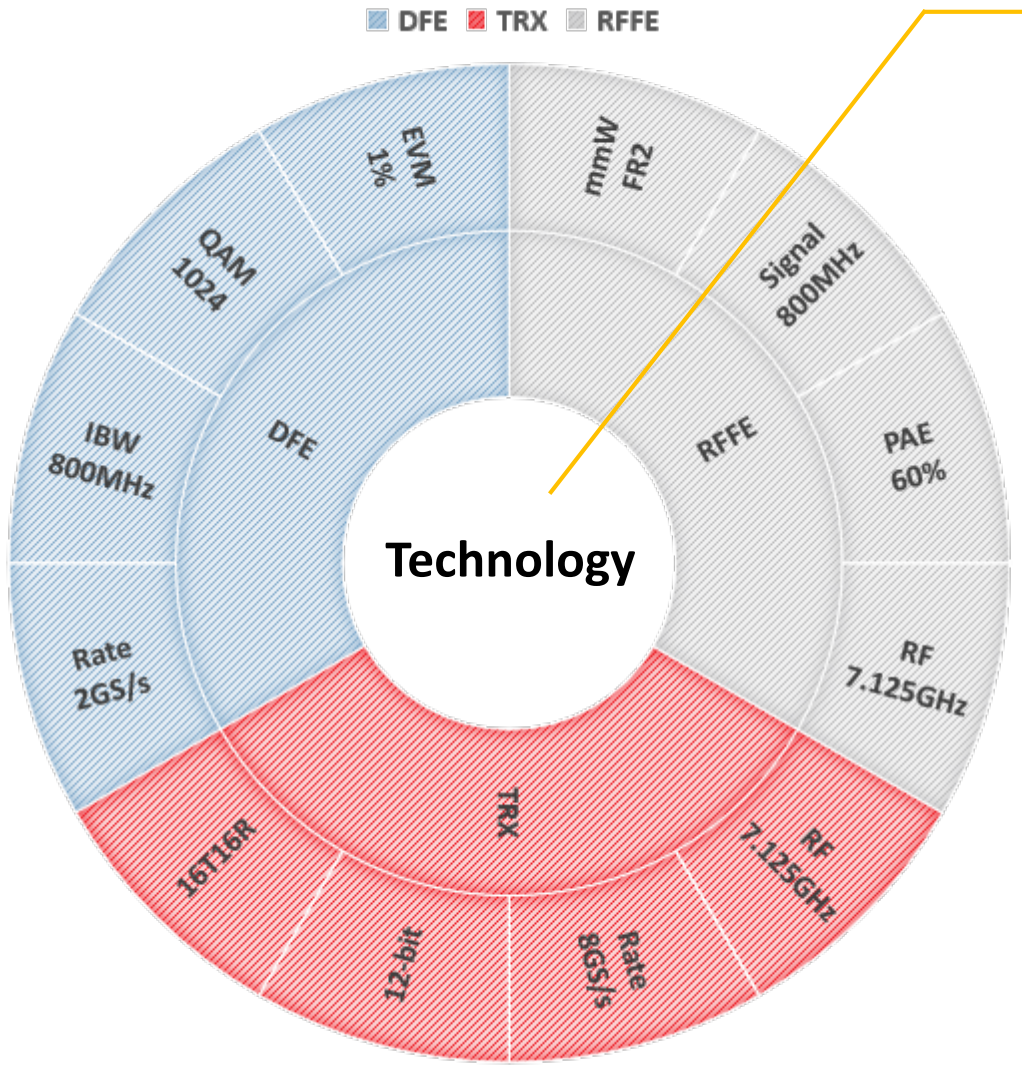
Maximize radio power efficiency and Simplify radio design

End-to-End System Performance Summary



- A path toward higher level of integration with a more capable Digital Front End (DFE) solution
- Maintain linearity over multiple carriers in 400MHz bandwidth during short transition period
- Radio power efficiency must improve despite wider bandwidth
- Cost
  - › 5G radio cost cannot be 16 times of 4G (e.g., 64x64 MIMO for 5G vs. 4T4R for 4G)
  - › Reduce PCB footprint without compromising performance
- Flexibility
  - › Must be able to support over 50 unique 3GPP bands

DPD Future Trends



- Algorithmic advance in massive MIMO technologies
  - › Sub-optimal power efficiency across the antenna arrays due to non-uniform power distribution in multi-user beamforming scenarios
- Hybrid of analog and digital predistortion systems for ultra wideband radios
- Co-evolution of DFE, Transceiver and RFFE
- Innovation of technologies to address size, power, performance and economics

Fin.