

# IEEE 5G Summit

## Panel Session: 5G Test and Measurement

**Malcolm Robertson, Keysight**

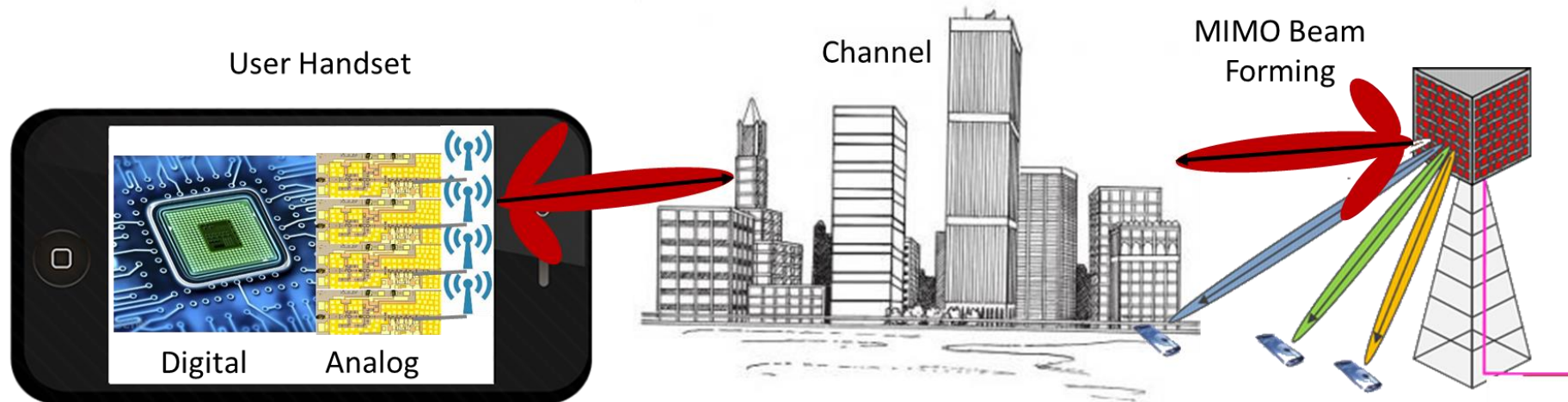
**Jon Martens, Anritsu**

**Chris Scholz, Rohde & Schwarz**

**Jason White, National Instruments**

***Moderator: Kate A. Remley, NIST***

# So Many Systems, So Much to Measure



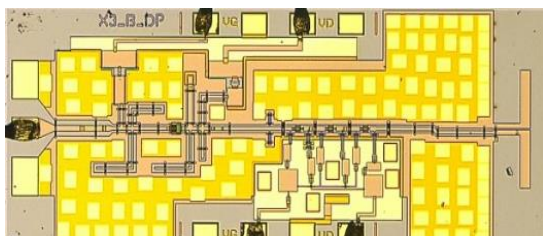
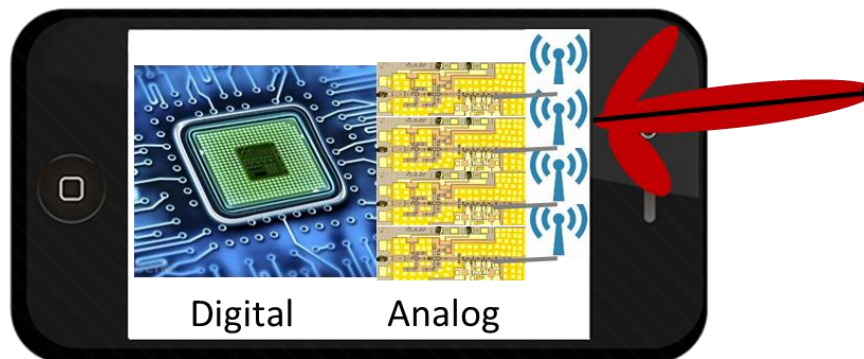
**mmWave  
Transistor and  
NL-Device  
Measurements**

**mmWave Signal  
Characterization**

**Channel  
Measurement  
and Modeling**

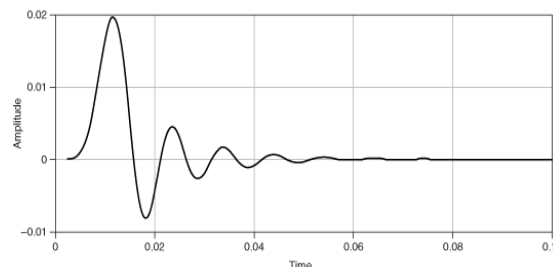
**Massive MIMO and  
Over-the-Air Test**

# Some Measurement Challenges



## Millimeter-wave Transistor and NL-Device Measurements

- mmWave Transistor Measurements and Models
- Acoustic-Wave Filters
- New Materials



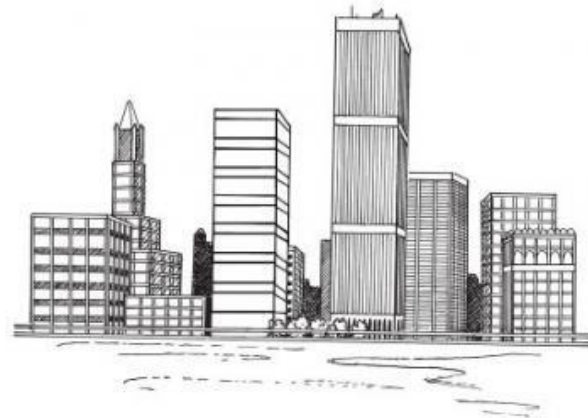
## Millimeter-Wave Signal Characterization

- Waveform Traceability
- Source and Transmitter Characterization
- Impedance, Power, Noise
- Uncertainty and Demodulation Errors

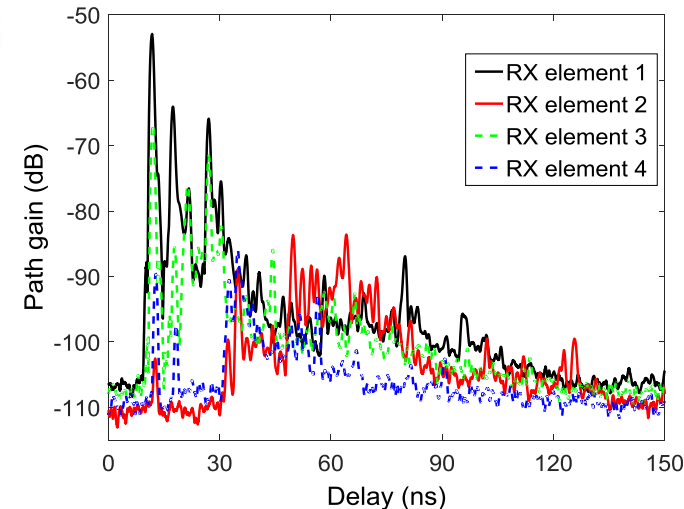
# Channel Measurement Challenges



Indoor 83 GHz channel measurements



Channel

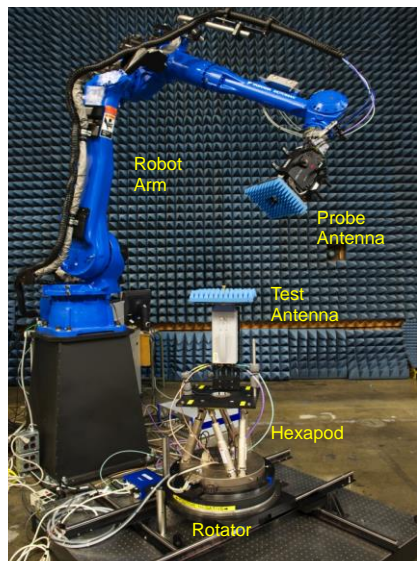


PDPs for a single location, different orientations

## Channel Measurement and Modeling

- Channel Sounding: Indoor and Outdoor
- Channel Modeling and Standards
- Effect of Uncertainty on Metrics, Models
- Angle of Departure, Angle of Arrival
- Many bands: 28, 38, 60, 72, 83 GHz, ...

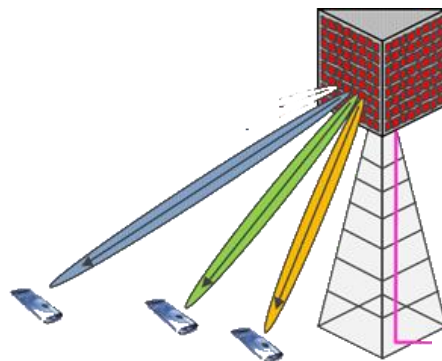
# Antenna Measurement Challenges



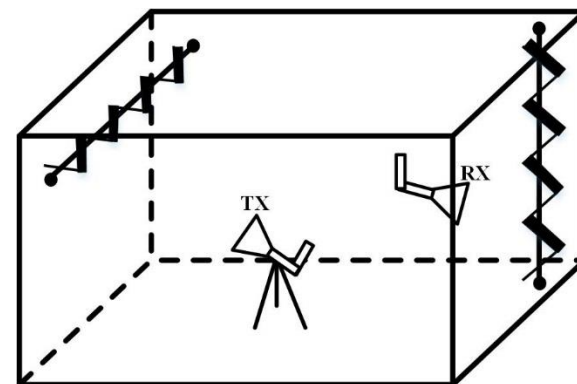
Antenna measurement over multiple angles

## Beam Forming

- Smart Path Beam Forming Based on Antenna and Channel Models
- Testing Beam-Forming Algorithms



MIMO Beam Forming and Over-the-Air Test

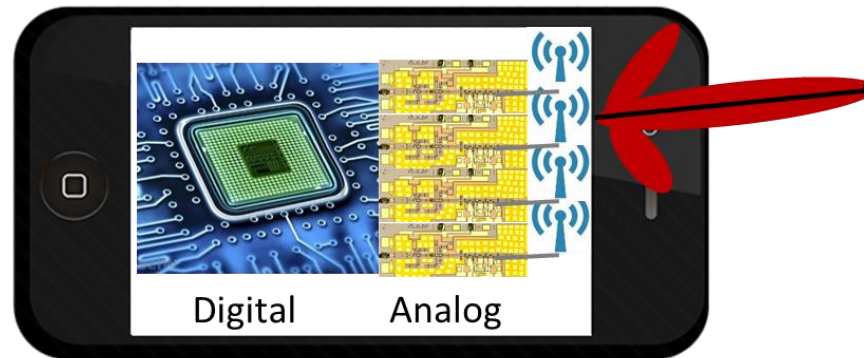


OTA test at mmWave in reverberation chamber

## OTA Test and Massive MIMO

- Wideband Antenna Calibrations
- MIMO Antenna Test
- Free-Field Modulated Signal Test
- Reverberation-Chamber Methods

# The Measurement Elephant in the Room



**On-Wafer to OTA – No connectors to test:**

- Efficiency
- Distortion
- Troubleshooting stages

**What is the answer??**

# Some Questions for Discussion

- **Devices and Materials:**
  - What are prospects for large-signal network analysis at mmWave frequencies?
  - What are issues tuning mmWave harmonics?
  - What is the role of materials measurements in future wireless?
- **Signal characterization:**
  - How to handle issues with cascading non-ideal, distortion-inducing instruments (similar to Additive EVM)?
  - How do you see the role of traceability in waveform measurements?
- **Channel measurements:**
  - Why is it more important to decouple the antenna from the channel measurement?
  - Will errors in channel sounders be more important at mmWave frequencies?
- **Antennas and Massive MIMO:**
  - How does one generate a known test field for multiple-element antenna arrays?
  - What is the role of statistics in testing arrays that operate in more states than you can count?
  - What are issues with distributed array timing and synchronization?
- **The Elephant in the Room:**
  - How to merge on-wafer and OTA test to verify performance?

# Test and Measurement in 5G – A Global Inflection

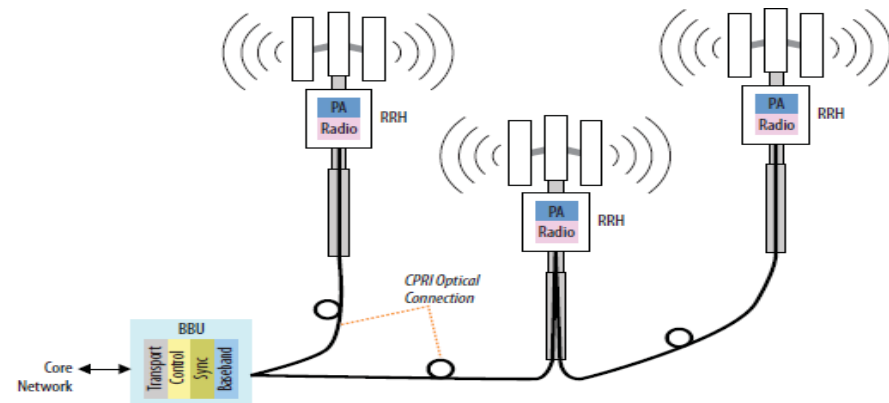
Malcolm Robertson





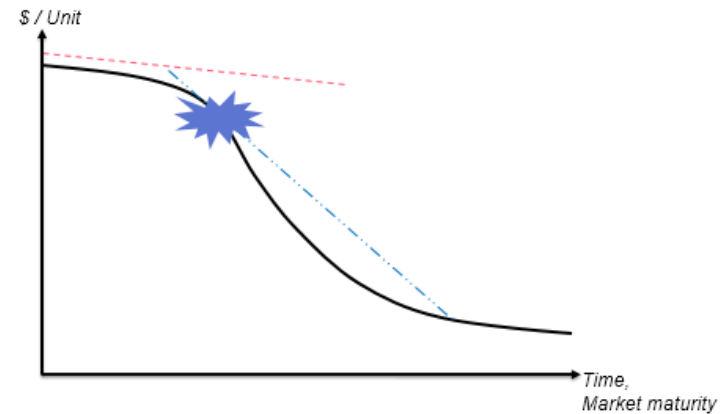
# 5G Technology Trends

- Exploding Data Growth
- Complex 5G Technologies
- Evolution of the RAN
- Accelerated Timelines



# 5G Economic Trends

- Falling Wireless Industry CAPEX
- Cost of Test Driven Down
- Intense Competition
- Cloud Economics



# Test and measurement over the entire ecosystem

- 5G changes impact everything from device level to conformance testing to installation and maintenance (I&M).
- Bringing in mmWave capabilities at usable costs.

OTA and I&M? Interference hunt ideas



Mobile Technology R&D



Device/Module Production



Access Network I&M



Core Network



Component / Antenna



Conformance / Acceptance



Data Center / Computing

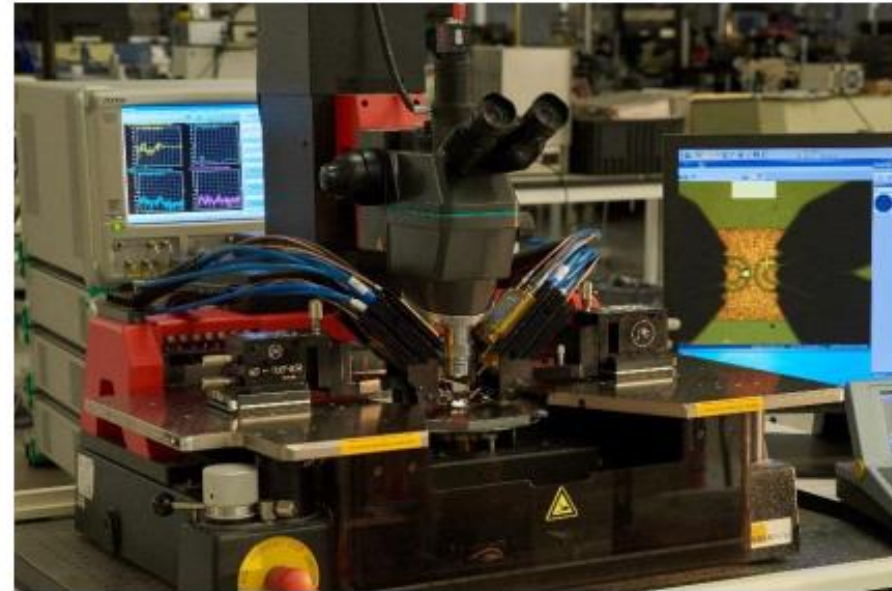


Service Assurance/ Big Data Analytics

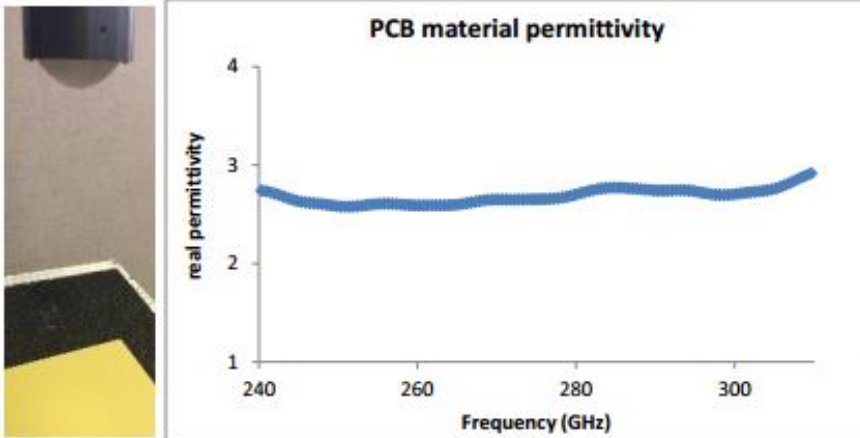


## Device modeling and design development

- Higher frequency tools exist for (quasi-) linear characterization to include AM-PM, intermodulation distortion, etc...
- How critical is harmonic characterization from a design (not modeling) perspective at higher frequencies?
- Will the PA continue to be a performance-defining element?



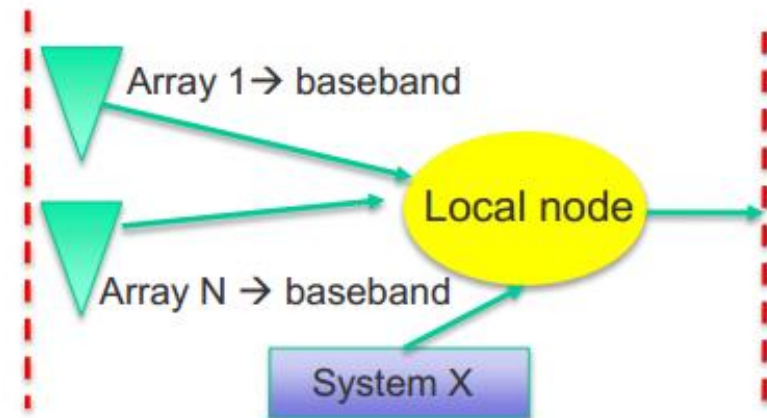
*4-port 70 kHz-145 GHz Vector Network Analysis for device/model development*



Materials measurement methods exist to the THz range. Adequate?

# Radio measurements and the integration question

- Some waveforms place more demands on measurement equipment (less of a concern) but can reduce achievable EVM (uncertainties?).
- OTA blocking: the best way to test efficiently? Channel-specific steering and traffic generation?
- Not just the analog-digital split, but where is the network split? How much data reduction happens before an access point?



# IMS2017 5G Summit

# 5G Test and Measurement Challenges

Chris Scholz

Product Manager, Vector Network Analyzers

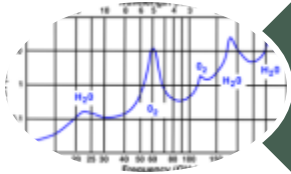
Rohde & Schwarz North America

[Chris.scholz@rsa.rohde-schwarz.com](mailto:Chris.scholz@rsa.rohde-schwarz.com)

(817) 422-2512

## Rohde & Schwarz North America

# Impact of 5G on Test & Measurement



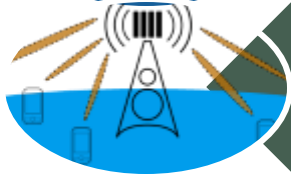
## mm-Wave Frequencies

- cm-Wave and mm-Wave frequency bands, wider bandwidths
- New channel models reflecting different propagation conditions



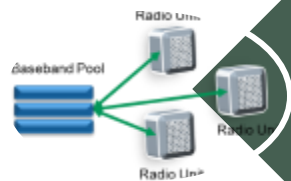
## New air interface technology/New protocols

- Multiple air interface candidates analyzed in research
- Obvious impact to the complete test portfolio



## Massive MIMO/mm-wave MIMO

- Significantly increased number of Tx/Rx elements
- Over the air measurements become essential



## Cloud based network architecture

- Centralized base station baseband with high number of distributed radio units ideally connected with no latency (fiber); SDN and NFV
- Traffic analytics and security will gain importance

# 5G Impact on Components Testing

## 4G Components/Devices

- Conventional Solution
  - Multiple discrete components
  - Designed/verified as component
  - Easy to Test
- Majority of Cost in Precision Metal
  - Antenna
  - Diplexer
  - Waveguide Elements
  - Transitions/Interconnections

Antenna

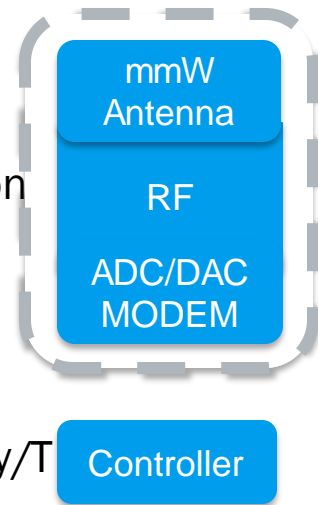
RF

ADC/DAC  
MODEM

Controller

## 5G Components/Devices

- Single Chip CMOS
  - RF/ADC/DAC/Modem
- Large part of cost is in Test
  - mmW test in production
  - Wafer-level functional test
- Cost
  - Test equipment
  - Accuracy/Repeatability/Traceability
  - Ease of use
  - Time of test





# 5G Measurement Issues in Brief

2017 International Microwave Symposium, June 2017

Jason White

Director, RF and Wireless Test  
National Instruments

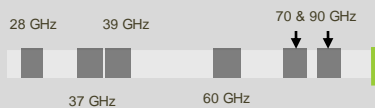


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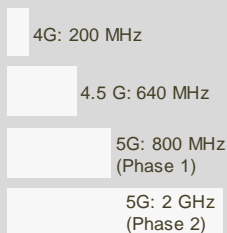


# Key Test Challenges for 5G

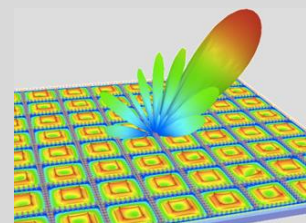
## Multi-Standard Coverage



## Ultra-wide Bandwidths, Multiple Carriers / Beams



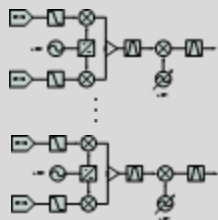
## Antenna Arrays



## Total Cost of Test

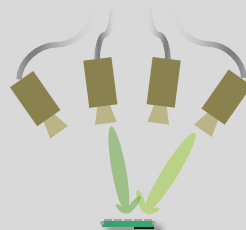


## Channel Scaling for MIMO / CA

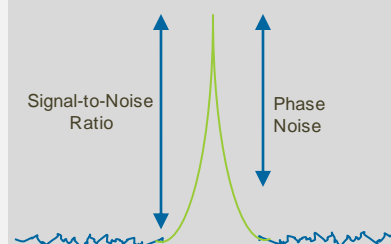


2 – 128 MIMO channels

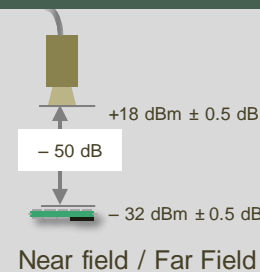
## Port Mobility



## OTA Calibration and Control



## Calibrated Air Interfaces and Chambers



[ni.com/5g](http://ni.com/5g)

# NI's Architectural Approach to 5G Test Challenges

## Modularity

- Add performance as future requirements emerge
- Integrate non-RF I/O into same system to maintain small footprint

## Frequency and Channel Agility

- Flexible mmWave configurations for multi-DUT, multi-frequency and beamforming test
- Tight timing and synchronization for MIMO configurations

## Software-defined Signal Processing

- Accelerated measurements using real-time FPGA processors programmed with LabVIEW FPGA
- Achieve demanding EVM requirements through more sophisticated calibration techniques

### Key Open Issues for Test:

- Test cost of millimeter wave and MIMO
- Over the air access / control

ni.com/5g



