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2023 AUSTIN

Navigating Wireless Infrastructure Test

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Senior Applications Engineer

Enabling faster, higher-quality test of base station components

Agenda

Market Segment Overview

Challenges In Infrastructure Test

- O-RU Test
- Multi-RAT
- High Power PA
- OTA Test

Wireless Infrastructure Offerings

- NI Platform: HW & SW
- Speed Improvements
  - RF Test Time
  - Chamber Time
- Data Insights

Conclusion & Questions

Market Overview

Market Overview

What is changing about this area and why is this a focus for NI?

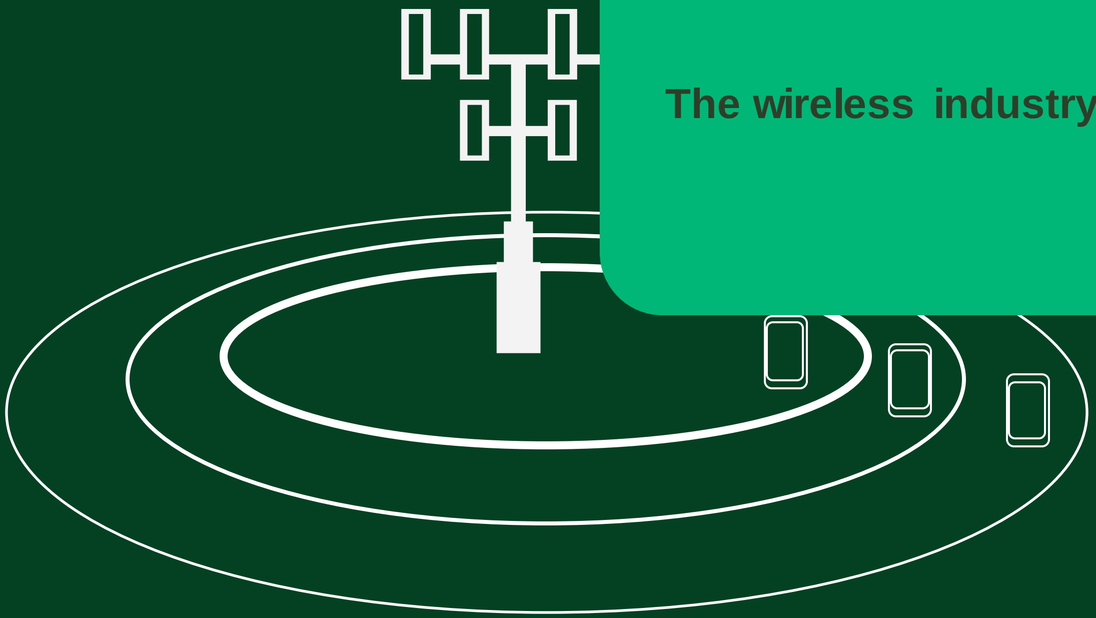
Wireless infrastructure is set to grow substantially in 2023

- **Expansion of 5G** – initial expectations vs reality, widespread adoption likely to continue over the next 5-10 years
- **Growing interest in FR3** – large DUTs that require OTA measurements
- **Open RAN proliferation** – a potential disruption to the status quo?
- **Multi-RAT** – a new way to add unique and differentiated value
- **Monolithic PCBs** – a new design for better efficiency

Anticipated Challenges in 5G Infrastructure – 2019

4G

Long distance broadcast at < 6 GHz with high-power devices and antennas



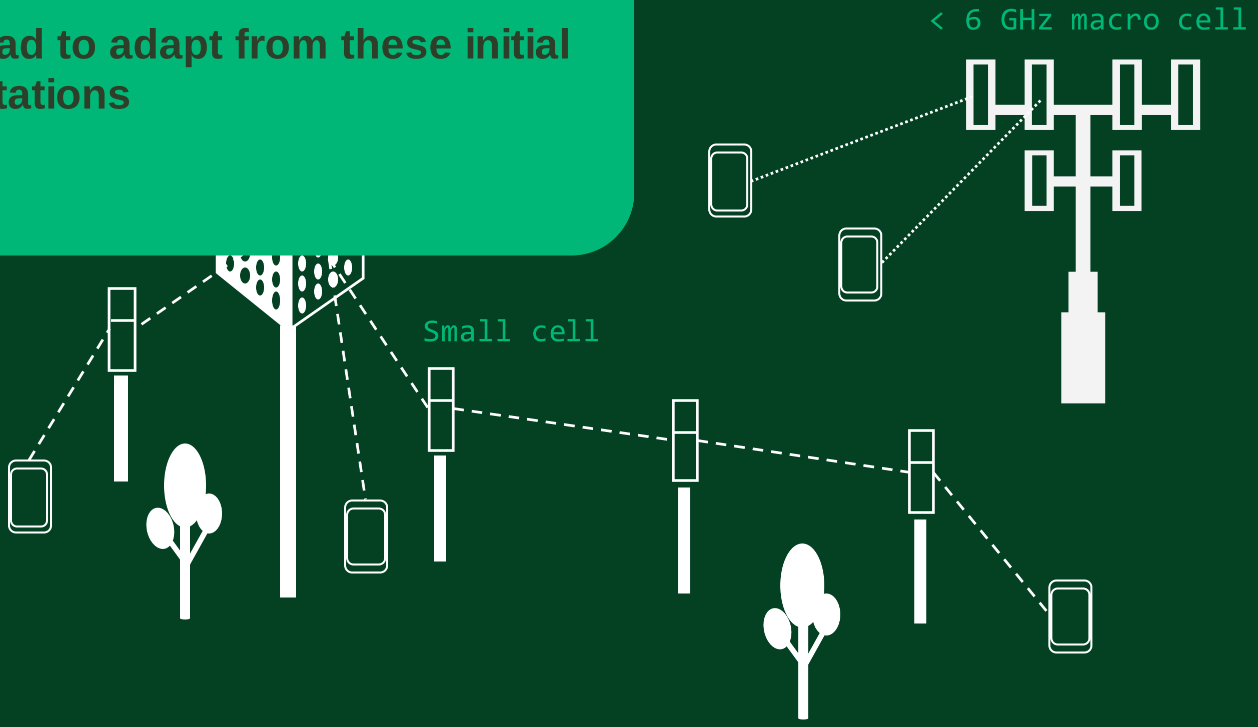
5G

Network densification

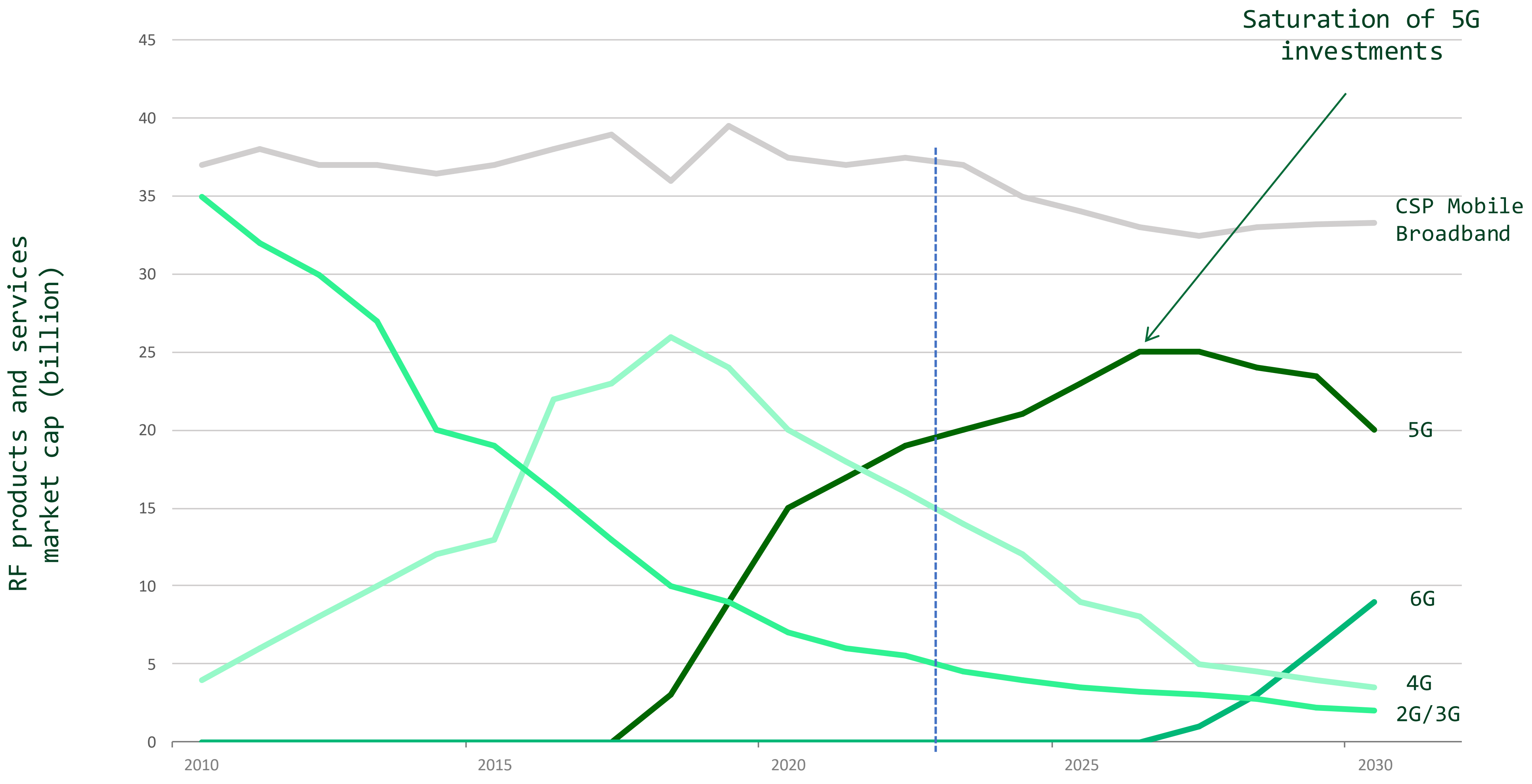
- Exponential increase in RF front-end device count
- Power level variety – both higher and lower

nds

The wireless industry has had to adapt from these initial expectations



Expansion of 5G



Growing interest in FR3

Spectrum for next-gen wireless

- mmWave adoption has not been as fast as initially anticipated
- Challenges with mmWave applications, development of small cell infrastructure, and cost of implementation has led to slow growth for mmWave
- FR3 is now being explored as the 'best of both worlds' – higher throughput than sub-6 GHz with less complexity than mmWave

Open RAN

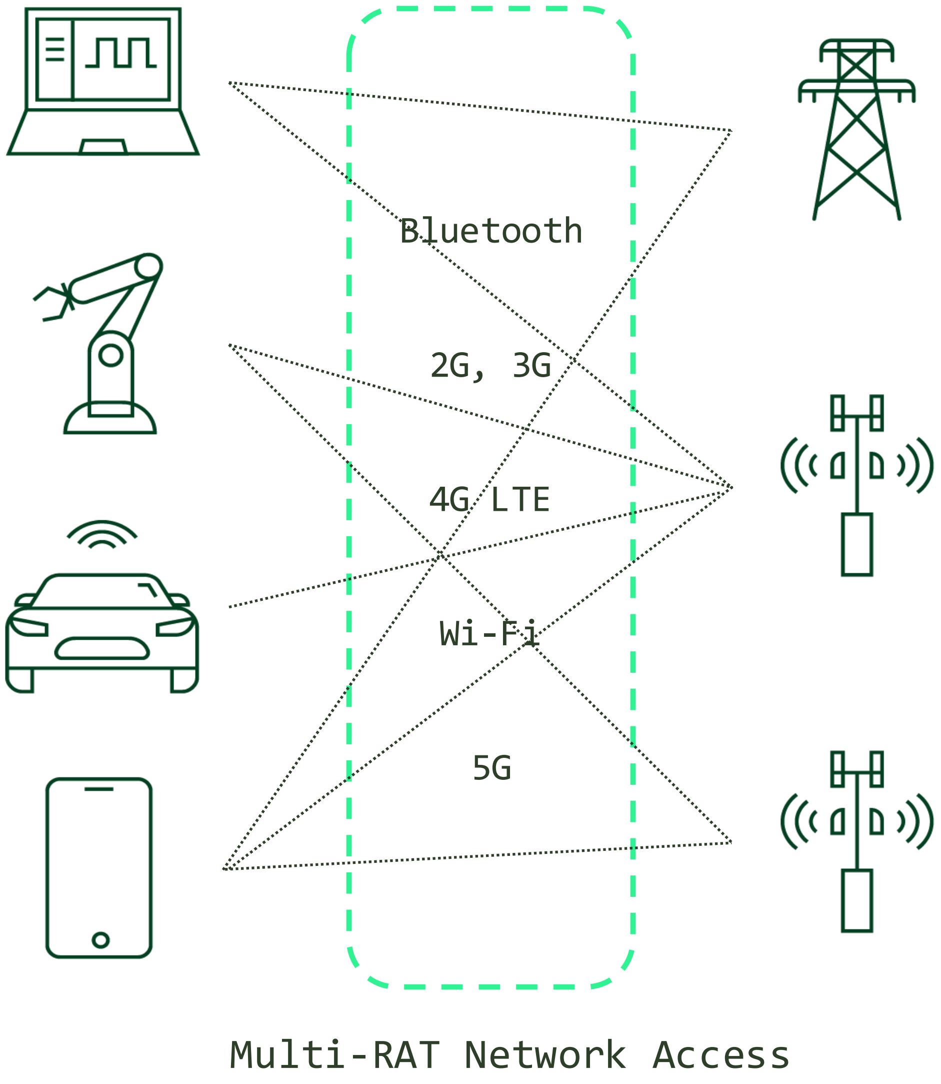
Fundamental Change in Network Infrastructure Development?

- RAN disaggregation has opened the door for new RAN vendors
- With an influx of new providers, competition in base station infrastructure market will increase drastically
- Market shift will be dynamic and regional
  - Commercial deployment of ORAN systems are expected to be first and largest in APAC
  - AMER and EMEA will likely focus on private networks first
- Network infrastructure developers need to innovate to retain profit and market share
  - Lower cost of development (improve cost in production test, innovate better/faster and make sense of data in validation)
  - Add new value with new capabilities (Multi-RAT components)

Multi-RAT

A way to add value in a competitive wireless infrastructure market

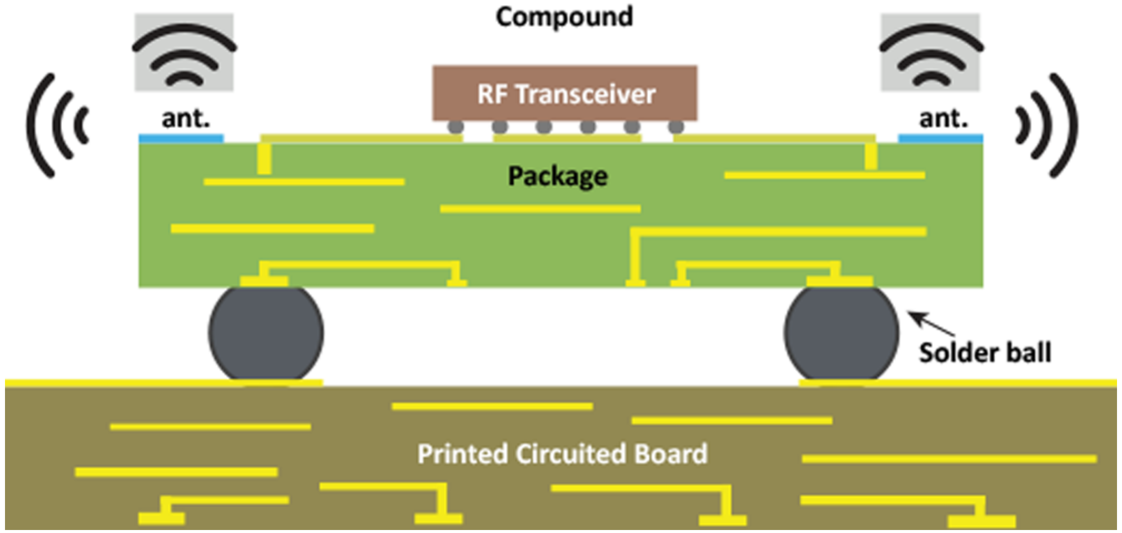
- Devices will increasingly be enabled with multiple wireless standards
- RF Front ends, Base stations, UEs need to be developed (and **tested**) for different wireless standards



Monolithic PCBs

Integrated, multi-RAT components are set to dominate wireless infrastructure

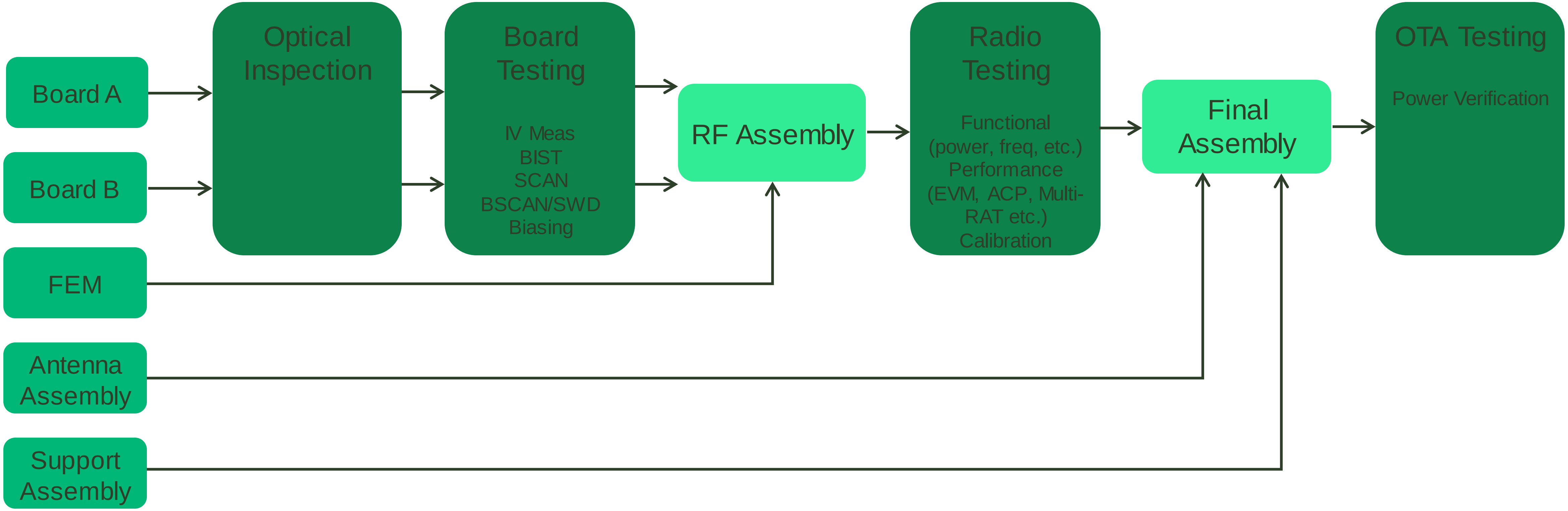
- AiP chipsets greatly reduce complexity for the system integrator and allow for all RF components to be tightly packed
- While beneficial in many ways, this will require OTA test in new use cases



Example Production Flow – Current State

These changes won't happen in isolation, and will have a cumulative effect

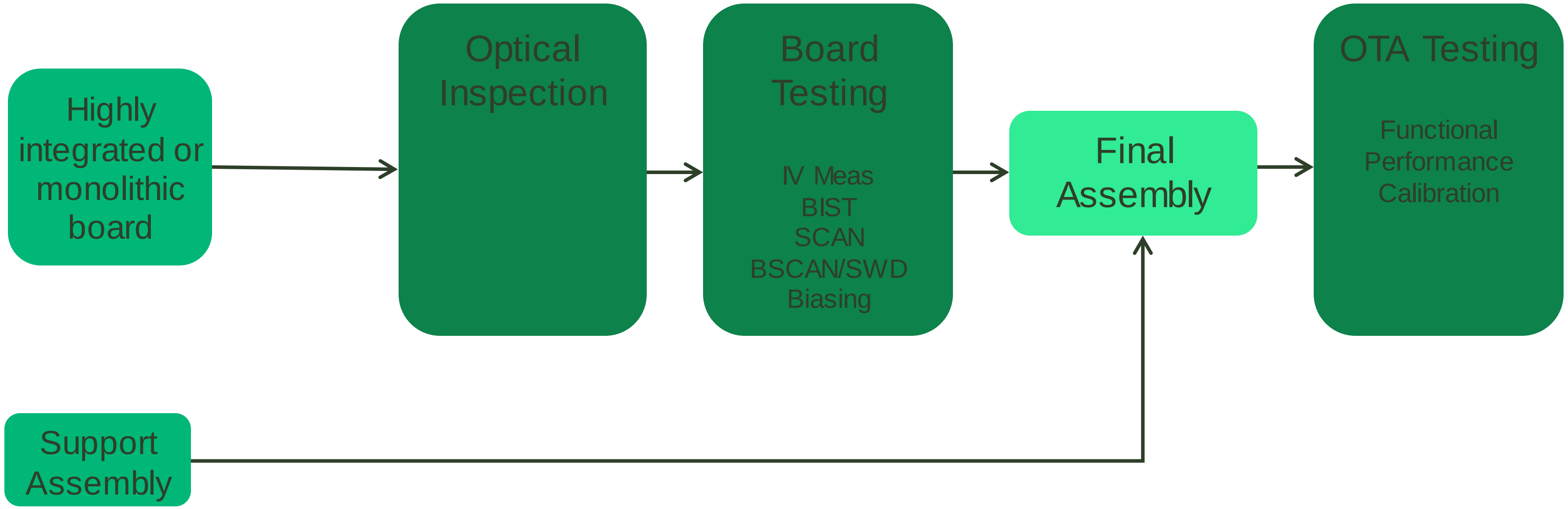
- Discrete Boards/assemblies/components requires many interconnected processes
- Multiple test points
- Conducted RF possible
- Simple OTA tests



More Efficient Test – Possible Future Test Flow

No more discrete subcomponents

- More complex DUTs with fewer test points
- All RF tests are Over-the-air
  - Higher number and more complex measurements in chamber

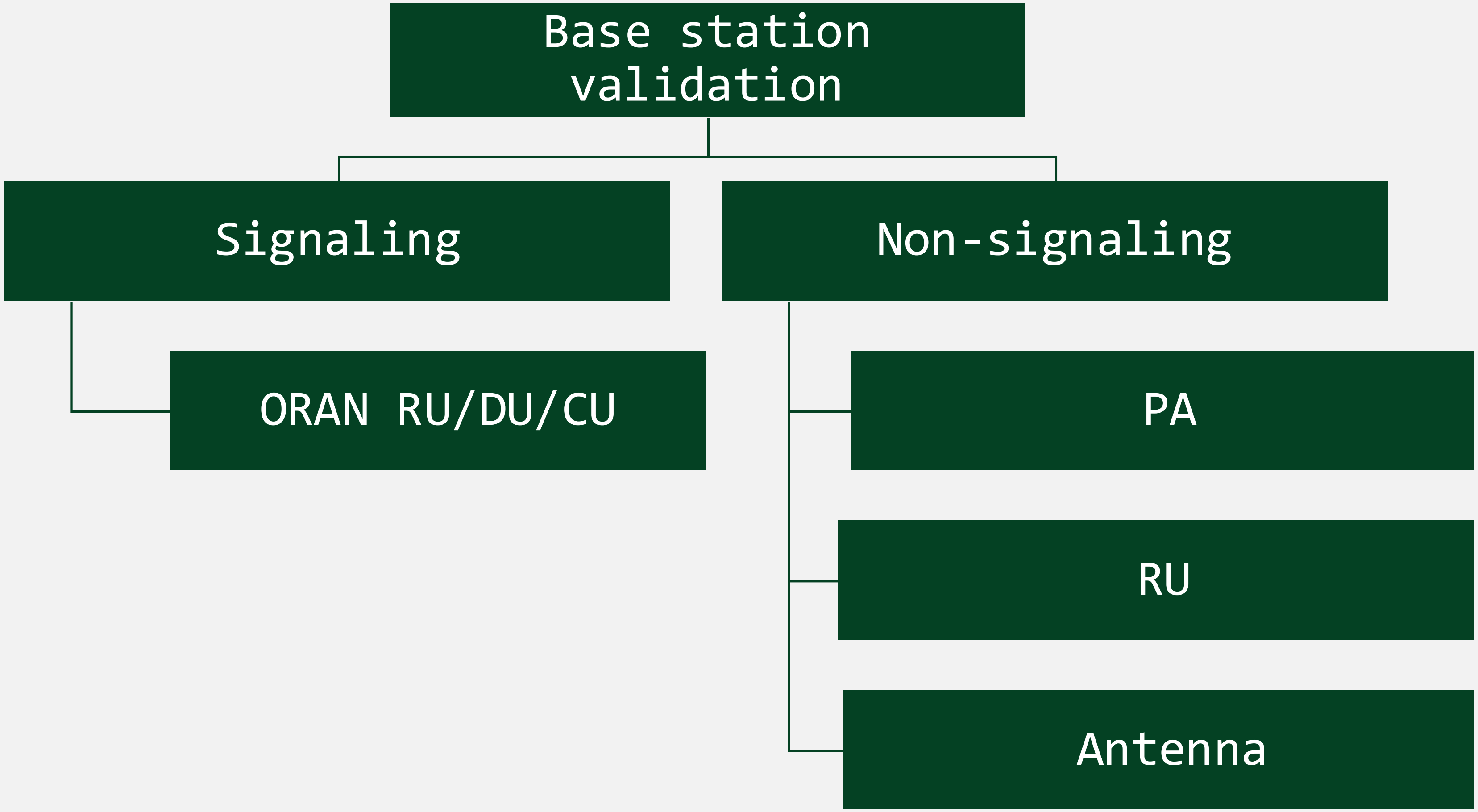


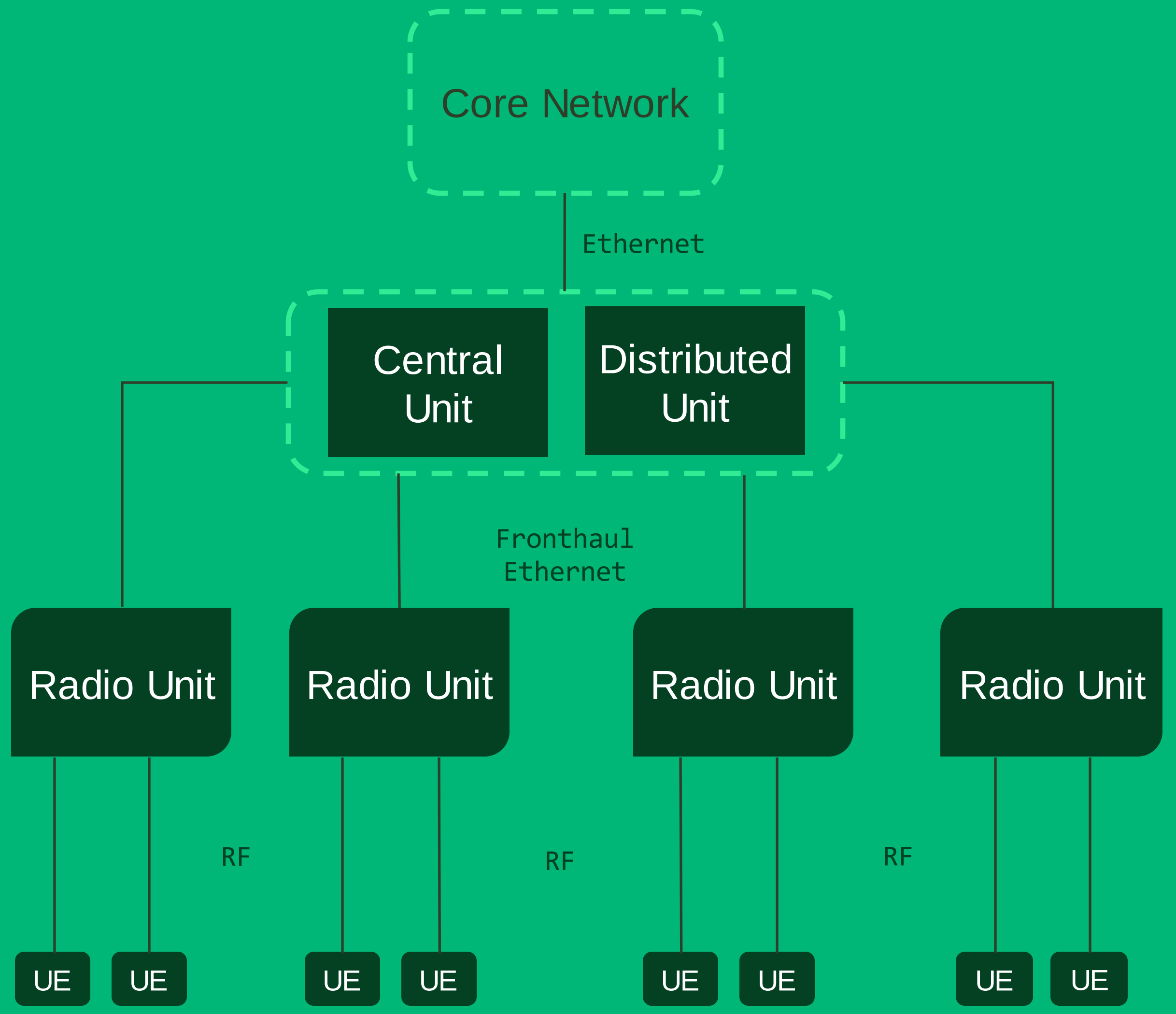
While changes in the industry could lead to more efficient test, they are also set to present many unique test challenges…

Challenges In Infrastructure Test

Challenges in Infrastructure Test

Infrastructure spans many DUTs, systems, test cases



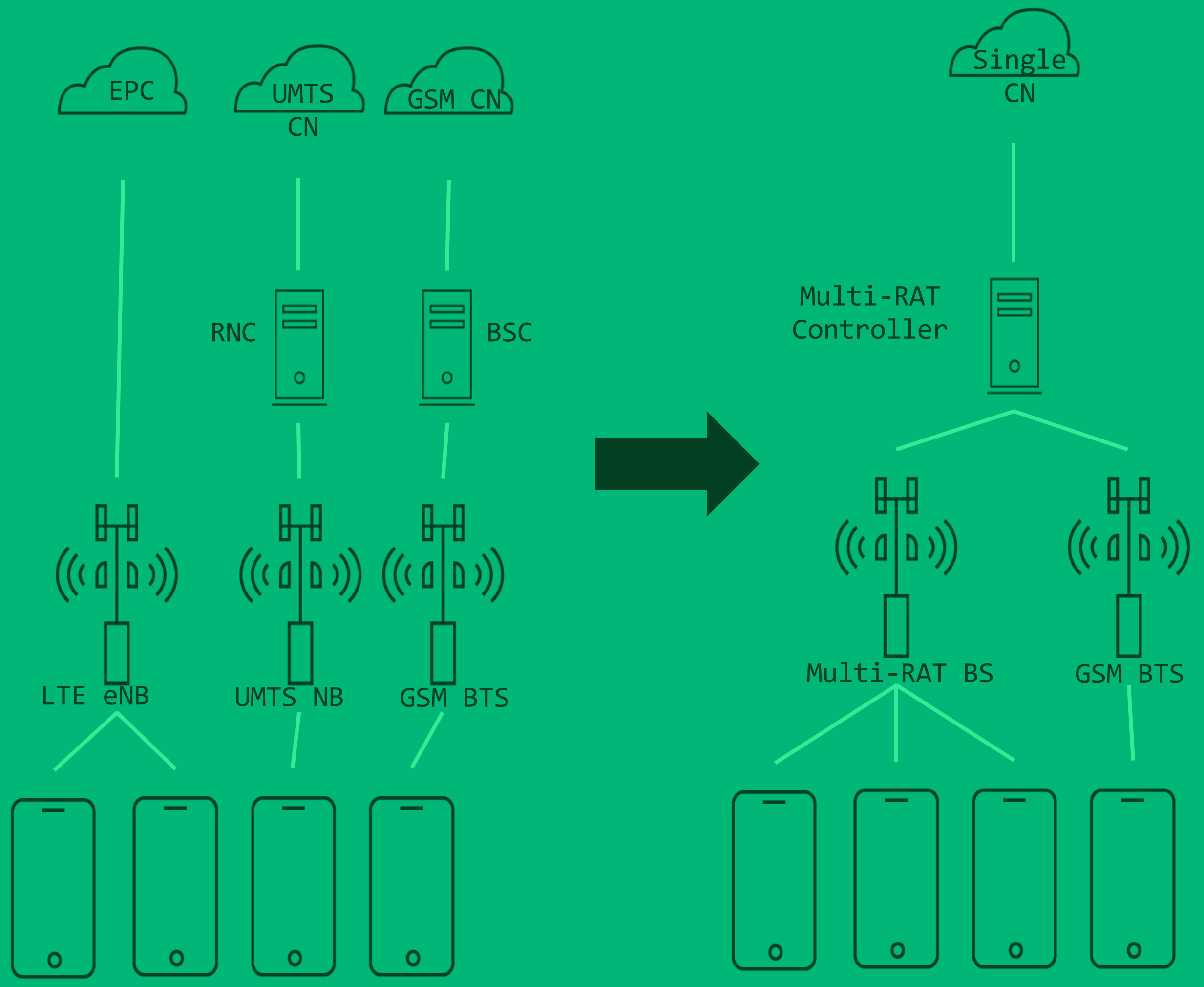


O-RAN O-RU Test Challenges

High competition = Lower prices, margins

- Lower cost requirements will drive the need for **fast** deployment and **efficient** test system usage.
- Flexible **DUT control**
  - DUT control can be done over **O-RAN FH**
  - Need flexibility for DUT control outside of FH
- Different protocols have introduced different requirements in DUT control

Challenges Testing Multi-RAT Infrastructure Transceivers

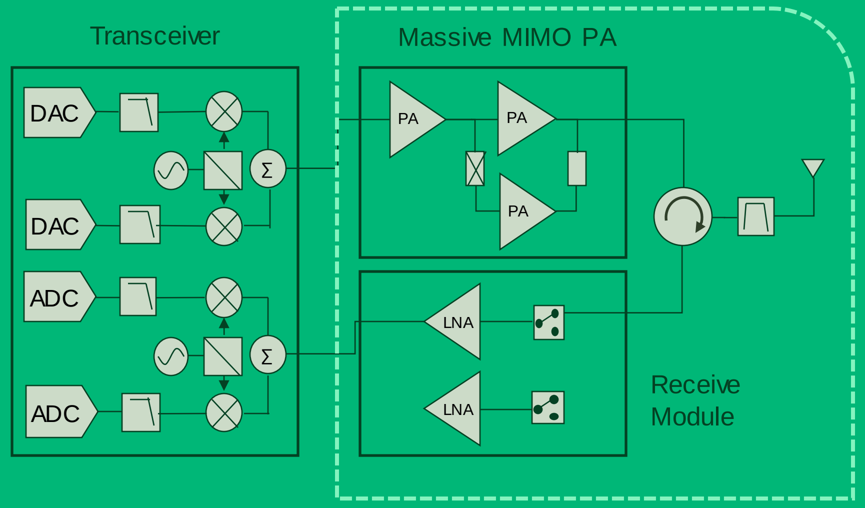


- **More band combinations** of 2G, 3G, 4G LTE, 5G, Wi-Fi, Bluetooth
  - **Wider bandwidth carriers**
  - **More complex modulation schemes** require better IQ modulation performance
- Increased **DUT complexity** means more test points per DUT
- Higher strain on tester flexibility
  - **Multi-standard software** must coexist
  - **More data** to handle
  - More stringent **phase coherency** and **triggering synchronization** for multi-channel, multi-RAT setups

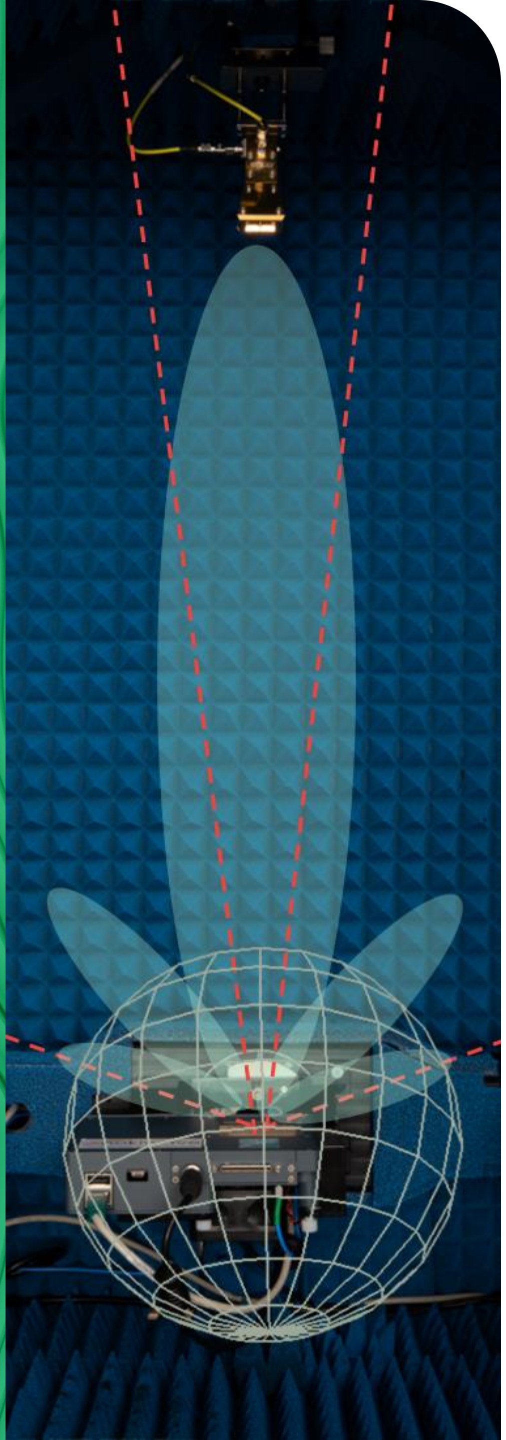
How do we make sure test time and resources don’t grow with each of these?

Challenges Testing High Power Front Ends

Sub-6 GHz Base Station Radio

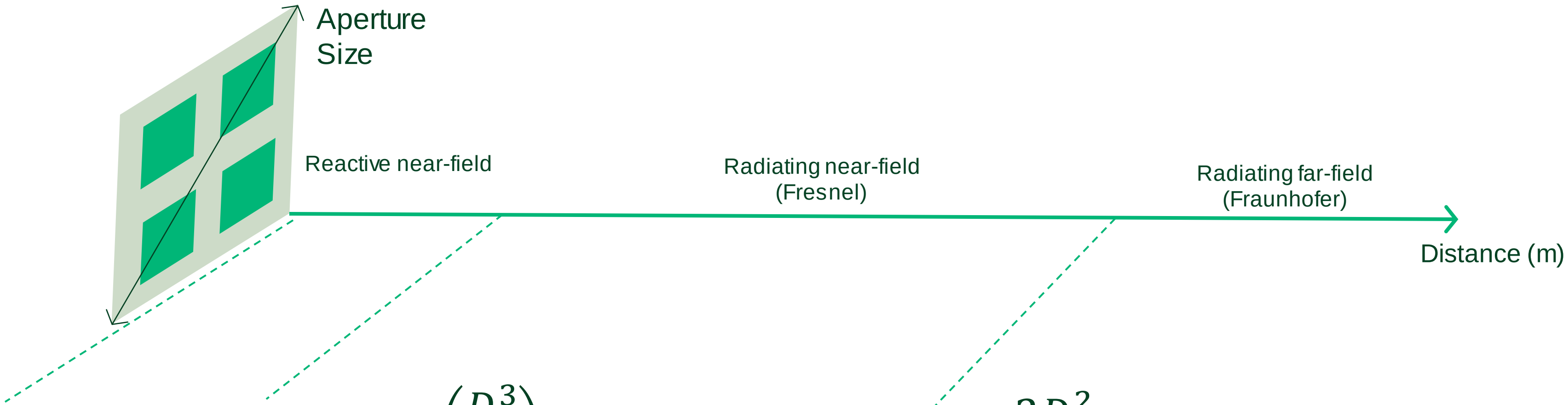


- Measure with CW, multi-tone CW, pulsed CW, pulse-modulated CW and modulated **2G - 5G signals**
- More precise **signal conditioning** and switching
- Requires intricate **calibrated** setups with proper gain/attenuation, configuring stable & linear high power DC supplies
- Multitude of different PA technologies, each with different challenges in different signal scenarios
  - **GaN** introduces immature processes with unpredictable performance
- **Higher power levels** create challenging fit for traditional ATE platforms



Challenges with OTA Test at FR3

OTA Measurement Distance Increases with Frequency and Aperture Size



$$r_{NF} = 0.62\left(\frac{D^3}{\lambda}\right)$$

$$r_{FF} = \frac{2D^2}{\lambda}$$

- Monolithic PCBs with AiP designs will require **more OTA test**
  - Board and antenna performance
- Larger/heavier, Multi-RAT DUTs present new challenges in OTA test
  - More chamber time
  - **Disruption in production line flow**

Challenges in Infrastructure Test

What test implications do these industry trends bring?

FR3 chambers
(limited floor space)

+

More Complex DUTs
(more test points)

Multi-RAT Devices
(longer test times)

+

Integrated PCBs
(more OTA test)

→

Serious bottleneck in chamber (OTA) validation and production

Need to speed up chamber testing without sacrificing test coverage or accuracy, while minimizing total cost of test

OTA Workflow Challenges

Product development → Sub system integration → Unit validation → Conformance validation → Production test

Flexibility

- Unique teams at each stage use disconnected tools, data formats, processes
- Disconnected workflows lead to long loss of time, insights

Scalability

- Different products differ in requirements at each stage of development
- When requirements change, there can be a long ramp up and high levels of NRE with each iteration, designing new OTA test cases, adapting these to a specific DUT

Data Management

- Lots of data is meaningless without the right insights and analytics

Automation

- Full characterization of complex devices can require 100’s to 1000’s of test cases
- Spatial OTA test parameters varying power, azimuth, direction, over a hemisphere is difficult to manage

OTA Workflow Challenges: Automation

More tests need to happen OTA

- Need to drive down test time to spend less time in chamber
- Add more chambers = test more DUTs*
  - Caveat: rethink factory flow to accommodate chamber footprint(s)
  - More than just an asterisk, could be a whole other presentation

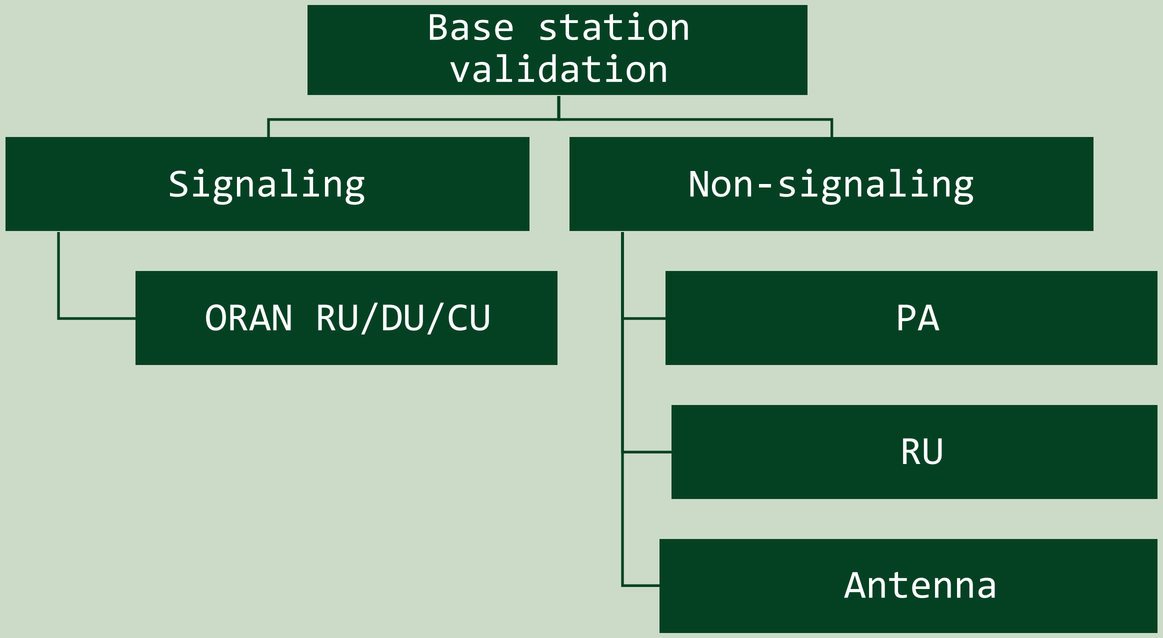
Increase number of chambers

Reduce amount of time in chamber

What is the long pole in the tent for **your** use case?

Summary: Infrastructure Test Challenges

- ORAN O-RU
- Multi-RAT flexibility
- High Power FEMs
- OTA test
  - Lots of time
  - Lots of data



Wireless Infrastructure Offerings

At **NI,** we’re **revolutionizing** how enterprises use test insights to **drive product** and **business performance.**

Reduce time to market by accelerating product development with faster OTA test

Deliver customer satisfaction by improving functionality, reliability, and delivering best-in-class RF performance

Improve the bottom line by reducing operational cost with scalable, versatile test instrumentation

Prepare for the future by adapting to evolving test needs, keeping in mind the next evolution of wireless standards

The Value of the NI Platform

Wireless Infrastructure Test

PXI Platform

NI Fit – Product Portfolio

Product development → Sub system integration → Unit validation → Conformance validation → Production test

DMM – generic voltage and current measurements)

RF Switches – Multi-DUT and Signal Conditioning)

Oscilloscopes – non-RF Signal Analysis

Sensor-based measurements

VST – RF Generation and Analysis

FlexRIO – Signal Processing and Data Streaming

PXIe-5842 | Most Versatile & Capable PXI VST in the Industry

23 GHz* VSA with up to
2 GHz Instantaneous BW
* 26.5 GHz available in H2.2023

High speed serial interface
MGT - 16 lanes @ 16Gbps
Full Rate (2GHz BW) IQ Data Streaming to
NI FPGA Co-processor
(*Available H2.2023)*

Integrated RF Signal Chain Pulse Modulation
Allows for optimization of On/Off Ratio
versus pulse width
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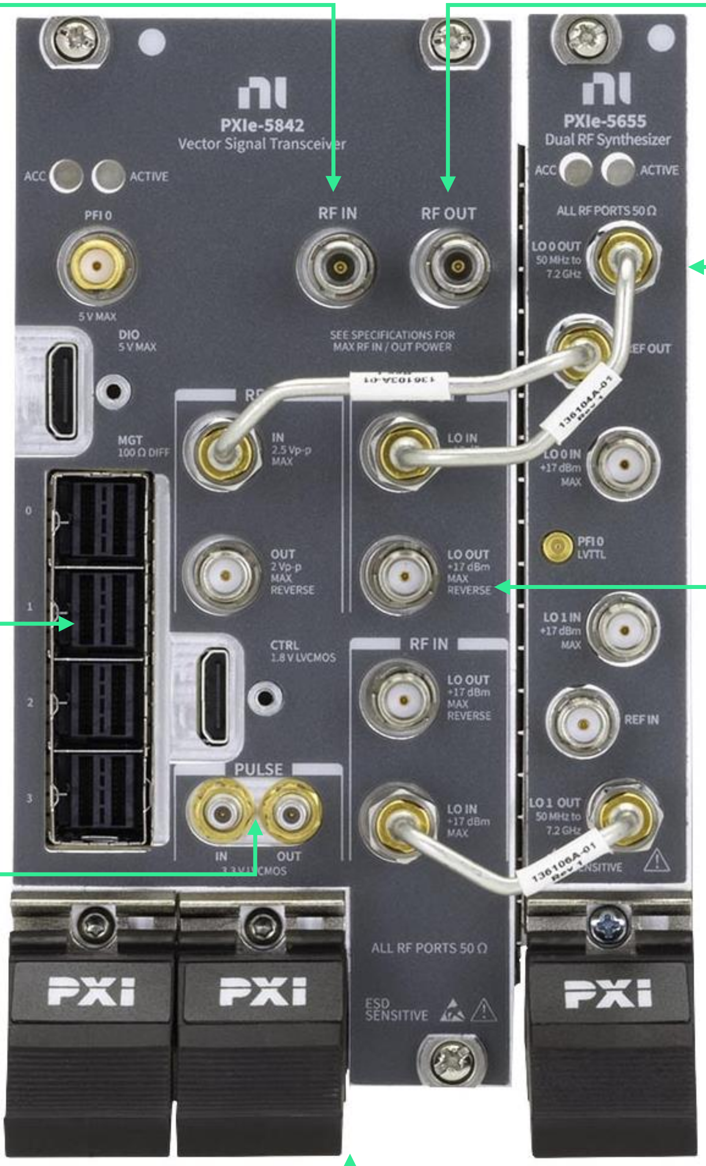

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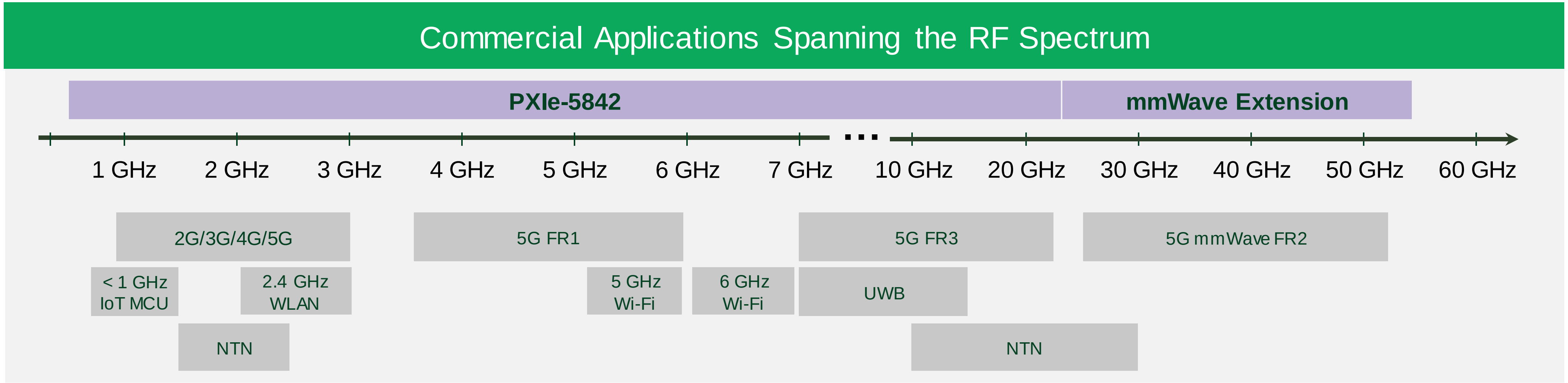
High Performance Dual LO Synthesizer
Unique LO chains for RF Out and RF In (from PXIe-5655)

Multi-Instrument Synchronization
Expand channel count with phase coherency LO / REF-sharing and TClk sync across the PXI backplane

Small form factor
Requires only 4 PXI slots

Flexible, Multi-RAT Ready: Continuous Frequency Coverage

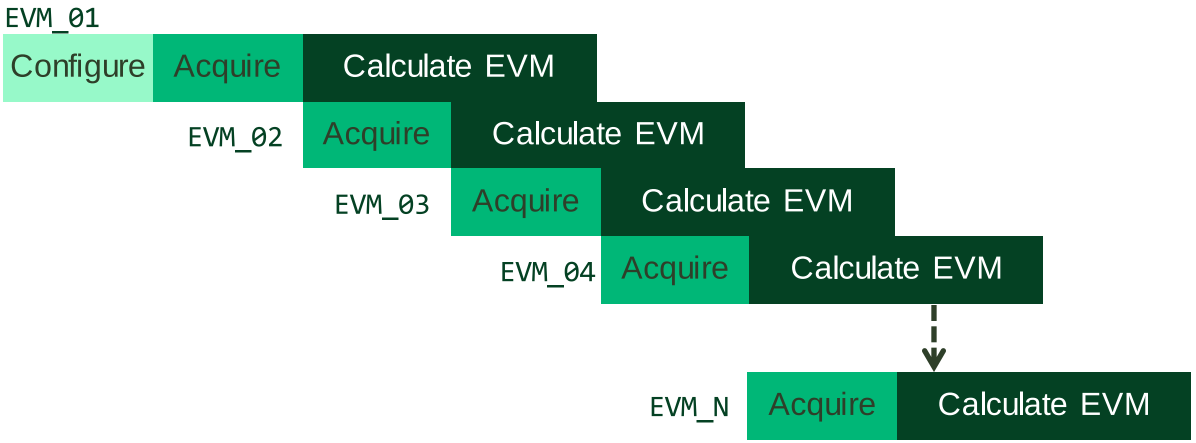


- Full coverage of Wireless Standards - tested with one capable and versatile instrument
  - Bluetooth
  - WLAN
  - 5G NR FR1, FR2, FR3
  - NTN
  - Ultra-Wideband (UWB)
  - Radio prototyping

Reduce Test Time:
RFmx Overlapped Measurements

Standard, sequential Execution

Overlapped Execution

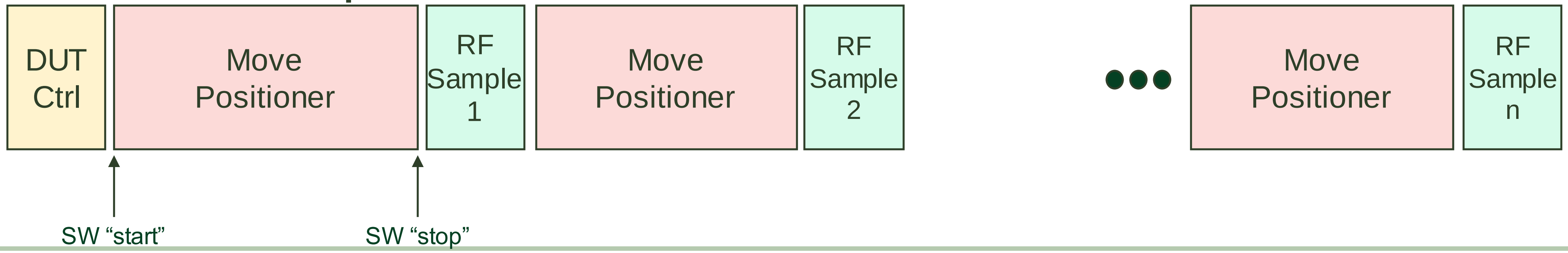


Real world example

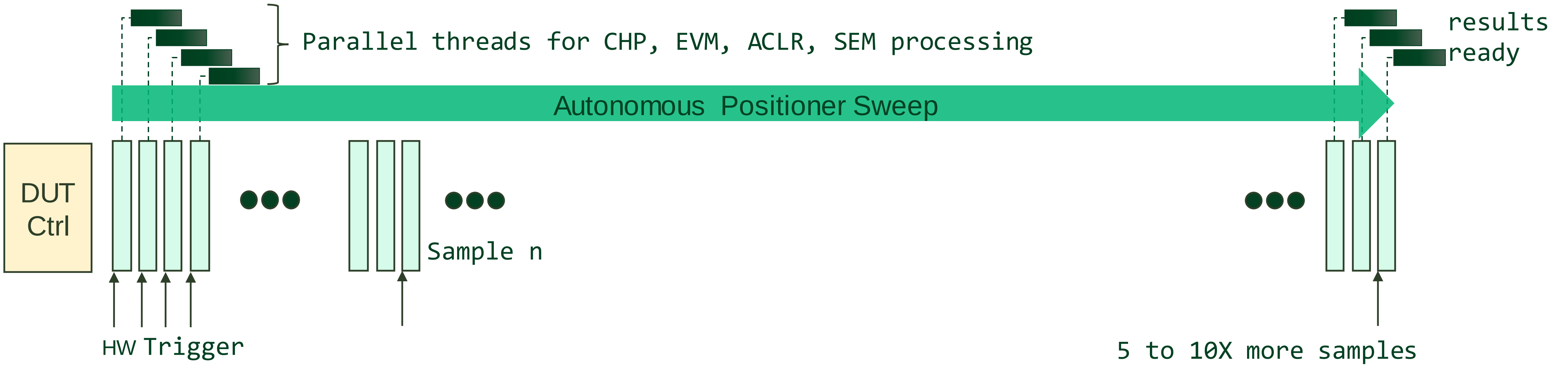
NR TM 3.1 100 MHz Carrier. 128 EVM and 64 ACP measurements
Sequential: **55 seconds**
Overlapped: **18 seconds**

Reduce Chamber Time: Software-based vs. Autonomous 3D Sweeping

Software-based sweep



NI approach with Autonomous sweep and pipelined measurements



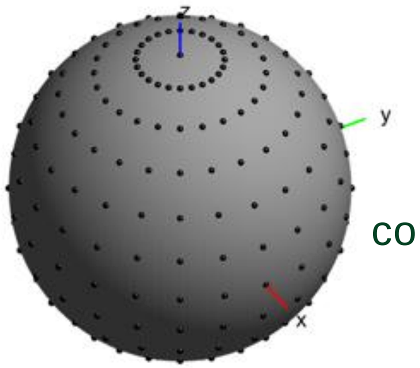
Fine OTA 3D Resolution in a Fraction of the Time

SW-based vs. Continuous, Autonomous, HW-accelerated measurements

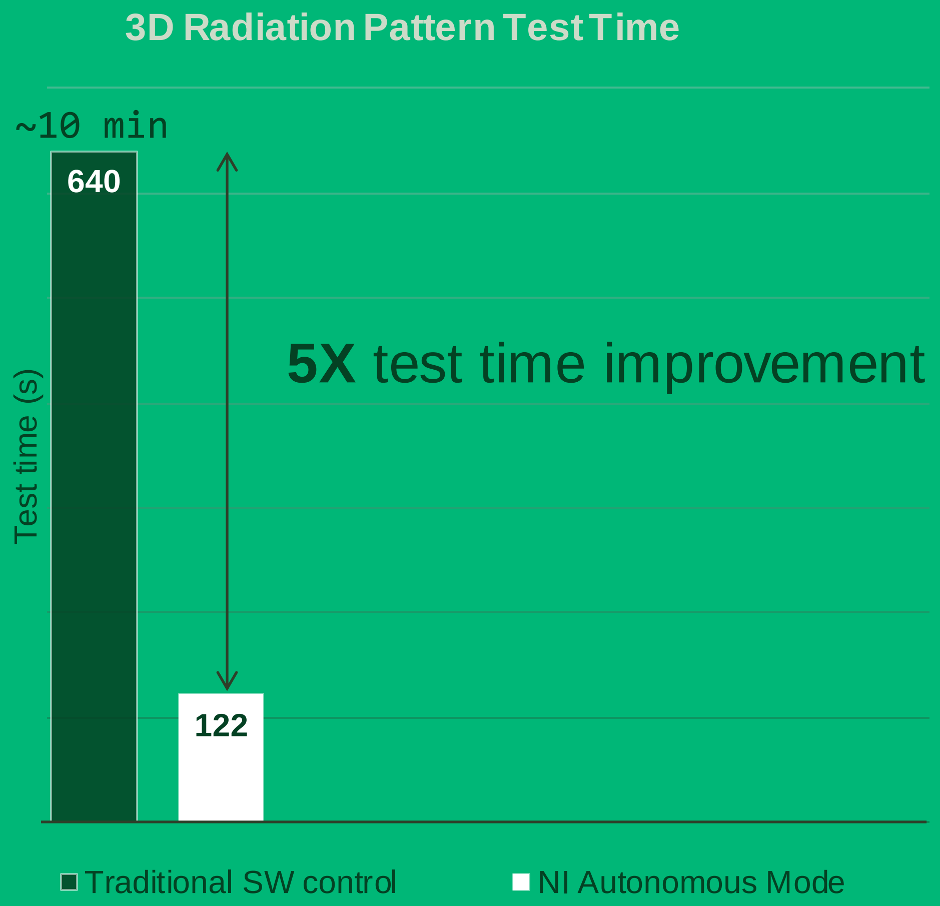
Measurement Conditions

4000 points
single frequency,
dual polarization

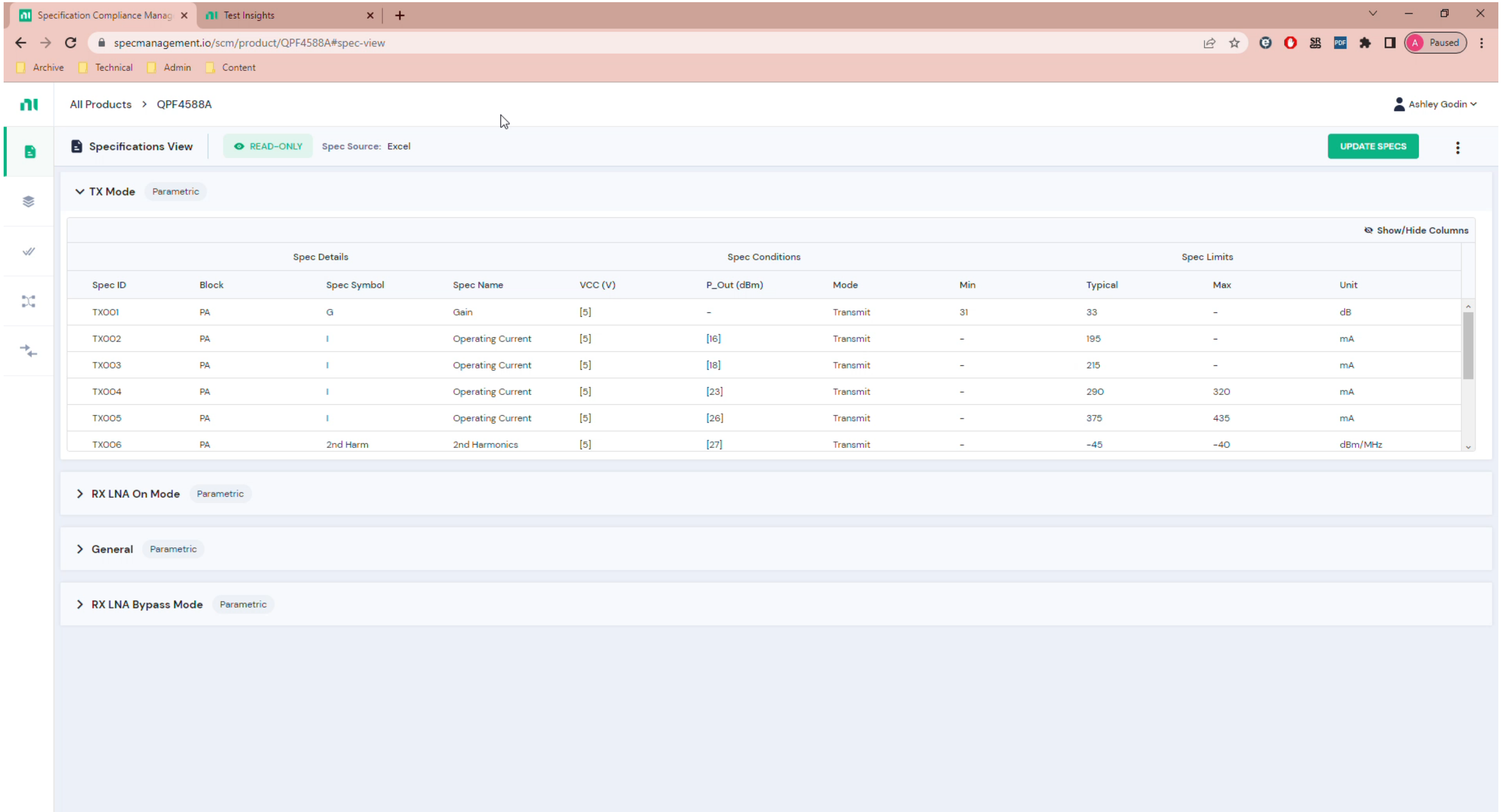
Every 4° azimuth and elevation



constant step-size grid



What to do with all the data?



Spec Details				Spec Conditions			Spec Limits			
Spec ID	Block	Spec Symbol	Spec Name	VCC (V)	P_Out (dBm)	Mode	Min	Typical	Max	Unit
TX001	PA	G	Gain	[5]	-	Transmit	31	33	-	dB
TX002	PA	I	Operating Current	[5]	[16]	Transmit	-	195	-	mA
TX003	PA	I	Operating Current	[5]	[18]	Transmit	-	215	-	mA
TX004	PA	I	Operating Current	[5]	[23]	Transmit	-	290	320	mA
TX005	PA	I	Operating Current	[5]	[26]	Transmit	-	375	435	mA
TX006	PA	2nd Harm	2nd Harmonics	[5]	[27]	Transmit	-	-45	-40	dBm/MHz

NI DataStudio Design-To-Test Across the Lifecycle

DataStudio Specification Compliance Manager

Spec Capture | Measurement Ingestion | Compliance Reporting

DataStudio Data Manager & Analysis Tools

Hot/Cold Storage | Search | Interactive Analysis | Batch Analysis

Ingestion and Data Mapping

DataStudio BDC
Validation Data Prep

VERIFICATION | TAPEOUT | VALIDATION | RELEASE | PRODUCTION

MathWorks | cadence

MATLAB Simulink

Spectre Analog Simulator

Xcelium Digital Simulator

PXI

Production Test

OPTIMAL+ is now NI

Production Analytics

Goals

Streamline the process from product definition to production

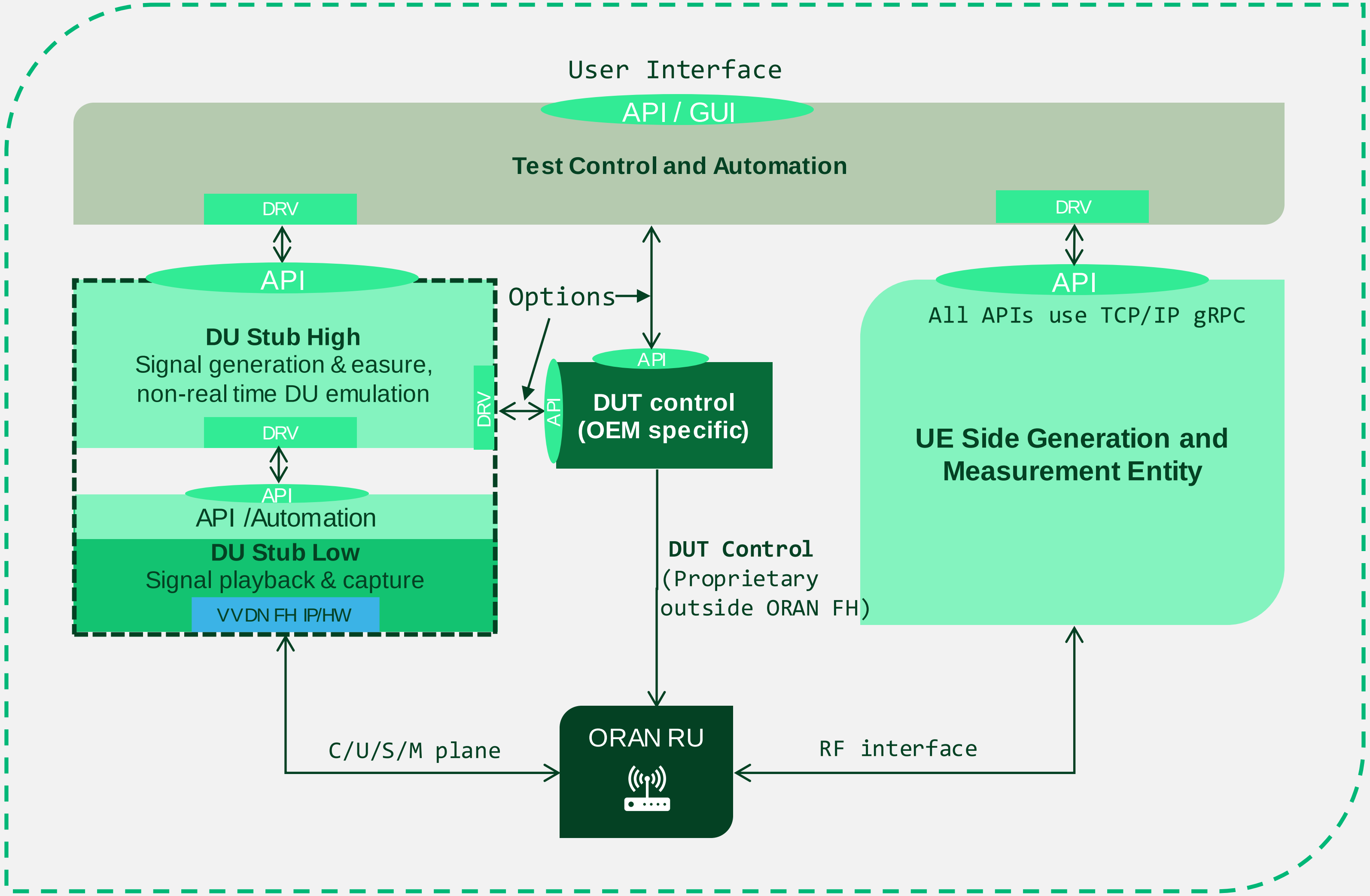
Integrate tools into a **complete flow**

Single "source of truth" for specifications and measurements

Provide **greater insight** in product development status and improve debugging

Reduce cost and accelerate time to market

NI O-RAN RU APT Solution – Block Diagram



NI Systems R&D

NI Product R&D

Customization by partners

Customization CCS AE

DUT

Many NI R&D teams will work together to deliver this solution

Customer deployment and customization with the help of NI **Partners**

NI's continued investment

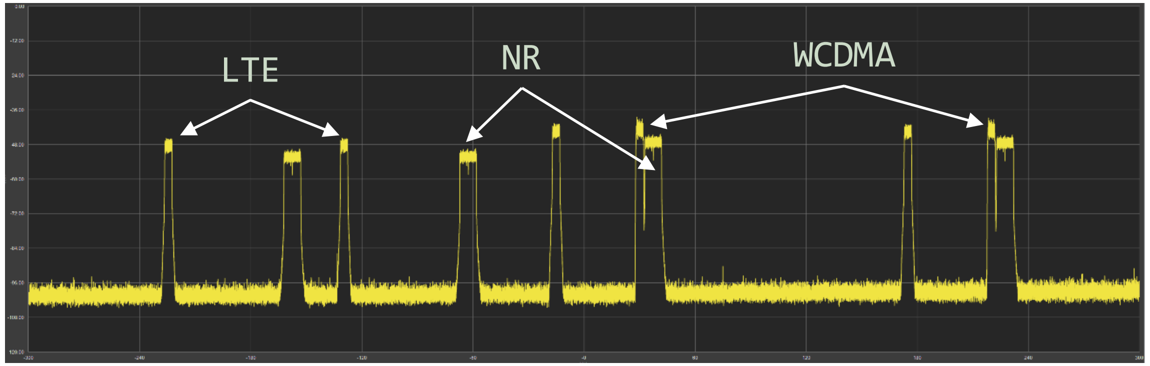
Areas of current work in concept and development stage set to address challenges in wireless infrastructure test

High power PA test

- Concept for testing RF amplifiers of any output power and ability to calibrate at DUT input
- High power PA characterization for validation and development purposes

Multi RAT test concept

- Make validation and production test of complex multi standard and multi carrier units faster and more cost efficient
- Implementing up- and downlink generation and analysis FW/SW that can run multiple standards and multiple carriers with one instrument



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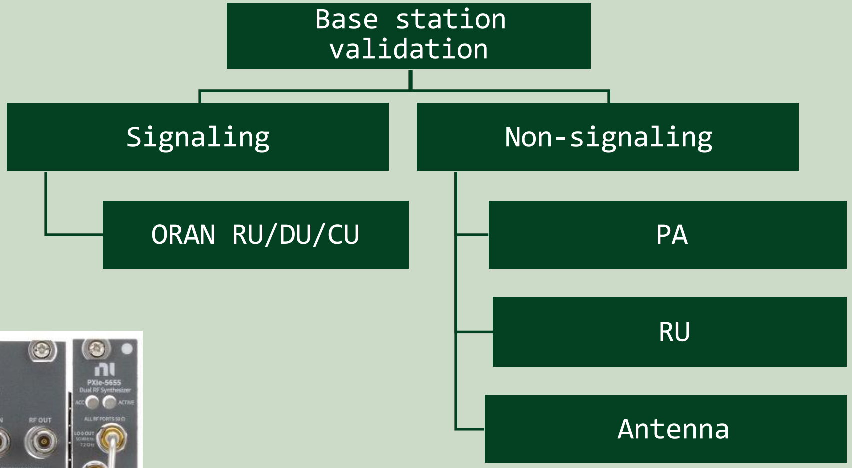

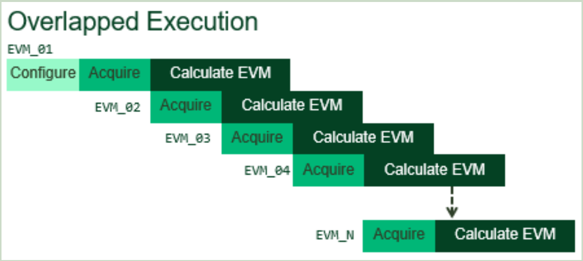

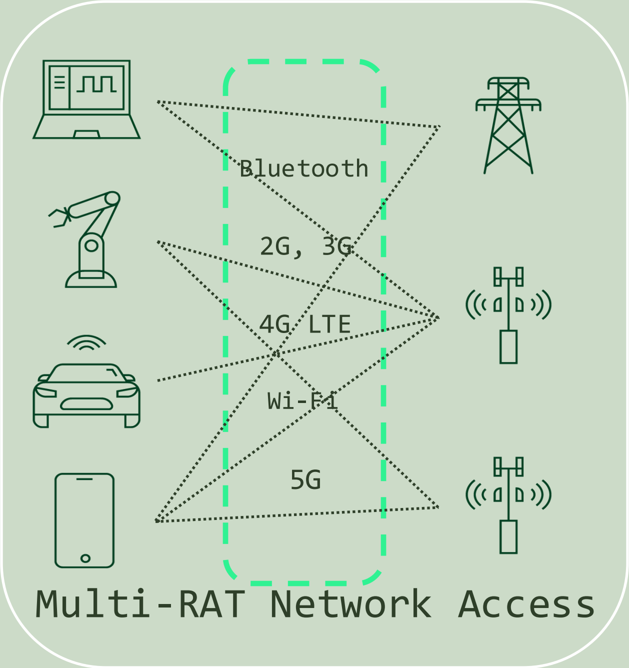

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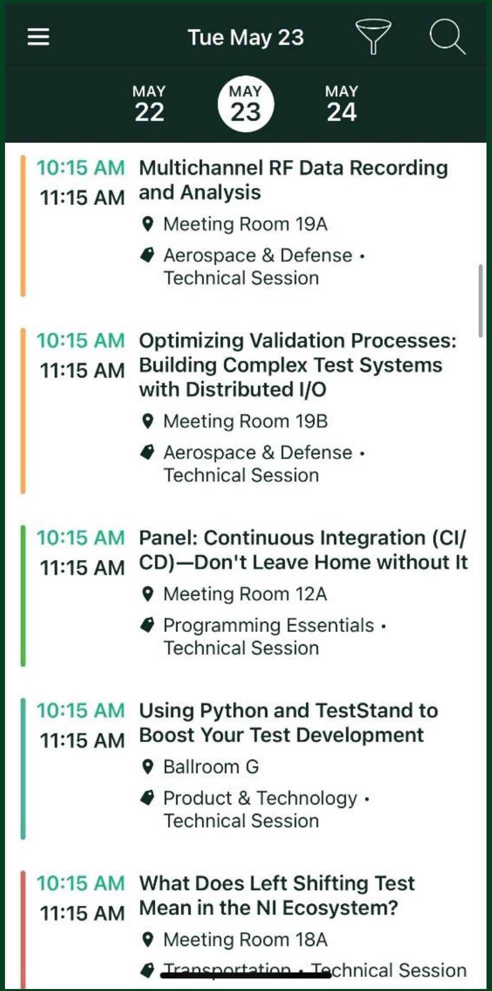

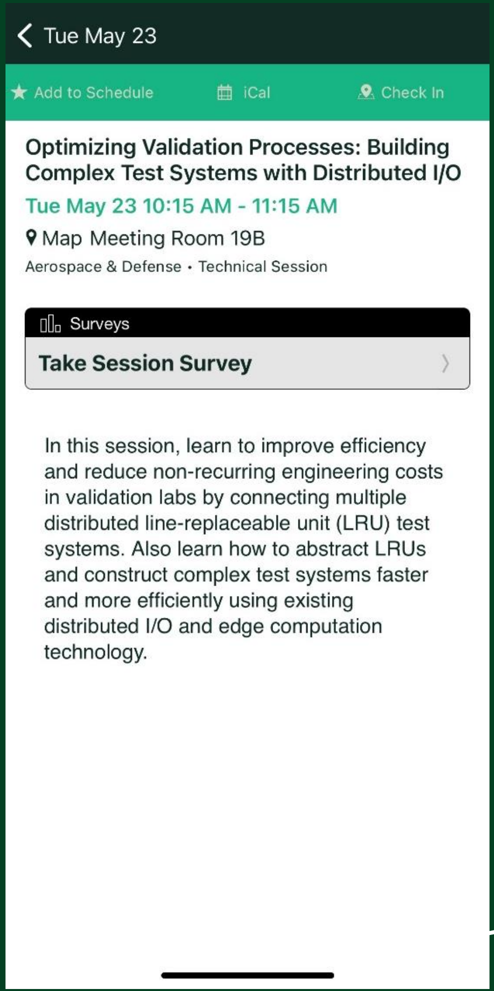

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CONNECT

NI RF Instrumentation

Delivering best-in-class performance

Test for Wireless Infrastructure

Two Platforms for RF Prototyping and Deployment

Low SWaP-C Prototyping with USRP

Differentiators:

- Broad portfolio of low-cost <$25k COTS SDRs
- Integration of RF with baseband and digital
- Open-source Software, wide toolchain adoption
- Enables software migration to tactical hardware

High-performance Prototyping and Validation with PXI RF

Differentiators:

- One instrument for all FR1, FR2, and FR3 frequency ranges up to 54 GHz
- Instrument-quality SDRs with latest ADC/DAC and RF Technologies
- Native mixed-signal capability (Digital, RF, Analog, etc.)
- Modularity and scalability supporting high channel counts
- Automated Sync Routines for Repeatable Phase Coherence
- Hardened Infrastructure for data streaming, real-time processing, and storage
- Future Real-Time 4 GHz BW with Coprocessor

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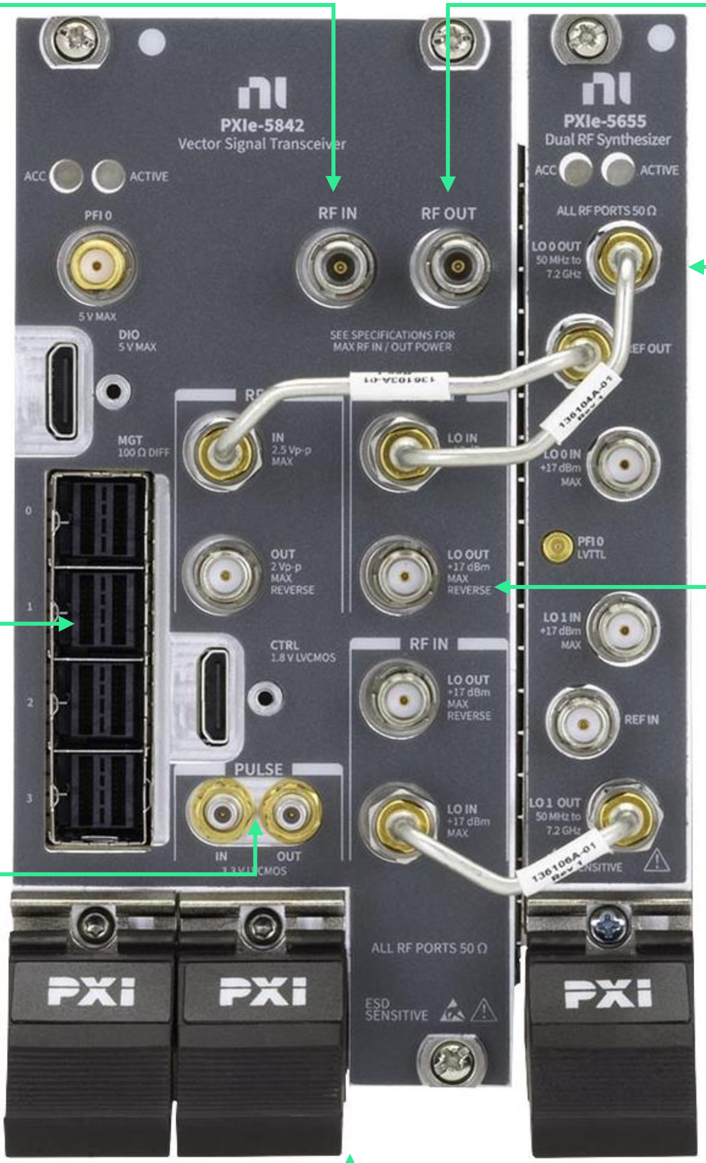

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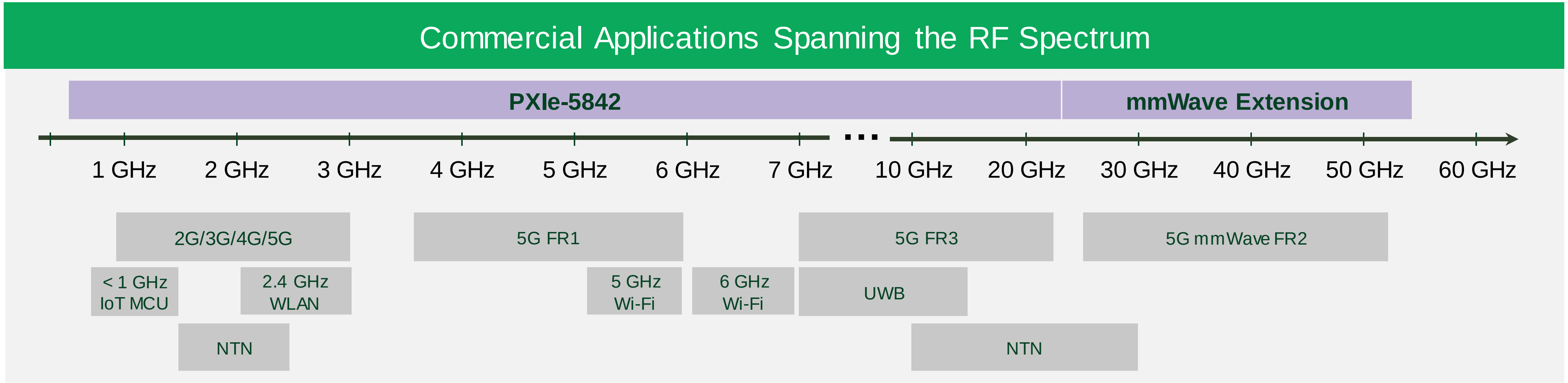

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High Performance PXI VSTs

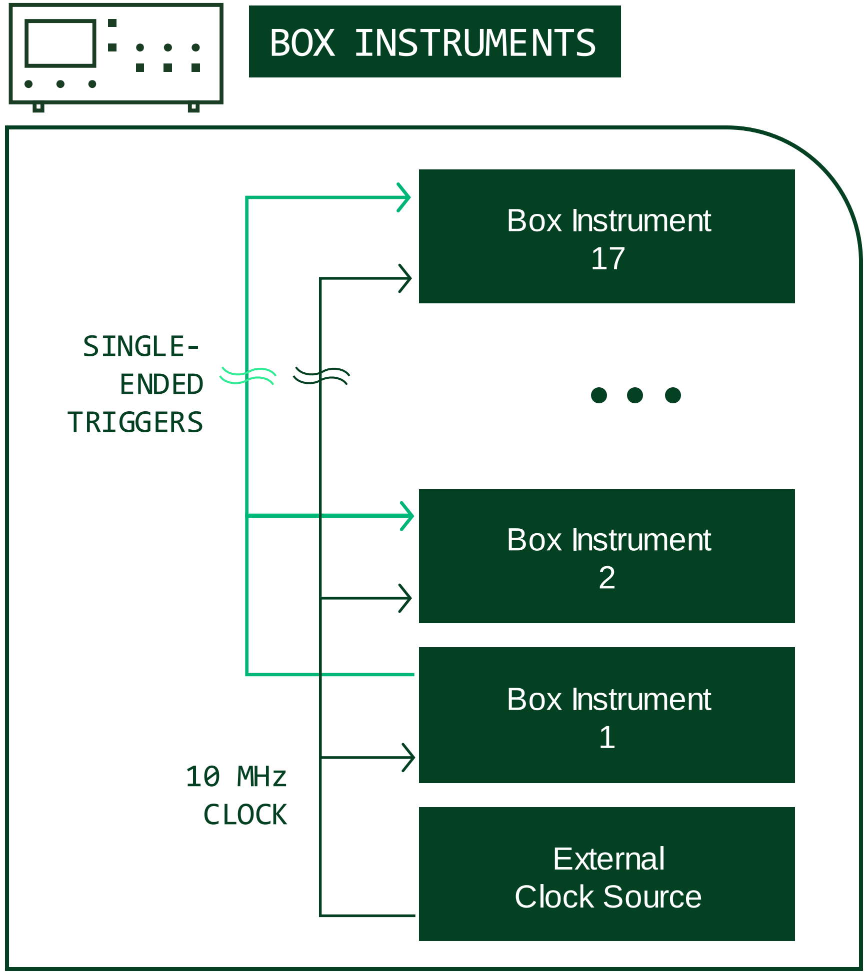
Model Name	PXIe-5841	PXIe-5830	PXIe-5831	PXIe-5842 (new)
Frequency	9 kHz – 6 GHz	5 GHz – 12 GHz	5 GHz – 21 GHz	50 MHz – 23 GHz 50 MHz - 26.5 GHz (H2.2023)
Bandwidth	1 GHz	1 GHz	1 GHz	Up to 2 GHz
Slot Count	2 / 3	4	6	4
Tuning Time	380 us / 175 µs	500 µs	500 µs	230 µs
VSG Maximum Output Power (CW @ 5 GHz)	+ 20 dBm	+ 12 dBm	+ 12 dBm	+ 20 dBm
EVM (5G NR, 100 MHz, loopback @ 5.5 GHz)	-49 dB	-51 dB	-51 dB	-56 dB
Frequency Response (max BW) typ.	± 0.85 dB	± 1.1 dB	± 1.2 dB	± 0.35 dB
RF IN Average Noise Density (+0 dBm Ref Level)	-144 dBm/Hz	-142 dBm/Hz	-141 dBm/Hz	-146 dBm/Hz

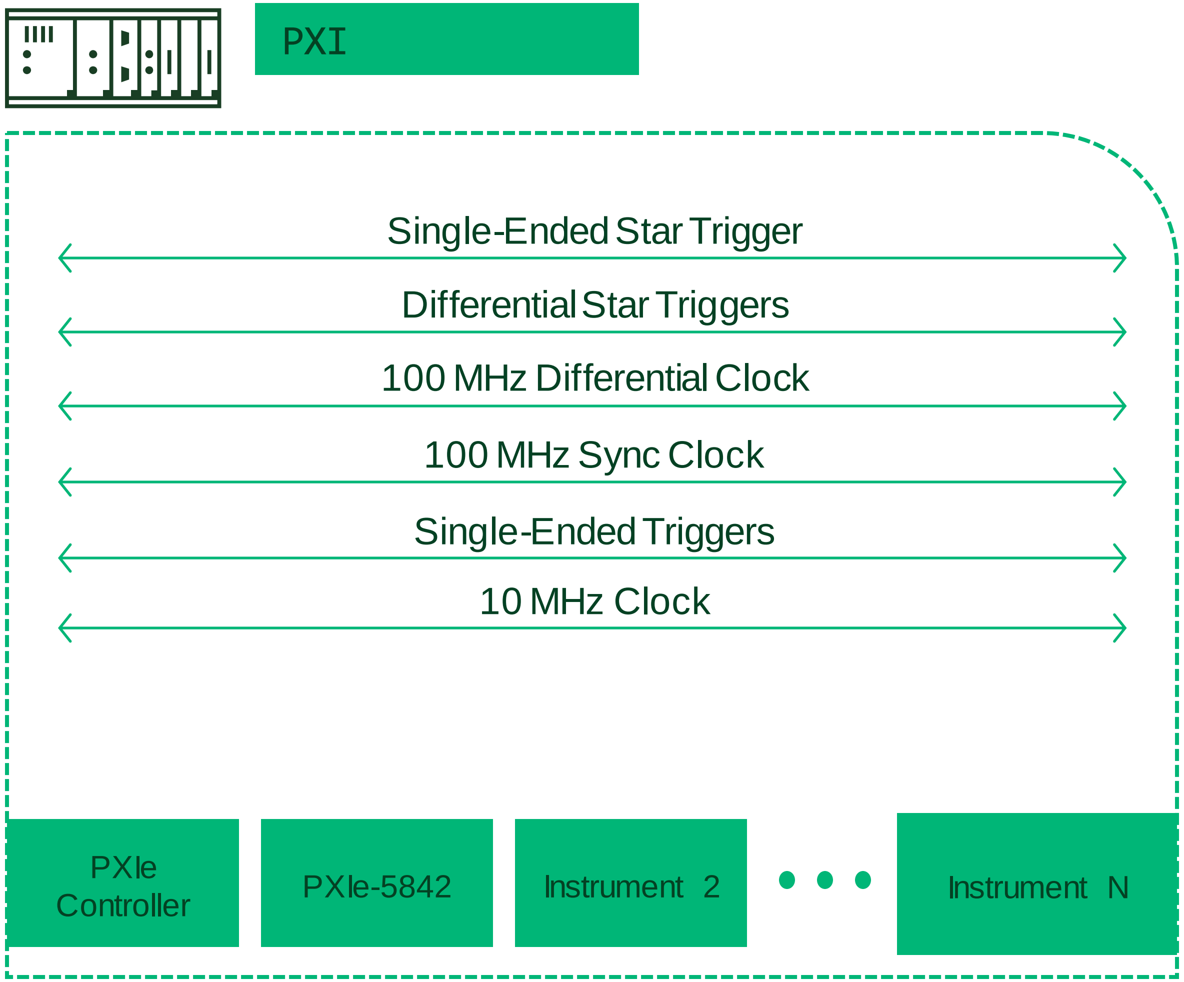
Achieve Best-in-class EVM

NI’s third generation VST, the PXIe-5842, offers best-in-class EVM performance over a single channel

PXIe-5842 EVM loopback, measured	
-54 dB	Wi-Fi 7, 80 MHz bandwidth, 6 GHz
-50 dB	Wi-Fi 7, 320 MHz bandwidth, 6 GHz
-56 dB	5G NR, 100 MHz bandwidth, 5.5 GHz

Advanced Timing and Synchronization with PXI





Software

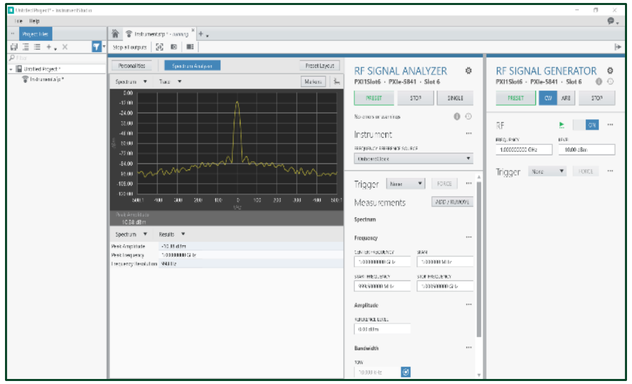
Same instrument drivers (RFSA, RFSG, RFmx) as other NI RF instrumentation

NI's RF instrumentation supports a breadth of programming languages: **LabVIEW, C/C++, C# .NET**

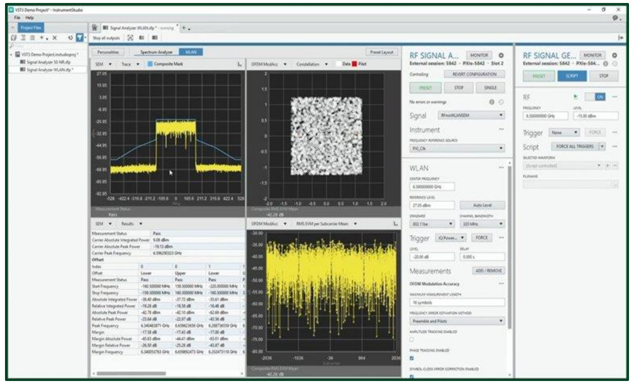
What you get with NI's best-in-class APIs:

- Well Documented API
- Shipped Examples
- Help Documentation

InstrumentStudio™



RFmx



RFIC Test SW