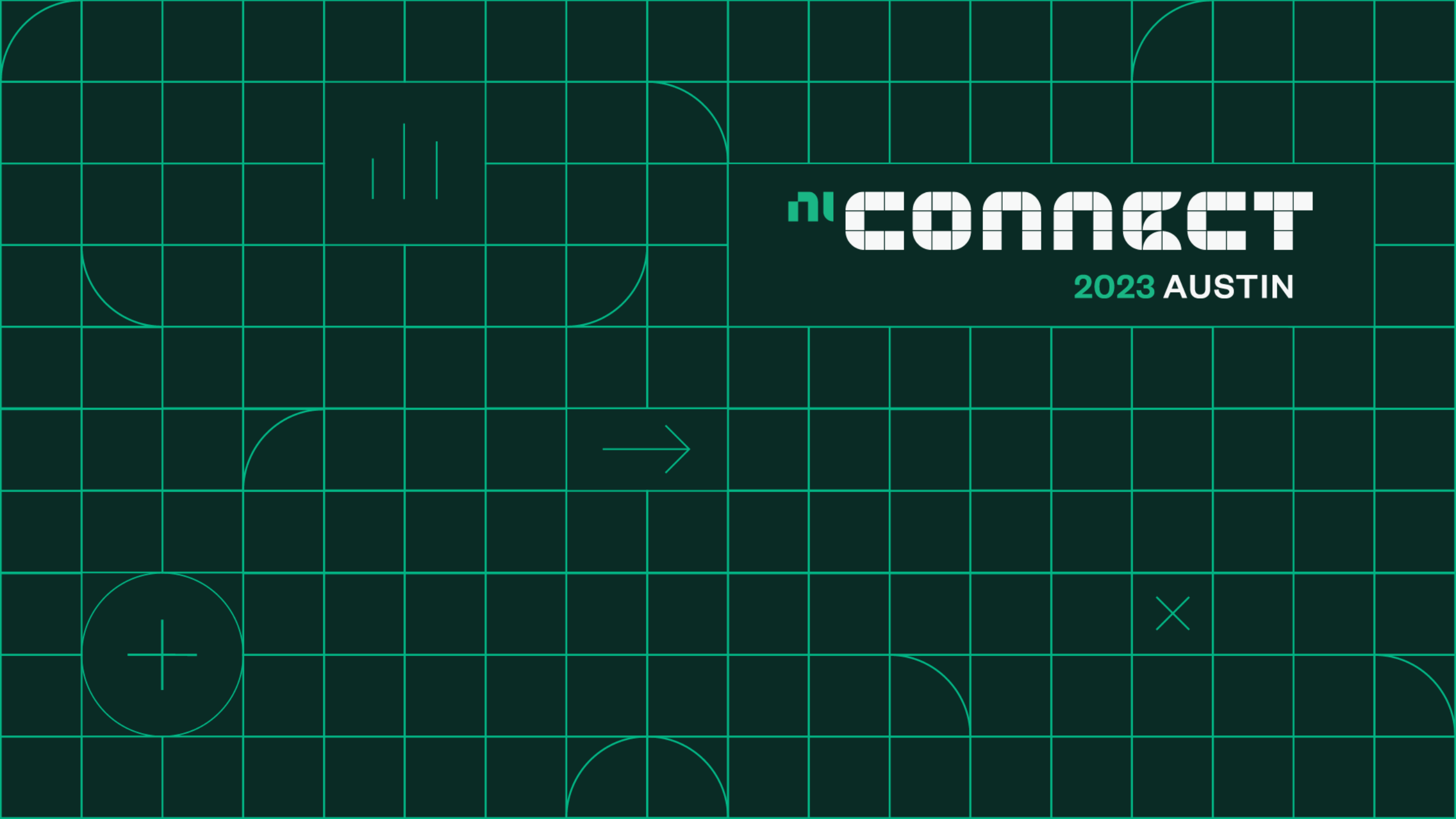

WELCOME TO AUSTIN


CONNECT
2023 AUSTIN

5G Midband, 5G mmWave, or Wi-Fi 7 – Which Will Consumers Adopt?

Joel Carroll
Business Development Manager

Agenda

The “Why” – Evaluating Each Standard

- 5G mmWave
- 5G mid-band
- Wi-Fi

Industry/Consumer Trends and Investments

Testing Challenges

How NI is Addressing These Challenges

Technology Comparison

5G Mid-band, 5G mmWave, or Wi-Fi 7

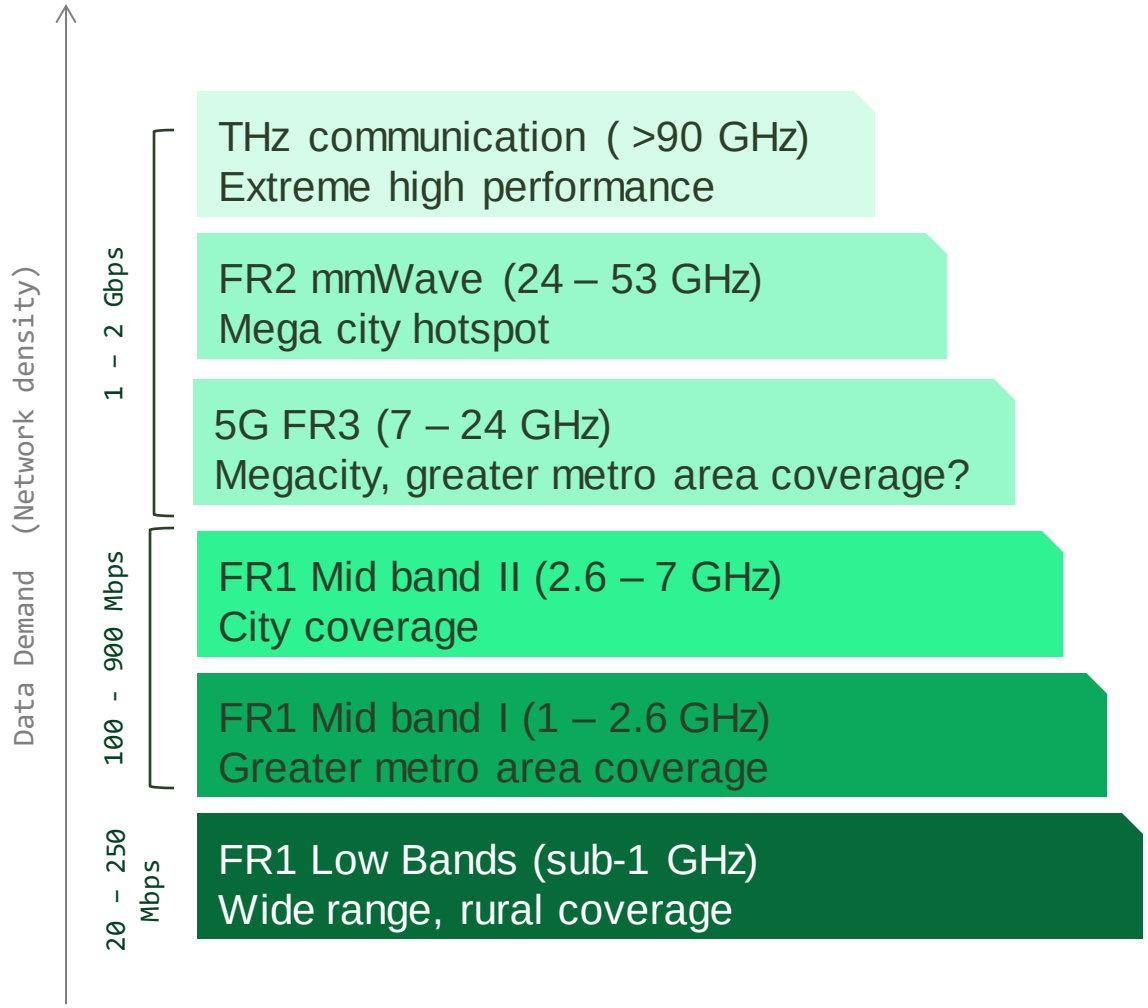
Why 5G mmWave?

- More available spectrum bandwidth = more channels
- Higher throughput
- Serves dense user areas and Fixed Wireless Access (FWA)
- Cost-effective spectrum

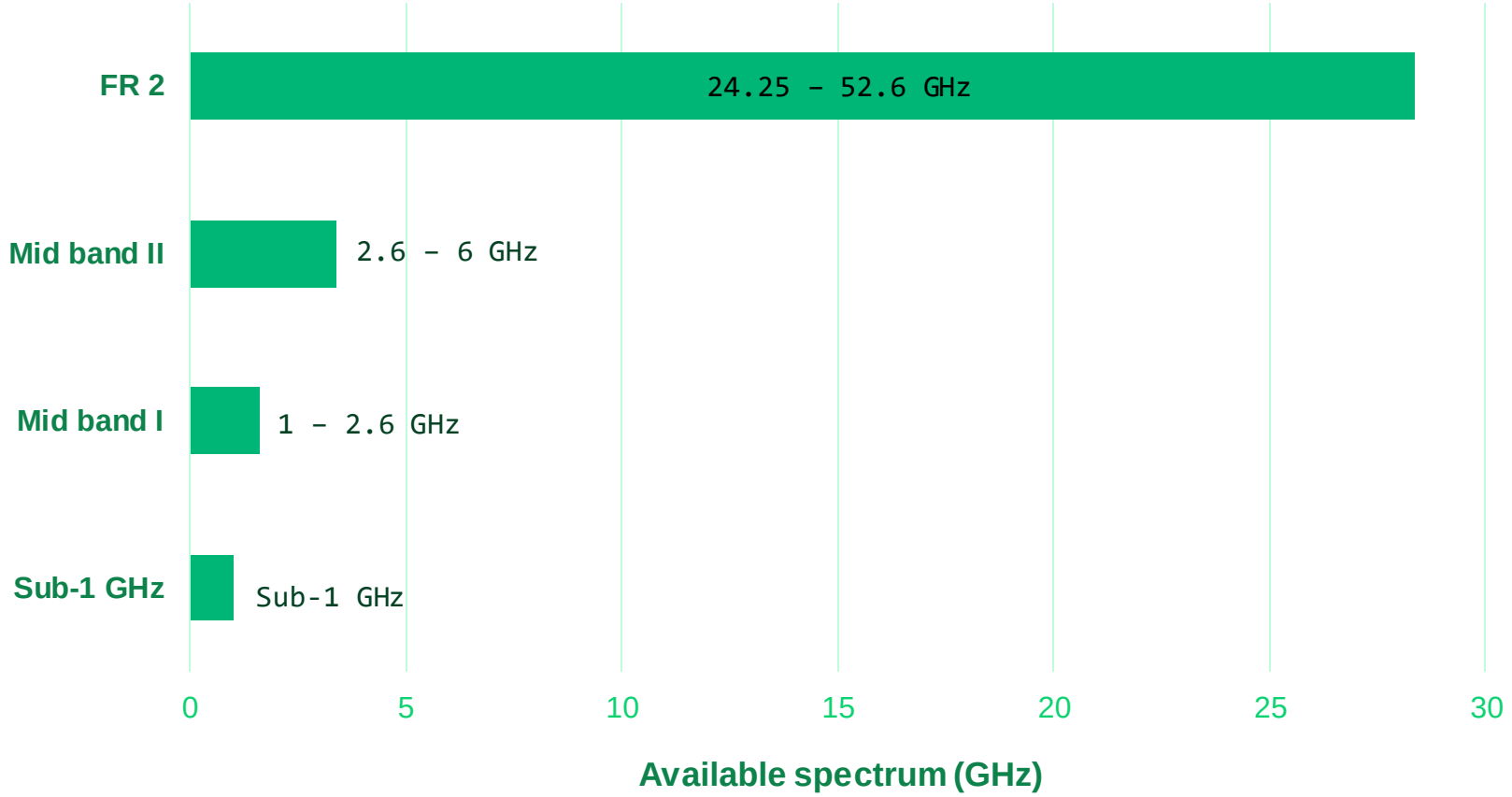
- Signal Propagation issues (line 0f sight needs, low-e glass)
- Users move
- Requires beamforming compensation
- High investment needed to deploy

mmWave Capacity

More available spectrum than mid and low band provides higher throughput and more channels to serve highly dense and high-demand areas



Wider Bandwidths and More Spectrum

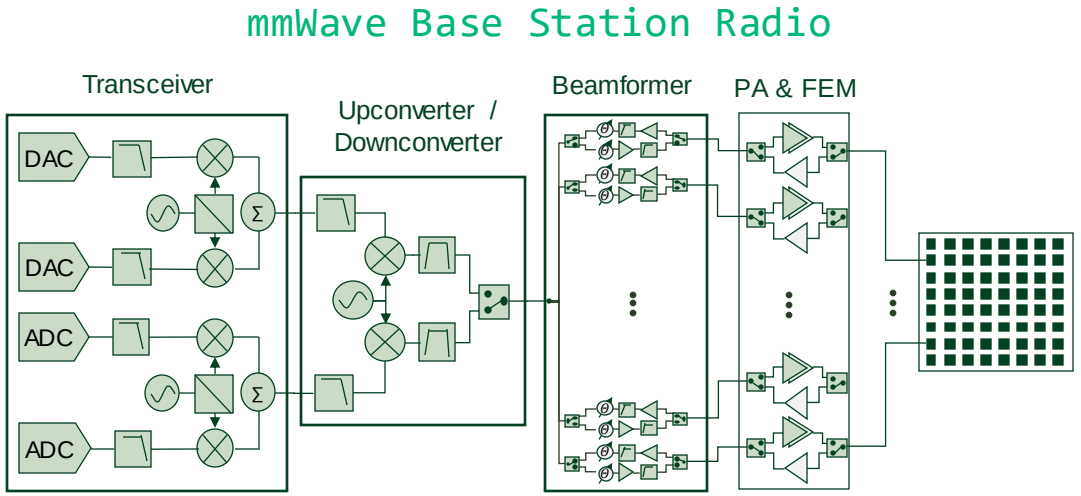


Signal Bandwidth

Cellular	
LTE-Advanced	100 MHz
5G NR FR1	400 MHz
5G NR FR2	**2000 MHz**

Wi-Fi	
802.11ac	80 MHz
802.11ax	160 MHz
802.11be	320 MHz

Challenges Testing mmWave 5G Beamformers and FEMs



Validation and Characterization

- FR2 wider bandwidth operation up to 2000 MHz
- Determining sub-component contribution to beamformer performance
- Multi-channel devices require efficient multi-channel switching and synchronization

Production Test

- Multi-channel nature requires characterization of channel-to-channel and absolute **phase measurements**
- Wide bandwidth and mmWave frequencies creates accuracy challenges with **EVM and power** measurements, -40 dB EVM for 100 MHz channel

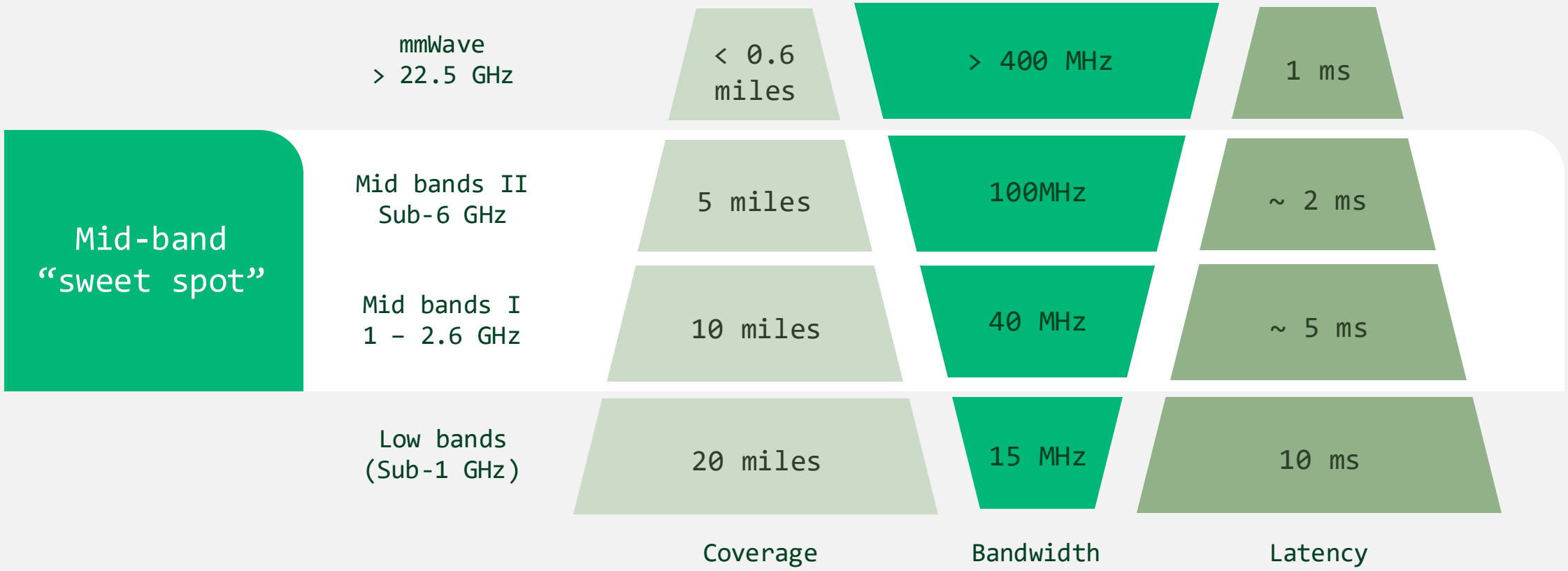
Why 5G mid-band?

- Increased range compared to mmWave
- Sweet spot between low band and mmWave, good compromise of throughput, capacity, and range

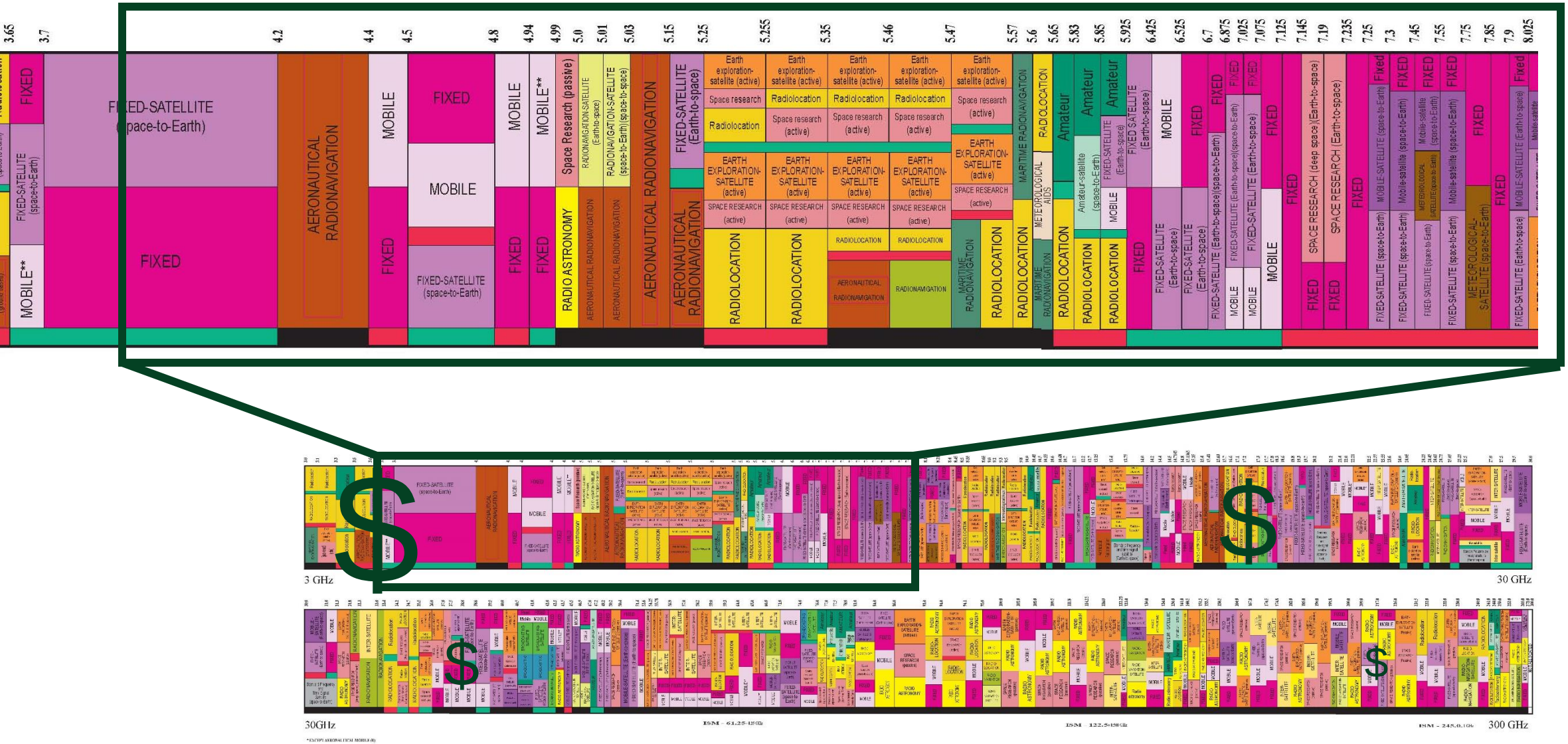
- Less bandwidth and capacity than mmWave
- Cost: Carrier competition for spectrum
- Availability of spectrum: not available until recently in US – due to FCC regulation

5G Mid-band

A COMPROMISE OF COVERAGE, BANDWIDTH, AND LATENCY

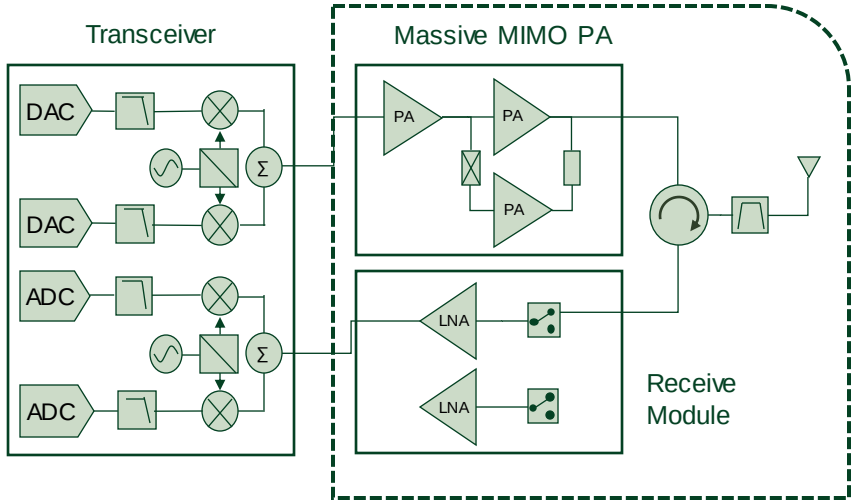


Competition for C-band increases its value



Challenges Testing Sub-6 GHz 5G Massive MIMO Front Ends

Sub-6 GHz Base Station Radio



Validation and Characterization

- More waveform test models, more bands, wider channels
- contiguous and non-contiguous **carrier aggregation** configurations
- Testing under DPD conditions requires **wide instrument bandwidth** and **complex DPD algorithms**

Production Test

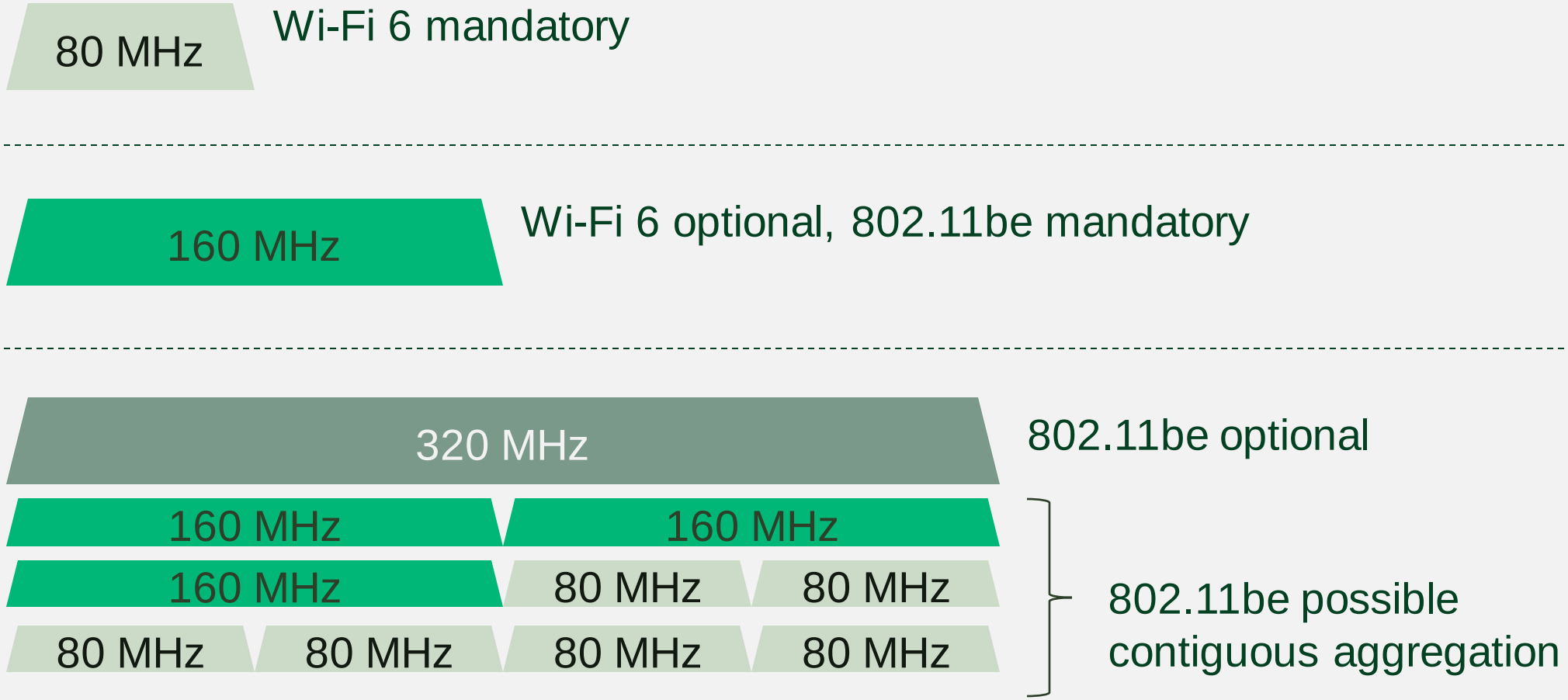
- Base station architectural changes lead to **exponential volume increases** – driving focus on test time & multi-site
- **Higher power levels** create challenging fit for traditional ATE platforms

Why Wi-Fi?

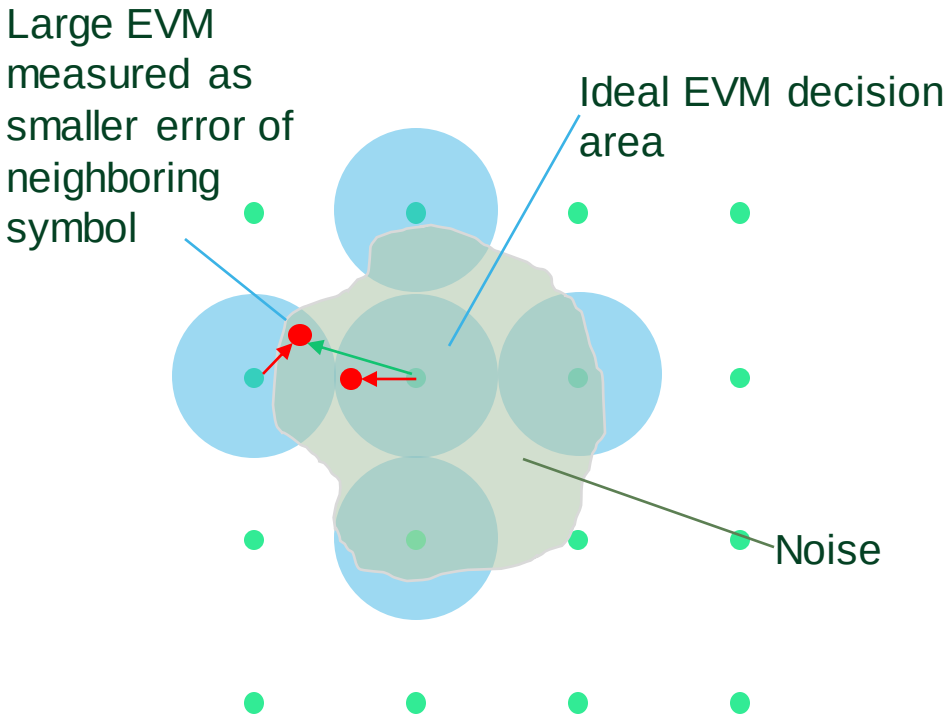
- Wide range of non-5G-compatible connected devices (laptops, smart home devices, TVs, etc.)
- Private administrator-controlled LAN
- High throughput
- Acts as a supplement to cellular connections
- Easy, ubiquitous connectivity

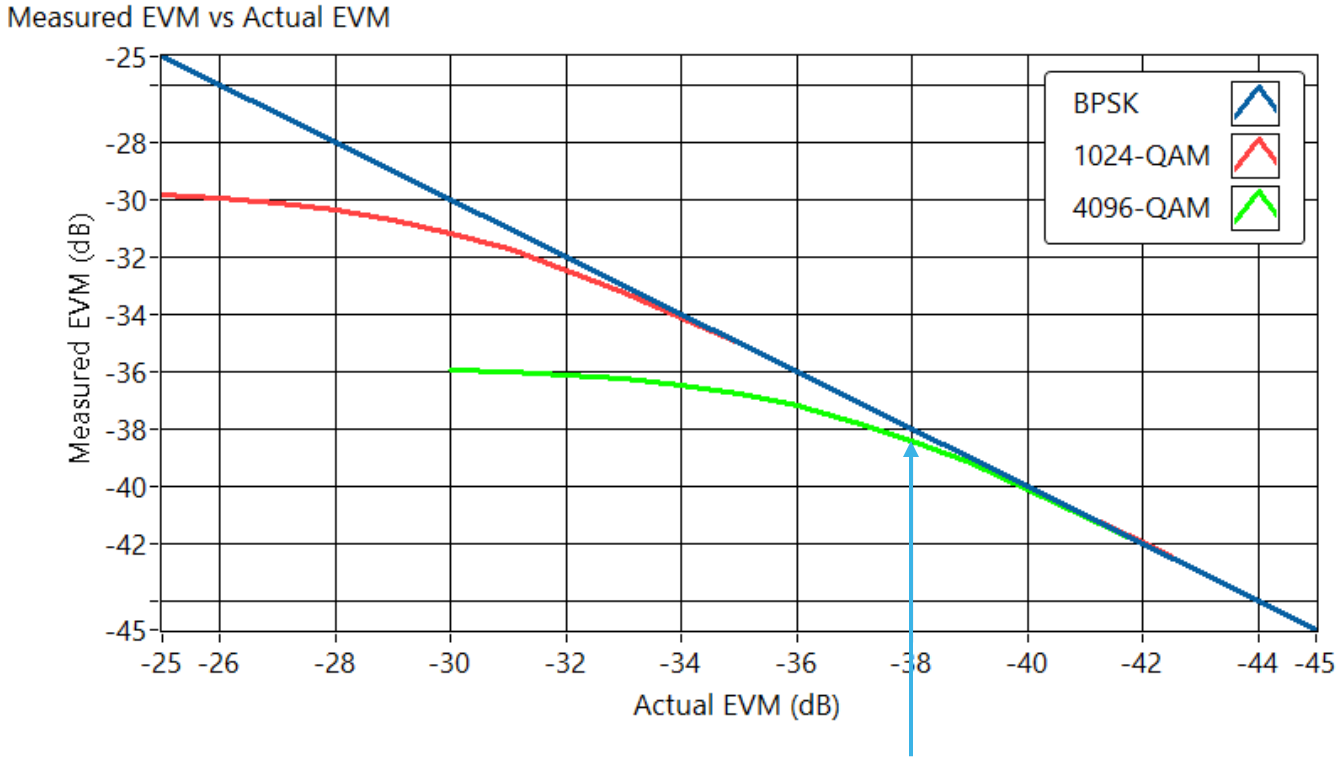
- Cellular speeds approaching Wi-Fi
- 5G speeds meet or exceed the needs of most individual devices
- Short range

Wider Channels



Testing Higher Order Modulation – 4096 QAM





Symbol errors challenge the Tx EVM computation

Industry Trends

What are Device Manufacturers (and Consumers) Trending Towards?

Carriers Spending for 5G has been mostly sub-8 GHz

- New spectrum opened in sub-8 GHz between 2019-2021
- Main US Carriers (T-Mobile, AT&T and Verizon) spent around 10x more on sub-8 GHz spectrum than on mmWave spectrum.
- The mmWave spectrum bought by these carriers has about 10x more bandwidth
- These carriers focused on the expansion of 5G in sub-8 GHz with better-than-LTE speeds

mmWave Expansion: Not as Expected

C-band 5G deployments are receiving a large portion of operators' capex budgets in 2022 *but that doesn't mean that millimeter wave (mmWave) 5G deployments are dead. In its latest 5G mmWave market forecast report, Mobile Experts said that it expects mmWave investments will return in late 2023 and 2024*

www.fiercewireless.com

→

Verizon spent $45.5 billion and AT&T spent $23.4 billion on C-band licenses. In addition, AT&T spent $9.1 billion on 3.45 GHz spectrum licenses

www.fiercewireless.com

T-Mobile bids $10 billion on top of recent $26 billion acquisition of Sprint.

www.forbes.com

only ~44 million iPhones shipped with mmWave in 2021, while ~196 million shipped without… Surprise, surprise, it's only the US model that has mmWave

www.semianalysis.com

With Jio's massive $25B investment, India looks poised to start adopting mmWave on the high end. Qualcomm owns the high-end. ***It seems clear that from 2023 to 2025, mmWave will begin deployment*** *in India, Japan, and South Korea*

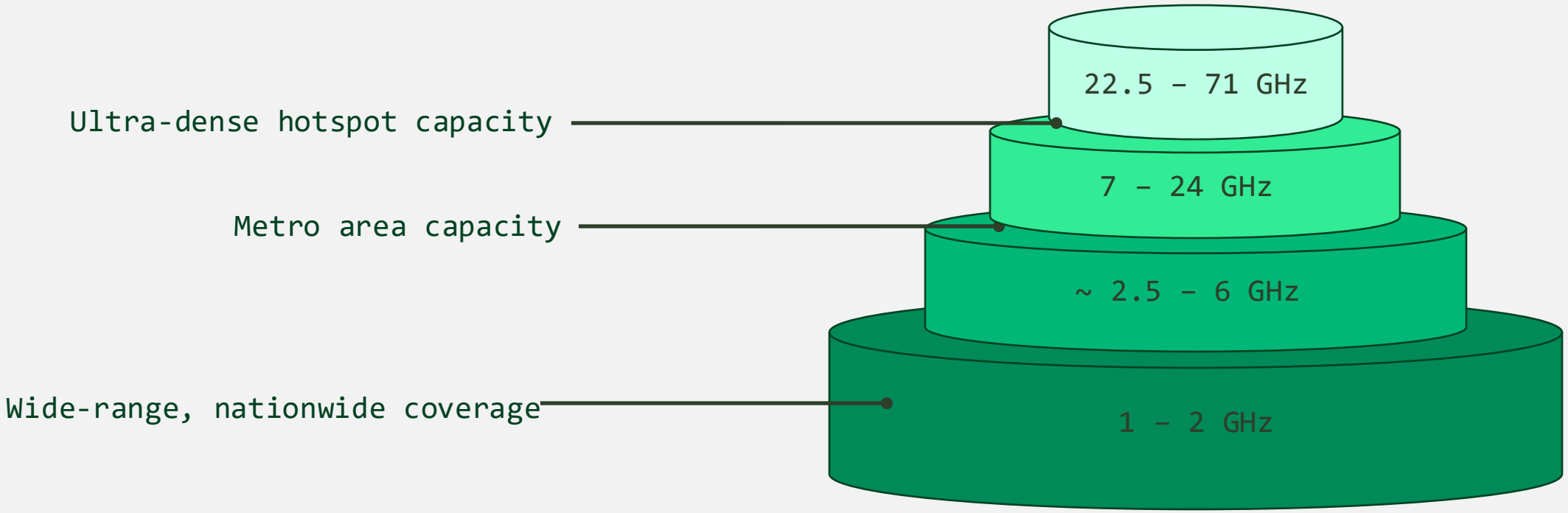
www.semianalysis.com

*"**2023 will be a breakout year for 5G mmWave deployments in major markets worldwide**, providing the high-speed, ultra-low-latency mobile networks end users need for broadband access, new services and emerging applications such as VR/AR and merged reality experiences," said Maryam Rofougaran, CEO and co-founder of Movandi*

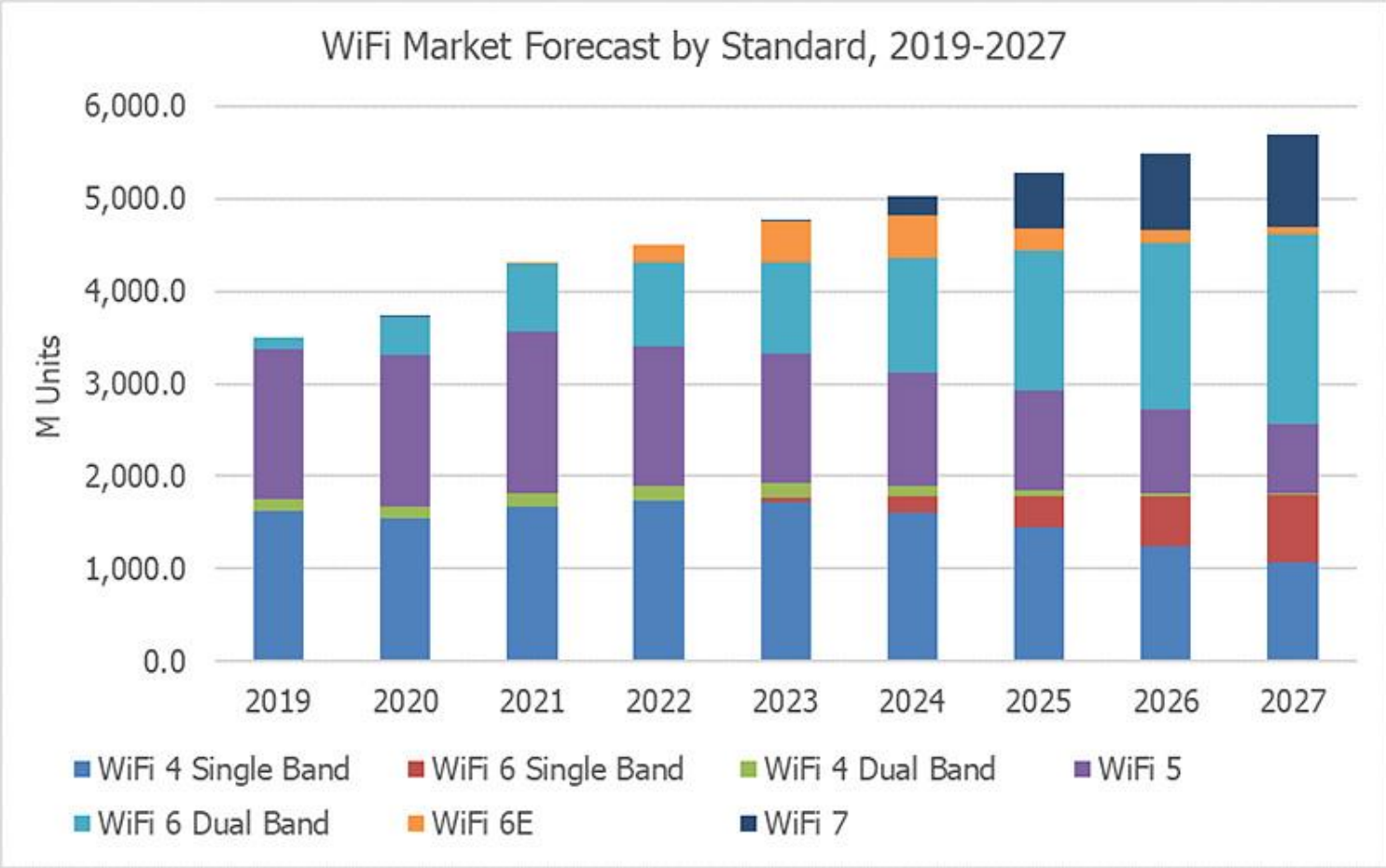
www.businesswire.com

“The Layer Cake” approach to deploying 5G

- Each band/standard has pros and cons
- Tradeoffs between capacity, coverage, density, ease of implementation, and cost
- All will have unique situations where they add considerable value

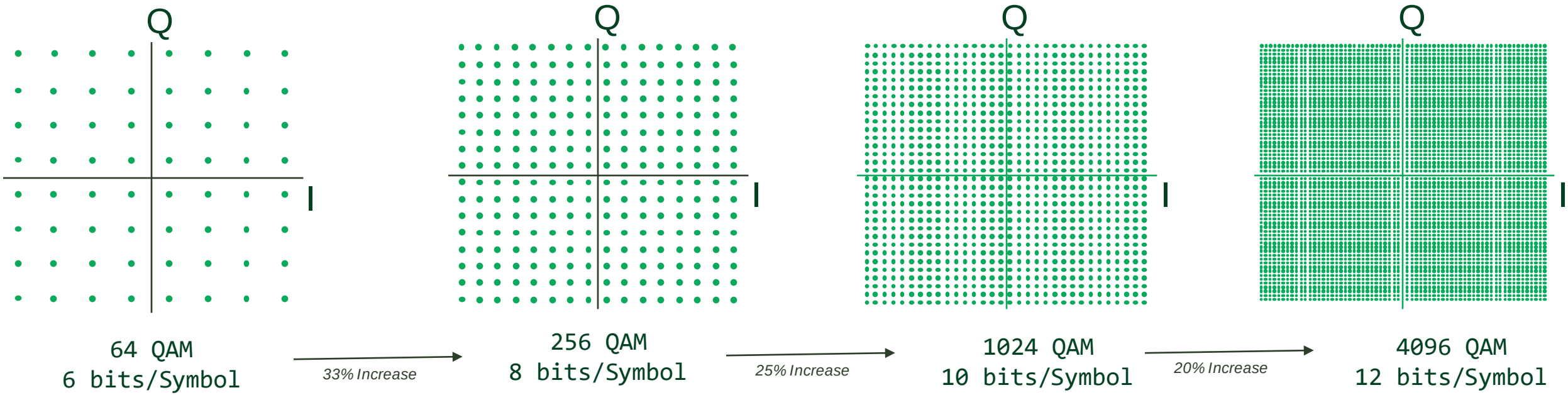


Wi-Fi 6/6E/7 set to take over market



Source: https://iotbusinessnews.com

Wifi Trend: Higher Modulation Orders

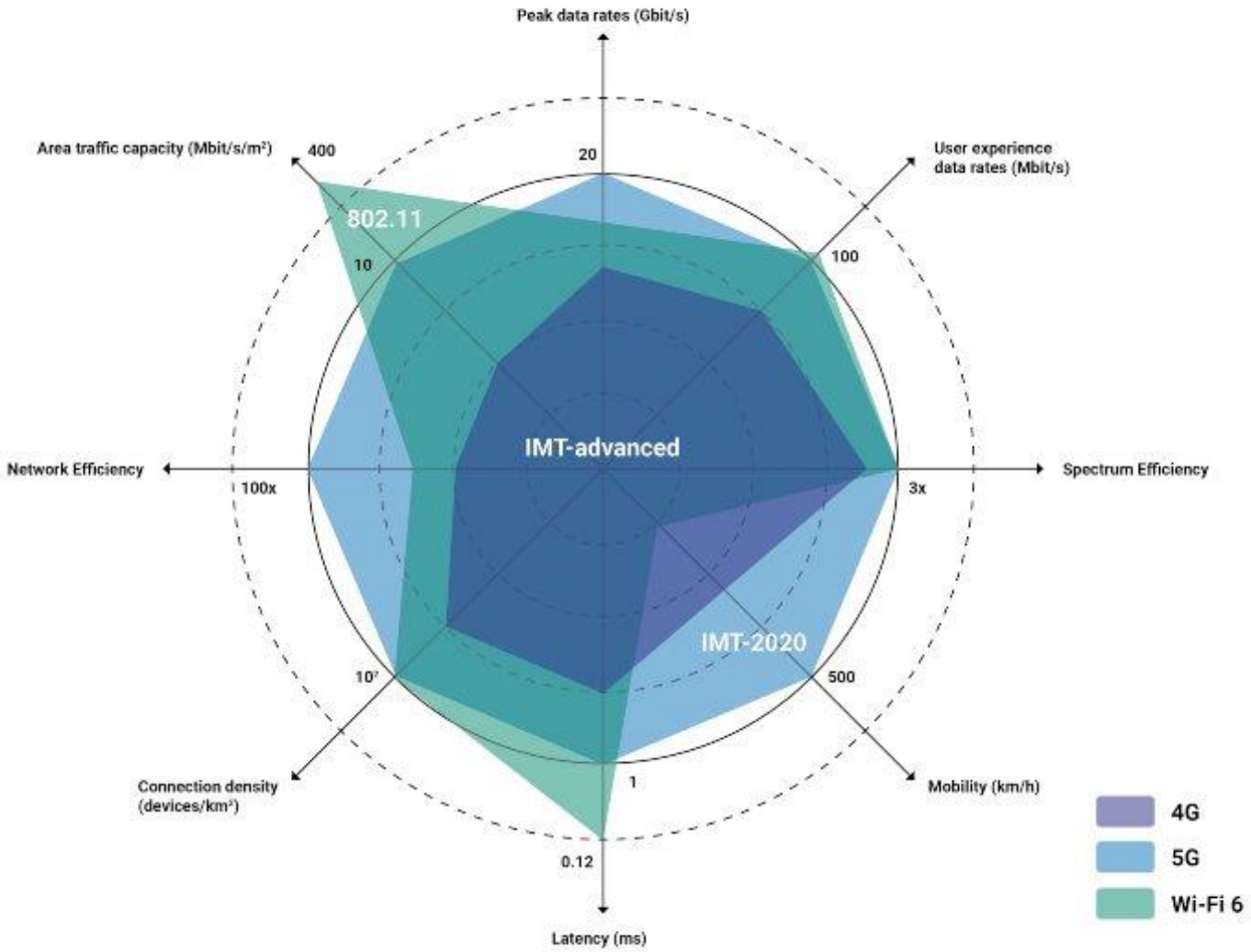


24dB SNR	30dB SNR	36dB SNR	42dB SNR
802.11n	802.11ac	802.11ax	802.11be

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



Coexistence, not Competition

Adoption of 5G midband, mmWave, Wi-Fi 7, and even FR3 will not be absolute

Each will have a role to play in interconnected, reliable, and accessible wireless communications of the future

Source: https://wballiance.com

Testing Challenges

Turning test into a Competitive Advantage

Requirements for 5G Test

Fast & Flexible Test Solution

Excellent Measurement Performance

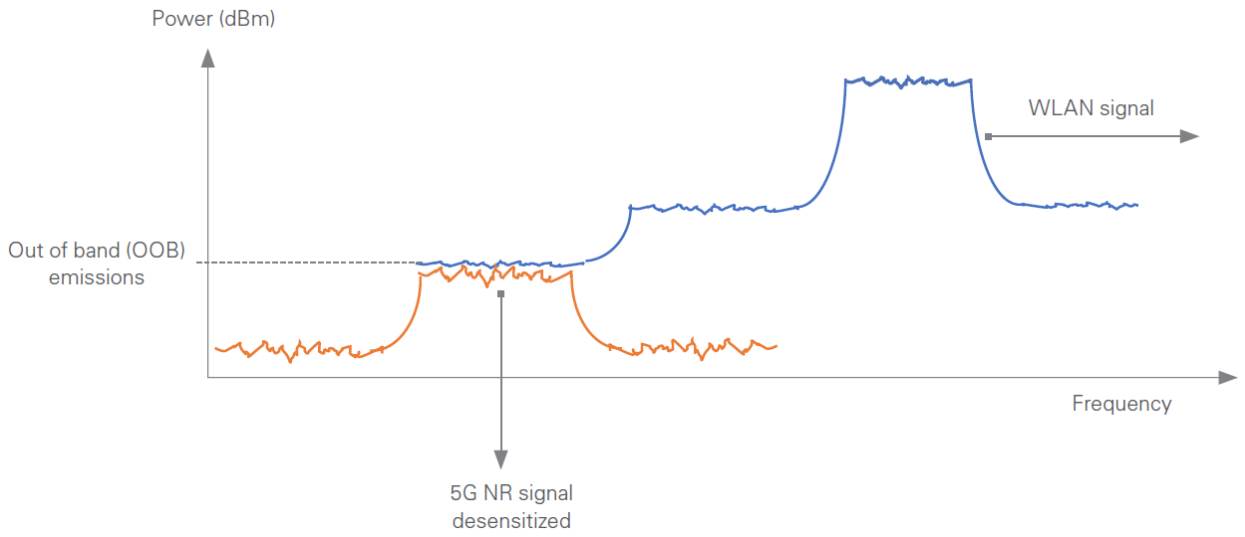
Agile Test Strategy

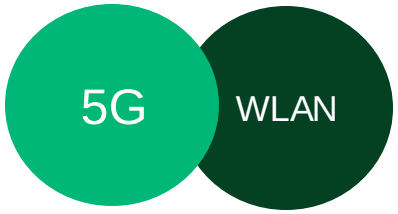
"Figures of merit like error vector magnitude (EVM) are highly dependent on yet-to-be-determined physical layer characteristics. We require test equipment that has not only the RF performance needed but also the flexibility to generate or acquire a wide range of IQ data using waveforms from various sources.

…We can't just recompile a PA to get better EVM performance, as getting better EVM requires a thorough understanding of the electromagnetics and thermals and requires lots of characterization."

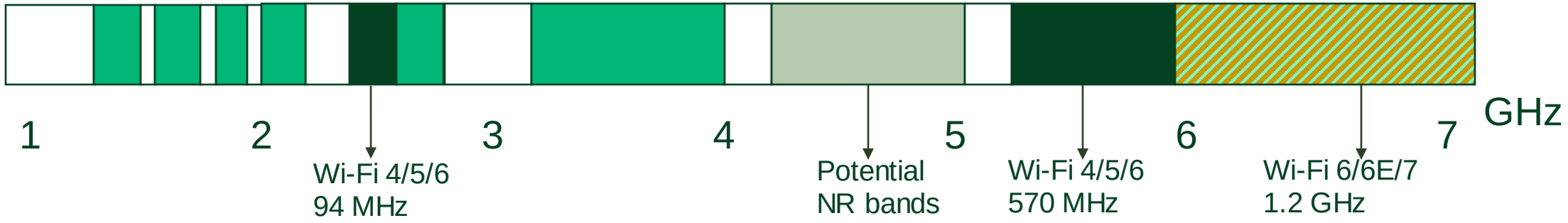
- Dirk Leipold, Qorvo

Wi-Fi Coexistence: NR-U, Mobility, and Expansion



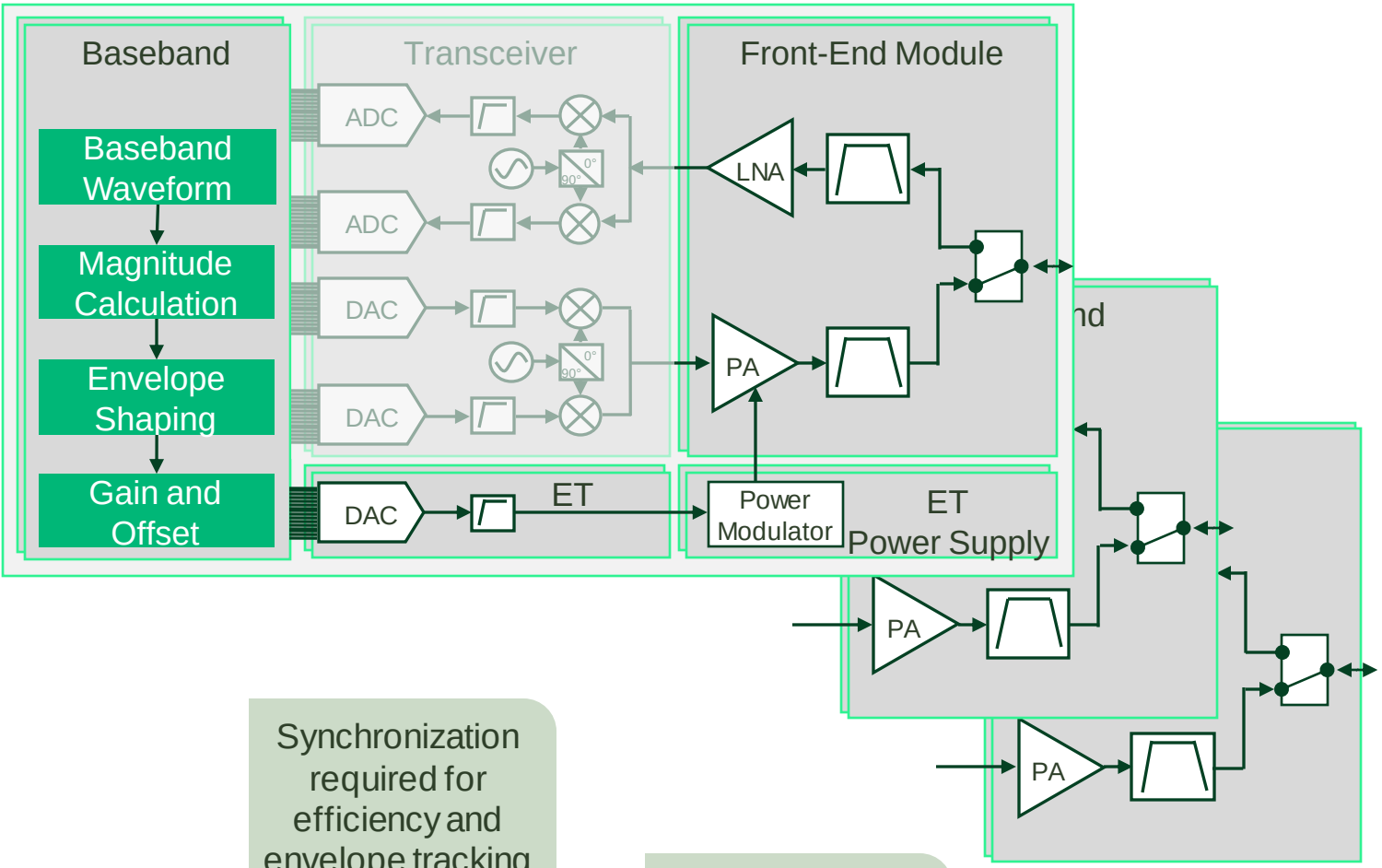


Integration of Multi-technology Radios



Need Flexibility to Test for Coexistence of 5G and Wi-Fi

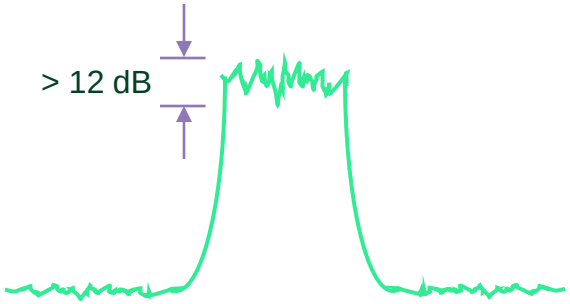
New RF Front-end Designs Drive More Complex Measurements



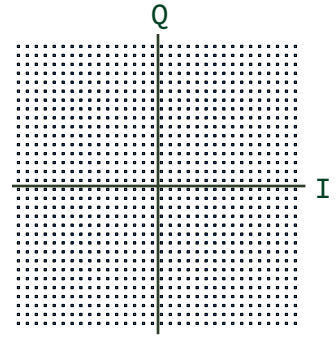
Synchronization required for efficiency and envelope tracking

Greater power efficiency

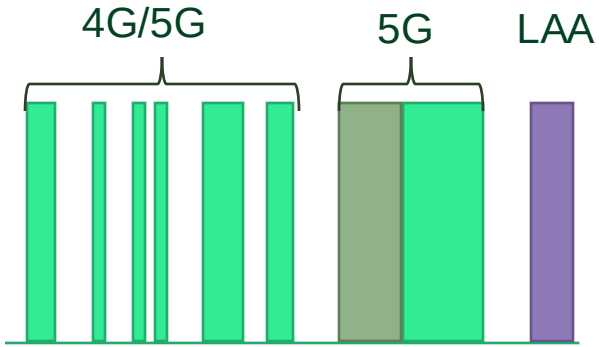
Higher Peak-to-Average Ratio Signals



Higher linearity for complex modulation



Wide, carrier-aggregated waveforms

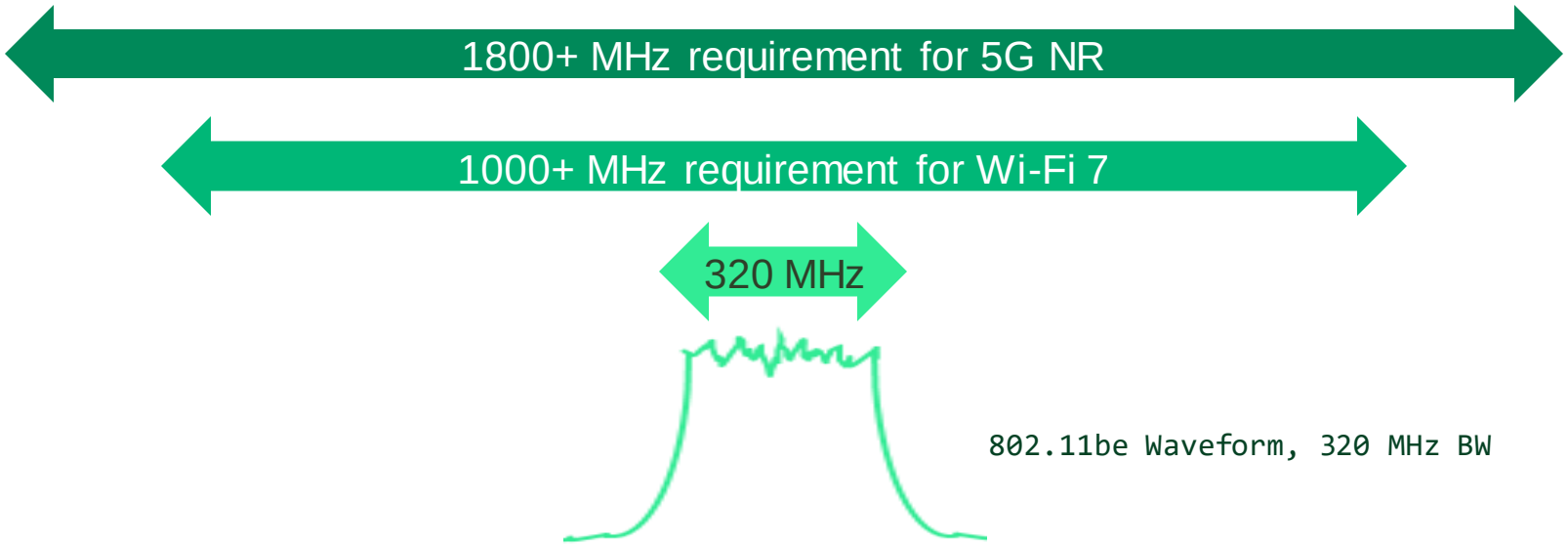


More Signal Chains for new bands and MIMO operation

Digital Pre-Distortion

Need for more bandwidth, more complex algorithms

- Digital pre-distortion can require 3-5 times signal bandwidth
- This can mean bandwidth requirements anywhere from 1000 MHz to 1800 MHz for the latest 5G NR and W-Fi 6E/7 waveforms



"The measurement speed of PXI was very attractive to us. In fact, the VST's measurement speed was about 5 times faster than our previous test equipment. This has allowed us to cut the characterization time for a typical LTE modem from one week to less than 2 days…With the additional testing that we were able to perform using PXI, we estimate that we have saved several million of dollars."

ni.com

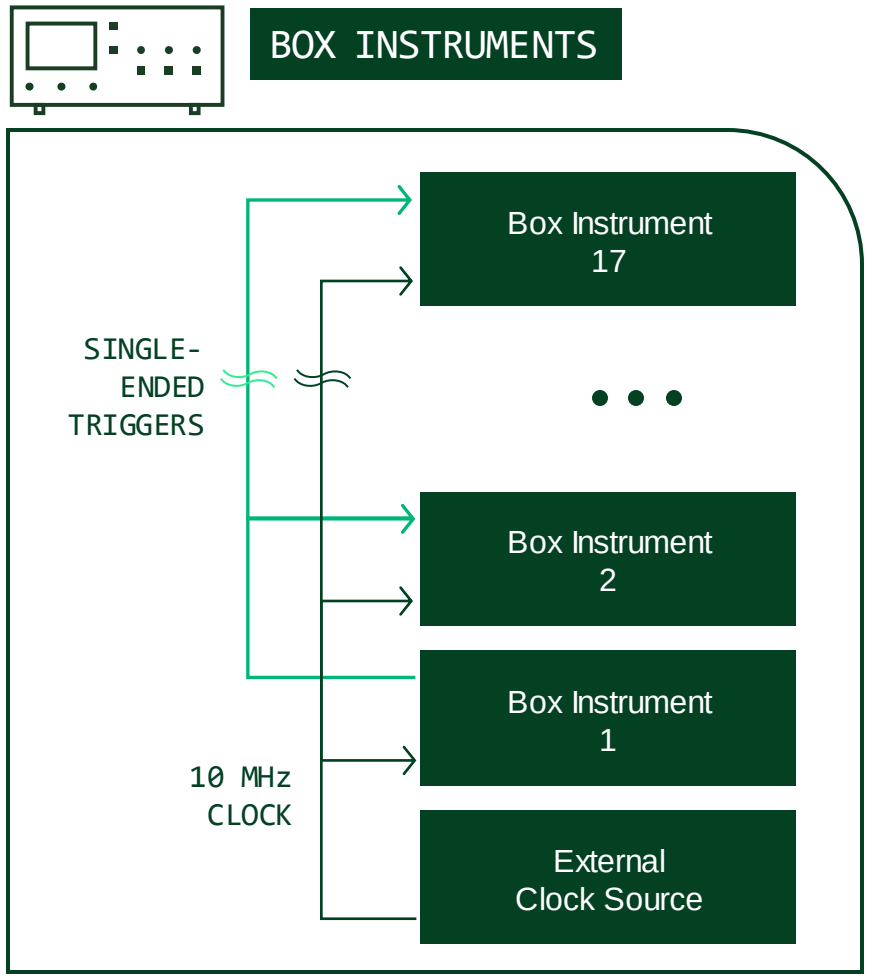
—Eike Ruttkowski, Head of RF Cellular Hardware, Intel

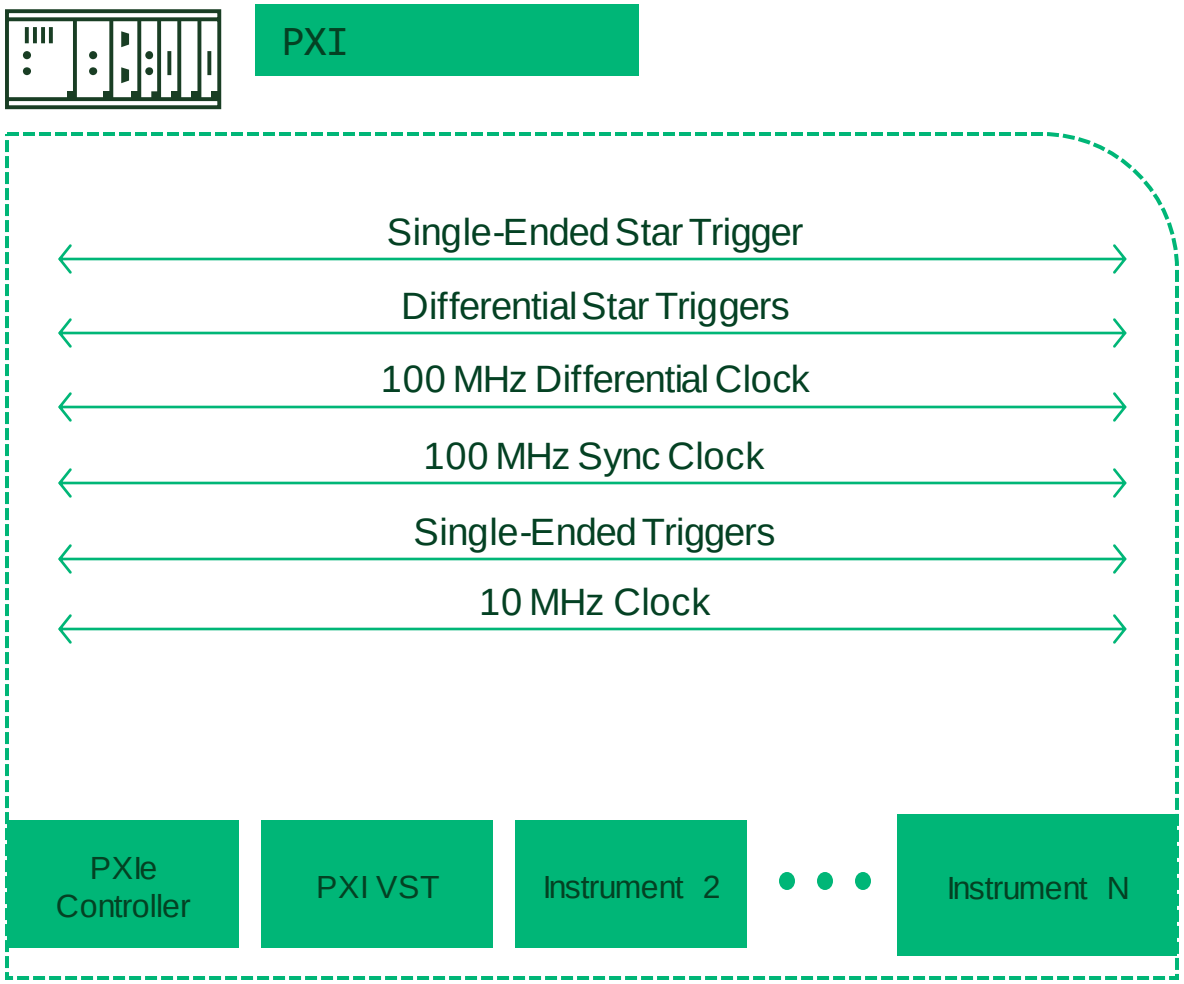
5x faster test times

Reduced tester footprint by 50%

Saved several million $$

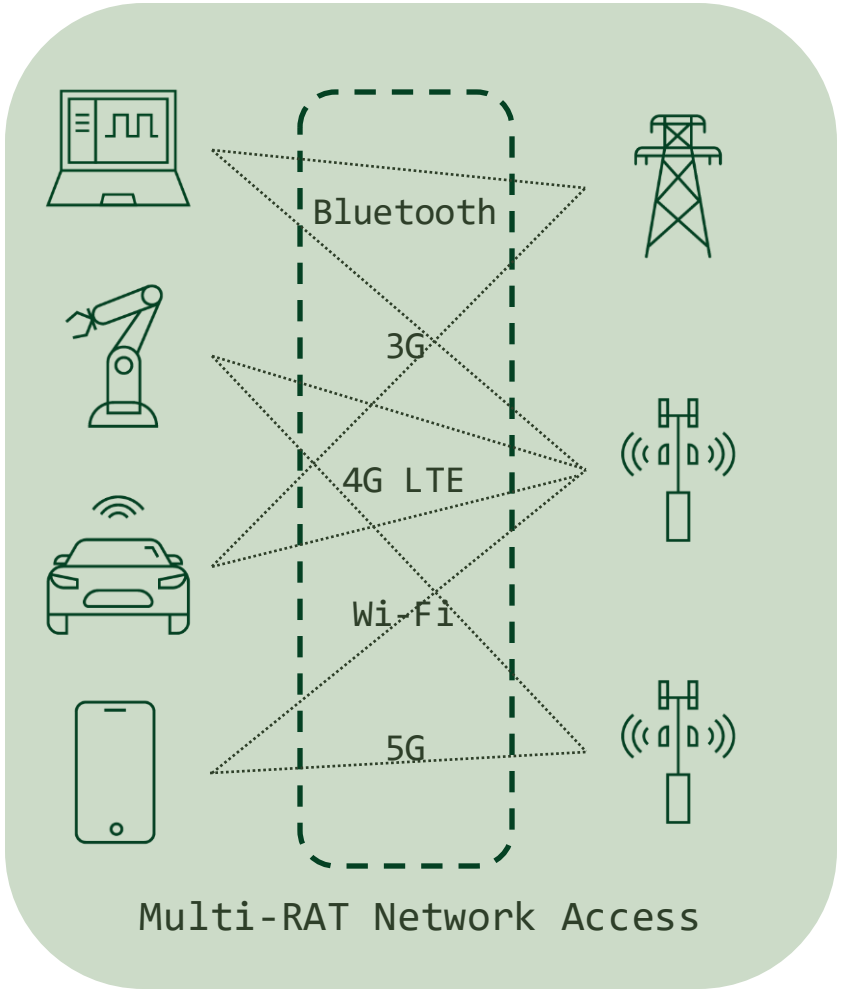
Speed & Synchronization – Crucial for Efficient Test

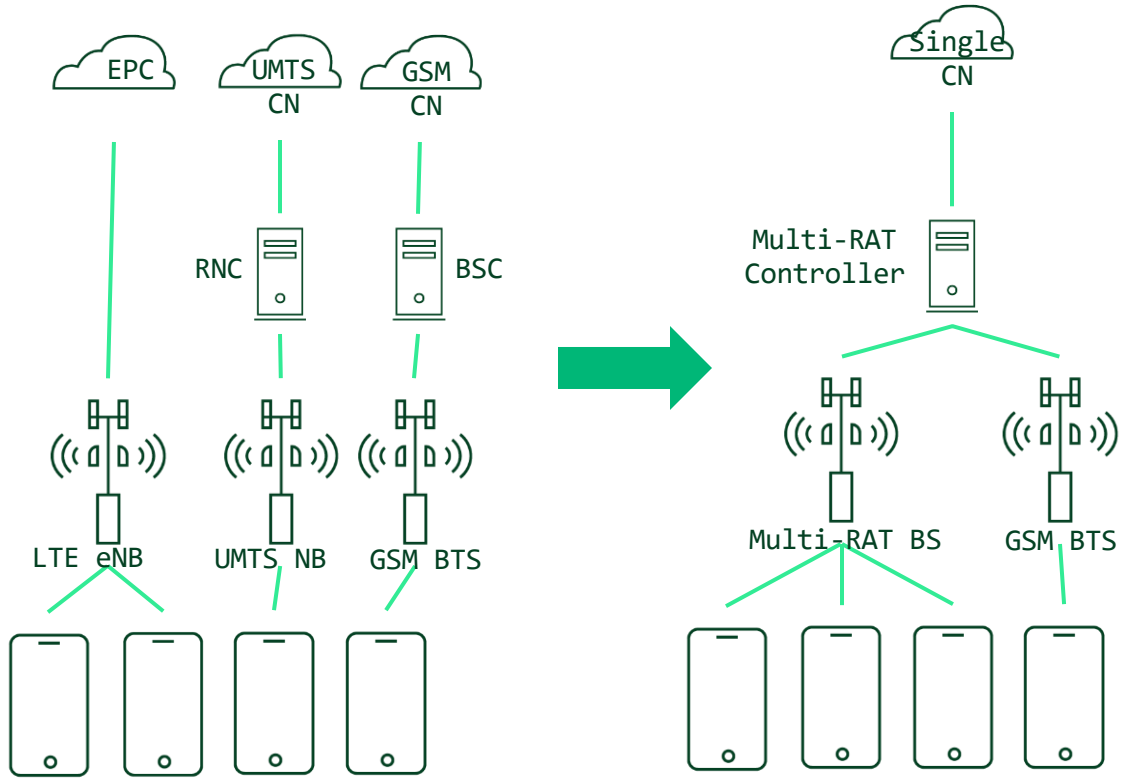




Multi-RAT

Device Complexity will increase





RF Front ends for base stations, UEs need to be developed (and tested) for different wireless standards

Testing Considerations…

- Capital equipment cost
- Speed
- Measurement Coverage
- Measurement Performance
- Usability
- Automatability
- Debuggability
- Waveform configurability
- Bandwidth: Dual-Band?
- Digital Predistortion
- Multi-instrument synchronization for measuring efficiency and envelope tracking
- The list goes on…

NI Approach

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

Reduce time to market by accelerating RF semiconductor development

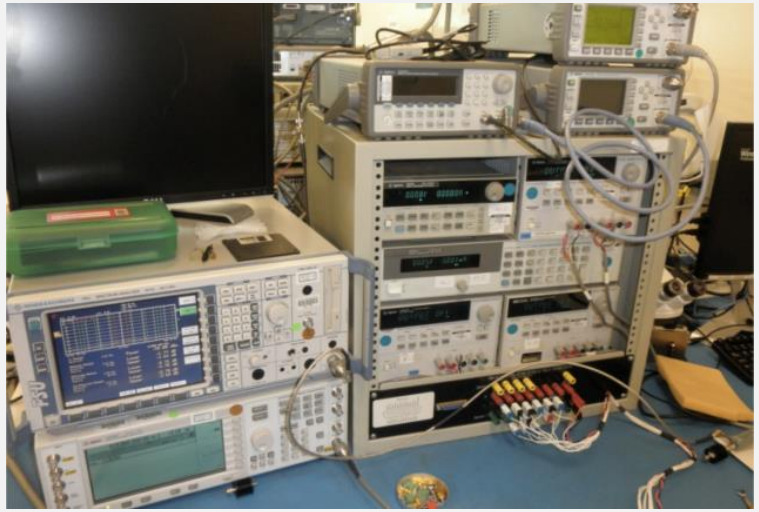
Deliver customer satisfaction by improving functionality and reliability

Improve the bottom line by reducing operational cost

Prepare for the future by adapting to evolving wireless standards needs

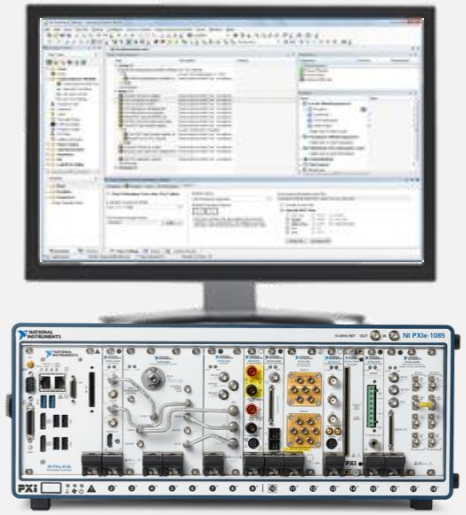
Two Distinct Approaches to FEM Characterization

Traditional Approach



- Familiar user experience for many engineers
- Slower measurement speed
- Expensive to upgrade or replace – even Software
- Difficult to synchronize for ET & DPD
- Large physical footprint
- Tradeoffs between speed and accuracy

Platform-Based Approach

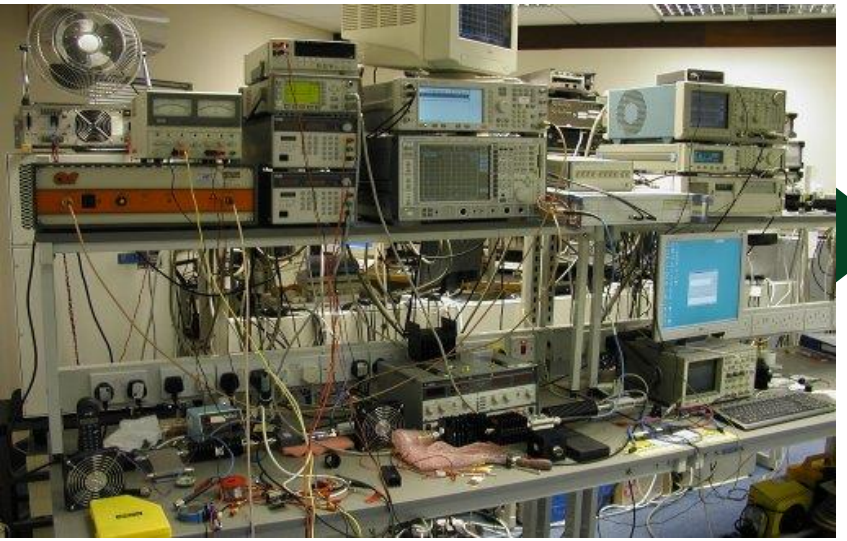


- Familiar measurement APIs with interactive SFPs
- Faster and FPGA-accelerated measurement speed
- Less expensive to upgrade – especially Software
- Native synchronization technologies
- Smaller physical footprint
- R&D grade accuracy with production test speed

Automation Drives Faster Device Characterization

INCREASING AUTOMATION

Traditional Lab Approach



- **Separate** workflow for design and validation
- **Different** waveforms, PA models, analysis algorithm
- **Expensive**, **large** footprint, **poor** synchronization

Modern Lab Approach

Interactive Measurement & Debug Stations

Standard Automation Platforms

Reproduceable & Scalable Automation

STREAMLINED, STANDARD AUTOMATION PLATFORM

- **Integrated** workflow for design and validation with R&D grade accuracy HVM speed
- **Same** waveforms and analysis algorithms to accelerate Time to market
- **Modular**, **small** footprint, **sub-nanosecond** synchronization

Modern RF Lab – Streamlined Workflow

From Interactive Bring-up to Extensive Automated Validation

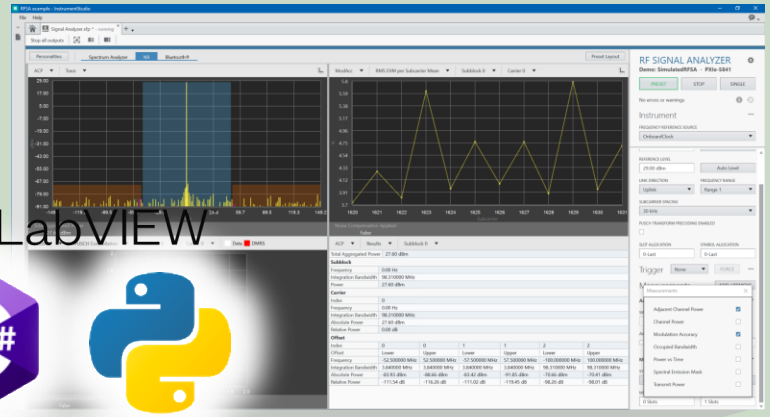
Rapid, Interactive Bring-up

Fully Automated Validation

Instrument Studio™

RFIC Software

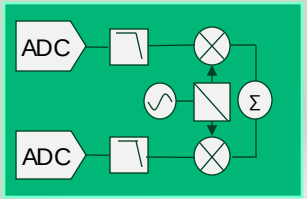
TestStand™



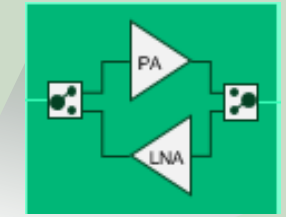
LabVIEW

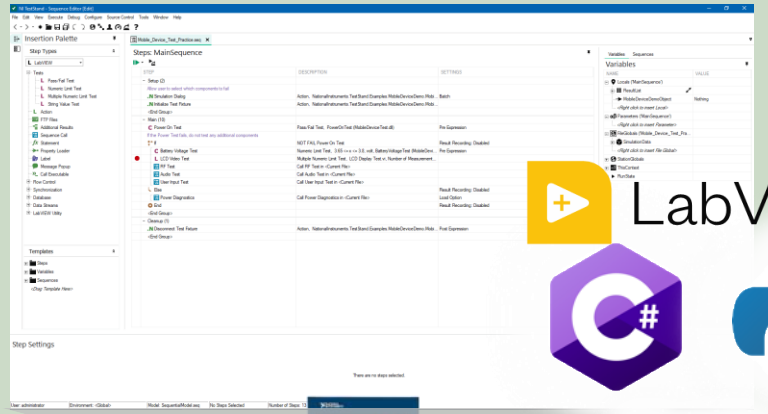
C/C++

Transceivers



Front-ends

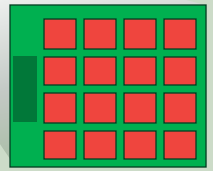




LabVIEW

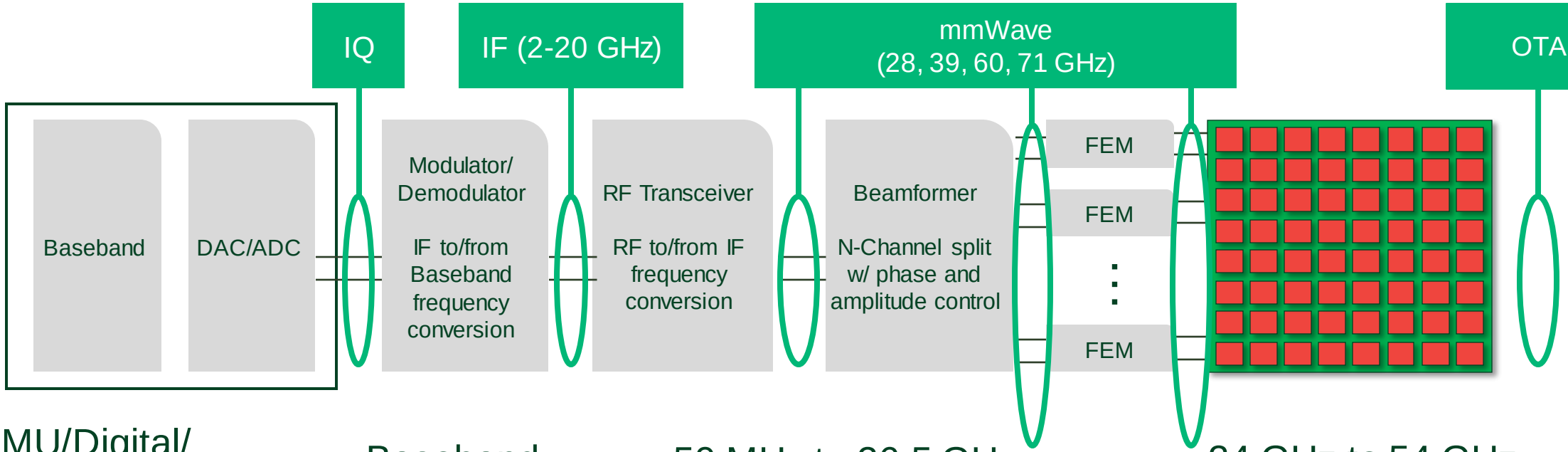
C/C++

Beamformers



Antenna Modules

Instruments Designed To Cover All Applications

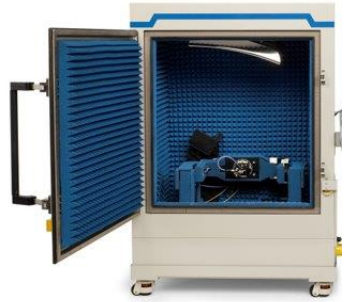


SMU/Digital/
DMM/Scope

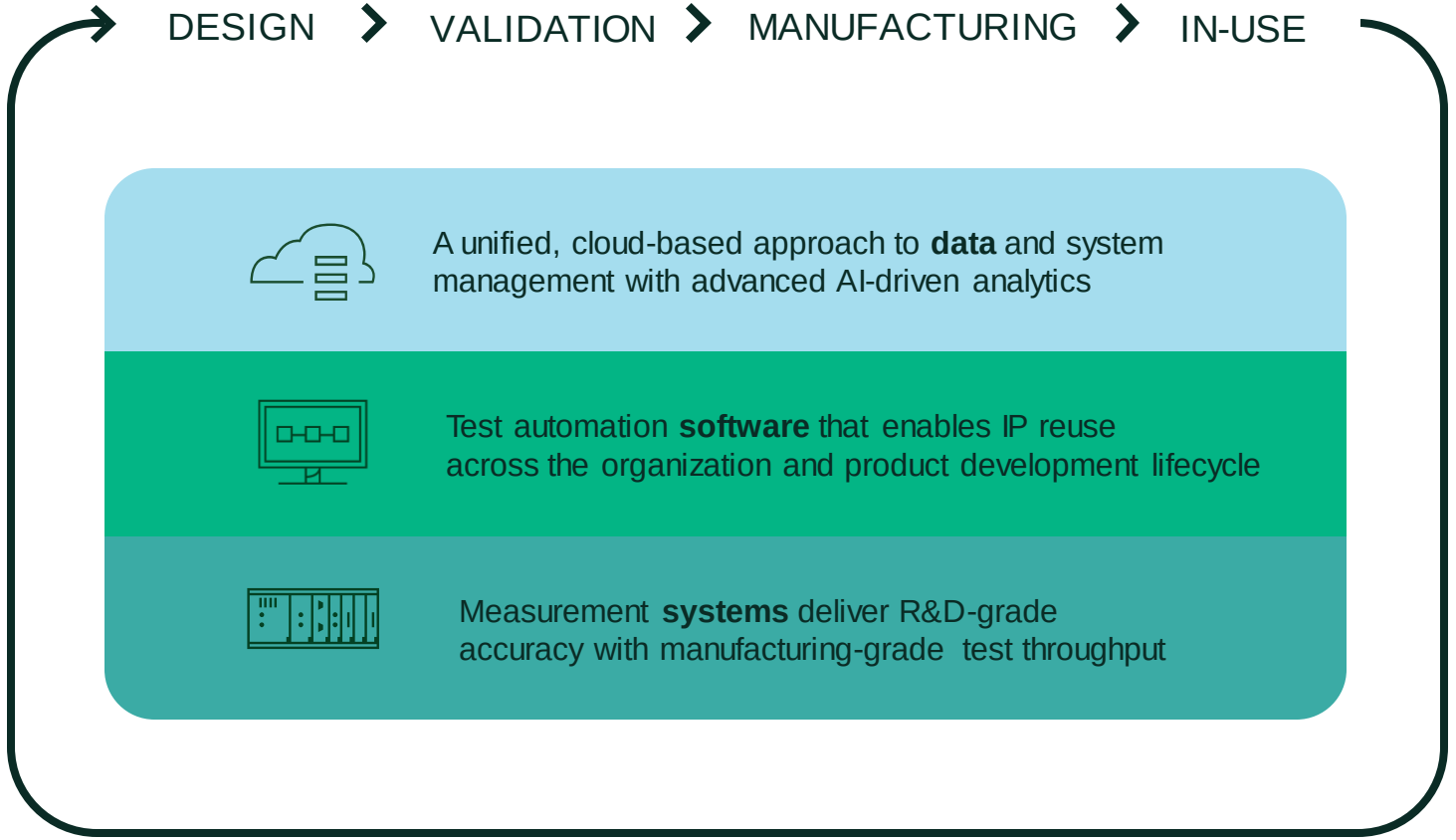
Baseband

50 MHz to 26.5 GHz

24 GHz to 54 GHz

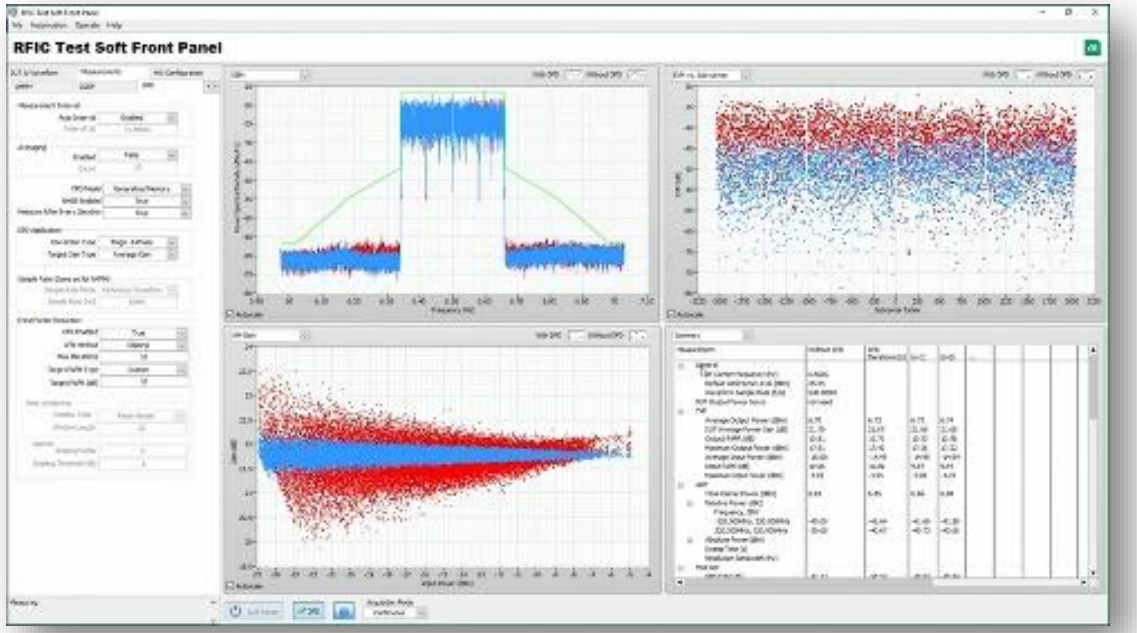


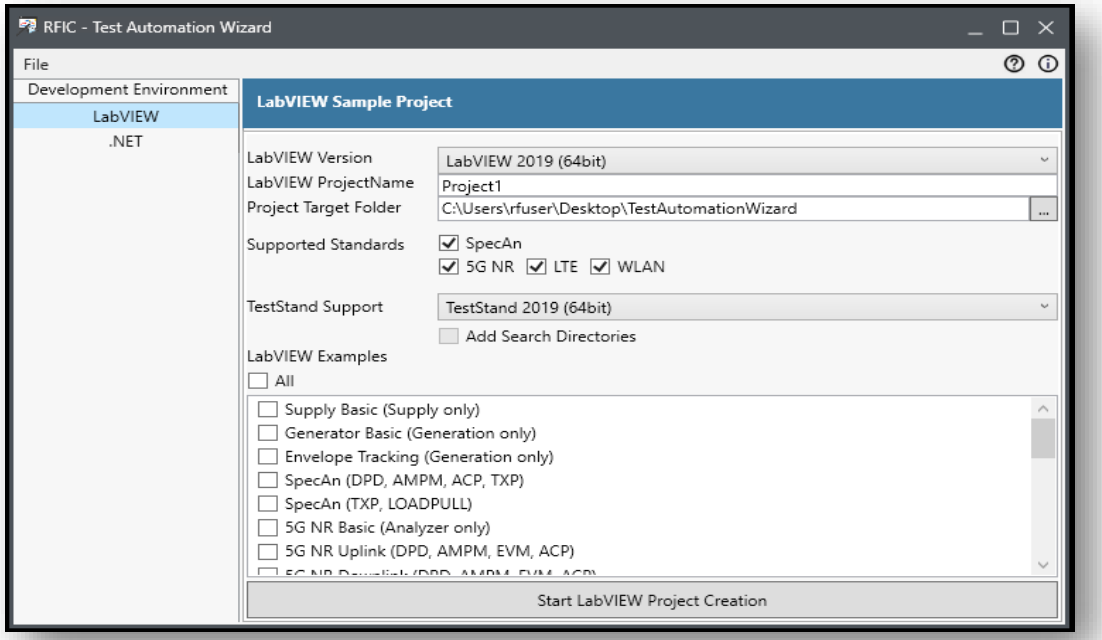
Our integrated, software-connected approach simplifies connecting systems and data across the enterprise, making it easier to gain insight through test.



What does RFIC Test Software offer?

General Introduction for RFIC Test Software





RFIC Test Soft Front Panel

- Targets for quick DUT bring up, validation, and interactive measurements
- Supports import/export configuration for reuse
- Supports export measurement results for post analysis

Test Automation Wizard

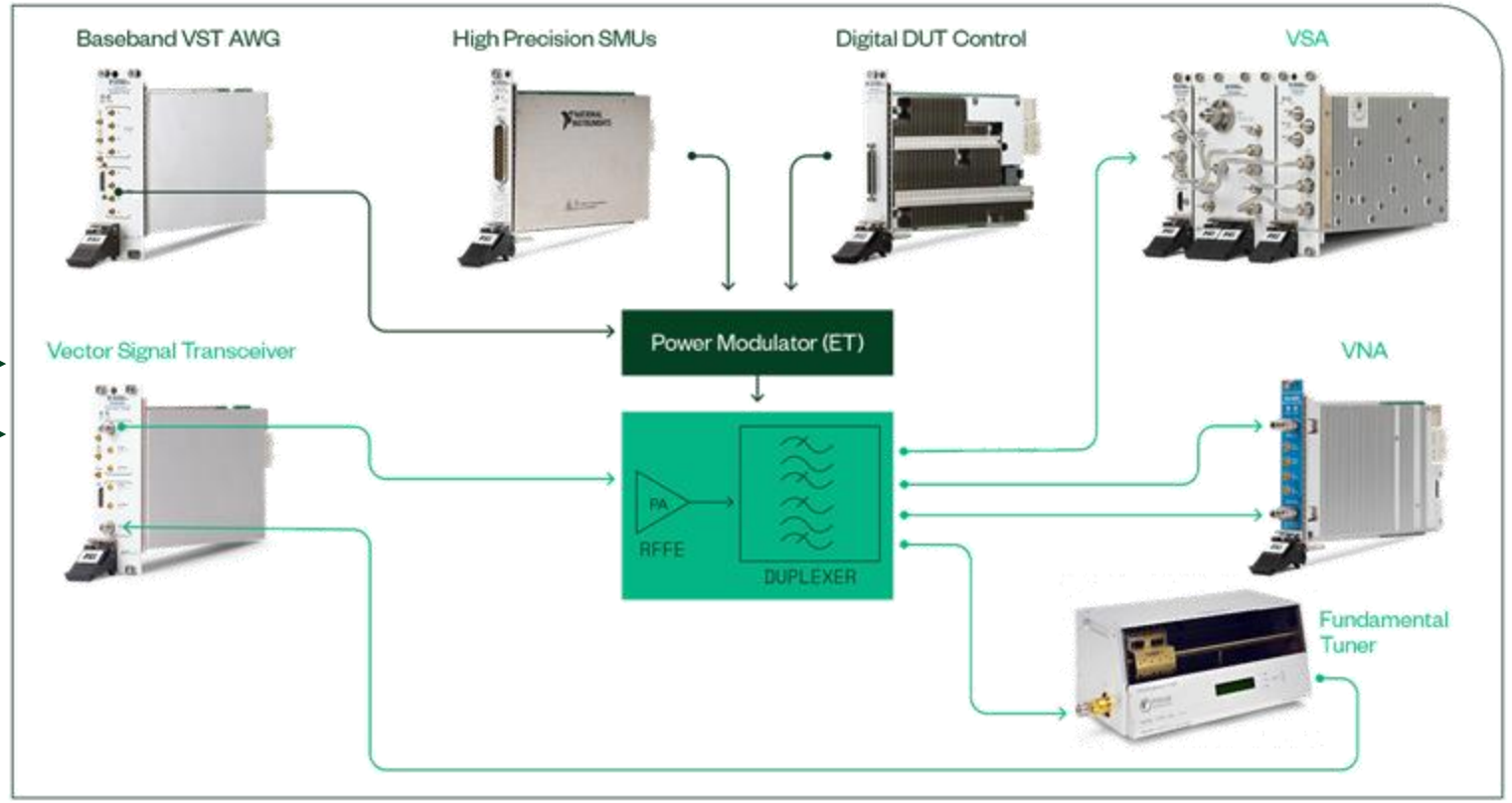
- Generates reference design libraries (RDLs) & examples
- Generates automatic TS sequences
- Supports both .NET and LabVIEW

Related Link: RFIC Test Software User Manual

Tight Synchronization of DC, Analog, Digital, and RF

RFIC Application

RF Reference Design Libraries and Example Code



- Complete lab bench automation for sub-8 GHz RFFE & TRx DUTs
- Leading adoption of industry standards in cellular & WLAN
- Bridge between design verification and production test

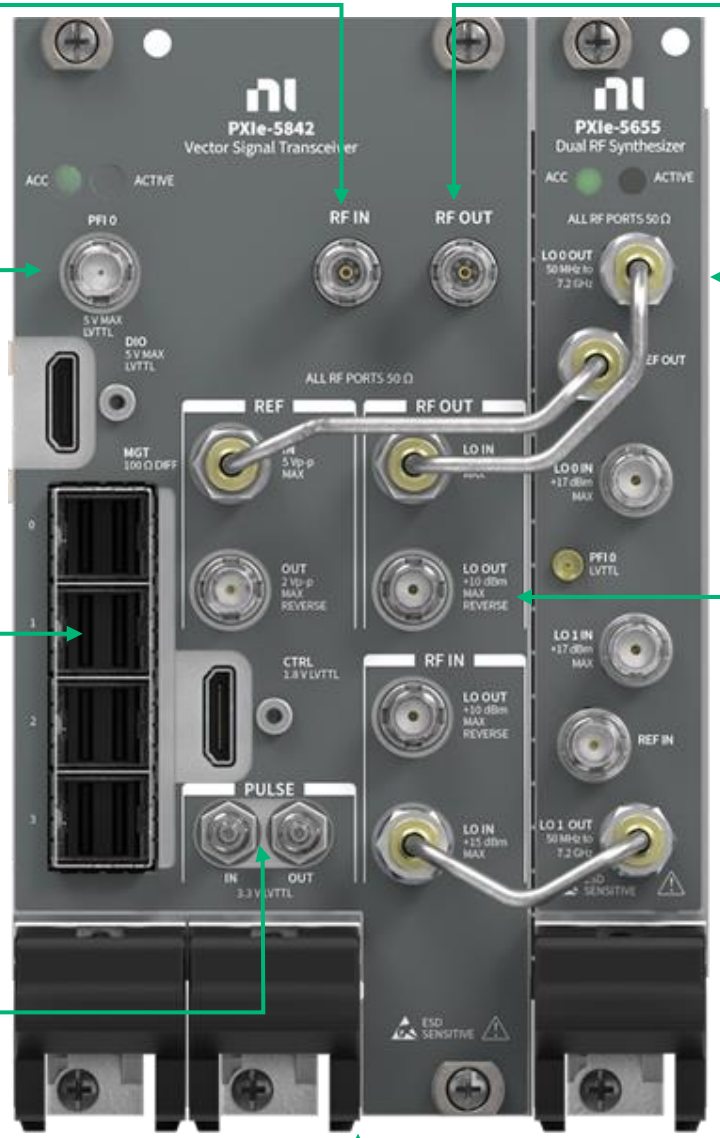
PXIe-5842 | Overview

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

PFI 0 (Trigger / Event)

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
(Available H2.2023)



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

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 Footprint
Requires only 4 PXIe slots

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
-49 dB	Wi-Fi 7, 320 MHz bandwidth, 6 GHz
-56 dB	5G NR, 100 MHz bandwidth, 5.5 GHz

SEMICONDUCTOR TEST

qorvo

Accelerating Complex 5G Front End Validation

"Without NI's platform, we would not have been able to meet our 5G release timelines."

—Ben Thomas, Director, Mobile 5G Business Development, Qorvo

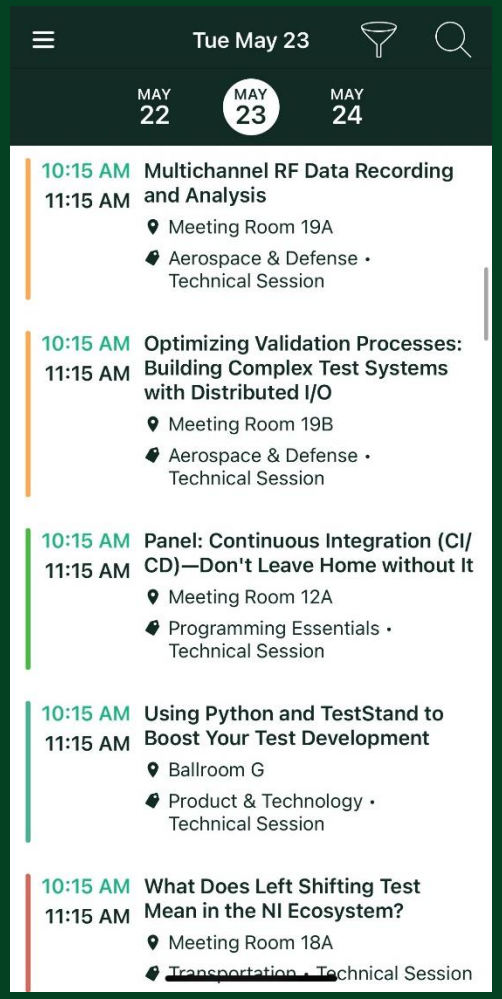
Learn more about NI's 5G, Wi-Fi Test Solutions

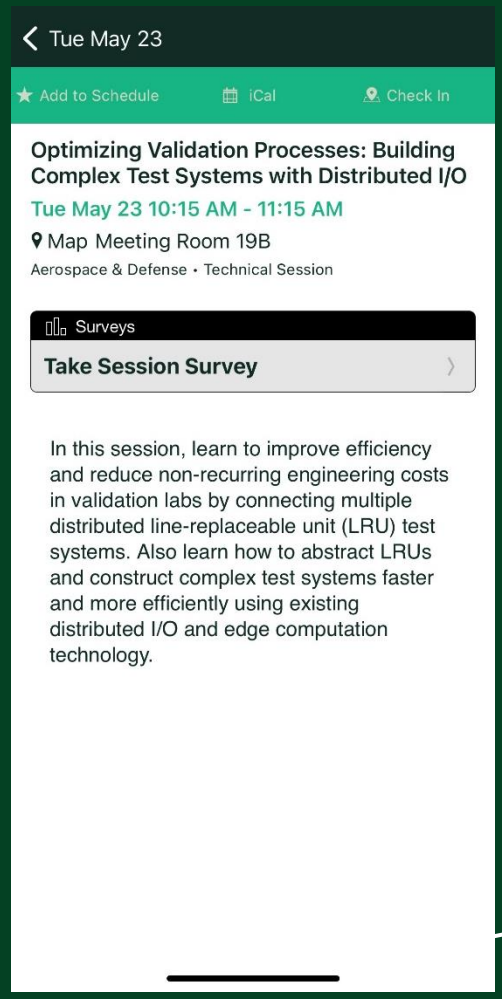
NI Connect Technical Sessions that dive deeper into concepts discussed here

How to get the most out of PXI VSTs	Wednesday 10:30 – 11:30
Navigating Wireless Infrastructure Test	Tuesday 2:00 – 3:00
Practical Implementation of a Standardized Test Architecture	Wednesday 11:45 – 12:45
Data, Analytics, and Specification Management with DataStudio	Tuesday 3:15 – 4:15
How to Build a MeasurementLink™ Plug-In	Tuesday 2:00 – 3:00

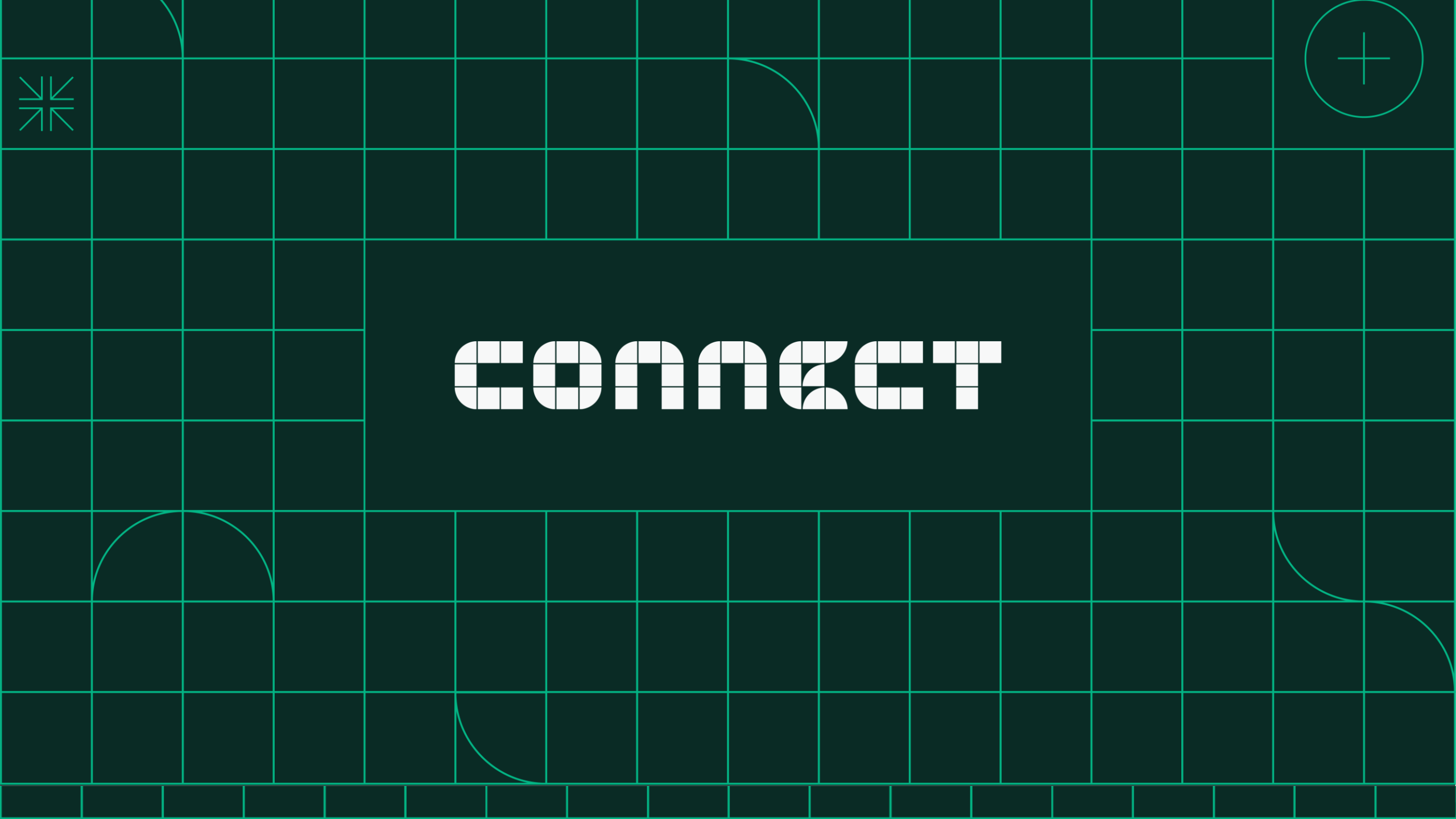
Give us your feedback!
Quick 2 Question Survey

In the mobile app, click into the session you would like to provide feedback for





Click “Take the Session Survey”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