NIDays09

WORLDWIDE GRAPHICAL SYSTEM DESIGN

CONFERENCE

NATIONAL INSTRUMENTS

Trends in Wireless Test

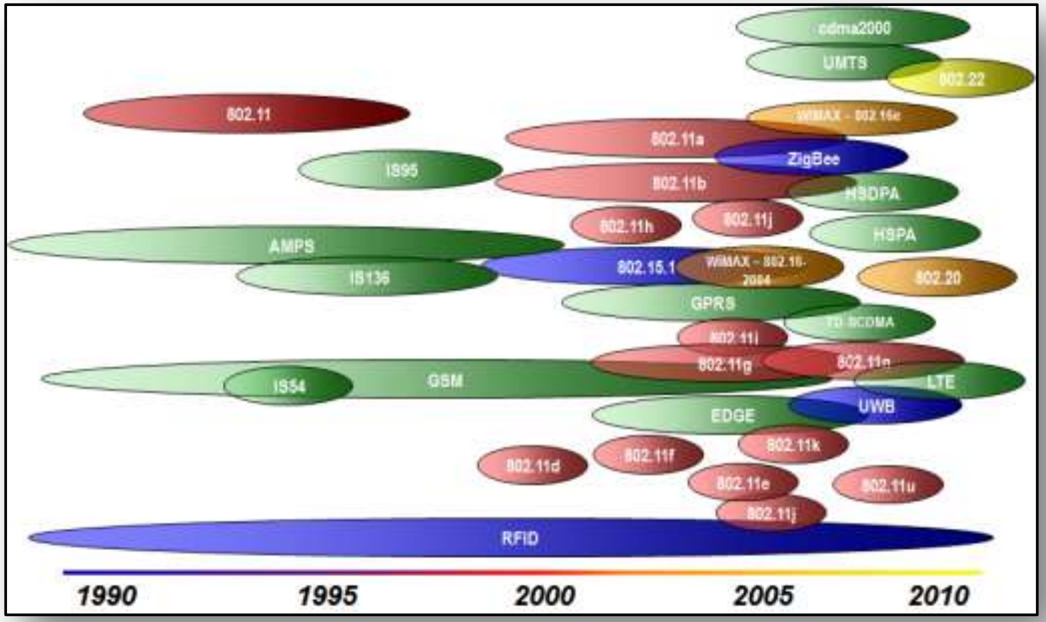
Benefits of Software-Defined Instruments for MIMO-OFDM Tests

"I do not think that the wireless waves I have discovered will have any practical application."

- Heinrich Rudolf Hertz (1857–1894)

Trends in the Wireless Industry

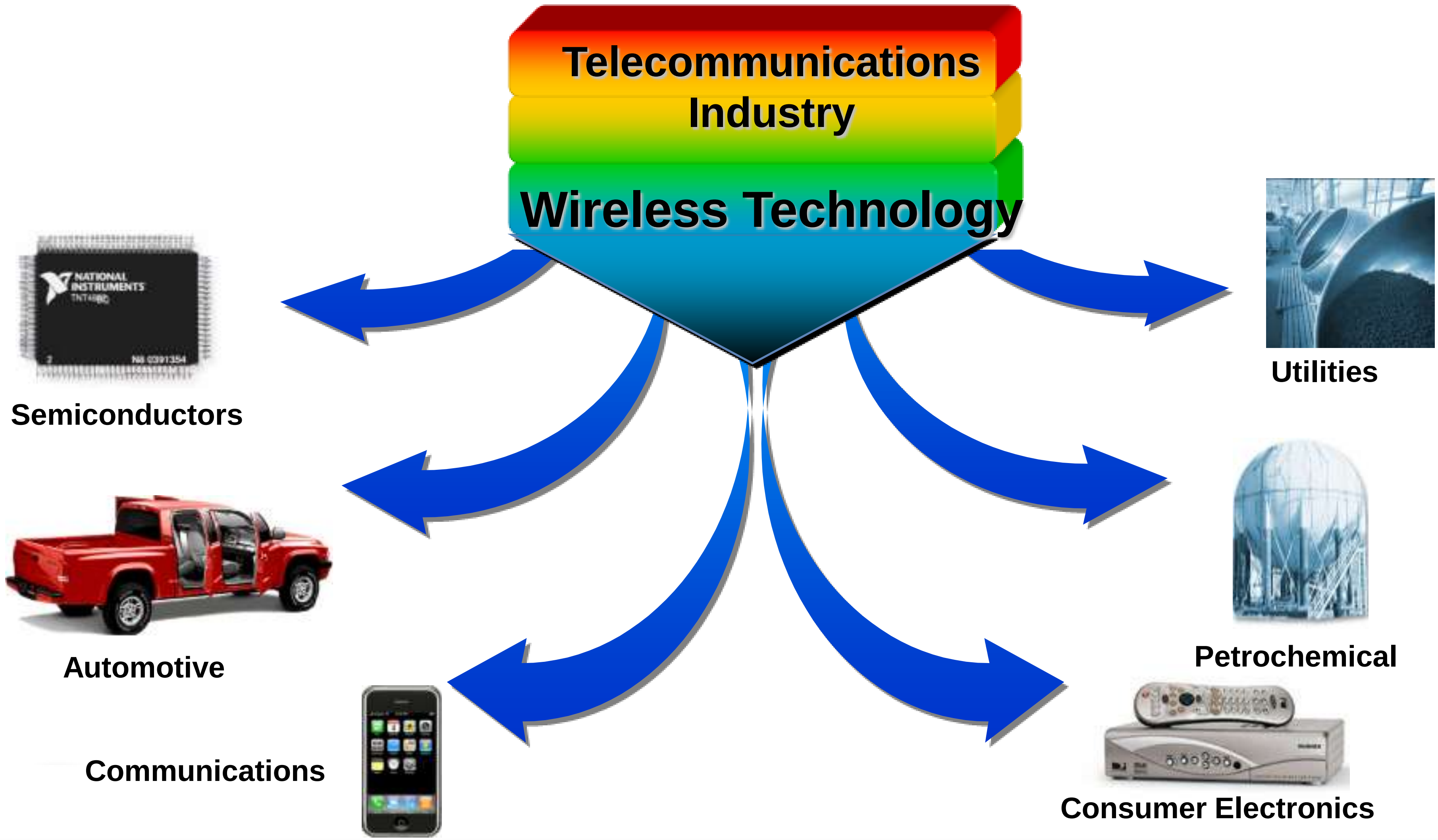
- New wireless standards continue to emerge
- Many devices require multiple protocols



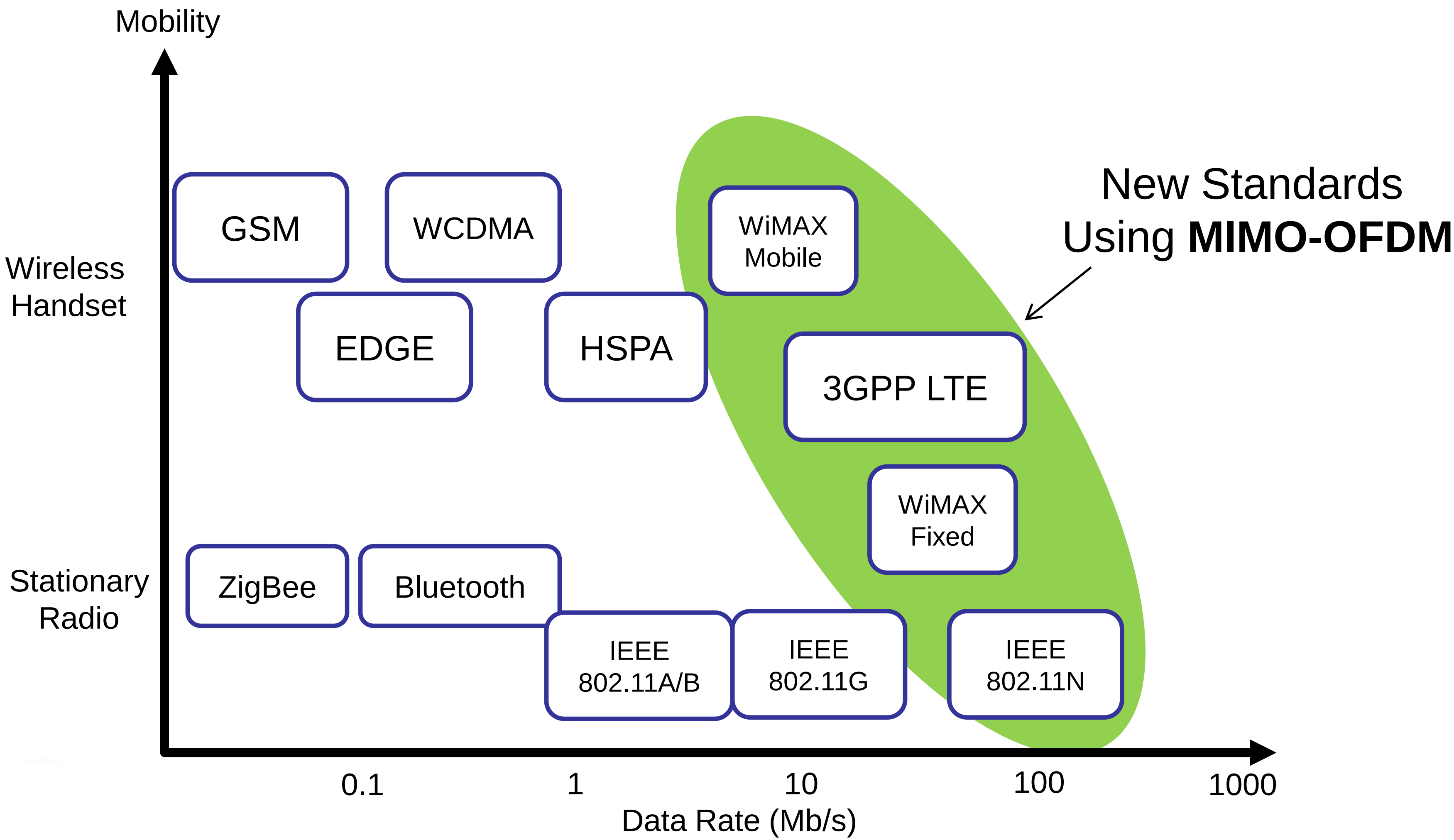
Agenda

- Trends in Wireless
  - New applications
  - Consumer needs drive innovation
- Challenges in RF Test
  - Reducing test time
  - Addressing multiple applications

Wireless Expands From Vertical to Horizontal



Increased Data Rate Drives MIMO-OFDM

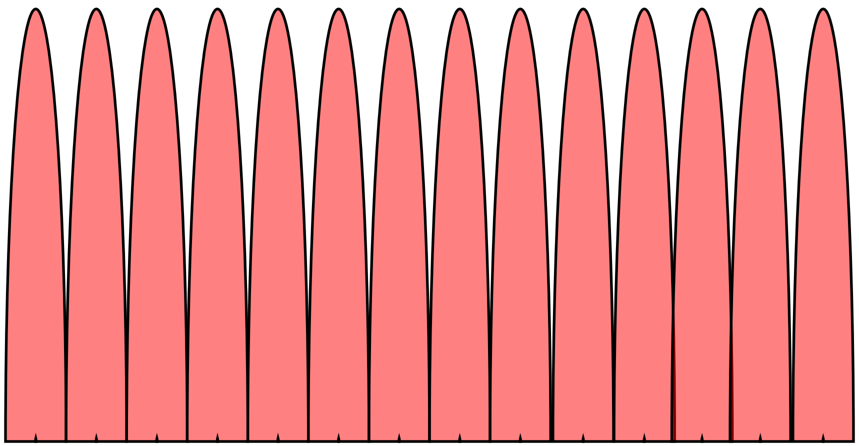


Emergence of MIMO-OFDM

- Commercial broadcast (DAB, DVB)
  - DAB requires OFDM
  - DVB uses OFDM and phase-diversity antennas
- WLAN Networks (802.11n)
  - Draft “N” standard uses up to 4x4 MIMO-OFDM
- WMAN Networks (WiMAX)
  - Already deployed in various regions (MIMO-OFDM)
- Fourth Generation Cellular (LTE)
  - In-work MIMO-OFDM standard
- Military (JTRS Wideband Networking Waveform)

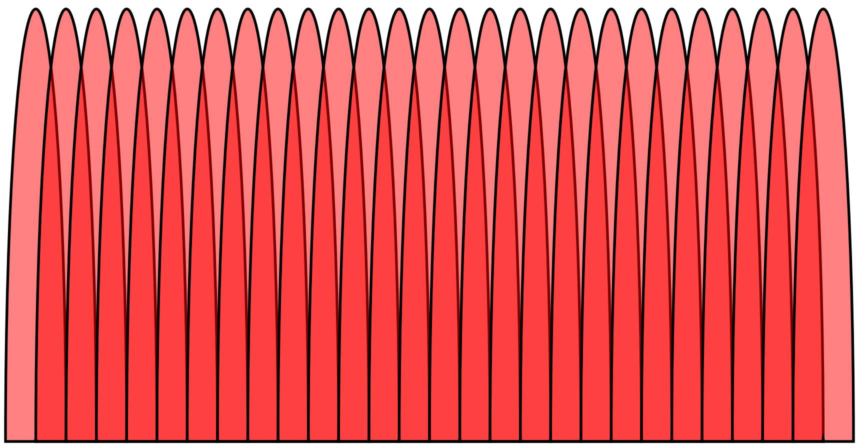
Ways to Utilize RF Spectrum

Traditional FDM



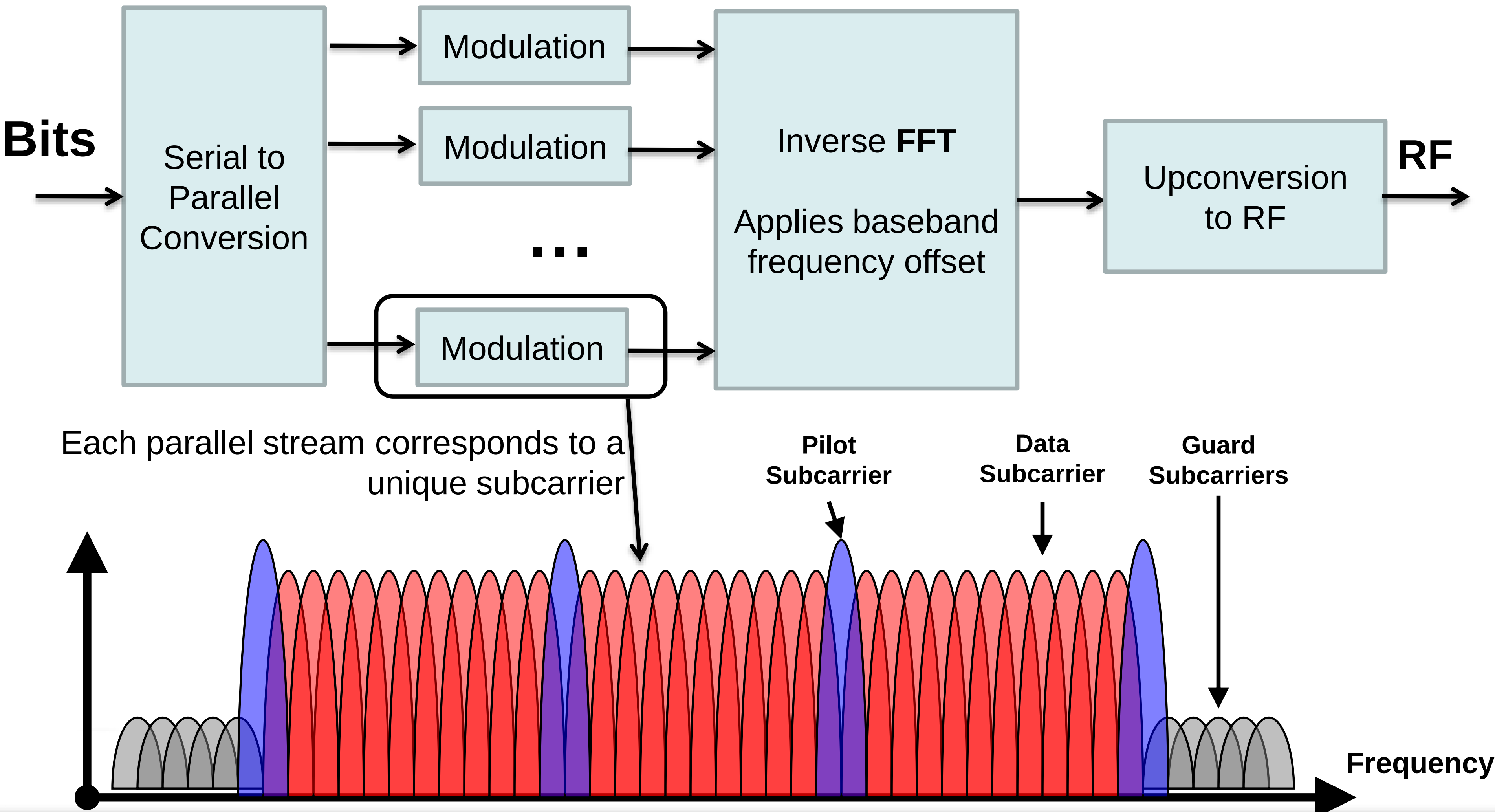
- Guard band needed to prevent adjacent channel interference
- Wide channels have significant inefficiency because of roll-off

Orthogonal Frequency Division Multiplexing (OFDM)



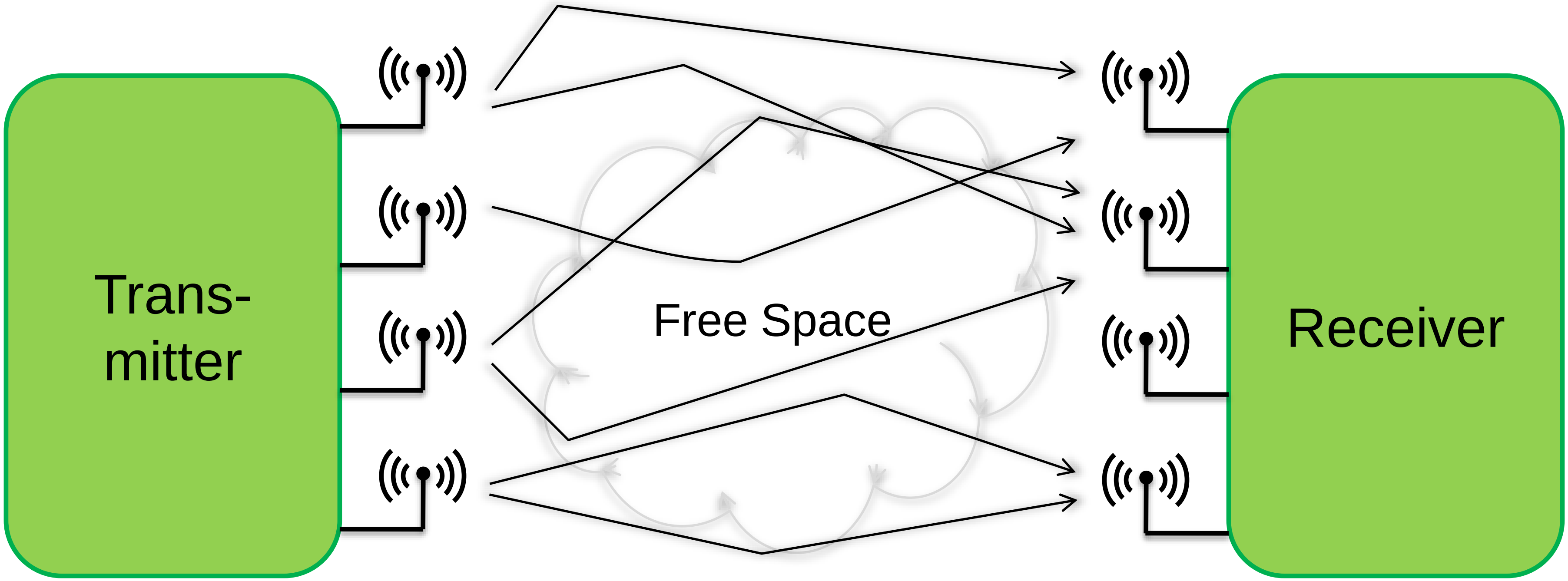
- Every subcarrier overlaps by 50%
- All subcarriers are transmitted together, preserving phase relationship
- Orthogonal subcarriers will not interfere
- WLAN, DAB, DVB, WiMAX, LTE

OFDM – A Detailed Look



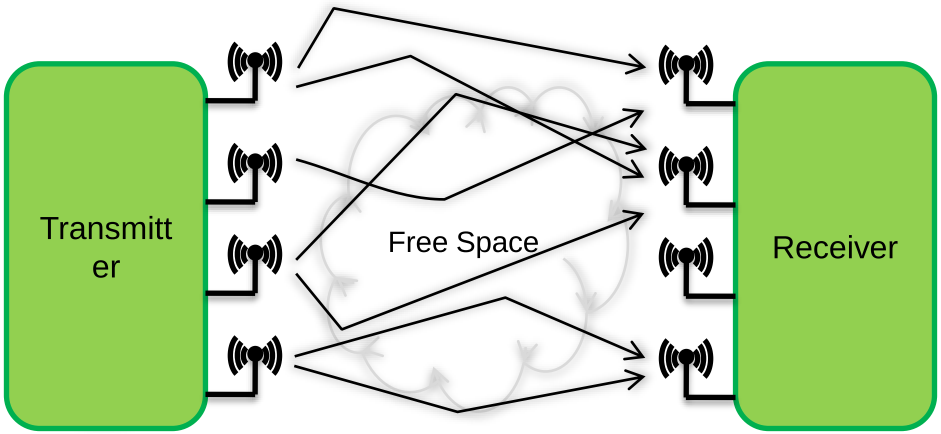
What Is MIMO?

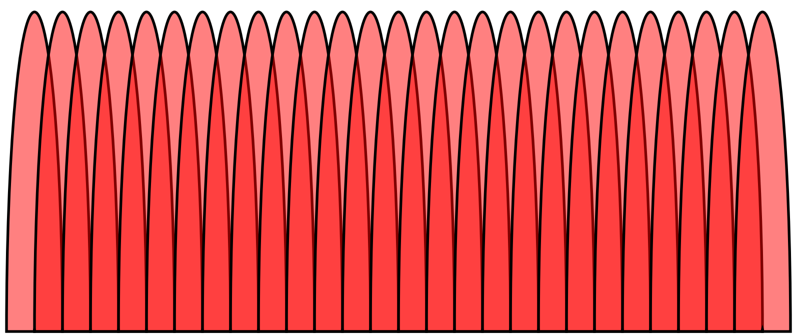
- Stands for “Multiple Input Multiple Output”
- Requires **phase-coherent** generation/acquisition
- Common configurations are 2x2 and 4x4
- Includes: 802.11n, WiMAX, LTE, and DVB



Why Combine MIMO and OFDM?

- Both provide optimal data rate for the bandwidth
- OFDM is resilient to multipath environments
- MIMO requires multipath environments





Trends Drive Test Platform Performance

- Many devices use multiple wireless standards
  - GPS devices using Bluetooth
  - Cellular devices using WLAN
  - RFID devices using GPS
- MIMO-OFDM measurements require software changes
- Instrumentation often required to test multiple protocols
  - Requires faster measurements than ever
  - Requires more unique measurements than ever

The NI RF Platform

Customizable in Software

Long-Term Stability

Customer Test Management Software

GSM/ WCDMA | *Bluetooth* | *RDS* | *GPS*

Communications Toolkits
Spectrum and Modulation VIs

Driver Software

PXI/PXIe Instrumentation

TestStand™

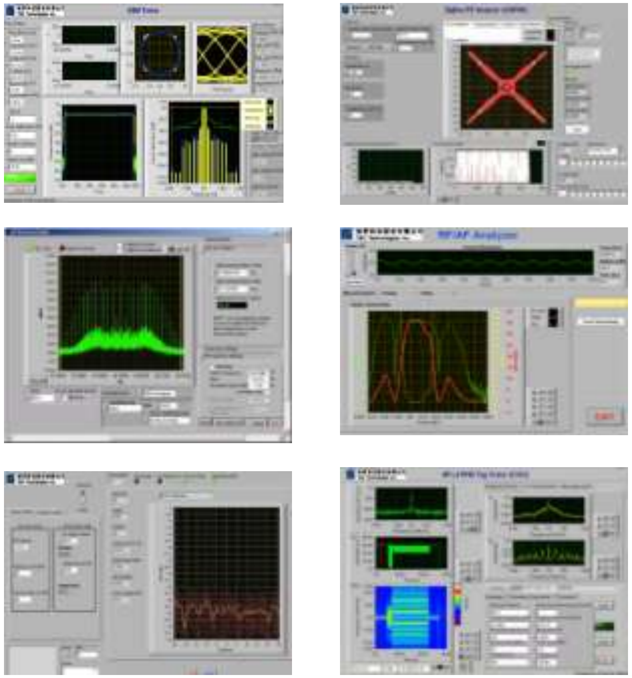
LabVIEW™

Software-Defined Advantage

All in one PXI Platform!

- **GSM Tester**
- **WLAN Tester**
- **Spectrum**
- **Radio Tester**
- **Power Meter**
- **RFID Tester**

Multiprotocol UUT



Images courtesy of Agilent, Tektronix, R&S, and Anritsu

Leveraging Technology Trends

- Multicore processors
- Platform architectures that feature the latest FPGA technology
- Software defined Instrumentation

New 6 GHz Analyzer and Generator

NI PXIe-5663 VSA

- Single-stage heterodyne downconverter
- 10 MHz to 6.6 GHz
- 50 MHz instantaneous bandwidth (3 dB)
- -112 dBc phase noise (10 kHz) at 1 GHz
- -158 dBm/Hz typical DANL at 1 GHz
- 80 dB SFDR

NI PXIe-5673 VSG

- Direct RF upconversion
- 85 MHz to 6.6 GHz
- >100 MHz instantaneous bandwidth
- -112 dBc phase noise (10 kHz) at 1 GHz
- Up to +10 dBm RF output power
- Better than -60 dBc carrier and image

Challenge 1: Reducing Measurement Time

- Sources of Measurement Time
- Effect of Processor Performance
- WCDMA (3 G Cellular) Measurements

Automated Test Time for DUT

Set up UUT (Synchronization, RF channel, power level) → **Acquire data for measurements** → **Perform measurements**

- Test modes in baseband chip software
- Control interface to UUT (Serial, USB,)

- Data defined by measurement
- Averaging
- **Instrumentation bus**

- Measurement defined by standard
- **Processor speed**
- **Software architecture**

NATIONAL INSTRUMENTS™ TestStand™

PCI EXPRESS®

Example 1: 50 MHz Spectrum

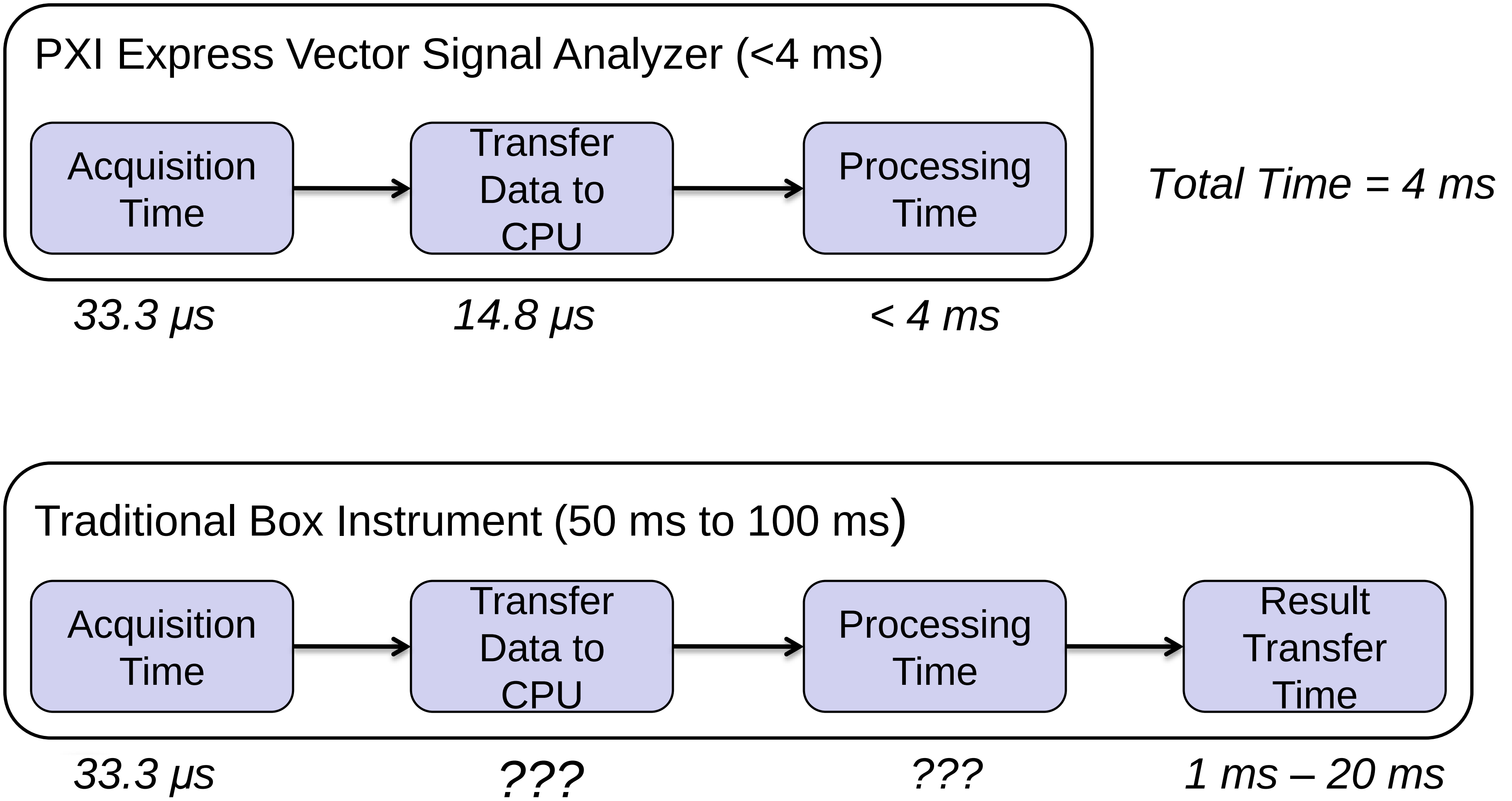
$$AcquisitionTime = \frac{1}{RBW}$$

$$FFTSamples = \left(\frac{1}{RBW}\right) \times 1.25 \times Bandwidth$$

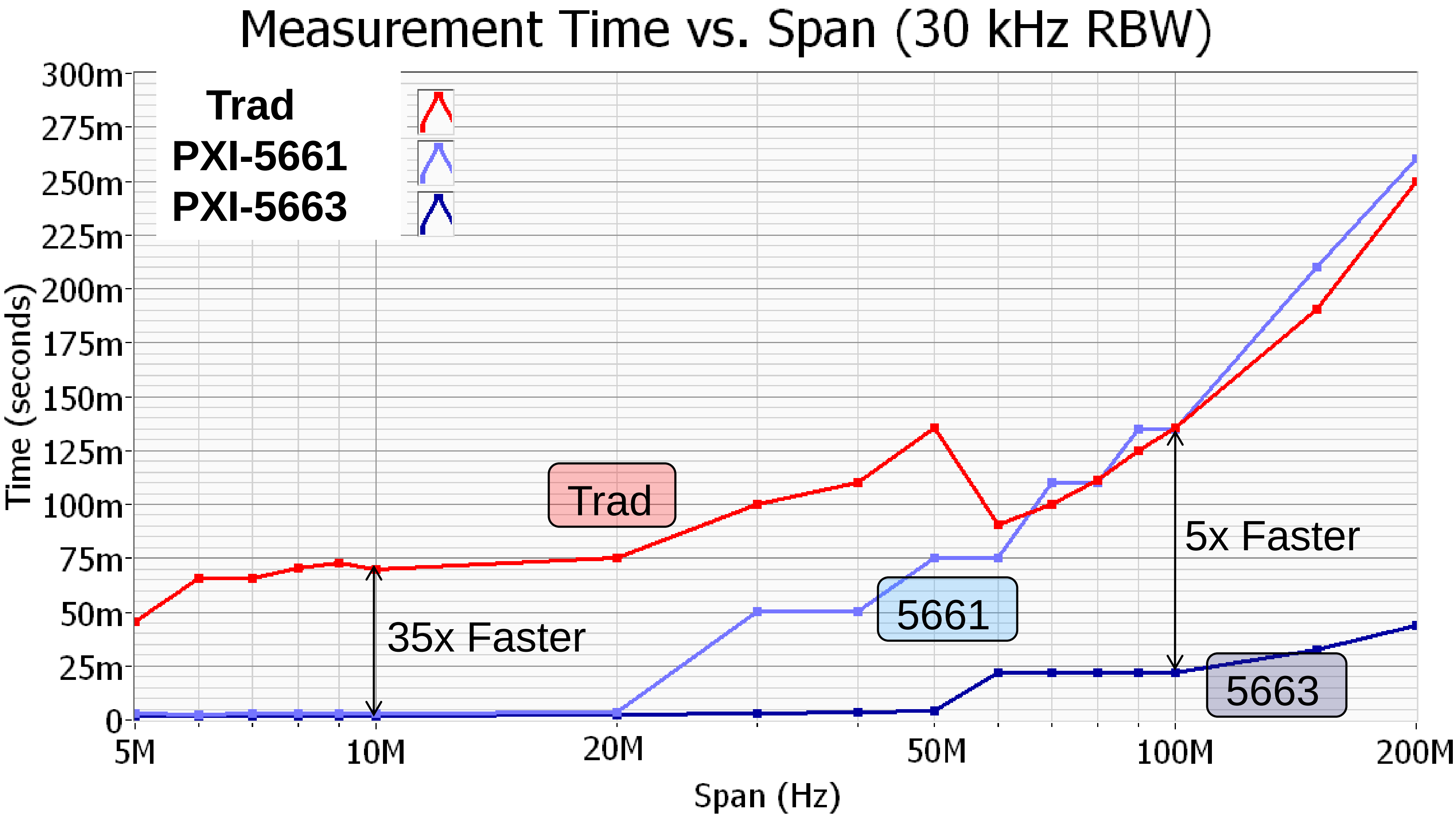
- For 50 MHz span, sample rate = 62.5 MS/s
- For 30 kHz RBW, acquisition time = 33.3 μs
- FFT Samples = 2082 (8328 bytes)
- Total transfer time over PCIe is ≈ 14.8 μs*

*assuming 1 μs latency and 600 MB/s data rate

Anatomy of Overall Measurement Time

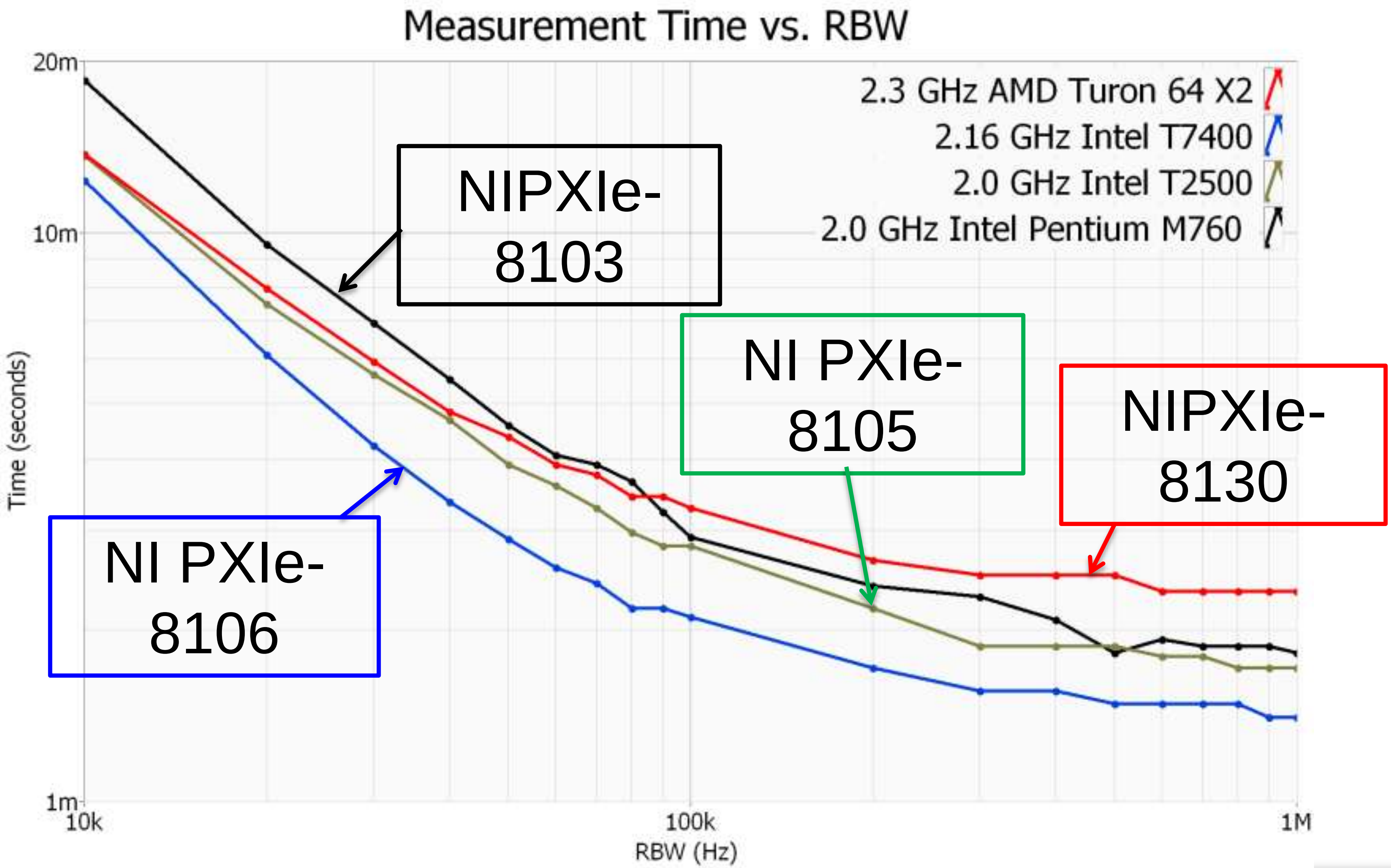


PXI-5661 versus PXIe-5663 Spectrum Sweep Times



Benchmark performed with NI 8353 quad-core controller, averaged over 100 measurements

Measurement Time for a 50 MHz Span



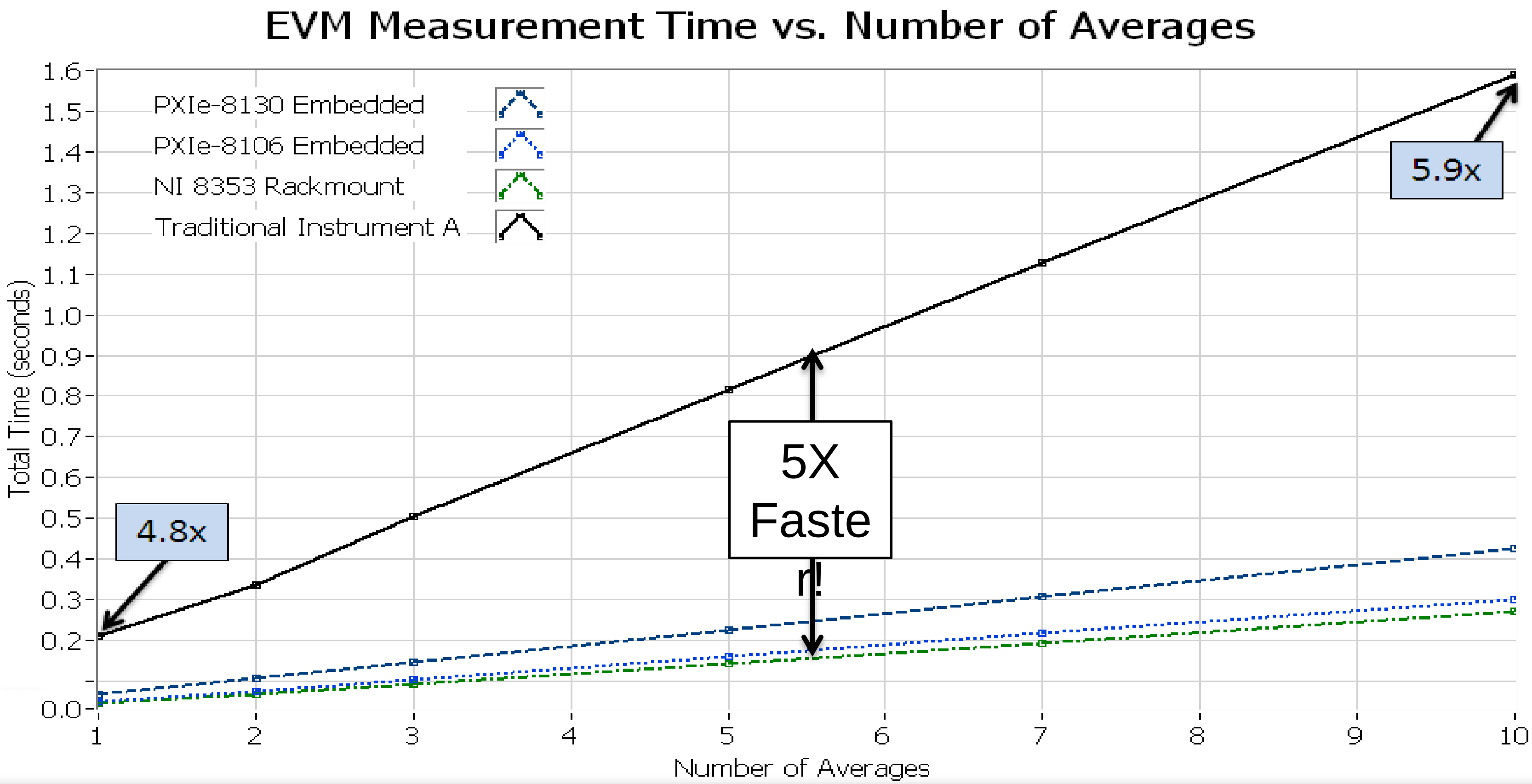
PXIe-5663: WCDMA Benchmark

- WCDMA is a good proxy for instrument performance
- Benchmark compares NI 5663 with traditional instruments
  - WCDMA measurement algorithms
  - Benchmark accounts for configure plus measurement time
- Compares measurement time with the number of averages
  - NI solution 5X to 30X faster than traditional instruments
  - CPU performance matters

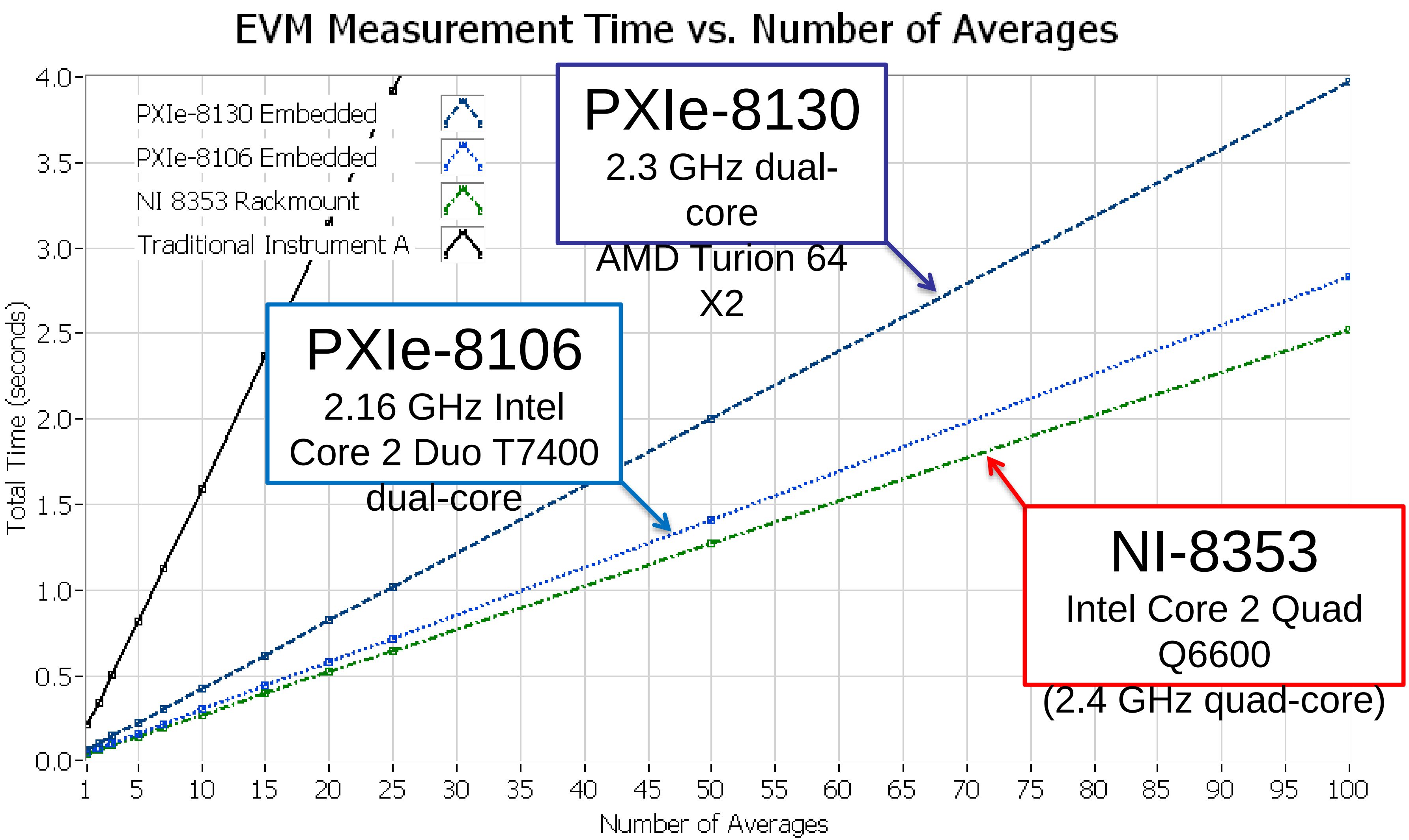
	GPIB A	GPIB B	PXIe-5663
Instrument Type	Traditional RF VSA	Traditional RF VSA	PXI Express RF VSA
Frequency Range	9 kHz to 8 GHz	1 MHz to 8 GHz	10 MHz to 6.6 GHz

PXIe-5663: EVM (W-CDMA)

- EVM = Error vector magnitude
- Characterizes modulation accuracy
- Both instruments report EVM results that are 0.7% to 0.8%



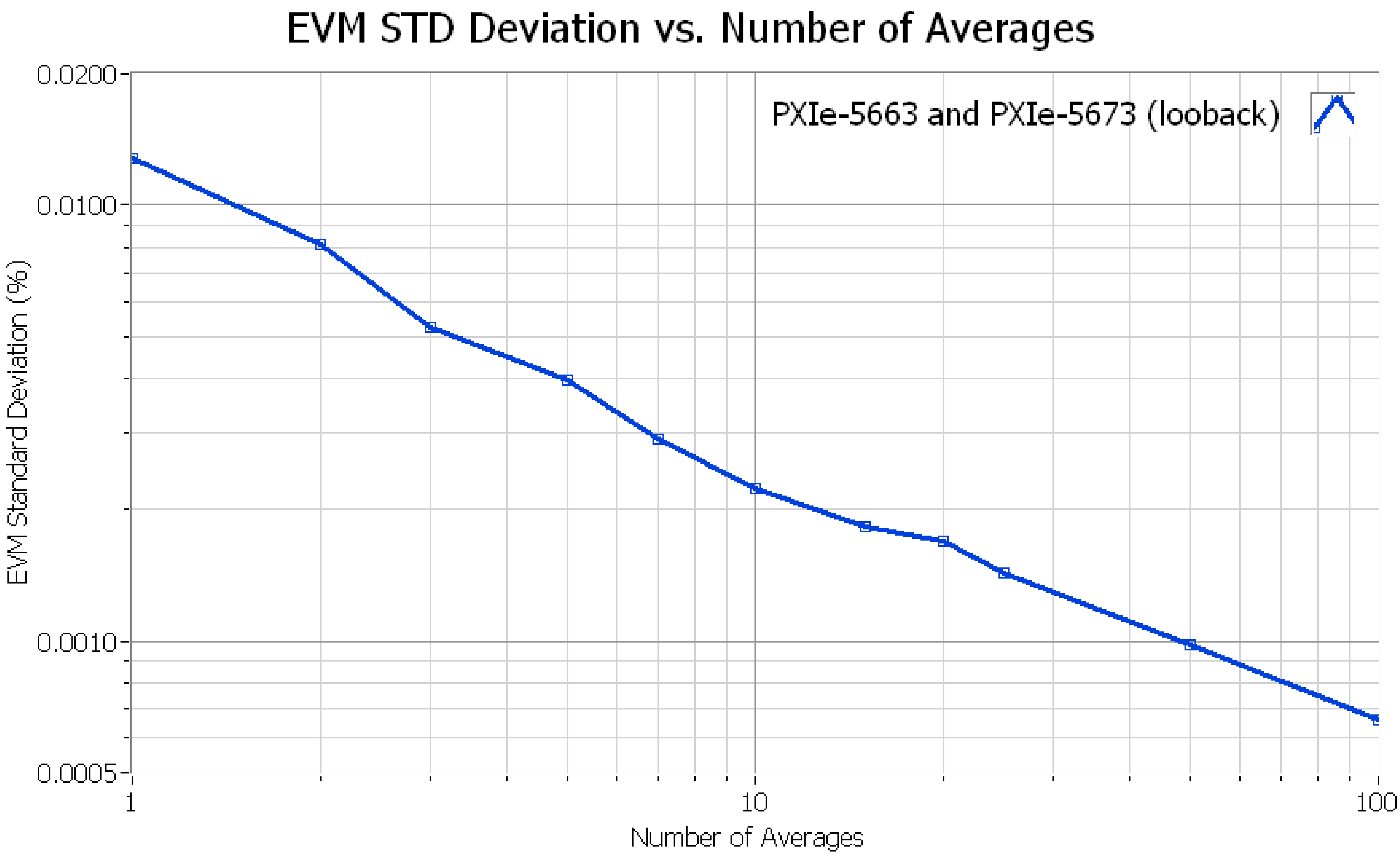
EVM Benchmark – Continued



How Many Averages Do I Use?

- Averaging increases measurement repeatability
  - Noise contributes to uncertainty – averaging mitigates its effect
  - Averaging also requires more measurements
- Production test
  - Engineers typically do 1 to 10 averages
- Design validation
  - Engineers can do up to 100 averages or more

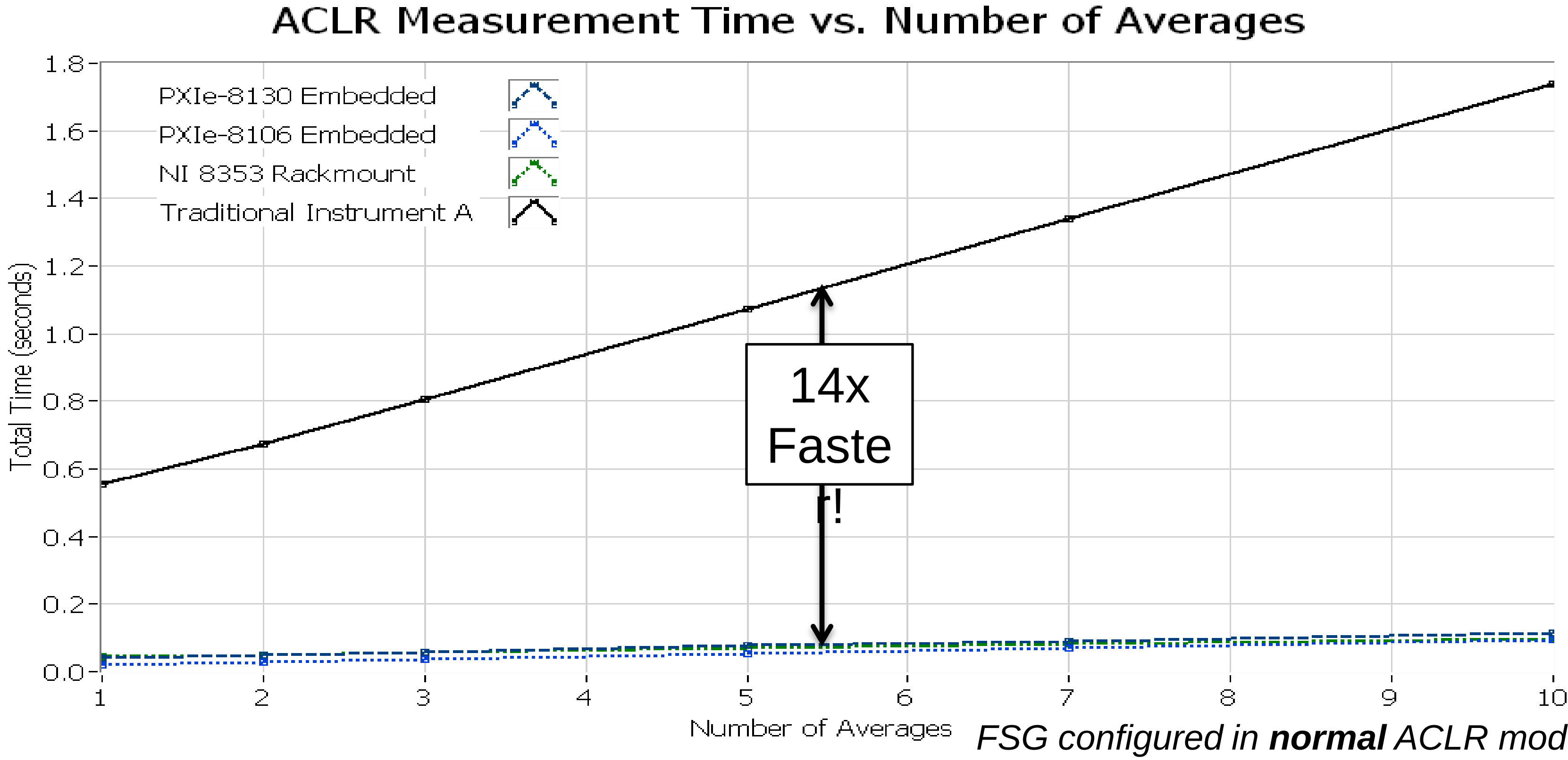
Averages versus Standard Deviation*



*Mean EVM was 0.692% over 2,600 chips – inherent instrument EVM ranges from 0.65% to 0.85%

PXIe-5663: ACLR (W-CDMA)

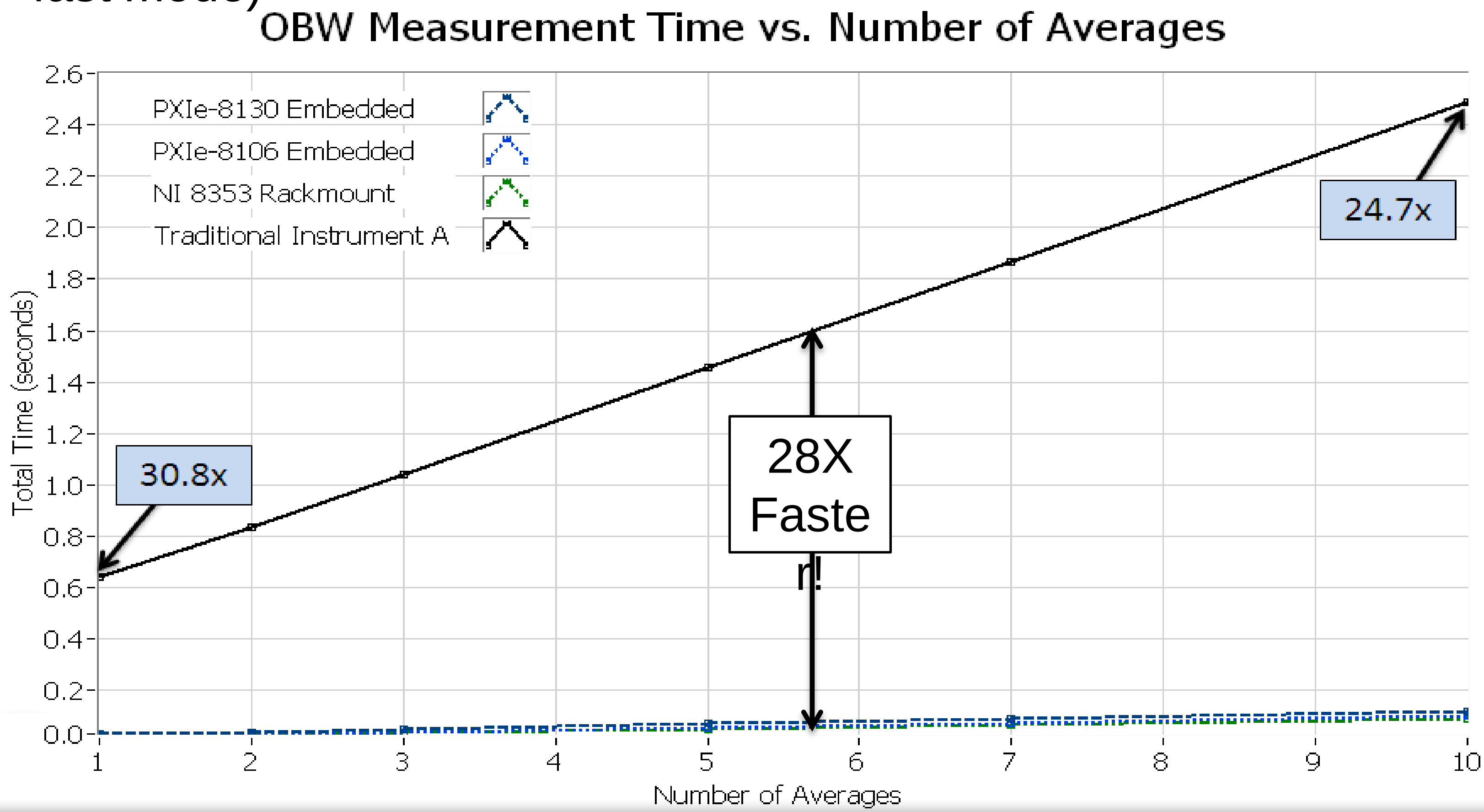
- ACLR (adjacent channel leakage ratio) measures dynamic ran
- NI performs ACLR measurement in less than 7 ms
- Some instruments have a “fast ACLR” mode – Agilent MXA is 14ms + 4ms for transfer



*FSG configured in **normal** ACLR mode*

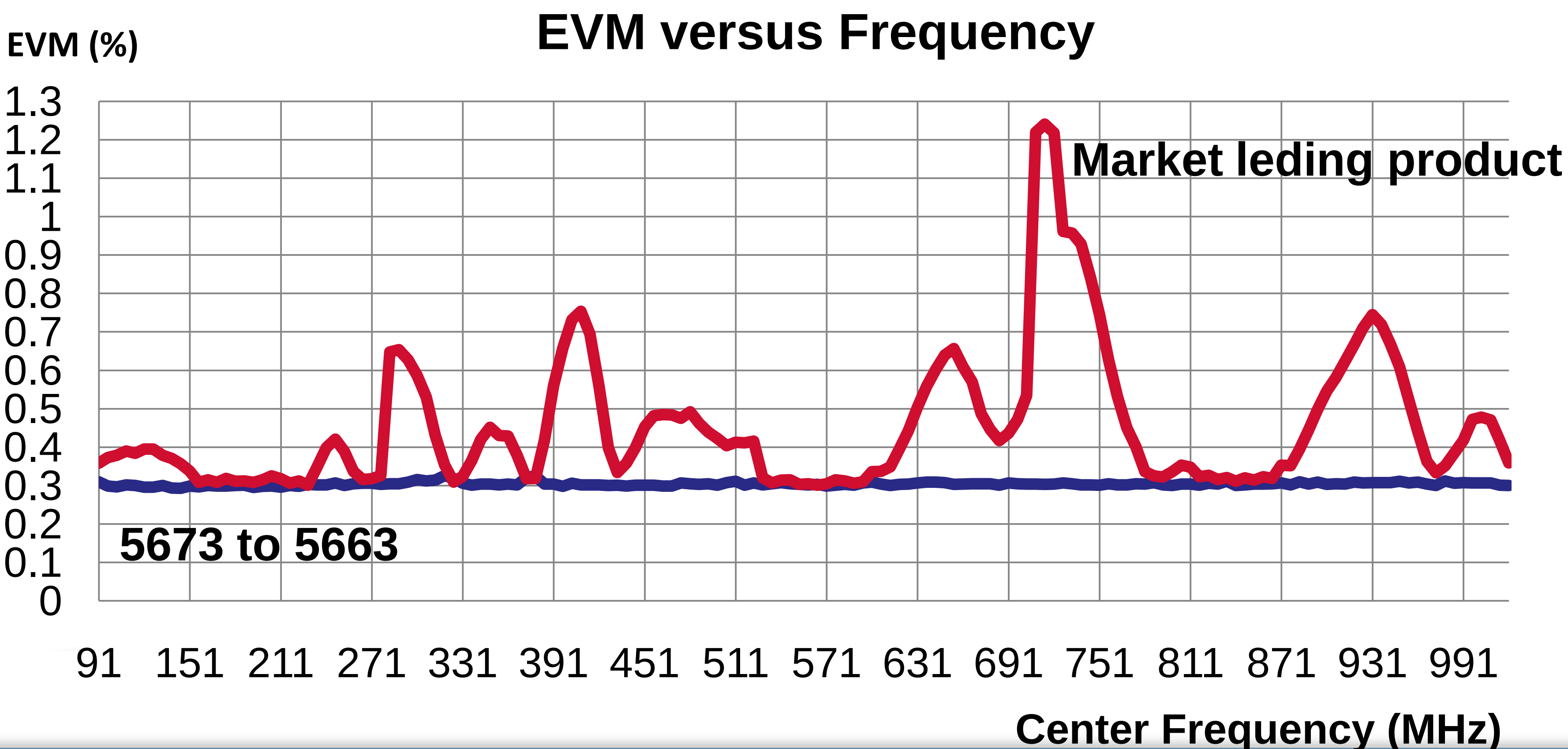
PXIe-5663: OBW (W-CDMA)

- WCDMA has occupied bandwidth of 4.175 MHz
- Measurement cannot be performed in the time domain (no fast mode)



Comparison with market leading product

- PXIe-5663 and PXIe-5673



Measurement Speed Summary

	GPIB A (ms)	NI PXIe-5663 Dual Core (ms)	NI PXIe-5663 Quad-Core (ms)
Spectrum Sweep (50 MHz, 10 KHz RBW)	500	13	12
EVM (5 averages)	810	162	144
ACLR (20 averages)	3069	157	125
Occupied BW (20 averages)	4554	188	157

Conclusion: The PXIe-5663 will perform many measurements **faster**

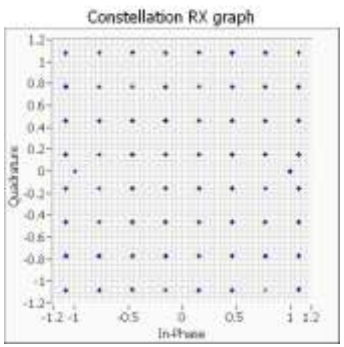
Challenge 2: Addressing Multiple Applications

Broadcast

MIMO/OFDM

Cellular

WiMAX



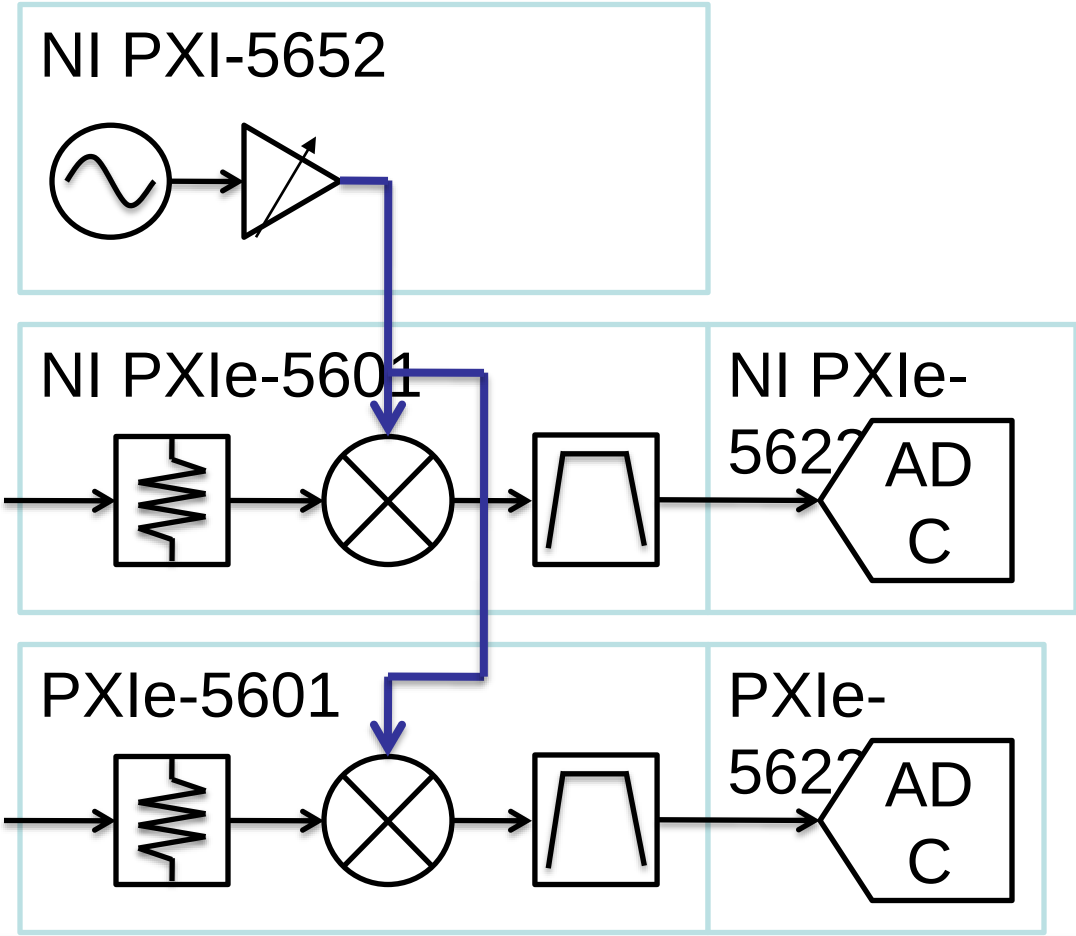
Streaming

GPS

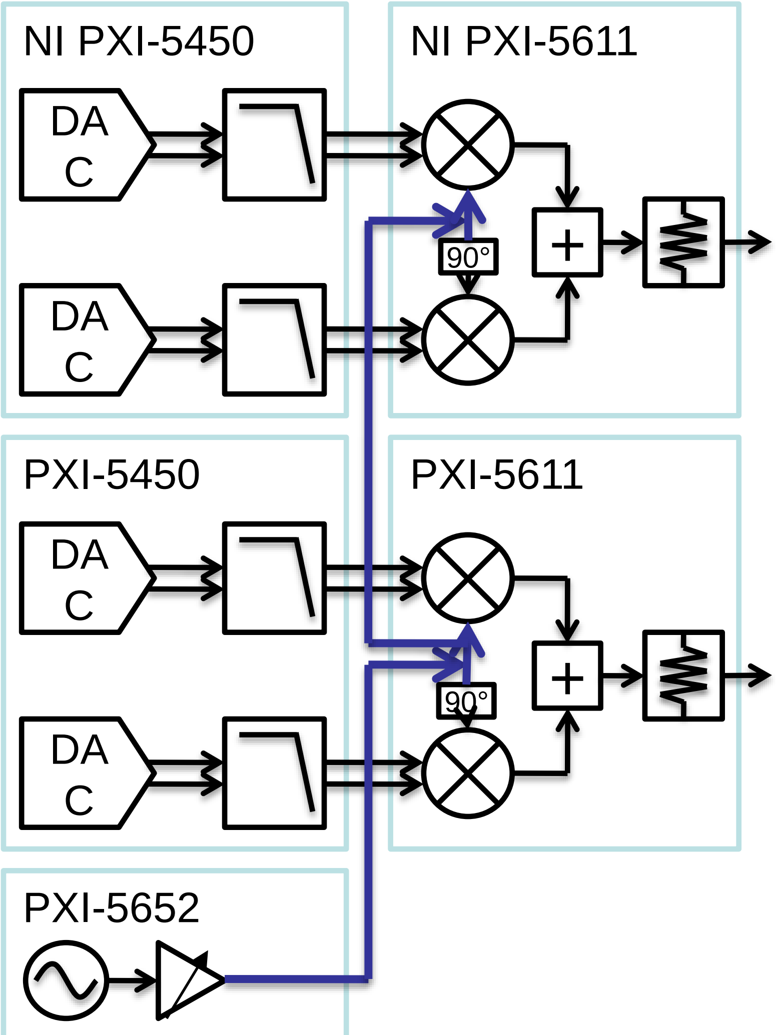
WLAN

Phase Coherent Acquisition

- Share the LO of PXIe-5663
- Single NI PXI-565x LO
- Up to 4 VSAs can be cascaded
- Can be used in 2x2 or 4x4 MIMO applications
- Phase can be tuned by DDC
- Less than 1° of phase variance



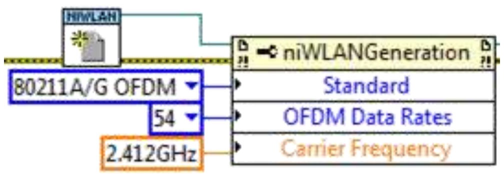
Phase Coherent Generation



- Share the LO of the PXIe-5673
- Single NI PXI-565x LO
- Up to 4 VSGs can be cascaded
- MIMO and beamforming applications
- Less than 1° of phase variance

NI WLAN Testing

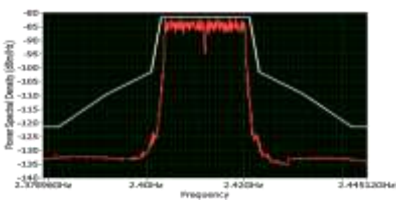
Creates 802.11a/b/g Signal in LabVIEW



PXIe-5673 VSG Generates Signal

WLAN DUT

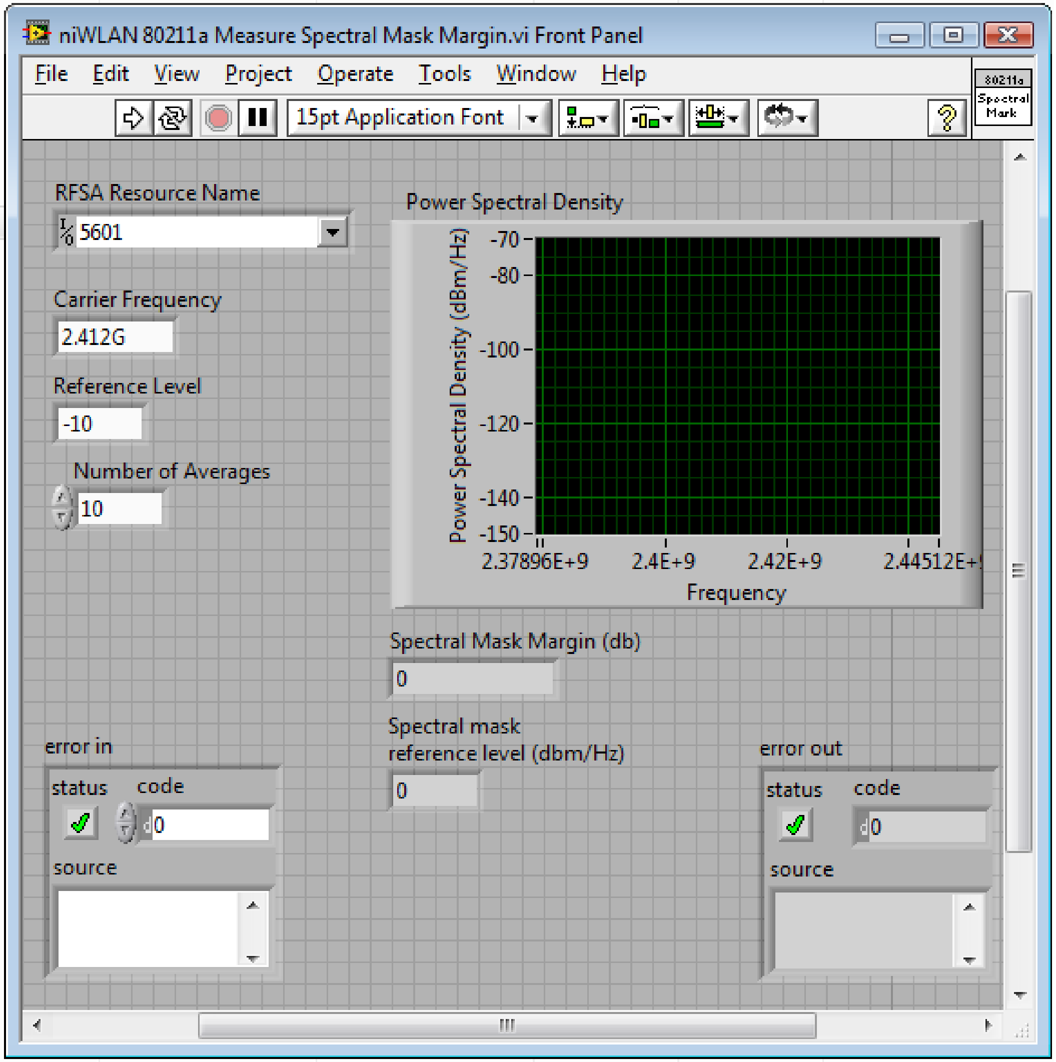
PXIe-5673 VSA Acquires Signal



Analyzes 802.11a/b/g Signal in LabVIEW

WLAN Signal Analysis

- Measurements Include:
  - Transmit Power
  - Frequency Offset
  - Carrier Leakage
  - Spectral Flatness
  - Spectrum Mask Margin
  - Power Ramp Time
  - EVM
- Traces include
  - Spectrum Mask
  - Power Versus Time
  - Constellation



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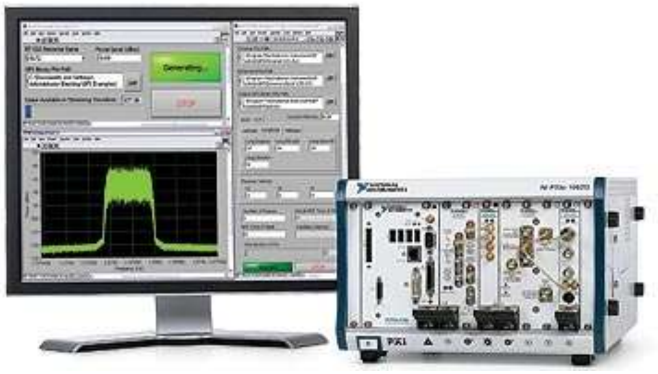
GPS Applications

- NI GPS Toolkit for LabVIEW simulation of up to 12 satellites
  - C/A codes in the L1 band (1.57542 GHz)
  - User-defined location and velocity
  - Up to 12.5 minutes of non-repeating genera
  - Multi-satellite and single satellite simulation
- Perform receiver measurements such a



  - Sensitivity – determines receiver noise figure
  - Time to first fix (TTFF)
  - Receiver position accuracy (toolkit accurate to within 2 meters)
- System can be augmented with RF record and playback

RF Record and Playback

- Record and playback up to 2 TB of data with NI HDD8264
- Use for long-duration signals and GPS / DVB receiver testing

PXIe-5663 ***to disk***

- 50 MHz BW (75 MS/s)
- 250 MB/s
- Record for 1.5+ hours
- May require pre-selection

PXIe-5673 ***from disk***

- 100 MHz BW (100 MS/s)
- 500 MB/s
- Playback for 1.25+ hours
- Large waveforms can also be created in software

Conclusions

- Increasing use of wireless technology
  - New protocols
  - Emergence of MIMO-OFDM
- Emerging requirements of RF test systems
  - Need for software-defined instrumentation
  - Squeeze the milliseconds from measurement time
  - Solve new and unique applications
    - Phase coherency
    - Higher order modulation schemes