

# The Art of Benchmarking Measurement Speed

*PXI Versus Rack-and-Stack Test Equipment*

# Agenda

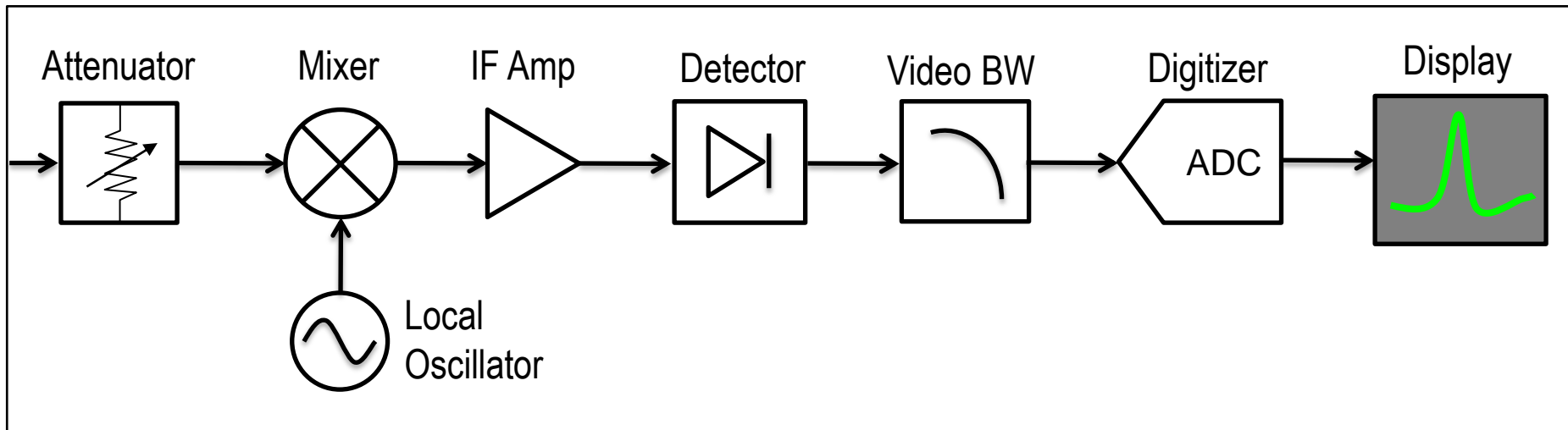
- Timeline of a measurement
- Factors that Affect Measurement Speed
  - Initialization, setup, and measurement personalities
  - Accurately measuring measurement speed
- Tips and Tradeoffs
  - Processor, Traces and composite measurements
  - Repeatability vs. Averaging
- Benchmark: PXIe-5663 vs. Agilent MXA
- Final Comparison Results

# The Traditional Spectrum Analyzer

- Uses swept-tune approach
- Automated through GPIB



## The Traditional Spectrum Analyzer

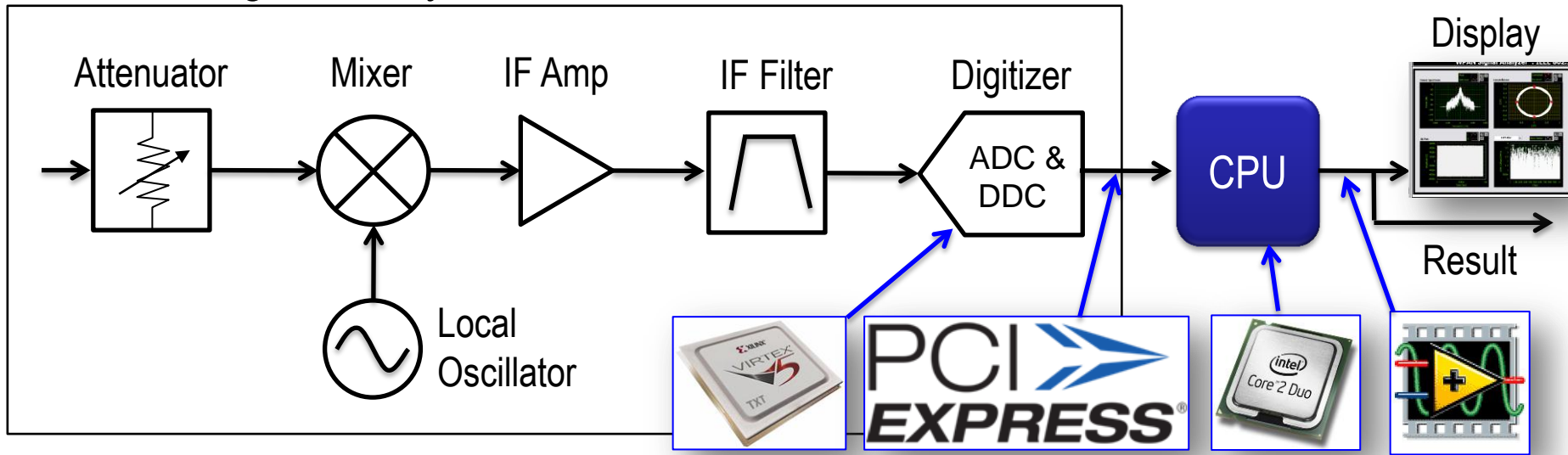


# The Modern RF Signal Analyzer

- Uses digital IF approach
- Fundamentally SW-defined

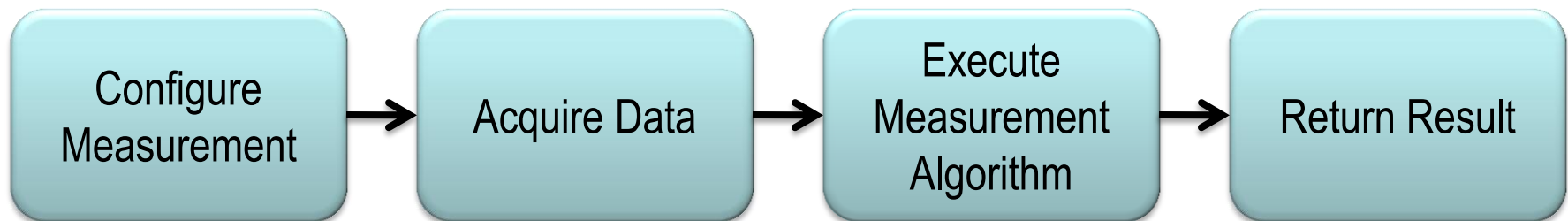


PXI RF Signal Analyzer



# Does Measurement Speed Matter?

- Automated Measurements: **YES!**
  - In characterization - speed gates time to market
  - In production - speed can gates throughput
- Interactive measurements: **Somewhat**
  - When times exceed 100ms, speed affects productivity
  - Most modulation measurements performed in  $< 100\text{ms}$
- Measurement speed affected by many variables



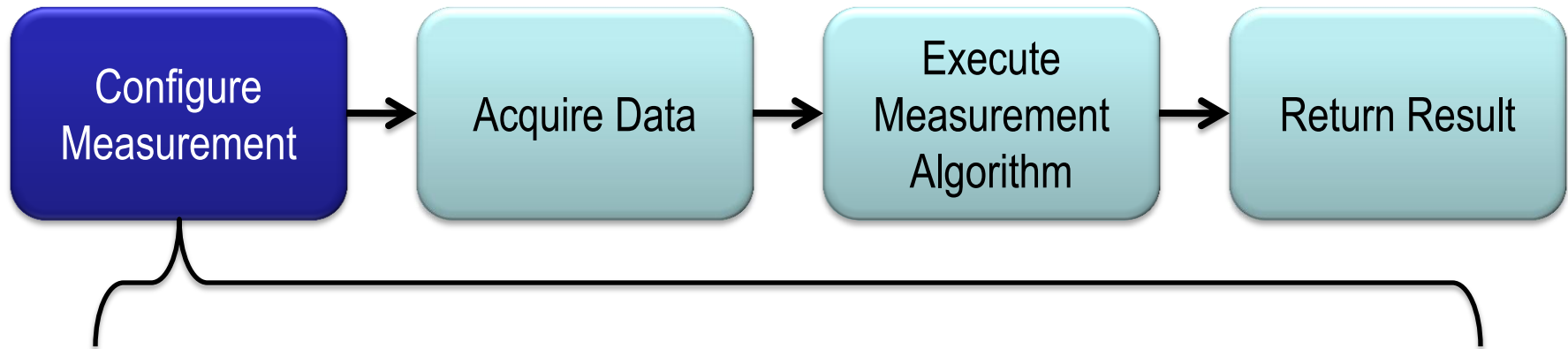
# Test Plan: WCDMA Power Amplifier

Step Description	Note	Time
Initialize Instrument	Not included in final time	-
Configure WCDMA Composite	Freq = 1.95 GHz	?
Servo to Appropriate Power Level	Requires 2 power measurements	?
Measure Power, EVM, and ACLR	Aperture = 666 $\mu$ s	?
Set Center Frequency	Freq = 3.90 GHz	?
Measure Power	Aperture = 666 $\mu$ s	?
Set Center Frequency	Freq = 5.85 GHz	?
Measure Power	Aperture = 1 ms	?
Close Instrument	Not include in final time	-
<b>Test Plan Complete</b>		?

*Note that is a simplified test plan with only RF measurements. Multi -band parts require a more measurements in more bands – also containing DC measurements*

# Optimizing and Measuring Test Time

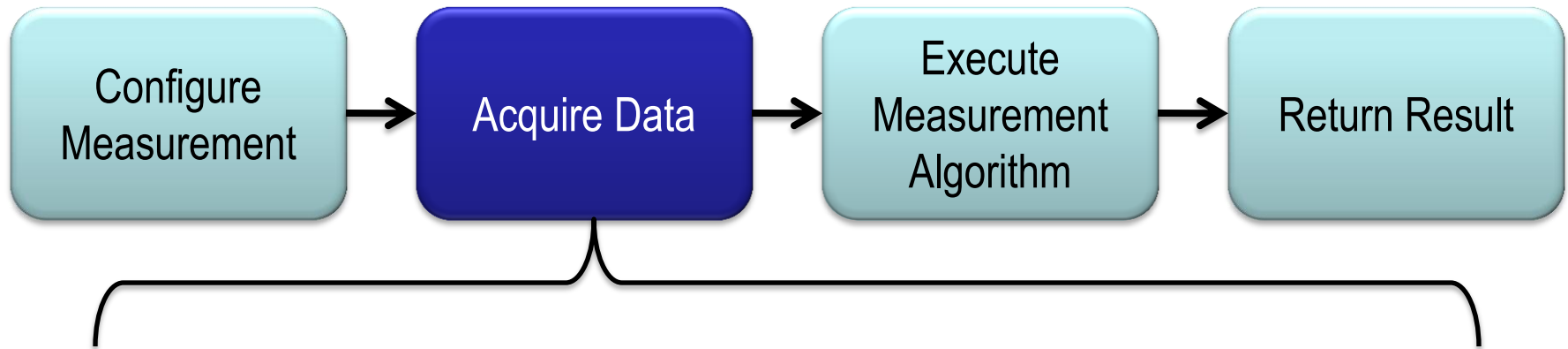
# Timeline of an Automated Measurement



- Instrument settings
  - Frequency and attenuation changes incur settling times
  - Tools such as “list modes” enable faster configuration
- Measurement settings
  - PXI: all measurement settings can usually be set in  $< 1$  ms
  - Rack-and-stack: LAN latency is  $\approx 1$  ms

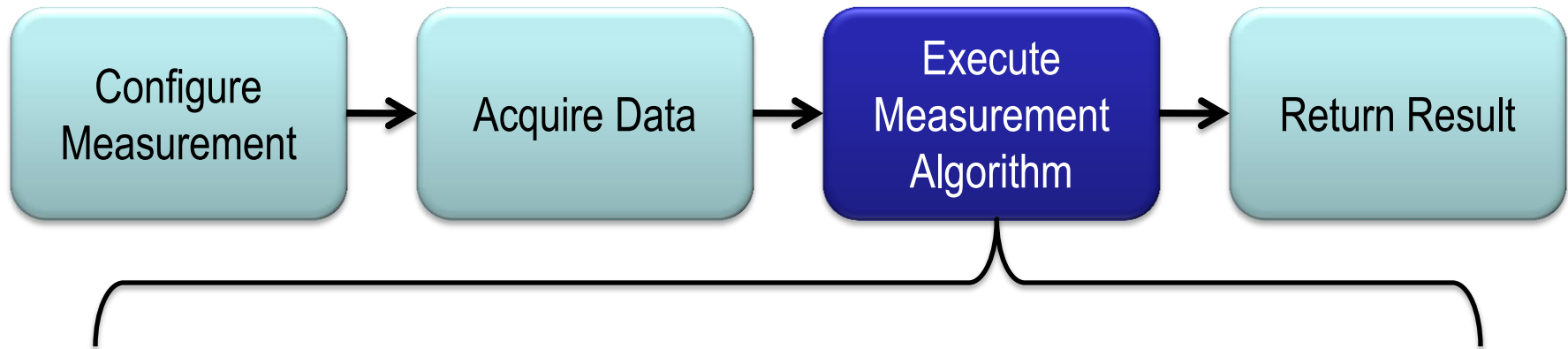


# Timeline of an Automated Measurement



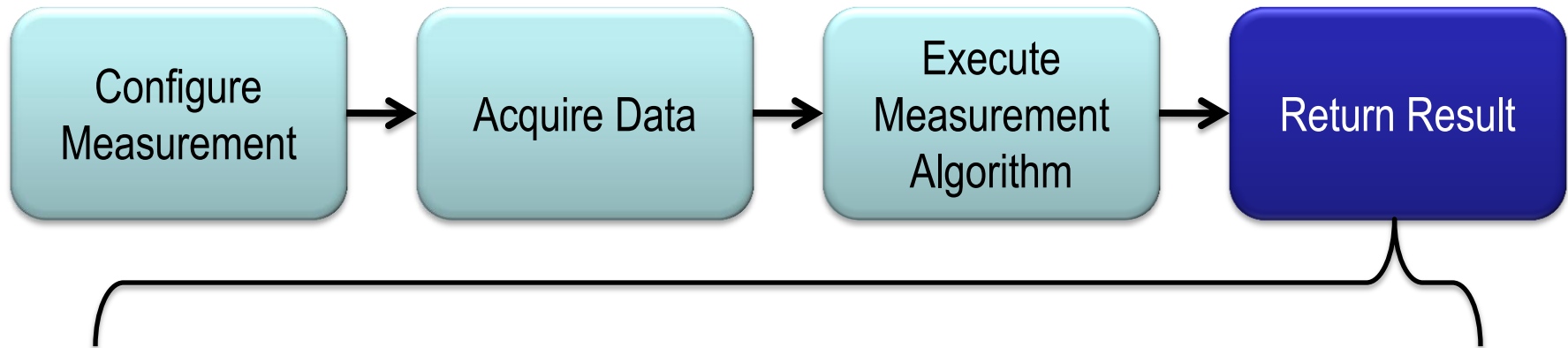
- Acquisition time depends on type of measurement
  - EVM: Acquisition time must be longer than burst
  - Spectral measurements: acquisition mostly depends on measurement settings (IF bandwidth, FFT mode, etc.)
- Averaging requires multiple acquisitions

# Timeline of an Automated Measurement



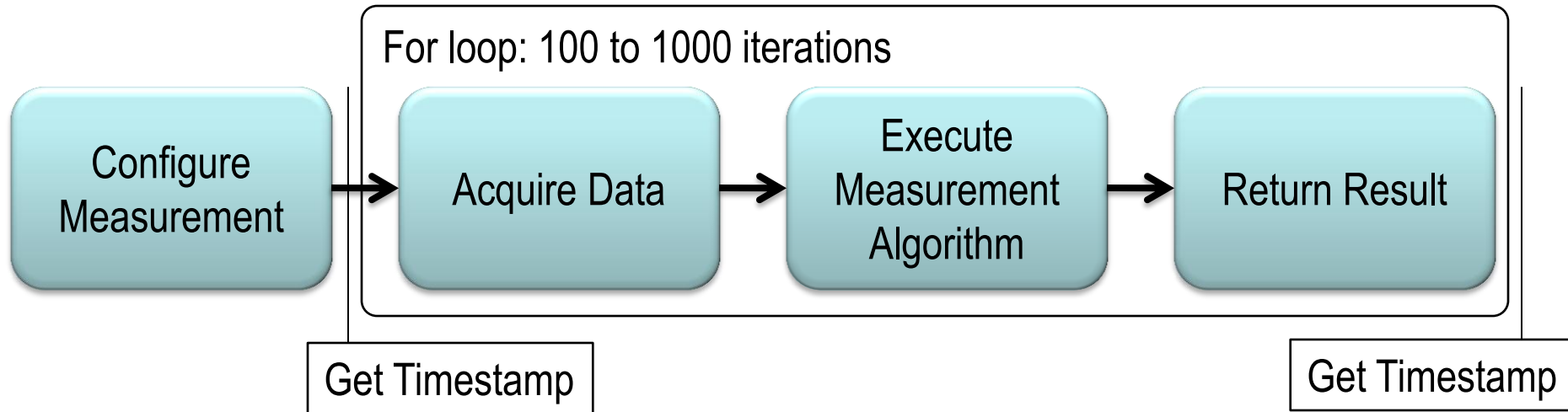
- Algorithm execution speed depends on:
  - Horsepower of processor (faster CPU = faster measurements)
  - Existence of other processes (measurements & traces)
  - Complexity of signal (OFDM, MIMO, etc.).
- Dominates total measurement time

# Timeline of an Automated Measurement



- Rack-and-Stack: results transferred via GPIB, LAN, etc.
  - Require both a data bus (internal) and a result bus (external)
- PXI: results are computed onboard
  - Instrument only uses a data bus
- Result transfers driven by bus latency
  - Typical LAN latency  $\approx 1$  ms

# Accurately Measuring Time



- Configure times can be measured independently
- “Acquire” to “Return Result” generally measured together
- Software timestamps have inherent jitter
  - Compute mean time of 100-1000 measurements
  - Use “Read” vs. “Fetch” command to ensure new data results

# Benchmark: PXI vs. Traditional

## PXIe-5663E RF Signal Analyzer

- Used with PXIe-8133 Controller
  - Intel i7 Q820 (1.73 GHz)
- 50 MHz analysis bandwidth
- Options installed:
  - GSM/EDGE
  - WCDMA/HSPA+
  - LTE
  - 802.11a/b/g/n

## Agilent MXA Signal Analyzer

- Uses embedded processor
  - Intel T2500 Core 2 Duo (2.0 GHz)
- 25 MHz analysis bandwidth
- Options installed:
  - GSM/EDGE\*
  - WCDMA\*
  - LTE
  - 802.11a/b/g\*

*\*Two options to enable composite measurements on the Agilent MXA: both the default standard personality and the “Single Acquisition Mode” option.*

# Best Practices for Benchmarking

- Evaluate and adjust appropriate measurement settings
  - Default settings do not always yield fastest measurements
    - Minimize acquisition time
    - Turn auto-detection off
    - Select “Fast” spectrum modes
    - Set appropriate number of averages
  - Not all instruments use same default settings
  - Turn off traces and front panel displays
- Use composite measurements for fastest measurements
  - All results computed on same set of IQ data
  - Introduces dynamic range tradeoff for spectrum measurements

# Do Composite Measurements Matter?

- PXI: Parallel measurements are up to 2x faster
- Benchtop: Composite modes require special firmware
  - Not all measurements applications have composite option
  - WCDMA: composite mode is 4.3x faster
  - LTE: “fast mode” mode does not exist

## Benchtop Measurement Mode Comparison

Measurement	Agilent MXA (normal mode)	Agilent MXA (composite mode)	Difference
WCDMA: EVM-QPSK & ACP	290 ms	67 ms	4.3x
LTE: EVM & Power	441 ms	NA	NA

# Benchmark: WCDMA Composite

- Signal characteristics
  - WCDMA = Wideband Code Division Multiple Access
  - Modulation Type: QPSK (5 MHz Channel)
  - Signal source: PXIe-5673E RF Signal Generator
- Composite measurement characteristics
  - EVM-QPSK
    - EVM = Error vector magnitude
    - Simpler modulation quality metric (versus modulation accuracy)
  - ACLR
    - ACLR = Adjacent Channel Leakage Ratio
    - Best metric of dynamic range



# Agilent MXA WCDMA Results

Signal type	Time Slots	RMS EVM	EVM STDEV	ACLR	Meas Time
WCDMA Uplink – 1 GHz	1	0.40%	0.02%	-67.9 dBc	67.3 ms
WCDMA Uplink – 1 GHz	3	0.40%	0.02%	-67.9 dBc	122.3 ms

- MXA configured with “N9073A-XFP Single Acquisition Combined W-CDMA Measurement Application”
- Measurement optimizations used
  - Acquisition time shortened to 666  $\mu$ s
  - Traces updates and display turned OFF

# NI PXIe-5663E WCDMA Results

Signal type	Time Slots	RMS EVM	EVM STDEV	ACLR	Meas Time
WCDMA Uplink – 1 GHz	1	0.32%	0.0098%	-71.7 dBc	26.5 ms
WCDMA Uplink – 1 GHz	3	0.32%	0.0052%	-71.7 dBc	65.8 ms

- Measurement optimizations used
  - All traces turned off (saves < 1 ms per result)
  - Acquisition time set to 666  $\mu$ s (saves 1-2 ms per result)
  - ACLR Noise Compensation Enabled

# NI PXle-5663 vs. Agilent MXA (WCDMA)

## Measurement Accuracy

Measurement	Agilent MXA	NI PXle-5663E	Difference
EVM-QPSK	0.40%	0.32%	0.08%
EVM Repeatability (1 slot)	0.02%	0.01%	0.01%
ACLR	-67.9 dBc	-71.7 dBc	3.8 dB

## Measurement Speed

Measurement	Agilent MXA	NI PXle-5663E	Difference
WCDMA Composite: 1 Time Slot	67.3 ms	26.5 ms	2.5x
WCDMA Composite: 3 Time Slots	122.3 ms	65.8 ms	1.9x

# Test Plan: WCDMA Power Amplifier

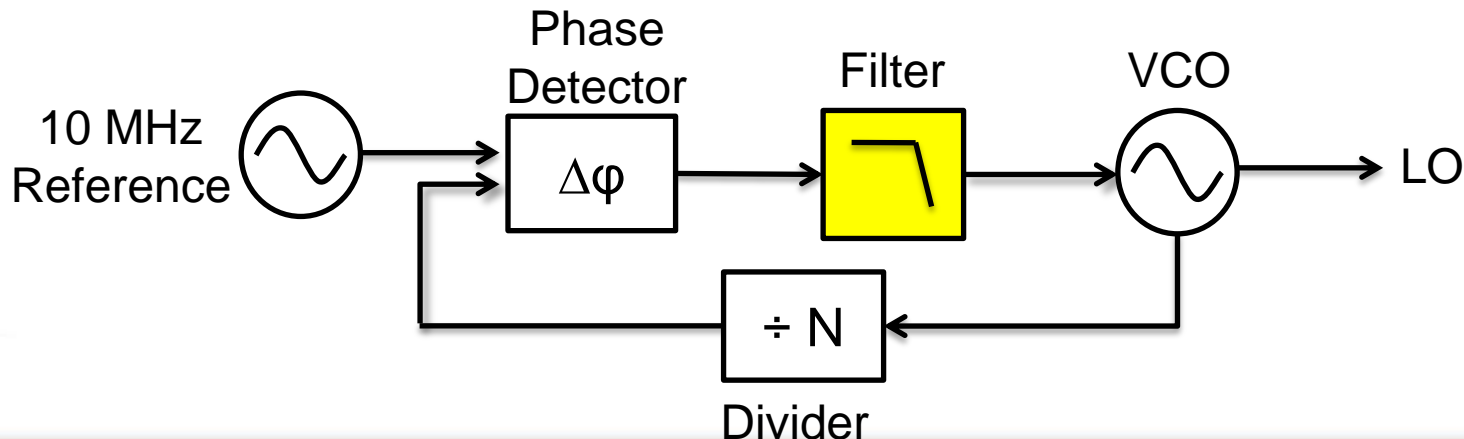
Step Description	Note	PXIe-5663E	Agilent MXA
Initialize Instrument	Not included in final time	-	-
Configure WCDMA Composite	Freq = 1.95 GHz	?	?
Servo to Appropriate Power Level	2 Power Measurements	2.0 ms	6.0 ms
Measure Power, EVM, and ACLR	Aperture = 666 $\mu$ s	<b>26.5 ms</b>	<b>65.8 ms</b>
Set Center Frequency	Freq = 3.90 GHz	?	?
Measure Power	Aperture = 666 $\mu$ s	1.0 ms	3.0 ms
Set Center Frequency	Freq = 5.85 GHz	?	?
Measure Power	Aperture = 1 ms	1.0 ms	3.0 ms
Close Instrument	Not include in final time	-	-
<b>Test Plan Complete</b>		?	?

# Additional Major Test Time Factors

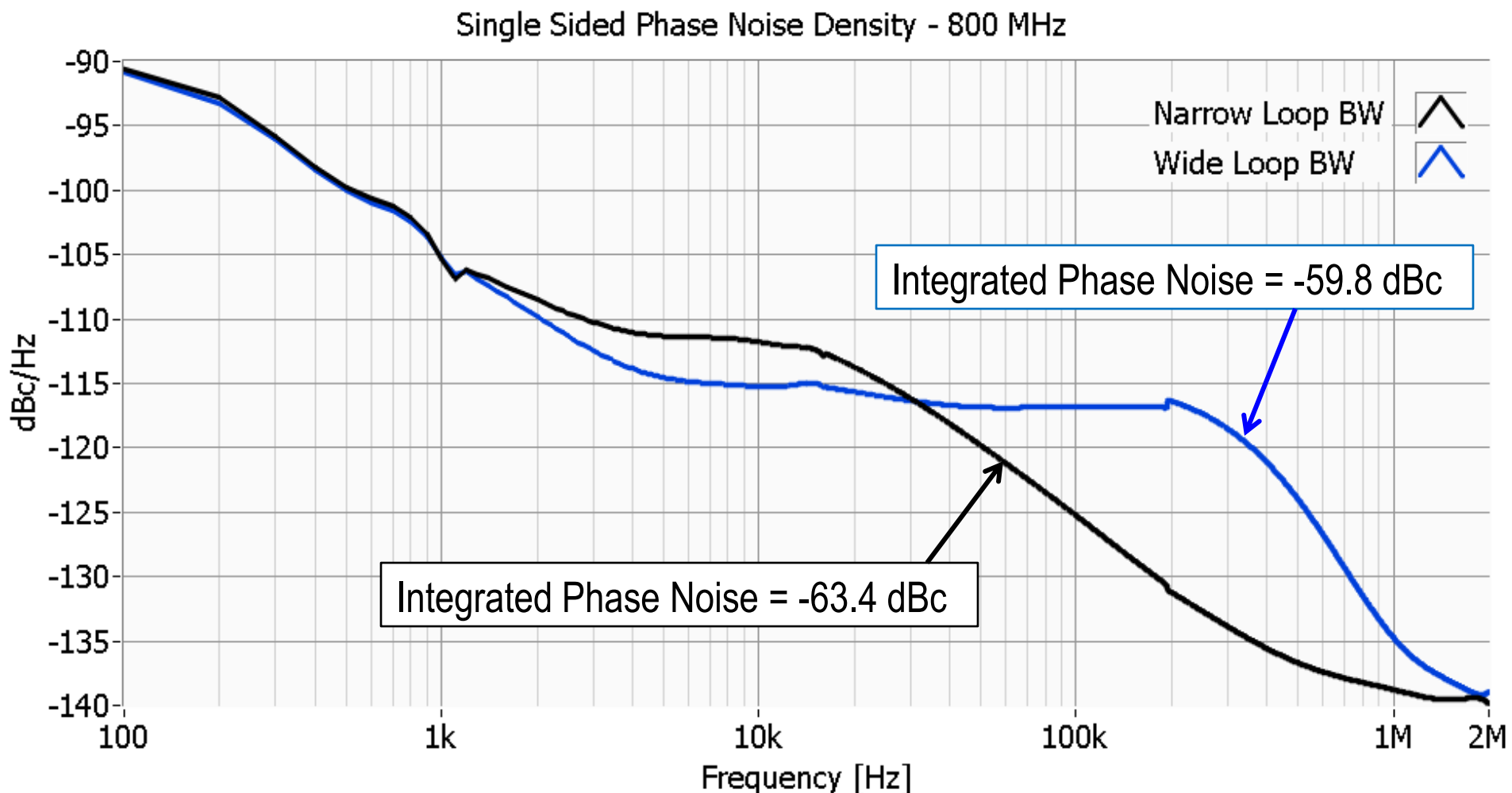
- Tuning and Settling Times
  - Example: change center frequency from 1 to 2 GHz
  - Dependent on synthesizer technology used
- Measurement personality load time
  - Example: switching from GSM/EDGE to WCDMA
  - Large factor in multi-standard testing
- Measurement settings configuration
  - Usually is a function of bus latency
  - Best to minimize number of bust transfers
- Implementation of parallel testing

# Understanding LO Tuning Time

- RF signal analyzers use two types of LO's
  - Voltage Controlled Oscillator (VCO)
  - Yttrium Iron Garnet (YIG)
- Loop bandwidth affects settling time on VCO's
  - Wide BW: faster settling and degraded phase noise
  - Narrow BW: longer settling and improved phase noise



# PLL Loop BW vs. Phase Noise (5663E)



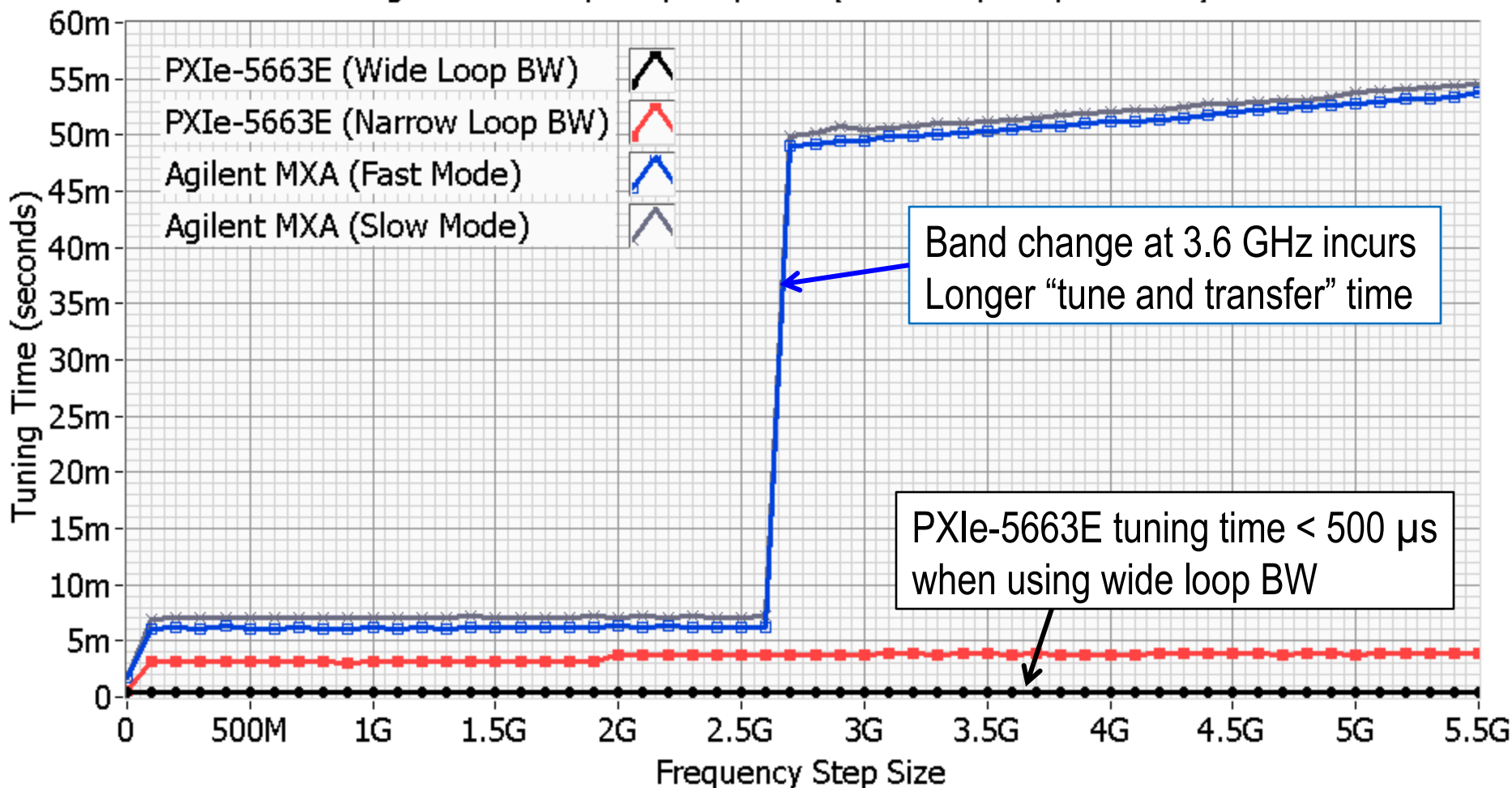
# Benchmarking Tuning Time

- Methodology
  - Use zero-span power measurement to minimize processing
    - Reduce acquisition time to minimum (1 $\mu$ s or less)
  - Configure instrument in list mode to minimize SW overhead
    - First item is start frequency, second is step size
    - Longer list = more precise timing results
    - Example: 1 GHz, 2 GHz, 1 GHz, 2 GHz, 1 GHz, 2 GHz (6 items)
    - Run list multiple times and measure average time
- Factors affecting tuning time
  - Use wide PLL loop bandwidth for faster settling
  - Settling accuracy (0.1 PMM = 100 kHz at 1 GHz)



# Tuning Time: 5663E vs. MXA

Tuning time vs Frequency Step Size (Start Frequency = 1 GHz)



# Benchmarking Personality Load Time

- Multi-mode DUT's require instrument mode switching
  - Traditional instruments operate in one mode at a time
  - PXI instruments capable of multiple modes in parallel
- Best practices for benchmarking a traditional VSA
  - Switch to each mode once before beginning benchmark
  - Call one config command to ensure mode completion

## Personality Load Times (after pre-loading)

Measurement Personality	Agilent MXA Time	PXI Load Time
WLAN Composite Application	62 ms	NA
W-CDMA Composite Application	42 ms	NA

# Test Plan: WCDMA Power Amplifier

Step Description	Note	PXIe-5663E	Agilent MXA
Initialize Instrument	Not included in final time	-	-
Configure WCDMA Composite	Freq = 1.95 GHz	<b>0.5 ms</b>	<b>51.0 ms</b>
Servo to Appropriate Power Level	2 Power Measurements	3.0 ms	6.0 ms
Measure Power, EVM, and ACLR	Aperture = 666 $\mu$ s	26.5 ms	65.8 ms
Set Center Frequency	Freq = 3.90 GHz	<b>0.5 ms</b>	<b>51.0 ms</b>
Measure Power	Aperture = 666 $\mu$ s	1.0 ms	3.0 ms
Set Center Frequency	Freq = 5.85 GHz	<b>0.5 ms</b>	<b>6.4 ms</b>
Measure Power	Aperture = 1 ms	1.0 ms	3.0 ms
Close Instrument	Not include in final time	-	-
<b>Test Plan Complete</b>		<b>33.0 ms</b>	<b>186 ms</b>

*NI PXI-5663E is **5.6x** Faster than Agilent MXA*

# Other Benchmark Data

## Wireless LAN (802.11g)

Signal type	PXIe-5663E Time	Agilent MXA Time*	Speedup
802.11a/g: EVM and Power	7.0 ms	93.9 ms	13.4x

*\*WLAN Measurements performed using N9077A-XFP, single acquisition composite measurement application (fast mode).*

## LTE (3GPP Long Term Evolution)

Signal type	PXIe-5663E Time**	Agilent MXA Time**	Speedup
5 MHz BW: EVM and Power	71 ms	541 ms	7.6x
10 MHz BW: EVM and Power	92 ms	703 ms	7.7x

*\*\* All Measurements made on a single sub-frame with auto-detection turned OFF.*

# Summary

- Measurement speed is tricky to benchmark
  - Requires careful attention to measurement settings
  - Many instrument settings affect speed (traces, etc.)
  - Many tradeoffs: speed vs. accuracy vs. repeatability
- PXI designed for extremely fast measurements
  - Speed is a function of CPU performance (multi-core)
  - Usually 3x to 20x faster than rack-and-stack
  - PXIe-5663E has accuracy similar to mid-range VSA's