M8190A Arbitrary Waveform Generator

Accelerated insight into your design with Signal Scenario Generator delivering High Resolution and Wide Bandwidth

Enhance your reality

Anticipate Accelerate Achieve

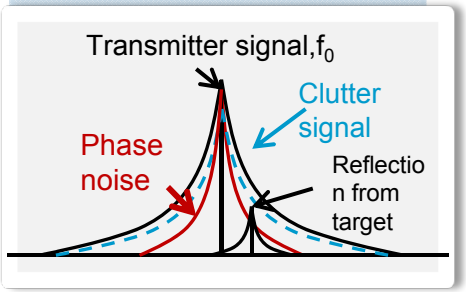
Agilent Technologies

Drivers for Target Markets

Realistic testing, today and tommorrow

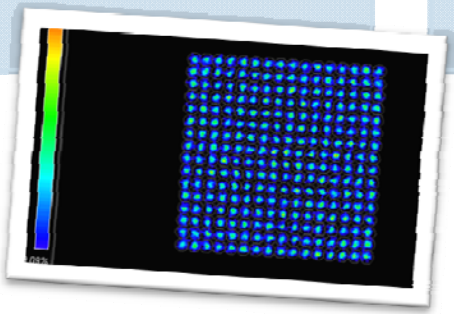
Radar
Highly realistic signal scenarios

- Simulate with the most realistic signal to avoid expensive life tests
- Need for low phase noise to detect slower moving targets



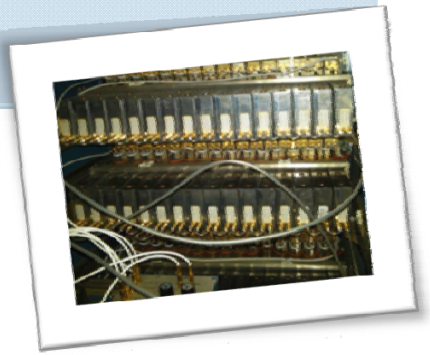
Communication
More data, faster

- Cram more information into existing bandwidth
- New standards require 100 times wider modulation bw than existing standards



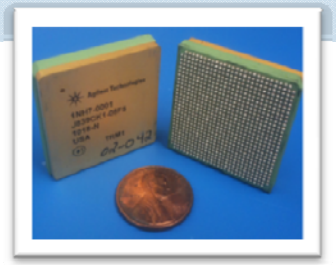
R&D and Research
Simulate real-world imperfections

- Ensure flexible adoption to new distortion requirements
- Mimic the analog real world imperfections



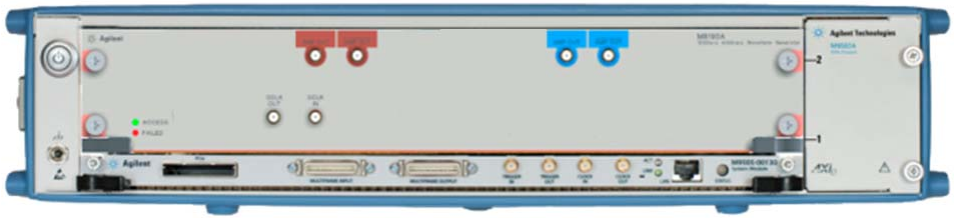
General Purpose
Head-room for the future

- Keep programs on spec, on budget and on time
- Never-ending changing environment calls for new innovation



Differences M8190A Rev 1 and Rev 2

There‘s obviously a difference ….



Revision 1 configuration: B02

- 2 channel version
- 14 bit
- 2 GSa memory

Revision 2 offering

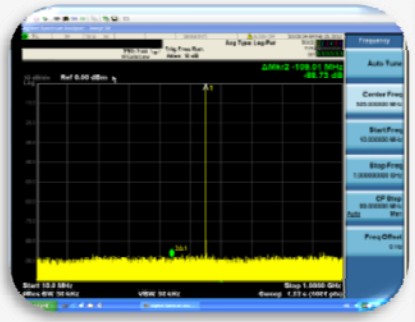
- Advanced Sequencer
- DC and AC Amplifier
- Fast switching (export control for 12GSa/s)
- Calibration ISO 17025 or Z54

- 1 channel or 2 channel
- 14 bit / 8 GSa/s or 12 bit / 12 Gsa/s
- 128 Msa or 2 GSa memory per channel

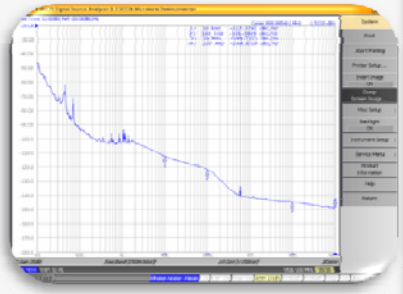
M8190A Arbitrary Waveform Generator

Accelerated insight into your design with Signal Scenario Generator

Reliable, repeatable measurements	• Low phase noise • Excellent SFDR and low harmonics
Optimize the output to match your application	• Three software selectable amplifier for different signal characteristics (DAC, AC, DC)
Create complex signal scenarios – efficiently	• Up to 2 Gsa memory per channel • Advanced sequencer
Flexiblity to stress your device to its limits	• Generate mulit-level signals with programmable ISI and jitter up to 3 GB/s

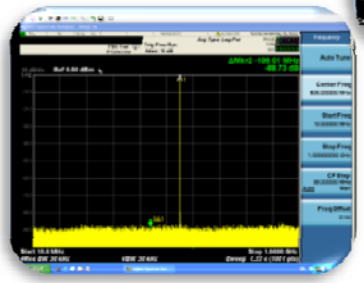


- 88 dBc, 555 MHz,
12 GSa/s DAC

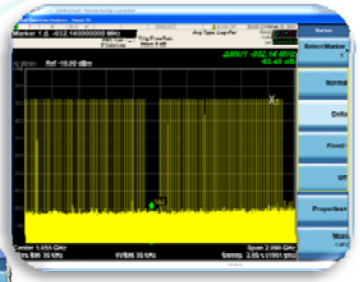


– 110 dBc @ 10 kHz DAC

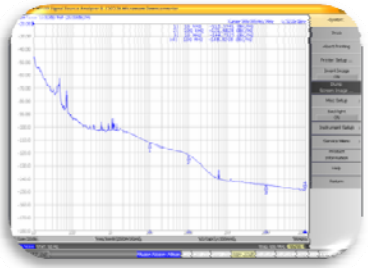
M8190A AWG - Reliable, repeatable measurements from precise signal simulation

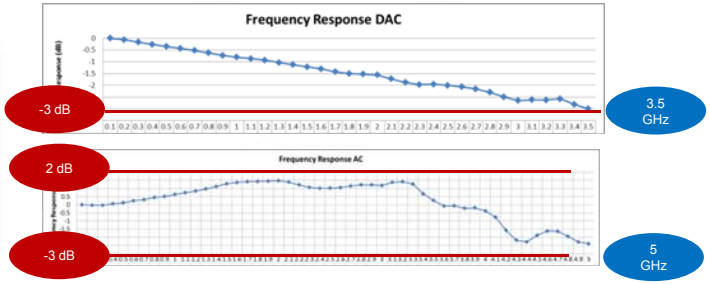


- 88 dBc, 555 MHz,12 GSa/s DAC



- 63 dBc, 2 GHz multi tone, DAC





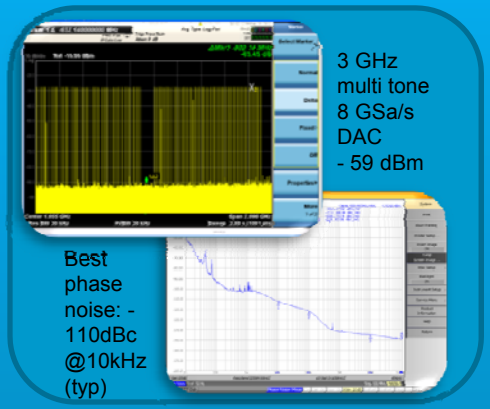
8 GSa/s; f_{OUT} = 1GHz; internal sample clock
-110dBc@10kHz (typ)

Excellent SFDR ensures that tones stand out from distortion even with hundreds of tones

Optimize the Output to match your application

Three Selectable Amplifiers!

Best SFDR, HD & phase noise



Direct DAC

Single-ended or differential

Amplitude 350 mV_{pp} to 700 mV_{pp}

Offset -20mV … +20mV

*

High bandwidth & power

2 Vpp (SE)

5 GHz

AC amplifier*

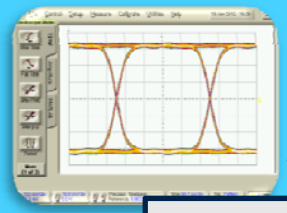
Single-ended

Amplitude (SE) 200 mV_{pp} to 2.0 V_{pp}

50 mHz to 5 GHz (3 dB) (typ)

*

Low jitter



Eye measurement 12 GSa/s, 3 Gb/s ~ 7 ps_{pp} Jitter 50 ps transition time

- 1.0 … + 3.3 Voltage window

DC ampliier*

Single ended or differential

Amplitude (se) 500 mV_{pp} to 1.0 V_{pp}

Output voltage window – 1.0 V … + 3.3V

* AMP option

More details

M8190A AWG

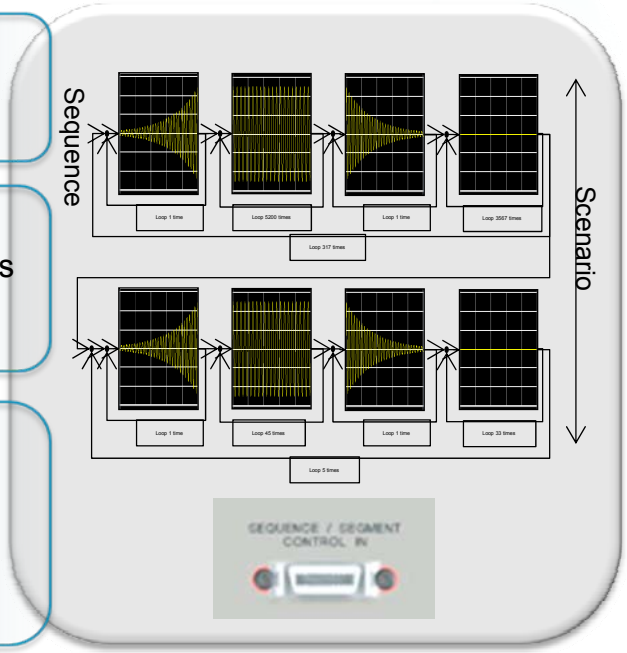
Create complex signal scenarios – efficiently

Waveform Memory
- 2 GSa memory
- 1/6 s playtime at highest sampling rate

Best Memory Usage Through Sequencing
- A sequence consists of a list of waveform segments
- Each segement can be looped up to 2^{32} times
- A sequence can contain up to 512 k steps

Real-time Memory Access

The dynamic control port on the front panel allows you to select one of 2^{13} (2^{19}) segments / sequences dynamically at runtime by applying a digital pattern to the connector



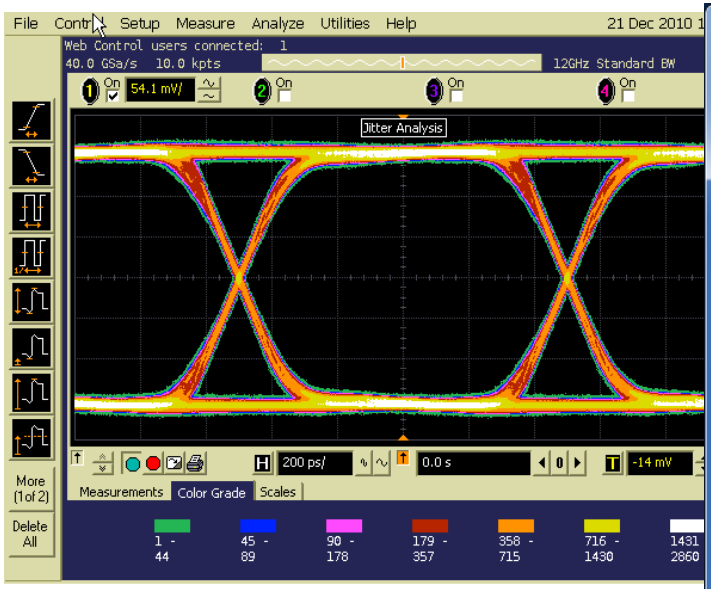
Long playtime and long signal scenarios for highly realistic testing

More Details

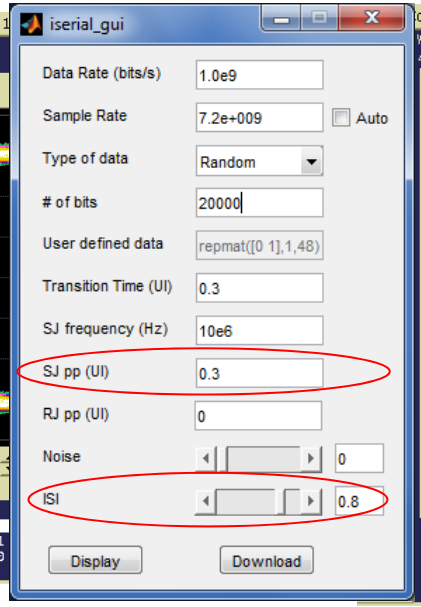
M8190A AWG

Flexibility to stress your device to its limits

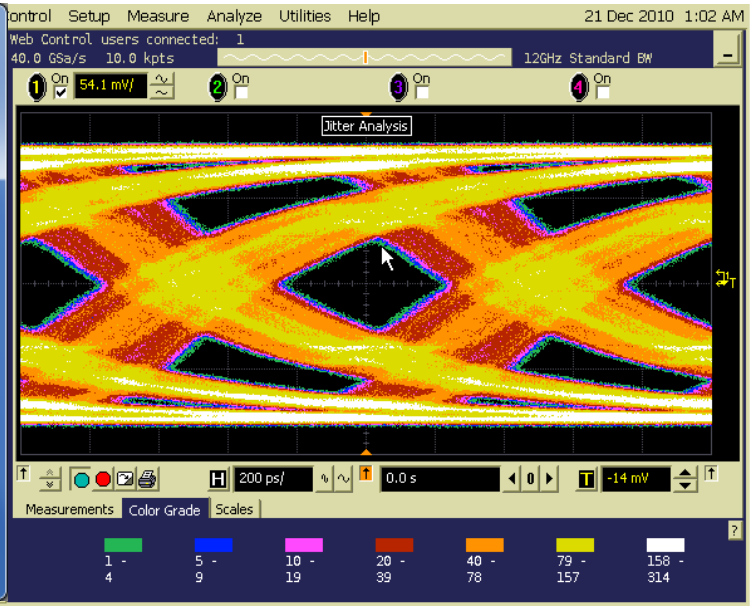
- Ensure flexible adoptions to new distortion requirements by just adopting the waveform itself
- Mimic the analog imperfections that occur in real-world environments by a mathematical descitions in tools like Matlab
- Reudce tests costs through realistic signal simlations that minimize the need for additional hardware like power combiners



1 Gbit/s data rate



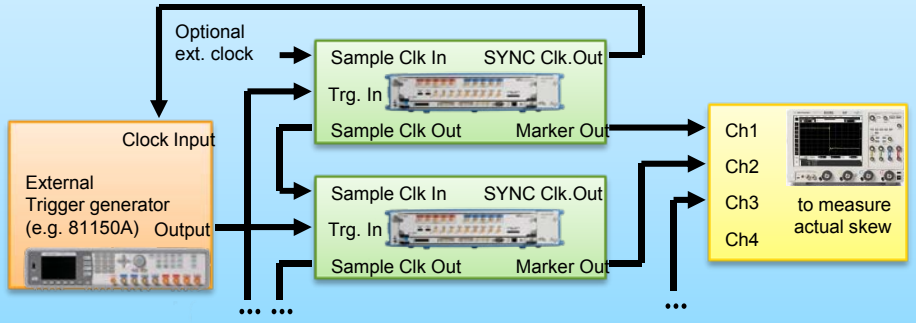
Matlab script



1 Gbit/s data rate with jitter and ISI

Synchronization of more than 2 channels

1. Set up an external trigger generator to generate a one-shot pulse synchronous with its clock input
2. Observe the skew between the marker outputs on the scope on recurring runs; make sure it is always the same skew. If not, see next slide
3. Adjust the waveforms and output delays to compensate the skew

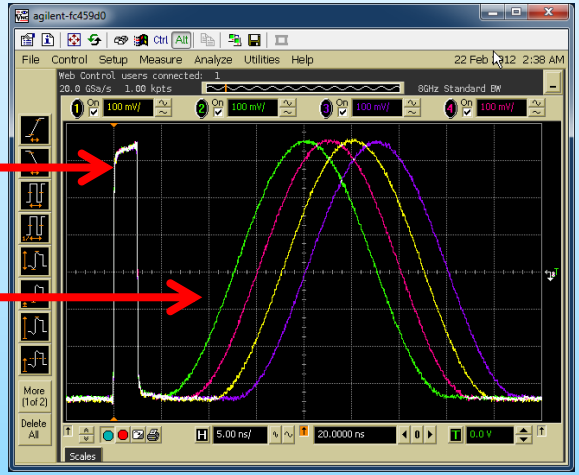


Four M8190A channels in sync

Waveforms consist of a pulse (to show perfect alignment)

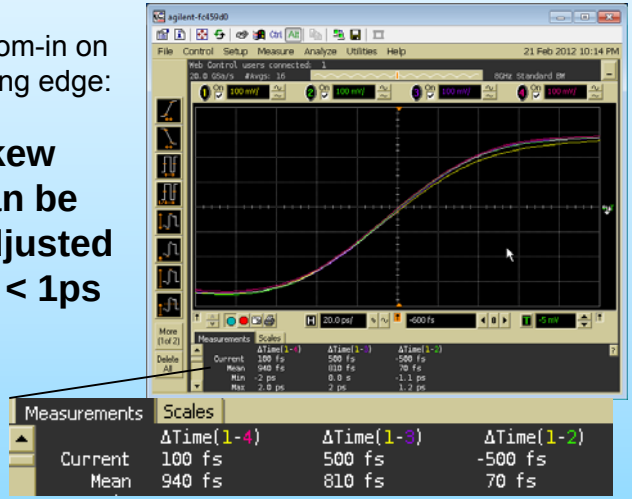
followed by a sinewave (to show that channels are independent)

In a real application, the waveform can of course be completely arbitrary



Zoom-in on rising edge:

Skew can be adjusted to < 1ps

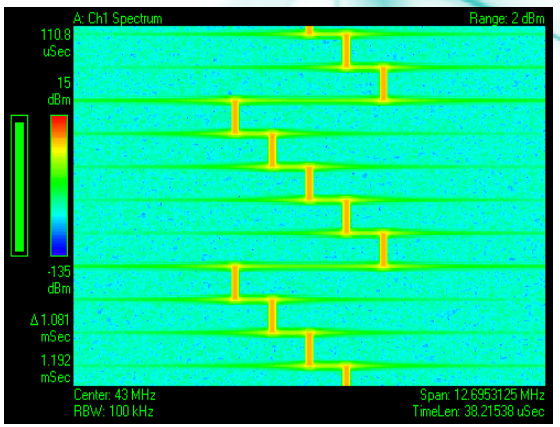


More details

Flexible signal generation that enables testing of FHSS devices

Carrier frequency is rapidly changed across a wide range of frequency channels.
A special receiver knew the frequency-hopping pattern.

- Interfernce, noise:
  - Spread-spectrum signals are highly resistant
  - Only a small piece of data is effected by interference because the frequency changes all the time, so error correction is much more successful.
- Secure transmission:
  - The next carrier frequency is not known, so nobody can listen in
- Effiecient use of bandwidth
- Transmission occurs only on a small portion of this bandwidth at any given time
- Spread-spectrum signals add minimal noise ot the communication,



With near-zero settling time, the COTS system enhances the testing of FHSS devices

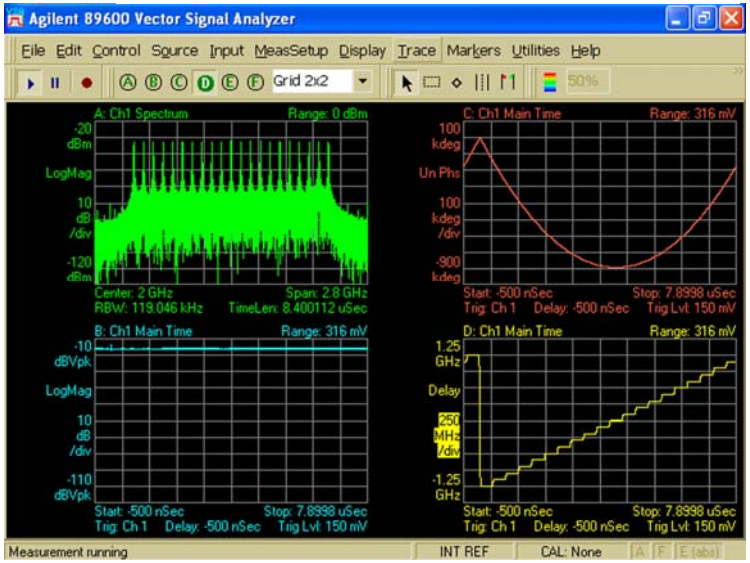
Frequency switching characteristics

Effective output frequency [1]	
Option: –14B	f_{max} = 3.2 GHz
Option: –12G	f_{max} = 4.8 GHz
Effective frequency switching time [2]	
Option: –14B [3]	313 ps (= 1/ f_{max})
Option: –12G	No option: –FSW 210 µs
Option: –12G	Option: –FSW 208 ps (= 1/f_{max})

1 Effective output frequency f_{max} is determined as $f_{Sa,max}$/2.5

2 Determines the minimum time to switch between selected segments in sequence mode

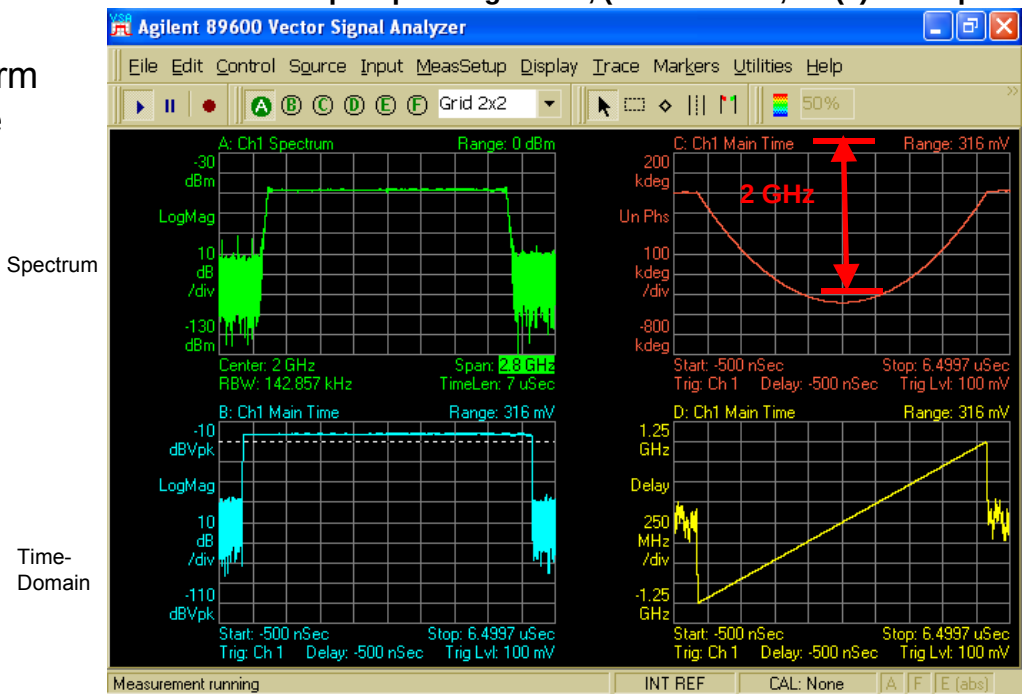
3 Option FSW does not affect switching time in 14 bit mode (Option 14B)



Key characteristics of a Radar Pulse

- Get up to 14 bits resolution and more than 5 GHz analog bandwidth per channel simultaneously
- Build long, realistic scenarios with 2 GSa memory per channel and a sophisticated sequencer
- Push radar designs farther with highly realistic signal scenarios
- Identify deviation from the desired waveform to avoid degradation of radar performance

Radar LFM chirp – spanning 2 GHz, (Fs = 7.2 GHz, sin(x)/x compensated)



Spectrum

Time-Domain

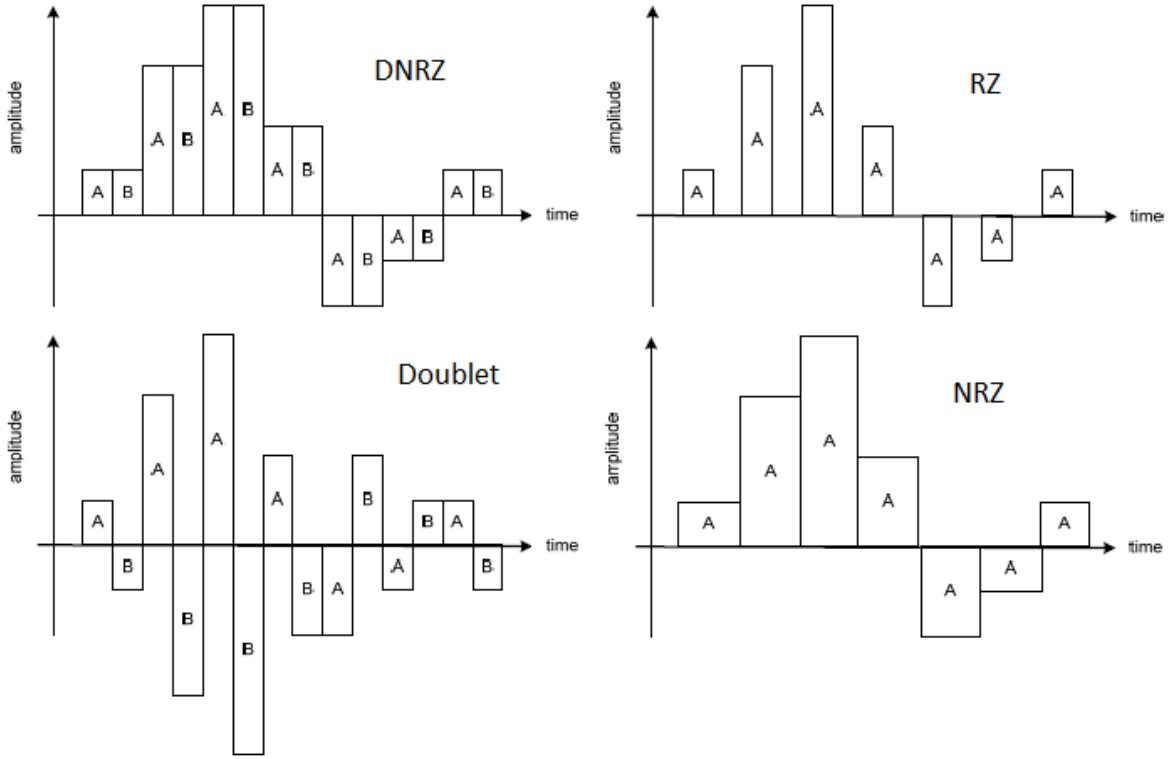
Phase vs. Time

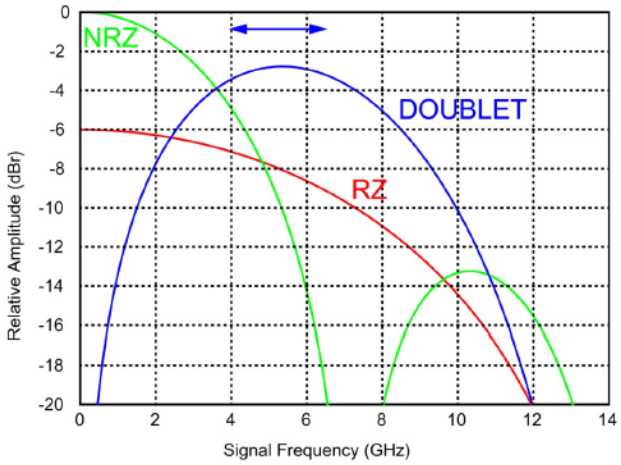
Frequency vs. Time

Typical Test Setup

New features in Rev. 2 available with SW 2.1

- **Output Formats (NRZ, DNRZ, RZ, Doublet)**
  - **For RF applications, select mode based on desired frequency response**
  - **For time-domain applications, NRZ provides better pulse performance**
  - **For frequency-domain apps, DNRZ provides better SFDR**



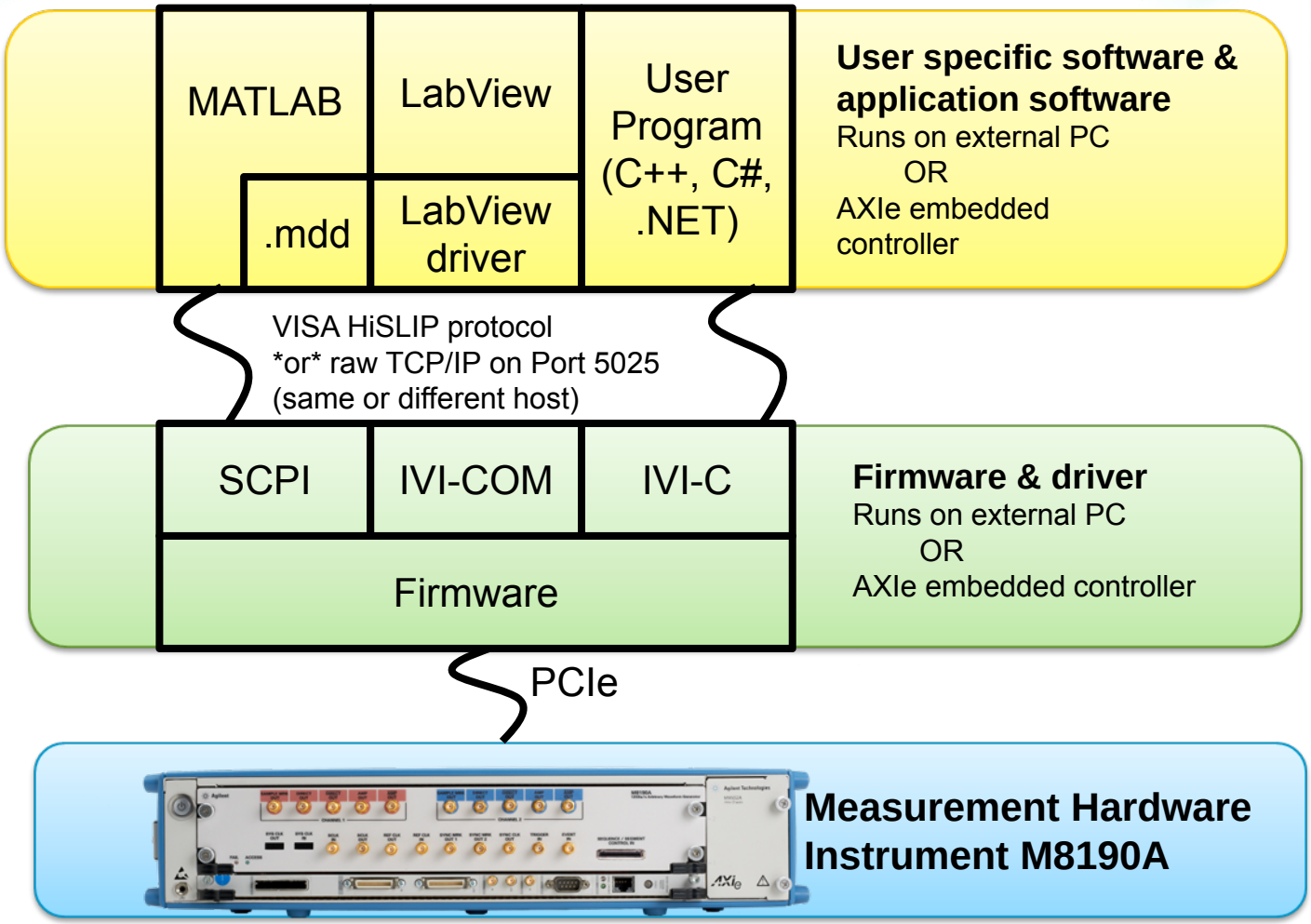


Frequency response (Fs=7.2 GHz)

More details

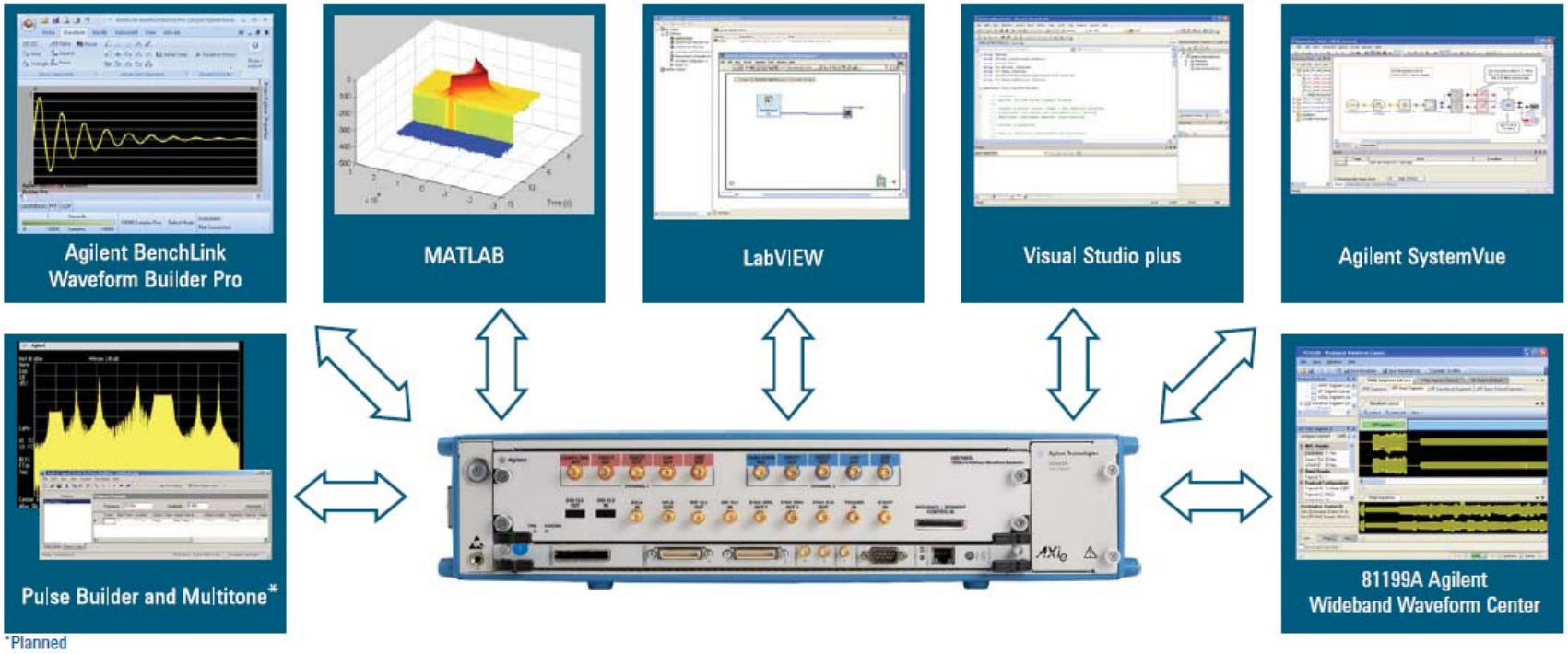
M8190A Programming Structure

SystemVue
Wideband Wavefor



More details

M8190A Operation with all leading software platforms



*Planned

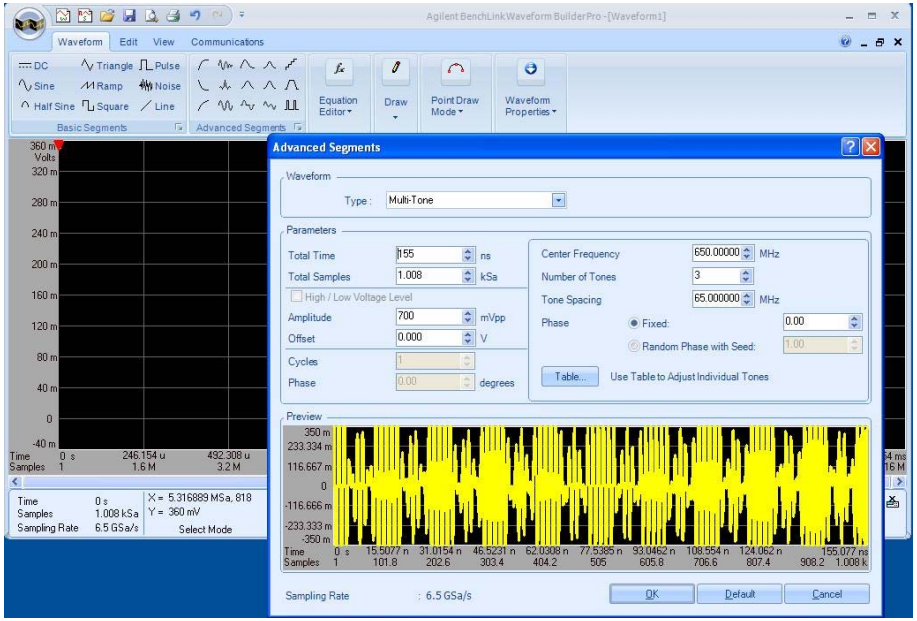
Agilent Benchlink Waveform Builder Pro

Waveform libraries provide quick and easy access to both common (sine, square, triangle, ramp, pulse, exponential) and complex signals

Free-hand, point, and line-draw modes to create custom shapes

Equation editor allows you create waveforms with exact polynomials

Advanced math functions provide additional flexibility for more complex signals

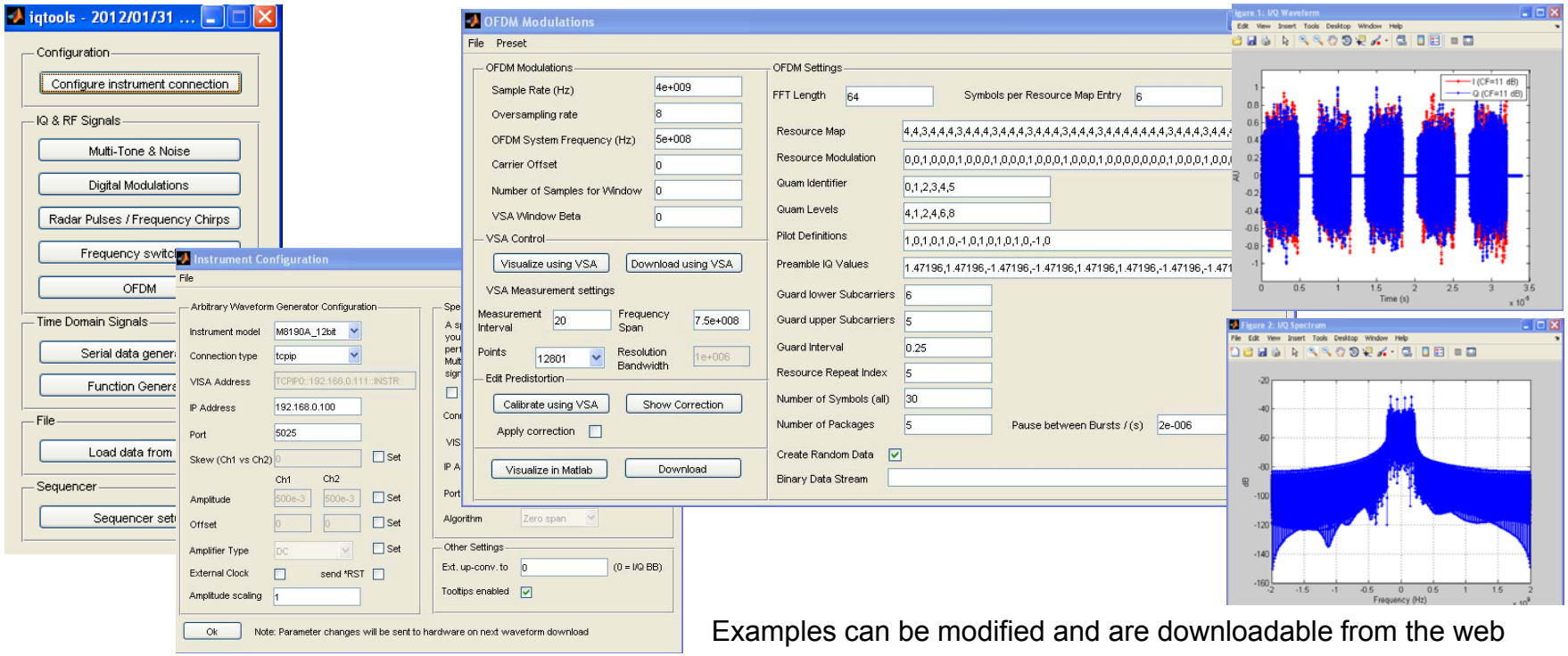


Feature	Basic	Pro
Basic Waveform Library	Yes	Yes
Cut, copy, past with Excle	Yes	Yes
Waveform math	Yes	Yes
Free hand	Yes	Yes
Line draw	Yes	Yes
Advance waveform library	No	Yes
Equatation editor	No	Yes
Point draw	No	Yes
FFT, CCDF, and contstallation diagrom	No	Yes
Filters	No	Yes
Windowing functions	No	Yes
Dual-channel operation	No	Yes

Basic version is part of M8190A shipments

Matlab

MATLAB software for the M8190A available directly from Agilent
for making your own arbitrary waveforms
(multi-tone signals, pulsed radar signals, and multi-carrier modulated waveforms),
measurement and analysis routines, and instrument applications.



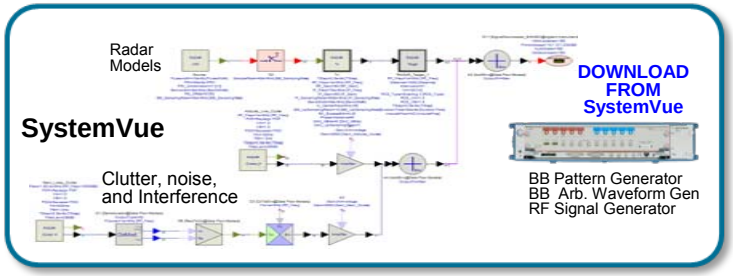
Examples can be modified and are downloadable from the web

www.agilent.com/find/81180_examples:

Accelerate “Design to Test” for Complex Waveforms

SystemVue + Agilent’s M8190A

SystemVue
Electronic System-Level Design



Digital I/Q
Analog I/Q
Modulated UWB RF

Design

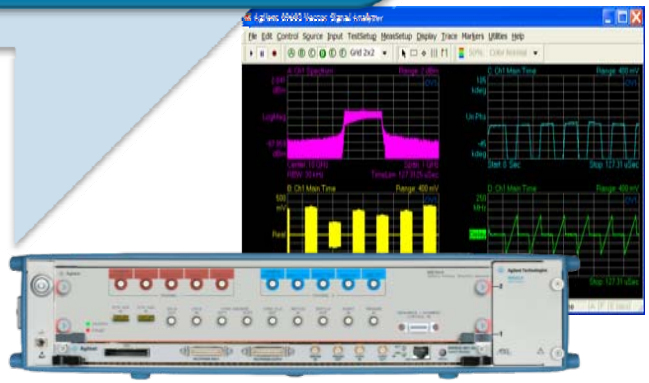
Validate

Test

UWB Radar
EW
SDR

802.11ac
802.11ad

MIMO



Introducing New 802.11ad Signal Creation and Signal Analysis Software or WWC

Compliant testing for Wireless HD, WiGig and IEEE802.11ad

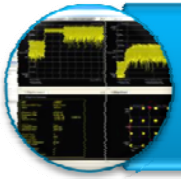
Wireless HD version 1.0
Supports HRP and PRP
Supports all transmit codes
WiGig & IEEE802.11ad
Fully compliant waveforms
Supports CPHY, SCPHY, OFMDPHY, LPSCPHY

Complete transmitter and receiver testing with the Wideband Waveform Center

Wideband Waveform Creator for transmitter testing:
General features:
IQ imparements and gaussian nois addition
Pre-distortion: complex and sin(x)/x
Output direct to Agilent AWG
Single-tone, two-tone and multitone
QPSK, 8-PSDK, 16-QAM, GMSK, Pi/2BPSK
Configurable baseband filtering

Wideband Waveform Creator: **Keep it simple** with drag & drop waveform creation

1. Drag & drop waveform
2. Assign attributes
3. Add predistortion for uplink compensation
4. Set sample rate and download waveform to the instrument



Wideband Waveform Analyzer: Modulation analysis **at at glance** of fully coded signals

Wideband Waveform Analyzer for receiver testing:
Color-coded composite constellation display
Multiple dockable windows, each independently configurable to display one of 13 measurement results

Agilent 60 GHz PHY Test Solution

Controlling PC
(Could be Desktop, Laptop or Embedded)

81199A Wideband Waveform Center (WWC)

Wfm Data

M8190A Wideband AWG (I/Q Generation)

8267D-520-016 (I/Q Modulation)

N5152A 5GHz/60GHz U.C.

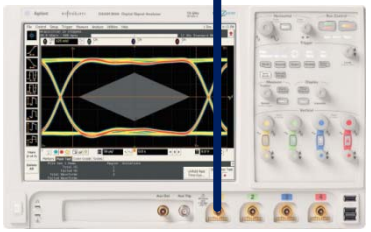
N5183A-520 MXG (Tx LO)

N5183A-520 MXG (Rx LO)

N1999A 60GHz/5GHz D.C.

DUT

Acq'd Signal



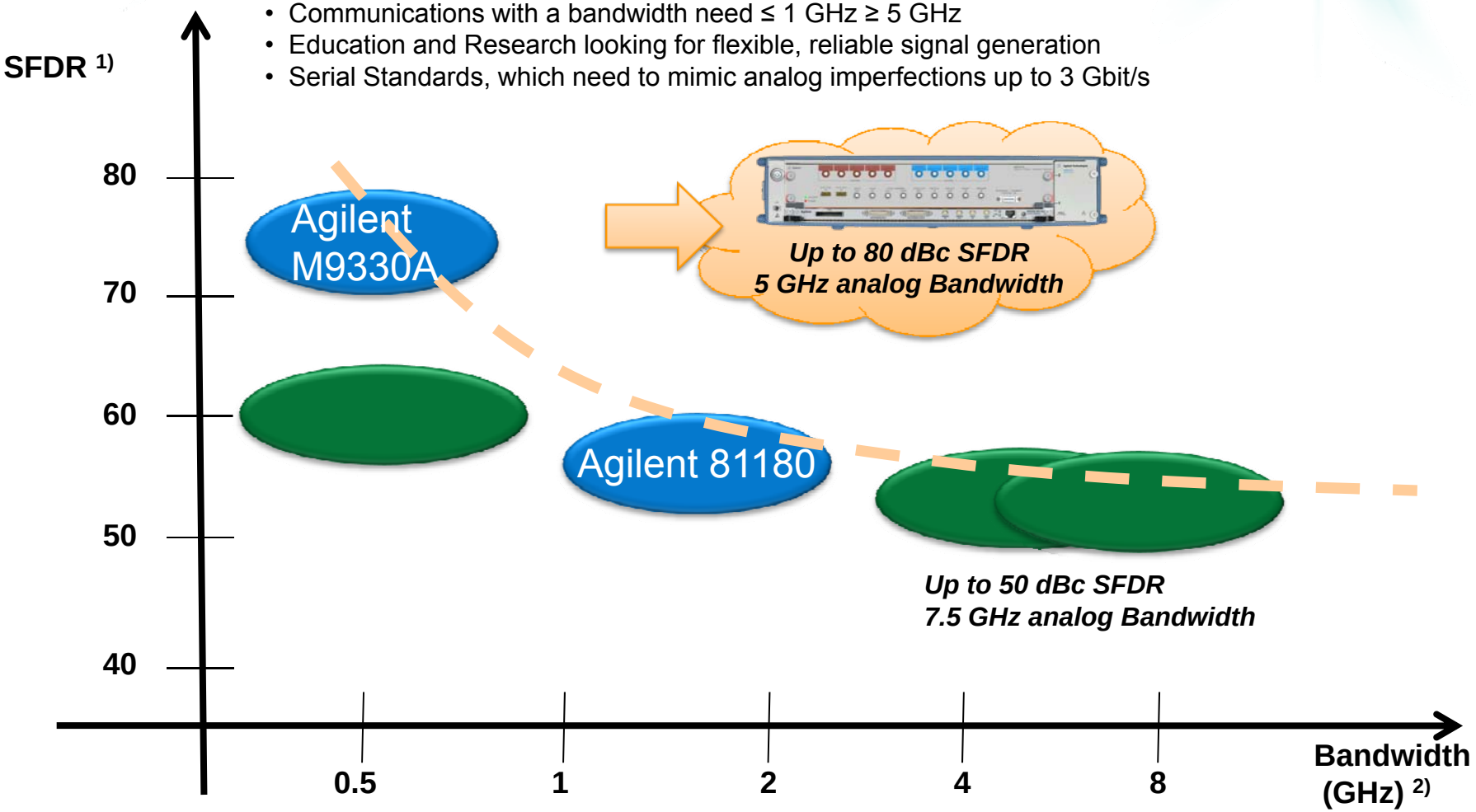
DSO90404A Infiniium Real-time Oscilloscope

More details

The new AWG picture

Do you care about waveform resolution?

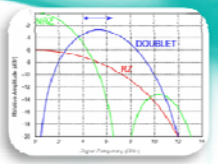
- Radar, EW & Satellite with modulation bandwidth ≤ 1 GHz ≥ 5 GHz
- Communications with a bandwidth need ≤ 1 GHz ≥ 5 GHz
- Education and Research looking for flexible, reliable signal generation
- Serial Standards, which need to mimic analog imperfections up to 3 Gbit/s

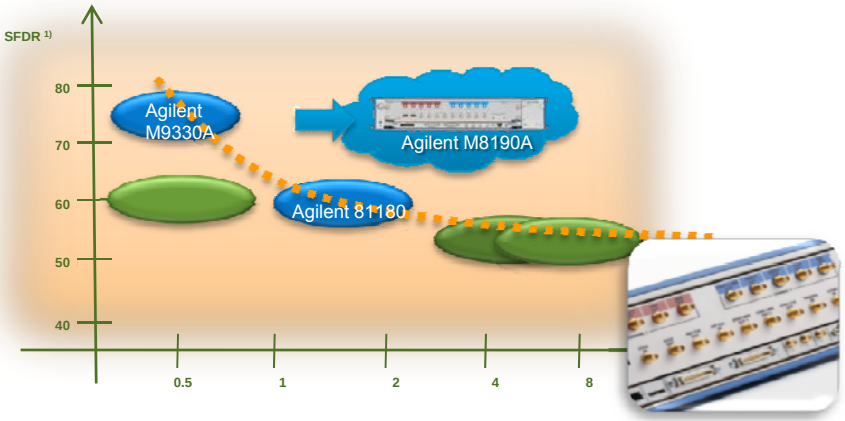


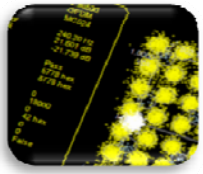
1) SFDR across Nyquist range with f_{out} = 150 MHz
2) Bandwidth of a single channel AWG output

Arbitrary Waveform Generator
Ongoing Innovation

...





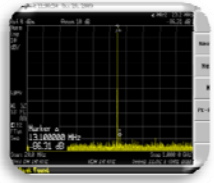


M8190A data formats

- Optimize signal performance through data formats

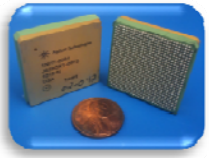
Wideband Waveform Center & M8190A

- New test tools for 60 GHz wireless: support of modulation bandwidht 100 times wider than 802.11n
- Complete and compliant test solution for wireless HD, IEEE802.11ad



M8190A revision 2 -

- Advanced sequencer allows even longer radar playtime
- Low phase noise of – 110 dbc/Hz improves detections of moving targets



M8190A revision 1 - breakthrough performance: up to – 80 dBc SFDR & 5 GHz analog bw

- Build a strong foundation for highly reliable Satellite Communications Excellent SFDR ensures that tones stand out from distortion even with hundreds of tones
- Push Radar design farther with highly realistic signal scenarios with 2 GSa memory per channel

Agilent Labs & high speed digital R&D designed a disruptive technology through BiCMOS silicon geranium process takes us years ahead

Ordering Instruction

M8190A	Option	Rev 1 shipment	Rev 2 shipment	Comment
1 channel	001		X	MUST order either 001 or 002
2 channel	002	X	X	
14 bit /8 GSa/s	14B	X	X	MUST order either 14B or 12G or both options
12 GSa/s/12 bit	12G		X	
Additional DC and AC amplifier	AMP		X	Optional options
Upgrade to 2 GSa memory per channel	02G	X	X	
Sequencer	SEQ		X	
Fast switching	FSW		X	Fast switching for 12 GSa/s requires export control license
ISO 17025	1A7		X	Calibration options
Z540	Z54		X	

Rev 1 configuration requires the Options 002, 14B, 02G. These options are bundled into Option B02. Ordering of additional options based on B02 configuration requires a hardware upgrade. Additional options of revision 2 are software upgradable.

AXIe infrastructure

- M9502A: Two-slot AXIe chassis with ESM
- M9505A: Five-slot AXIe chassis with ESM
- M9045A and M9045B: PCIe laptop card adapter Gen 1 x4
- M9047A: PCIe desktop card adapter Gen 2 x8
- Y1200A: x4 – x8 PCIe cable
- Y1202A: x8 – x8 PCIe cable
- M9536A: Embedded AXIe controller

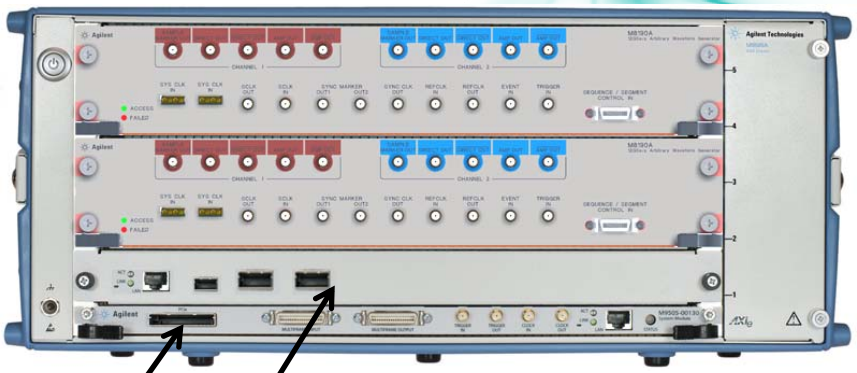
Acccessories

M8190A-801	Microwave phase matched balun, 6.5 GHz, max SMA jack
M8190A-805	Low pass filter, 2800 MHz, max SMA, VLF 2850+
M8190A-806	Low pass filter, 3900 MHZ max SMA, VLF 3800+
M8190A-810	Cable assembly coaxial–50 Ω, SMA to SMA, 457 mm length
M8190A-811	Cable assembly coaxial–50 Ω, SMA to SMA, 1220 mm length
M8190A-815	Dynamic control input cable
M8190A-820	Connector-RF, SMA termination, plug straight, 50 Ω, 12.4 GHz, 0.5 W

Configurations

5-slot AXIe chassis

- fits up to 2 M8190As + system controller + ESM module
- Only a monitor is needed to form a complete instrument



System controller (= embedded PC)

ESM module (provides PCI-Express connectivity)

2-slot AXIe chassis

- Fits one M8190A + ESM module
- **Requires PC or Laptop** with PCI-Express interface card to control it

ESM module (provides PCI-Express connectivity)

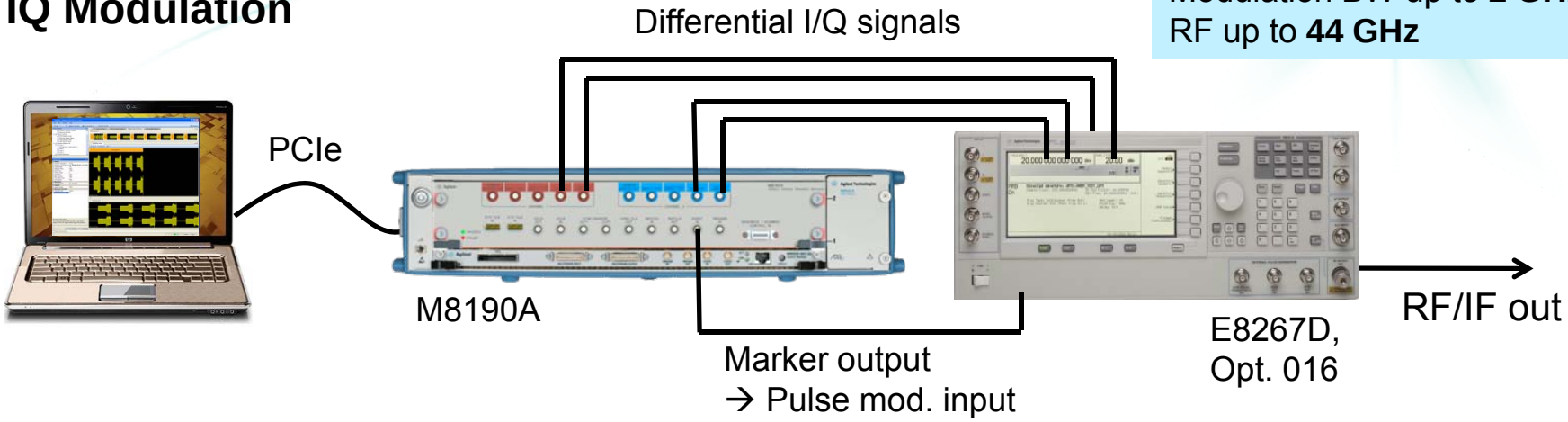
Backup

Typical Setup

Signal Generation Setups

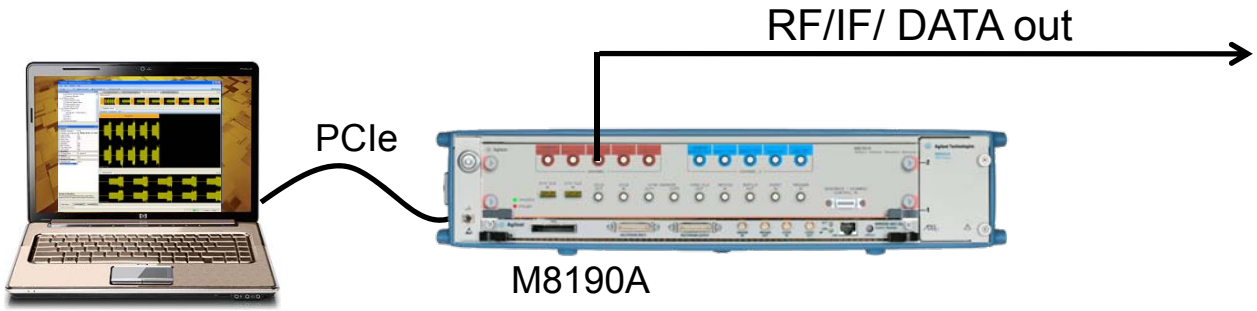
IQ Modulation

Modulation BW up to **2 GHz**
RF up to **44 GHz**



Direct IF/RF

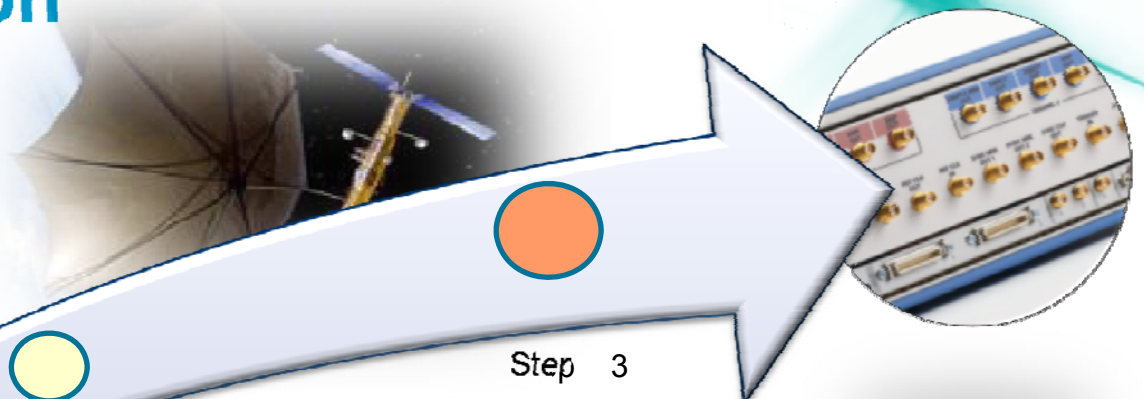
IF/RF up to **5 GHz**
Modulation BW up to
2 x (4.5 GHz – IF)
Data up to 3 Gb/s



Agilent Arbitrary Waveform Generator Portfolio Expansion

Enhance your Reality

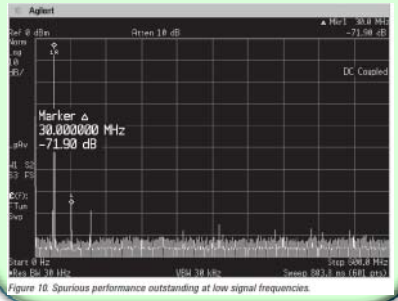
- High Resolution
- Wide Bandwidth



Step 1
High Resolution

M9330A / N8241A
15 bit, 1.2 GSa/s

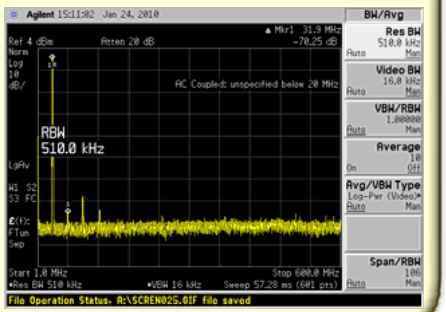
71.9 dB



Step 2
Economic Version

81180A
12 Bit, 4.2 GSa/s AWG
Released April 2010

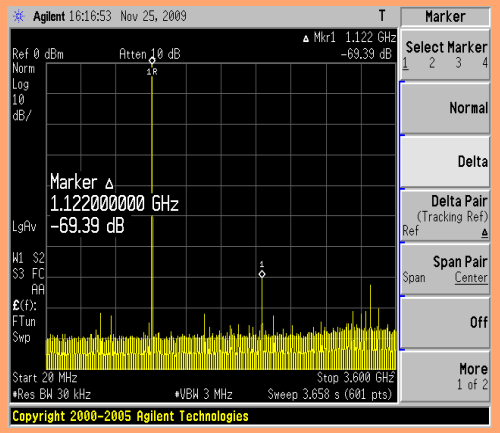
64 dB



Step 3
High Resolution **and** Wide Bandwidth

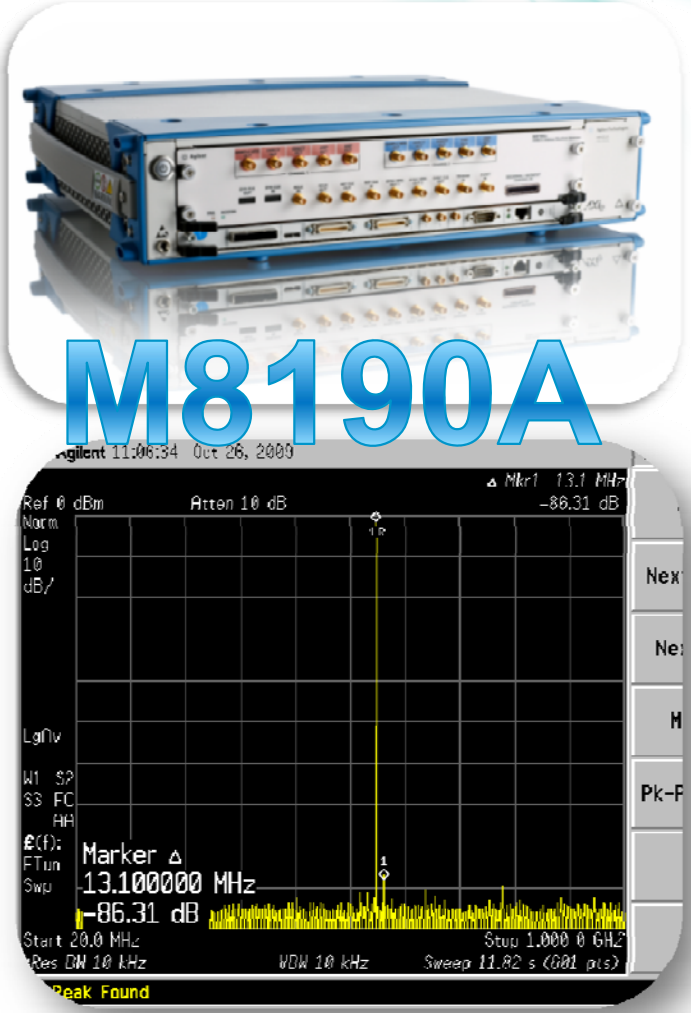
M8190A
14 bit 8 GSa/s / 12 bit 12 GSa/s

69.4 dB



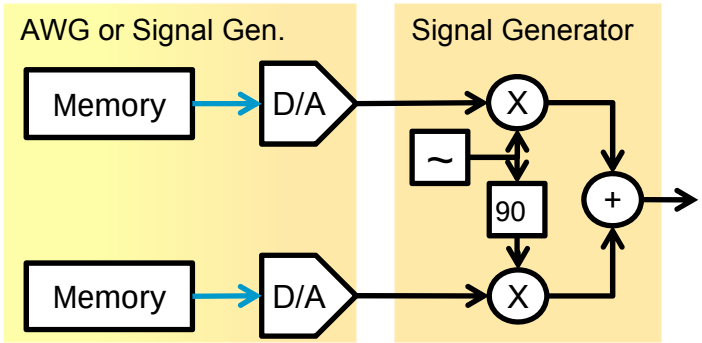
Enhance your Reality with a Source of Greater Fidelity

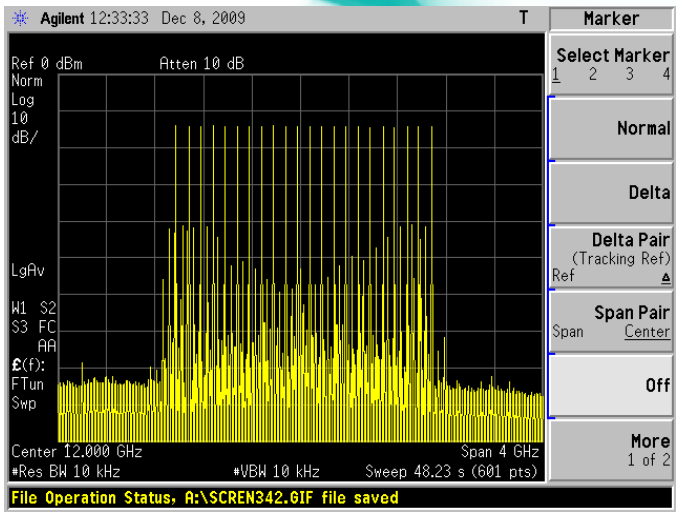
- Breakthrough performance
- 30 dB better dynamic range
- 30X deeper memory
- 5 GHz analog bandwidth
- Operation with all leading software platforms



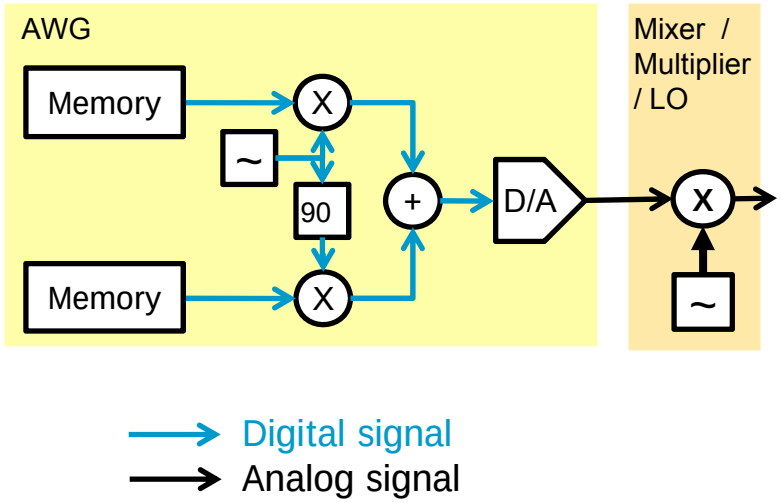
Analog vs. Digital Up-Conversion

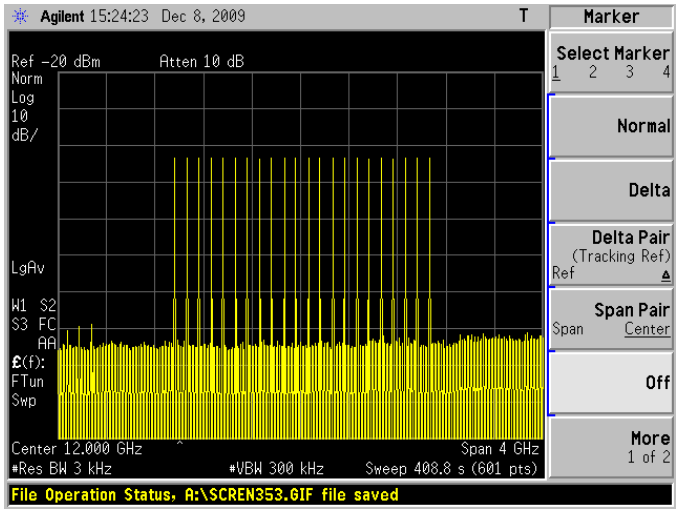
Analog I and Q signals are generated using an AWG. An (analog) I/Q modulator generates the IF or RF signal



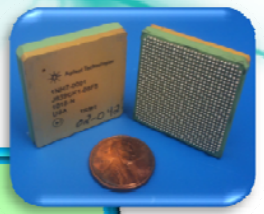


In digital I/Q modulation, the multiplication with a carrier signal is performed digitally – either in real-time or in software





Delivering High Resolution and Wide Bandwidth simultaneously

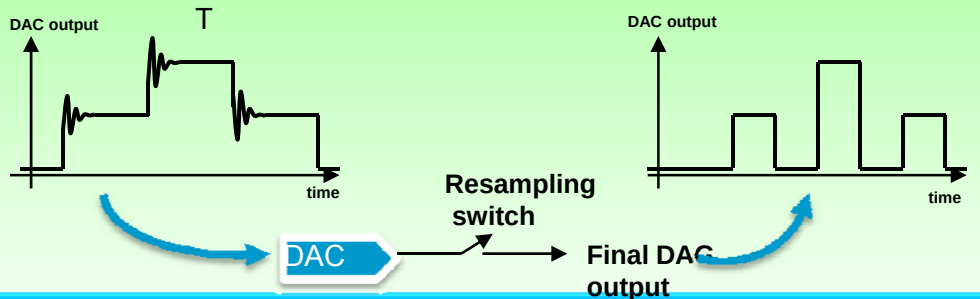


Bandwidth is limited by DAC sample rate

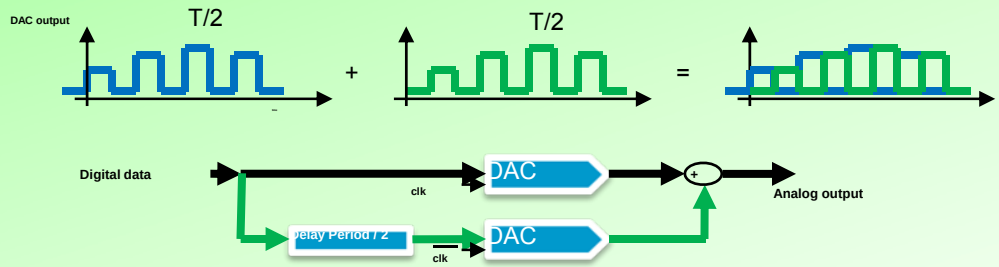
Accuracy is limited by all analog components

Performance mostly depends on DAC

Sample after transient is settled

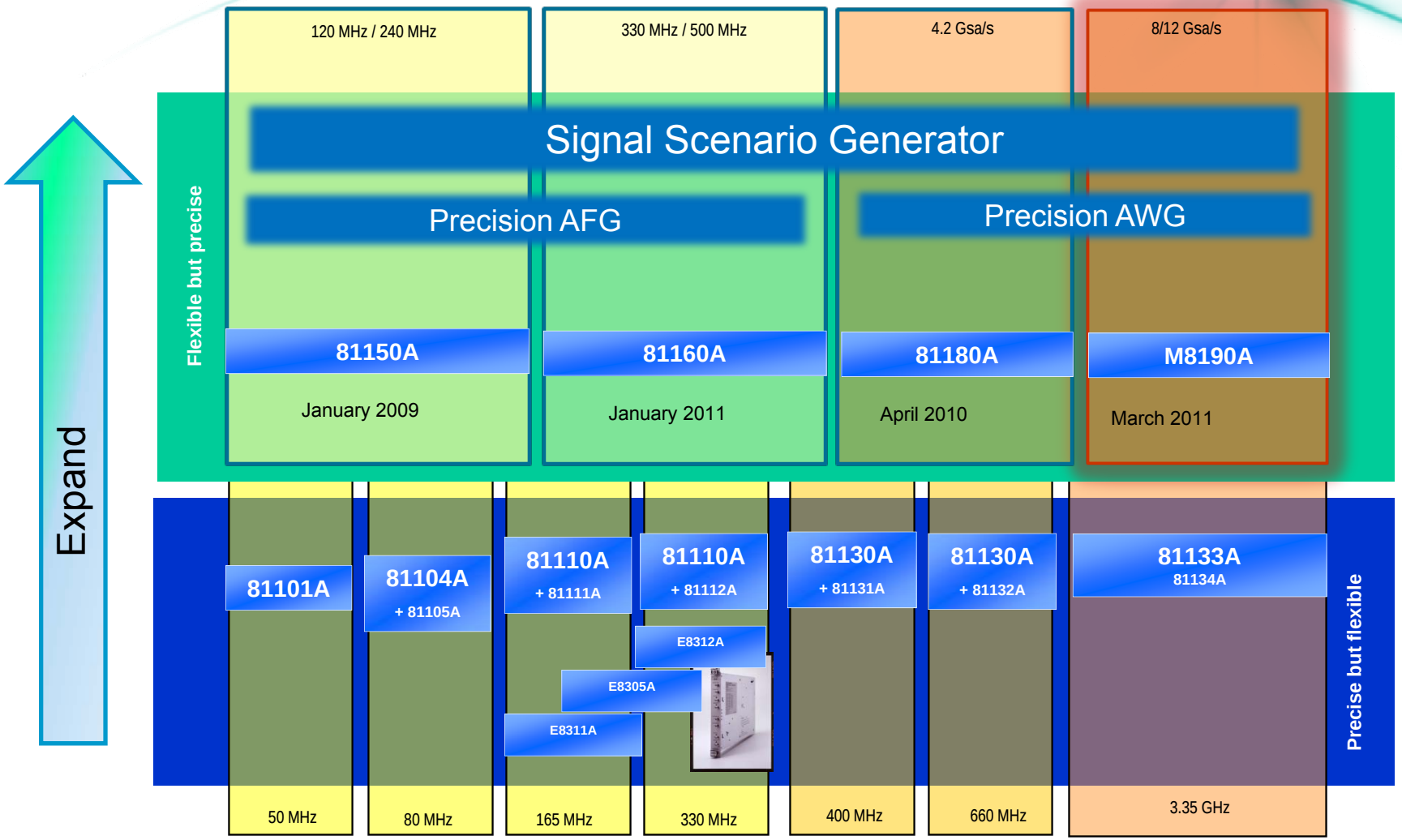


Shifting and adding 2 DAC's for more power and area

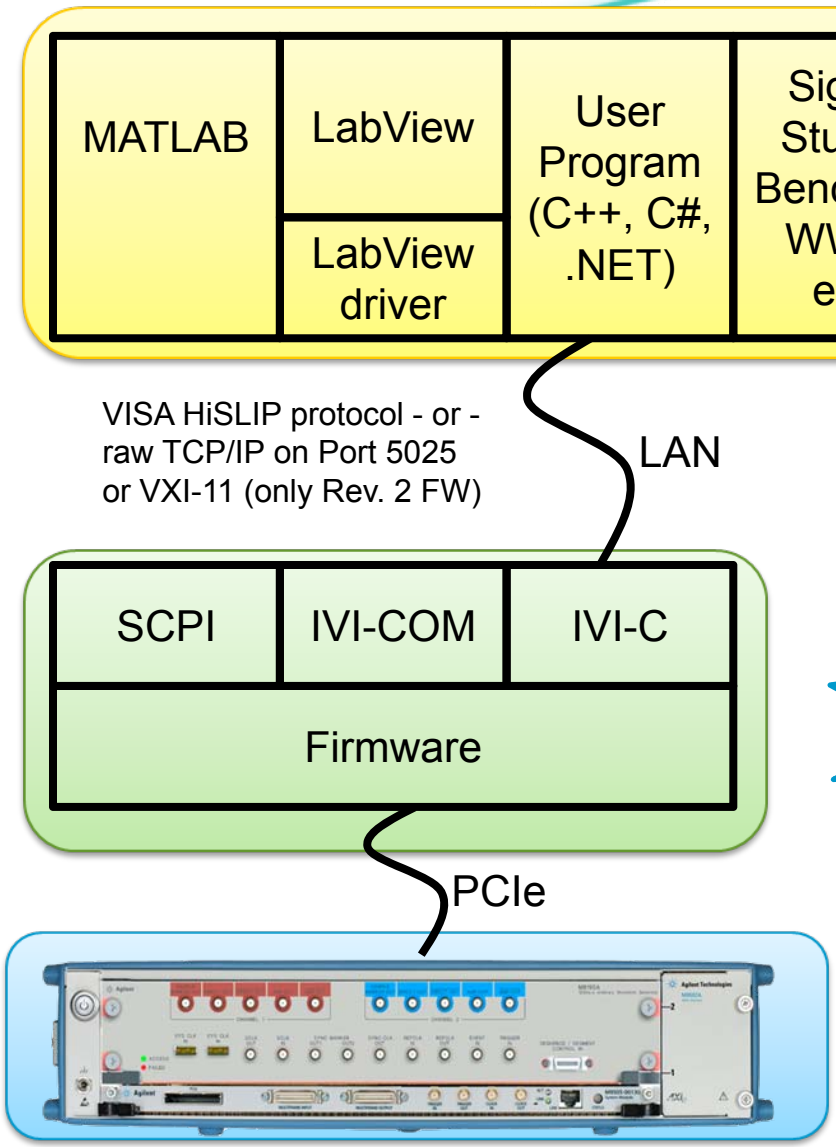


Back

Expansion into Signal Scenario Generators



M8190A Software Structure



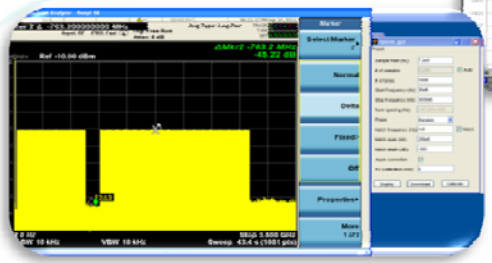
Remember:

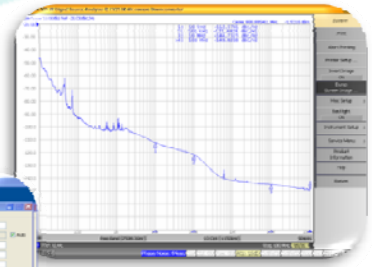
-You can **only** communicate with the M8190A through the firmware. Make sure it is running and connected to the hardware…

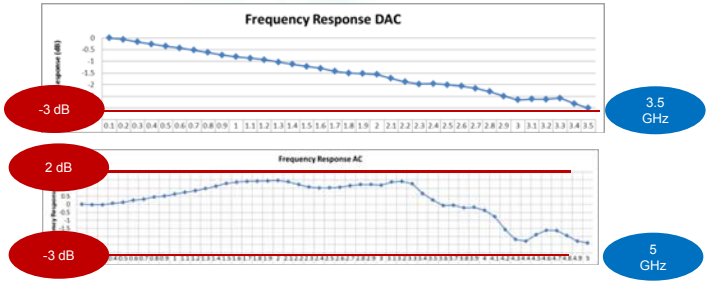
- The firmware acts as a LAN instrument. Do not attempt to connect your user software to PXIn:nnnn:nnnn

Back

M8190A AWG - Reliable, repeatable measurements from precise signal simulation

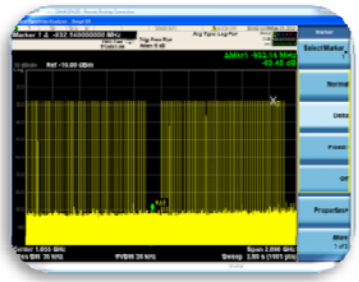






8 GSa/s; f_{OUT} = 1GHz; internal sample clock
-110dBc@10kHz (typ)

- 45 dBc, 3 GHz 1000 tones, 8 Gsa/s, DAC

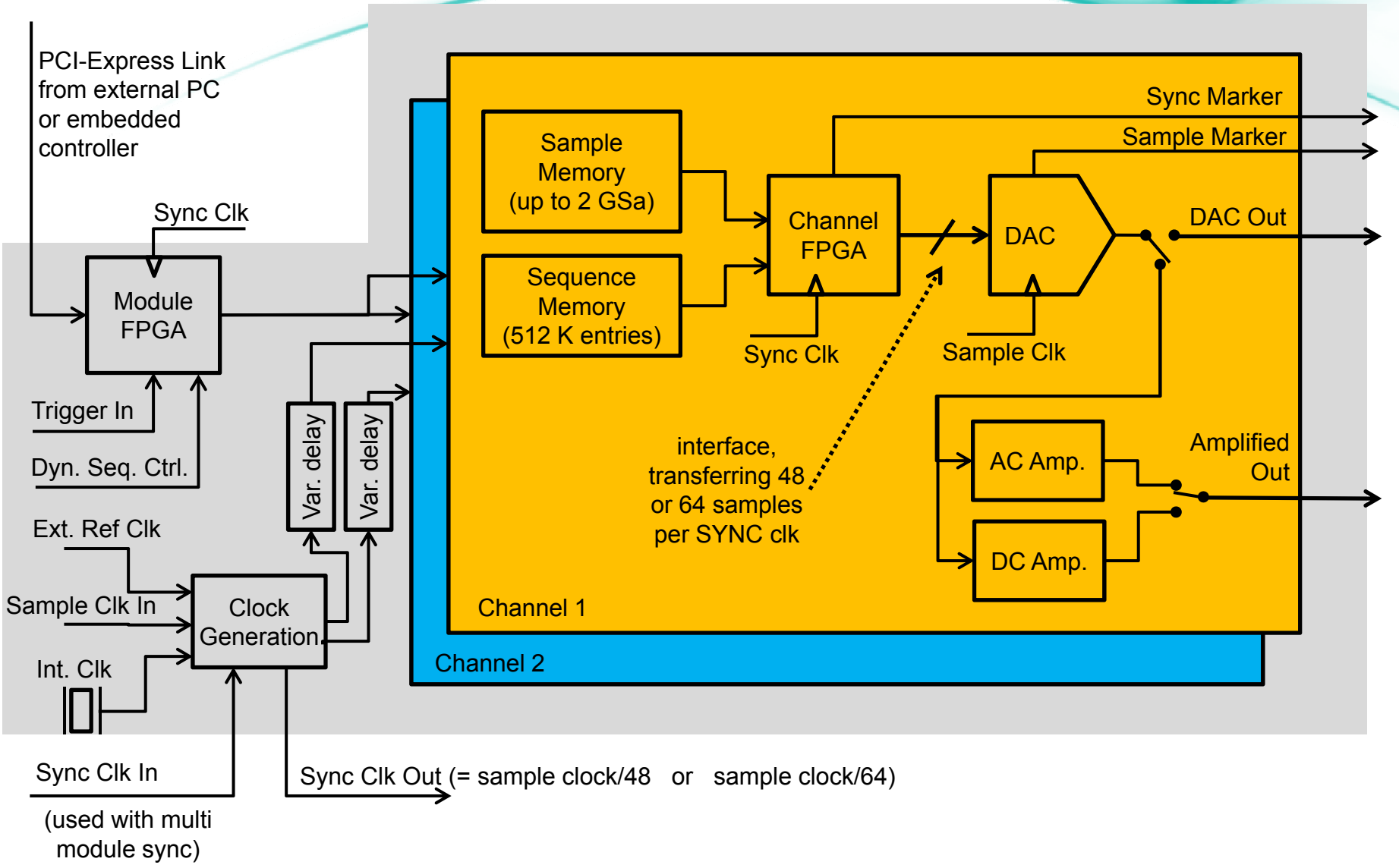


- 63 dBc, 2 GHz, 100 tones, 12 Gsa/s, DAC

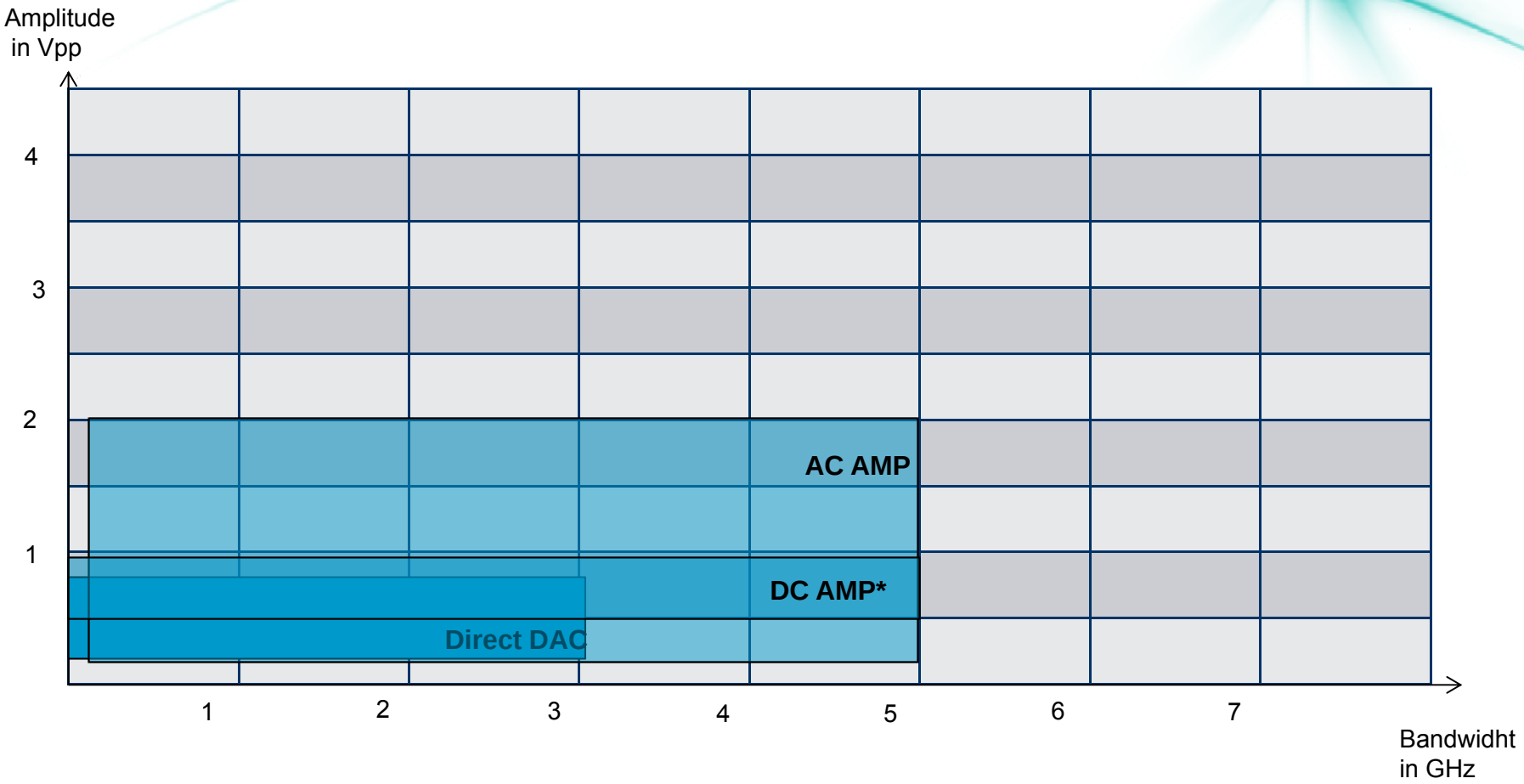
Excellent SFDR ensures that tones stand out from distortion even with hundreds of tones

Back

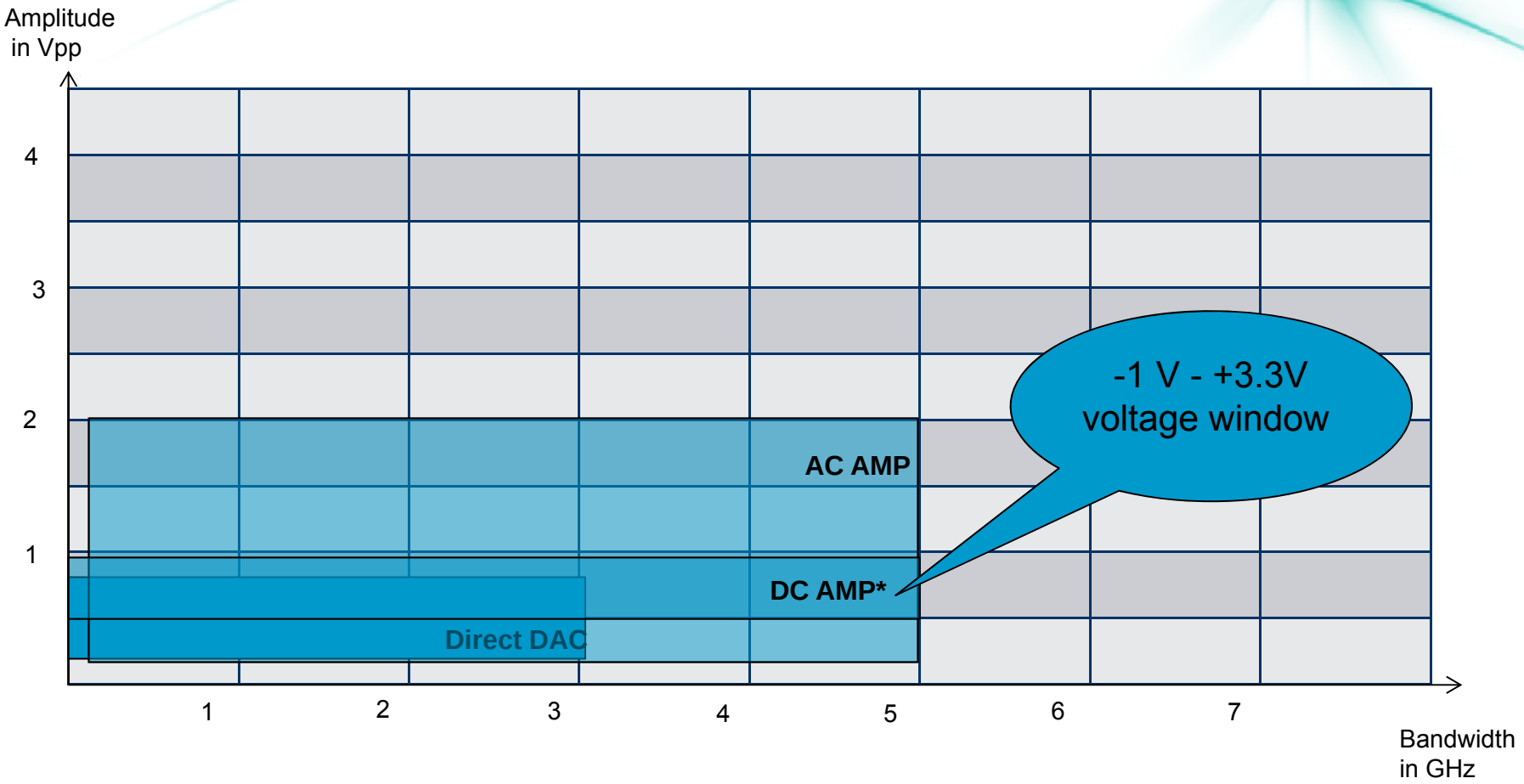
M8190A Block Diagram



Agilent Amplifier Concept



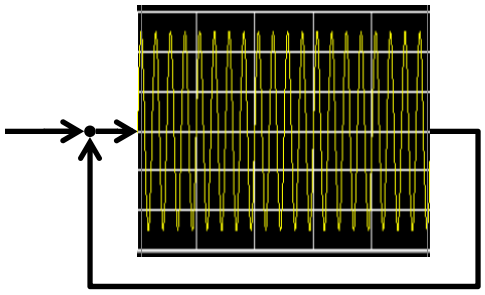
Agilent Amplifier



Back

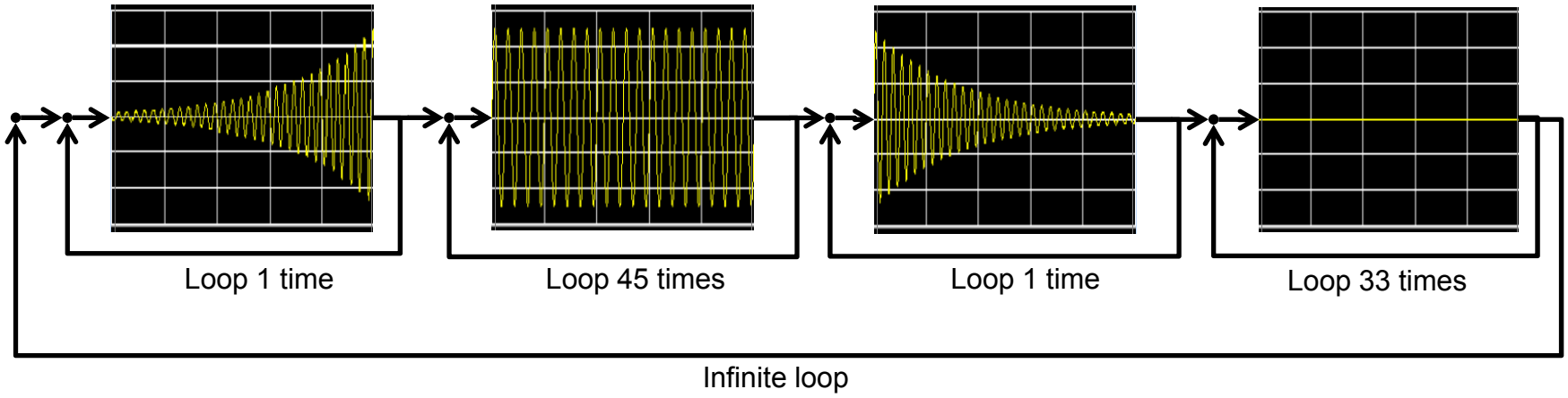
M8190A without sequencing

- Only a **single** waveform segment is available
- Waveform segment can be up to 2 GSamples long



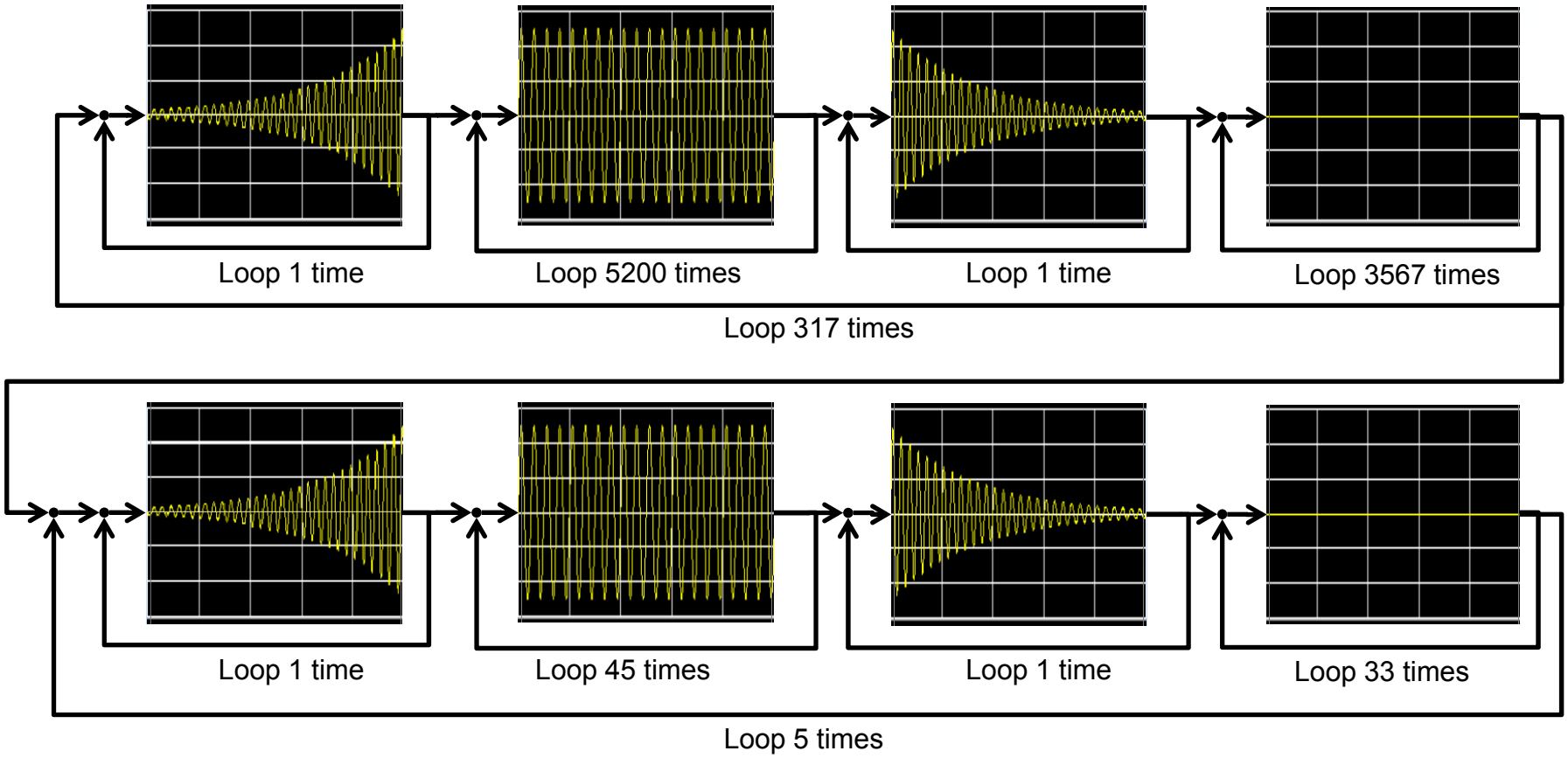
Sequence

- A **sequence** consists of a list of waveform segments
- Total size of waveform segments can be up to 2 GSamples
- Each segment can be looped up to 2^{32} times
- A sequence can contain up to 512K steps



Scenario

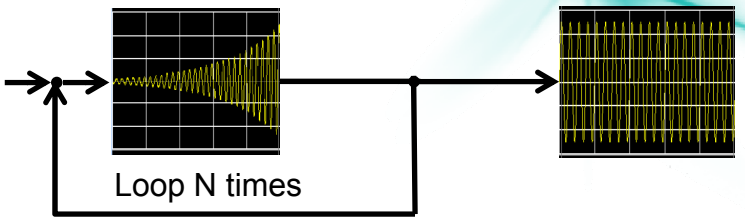
- A **scenario** consists of a list of sequences



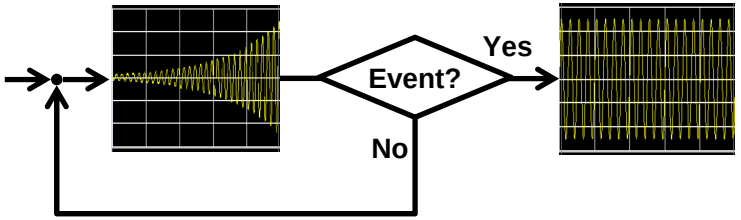
Advancement modes

Advancing from one segment/sequence to the next can be…

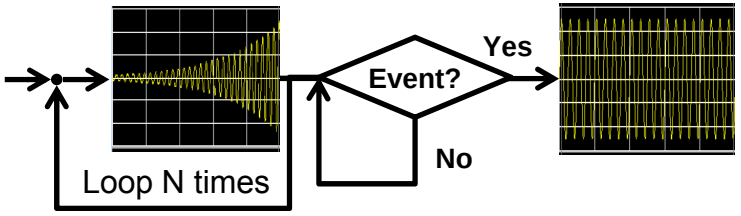
- **Automatic**
  - Loop N times, then go to next segment/sequence (un-conditional)



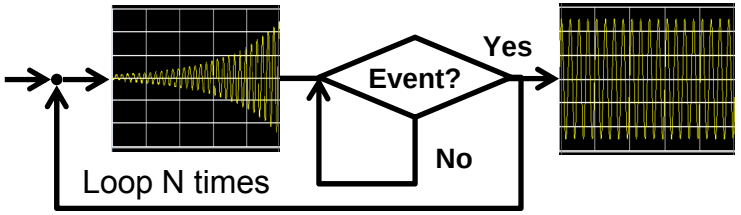
- **Conditional**
  - Loop until an event occurs, then go to next segment/sequence



- **Repeat**
  - Loop N times, then wait until an event occurs before going to the next segment/sequence



- **Stepped**
  - Same as “Repeat”, but wait for an event on every loop

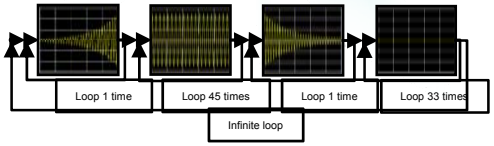


All transitions are “seamless”. Event can be an external signal or a software command

Selection of segment/sequence to be generated

Selection of segment/sequence can be determined by…

- **Pre-defined sequence**
  - If the **order** of waveform segments is known ahead of time, it can be set up as a “sequence”



- **Dynamic Control Port**
  - The dynamic control port on the front panel allows you to select one of 2^{13} (2^{19}) segments/sequences **dynamically at runtime** by applying a digital pattern to the dynamic control port connector

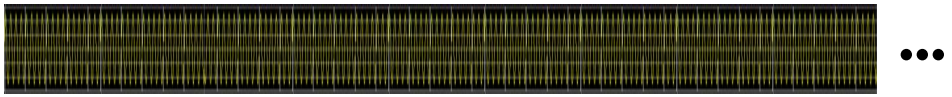
- **Software**
  - Instead of applying a digital pattern to the dynamic control port, you can also select a segment/sequence using software by sending a command to the firmware

In all cases, transitions are “seamless” – without any gaps

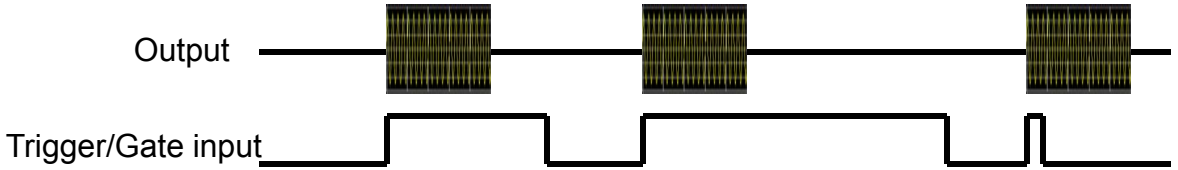
Trigger modes

All of the previously mentioned cases can be combined with the following trigger modes. This applies to **segments** or **sequences**.

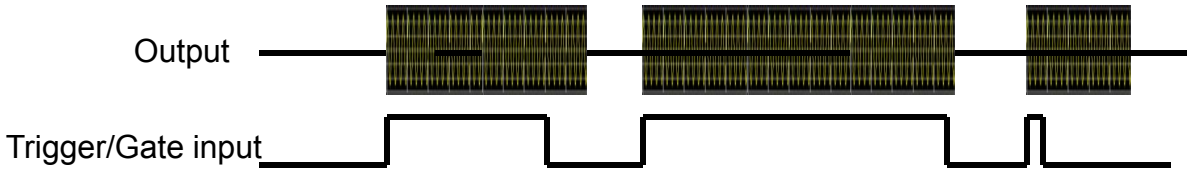
- Continuous



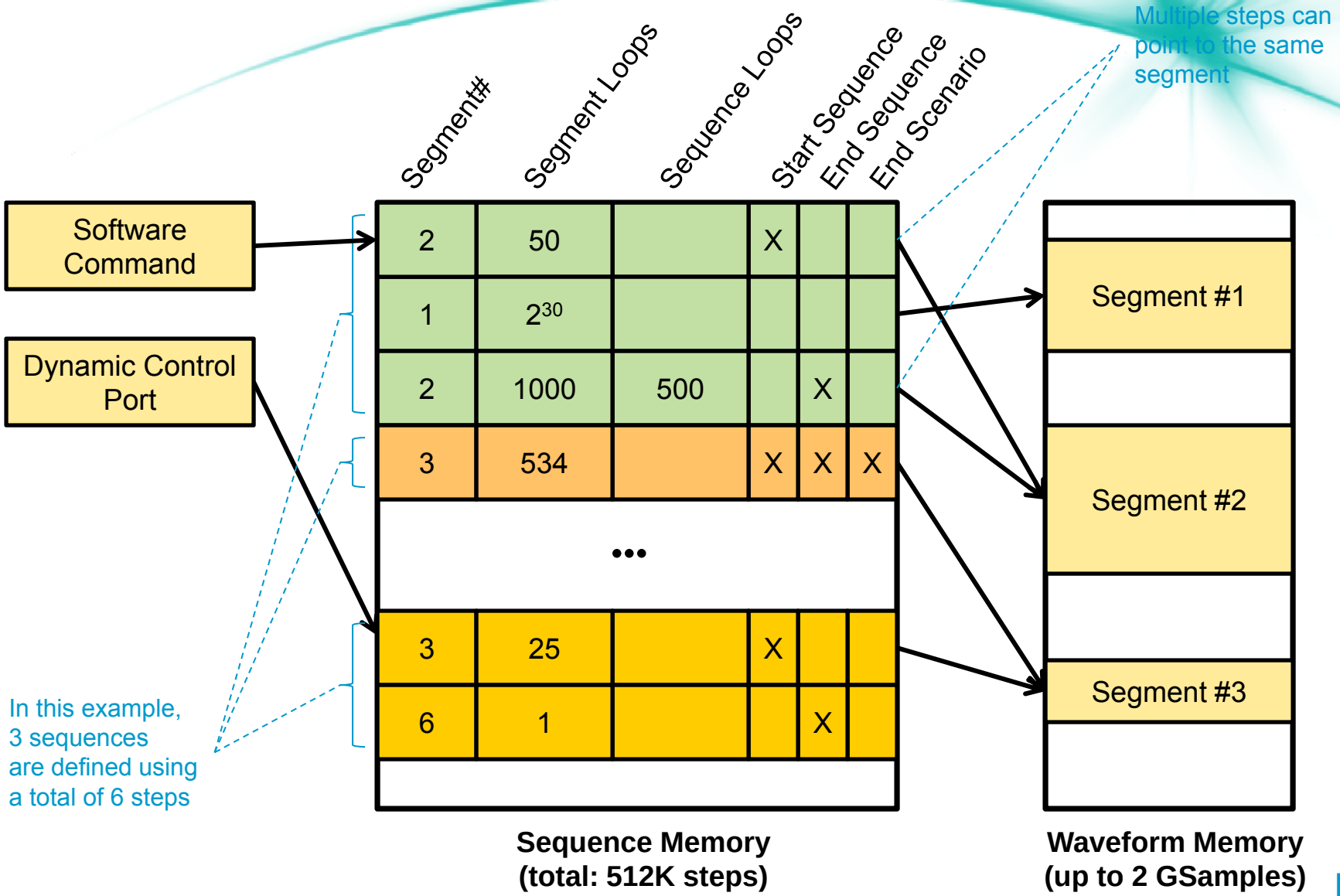
- Triggered
  - Each edge of the trigger signal starts the selected segment/sequence.



- Gated
  - Segments are always completed



…and how does it work internally?



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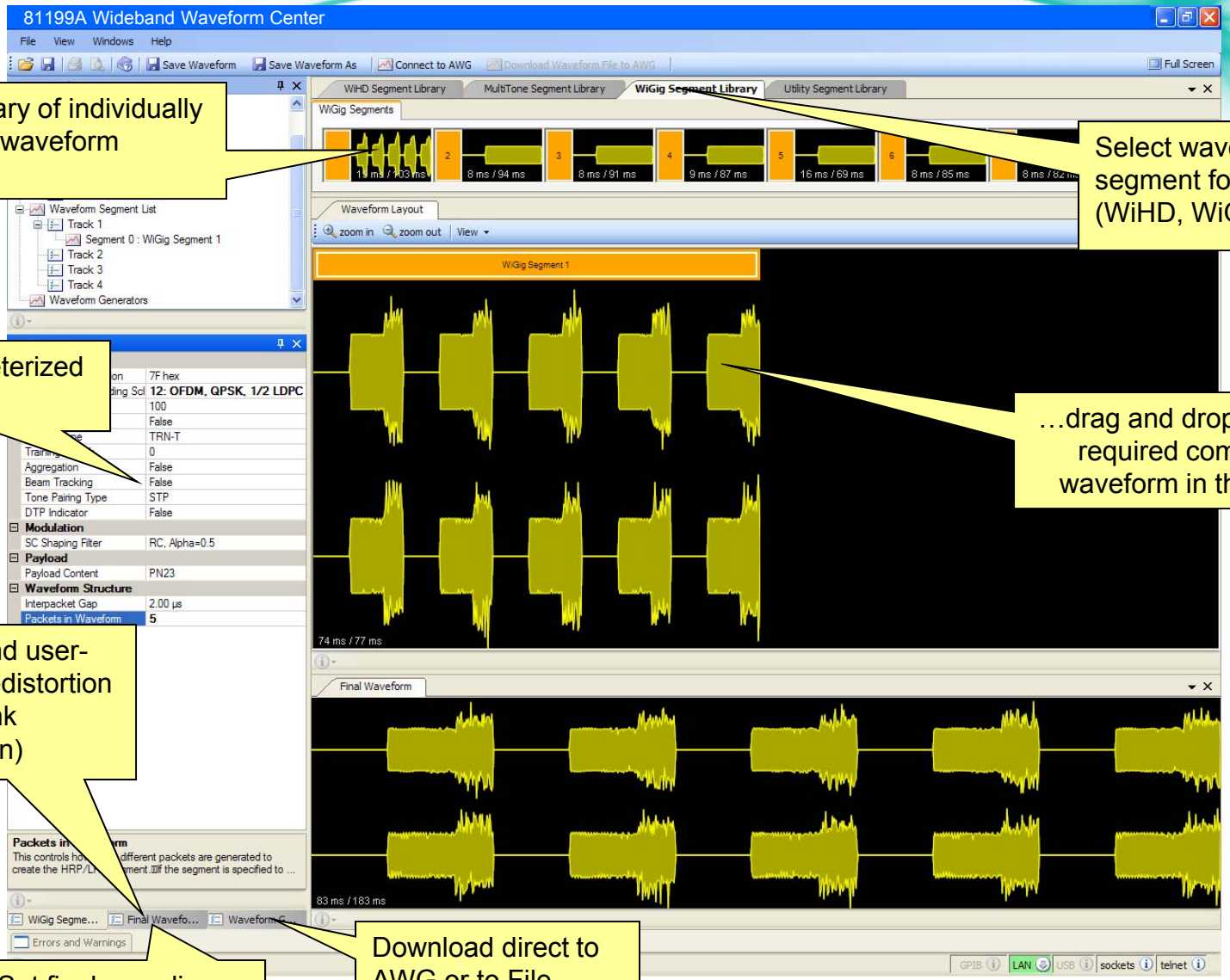
81199A Wideband Waveform Creator (GUI)



Create a library of individually configurable waveform segments…

Select waveform segment format from (WiHD, WiGig etc.)

Fully parameterized encoding

…drag and drop to create required composite waveform in the editor

Add noise and user-definable predistortion (e.g. for uplink compensation)

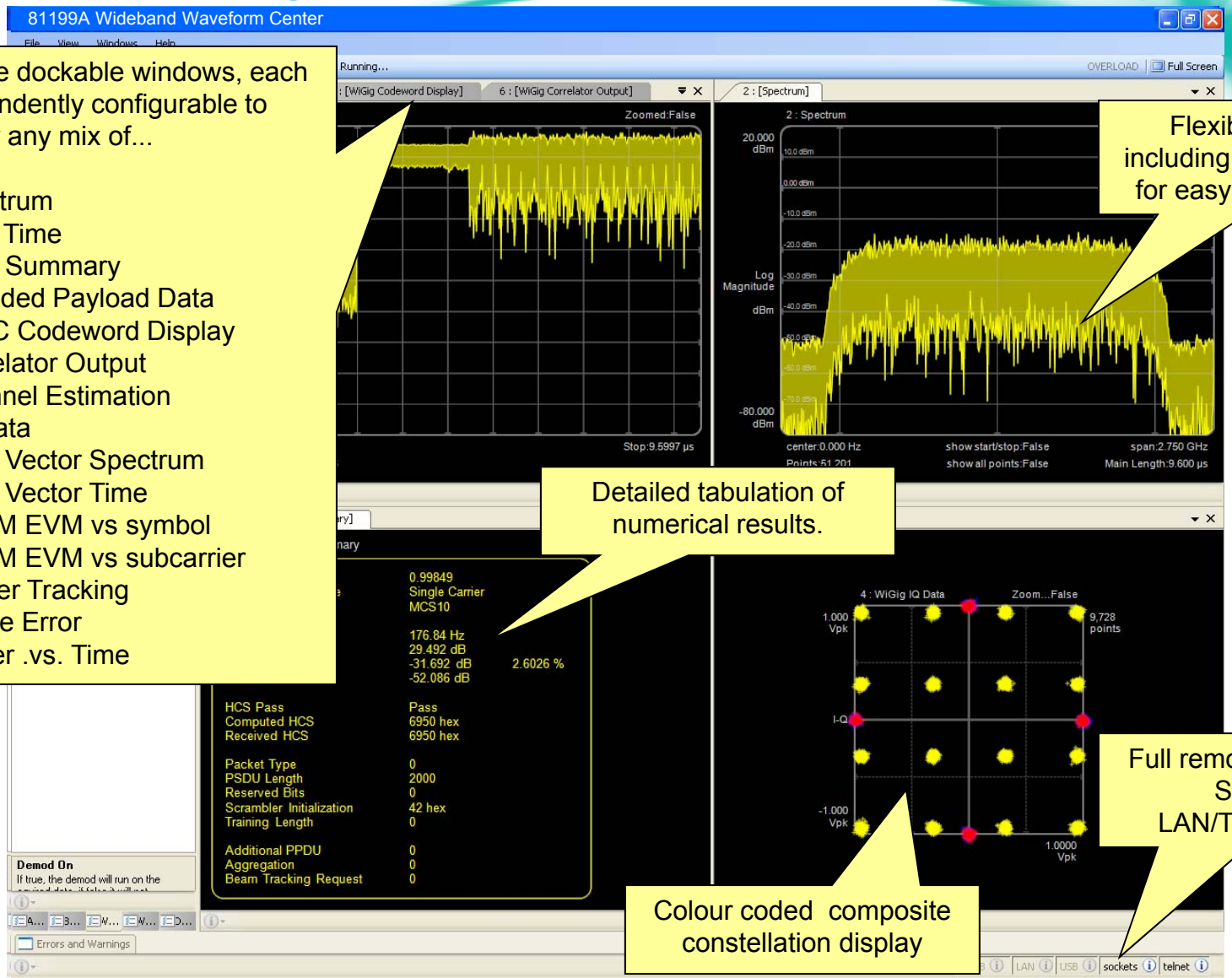
Set final sampling rate to match AWG

Download direct to AWG or to File

81199A WiGig / 802.11ad Modulation Analyzer

Multiple dockable windows, each independently configurable to display any mix of...

- Spectrum
- Main Time
- Error Summary
- Decoded Payload Data
- LDPC Codeword Display
- Correlator Output
- Channel Estimation
- IQ Data
- Error Vector Spectrum
- Error Vector Time
- OFDM EVM vs symbol
- OFDM EVM vs subcarrier
- Carrier Tracking
- Phase Error
- Power .vs. Time

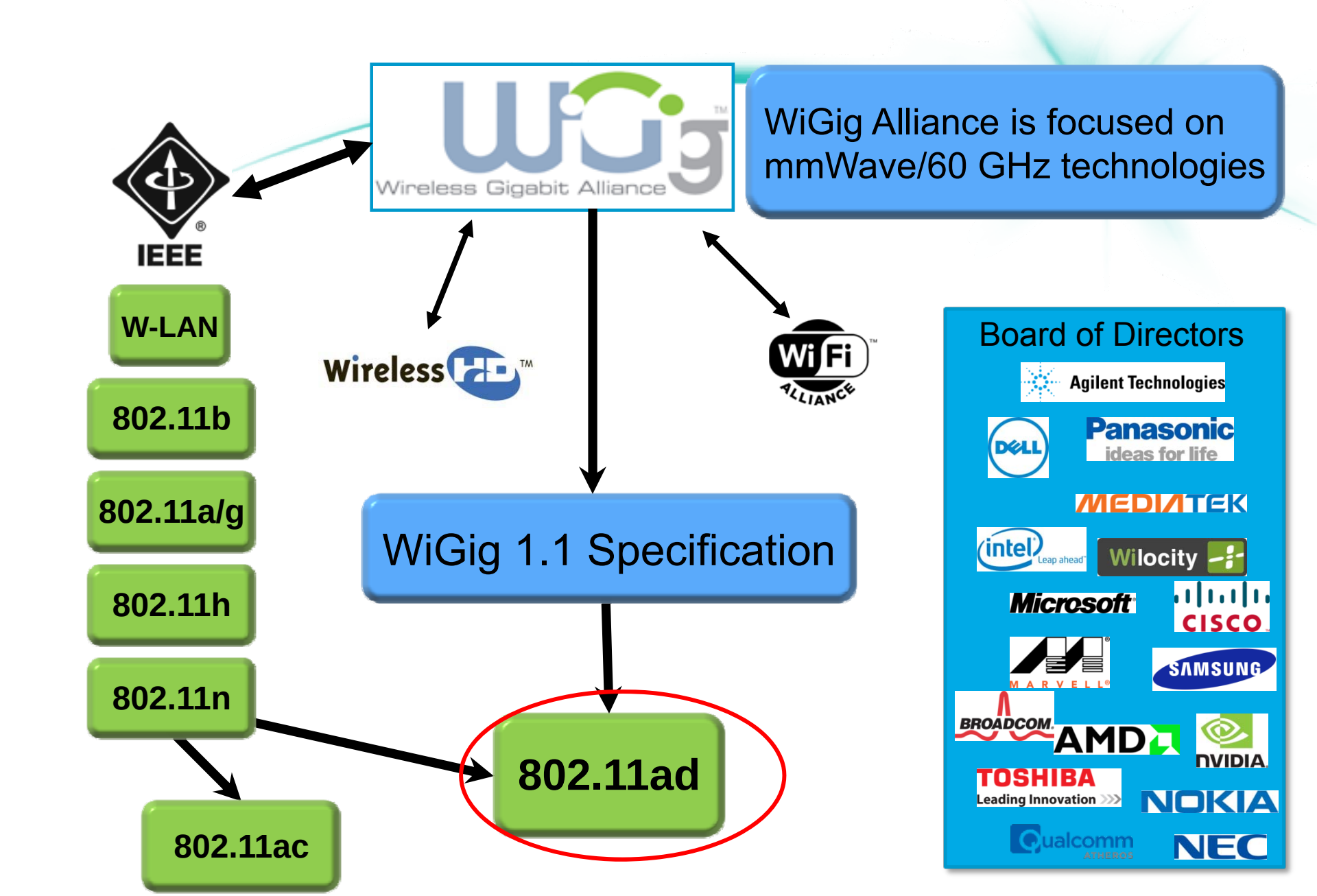


Flexible graphing, including image cut/paste for easy documentation

Detailed tabulation of numerical results.

Colour coded composite constellation display

Full remote control using SCPI over LAN/Telnet/Sockets


WiGig
Wireless Gigabit Alliance
WiGig Alliance is focused on mmWave/60 GHz technologies
IEEE
W-LAN
802.11b
802.11a/g
802.11h
802.11n
802.11ac
WirelessHD
Wi Fi ALLIANCE
WiGig 1.1 Specification
802.11ad
Board of Directors
Agilent Technologies
DELL
Panasonic ideas for life
MEDIATEK
intel Leap ahead
Wilocity
Microsoft
CISCO
MARVELL
SAMSUNG
BROADCOM
AMD
NVIDIA
TOSHIBA Leading Innovation
NOKIA
Qualcomm ATHEROS
NEC

802.11ad Technology

57 – 66GHz Unlicensed, globally available

7 Gbps Data Rates

Wider channels, enabling higher data rates over short distances (1m – 10m)

First commercial devices expected to be announced at CES in Jan 2012 (covert meetings occurred at CES2011 last January)

	Single Carrier	OFDM
	For Preamble and Data	For Higher Data Rates
Bandwidth	1.76 GHz	1.825 GHz
Modulation	p/2-BPSK, p/2-QPSK,16-QAM	SQPSK, QPSK,16-QAM, 64-QAM

Why New Test Tools for for 60 GHz Wireless

mm Technology

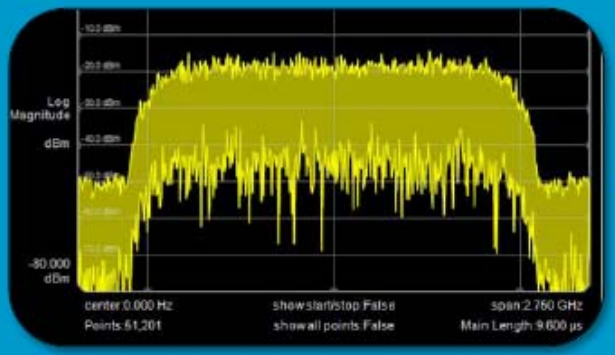
- Performance taken for granted at lower frequencies not so easy to acheive
- Mismatch, skew, cable lengths matter

Baseband Modulation & Demodulation

- 2 GHz Modulation BW
  - Data rates up to 7 Gbps
  - **100 times wider modulation** bandwidth than 802.11n.
  - 1.5 times wider than 802.11ac
- Traditional sources and analyzers lack BW
- Complex frequency response (flatness) difficult

No connectors at 60 GHz

- Built-in multi-element anntenas lack test connection
- No place to insert 1.85mm connectors
- Over-the-air (OTA) testing required
- Multi-path intrinsic in performance and in measurement environment



Agilent Participation in the WiGig Alliance

In the Alliance and Participation in the PlugFest

- Agilent representatives have chaired the WGA Interoperability Working Group (IWG) for the last two years.
- Agilent exclusively provided the test equipment for the PlugFest

From WiGig Alliance Press Release

"Key test instrumentation for the PlugFest is being provided by Agilent Technologies, the leader in test and measurement and the only commercial provider of signal creation and modulation analysis SW and HW solutions for the WiGig Standard."

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Triggering of M8190A modules

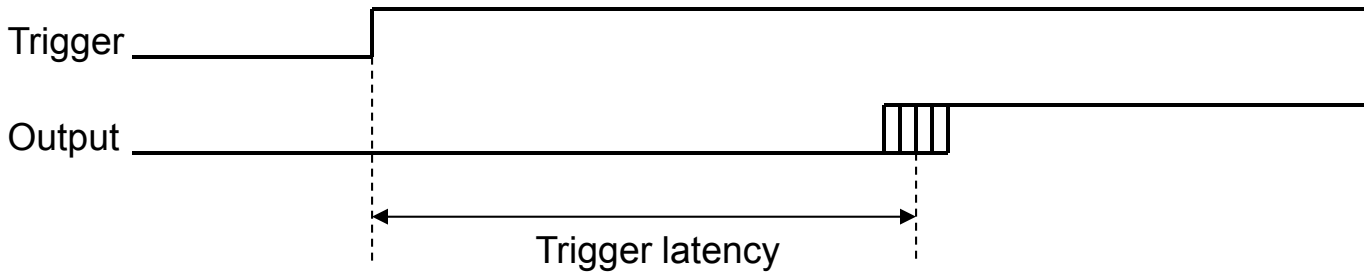
Definition: Trigger latency

Trigger latency is the amount of time it takes from the (active) **edge of the trigger** input to the **start of the output** signal

- The trigger latency can typically be broken down into
  - a **fixed amount** (due to the delay in cables & asynchronous circuits)
  - a certain **number of clock cycles** (due to internal flip-flop stages)
  - and an amount of **uncertainty** (see next slide)

e.g. 2.6 ns + 7680 clk.cycles +/- 24 clk.cycles are nominal values for the M8190A in 14-bit mode

fixed number of clocks uncertainty



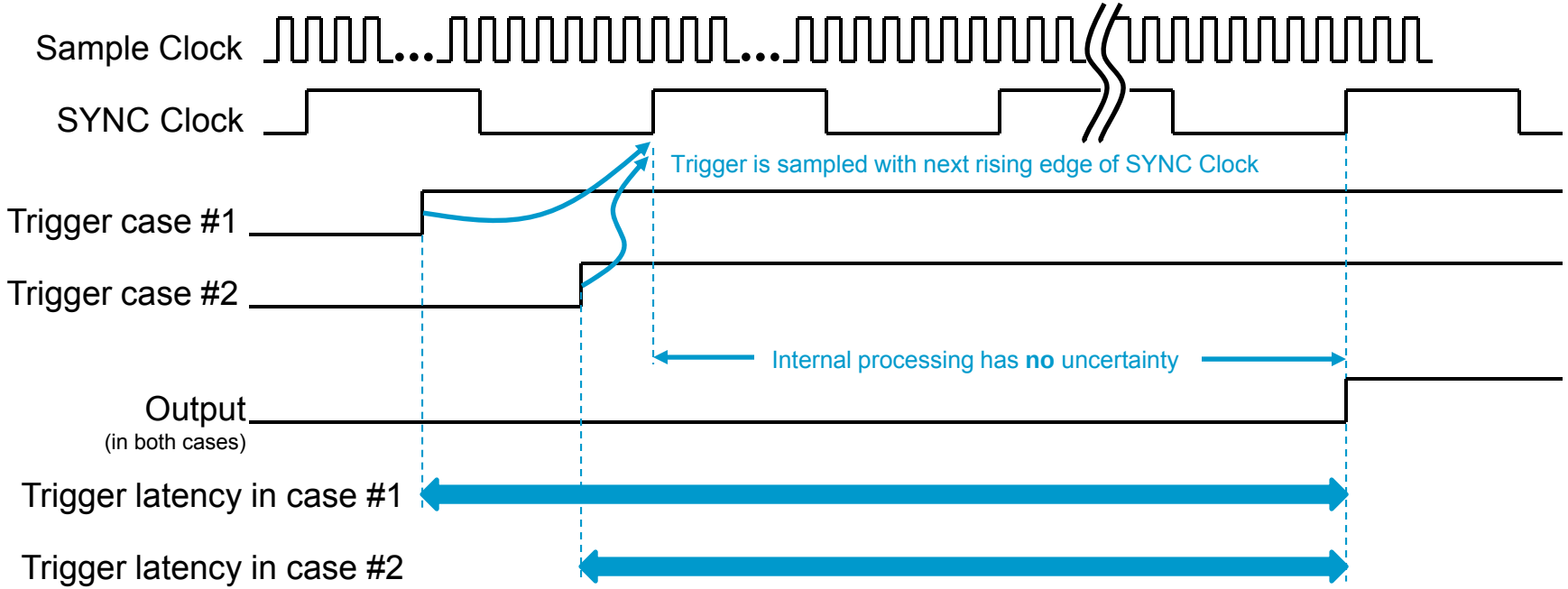
Definition: Trigger uncertainty

Trigger **uncertainty** is the worst case variation of trigger latency that can be observed on recurring trigger events

- Without any precautions (= asynchronous trigger input), the trigger uncertainty in the M8190A is ***+/-* 3 ns** @ 8GHz sample rate. At slower sample rates proportionally more!!
- While the fixed and clock-dependent amounts of trigger latency can easily be compensated by the system setup, a large **trigger uncertainty** might be **not acceptable** for many applications

Why does the M8190A have a large trigger uncertainty? (when using asynchronous triggering)

- Inside the M8190A, the trigger input is **sampled** with the SYNC clock. [SYNC clock = Sample clock divided by 48 (64) in 14-bit (12-bit) mode]
- Now consider two different scenarios of when a trigger input can occur **relative** to SYNC Clock



→ Different Trigger latencies are observed by the user

How can the trigger uncertainty be avoided?

Make sure the **trigger input** is **synchronized** with the **SYNC Clock** Output of the M8190A. This reduces the trigger uncertainty to an excellent **+/- 5 ps** (typ.) !!

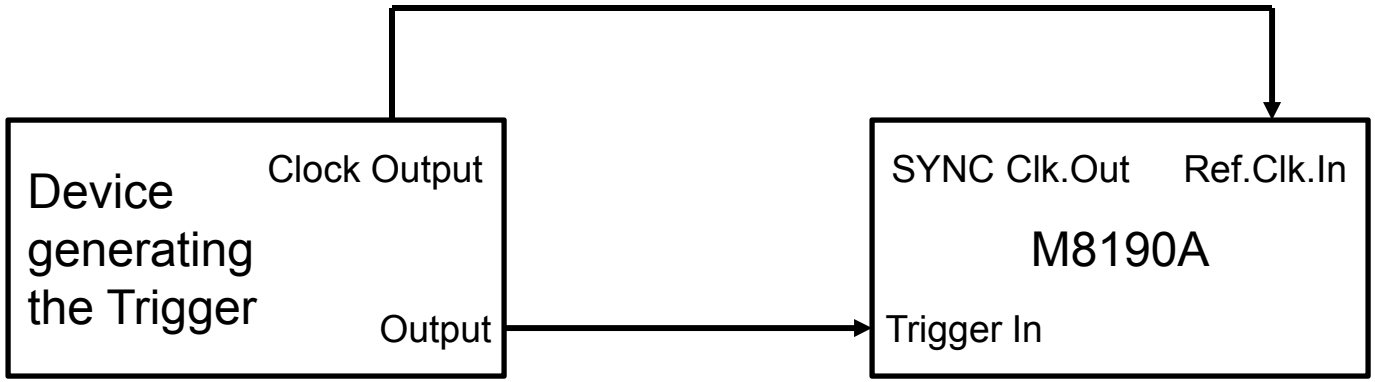
…of course this only works if the DUT can operate at the SYNC clock frequency (= M8190A sample rate divided by 48 or 64(*))

(*) SYNC clock = Sample clock divided by 48 in 14-bit mode, divided by 64 in 12-bit mode

How to use synchronous triggering at other frequencies?

Use the device's clock output to drive the Ref.Clk Input of the M8190A. This works under the following conditions:

- M8190A sample clock is set to the Ref.Clk Input frequency times 48 or 64(*) divided by an integer ≥ 1. (Example: Ref.Clk = 100 MHz, Sample Clk = 4.8 / 2.4 / 1.6 / 1.2 GHz, etc. in 14-bit mode)
- The other device generates its output synchronous to its Clock Output
- The Clock Output frequency is a multiple of 1 MHz in the range 1...200 MHz

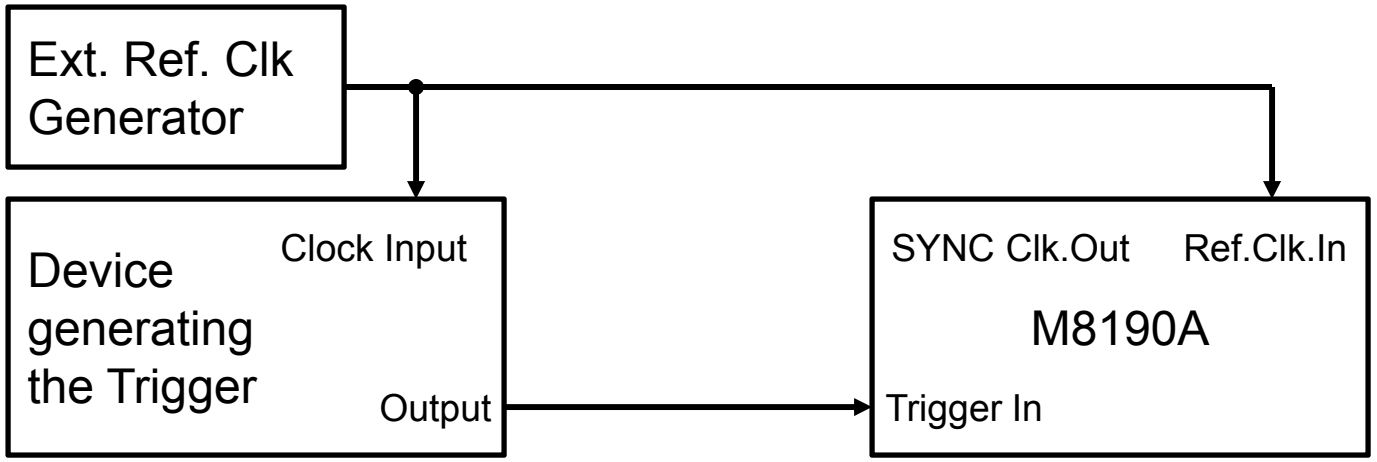


(*) SYNC clock = Sample clock divided by 48 in 14-bit mode, divided by 64 in 12-bit mode

…or use an external Reference Clock

Use an external Ref.Clk to drive both the device's clock input and the Ref.Clk Input of the M8190A

- M8190A sample clock must be set to the Ref.Clk Input frequency times 48 or 64(*) divided by an integer ≥ 1
- The other device generates its output synchronous to its Clock Input
- The Ref.Clk. frequency is a multiple of 1 MHz in the range 1…200 MHz



(*) SYNC clock = Sample clock divided by 48 in 14-bit mode, divided by 64 in 12-bit mode

Synchronization of two or more M8190A modules

Synchronization of two or more M8190A modules - Timeline

- Synchronization between **two** M8190A modules (up to 4 channels) will be officially supported in fall 2012
  - The current plan is to support the synchronization without any hardware changes – just an FPGA / Firmware update and a sync cable
- Synchronization between **more than two** M8190A modules (more than 4 channels) is on the roadmap to be supported at a later date
  - This will require an extra “clock distribution” module. Other than that, the plan is to work without any hardware changes to the modules
- **In the meantime, the approach that is described on the following slides can be used as a *work-around* to synchronize two or more modules**

What does it exactly mean to “synchronize” two or more M8190A modules? (1)

Synchronization requires **two** things:

1. Frequency Synchronization
   - This is to make sure that the modules run at the same sample rate which must be derived from the same master oscillator for all modules
   - This can easily be achieved in one of two ways:
     – Feed all modules with a **common reference clock**. In case of two modules in the same AXI chassis, this is the default
     – Feed all modules with a **common sample clock**. The common sample clock can either come from an **external generator** or one module acts as a master and the clock is **daisy chained** to the other ones
2. (see next slide)

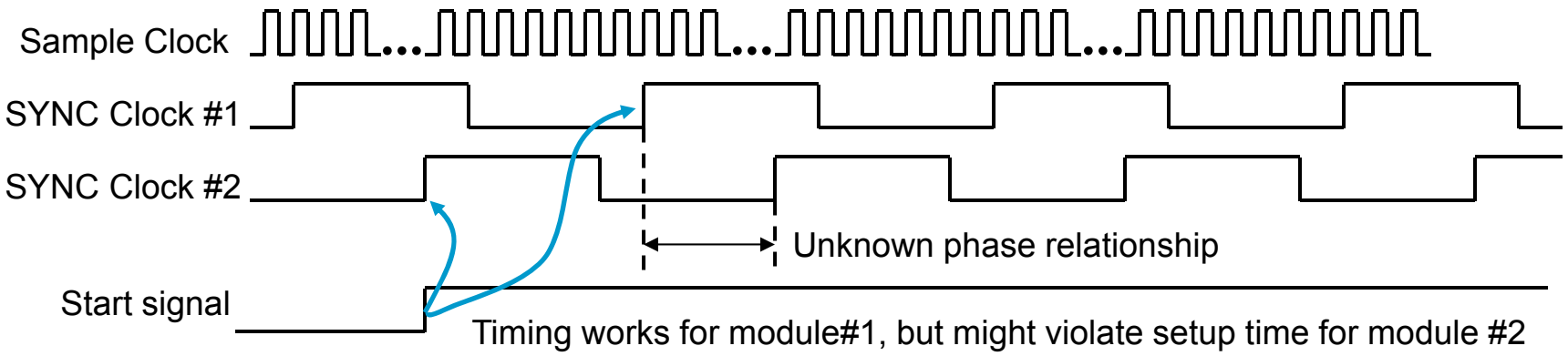
What does it exactly mean to “synchronize” two or more M8190A modules? (2)

2. All modules must be started at the same time and run with a repeatable skew

- Starting the modules at the **exact same time** is practically impossible without the means that will be implemented inside the modules later
- Starting the modules with a **repeatable skew** is possible.
  - Repeatable skew means it stays the same across multiple “runs” and waveform downloads - as long as the sample rate and other operation modes are unchanged
  - The procedure is to download “test waveforms” that are used to measure the skew between the outputs of multiple modules during a “test run”.
  - Once the skew values are known, the waveforms and delays can be adjusted to compensate for the measured skew
  - Finally, the adjusted waveforms can be downloaded and the modules started again – this time with zero skew between the outputs

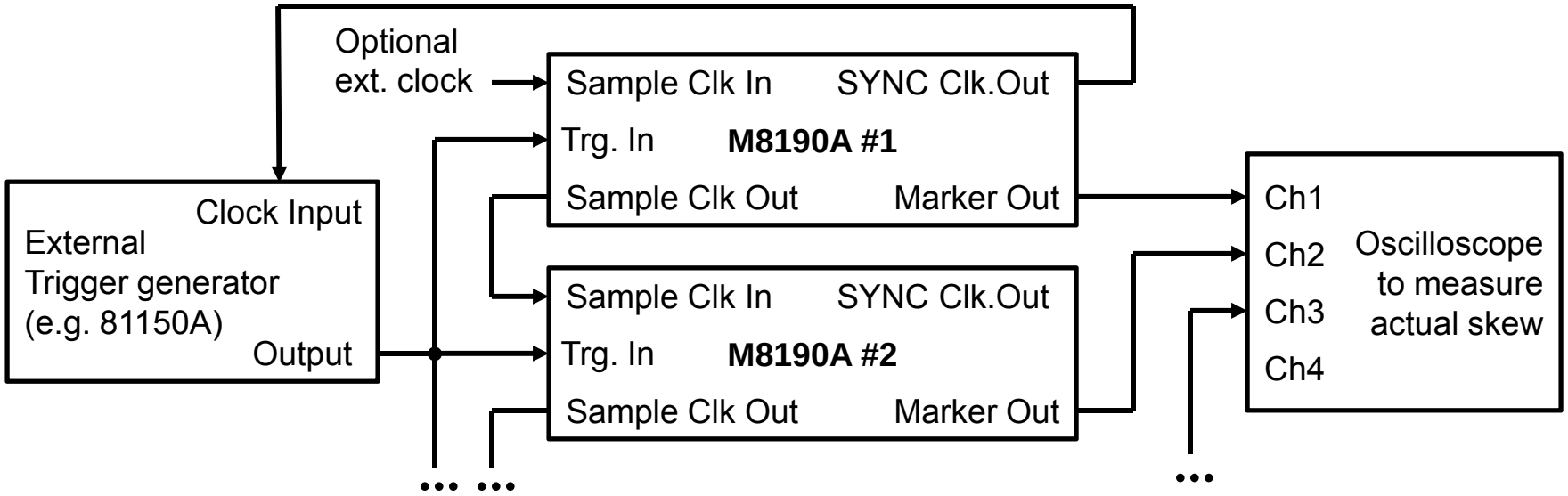
Why is it so difficult to start multiple modules at the exact same time?

- Consider the Sync Clock timing of two or more modules. Even though they are both derived from the same sample clock, they can have 1 of 48 (or 64) **different phase relationships** to each other
- An **asynchronous** start signal might be sampled by the different modules in different order every time → no repeatable skew → **useless**
- A start signal that is **synchronous** to the first module's SYNC Clock is better but **might violate setup/hold** times of other modules – depending on their phase alignment



Synchronization setup
(shown for two M8190A, but can be extended to more)

1. Set up the M8190A in “armed” mode; load waveforms to all module that contain a marker at the start of the waveform; start all modules
2. Set up an external trigger generator to generate a one-shot pulse synchronous with its clock input
3. Observe the skew between the marker outputs on the scope on recurring runs; make sure it is always the same skew. If not, see next slide
4. Adjust the waveforms and output delays to compensate the skew



What if the skew is not repeatable?

- …then you have a setup or hold-time violation on one of the modules
- identify which module does not generate a repeatable timing (expect the skew to “jump” by SYNC clk period)
- Change the sample rate of the module to a different sample rate and change it back to the original sample rate. This will cause the sync clock divider to find a new (random) phase. Go back to the previous step

- With a little programming effort it should be possible to automate this procedure
- Note: After every power cycle / change of sample rate / change of 12-/14-bit mode, synchronization is LOST

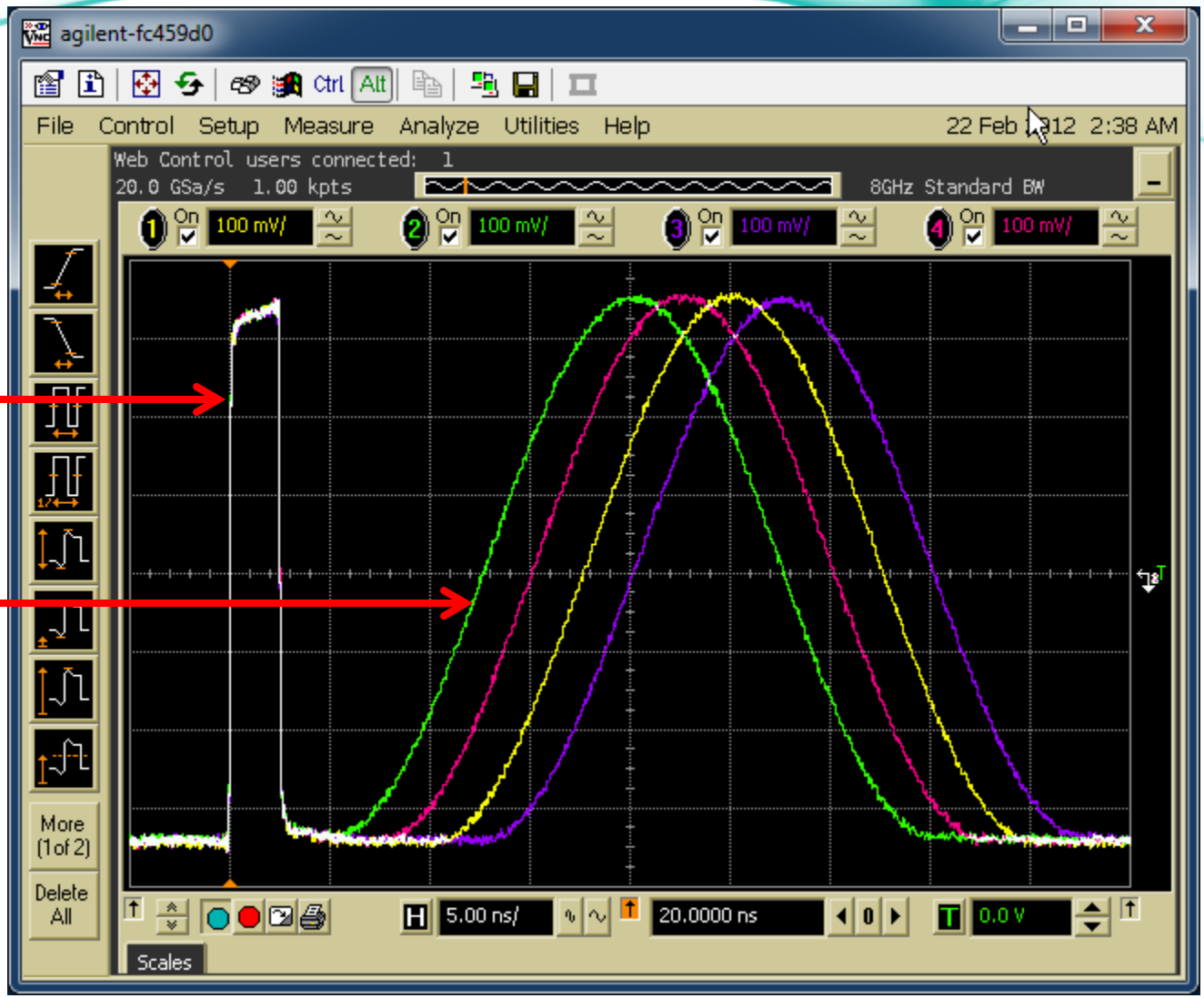
Example

Four M8190A channels in sync

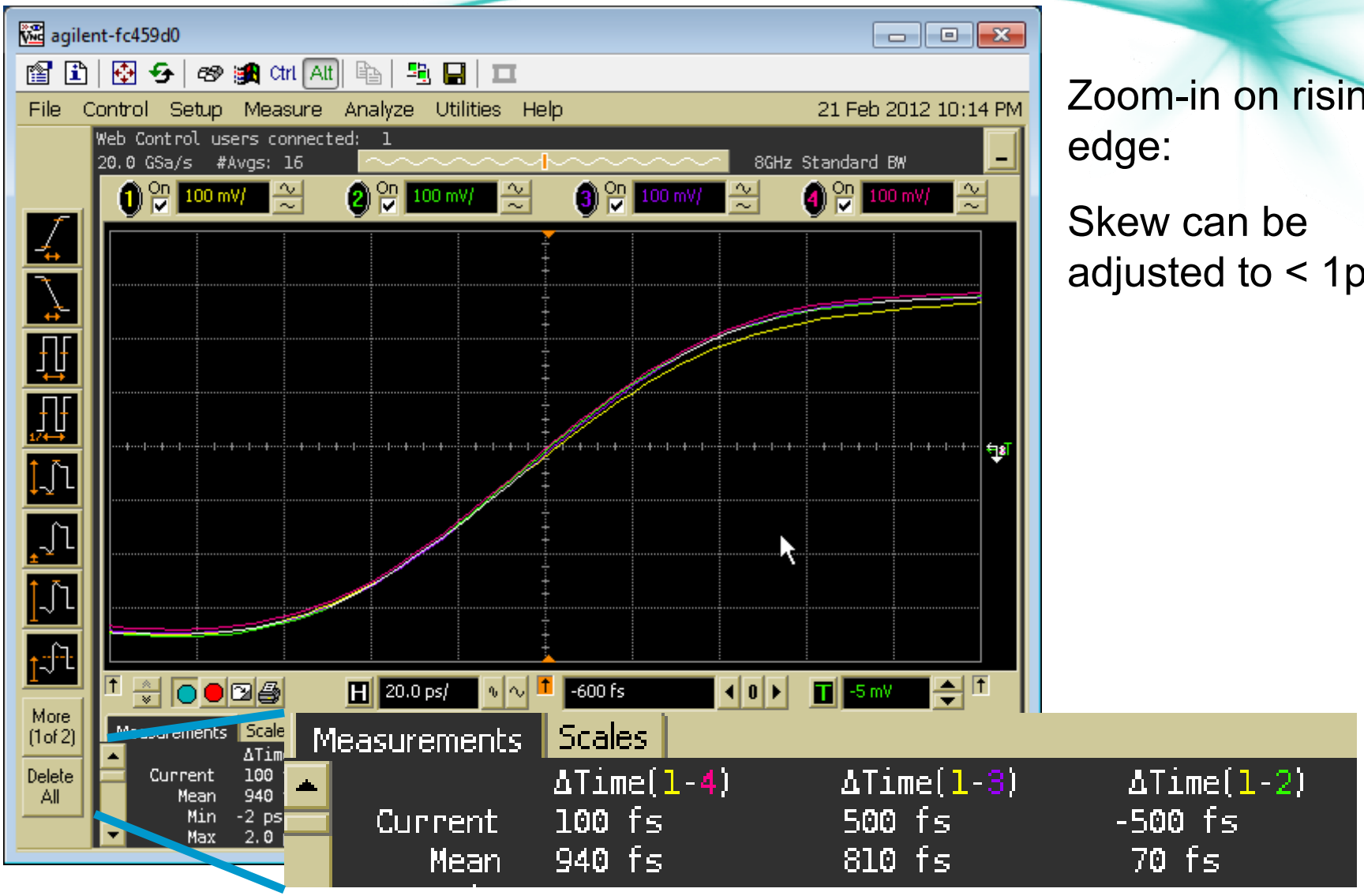
Waveforms consist of a pulse (to show perfect alignment)

followed by a sinewave (to show that channels are independent)

In a real application, the waveform can of course be completely arbitrary



Example



Zoom-in on rising edge:

Skew can be adjusted to < 1ps

Other considerations for multi-module operation

- **Two** M8190A modules can be plugged into a 5-slot AXI frame (plus an optional embedded controller). That's the simplest configuration, since the sample clock can easily be shared between the modules
- **Three** or **four** M8190A modules will have to be split up into two AXI 5-slot chassis. In order to run such a configuration, you will either need
  - One compatible PC with **two PCIe slots** (we don't know if that exists) or
  - **Two separate, compatible PCs** or embedded controllers (which is expensive, but probably OK for someone who can afford 3 or 4 modules)
- If a customer wants two M8190A modules in two separate 2-slot chassis (e.g. because he wants to use them separately as well as together), the same applies

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