

Keysight Technologies

# Wideband MIMO PXI Vector Signal Analyzer

Multichannel Wideband Configuration

White Paper

## Abstract

The wideband MIMO PXI vector signal analyzer (VSA) provides up to four or more synchronized channels of wideband analysis capability at much higher speeds than oscilloscope based solutions. This white paper provides instructions for creating various solutions including:

- Hardware and software configurations for different applications
- Use of 89600 VSA software with the M9362A-D01 for standards based demodulation measurements
- Ways to customize the system using modular software API's
- Examples for:
  - MIMO 802.11ac
  - 80+80 MHz 802.11ac



## Introduction

Increased use of wireless video and high speed wireless data networking drive demand for new standards, such as 802.11ac to enable higher throughput. Design validation engineers must ensure their 802.11ac designs will perform well under the most demanding modulation schemes, including MIMO spatial multiplexing configurations.

To validate 802.11ac and wideband MIMO transmitter performance for other formats, a multichannel signal analyzer should be used to demodulate the multistream waveforms and measure EVM and other physical layer parameters.

Keysight's wideband multichannel PXI signal analyzer solutions enable R&D and test engineers to validate their 802.11ac designs with a mixture of measurement accuracy, fast speed, flexibility and scalability in a small form factor.

This white paper provides detailed step by step instructions for configuring a wide bandwidth, high speed multichannel PXI VSA. It also explains how to understand performance tradeoffs for various configurations.

The MIMO VSA is typically comprised of the following modules (one module can accommodate up to four channels, unless otherwise noted):

- M9302A PXI Local Oscillator
- M9352A PXI Hybrid Amplifier/Attenuator
- M9362A-D01 PXIe Microwave Quad Downconverter
- M9168C PXI Programmable Step Attenuator Module (one per channel)
- M9202A PXIe 12-bit Wideband Digitizer (one per channel)

Optional configurations are also presented for an external local oscillator such as the MXG Signal Generator and the M9300A PXIe Frequency Reference. Please see the Hardware Configurations section for more information.

Please also refer to the standard documentation provided for the M9362A-D01 PXIe Quad Downconverter:

- Configuration Guide—Keysight literature number 5990-9968EN
- Datasheet—Keysight literature number 5990-6624EN
- Startup Guide—Keysight literature number M9499-90001

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# Multichannel Wideband Streaming with PXI M9392A

## 1. Software Installation Instructions

This section lists the software required to control the various modules and provides step-by-step instructions for installation. The table below provides a list of software and the URL where the software can be downloaded.

Instrument	Software download webpage
M9018A chassis drivers	Pre-installed on M9036A embedded controller or <a href="http://www.keysight.com/find/M9018A">www.keysight.com/find/M9018A</a>
Keysight IO Libs 16.1 <sup>1</sup>	<a href="http://www.home.keysight.com/keysight/product.jsp?cc=US&amp;lc=eng&amp;ckey=1985909&amp;nid=-33330.977662.00&amp;id=1985909&amp;cmpid=zzfindiosuite">http://www.home.keysight.com/keysight/product.jsp?cc=US&amp;lc=eng&amp;ckey=1985909&amp;nid=-33330.977662.00&amp;id=1985909&amp;cmpid=zzfindiosuite</a>
89600 VSA software	<a href="http://www.keysight.com/find/vsa">http://www.keysight.com/find/vsa</a>
M9392A drivers, v1.2	<a href="http://www.keysight.com/find/m9392a">http://www.keysight.com/find/m9392a</a>
M938x drivers: M9300A frequency reference required. Other modules are optional. Choose custom installer.	<a href="http://www.keysight.com/find/m9381a">http://www.keysight.com/find/m9381a</a>
N7617B Signal Studio for WLAN (optional)	<a href="http://www.keysight.com/find/n7617b">http://www.keysight.com/find/n7617b</a>
M9362A-D01 driver	Included on CD that ships with M9362A-D01
M9352A driver	Included on CD that ships with M9352A
M9168C driver	<a href="http://www.keysight.com/find/pxiattenuator">http://www.keysight.com/find/pxiattenuator</a>
Multichannel wideband VSA example	Contact your Keysight sales representative
Multichannel wideband VSA with external local oscillator example	Contact your Keysight sales representative
M9202 digitizer firmware v512 or greater	Included with M9392A driver, v1.2. See instructions for checking version number at page 4.

**Step 1.** Install these software packages in the order listed, following prompts for reboot whenever requested.

**Step 2.** Install licenses for the 89600 VSA software, if applicable.

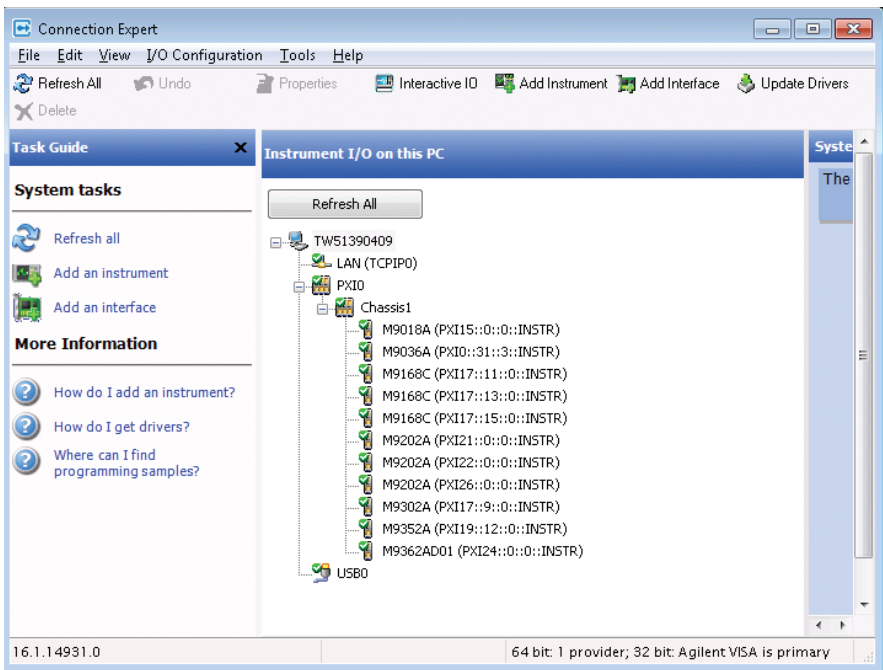
**Step 3.** After all software has been installed, reboot the system.

**Step 4.** Run the Keysight connection expert to verify that all modules enumerate with a VISA resource ID, and each module appears with the correct slot number identified on the information pane on the right when you click on each module.

1. At time of writing, upgrade from version 16.1 to 16.2 causes problems. Repairing VISA shared resources from Windows control panel should resolve the issues.

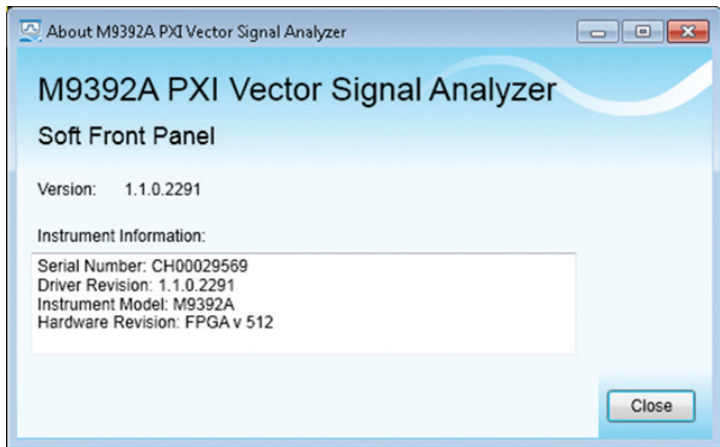


The screenshot below provides an example of a 3-channel configuration.



### Potential M9202A digitizer firmware upgrades

If upgrading an existing system for multichannel, please check to ensure that the M9202A digitizer firmware is of version 512 or greater. Documentation describing the upgrade process can be found in the M9392A help system. To check whether a digitizer upgrade is required, run the M9392A soft front panel (SFP), connect to the digitizer, then select Help>About, to view the digitizer hardware field programmable gate array (FPGA) version number. Please follow the upgrade instructions if the version number is less than 512. This must be done for each digitizer in the configuration.



## 2. Hardware Configurations

### M9202A trigger setups

M9202A multichannel setups are synchronized via distribution of a trigger out from the master digitizer to the trigger input of all digitizers. Synchronization performance of the multichannel VSA is  $\pm 2$  samples of trigger uncertainty from acquisition to acquisition. This means the operation is not phase coherent but still adequate for MIMO PHY-layer EVM measurements. At full data rate, or 2 GSa/s,  $\pm 2$  samples of trigger uncertainty equates to  $\pm 1$  ns. When using digital down conversion (DDC) modes, the uncertainty is based on the output sample rate. For example, at 100 MHz bandwidth (BW), 125 MSa/s is used, equating to a trigger uncertainty of  $\pm 16$  ns between channels which cannot be calibrated out. However, in the case of multichannel recording to disk capability, a technique was devised to calibrate out the timing difference between channels during a single acquisition, using a training sequence that is switched in at the beginning or end of the acquisition. Please see the *Multichannel Wideband Streaming White Paper* literature number 5991-0221EN for information on example software created for multichannel streaming time alignment.

There are three primary trigger modes: free run, IF magnitude, and external. The following table describes the conditions for which the various trigger modes are valid.

Mode	Single channel input	Multichannel input
Free run (software trigger)	Auto-trigger	Auto-trigger (unsynchronized acquisition)
IF magnitude	Master input 1	Master input 1
External	Master TRG 1	Master TRG 2

There is no software trigger mode synchronization for multichannel operation. Therefore, free run with a multichannel system will result in unsynchronized results. It is necessary to use either external or IF magnitude trigger modes for synchronized operation.

### IF magnitude trigger mode <sup>1</sup>

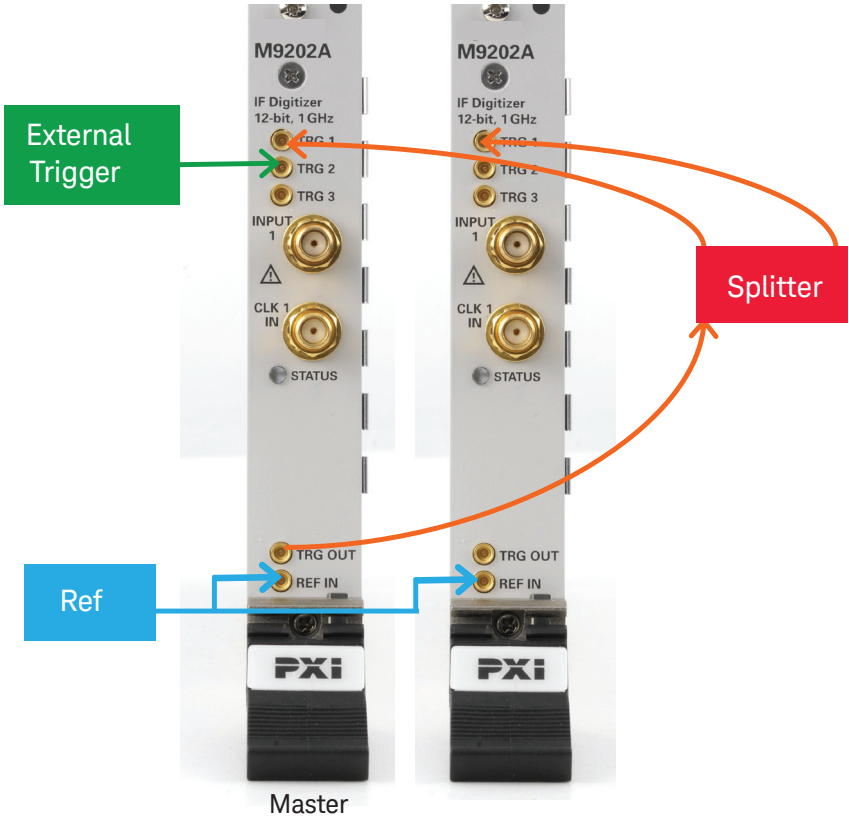
In IF magnitude trigger mode, the master digitizer triggers on the input signal into Input 1 connector. It is an envelope edge trigger, and not a level trigger. The master digitizer outputs a trigger output pulse of amplitude approximately 0 to -1 V. This must be routed into all digitizers' TRG 1 inputs including the master digitizer's input.

### External trigger mode

In external trigger mode, the master digitizer triggers on the TRG 2 input. The master digitizer outputs a trigger output pulse of amplitude approximately 0 to -1 V. This must be routed into the slave digitizers' TRG 1 inputs. It is not necessary to route the signal into the master digitizer's TRG 1 input, but doing so will not impair performance.

1. This mode is only available when using hardware DDC. In basic digitizer mode, only external trigger mode is available. Refer to the appendix "M9202A HW DDC Operation" for details on HW and SW DDC modes.

Trigger connections for a 2-channel configuration.



This setup works for both IF magnitude and external trigger modes. In both cases, it is necessary to set the trigger input threshold for the TRG 1 input to a negative voltage.

An inherent delay exists between the master and slave digitizers, as well as from trigger arrival at the master to signal acquisition. An effort is made in the 89600 VSA software to correct for this. However, if the trigger timing needs to be precise, this will need to be manually calibrated out.

### 2-channel and 3-channel configurations with PXI local oscillator

2-channel and 3-channel configurations using the M9362A-D01 quad down-converter and M9202A digitizer can easily be configured in a single 18-slot PXI chassis. This is expected to be the most common use model for the wideband MIMO PXI vector signal analyzer. These configurations include:

- M9168C attenuator module – one per channel
- M9362A-D01 quad downconverter module
- M9302A local oscillator module
- M9352A IF amplifier and attenuator module
- M9202A IF digitizer – one per channel.

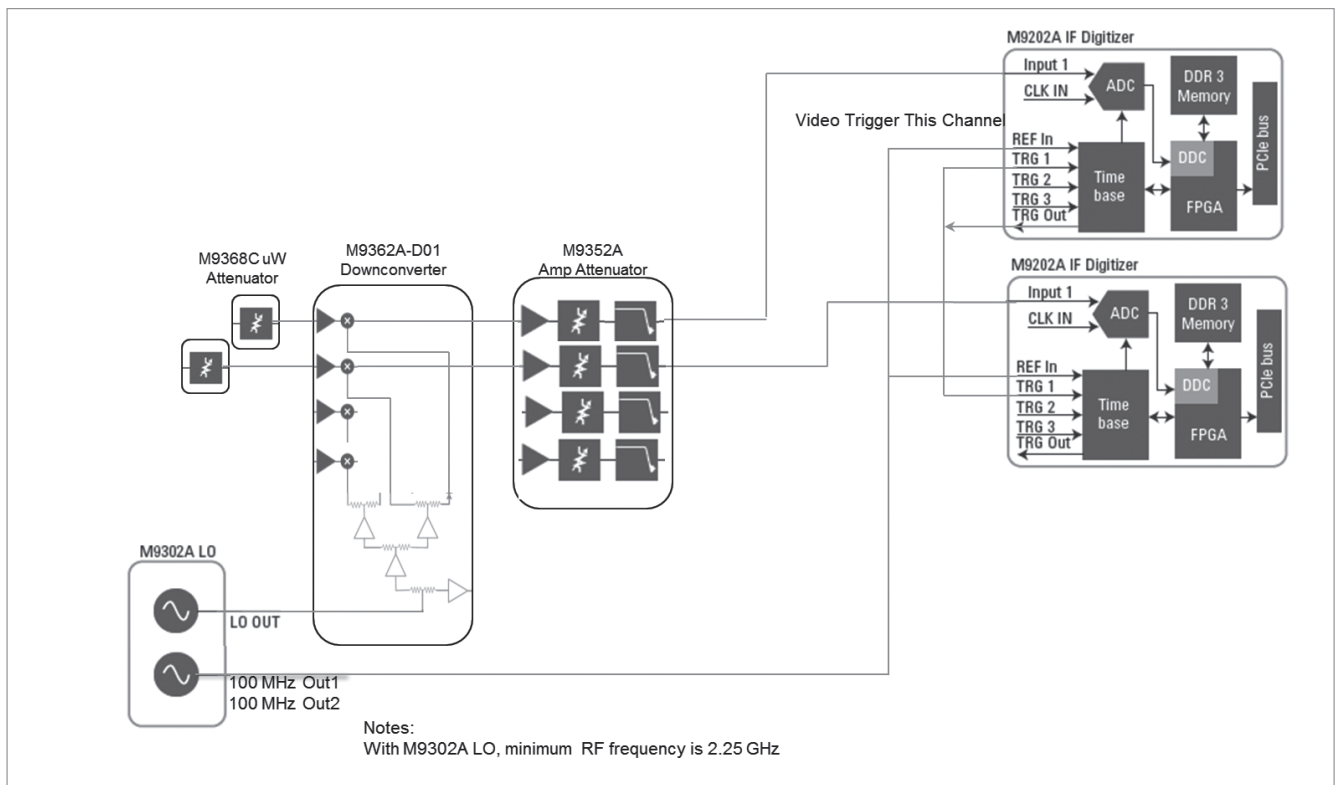
If the expected signal level is less than  $-10$  dBm, the M9168C attenuator modules may not be needed. Please refer to *M9362A-D01 PXIe Quad Downconverter 10 MHz to 26.5 GHz Configuration Guide* (literature number 5990-9968EN) for details on ordering options including cable kits, model numbers, etc.

## 2-channel configuration with PXI local oscillator

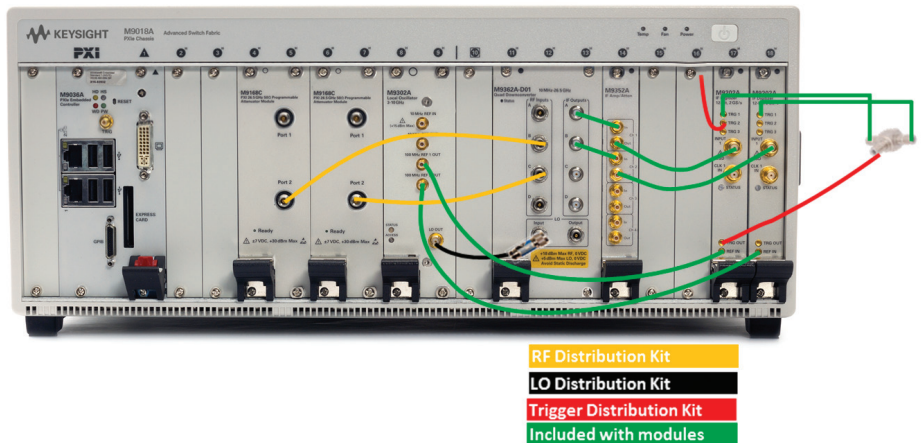
2-channel photo



2-channel block diagram



2x2 cabling

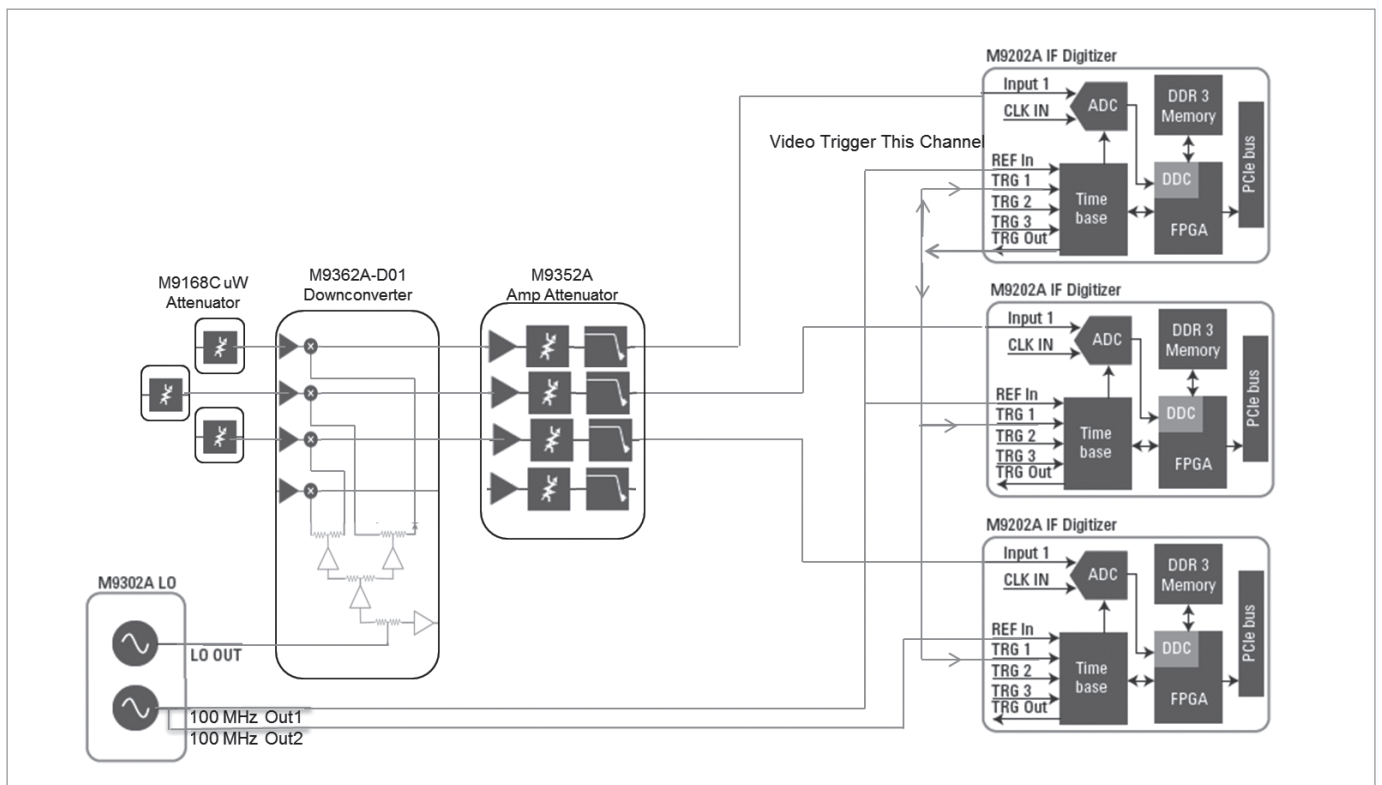


### 3-channel configuration with PXI local oscillator

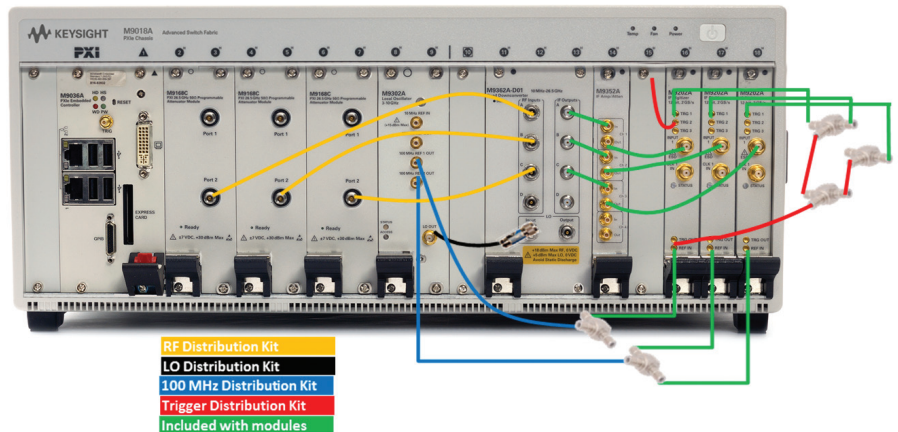
3-channel photo



3-channel block diagram



3x3 cabling



## 2- to 4-channel configurations with external local oscillator

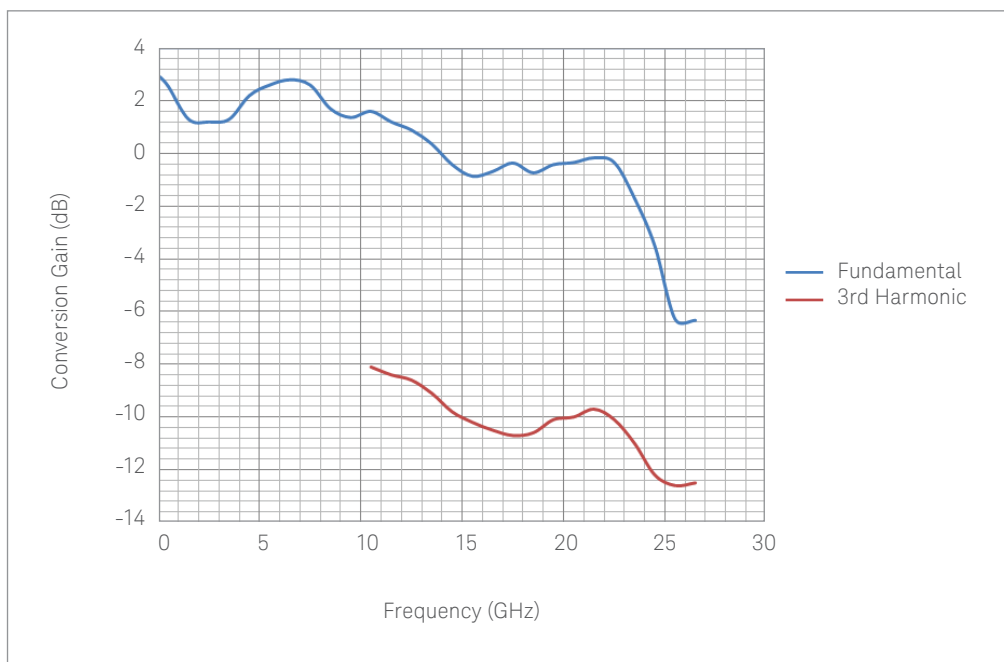
There are situations when you might choose configurations with an external local oscillator (LO), such as an MXG signal generator.

**Space Considerations.** To fit a 4-channel configuration in a single chassis, there may not be enough space for all modules, particularly if the M9168C attenuator modules are used for RF attenuation. In this case, removing the M9302A LO and using an MXG as the LO frees up space. If space is a primary concern, the M9170A attenuator/switch driver module supports up to two attenuator channels per PXI slot, controlling an external attenuator which can be placed close to the test fixture.

**Frequency Range.** The M9302A LO's lower frequency range is 2.75 GHz, resulting in a minimum RF frequency of about 2.25 GHz. On the high-end, third harmonic mixing is used above 10 GHz. The use of a microwave MXG as LO enables fundamental mixing mode all the way to 26.5 GHz, avoiding the 10-12 dB penalty to conversion gain, and hence dynamic range, incurred from the use of third harmonic mixing.

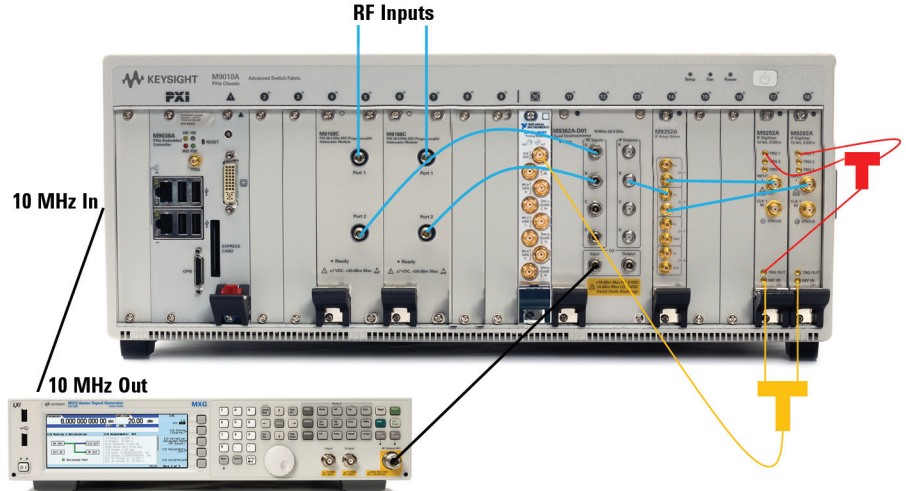
A side-effect of using an external LO is the absence of 100 MHz reference signal to lock the M9202A digitizers via their external reference inputs. The M9302A LO has 100 MHz outputs that are used for this purpose. In lieu of this, an M9300A frequency reference module can be used to generate a clean 100 MHz clock which can be input into the external reference inputs of the two M9202As. The M9300A has five 100 MHz outputs which can be routed directly into each of the M9202A's reference inputs, or a single output distributed via tees to up to four M9202A modules. An example program is available which will automatically detect an M9300A installed in the chassis and set it up to output 100 MHz from the 100 MHz "out" ports on the front panel. Using this example, the M9300A can also be configured to output a 10 MHz reference signal on the front panel, but not to accept an external reference. The example program can be modified as required.

The plot at right shows the conversion gain versus frequency. Conversion gain M9362A-D01 with high frequency vs 3rd harmonic (M9302A)

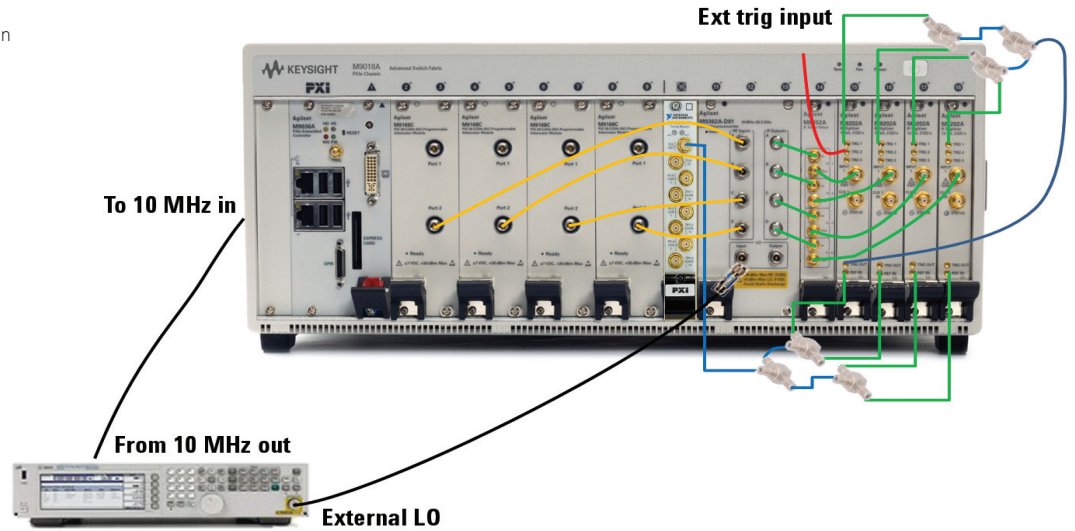




2-channel external LO configuration with timing module and cabling



4-channel external LO configuration



The following table summarizes the tradeoffs between the PXI LO and external LO configurations.

	Analog MXG as LO	M9302A PXI LO
RF frequency range	10 MHz $\geq$ 26.5 GHz	2.25 GHz $\geq$ 10 GHz (fundamental) 10 GHz $\geq$ 26.5 GHz (3rd harmonic)
100 MHz clock for digitizer sync	M9300A frequency reference is recommended	Included in M9302A
Form factor	Up to 4 channels VSA in one PXI chassis	3 channels VSA in one chassis (with M9168C attenuator)

## 4- to 8-channel configurations

Though the 89600 VSA software supports only 4-channel configurations, configurations of five or more channels can be created. Those configurations can be controlled outside of the VSA software, using the M9392A IVI driver.

When configuring a 5-8 channel PXI analyzer, please consider the following:

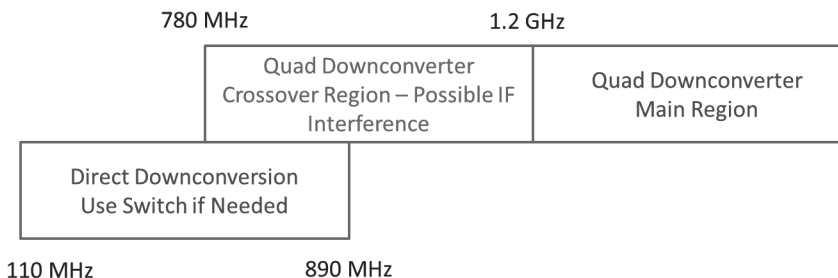
- The M9362A-D01 quad downconverter makes it simple to daisy chain the LO from one module to the next, allowing easy 8-channel synchronous downconversion.
- Attenuator modules require no synchronization, so simply add four additional M9168C attenuator modules (or use external attenuation if preferred), and a second M9352A 4-channel IF amplifier/attenuator module.
- The M9202A digitizers will require some extra consideration. For greater than four channels, passive trigger distribution will not be adequate, as the trigger signal level may be too low for reliable triggering. An NI PXIe-6674T timing module may be used to distribute the triggers in this case. A single PXIe-6674T module should be adequate to distribute triggers to at least eight M9202A digitizer modules.<sup>1</sup>
- If two or more chassis are required, it may be necessary to use two M9021A PCI Express® extender cards with a desktop controller to connect both chassis.

## Bypass for lowband

Measuring signals below 1.2 GHz RF frequency poses potential problems. Since the quad downconverter is a single-conversion downconverter, there is potential for LO and RF feed through to appear as interference with the IF signal. There is a 1 GHz low pass filter (LPF) in the M9352A IF amplifier/attenuator module, and further digital filtering in the 89600 VSA software, so keeping the RF and LO above 780 MHz will help greatly to reduce problems related to feed through. As a rule of thumb, if your center frequency minus half of your IF bandwidth is less than 780 MHz, you may encounter IF interference problems.

One way to mitigate these problems is to bypass the downconversion chain entirely for frequencies in the lowband. A M9155C PXI microwave switch can be used between the M9168C attenuator and M9352A IF amplifier/attenuator module. As long as the occupied bandwidth of the RF signal to be measured fits within the frequency range 110 MHz to 890 MHz, you can use the direct path to the digitizer to capture the signal. For frequencies below 110 MHz, and between 890 MHz and 1.2 GHz, you will still need to use the downconverter path and may encounter some problems with RF and IF feed through.

Frequency bands where bypass is recommended



1. An M9300A frequency reference module may be needed to provide a high enough 100 MHz clock signal level for configurations with five or more channels.



### 3. Using Soft Front Panels to Make Multichannel Measurements

This section covers the use of soft front panels (SFP) to control the modules.

#### M9392A – PXI vector signal analyzer

The M9392A SFP is used primarily to configure and control a complete M9392A signal analyzer or a single M9202A digitizer in digitizer only mode. Generally, it can only be used to control one channel of M9392A or M9202A digitizer at a time. It is possible to launch multiple running SFP's to control multiple channels concurrently. However, the multichannel trigger capability cannot be controlled via the SFP. The primary use of the M9392A SFP for multichannel solutions is to create and export configurations to be used in automation or in the 89600 VSA software.

The M9392A SFP help describes the process of selecting modules and creating configurations. This document introduces new types of configurations in the section on creating 89600 VSA hardware configurations covered in section 4.

#### M9352A – PXI amplifier attenuator

The M9352A SFP can be used to set the gain on each of four channels from 8 to 39.5 dB. The channels can be controlled independently or set to track together.

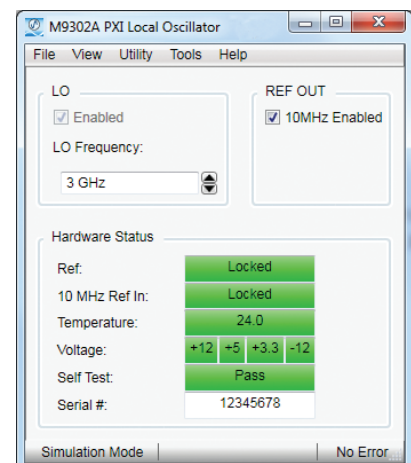
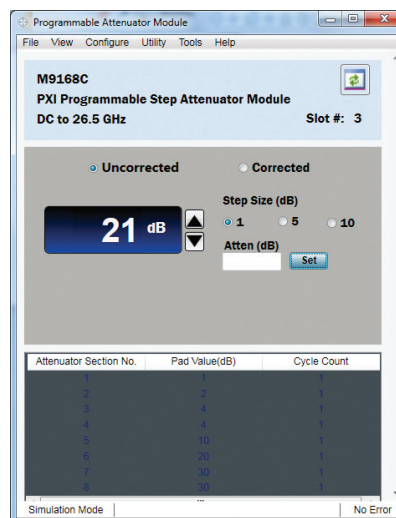
#### M9168C – PXI programmable step attenuator

The M9168C SFP can be used to control one M9168C attenuation value, including reporting calibration information, so you can see the exact loss at a particular attenuation state after setting it. To control multiple M9168C modules, you will need to run one SFP per module.

#### M9302A – PXI local oscillator

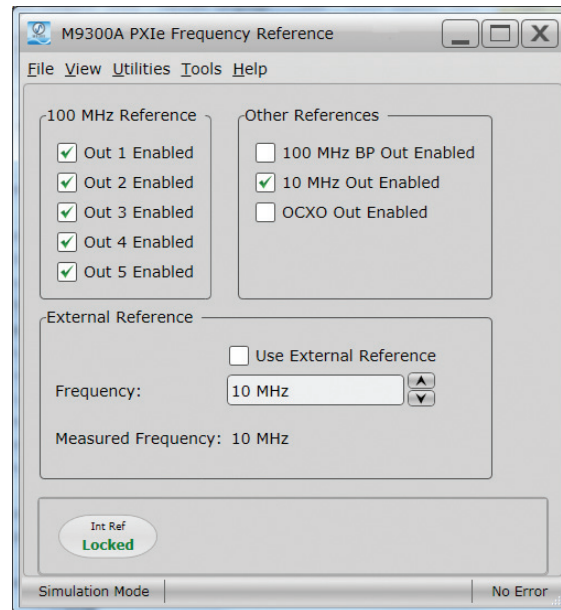
The M9302A SFP can be used to set the center frequency and 10 MHz reference output state. Typically, the high-side LO is used, with an IF center frequency of 500 MHz, so the LO frequency would be set to the RF center frequency + 500 MHz.

At right, the SFPs for the M9168C Programmable Step Attenuator and the M9302A Local Oscillator.



## M9300A – Frequency reference

The M9300A SFP can be used to enable the 100 MHz reference output and configure the 10 MHz reference input and output.



## 4. Using 89600 VSA Software for Multichannel Measurements

This section covers configuring and using the 89600 VSA software to make multichannel measurements with the wideband MIMO PXI vector signal analyzer hardware.

### Hardware configurations

The standard M9392A configuration, documented in the M9392A SFP help includes:

- M9360A, a front-end preselector/attenuator module
- M9302A, local oscillator,
- M9202A digitizer, and
- Two downconverters: the M9351A for low-band, and the M9361A for high-band.

This section introduces the concept of two additional types of hardware configurations which are supported by the M9392A software: digitizer-only and simulated downconverter. It discusses the uses of digitizer-only mode, and a configuration using simulated modules.

As a rule of thumb, use the digitizer-only mode for bandwidths wider than 250 MHz or for tuning each channel to different center frequencies within the IF bandwidth, such as when measuring 802.11ac 80+80 mode.

### Digitizer only

The digitizer-only mode produces a solution with the widest bandwidth and widest RF frequency range. In this mode, the M9392A software controls only the M9202A digitizer. Frequency range is limited to the range of the IF bandwidth, or 800 MHz, centered on 500 MHz. If 500 MHz is selected as the center frequency, with less than 250 MHz span, hardware digital downconversion (DDC) is automatically used. See the appendix M9202A HW DDC Operation at page 39 for details. In this mode, complex IQ data is stored with 32 bits per sample, allowing up to 128 megasamples to be captured in a single acquisition to the internal digitizer memory. The data is stored at a lower sample rate. For example, at the widest DDC frequency of 250 MHz, 500 MSa/s is used, allowing approximately 0.25 seconds maximum capture length for a single capture.

If a different center frequency and/or wider than 250 MHz bandwidth is chosen, then basic digitizer mode or a hybrid DDC mode may be used, with real data captured to the digitizer memory. For example, 200 MHz span centered on 700 MHz would require at least 600 MHz of actual bandwidth (pre-DDC). In this mode, up to 256 megasamples can be captured in a single acquisition to the internal digitizer memory. The 2 GSa/s rate is always used, so the maximum capture time is approximately 0.125 s.

The M9202A digitizer does not have a front-end range adjustment, so any range adjustments made by the M9392A software or 89600 VSA software will not have any effect. It is necessary to control the RF and IF attenuators directly, or utilize a technique provided by the macro example software program covered in section 5.<sup>1</sup>

1. The M9392A SFP control functionality may be limited when using digitizer-only mode. Certain controls may still be active, but serve no function when in digitizer-only mode.

## Simulated downconverter

Simulated downconverter mitigates some of the challenges of operating in digitizer only mode, at the cost of maximum bandwidth flexibility and ability to tune the channels independently within the IF bandwidth. Used in conjunction with the macro example program, simulated downconverter capability offers a fairly seamless operation directly from the 89600 VSA software user interface. In this mode, the M9392A software controls both the digitizer and the M9302A LO. This means the user can set the RF center frequency directly on the 89600 VSA user interface, and the M9392A drivers will set the LO and IF frequencies automatically.

Attenuators will still need to be controlled from outside of the VSA software, and amplitude values returned will not be calibrated. Both of these will be addressed by the macro example program. Because the attenuator control is outside of the VSA software, the range settings made on the VSA software will not have any effect. Additionally, the maximum span will be 250 MHz, the same as the M9392A hardware limits. If wider span is required, you must use digitizer-only mode.

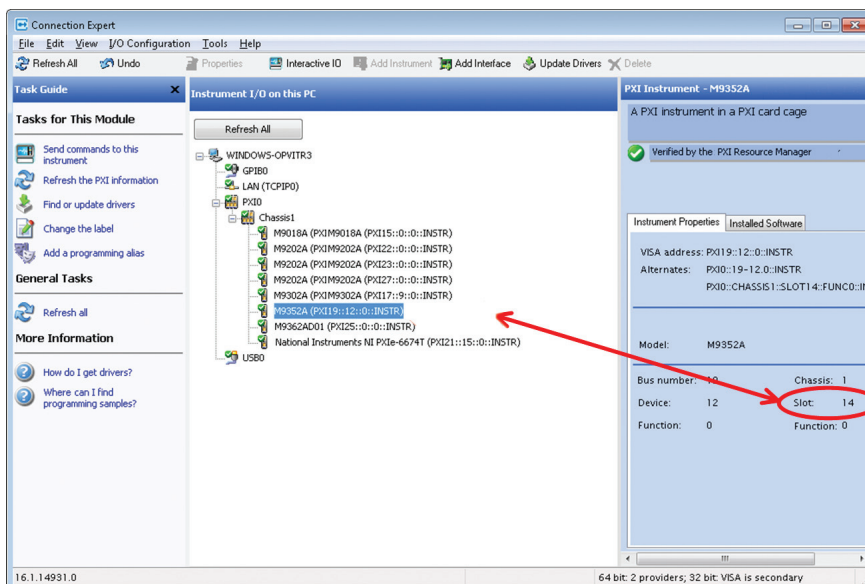
## Creating IVI configuration store entries

A prerequisite to using the M9392A software is to create an IVI configuration store entry for each channel. This is accomplished via the M9392A SFP. After launching the M9392A SFP, select hardware via the dialog box. Any modules recognized by the M9392A software will appear. For wideband MIMO PXI VSA configurations, these will be the M9202A digitizers and possibly the M9302A LO. For synchronized multichannel operation, you will need to designate one of your digitizers as master, and the remaining as slaves. It helps to pick a convention, such as master on left, slave 1 in the next slot to the right, slave 2 to the right of slave 1, etc. Follow the same convention for M9168C attenuator modules.

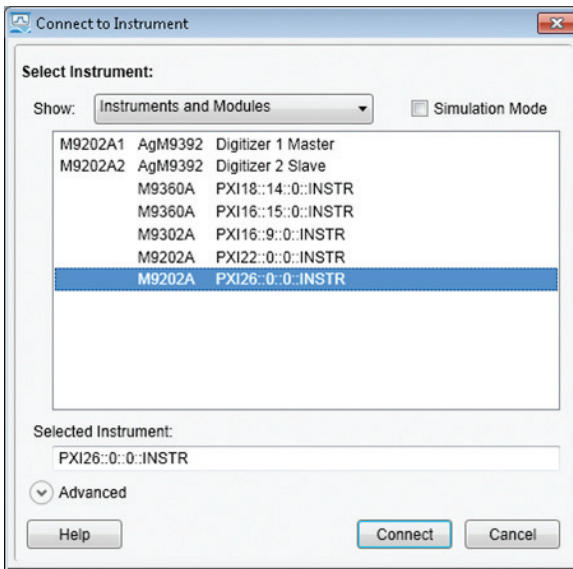
## Configuring the digitizer-only mode

**Step 1.** Use the Keysight Connection Expert tool to identify the M9202A digitizer in the left-most slot.

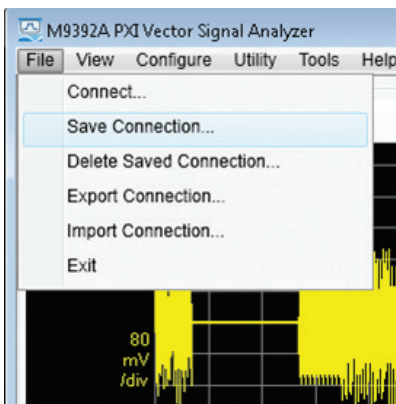
Note the VISA resource ID  
(for example, PXI17::12::0::INSTR).



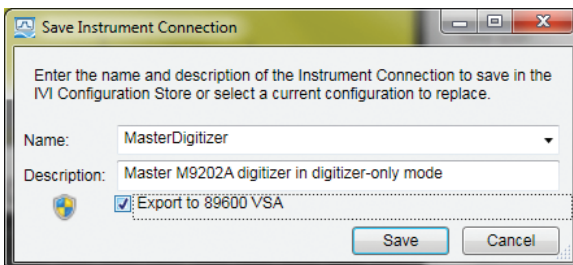
**Step 2.** Start the M9392A SFP, and choose only the M9202A digitizer with this resource ID.



**Step 3.** Press connect, and wait for hardware initialization to complete. Choose File>Save Connection.



**Step 4.** In the dialog box, give the configuration a recognizable name, avoiding spaces and underscore (\_) characters. Enter a description in the description field, and be sure to check Export to Keysight 89600 VSA before pressing the Save button.



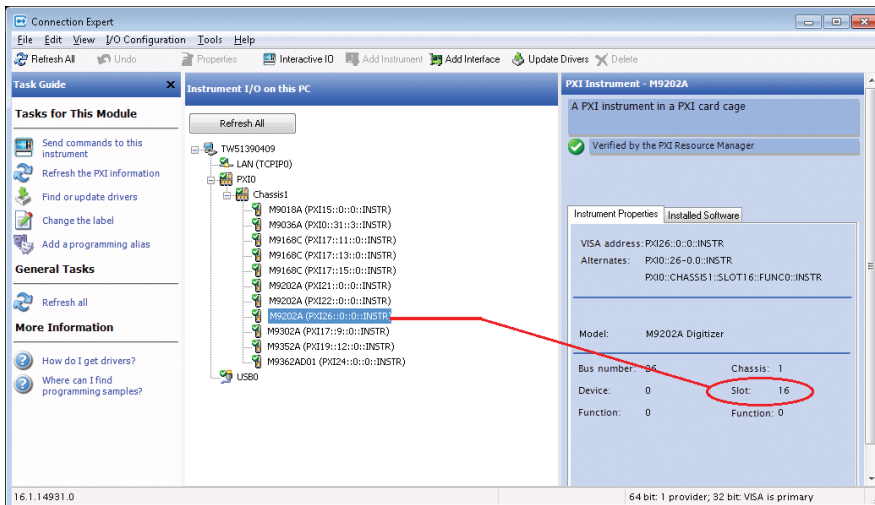
**Step 5.** Choose the File>Connect menu, and connect to the first slave digitizer.

**Step 6.** Save a configuration for this digitizer, repeating for all channels in your configuration.

### Configuring the simulated downconverter mode

**Step 1.** Use the Keysight Connection Expert tool to identify the M9202A digitizer in the left-most slot.

Note the VISA resource ID (for example, PXI17::12::0::INSTR).

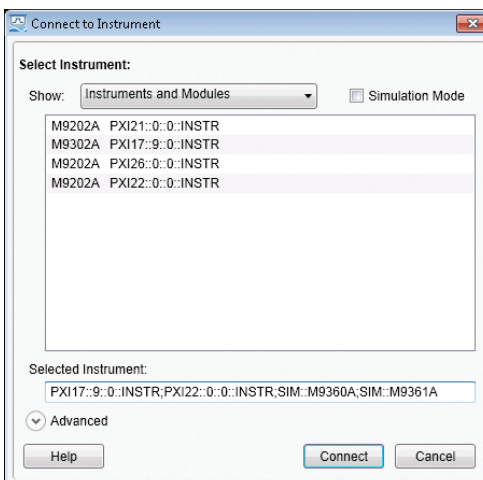


**Step 2.** Start the M9392A SFP, and choose only the M9202A digitizer with this resource ID.

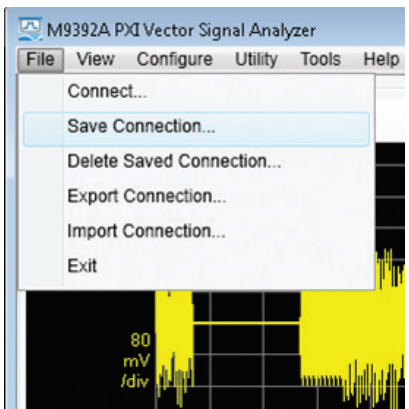
**Step 3.** Add to this the M9302A LO module.

**Step 4.** Add entries manually in the selected instrument: field for a simulated M9360A front-end module and M9361A microwave attenuator module. These simulated entries should look like this: SIM::M9360A;SIM::M9361A. Shown below, a complete master selection.

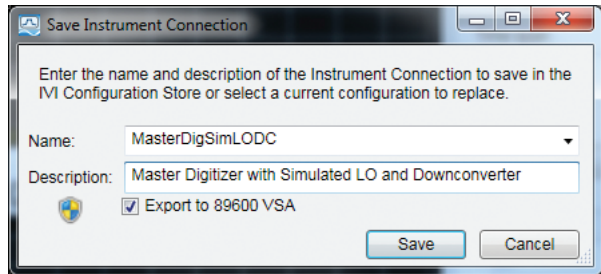
Type simulated modules in selected instrument field.



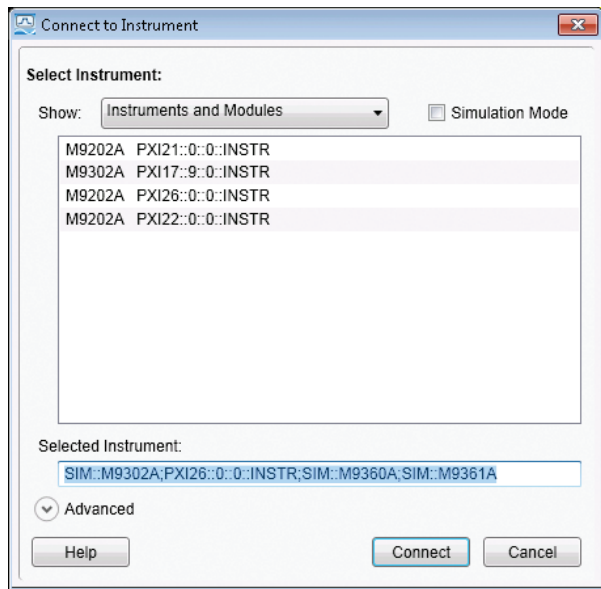
**Step 5.** Click connect, and wait for hardware initialization to complete. Choose File>Save Connection.



**Step 6.** In the dialog that appears, give the configuration a recognizable name, avoiding spaces and underscore (\_) characters. Enter a description in the description field, and be sure to check the Export to Keysight 89600 VSA checkbox before pressing the Save button.



**Step 7.** Choose the File>Connect... menu, and connect to the first slave digitizer, with simulated LO, downconverter, and front-end module. The simulated LO entry is similar to the previous simulated entries: SIM::M9302A. The figure at right shows a slave configuration selection.

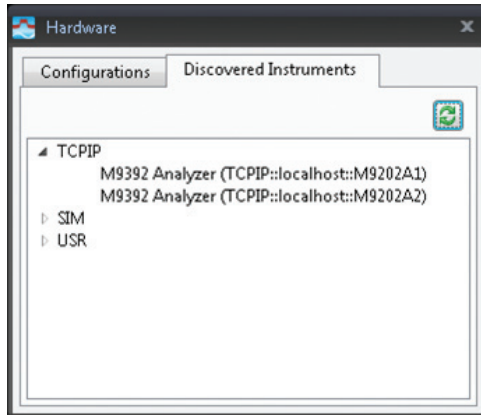


**Step 8.** Save the instrument connection as you did for the master connection, and repeat for all slave channels.

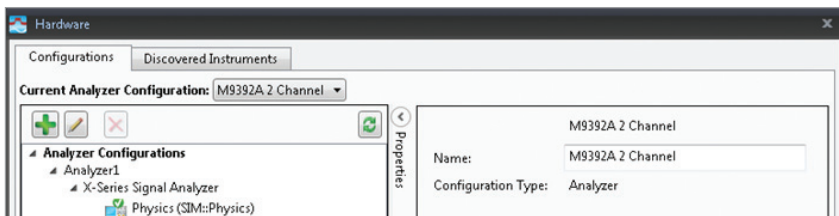
## Creating an 89600 VSA hardware configuration

The next step will be to create the hardware configuration in the 89600 VSA software. If the VSA software is already running, you will need to restart it or re-discover hardware now. This will allow it to recognize the new IVI configuration store entries that you exported in the previous step.

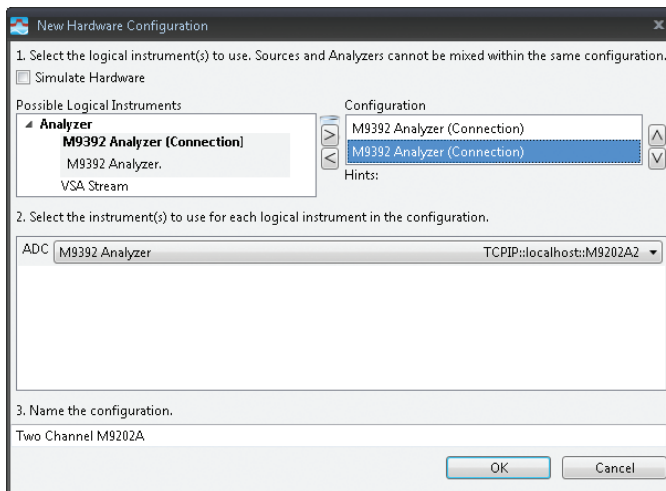
**Step 1.** On the Utilities > Hardware dialog in the VSA software, click on the discovered instruments tab. The configurations you just added will be present under the TCP/IP tree element.



**Step 2.** Switch back to the configurations tab, and create a new configuration by pressing the button with the green '+' symbol.



**Step 3.** Add one Keysight M9392A analyzer connection per channel to the configuration box by clicking the right-arrow button. Select the master channel configuration – either digitizer-only or simulated downconverter you created for the top-most entry in the configuration box from the drop-down list labeled 'ADC.' Repeat this for the slave channels.<sup>1</sup>

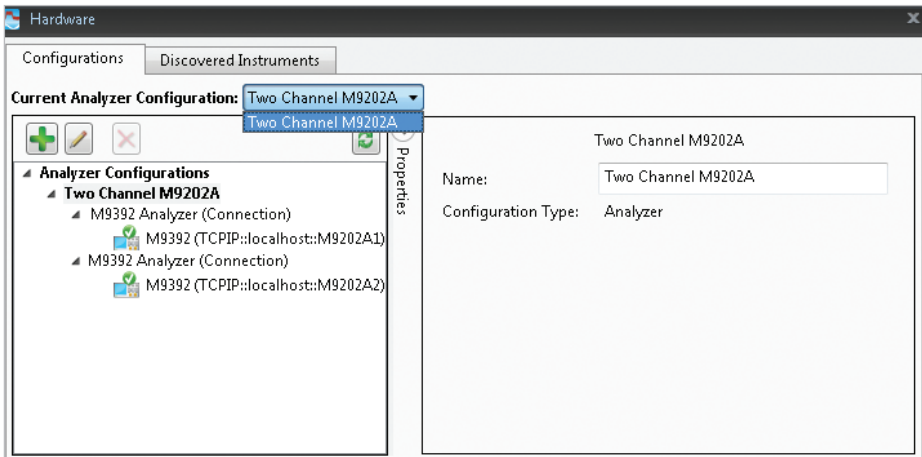


1. It is important that the master channel be associated with the topmost entry for synchronized operation.



**Step 4.** Now you are ready to start using your hardware. Give the configuration a name and click OK.

**Step 5.** On the hardware dialog, choose the newly created configuration from the 'Current Analyzer Configuration' listbox, and wait for the hardware to initialize.

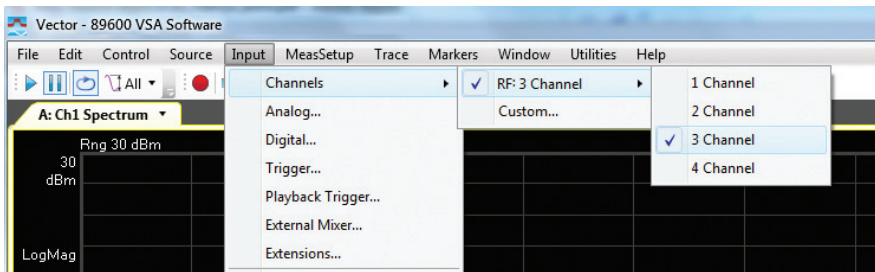


### Adjusting trigger delay and channel to channel skew

Trigger delay for all channels can be adjusted by using the delay setting on the Input>Trigger dialog. To adjust the channel to channel skew between the master and all slave channels, use Input>Extensions: SlaveTriggerSkew. See the following section for details on new trigger delays and slave trigger level input extensions at page 25.

By default, after selecting a multichannel PXI VSA hardware configuration, only 1 input channel will be enabled. To enable more channels, use the Input>Channels menu, or load a multichannel configuration.

Setting the number of channels

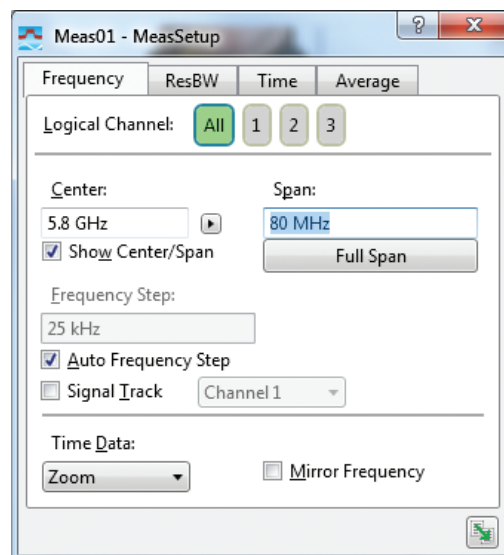


In digitizer-only mode, the spectrum may be inverted, depending on whether you are using high-side or low-side LO. If you are using high-side LO, you should use the VSA software's mirror spectrum capability. This can be accomplished in several ways:

- The demodulation properties for a given standard usually have a mirror spectrum option for 802.11n/ac demodulation.
- The User Correction>Frequency Converter capability allows setting spectrum to inverted. This is also one way to enable the 89600 VSA software to display the actual RF center frequency, rather than the IF frequency.
- The simulated downconverter technique provides another way to accomplish this, as discussed below.

Once the trigger levels and other settings are complete, start making measurements. Set your center frequency to the IF center frequency (nominally 500 MHz for DDC operation in digitizer-only mode) and your bandwidth. It is possible to set different IF center frequencies for synchronous analysis of signals on different channels, such as 80+80 MHz bandwidth. An example of this is covered in Section 8. With a 500 MHz center frequency, a span of up to 800 MHz (781 MHz in 802.11n/ac demodulation mode) is settable. If a higher or lower center frequency is chosen, the span will be limited.

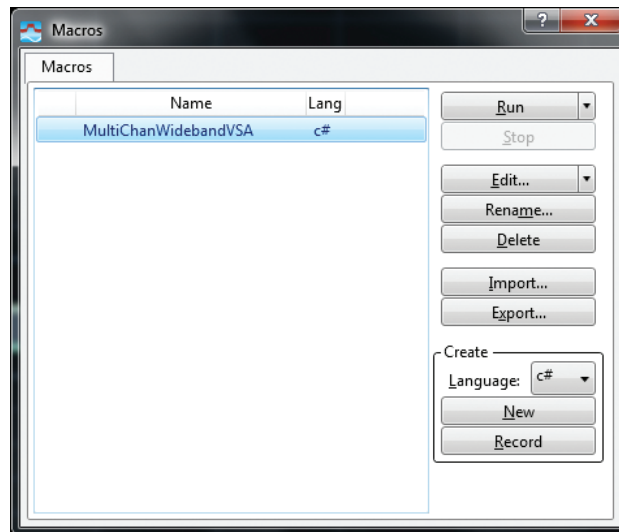
In simulated downconverter mode, while it is possible to set different RF center frequencies for each channel, only the setting on the master channel (channel 1) will have any effect. With version 14.2 of the 89600 VSA software, the spans must be set to the same value for all channels.



## 5. The VSA Macro Example Program for Multichannel Measurements

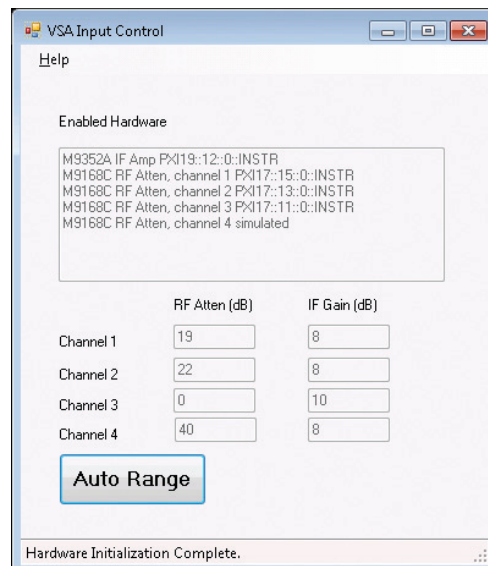
An example program was created for use with the VSA which allows seamless operation through the VSA software user interface. Copy the entire directory containing the MultiChanWidebandVSA to the user's VSA Software Macros directory, which is found in <User home>\My Documents\Keysight\89600B VSA\ Macros.

You will need to restart the VSA software for the new macro to be recognized. After restarting the 89600 VSA software, run the macro by selecting Utilities> Macros on the VSA software menu. Select **MultiChanWidebandVSA** and click run.



A dialog will appear with the addresses of M9168C attenuator modules and the M9352A IF Amp/Atten module. It also indicates the status of the hardware, including attenuator and gain settings of the hardware. This dialog will minimize after a few seconds.

It is important to set the number of channels before starting the MultiChan-WidebandVSA macro. If you need to change the number of input channels while the macro is running, change the number of input channels and then restart the macro program by closing its window, then selecting the macro again and clicking run.



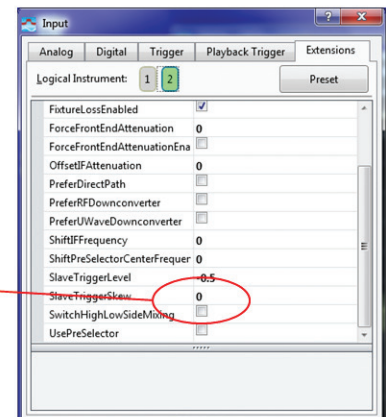
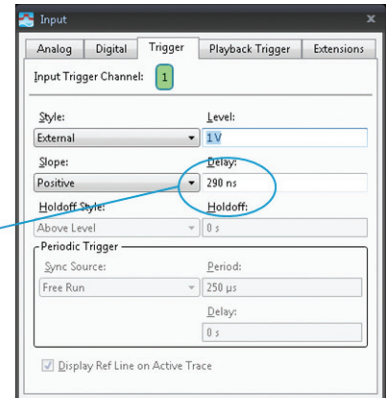
The macro program runs in the background, and performs several functions:

- Changing the input range on any channel in the VSA software will result in the attenuator and IF gain settings to change accordingly. The algorithm is simple: above -10 dBm input range, 1 dB of RF attenuation is added per dB above -10 dBm. Below -10 dBm input range, 1 dB of IF gain is added per dB below -10 dBm. The Input>Extensions IF offset and force RF front end attenuation settings can be used to adjust this algorithm if desired.
- Coarse amplitude correction is performed based on the input range setting by setting the VSA software user correction gain to compensate for the RF and IF attenuator loss.
- The auto range button can be pressed to perform input auto ranging. Both channels will be auto ranged to the same level. The algorithm used is a search for input overrange, and requires that an acquisition time is set that guarantees signal presence on every acquisition. It is not recommended to use IF magnitude trigger mode for this auto range, as the signal level could fall below the trigger threshold during the search. The auto range capability in the macro user interface should be used instead of the auto range button on the 89600 VSA software toolbar.

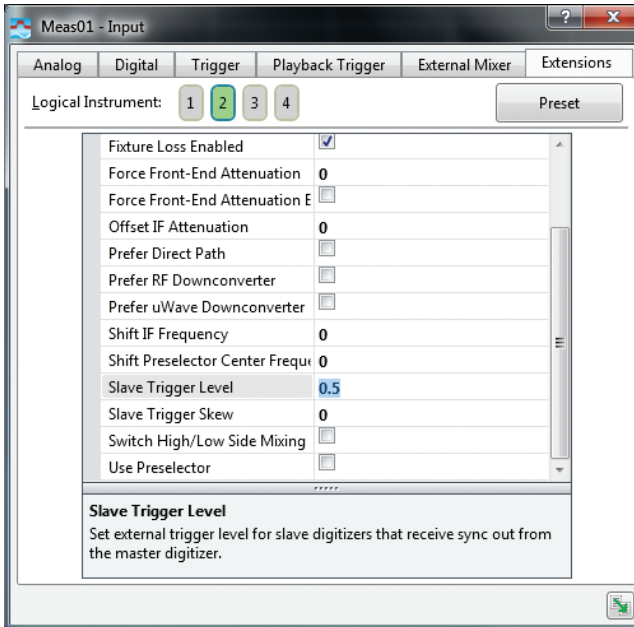
## 6. New Trigger Delay and Slave Trigger Level Input Extensions

Trigger delay for all channels can be adjusted by using the delay setting on the Input>Trigger dialog. To adjust the channel to channel skew between the master and all slave channels, a new parameter has been added to Input>Extensions: SlaveTriggerSkew.

Enter a number in seconds to move the slave trigger point relative to the master digitizer, as shown on below.



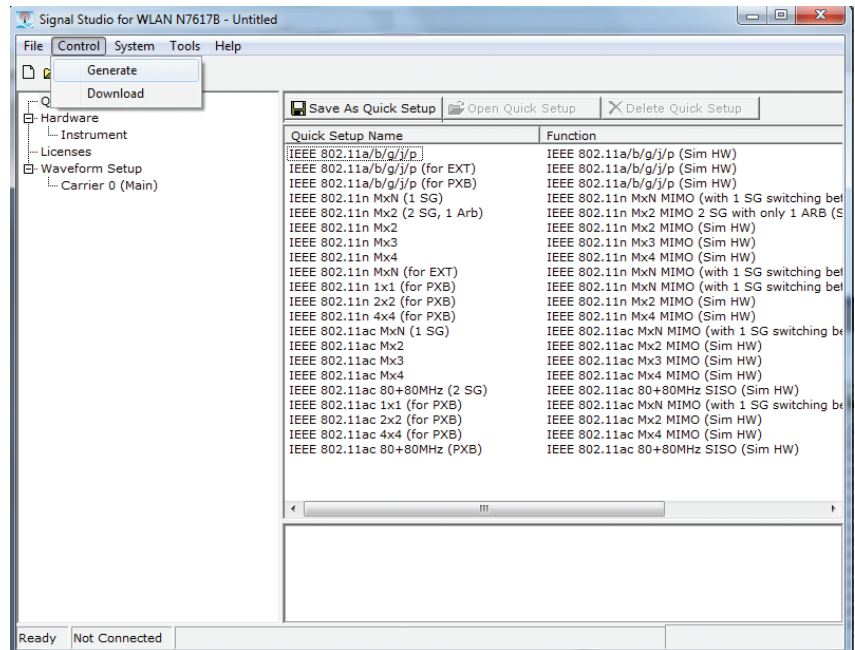
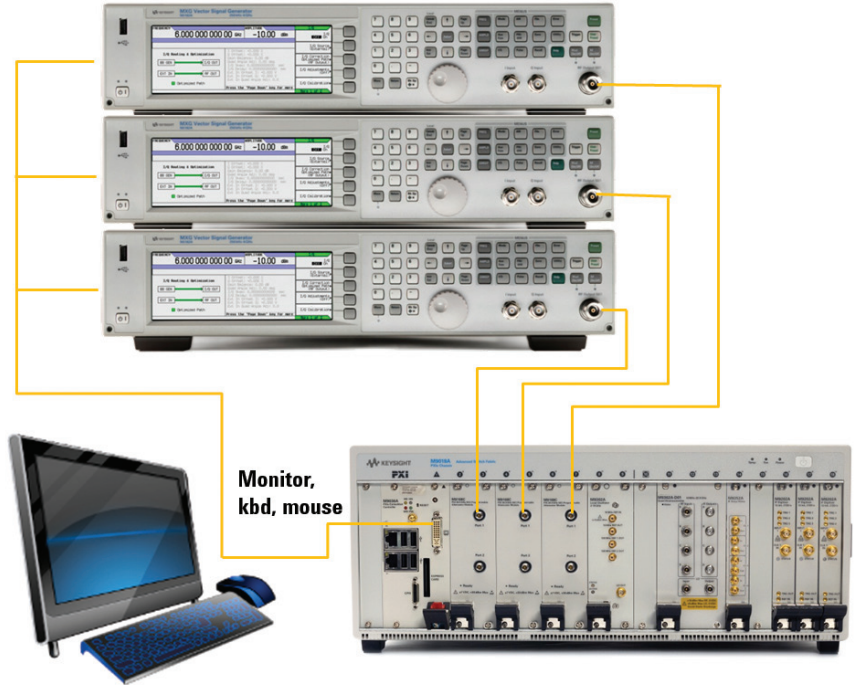
The trigger level setting on the Input>Trigger dialog will set the trigger input threshold for the master digitizer's input, either on the signal input, or on the trigger input (TRG 1 for single channel, TRG 2 for multichannel). The default slave sync trigger level will be set to  $-0.5$  V. This will need to be changed if more than 2 channels are used, or if a different trigger distribution mechanism is used. For example, using a timing module with default output levels will require setting to a  $0.5$  V trigger input level. Using a TEE for up to 4 channels will require setting a trigger input threshold between  $-0.1$  to  $-0.25$  V. To set the slave sync trigger threshold, set the SlaveTriggerLevel parameter on Input>Extensions, as depicted in the diagram below.



# 7. MIMO 802.11 ac Example

The signal is generated by Signal Studio, setting up the three MXG's in an Mx3 MIMO 802.11ac generation with 3 spatial streams.

This section describes an example created for multichannel wideband measurements of MIMO 802.11ac. The example uses three N5182A MXG vector signal generators (VSG) with synchronization cables, and Signal Studio N7617B WLAN signal generation software to generate a 3-stream 80 MHz bandwidth 802.11ac waveform with 256-QAM modulation format.





For best operation, the MXG's should have had an IQ skew calibration and channel flatness calibration performed. Please see the MXG MIMO optimization appendix for detailed instructions.

To make the measurement using the 89600 VSA software, perform the following steps:

- Enable three input channels.
- Enable external or IF magnitude trigger for proper synchronization of the analyzer channels.
- Switch the 89600 VSA software to the 802.11n/ac demodulation mode.
- Set to 80 MHz bandwidth.
- Set the center frequency to your RF center frequency if using simulation mode, or to the IF frequency (nominally 500 MHz).
- Set the span to 80 MHz or greater.
- Adjust the input range until the overload indicator appears, and then increase range until the overload indicator goes away. This will ensure the signal level is very close to the full scale input of the digitizer for optimal signal to noise and therefore optimal error vector magnitude (EVM) performance.

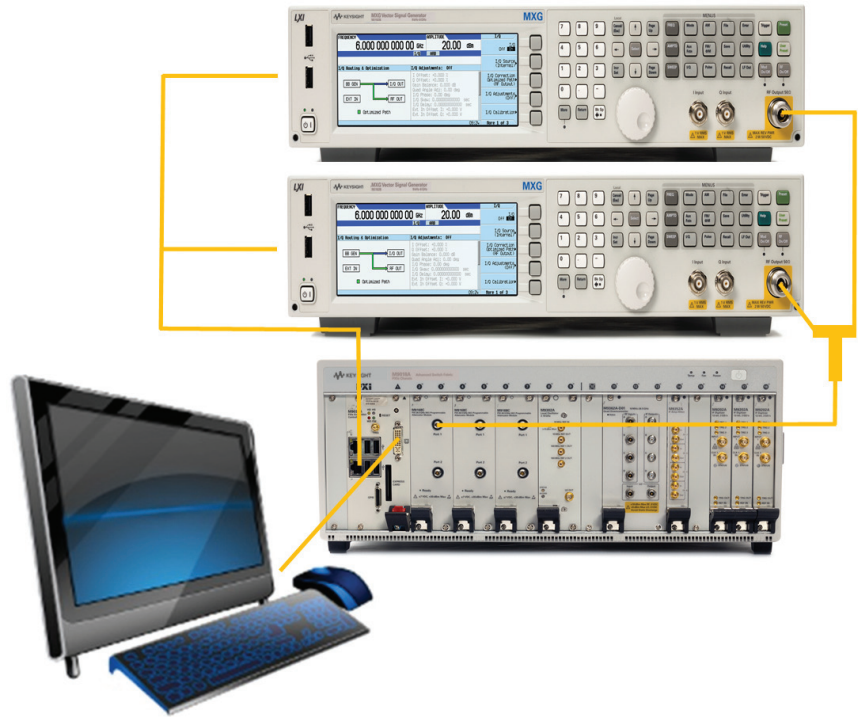
The results should look something like this:





## 8. 80+80 MHz 802.11ac Example

Use the digitizer-only mode to measure 80+80, and independently tune the IF center frequency on two input channels of the PXI vector signal analyzer (VSA). First, set up the hardware with two N5182A MXG VSG's in a MIMO configuration. The signal can be analyzed as a single-channel 160 MHz bandwidth input, if the channels are contiguous, as shown below. Alternatively, each output can be connected to a different channel and analyzed using the 89600 VSA's 80+80 mode. The following example shows 80+80 mode.



Generate the waveform using Signal Studio for WLAN N7617B, using the 80+80 mode, and specifying the channel spacing in the user interface. Optimize the MXG signal generators by performing IQ skew and channel flatness correction. See the appendix on MXG MIMO optimization for instructions. After playing the waveform, set up the 89600 VSA software.

- Select digitizer-only hardware.
- Enable two input channels.
- Enable the WLAN 802.11n/ac demodulation mode.
- Select 80+80 MHz mode from the demodulation properties.
- Ensure that trigger mode is external or IF magnitude for proper capture synchronization.
- Set LO frequency (this can be done manually using the M9302A SFP).
- Set the RF attenuators and IF gain (using the M9168C SFP and M9352A SFP).
- Set your IF center frequency on each channel to an appropriate offset.
- Set the span to 80 MHz.

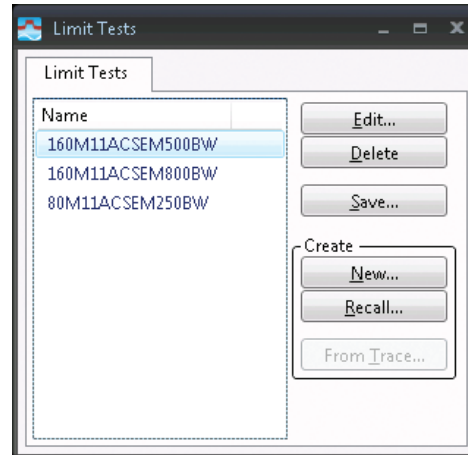
If channels are spaced 160 MHz apart, the LO can be set to the mid point between the two channels, plus 500 MHz. IF center frequencies can be set to 420 MHz and 580 MHz. Remember to enable spectrum mirroring in the 802.11n/ac demodulation properties dialog.

The results should look something like the following. There will be two streams displayed, and the available data is organized differently than for single channel SISO or from multi-channel MIMO modes. See the Keysight 89600 VSA software documentation for details on data display for this mode.



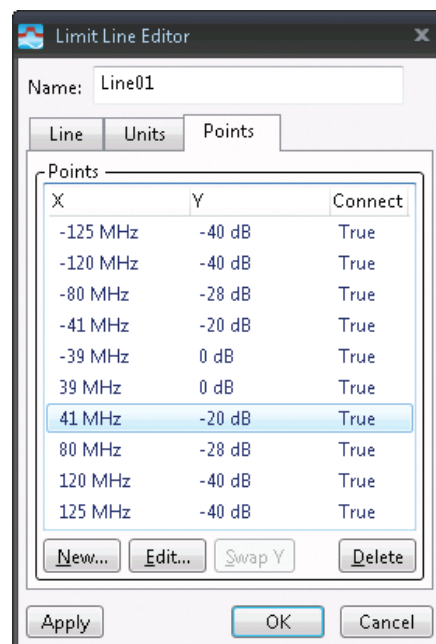
## 9. Making Spectral Emission Mask (SEM) and Sub-Carrier Flatness Measurements

The limit markers in the 89600 VSA software can be used to measure spectral mask on a spectrum display or on a channel frequency response display. Pre-configured limits files are available for various channel bandwidths, or you can create your own. To import existing files, use the Utilities>Limit Tests menu, and press the recall button. You can import .lim files to create a suite of limits that are available for use with traces on the VSA software display.



To create your own, press the new button and configure the limit parameters. For SEM, use relative to reference level mode for best performance. You will need to adjust the reference level to be at the peak amplitude of the signal.

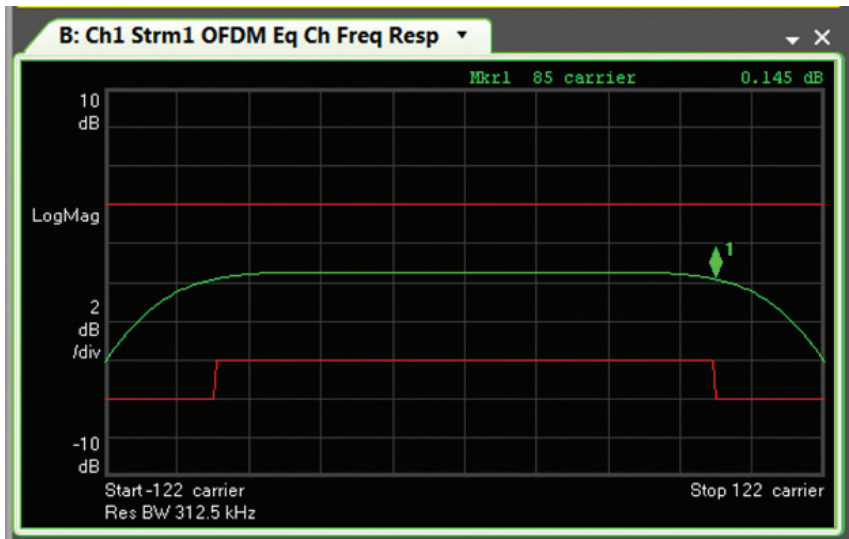
At right, is an example of the limit definition for an 80 MHz bandwidth signal with a span of 250 MHz.



After application of the limit line on the spectrum trace, the limit line appears on the display and the output window will include a pass/fail result. These results can be queried in the 89600 VSA software API. See the screenshot, below.



Channel flatness limits can be applied in a similar way. In this case, two limit lines are used instead of one.



## 10. API Programming Instructions

The following API are documented with their respective products. This section gives an overview of functions needed for automating the wideband MIMO PXI VSA.

### 89600 VSA software

89600 VSA software has several API interfaces including SCPI, .NET and COM. The 89600 VSA API documentation contains details and examples for automating measurements and querying results with APIs.

A connection can be made to an existing VSA session , or launch a new session. Complete control over the VSA software can be exercised, including sweep control, querying measurement results, setting user corrections, etc.

### M9392A

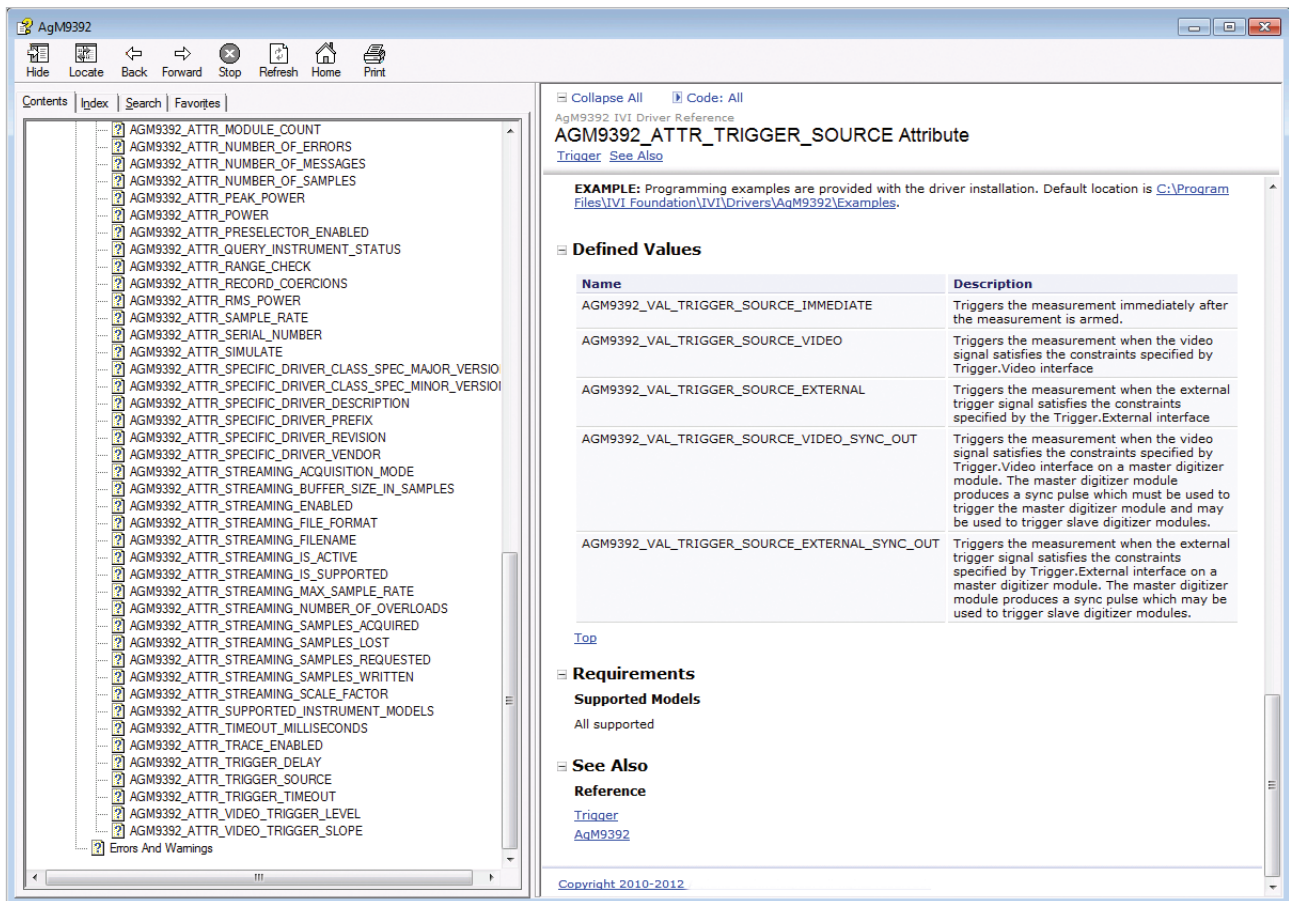
M9392A software is used to control the digitizers and in simulation mode, the M9302A LO as well. Because the M9392A API documentation contains examples and details of this API only the commands needed for control of multichannel hardware will be covered below.

## New commands

The following new methods and properties are available for multichannel setups and are documented in the M9392A API.

The AGM9392\_ATTR\_CURRENT\_TRIGGER\_SOURCE\_Attribute has two new settings. These should be used for the master digitizer when in IF magnitude or external trigger modes. The slave digitizers should be set to external trigger mode.

When setting up for each acquisition, it is important to arm the slave modules before the master digitizer, so that when the master digitizer triggers, the slave modules are ready to receive the trigger generated by the master digitizer.



The screenshot shows the AgM9392 API documentation window. The left pane displays a list of attributes, including AGM9392\_ATTR\_MODULE\_COUNT, AGM9392\_ATTR\_NUMBER\_OF\_ERRORS, AGM9392\_ATTR\_NUMBER\_OF\_MESSAGES, AGM9392\_ATTR\_NUMBER\_OF\_SAMPLES, AGM9392\_ATTR\_PEAK\_POWER, AGM9392\_ATTR\_POWER, AGM9392\_ATTR\_PRESELECTOR\_ENABLED, AGM9392\_ATTR\_QUERY\_INSTRUMENT\_STATUS, AGM9392\_ATTR\_RANGE\_CHECK, AGM9392\_ATTR\_RECORD\_COERCIONS, AGM9392\_ATTR\_RMS\_POWER, AGM9392\_ATTR\_SAMPLE\_RATE, AGM9392\_ATTR\_SERIAL\_NUMBER, AGM9392\_ATTR\_SIMULATE, AGM9392\_ATTR\_SPECIFIC\_DRIVER\_CLASS\_SPEC\_MAJOR\_VERSION, AGM9392\_ATTR\_SPECIFIC\_DRIVER\_CLASS\_SPEC\_MINOR\_VERSION, AGM9392\_ATTR\_SPECIFIC\_DRIVER\_DESCRIPTION, AGM9392\_ATTR\_SPECIFIC\_DRIVER\_PREFIX, AGM9392\_ATTR\_SPECIFIC\_DRIVER\_REVISION, AGM9392\_ATTR\_SPECIFIC\_DRIVER\_VENDOR, AGM9392\_ATTR\_STREAMING\_ACQUISITION\_MODE, AGM9392\_ATTR\_STREAMING\_BUFFER\_SIZE\_IN\_SAMPLES, AGM9392\_ATTR\_STREAMING\_ENABLED, AGM9392\_ATTR\_STREAMING\_FILE\_FORMAT, AGM9392\_ATTR\_STREAMING\_FILENAME, AGM9392\_ATTR\_STREAMING\_IS\_ACTIVE, AGM9392\_ATTR\_STREAMING\_IS\_SUPPORTED, AGM9392\_ATTR\_STREAMING\_MAX\_SAMPLE\_RATE, AGM9392\_ATTR\_STREAMING\_NUMBER\_OF\_OVERLOADS, AGM9392\_ATTR\_STREAMING\_SAMPLES\_ACQUIRED, AGM9392\_ATTR\_STREAMING\_SAMPLES\_LOST, AGM9392\_ATTR\_STREAMING\_SAMPLES\_REQUESTED, AGM9392\_ATTR\_STREAMING\_SAMPLES\_WRITTEN, AGM9392\_ATTR\_STREAMING\_SCALE\_FACTOR, AGM9392\_ATTR\_SUPPORTED\_INSTRUMENT\_MODELS, AGM9392\_ATTR\_TIMEOUT\_MILLISECONDS, AGM9392\_ATTR\_TRACE\_ENABLED, AGM9392\_ATTR\_TRIGGER\_DELAY, AGM9392\_ATTR\_TRIGGER\_SOURCE, AGM9392\_ATTR\_TRIGGER\_TIMEOUT, AGM9392\_ATTR\_VIDEO\_TRIGGER\_LEVEL, and AGM9392\_ATTR\_VIDEO\_TRIGGER\_SLOPE. The right pane shows the details for the AGM9392\_ATTR\_TRIGGER\_SOURCE attribute, including an example, defined values, requirements, and see also information.

**AGM9392\_ATTR\_TRIGGER\_SOURCE Attribute**

**EXAMPLE:** Programming examples are provided with the driver installation. Default location is <C:\Program Files\IVI Foundation\IVI\Drivers\AgM9392\Examples>.

**Defined Values**

Name	Description
AGM9392_VAL_TRIGGER_SOURCE_IMMEDIATE	Triggers the measurement immediately after the measurement is armed.
AGM9392_VAL_TRIGGER_SOURCE_VIDEO	Triggers the measurement when the video signal satisfies the constraints specified by Trigger.Video interface
AGM9392_VAL_TRIGGER_SOURCE_EXTERNAL	Triggers the measurement when the external trigger signal satisfies the constraints specified by the Trigger.External interface
AGM9392_VAL_TRIGGER_SOURCE_VIDEO_SYNC_OUT	Triggers the measurement when the video signal satisfies the constraints specified by Trigger.Video interface on a master digitizer module. The master digitizer module produces a sync pulse which must be used to trigger the master digitizer module and may be used to trigger slave digitizer modules.
AGM9392_VAL_TRIGGER_SOURCE_EXTERNAL_SYNC_OUT	Triggers the measurement when the external trigger signal satisfies the constraints specified by Trigger.External interface on a master digitizer module. The master digitizer module produces a sync pulse which may be used to trigger slave digitizer modules.

**Requirements**

**Supported Models**

All supported

**See Also**

**Reference**

[Trigger](#)  
[AgM9392](#)

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## MD1

The MD1 driver is used to control many Keysight digitizers, including the M9202A. This is the underlying driver used by the M9392A API to control the digitizer. You should not need to control the digitizer directly using this driver, but you may in some circumstances want to access functionality that is not exposed by the M9392A API.

## M9302A

The M9302A control is very straightforward. You will primarily be setting the center frequency of the LO when controlling the system via digitizer-only mode. To do this, you'll need to call two methods:

- `AgM9302 _ ConfigureBandSwitchFrequency(uint32 _ t Vi, double BandSwitchFrequency)`. This method is used for an internal frequency band setting. We typically set this to 5.0e9.
- `AgM9302 _ Configure(uint32 _ t Vi, double Frequency, int16 _ t Enabled)`. This method is used to set the actual center frequency of the LO. Keep in mind that this is not the input RF center frequency, but the LO frequency, which typically should be 500 MHz above your RF center frequency, or one third of this frequency if operating in third harmonic mode (above 10 GHz).

## M9168C

The M9168C API is also very straightforward. The attenuation is simply set to the desired value in dB.

```
ViStatus AgM9168x _ SetAttenuation(  
    ViSession Vi,  
    ViInt32 Attenuation  
);
```

## M9352A

The M9352A has an interface for setting up the attenuator state at a register level, but there is a gain property that makes this much easier. The gain can be set from 8 dB to 39.5 dB. The module has a fixed gain amplifier and that setting is adjusting a variable attenuator.

The following is set as a property or attribute. There is not a dedicated function to set this.

```
#define AGAMPATTEN_ATTR_GAIN 1150006

ViStatus AgAmpAtten_GetAttributeViReal64(
    ViSession Vi,
    ViConstString RepCapIdentifier,
    ViAttr AttributeID,
    ViReal64* AttributeValue
);

ViStatus AgAmpAtten_SetAttributeViReal64(
    ViSession Vi,
    ViAttr AttributeID,
    ViReal64* AttributeValue
);
```

## M9362A-D01

The M9362A-D01 has no settable parameters and nothing that can be queried, so there is no API for this module.

## M9300A

Upon initialization, the default state of the M9300A will have all of its 100 MHz reference outputs enabled and the 10 MHz reference input enabled. To enable the 10 MHz reference output, use the following property/method (C# example):

```
driver.ReferenceBase.Ref10MHzOutEnabled = true;
```



## Characteristic performance

### VSA Option B7Z 802.11n, Option B7H 802.11ac

Wideband MIMO PXI VSA

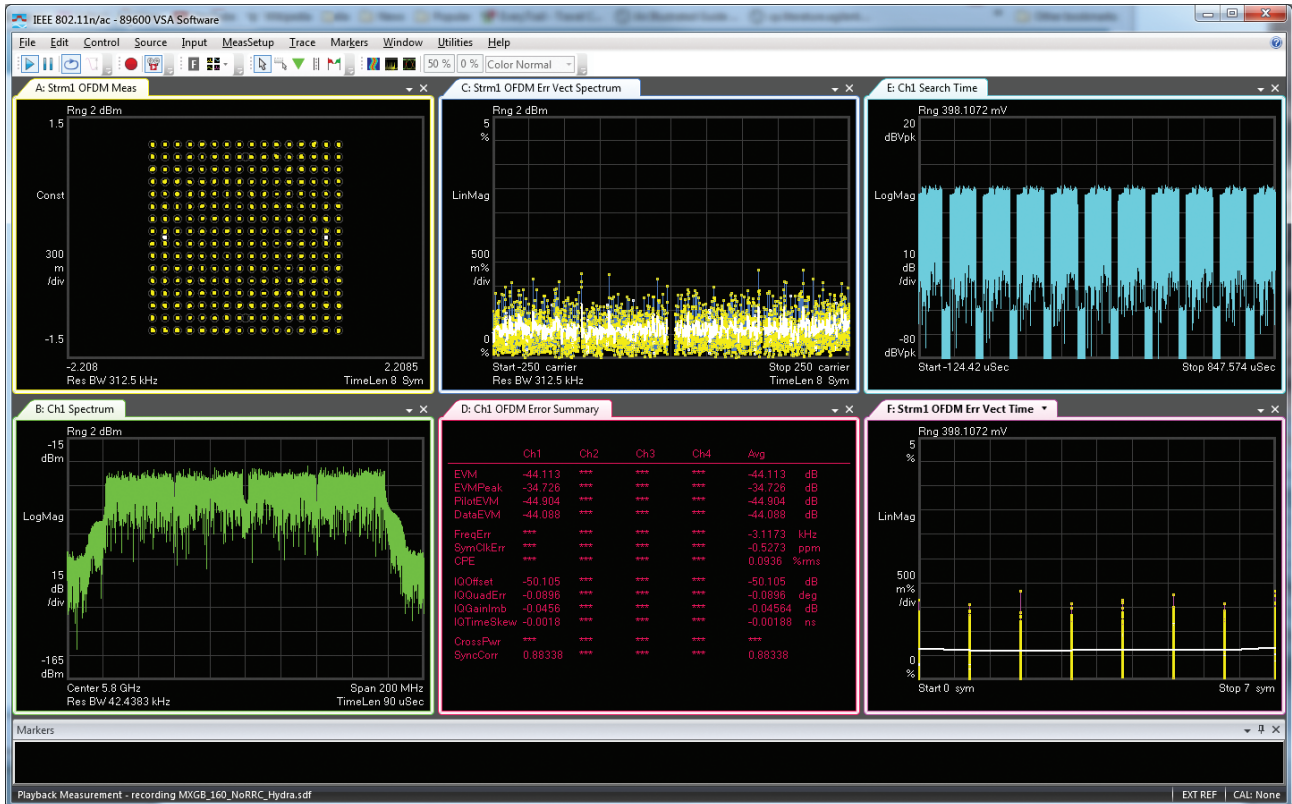
Measurement inputs: 1,2,3 or 4 channels

#### Signal playback

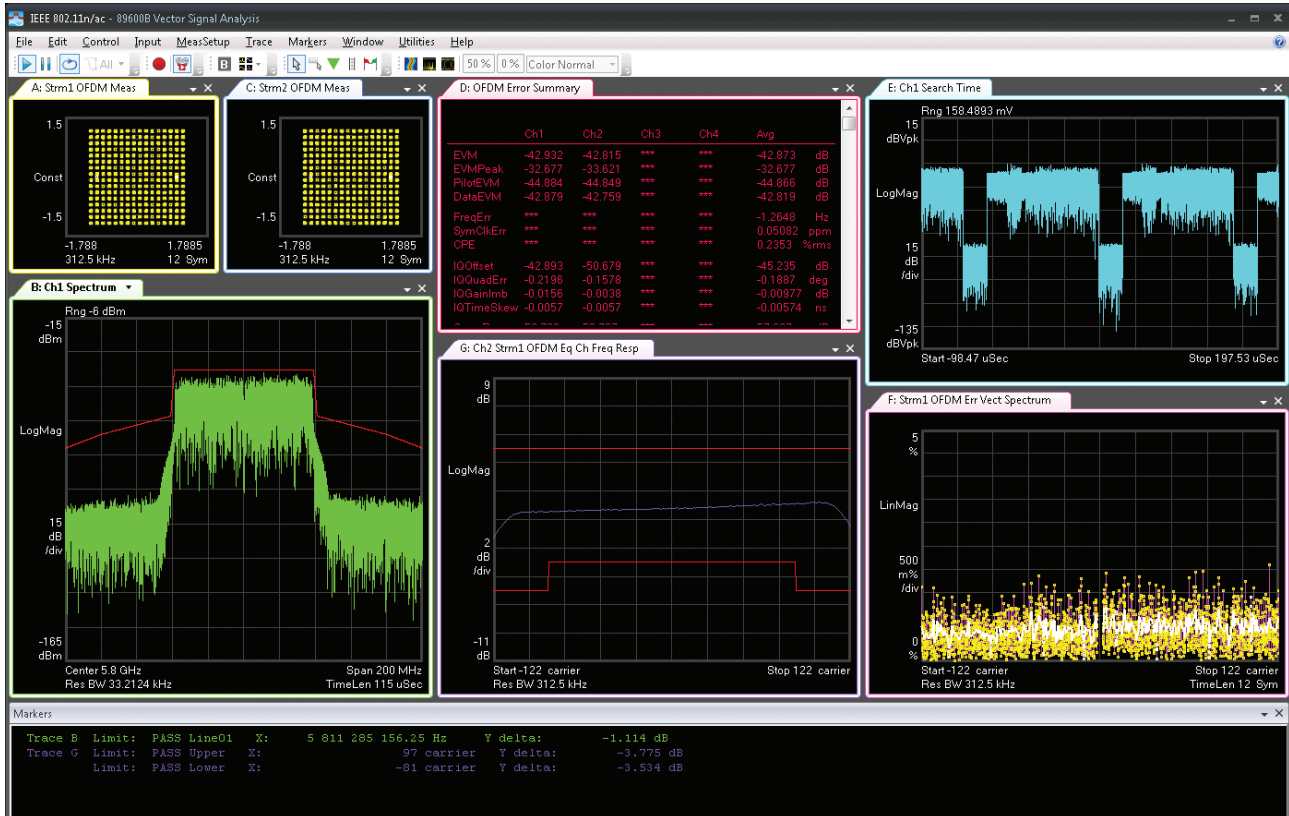
Result length Auto-detect or manually adjustable.

Capture length Dependent on span, center frequency. 100 MHz span: 8.4 ms

Accuracy	Input at average -15 dBm on all input channels. RMS averaging with average count = 20. At least 16 data symbols analyzed in each burst. Analyzer span set to default.			
		Signal BW		
		20 MHz (31.25 MHz span)	40 MHz (62.5 MHz span)	80 MHz (125 MHz span)
Equalizer training = channel estimated sequence only	2.4 GHz center freq	-43 dB	-45 dB	-44 dB
	5.8 GHz center freq	-43 dB	-43 dB	-42 dB
Equalizer training = channel estimated sequence & data	2.4 GHz center freq	-46 dB	-48 dB	-46 dB
	5.8 GHz center freq	-45 dB	-46 dB	-45 dB
Frequency lock range	$\pm 2 \times$ subcarrier spacing = $\pm 625$ kHz at default subcarrier spacing			



Sample data for 160 MHz (signal generated by N5182B MXG)



Sample measurement for 2x2 including SEM mask limits and subcarrier flatness limits.

## Dynamic range

This data was measured by terminating the input of an M9168C attenuator set to 0 dB attenuation, through the M9362A-D01 quad downconverter, and the M9352A IF attenuator/amplifier module, and finally into M9202A digitizer with DDC enabled. The noise floor was measured in a 10 kHz span and the gain of the input chain used to calculate signal to noise based on maximum input signal at P0.1 dB level of the downconverter.

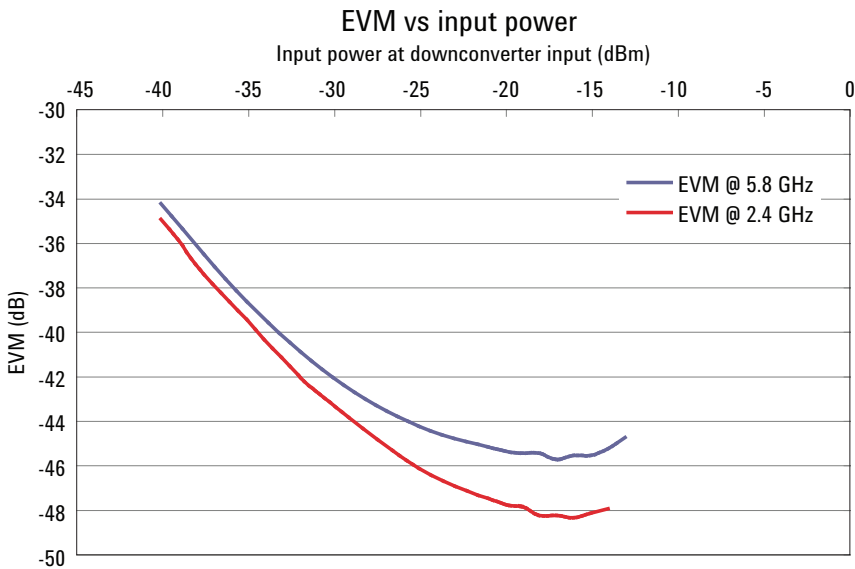
At minimum gain on M9352A attenuator module (assume max input signal of -10 dBm):

Noise floor: -136.7 dBm/Hz  
S/N ratio: 135 dB

At maximum gain on M9352A attenuator module (assume max input signal of -40 dBm):

Noise floor: -115.5 dBm/Hz  
S/N ratio: 107 dB

EVM versus input level was measured, to provide some insight into optimal settings for RF and IF attenuation. For these measurements, a 40 MHz 802.11n signal was measured at 2.4 GHz and 5.8 GHz. Signal level input to the M9168C module was kept at -2 dBm average power, and RF attenuation was adjusted to measure the effect of input level on the M9362A-D01 quad downconverter performance. At each power step, the gain of the M9352A IF amplifier/attenuator module was adjusted to obtain optimal input level at the input of the M9202A IF digitizer. Channel estimation on preamble only was used. The optimal EVM was achieved with average input power of the 802.11n signal at the input of the downconverter between approximately -19 and -15 dBm.



### TOI

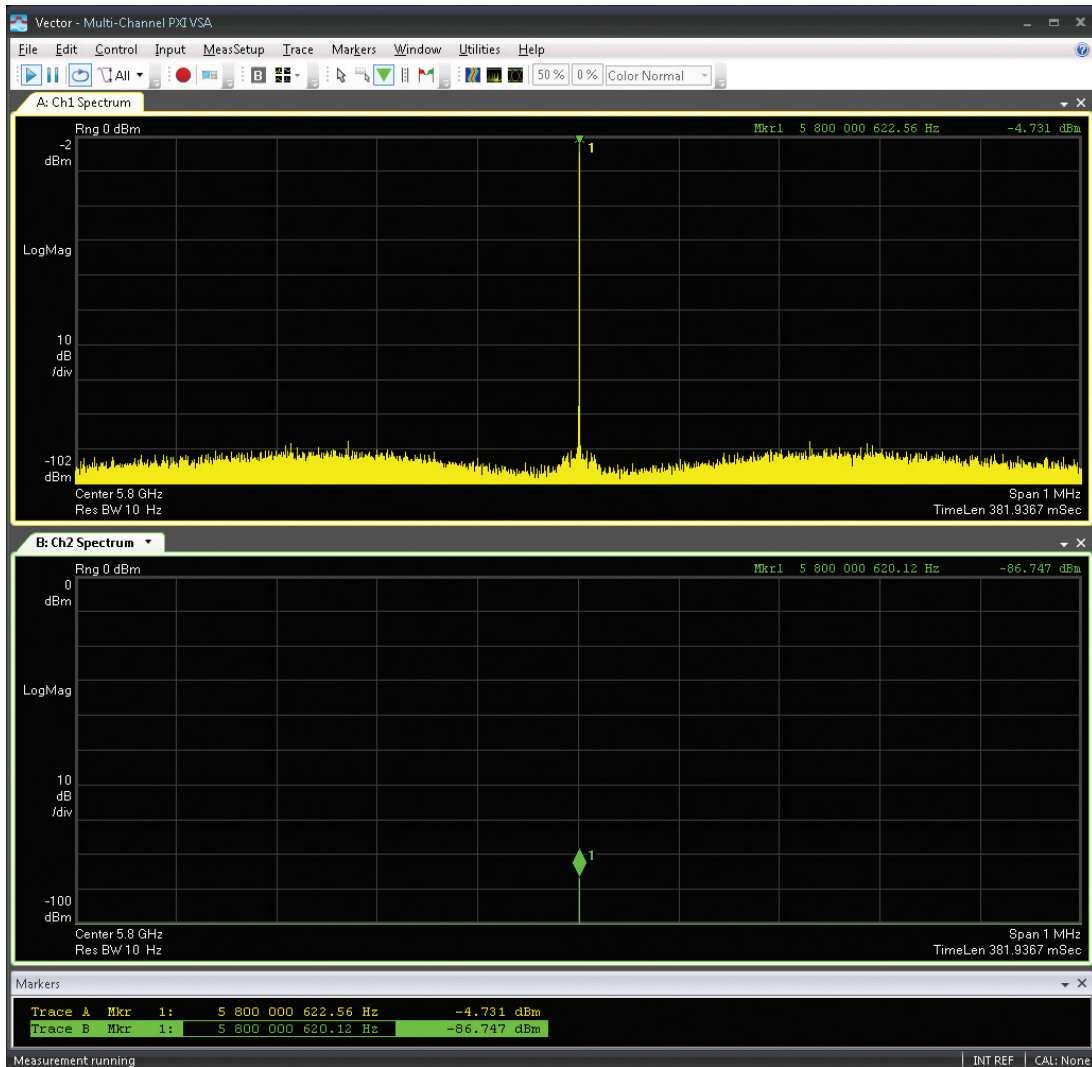
TOI was measured using two N5182A MXG signal generators with a 10 dB attenuator on the output of each, into a precision 2-resistor power splitter. The signal generators were set to a fixed output power and the M9168C was adjusted to measure TOI at various mixer drive levels. The M9352A IF amplifier/attenuator module was adjusted at each level to achieve optimal signal level at the input of the M9202A digitizer.

Two tones, at 2.41 GHz and 2.39 GHz were used for this measurement.

Input level of each tone at downconverter (dBm)	TOI (dBm)
-28	28.9
-18	25.5
-15	22.1
-13	19.7

## Crosstalk

Crosstalk was measured by terminating the input of one channel at the input of the M9168C, and applying a CW signal to the input of a second channel. The signal levels were measured using the 89600 VSA software, and isolation between channels measured to be better than  $-80$  dBc.



## LO feedthrough

LO feedthrough was measured using a E4440A Performance Spectrum Analyzer (PSA) signal analyzer measuring the output of the M9352A IF amplifier/attenuator module, with the input of the M9168C RF attenuator terminated. An N5182A MXG was used to drive the LO input of the M9362A-D01 quad down-converter at different signal levels and the power of the LO at the output of the M9352A was measured. The feedthrough below 1 GHz can be mitigated by bypassing the downconverter in this frequency range.

LO frequency	LO feedthrough (dBc)
5.5 GHz	< -80
4.0 GHz	< -80
3.0 GHz	< -75
2.75 GHz	< -80
2.0 GHz	< -80
1.5 GHz	< -80
1.1 GHz	< -60 + M9352A gain
1.0 GHz	< -40 + M9352A gain
500 MHz	< -40 + M9352A gain
100 MHz	< -40 + M9352A gain
10 MHz	< -35 + M9352A gain

## RF feedthrough

RF Feedthrough was measured for a 200 MHz CW tone input to M9168C attenuator input with various LO frequencies.

LO frequency (MHz)	Feedthrough (dBc)
400	-30 + M9352A Gain
500	-15 + M9352A Gain
600	0 + M9352A Gain

## Timing synchronization

$\pm 2$  samples of trigger uncertainty from acquisition to acquisition, at output sample rate if using hardware DDC.

## 11. Appendix

### M9202A hardware DDC operation

The M9202A digitizer used with the M9392A software, takes advantage of a hardware digital down conversion (DDC) in the digitizer's FPGA under certain conditions. This DDC allows for data reduction, which results in faster throughput and reduced capture sizes, which increases the maximum length of a capture by more efficiently utilizing the digitizer's memory. It also improves signal to noise ratio, resulting in improved residual EVM, among other effects. The hardware DDC is enabled under a limited set of conditions. When the hardware DDC is not enabled, a software DDC is used instead, which is less efficient because captures in this mode are stored to digitizer memory as real, full sample rate data, and the software DDC is performed in the controller by the M9392A driver. This appendix describes the conditions under which hardware DDC is available for both complete M9392A (including simulated LO/downconverter modes), and digitizer-only modes.

### Complete M9392A including simulated LO/downconverter

In this mode, hardware DDC is almost always used, as the IF center frequencies and bandwidth are chosen by the M9392A driver to ensure hardware DDC operation. The only exception is through the use of an IF offset hint. The hint usage is documented in the M9392A software, and is available through the M9392A IVI API as well as exposed in the input extensions interface in the 89600 VSA software. When an IF offset (other than 0) is used, you may encounter a "mixed mode DDC," in which the following conditions apply:

- HW DDC decimates down to 2x the final bandwidth and sample rate
- The M9392A driver applies a frequency shift to the final IF offset
- SW DDC in the M9392A driver does a final decimation by a factor of 2

Note that pure hardware DDC may still be available under a specific set of conditions, if the entire IF span is contained between 375 and 625 MHz, and with a valid IF center frequency as defined below.

Bandwidth (MHz)	Valid IF center frequency for hardware DDC (MHz)
250	500
125	500
62.5	437.5, 500, 562.5 (previous row $\pm$ 62.5)
31.25	406.25, 437.5, 468.75, 500, 531.25, 562.5, 593.75 (previous row $\pm$ 31.25)
15.625	(previous row $\pm$ 15.625)
Etc. (7.8125, 3.90625, 1.953125, ...)	Etc. (previous row $\pm$ bandwidth)

In some cases, hardware DDC cannot be used. Conditions that trigger this include:

- IF bandwidth greater than 250 MHz
- IF center frequency outside the range of 375 to 625 MHz
- IF center frequency within 375 to 625 MHz, but the IF bandwidth causes part of the IF signal to fall outside the 375 to 625 MHz range

If one of these conditions holds true, software DDC is used exclusively and all decimation and frequency shifting is performed by the M9392A driver.

## Digitizer-only mode

In digitizer-only mode, it is possible for any of the three operation modes described above to occur. Because the IF center frequency can be set directly in the 89600 VSA software or through the M9392A API, it is much more likely for either the mixed mode DDC or software DDC modes to be used. The same rules from the previous section apply, but the IF offset hint is not needed to set the IF center frequency. All other settings will either utilize mixed mode DDC or software DDC, depending on whether the IF span is fully contained within the 375–625 MHz range.

## Additional notes

IF (video) triggering only operates in pure hardware DDC mode. The M9392A driver will automatically switch to external trigger if video trigger is enabled and the digitizer is operating in mixed mode DDC or software DDC modes.

The maximum acquisition time for a given bandwidth will be different in each of the three DDC modes. The nominal trigger delay may be different in each of the three DDC modes.

## MXG MIMO optimization

### MXG I/Q skew and channel correction

New calibrations were introduced in version A.01.60 of the MXG firmware to compensate for the I/Q skew of the internal modulator and provide magnitude and phase corrections across the 100 MHz modulation bandwidth over all RF frequencies. These calibrations were performed at Keysight for all instruments shipped with version A.01.60 or later and do not need to be repeated. Newly announced EXGs and MXGs (model #s N5171B/72B & N5181B/82B) have IQ skew correction from the factory, so only the channel flatness correction needs to be considered. Older MXGs can get the benefit of these calibrations by upgrading the firmware and performing the calibrations. An N9020A MXA or N9030A PXA signal analyzer is required to perform the I/Q skew calibration.

The I/Q skew correction is highly recommended for improving the EVM performance of 802.11ac signals, especially for 80 MHz bandwidth. With this correction, typical EVM should be  $-45$  dB or better ( $-46$  dB = 0.5%). The channel correction has less impact, and it is turned off by default because it slows down the switching speed of the instrument.



To check if your MXG has these calibrations, press these keys on the front panel of the MXG: I/Q, More, Int Channel Correction. The display will tell you if the I/Q skew calibration needs to be performed. To perform the calibrations, connect an MXA or PXA signal analyzer to the MXG with LAN or GPIB and RF connections. Follow the instructions on the front panel. LAN connections need to be made using a networked LAN, not using direct connection or a local hub.

The Int Channel Correction can be turned on from this menu. Note that this must be done after the waveform is downloaded into the MXG, since a preset is performed during the download process and that turns off the channel correction. For 80+80 MHz signal generation, turning on the channel correction will cause the MXGs to display the WATRG annunciator, indicating that the box is waiting for a trigger to restart waveform playback. To manually trigger the waveforms in the MXGs, from the master MXG press these keys: Mode, Dual ARB, Trigger Source (Bus), Trigger Source (Bus), Trigger Key.

Press the trigger hard key on the master MXG to restart the waveform playback. If the latest version of Signal Studio is used, internal channel flatness corrections can be enabled from the IQ section of the instrument controls pane.

## I/Q calibration and adjustments

The following steps may be performed on an ESG, MXG, or PSG signal generator to improve the EVM of the output signal.

- a. Run a DC calibration to improve the DC offset, gain and quadrature error of the I/Q modulator. This applies to a single frequency. Changing any settings after the calibration except for I/Q adjustments will void the calibration and the instrument will revert to the factory calibration data. Press these keys: I/Q, I/Q Calibration, DC, Execute Cal.
- b. Calibrate the I/Q offset, gain, and quadrature errors over a user-defined frequency span. Press these keys: I/Q, I/Q Calibration, User. Set the start/stop frequencies, then execute calibration. You can also perform a full calibration over the full frequency span of the signal generator, which takes longer.
- c. Use the I/Q adjustments menu to correct for specific I/Q errors. You can analyze the signal using the 89601B VSA software to see the amounts of the I/Q quadrature error, gain imbalance, or I/Q skew and use the information to correct for these errors in the signal generator.

For more information on int channel correction for EXG and N5182B signal generators, please see the *Keysight X-Series Signal Generators Users Guides*, page 106 (literature number N5180-90056).

For more information on int channel correction/IQ skew for N9182A signal generators, please see *MXG Signal Generators User Guide*, page 111, (literature number N5180-90003).

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