MXG Vector Signal Generator

N5186A MXG Vector Signal Generator

This manual provides documentation for the N5186A running on the Linux operating system and X-Series Signal Analyzer running on the Windows operating system.

KEYSIGHT

MEASUREMENT GUIDE

Notices

Trademark Acknowledgments

Bluetooth and the Bluetooth logos are trademarks owned by Bluetooth SIG, Inc., U.S.A. and licensed to Keysight Technologies, Inc.

Manual Part Number

N5186-90003

Edition

Edition 1, February 2025
Supersedes: October 2023

Published by:
Keysight Technologies
1400 Fountaingrove Parkway
Santa Rosa, CA 95403

Warranty

THE MATERIAL CONTAINED IN THIS DOCUMENT IS PROVIDED “AS IS,” AND IS SUBJECT TO BEING CHANGED, WITHOUT NOTICE, IN FUTURE EDITIONS. FURTHER, TO THE MAXIMUM EXTENT PERMITTED BY APPLICABLE LAW, KEYSIGHT DISCLAIMS ALL WARRANTIES, EITHER EXPRESS OR IMPLIED WITH REGARD TO THIS MANUAL AND ANY INFORMATION CONTAINED HEREIN, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. KEYSIGHT SHALL NOT BE LIABLE FOR ERRORS OR FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH THE FURNISHING, USE, OR PERFORMANCE OF THIS DOCUMENT OR ANY INFORMATION CONTAINED HEREIN. SHOULD KEYSIGHT AND THE USER HAVE A SEPARATE WRITTEN AGREEMENT WITH WARRANTY TERMS COVERING THE MATERIAL IN THIS DOCUMENT THAT CONFLICT WITH THESE TERMS, THE WARRANTY TERMS IN THE SEPARATE AGREEMENT WILL CONTROL.

Technology Licenses

The hardware and/or software described in this document are furnished under a license and may be used or copied only in accordance with the terms of such license.

U.S. Government Rights

The Software is “commercial computer software,” as defined by Federal Acquisition Regulation (“FAR”) 2.101. Pursuant to FAR 12.212 and 27.405-3 and Department of Defense FAR Supplement (“DFARS”) 227.7202, the U.S. government acquires commercial computer software under the same terms by which the software is customarily provided to the public. Accordingly, Keysight provides the Software to U.S. government customers under its standard commercial license, which is embodied in its End User License Agreement (EULA), a copy of which can be found at http://www.keysight.com/find/sweula. The license set forth in the EULA represents the exclusive authority by which the U.S. government may use, modify, distribute, or disclose the Software. The EULA and the license set forth therein, does not require or permit, among other things, that Keysight: (1) Furnish technical information related to commercial computer software or commercial computer software documentation that is not customarily provided to the public; or (2) Relinquish to, or otherwise provide, the government rights in excess of these rights customarily provided to the public to use, modify, reproduce, release, perform, display, or disclose commercial computer software or commercial computer software documentation. No additional government requirements beyond those set forth in the EULA shall apply, except to the extent that those terms, rights, or licenses are explicitly required from all providers of commercial computer software pursuant to the FAR and the DFARS and are set forth specifically in writing elsewhere in the EULA. Keysight shall be under no obligation to update, revise or otherwise modify the Software. With respect to any technical data as defined by FAR 2.101, pursuant to FAR 12.211 and 27.404.2 and DFARS 227.7102, the U.S. government acquires no greater than Limited Rights as defined in FAR 27.401 or DFAR 227.7103-5 (c), as applicable in any technical data.

Safety Notices

CAUTION

A **CAUTION** notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

WARNING

A **WARNING** notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

Where to Find the Latest Information

Documentation is updated periodically. For the latest information about this product, including instrument software upgrades, application information, and product information, browse to the following URL:

https://www.keysight.com/us/en/product/N5186A/N5186A.html

Information on preventing instrument damage can be found at:

http://keysight.com/find/PreventingInstrumentRepair

Is your product software up-to-date?

Periodically, Keysight releases software updates to fix known defects and incorporate product enhancements. To search for software updates for your product, go to the Keysight Technical Support website at:

http://www.keysight.com/find/techsupport

1 Basic Measurements

KEYSIGHT TECHNOLOGIES

Overview

Keysight's N5186A MXG is optimized to be your ideal signal generator with the outstanding performance you desire, all in one easy-to-use box capable of signal generation up to 8.5 GHz with 960 MHz of modulation bandwidth per channel.

The measurement examples use an X-Series Signal Analyzer to view the results. For information on using the Signal Analyzer multi-touch user interface, refer to the Online Help.

CAUTION

Please refer to the MXG data sheet and signal analyzer data sheet to ensure your measurement setup has adequate power.

https://www.keysight.com/us/en/product/N5186A/N5186A.html

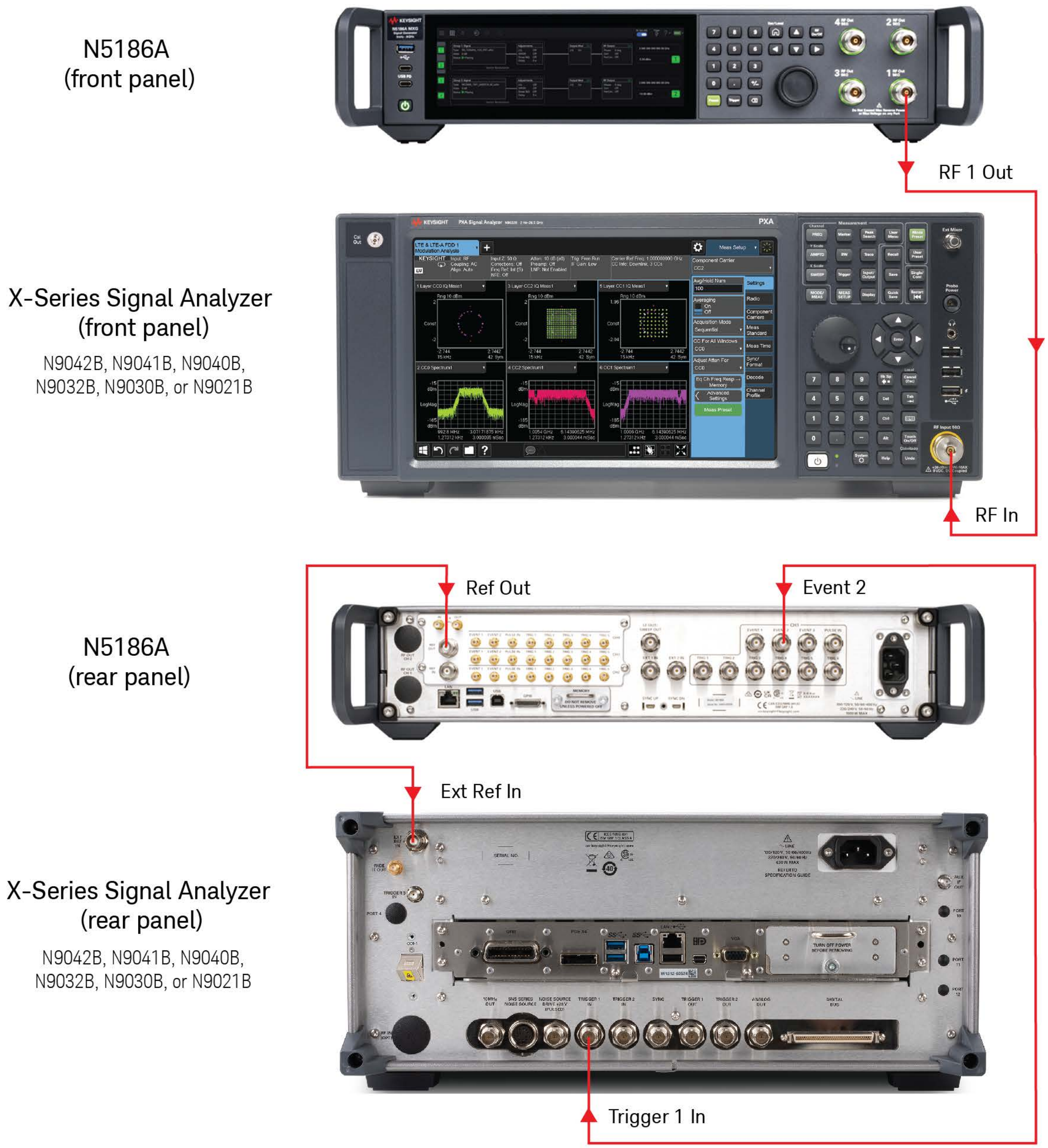
NOTE

The software versions used in this measurement guide are:

- MXG: A.13.01
- Signal Analyzer/N9063EM0E: Version 2021 A.31.xx or later
- 89601 VSA: Version 2019

Equipment Setup

- N5186A front panel RF 1 Out to N9032B front panel RF In
- N5186A rear panel Event 2 to N9032B rear panel Trig 1 In
- N5186A rear panel Ref Out to N9032B rear panel Ext Ref In



Setting Up Triggers on the Signal Analyzer

1. From the Signal Analyzer Menu Panel (on the top right of the display), select **Mode/Meas** > **Spectrum Analyzer** mode.

NOTE

If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

2. Select **Mode Preset** to set Spectrum Analyzer mode to a known state.
3. From the dropdown on the top right, select **Trigger** and set Trigger Source to **Free Run.**

Making Measurements

Creating a Continuous Waveform (CW)

This procedure will demonstrate the amplitude and frequency accuracy of the MXG.

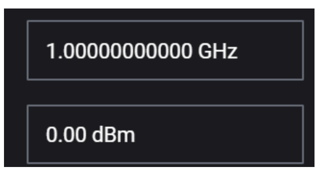
NOTE Ensure the equipment and triggers are properly configured. Refer to “Equipment Setup” on page 9 and “Setting Up Triggers on the Signal Analyzer” on page 10.

Using the graphical user interface

On the MXG:

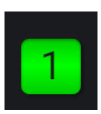
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. In the Output area, set Frequency to **1 GHz** and Power to **0 dBm**.

   These values are coupled to CW Frequency and Total Power (RMS) in the corresponding RF Output Block.



3. Set RF Out to **On** by selecting the numbered channel indicator switch.

   This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel MXG.



4. **For multi-channel instruments only:** In the top right corner of the display, set RF Out (All) to **On** by selecting the switch.

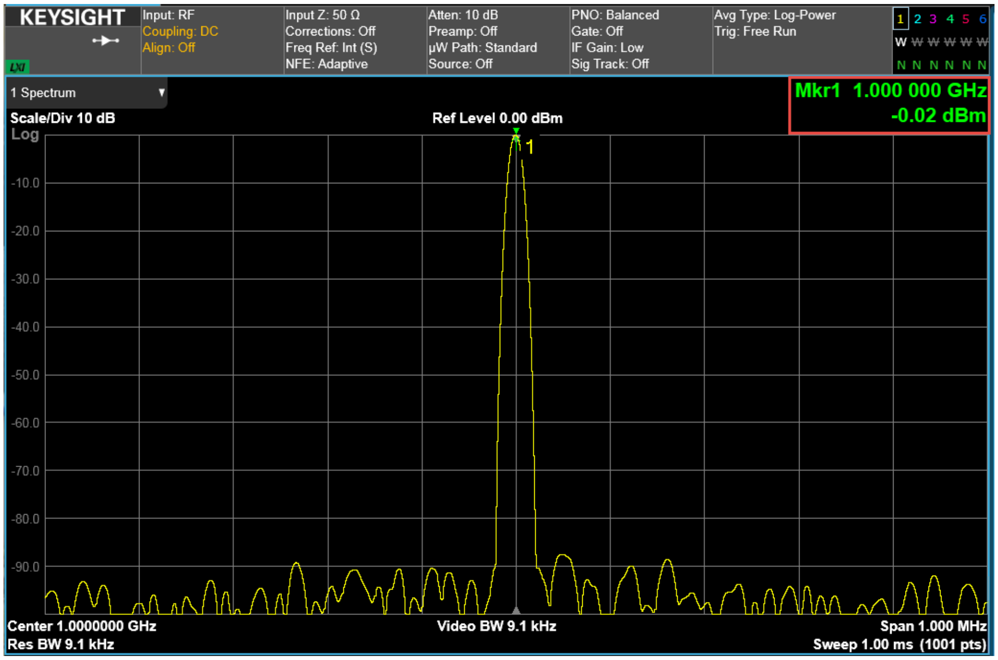
NOTE In order to turn on RF for any channel, both the RF Out for the specific channel (for example, Channel 1 or Channel 2), and RF Out All must be turned on.

On the Signal Analyzer:

1. Select **Mode Preset** to set Spectrum Analyzer mode to a known state.

2. From the Menu Panel, select **Frequency** and set Center Frequency to **1 GHz** and Span to **1 MHz**.
3. Select **Peak Search**.

   Observe the accuracy of the amplitude and frequency of the signal.



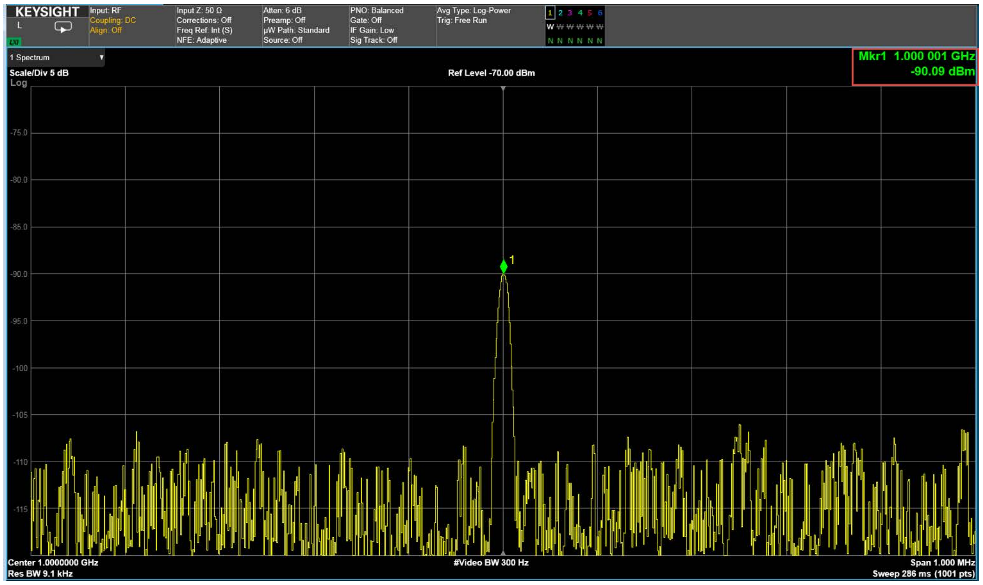
On the MXG:

1. Set Output 1 Power to **–90 dBm.**
2. Ensure that **RF Out** is On.

On the Signal Analyzer:

1. Select **Amplitude** and set Ref Level to **–70 dBm** and Scale/Div **5 dB**.
2. Select **BW** and set Video BW to **300 Hz**.
3. Select **Peak Search**.

Observe the frequency and amplitude accuracy of the MXG at low power levels.

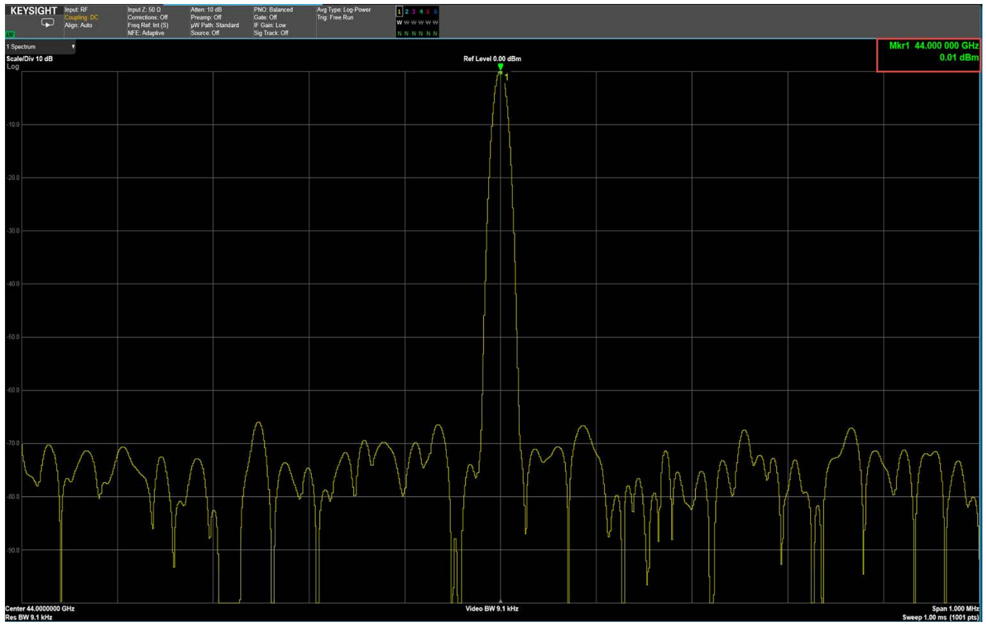


On the MXG:

1. Set Frequency to **8 GHz** and Power to **0 dBm**.

On the Signal Analyzer:

1. Select **Frequency** and set Center Frequency to **8 GHz**.
2. Select **Amplitude** and set Ref Level to **0 dBm** and Scale/Div to **10 dB**.
3. Select **BW** > **Video BW** and set to **Auto**.
4. Select **Peak Search**.



Observe the frequency and amplitude accuracy at higher frequency levels.

Using the equivalent SCPI commands

Creating a CW signal on Channel 1.

On the MXG:

```
SYSTem:PRESet
RF1:FREQuency:CW 1GHZ
RF1:POWer:AMPLitude 0dBm
RF1:OUTPut:STATe ON
```

For multi-channel instruments, set RF Out (all) to On.

```
RFALl:OUTPut ON
```

On the Signal Analyzer:

```
FREQuency:CENTer 1GHZ
FREQuency:SPAN 1MHZ
CALCulate:MARKer1:MAXimum
```

On the MXG:

```
RF1:FREQuency:CW 1GHZ
RF1:POWer:AMPLitude -90dBm
RF1:OUTPut:STATe ON
```

On the Signal Analyzer:

```
DISPlay:WINDow1:TRACe:Y:RLEVel -70
DISPlay:WINDow1:TRACe:Y:PDIVision 5
BWIDth:VIDeo 300Hz
CALCulate:MARKer1:MAXimum
```

On the MXG:

```
RF1:FREQuency:CW 8GHZ
RF1:POWer:AMPLitude 0dBm
```

On the Signal Analyzer:

```
FREQuency:CENTer 8GHZ
DISPlay:WINDow1:TRACe:Y:RLEVel 0
DISPlay:WINDow1:TRACe:Y:PDIVision 10
BANDwidth:VIDeo:AUTO ON
CALCulate:MARKer1:MAXimum
```

Setting Up Amplitude Modulation

NOTE The MXG must have the E7642APPC PathWave Signal Generation for IQ Based AM, FM, and Phase license installed.

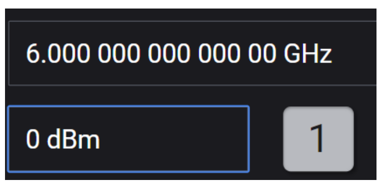
NOTE Ensure the equipment and triggers are properly configured. Refer to "Equipment Setup" on page 9 and "Setting Up Triggers on the Signal Analyzer" on page 10.

Follow the steps below for AM analog modulation using the internal I/Q modulation source.

Using the graphical user interface

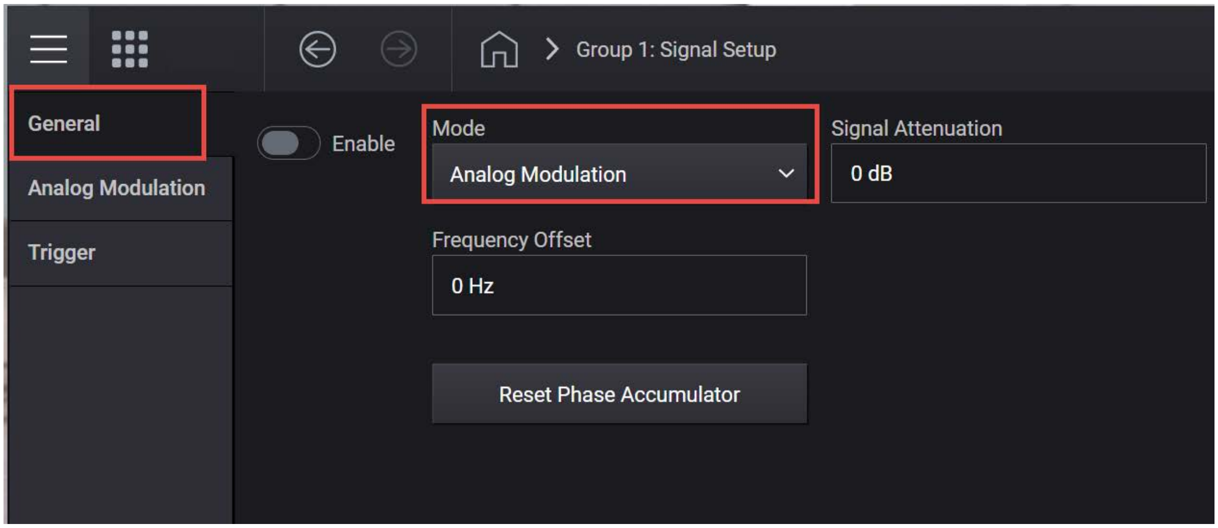
On the MXG:

1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Set Frequency to **6 GHz** and Amplitude to **0 dBm**.

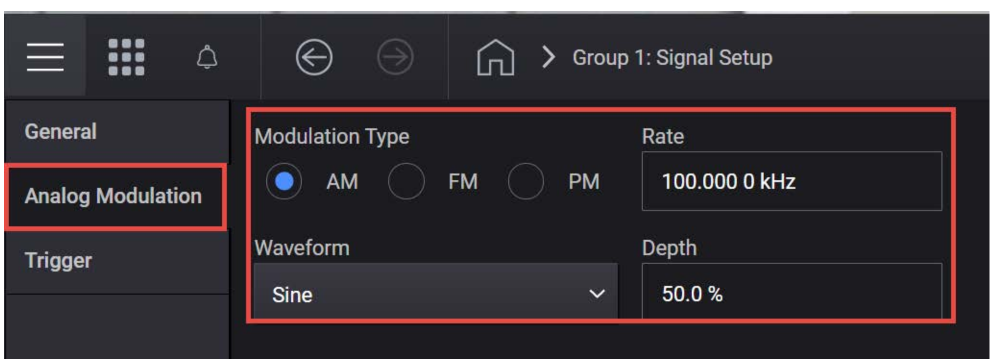


3. Select the **Signal** block.

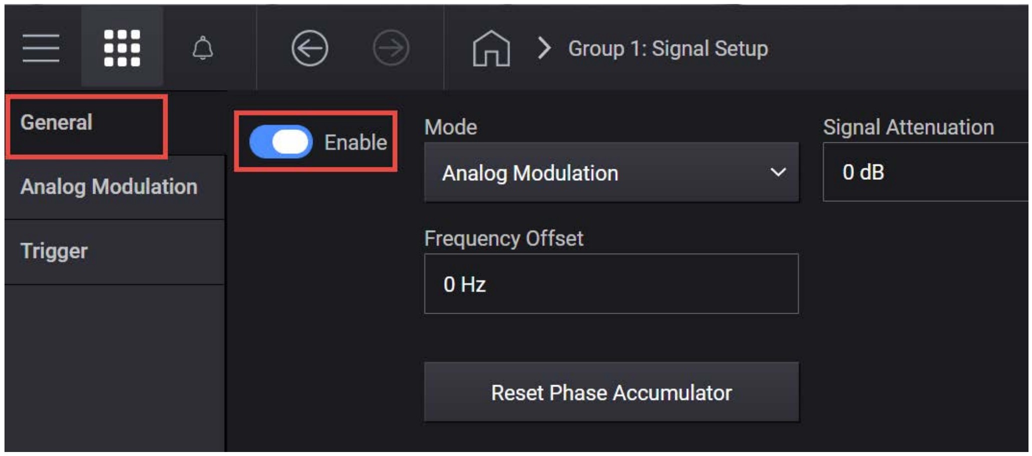
4. From the **Mode** dropdown, select **Analog Modulation.**



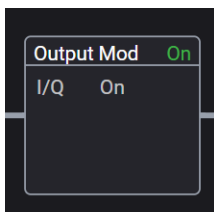
5. Select the **Analog Modulation** tab and set:
   a. Modulation Type to **AM**.
   b. Waveform to **Sine**.
   c. Rate to **100 kHz**.
   d. Depth to **50%**.



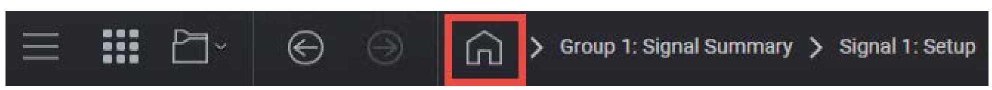
6. Select the **General** tab > **Enable.**



Selecting Enable automatically turns on both Output Modulation and Internal I/Q Modulation as displayed in the Output Modulation block.

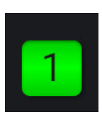


7. Close the Vector Modulation Signal Setup by selecting the **Home** icon at the top of the display.



8. Set RF Out to **On** by selecting the numbered channel indicator switch.

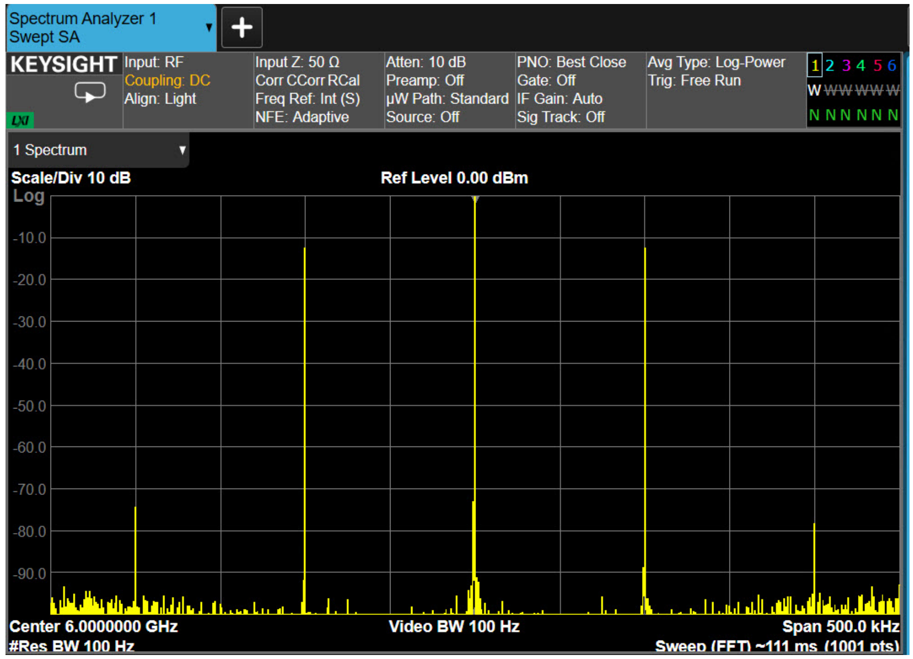
   This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel MXG.



On the Signal Analyzer:

1. Select **Mode Preset** to set Spectrum Analyzer mode to a known state.
2. Select **Frequency** and set Center Frequency to **6 GHz** and Span to **500 kHz**.

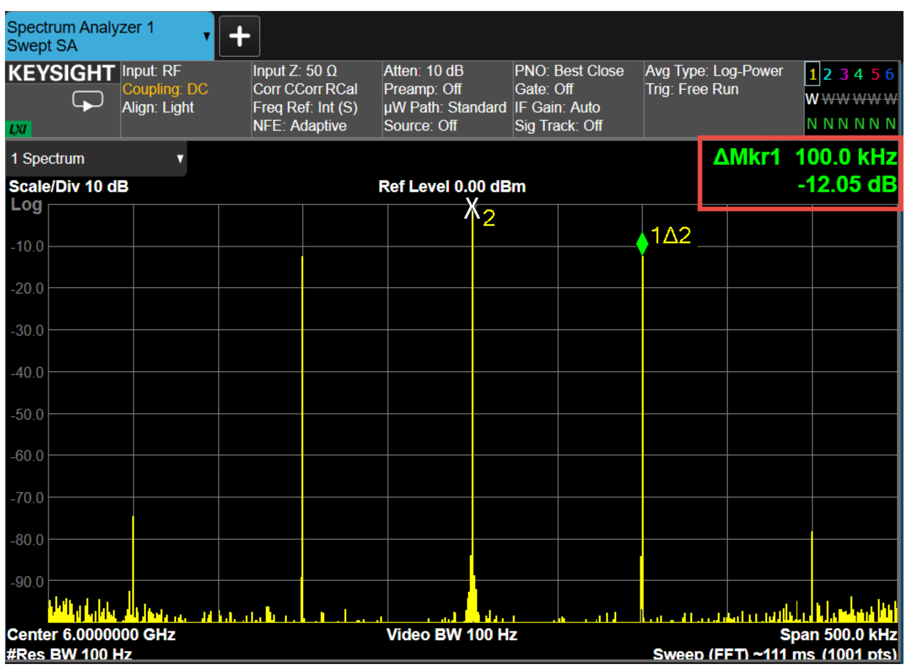
3. Select **BW** and set Res BW to **100 Hz**.



4. Select **Peak Search**.

5. Use markers to measure sideband power relative to the center frequency by selecting **Marker Delta**. Select **Next Pk Right** until the second marker is at the next highest peak.

   The Delta Marker should be approximately –12 dB for 50% AM.



Using the equivalent SCPI commands

On The MXG:

```
SYSTem:PRESet
RF1:FREQuency:CW 6GHZ
RF1:POWer:AMPLitude 0dBm
SIGNal:MODE AMODulation
SIGNal1:AMODulation:TYPE AM
SIGNal1:AM:SHAPe SINE
SIGNal1:AM:FREQuency 100KHZ
SIGNal1:AM 50
SIGNal1 ON
RF1:OUTPut:STATe ON
```

For multi-channel instruments, set RF Out (all) to On.

```
RFALl:OUTPut ON
```

On the Signal Analyzer:

```
FREQuency:CENTer 6GHZ
FREQuency:SPAN 500KHZ
BANDwidth 100 Hz
CALCulate:MARKer1:MODE DELTa
CALCulate:MARKer1:MAXimum:RIGHt
```

Repeat the above command until the marker is at the next highest peak.

To retrieve the delta marker:

```
CALCulate:MARKer1:Y?
```

Setting Up Frequency Modulation

NOTE The MXG must have the E7642APPC PathWave Signal Generation for IQ Based AM, FM, and Phase license installed.

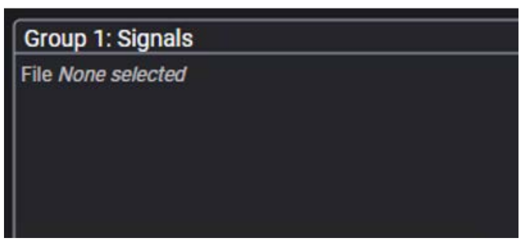
NOTE Ensure the equipment and triggers are properly configured. Refer to “Equipment Setup” on page 9 and “Setting Up Triggers on the Signal Analyzer” on page 10.

Follow the steps below for FM analog modulation using the internal I/Q modulation source.

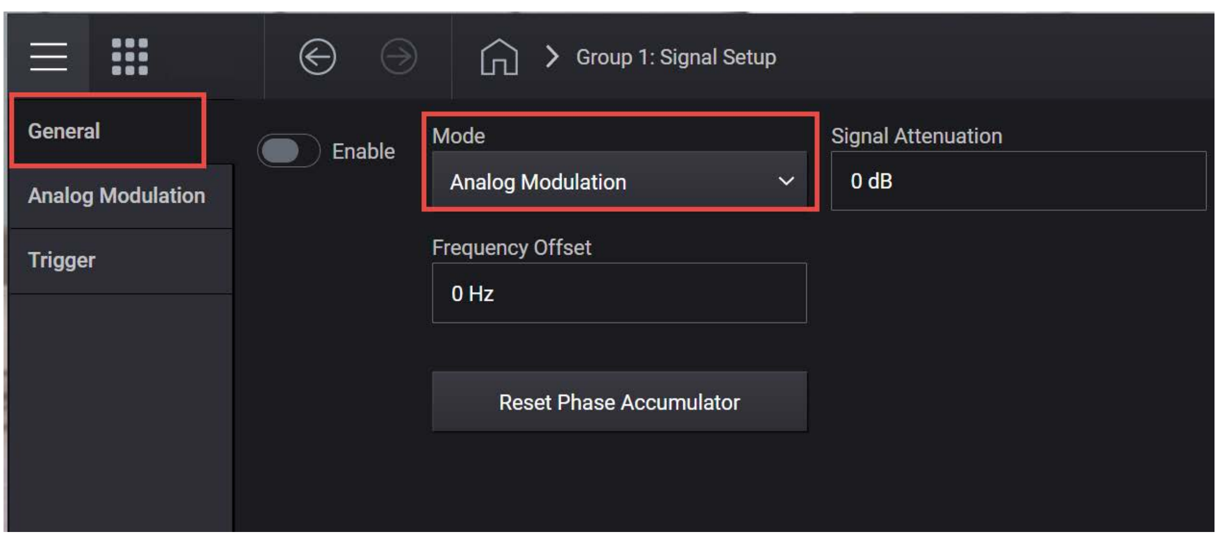
Using the graphical user interface

On the MXG:

1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Set Frequency to **6 GHz** and Amplitude to **0 dBm**.
3. Select the **Signal** block.



4. From the **Mode** dropdown, select **Analog Modulation**.

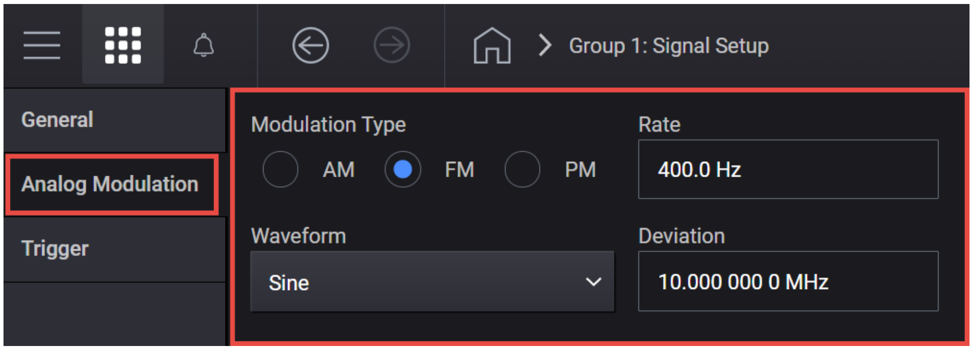


5. From the left pane, select the **Analog Modulation** tab and set:
   a. Modulation Type to **FM**.

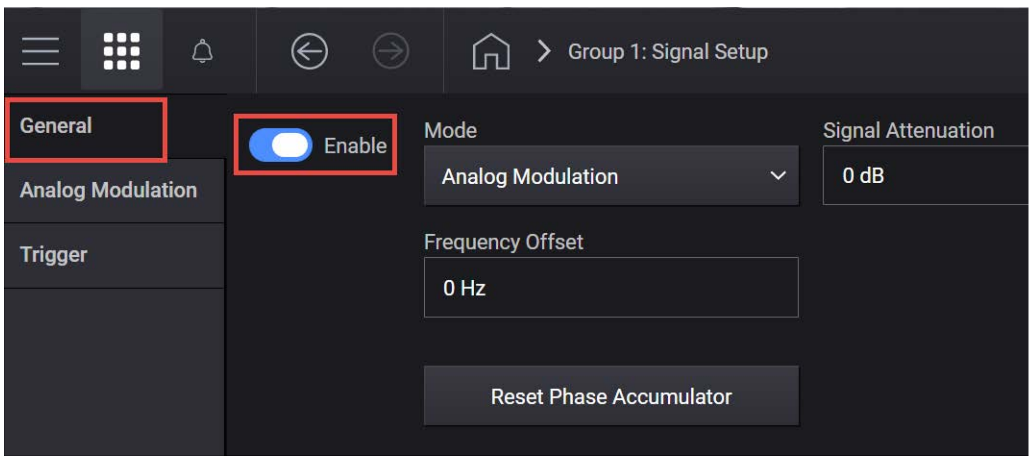
b. Waveform to **Sine**.

c. Rate to **400 Hz**.

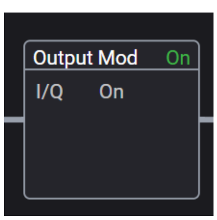
d. Deviation to **10 MHz**.



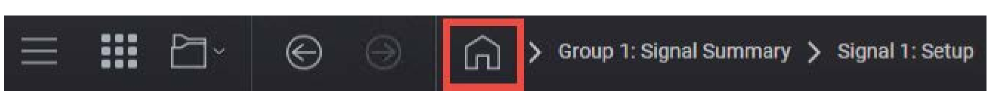
6. Select the **General** tab > **Enable**.



Selecting Enable automatically turns on both Output Modulation and Internal I/Q Modulation as displayed in the Output Modulation block.



7. Close the Vector Modulation Signal Setup by selecting the **Home** icon at the top of the display.

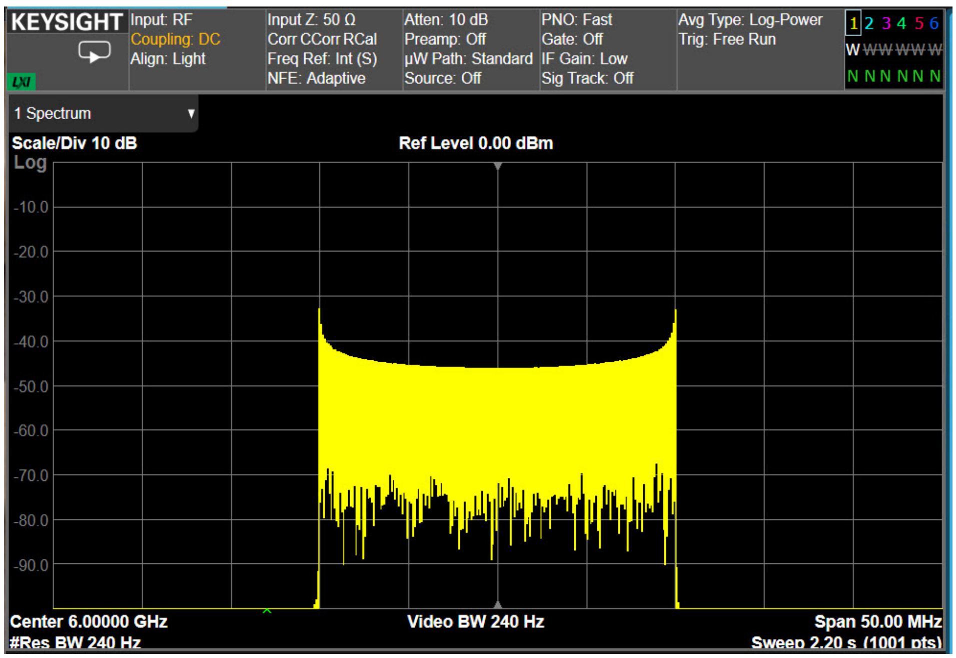


8. Set RF Out to **On** by selecting the numbered channel indicator switch.

This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel MXG.

On the Signal Analyzer:

1. Select **Mode Preset** to set Spectrum Analyzer mode to a known state.
2. Select **Frequency** and set Center Frequency to **6 GHz** and Span to **50 MHz**.
3. Select **BW** and set Res BW to **240 Hz**.



Using the equivalent SCPI commands

On the MXG:

```
SYSTem:PRESet

RF1:FREQuency:CW 6GHZ

RF1:POWer:AMPLitude 0dBm

SIGNal:MODE AMODulation

SIGNal1:AMODulation:TYPE FM

SIGNal1:FM:SHAPe SINE

SIGNal1:FM:FREQuency 400HZ

SIGNal1:FM 10MHZ
```

```
SIGNal1 ON
```

```
RF1:OUTPut:STATe ON
```

For multi-channel instruments, set RF Out (all) to On.

```
RFALl:OUTPut ON
```

On the Signal Analyzer:

```
FREQuency:CENTer 6GHZ
```

```
FREQuency:SPAN 50MHZ
```

```
ACPower:BANDwidth 240 Hz
```

Setting Up Phase Modulation

NOTE The MXG must have the E7642APPC PathWave Signal Generation for IQ Based AM, FM, and Phase license installed. The X-Series Analyzer must have N9063EM0E Analog Demodulation Measurement license installed.

NOTE Ensure the equipment and triggers are properly configured. Refer to "Equipment Setup" on page 9 and "Setting Up Triggers on the Signal Analyzer" on page 10.

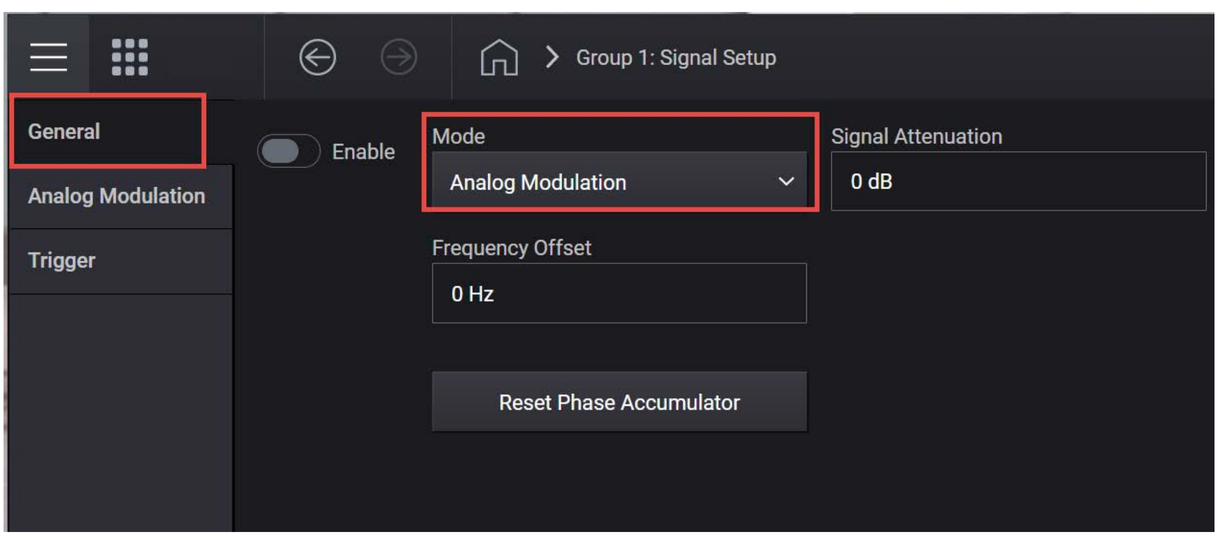
Follow the steps below for PM analog modulation using the internal I/Q modulation source.

Using the graphical user interface

On the MXG:

1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Set Frequency to **6 GHz** and Amplitude to **0 dBm**.
3. Select the **Signal** block to open.

4. Select the **Mode** dropdown and select **Analog Modulation**.



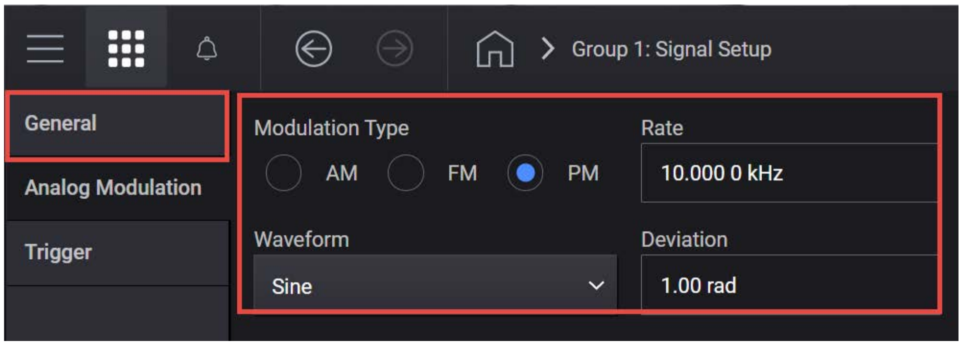
5. From the left pane, select the **Analog Modulation** tab and set:

    a. Modulation Type to **PM**.

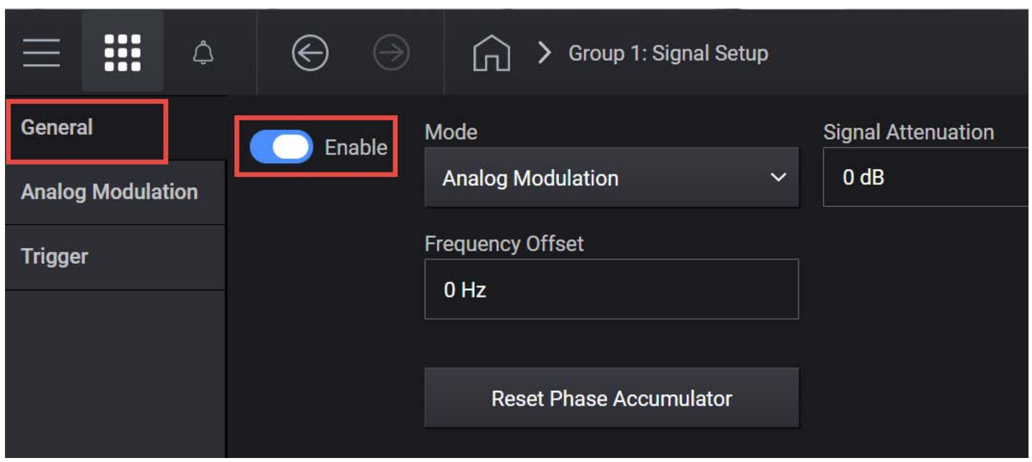
    b. Waveform to **Sine**.

    c. Rate to **10 kHz**.

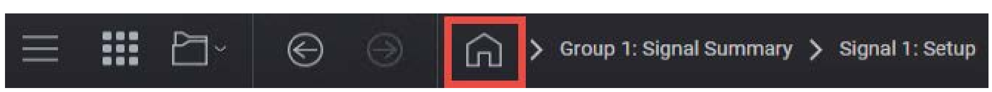
    d. Deviation to **1 rad**.



6. Select the **General** tab > **Enable**.

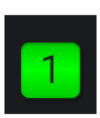


7. Close the Vector Modulation Signal Setup by selecting the Home icon at the top of the display.



8. Set RF Out to **On** by selecting the numbered channel indicator switch.

    This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel MXG.

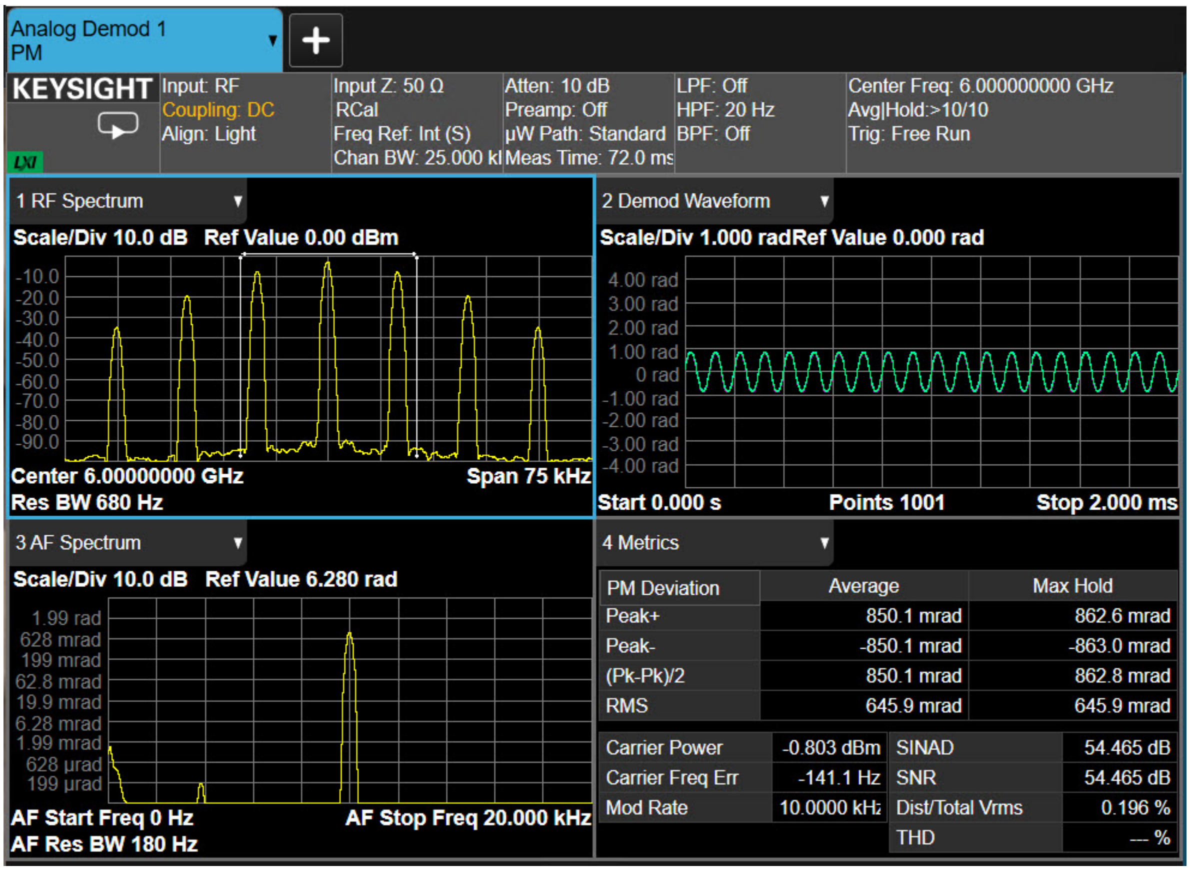


On the Signal Analyzer:

1. From the Menu Panel (on the top right of the display), select **Mode/Meas** > **Analog Demod** mode > **PM** Measurement > **Quad** View.

NOTE If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

2. Select **Mode Preset** to set Spectrum Analyzer mode to a known state.
3. Select **Frequency** and set Center Frequency to **6 GHz**.



Using the equivalent SCPI commands

On the MXG:

```
SYSTem:PRESet
RF1:FREQuency:CW 6GHZ
RF1:POWer:AMPLitude 0dBm
SIGNal:MODE AMODulation
SIGNal1:AMODulation:TYPE PM
SIGNal1:PM:SHAPe SINE
SIGNal1:PM:FREQuency 10KHZ
SIGNal1:PM 1
SIGNal1 ON
RF1:OUTPut:STATe ON
```

For multi-channel instruments, set RF Out (all) to On.

```
RFALl:OUTPut ON
```

On the Signal Analyzer:

```
INSTrument:CONFigure:ADEMOD:PM
SYSTem:PRESet
DISPlay:VIEW:ADVanced:SELect "QUAD"
FREQuency:CENTer 6GHZ
```

Setting Up a Multitone Signal

This example shows you how to create a multitone signal, which allows you to separate the usable frequency band into multiple channels. This can make a signal that is difficult to characterize in the time domain more readable.

NOTE The MXG must have the E7621APPC PathWave Signal Generation for Multitone license installed.

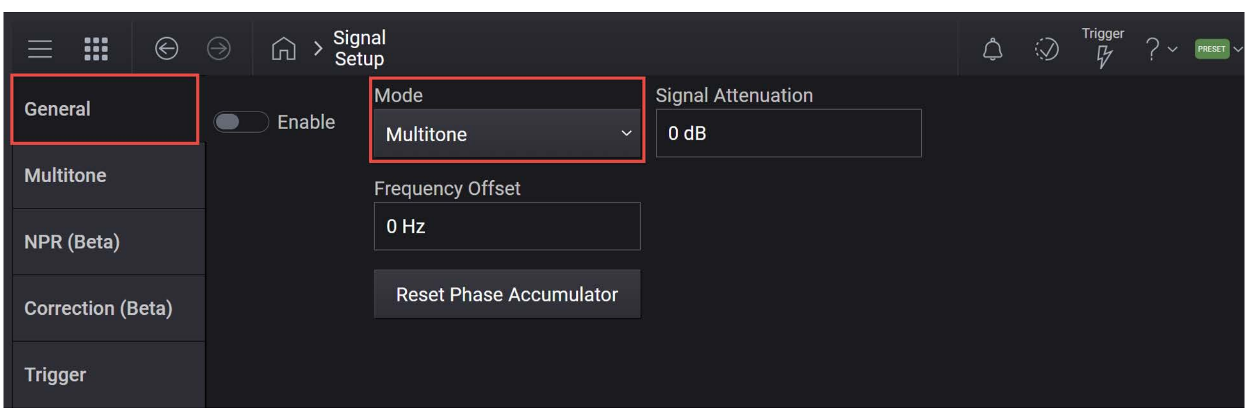
NOTE Ensure the equipment and triggers are properly configured. Refer to "Equipment Setup" on page 9 and "Setting Up Triggers on the Signal Analyzer" on page 10.

Using the graphical user interface

On the MXG:

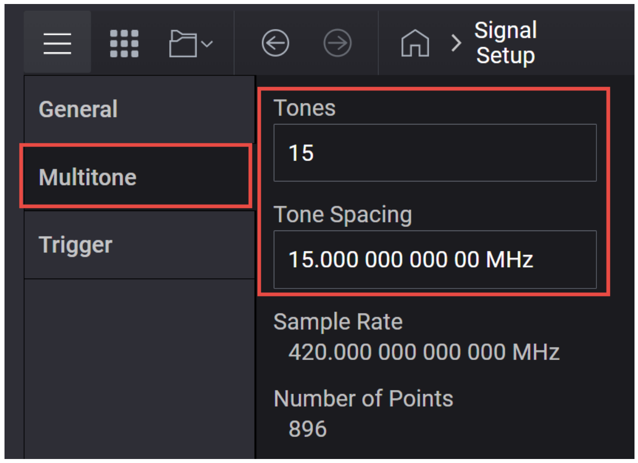
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Set Frequency to **6 GHz** and Amplitude to **-10 dBm**.
3. Select the **Signal** block to open.

4. Select the **Mode** dropdown and select **Multitone**.

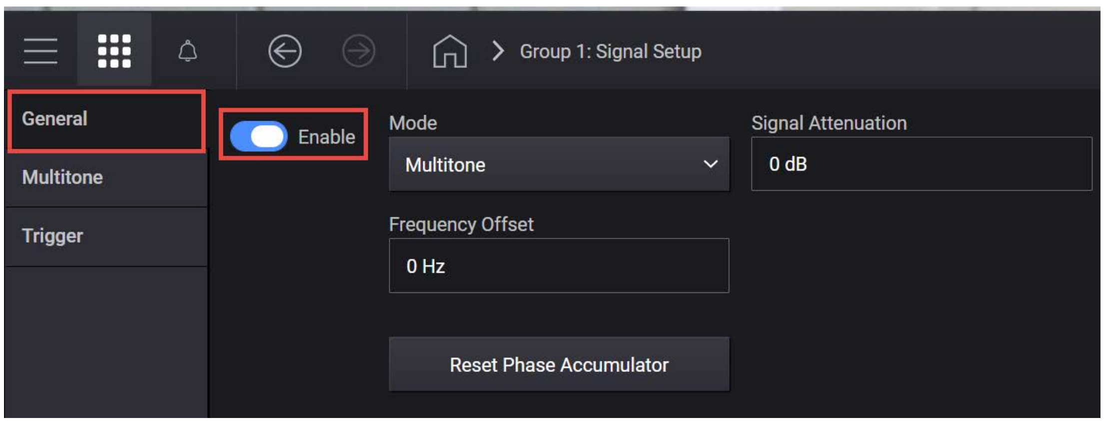


5. Select the **Multitone** tab and set:
   a. Set Tones to **15** >**x1**.

b. Set Tone Spacing to **15 MHz**.



6. Select the **General** tab > **Enable**.



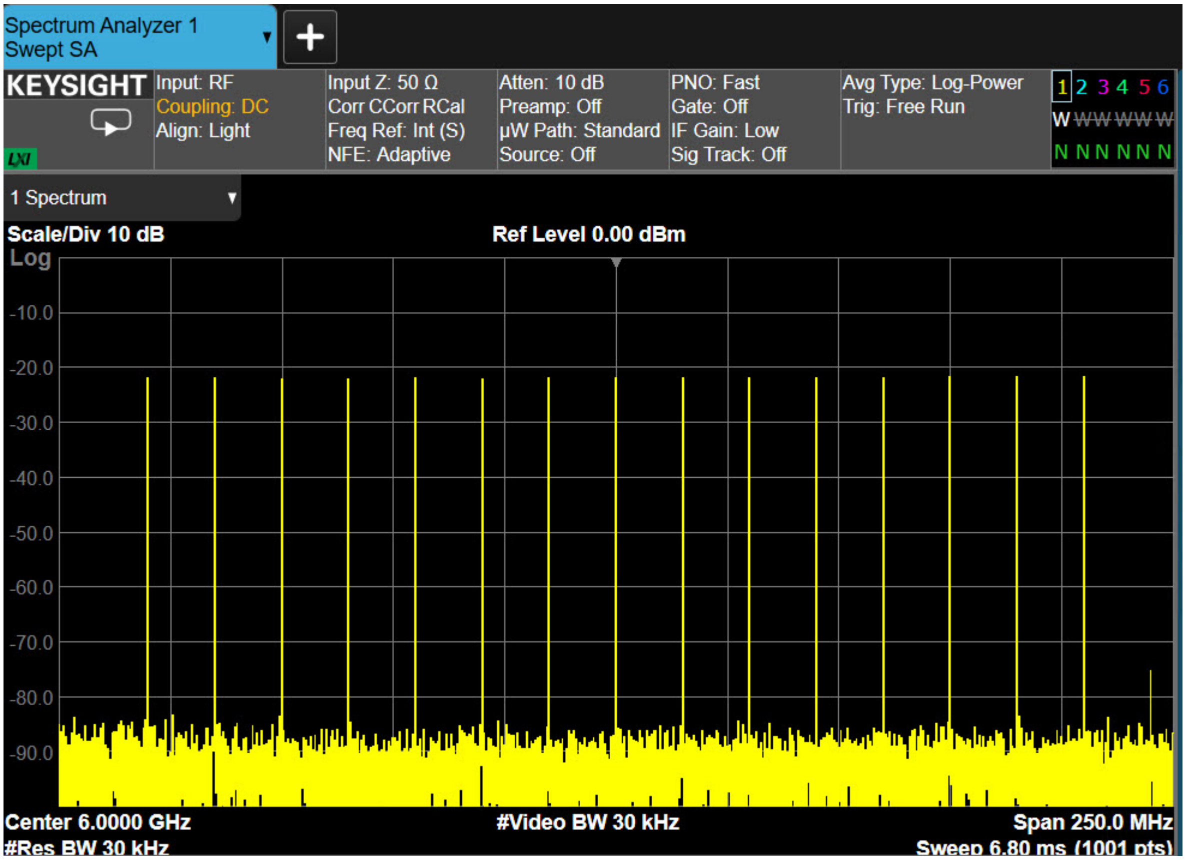
7. Close the Vector Modulation Signal Setup selecting the **Home** icon at the top of the display.

8. Ensure that **RF Out** is On.

On the Signal Analyzer:

1. Select **Mode Preset** to set **Spectrum Analyzer** mode to a known state.
2. Select **Frequency** and set Center Frequency to **6 GHz** and Span to **250 MHz**.
3. Select **BW** and set Res BW to **30 kHz**.

   Observe the 15 tones.


Spectrum Analyzer 1
Swept SA
KEYSIGHT
Input: RF
Coupling: DC
Align: Light
Input Z: 50 Ω
Corr CCorr RCal
Freq Ref: Int (S)
NFE: Adaptive
Atten: 10 dB
Preamp: Off
µW Path: Standard
Source: Off
PNO: Fast
Gate: Off
IF Gain: Low
Sig Track: Off
Avg Type: Log-Power
Trig: Free Run
1 2 3 4 5 6
W W W W W W
N N N N N N
1 Spectrum
Scale/Div 10 dB
Ref Level 0.00 dBm
Log
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
Center 6.0000 GHz
#Res BW 30 kHz
#Video BW 30 kHz
Span 250.0 MHz
Sweep 6.80 ms (1001 pts)

Using the equivalent SCPI commands

On the MXG:

```
SYSTem:PRESet
RF1:FREQuency:CW 6GHZ
RF1:POWer:AMPLitude -10dBm
SIGNal1:MODE MTONes
SIGNal1:MTONe:ARB:NTON 15
SIGNal1:MTONe:ARB:FSP 15MHZ
SIGNal1 ON
RF1:OUTPut:STATe ON
```

For multi-channel instruments, set RF Out (all) to On.

```
RFALl:OUTPut ON
```

On the Signal Analyzer:

Change to Spectrum Analyzer mode, Swept SA measurement.

```
INSTrument:CONFigure:SA:SAN
DISPlay:VIEW:ADVanced:SELect "NORMAL"
FREQuency:CENTer 6GHZ
FREQuency:SPAN 250MHZ
BANDwidth:RESolution 30KHZ
```

Setting Up Waveform File Vector Modulation

In this section, we will load a GSM and a WCDMA waveform into the MXG to demonstrate the accuracy of the MXG's vector modulation.

The MXG supports all ARB waveforms that are provided on the X-Series sources. This section will use a few of the ARB files that come with the X-Series sources.

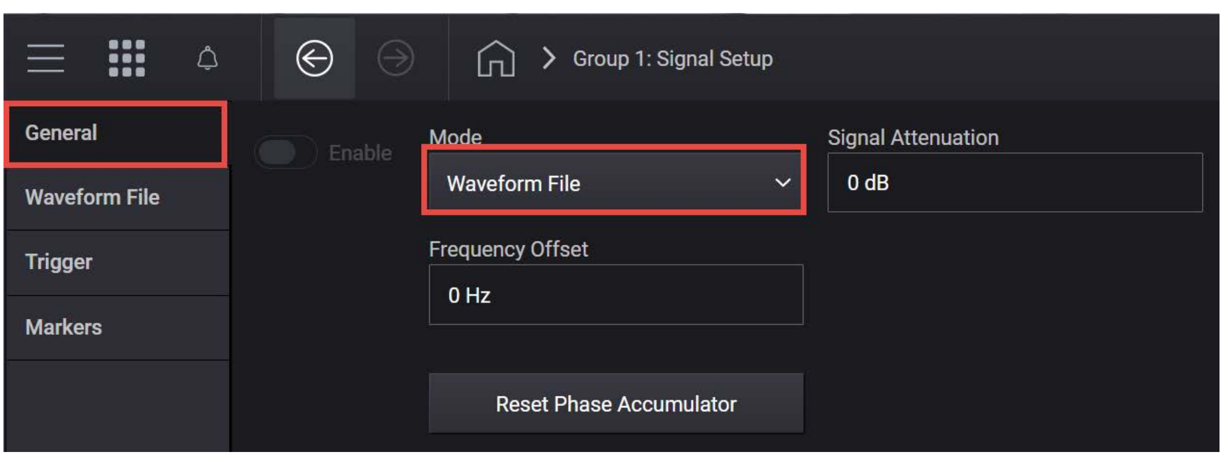
NOTE Ensure the equipment and triggers are properly configured. Refer to "Equipment Setup" on page 9 and "Setting Up Triggers on the Signal Analyzer" on page 10.

Using the graphical user interface

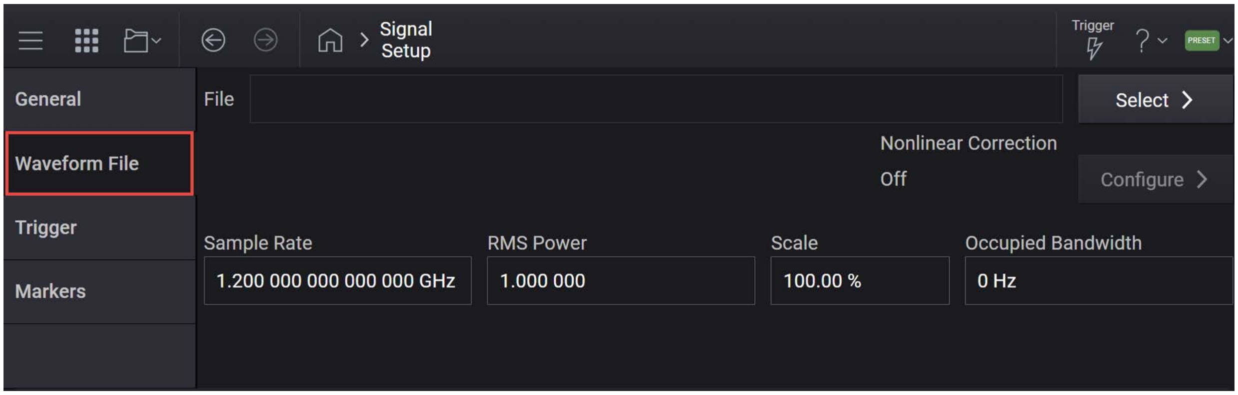
On the MXG:

1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Set Frequency to **6 GHz** and Amplitude to **0 dBm**.
3. Select the **Signal** block to open.

4. In the Vector Modulation Signal Setup:
   a. Set Mode to **Waveform File**.

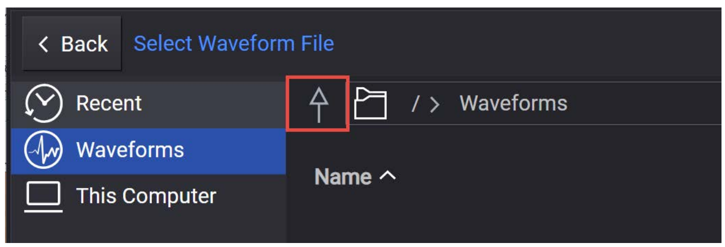


b. In the left panel, select the **Waveform File** tab.

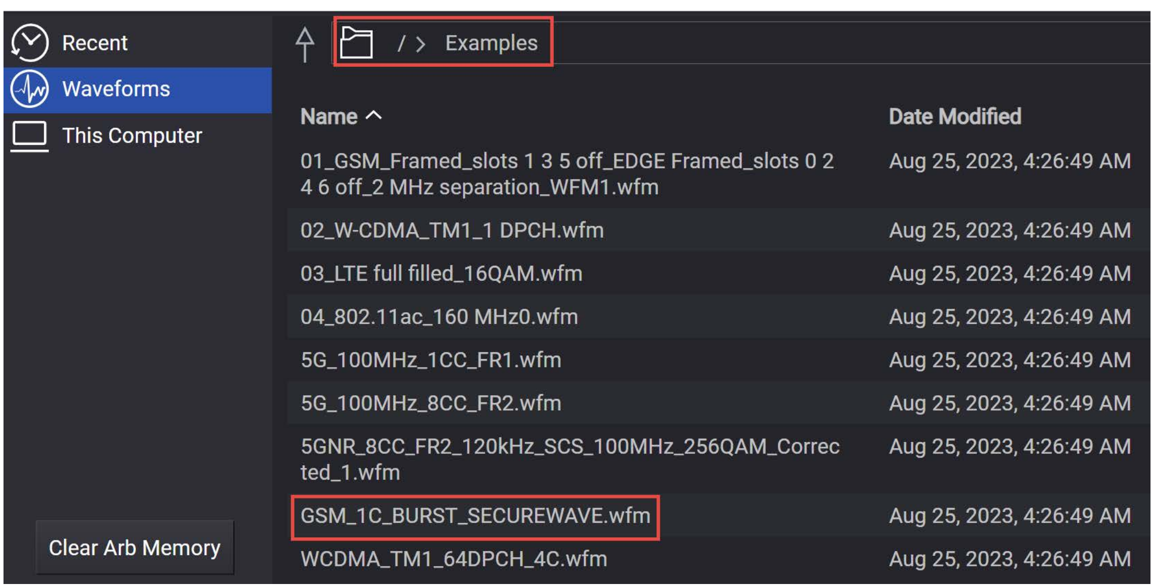


c. Use File **Select** to navigate to the **Waveforms** folder.

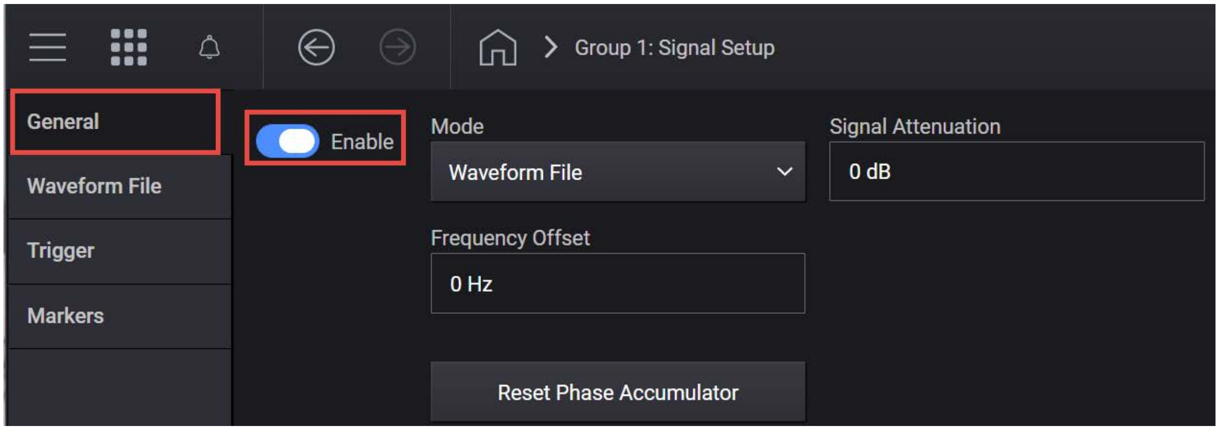
d. Select the **Up arrow** icon to access the Examples folder.



e. Open the Examples folder and highlight `GSM_1C_BURST_SECUREWAVE.wfm`, then **Select**.



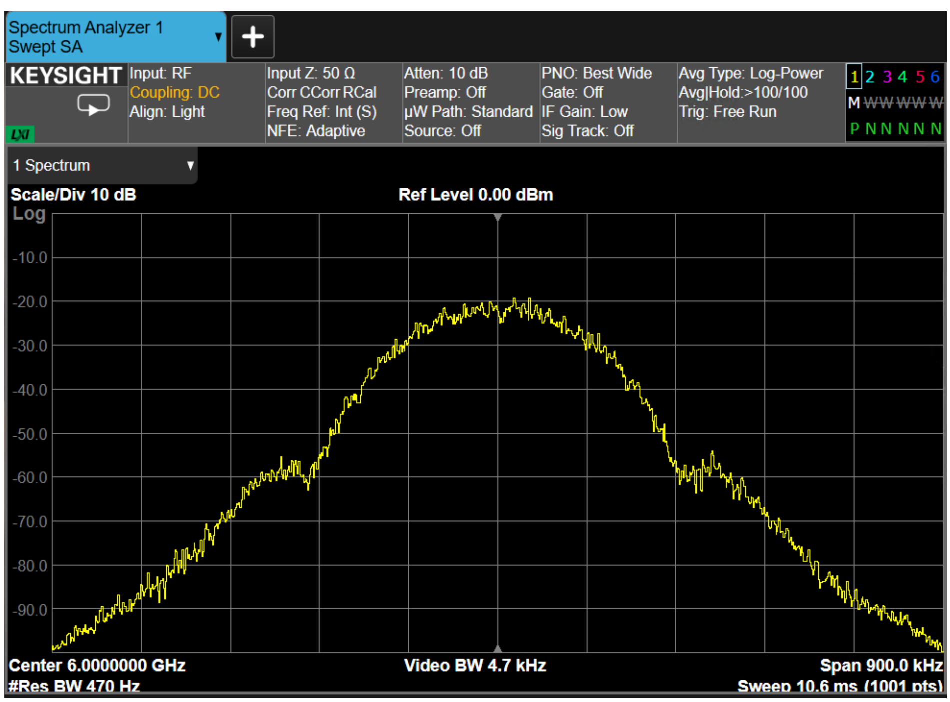
f. Select the **General** tab > **Enable.**



5. Select the **Home** icon and ensure that **RF Out** is on.

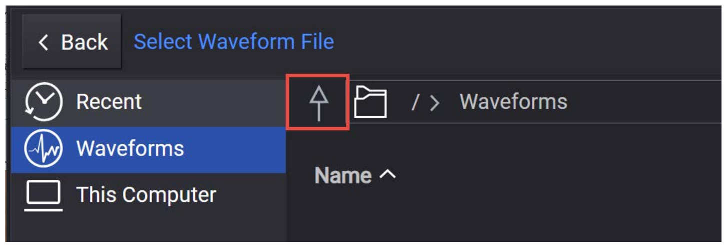
On the Signal Analyzer:

1. Select **Mode Preset** to set Spectrum Analyzer mode to a known state.
2. Select **Frequency** and set Center Frequency to **6 GHz** and Span to **900 kHz**.
3. Select **BW** and set Res BW to **470 Hz**.
4. Select **Trace** and set Trace Type to **Max Hold**.
5. Observe the GSM signal.

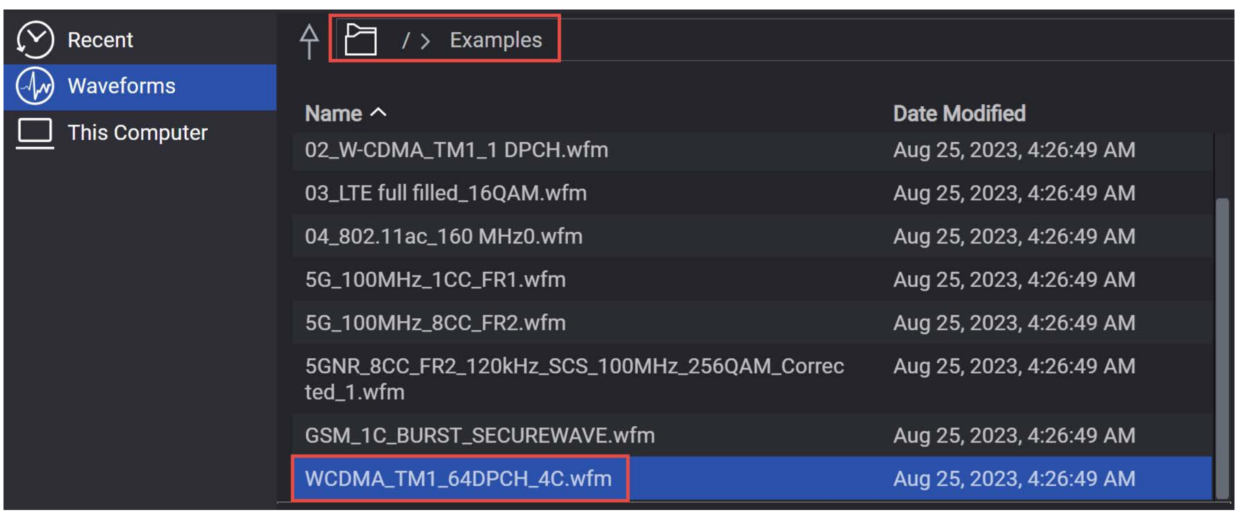


On the MXG:

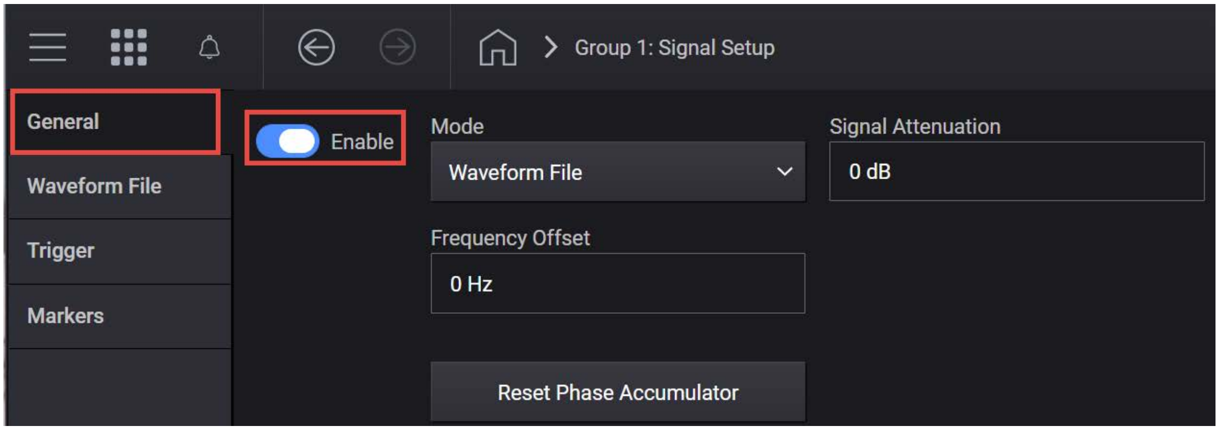
1. Select the **Signal** block to open the Vector Modulation Signal Setup.
2. From the **Waveform** tab on the left side of the display, choose File **Select** to navigate to the **Waveforms** folder.
3. Select the **Up arrow** icon to access the Examples folder.



4. Open the Examples folder and highlight `WCDMA_TM1_64DPCH_4C.wfm`, then **Select**.



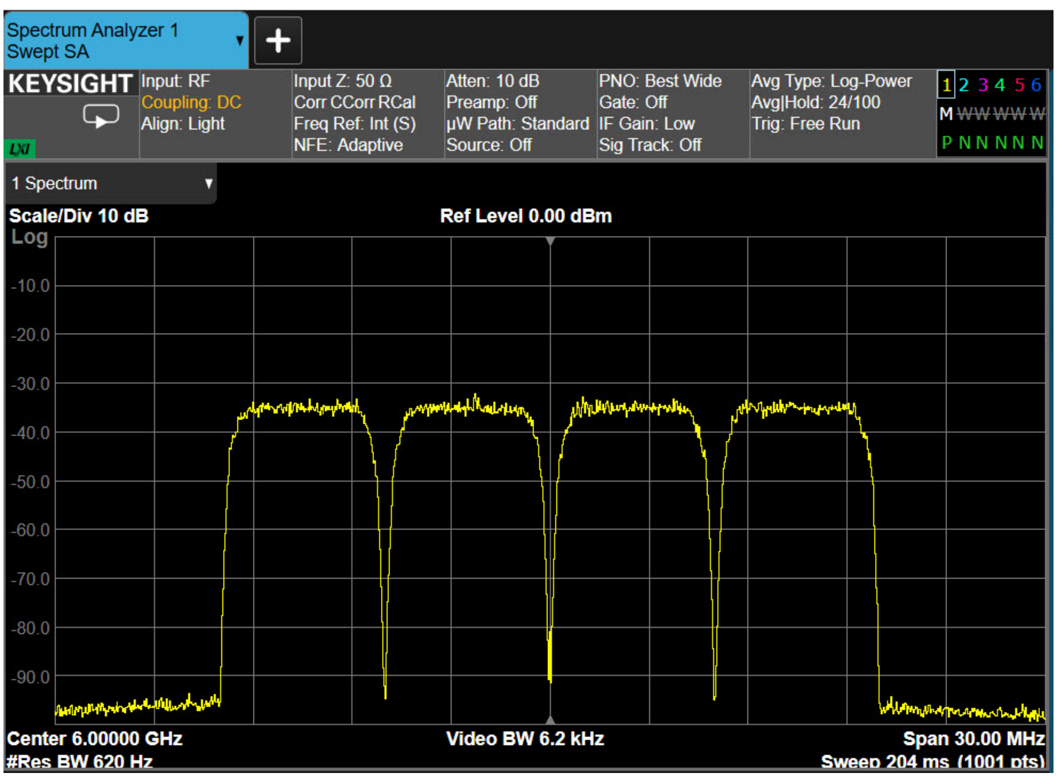
5. Select the **General** tab > **Enable.**



6. Select the **Home** icon and ensure that **RF Out** is on.

On the Signal Analyzer:

1. Select **BW** and set Res BW to **620 Hz**.
2. Select **Frequency** and set Center Frequency to **6 GHz** and Span to **30 MHz**.
3. Observe the WCDMA signal.



Using the equivalent SCPI commands

On the MXG:

```
SYSTem:PRESet
RF1:FREQuency:CW 6GHZ
RF1:POWer:AMPLitude 0dBm
SIGNal1:MODE WAVeform
SIGN1:WAV "/Examples/GSM_1C_Burst.wfm"
SIGNal1 ON
RF1:OUTPut:STATe ON
```

For multi-channel instruments, set RF Out (all) to On.

```
RFALl:OUTPut ON
```

On the Signal Analyzer:

```
FREQuency:CENTer 6GHZ
FREQuency:SPAN 900KHZ
ACPower:BANDwidth 470 Hz
DISPlay:TXPower:WINDow1:TRACe:MAXHold ON
```

On the MXG:

```
SIGN1:WAV "/Examples/WCDMA_TM1_64DPCH_4C.wfm"
SIGNal1 ON
RF1:OUTPut:STATe ON
```

On the Signal Analyzer:

```
ACPower:BANDwidth 620 Hz
FREQuency:SPAN 30MHZ
```

Using the N5186A as a Multifunction Generator

Introduction

A function generator is a type of signal generator that is used to generate various waveforms with adjustable parameters to generate complex signals. Keysight's Multifunction Generator option 303 and UNT, first seen on the N5171B, includes a slew of function generators which can output complex signals. These signals can either be output directly to the LF port or routed to the modulators, ultimately output through the RF port. When using the function generators for modulation, the adjustable parameters include modulation type, frequency, amplitude, and phase. Often used in the fields of prototyping, development, testing, and calibration especially in the context of communication systems. An accurate function generator can help engineers accelerate the research and design process to bring high performance designs to the market quicker.

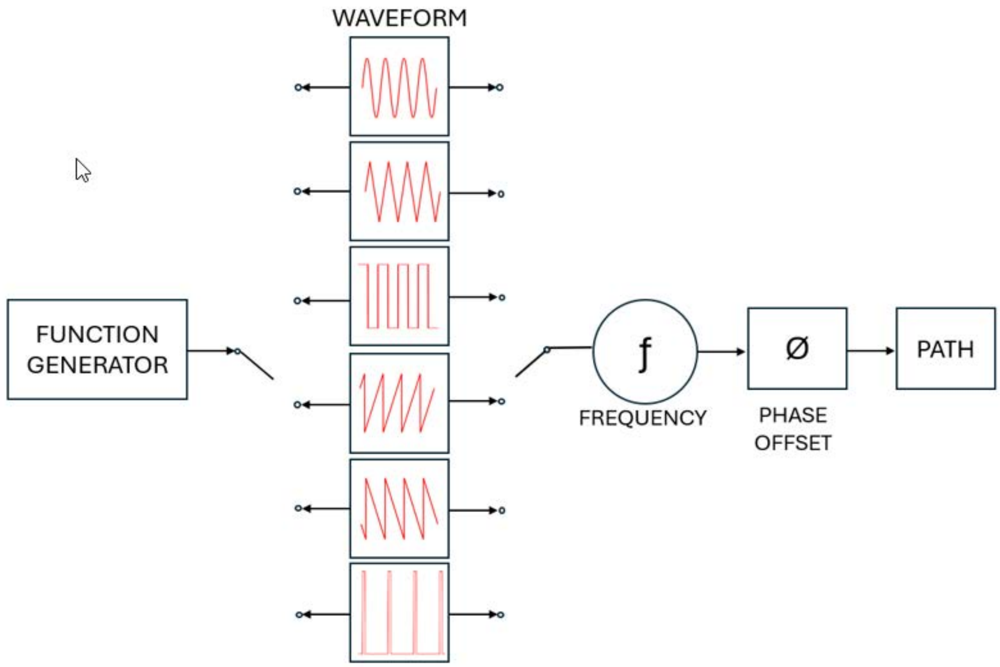
Supported Signal Generators with Option 303 and UNT

- N5171B
- N5172B
- N5173B
- N5181B
- N5182B
- N5183B
- N5185A
- N5186A
- M9484C

Theory of Operation

Multifunction generator N5186A Option 303 is a collection of six function generators that can be used independently or in parallel (up to five), ultimately being applied to the RF signal of choice or routed to the Low Frequency (LF) Output port. The LF Output port is designed to output low-frequency signals, making it ideal for directly using the function generators as well as measuring them. Ignoring the external function generator inputs (Ext 1 and Ext 2), there are six selectable function generators: Function Generator 1 (Func Gen 1), Function Generator 2 (Func Gen 2), Dual Function Generator (Dual Func Gen), Swept Function Generator (Swept Func Gen), Noise Generator 1 (Noise Gen 1), and Noise Generator 2 (Noise Gen 2).

Figure 1-1 **Multifunction Generator Block Diagram**

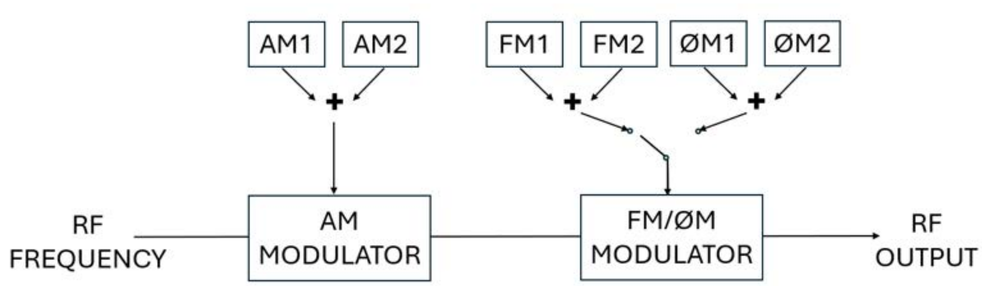


In Figure 1-1, each function generator (except Noise Gen 1 and Noise Gen 2) can access six periodic waveforms (sine, triangle, square, positive ramp, negative ramp, and pulse), with controllable frequency and phase offset.

The six periodic waveforms are considered the "Basic Waveforms". The Basic Waveforms can be made more complex by combining them using the Dual Function, demonstrated in "Dual Function" on page 49. The Basic Waveforms can also be swept using the Swept Function, demonstrated in "Swept Function" on page 55.

The output of the function generators can be routed to the Amplitude Modulator and the Frequency/Phase modulator. A function generator can be assigned to each of the paths (AM1, AM2, FM1, FM2, ØM1, ØM2) which are summed and applied to the AM and FM/ØM modulators. The modulators are then applied to the RF output signal.

Figure 1-2 **Function Generator Paths**



Using Multifunction Generator Option 303

Functions can be combined by summation and applied to modulations on the RF output. Modulation formats include AM, FM, and ØM. The LF port can be used to monitor the behavior of a single function generator that is being used by a modulator.

The multifunction generator's flexibility enables a wide range of configurations, catering to numerous testing applications. This adaptability ensures efficient and effective simulation of real-world scenarios for testing RF and LF designs. Ultimately, the multifunction generator enhances testing capabilities, allowing quicker problem solving.

Figure 1-3 Modulation Types

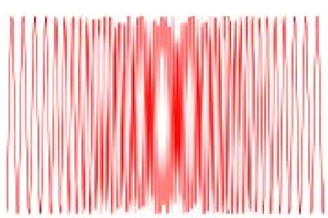
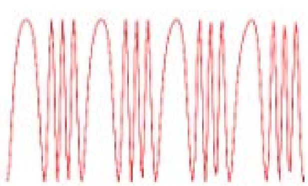
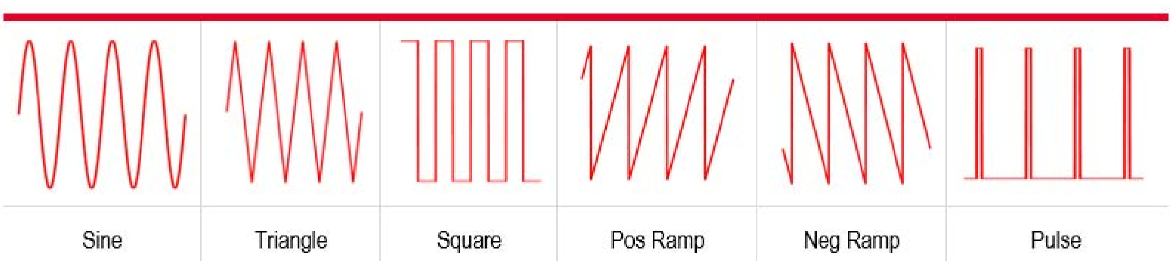
Modulation	Parameters	Description
AM: 	• AM Type • AM Path • AM Depth • AM Source • AM Waveform • AM Rate • AM Phase Offset	The AM modulator allows the user to select a carrier frequency, message frequency, message shape, depth of modulation, modulation rate, and phase offset. Giving the user full freedom to generate the desired amplitude modulated signal.
FM: 	• FM Path • FM Dev • FM Source • FM Waveform • FM Rate • FM Phase Offset	The FM modulator allows the user to select a carrier frequency, deviation from carrier frequency, the modulation rate, the modulation waveform, and phase offset. Giving the user full freedom to generate their desired frequency modulated signal.
ØM: 	• ØM Path • ØM Dev • ØM Source • ØM Waveform • ØM Rate • ØM Phase Offset	The ØM modulator allows the user to select a carrier frequency, phase deviation, modulation rate, modulation waveform, and phase offset. Giving the user full freedom to generate their desired phase modulated signal.

Figure 1-4 LF Output

Function	Parameters	Description
DC:	• DC Offset	The DC function allows the user to choose a DC offset voltage between -1 V to 5 V in 1 mV increments for MXG and -5 V to 5 V for VXG
Monitor:	• Source	This Monitor function allows the user to monitor the behavior of a single function generator. This is for validating the behavior of the function generator when it is being used for modulation.
Function 1 & 2:	• Frequency • Phase Offset • Shape	These functions can take on any of the basic waveforms with a selectable frequency and phase offset.
Dual Function:	• Amp Percent 1 • Amp Percent 2 • Frequency 1 • Frequency 2 • Shape 1 • Shape 2 • Phase Offset 2	The Dual Function generator is useful for applications where two function generators with a known phase offset are needed.
Noise 1 & 2:	• Type	The noise source functions allow the user to select either Uniform or Gaussian Noise.
Swept Function:	• Sweep Waveform Shape • Sweep Start to Stop Time • Start Frequency • Stop Frequency • Sweep Shape	The Sweep function allows the user to configure a sawtooth or triangle sweeping signal, with selectable start and stop frequencies and sweep time.

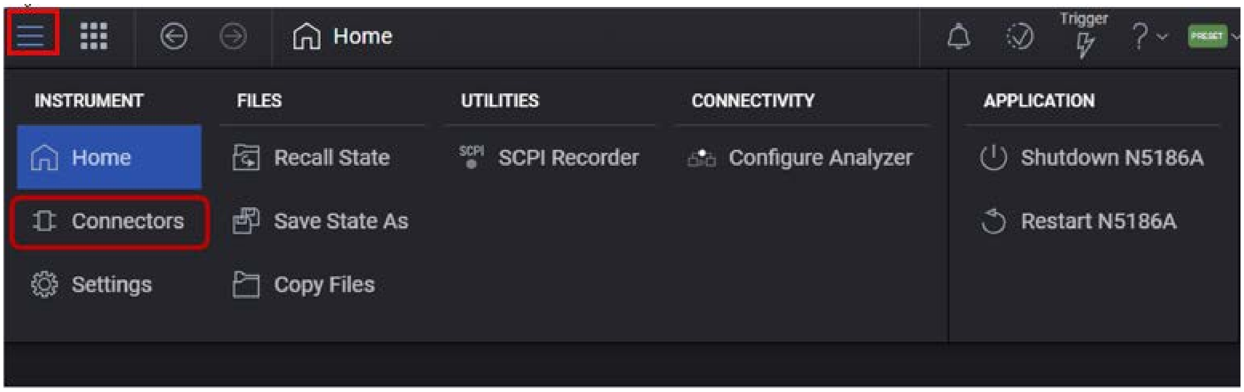
Figure 1-5 Basic Waveforms



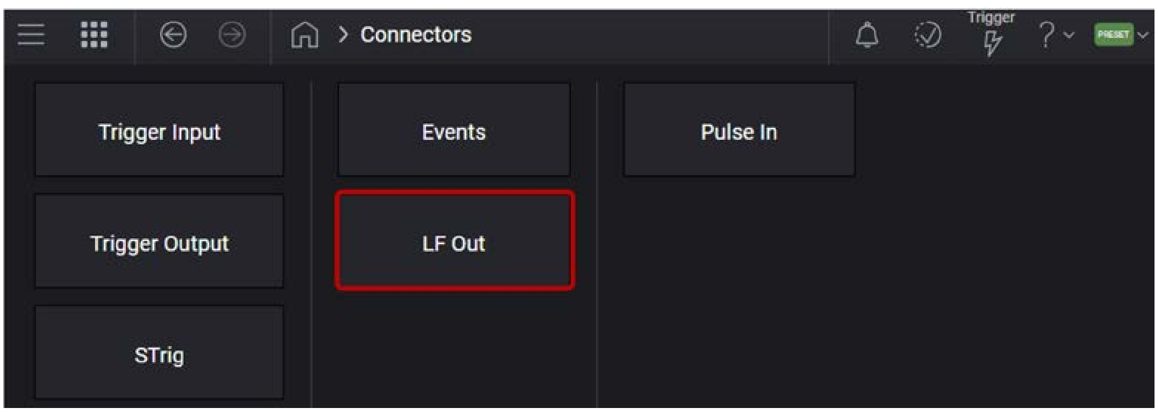
Multifunction Generator Demonstrations

An easy way to visualize the behavior of the internal function generators in the time domain is to use the LF Out port. By routing the function generator of choice to the LF Out, an Oscilloscope can capture its behavior.

1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Select the **System** menu > **Connectors**.

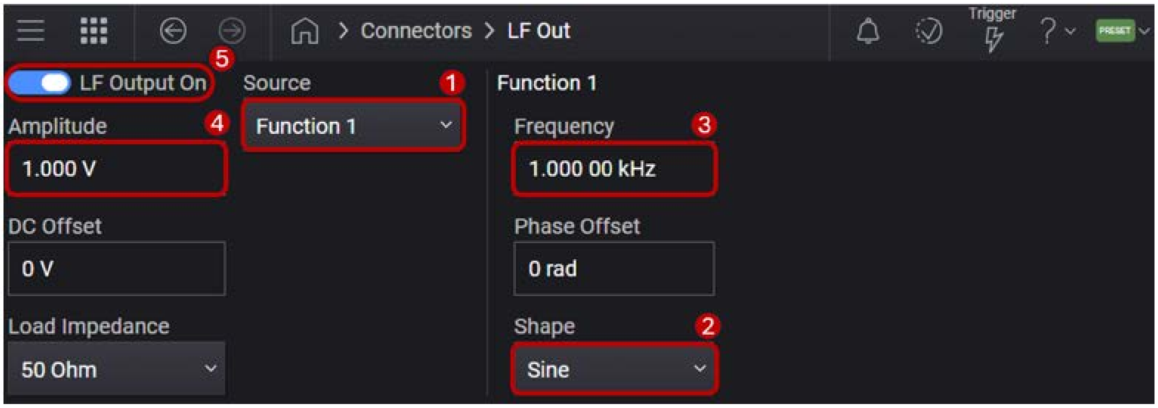


3. In the Connectors window, select **LF Out**.

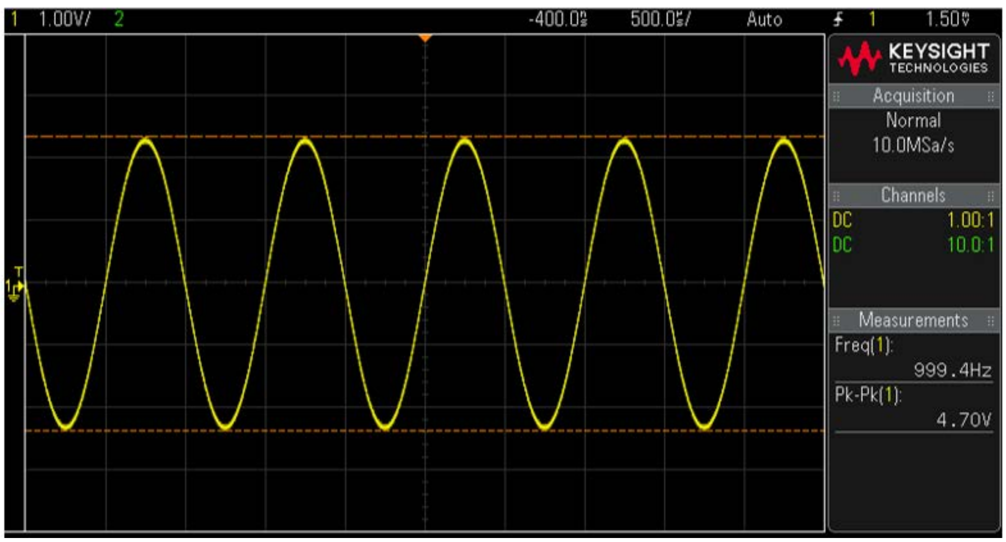


4. In the LF Out window, set:
   - Source to **Function 1**
   - Shape to **Sine**
   - Frequency to **1 kHz**
   - Amplitude to **1 V**

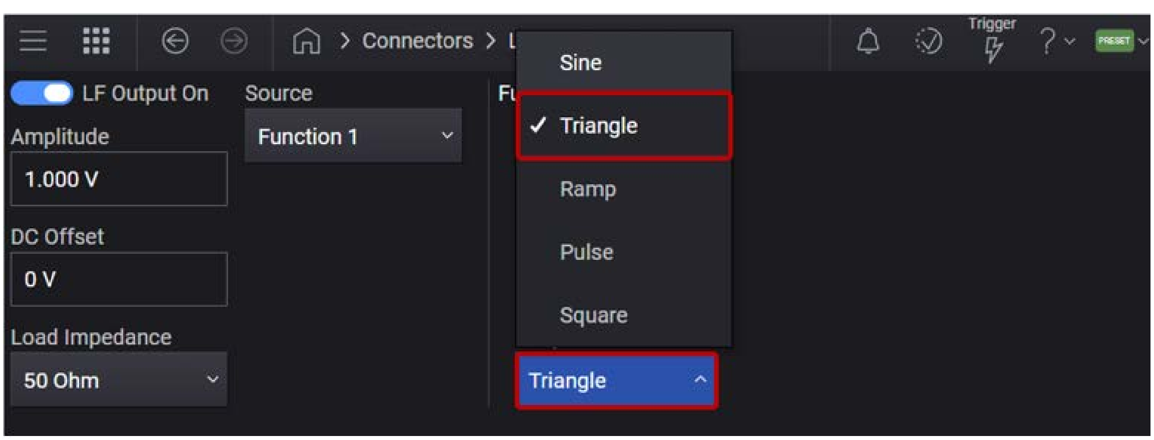
– LF Output **On**



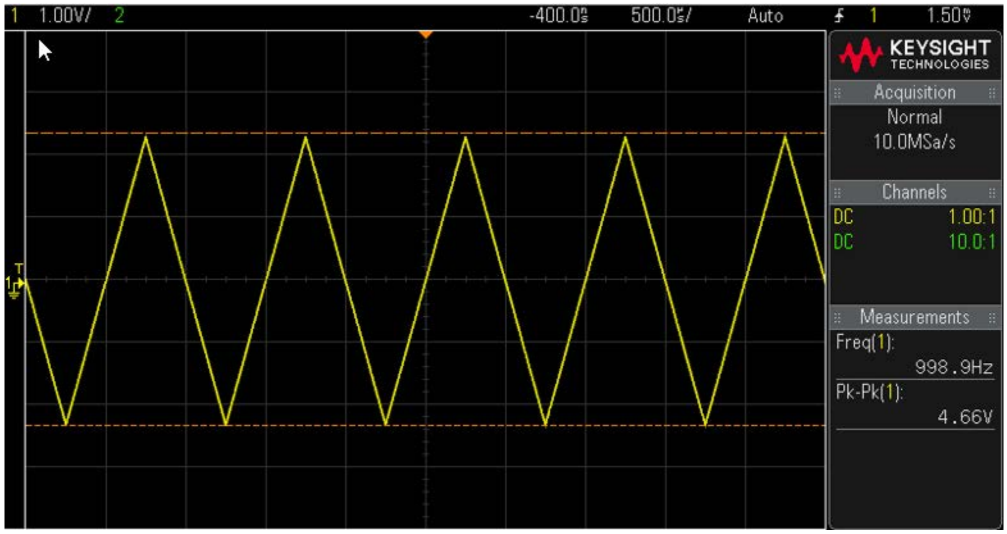
5. Capture the signal on the oscilloscope.



6. On the MXG, change the shape to **Triangle**.

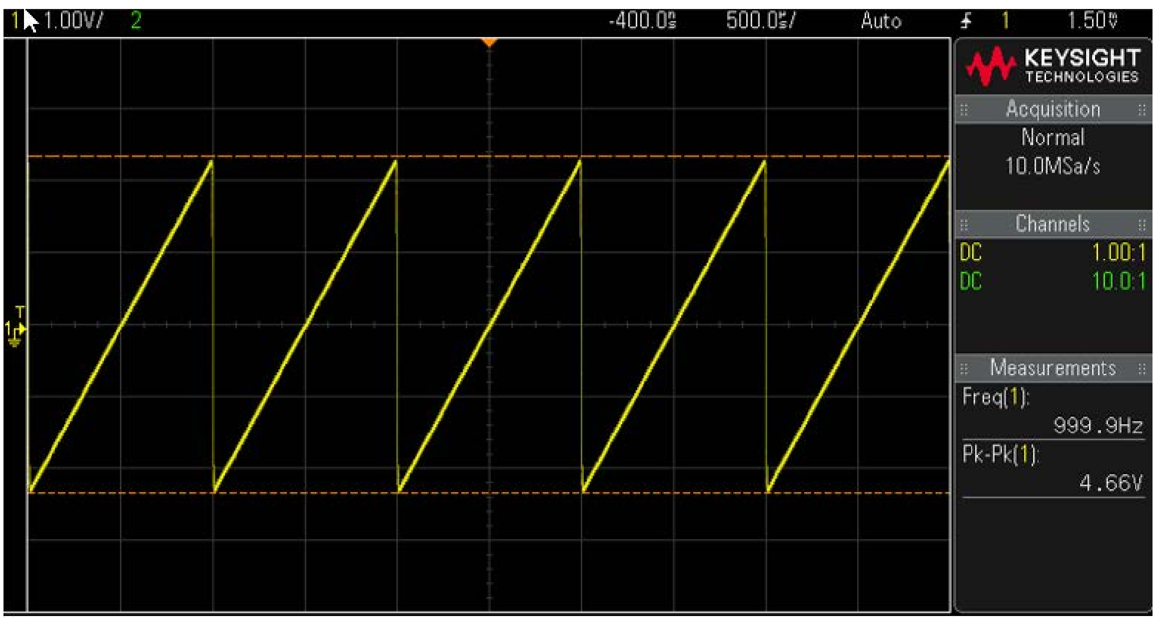


7. Capture the signal on the oscilloscope.

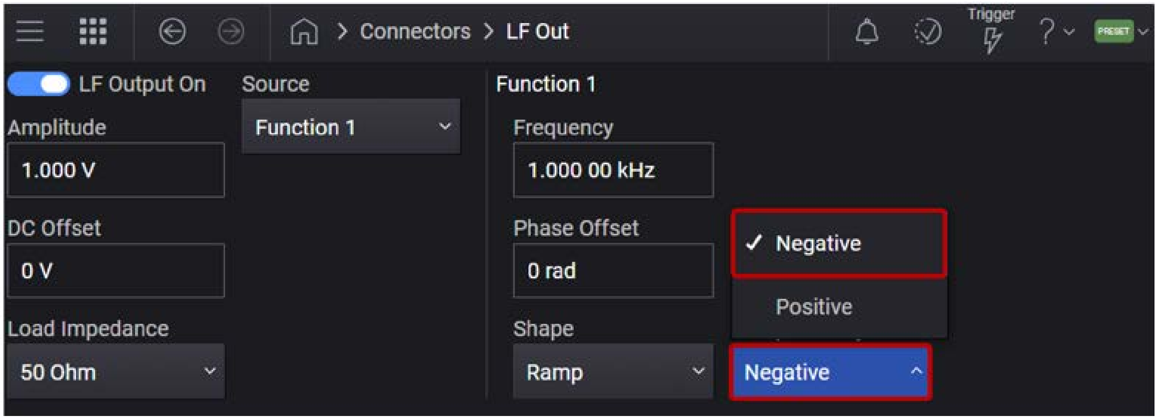


8. On the MXG, change the shape to **Ramp**.

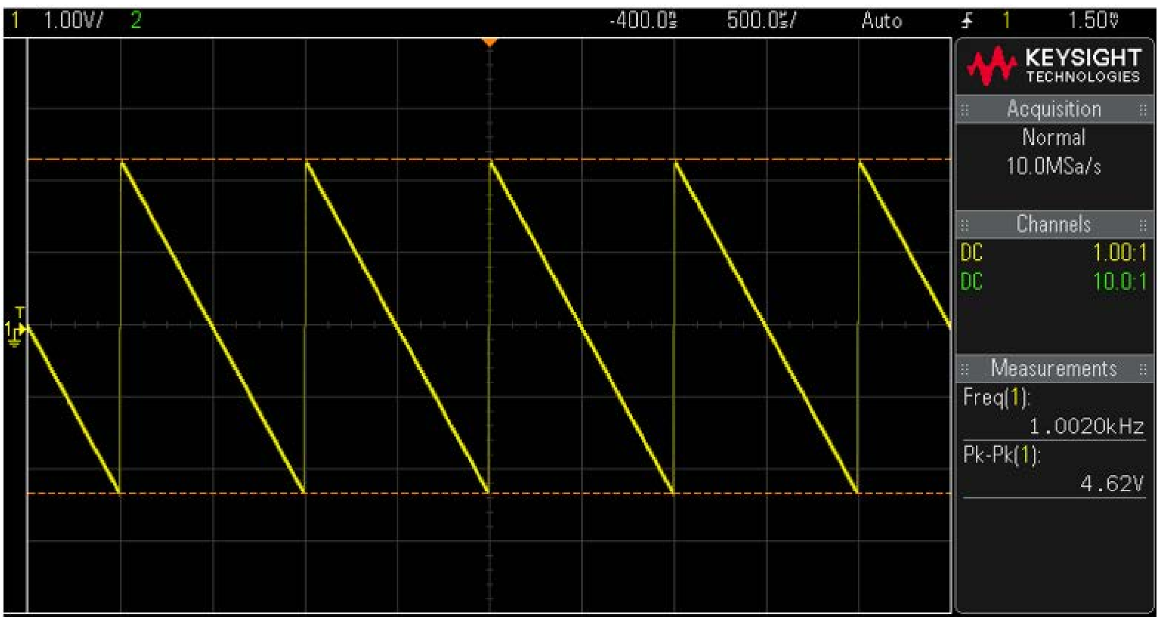
9. Capture the signal on the oscilloscope.



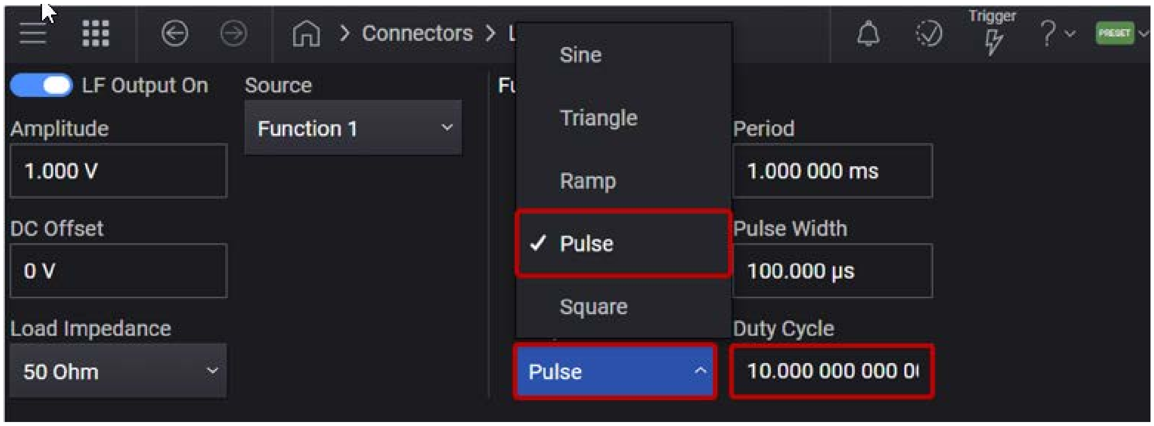
10. Set the Ramp Polarity to **Negative.**



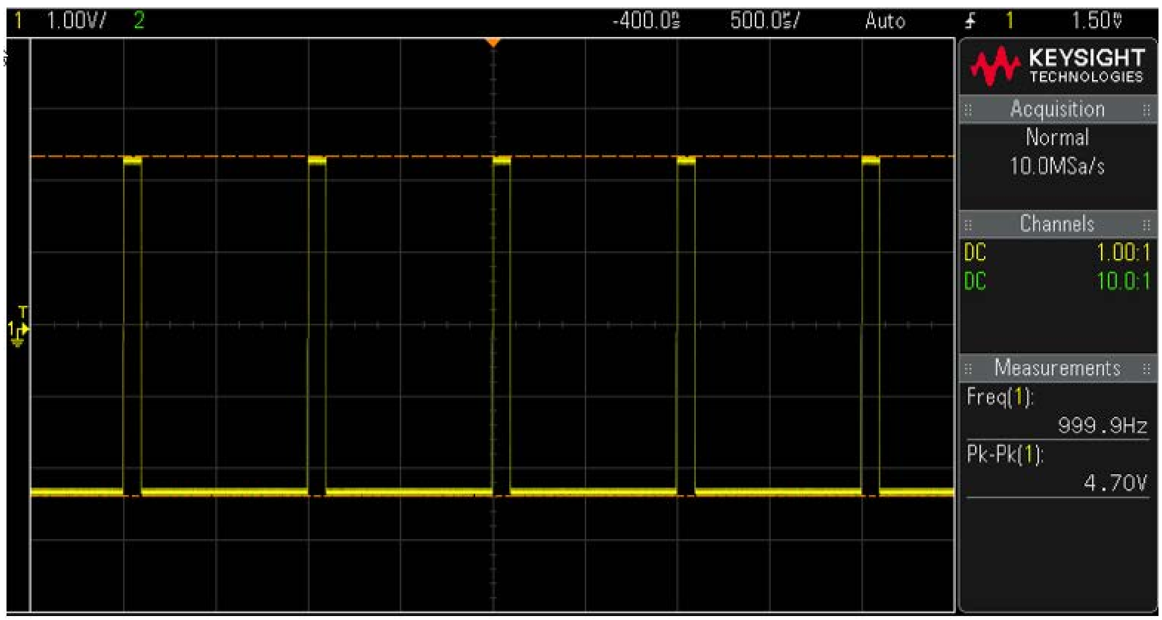
11. Capture the signal on the oscilloscope.



12. Set Shape to **Pulse** and set Duty Cycle to **10%**.

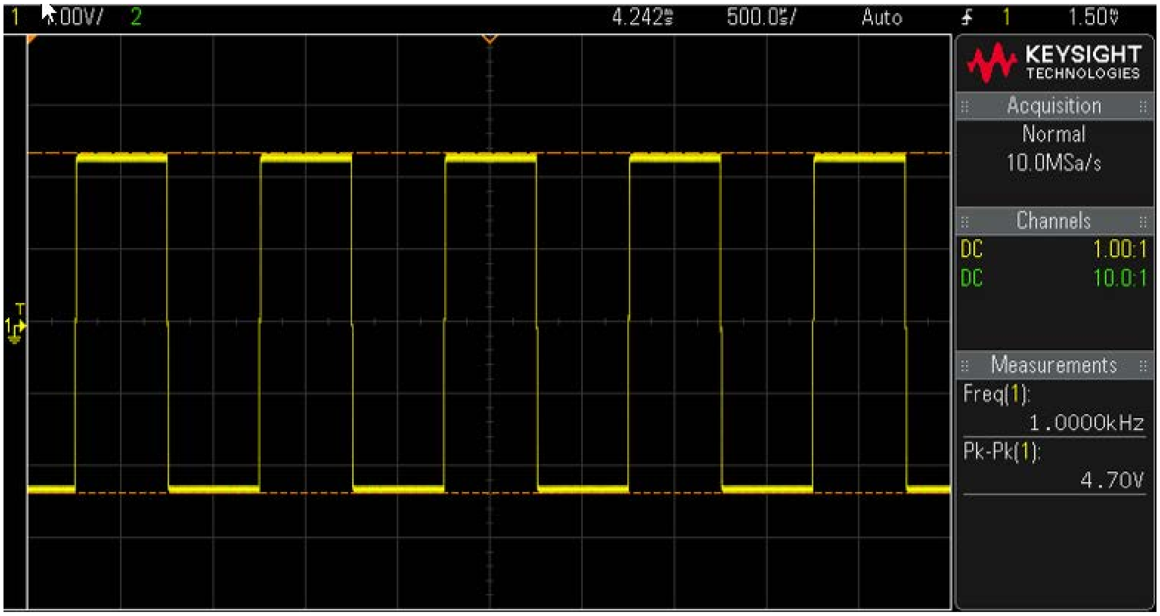


13. Capture the signal on the oscilloscope.



14. Set the Shape to **Square**.

15. Capture the signal on the oscilloscope.


1.00V/ 2
4.242s
500.0s/
Auto
1 1.50V
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
10.0MSa/s
Channels
DC 1.00:1
DC 10.0:1
Measurements
Freq(1):
1.0000kHz
Pk-Pk(1):
4.70V

Special Function Generators

The list of available function generators that are included with Option 303 are:

– Function 1
– Function
– Dual Function
– Noise 1
– Noise 2
– Swept function

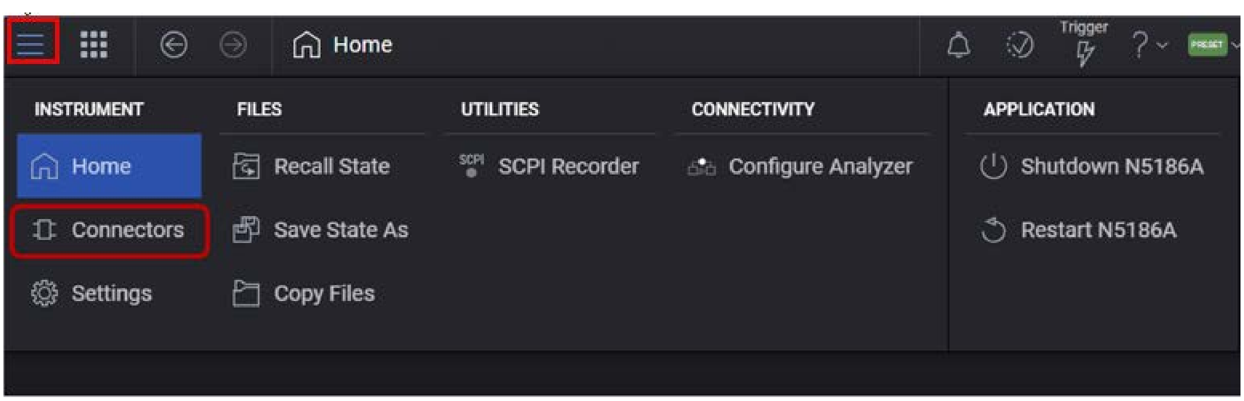
In the “Multifunction Generator Demonstrations” on page 43, the characteristics of function generators 1 and 2 are captured. Function generators such as Dual Function, Noise 1 & 2, and Swept Function have unique functions that can also be visualized using an oscilloscope and signal analyzer.

Dual Function

The Dual Function generator is similar to having both Function 1 and Function 2 operating at the same time, but with an adjustable phase offset. Providing precise control of phase difference between two functions.

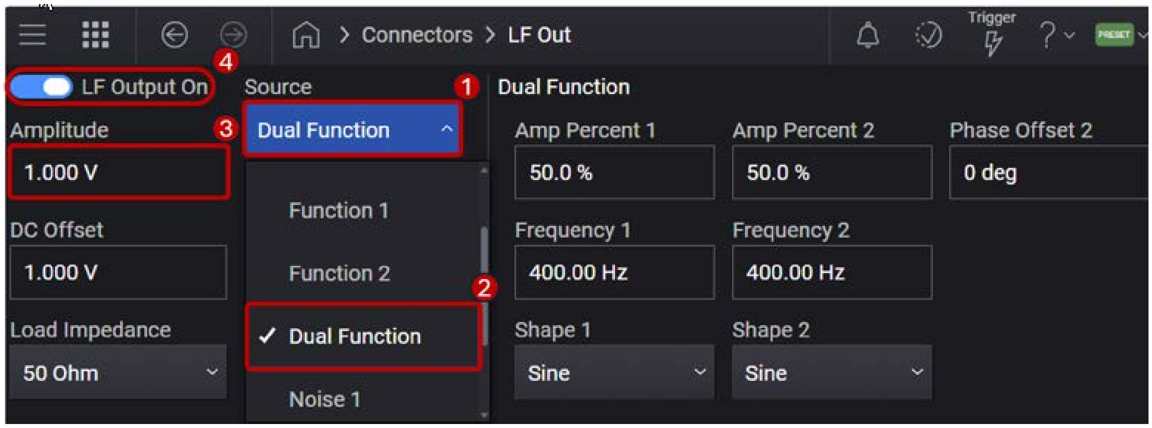
An easy way to visualize the behavior of a dual function generator is by using an oscilloscope.

1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Select the **System** menu > **Connectors**.



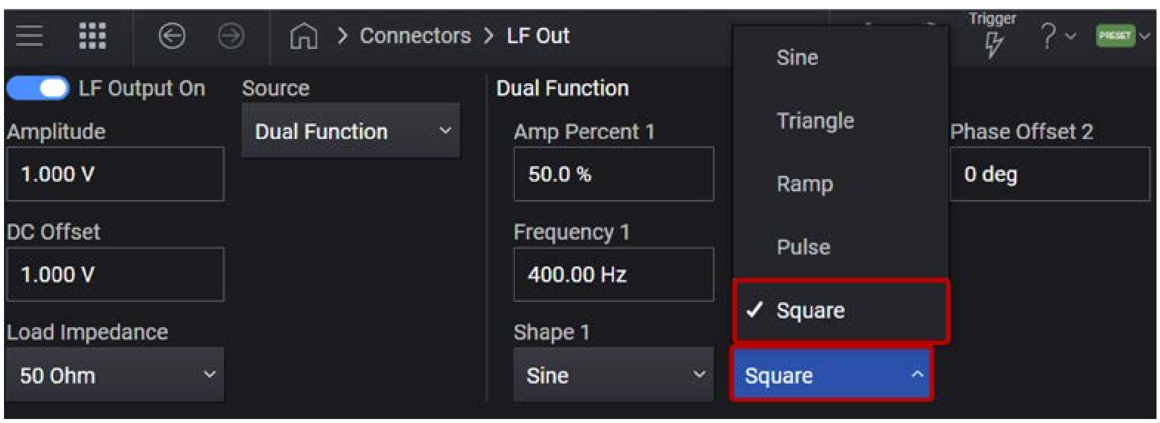
3. In the Connectors window, select **LF Out**.
4. In the LF Out window, set:
   – Source to **Dual Function1**
   – Amplitude to **1 V**

– Toggle LF Output **On**



5. Set Shape 2 to **Square**.

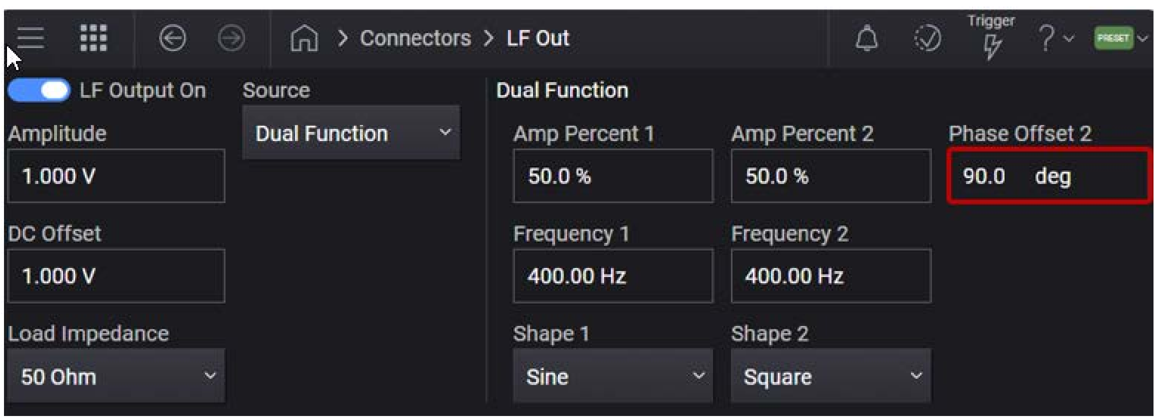
   A simply way to demonstrate the phase relationship between functions is to set one to square and adjust the phase and monitor the output.



6. Capture the signal on an oscilloscope.

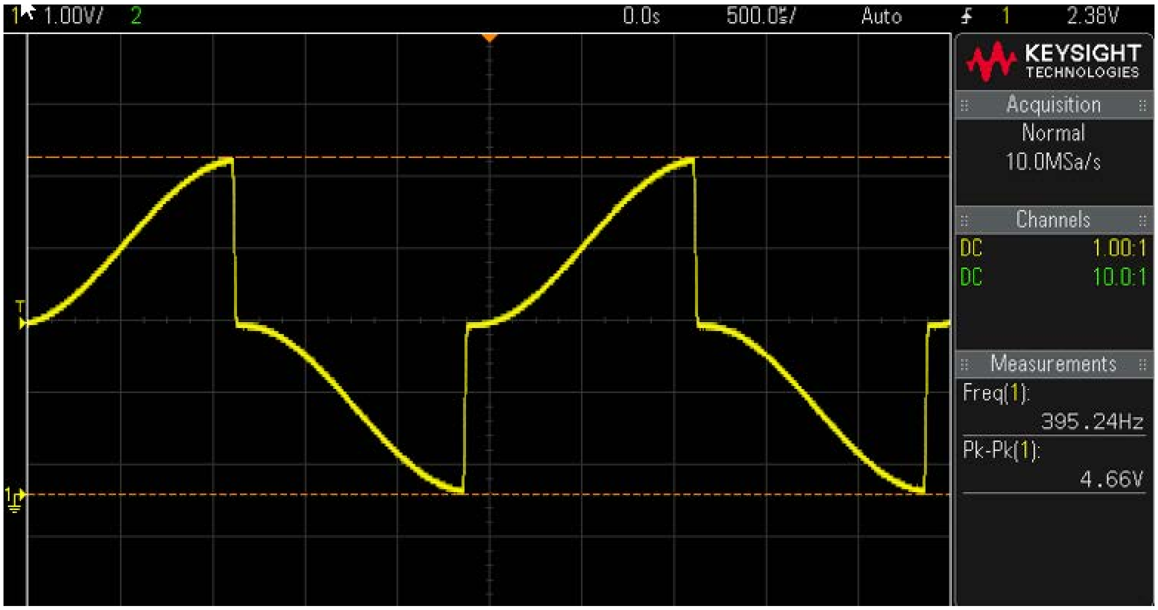
You can see the Sine and Square waves are in phase.

7. In the LF Out window, change the Phase Offset 2 to **90 degrees**.

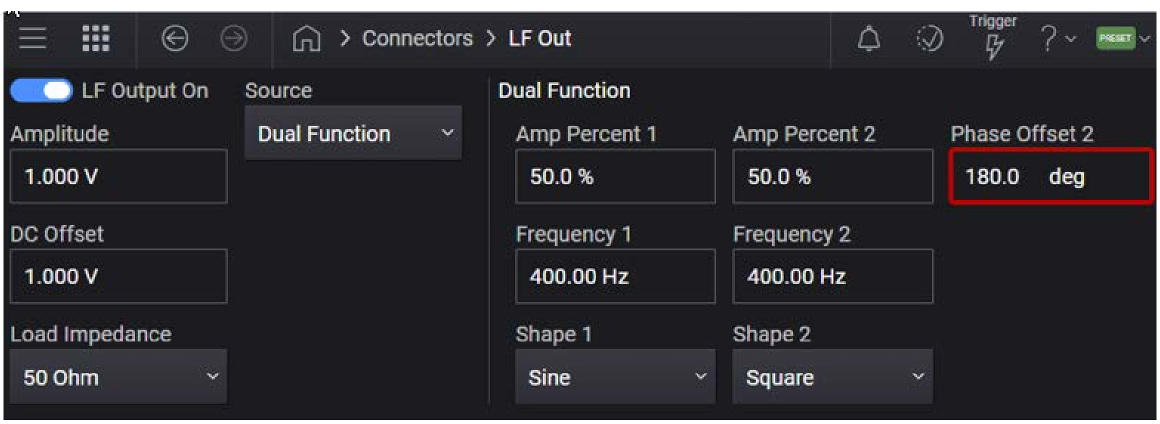


8. Capture the signal on the oscilloscope.

You can see the Sine and Square waves are 90 degrees out of phase.

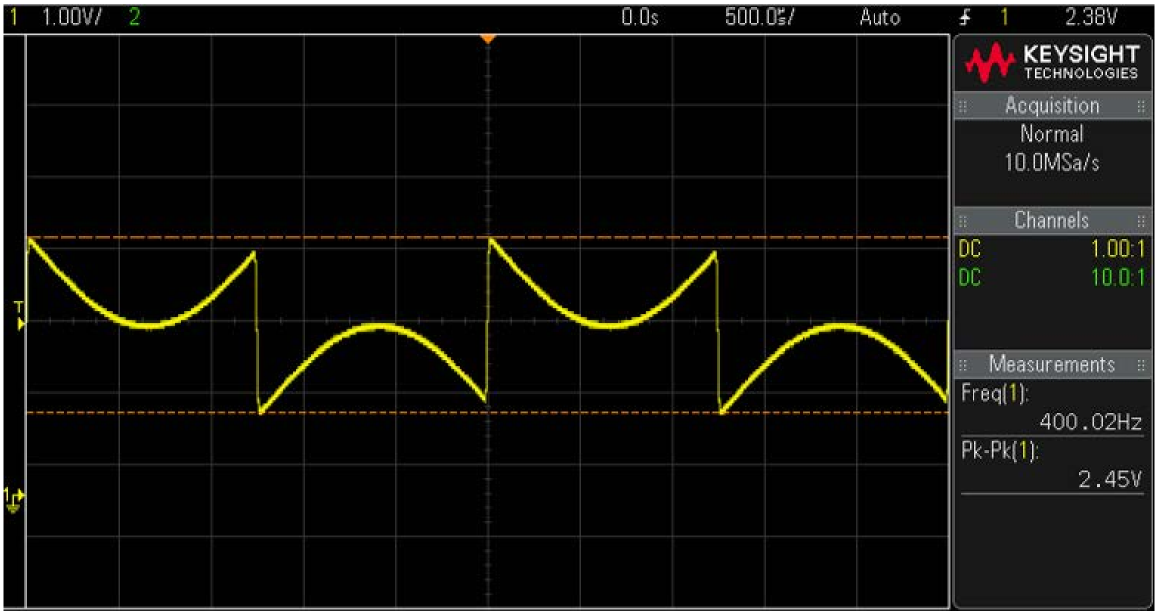


9. Change the Phase Offset 2 to **180 degrees**.



10. Capture the signal on the oscilloscope.

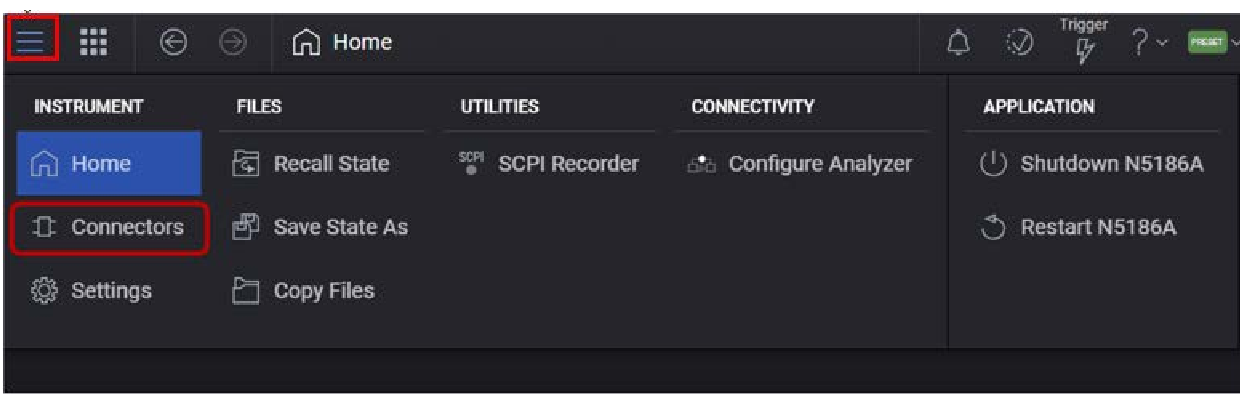
The Sine and Square waves are 180 degrees out of phase.



Noise Generator

There are two noise generators (Noise 1 and Noise 2) that both provide the same functionality. The noise generators have selectable noise type (Uniform or Gaussian). Noise generators play a critical role in RF immunity testing, fault isolation testing, and many more. The noise generators can be routed to the LF port to observe their behavior.

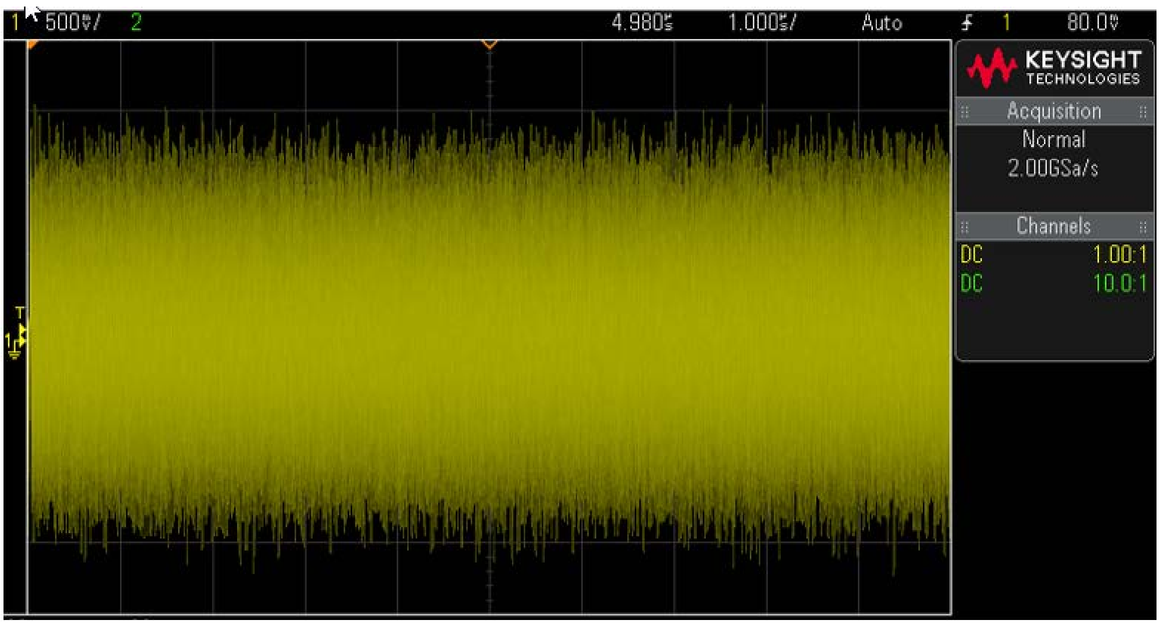
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Select the **System** menu > **Connectors**.



3. In the Connectors window, select **LF Out**.
4. In the LF Out window, set:
   – Source to **Noise 1**

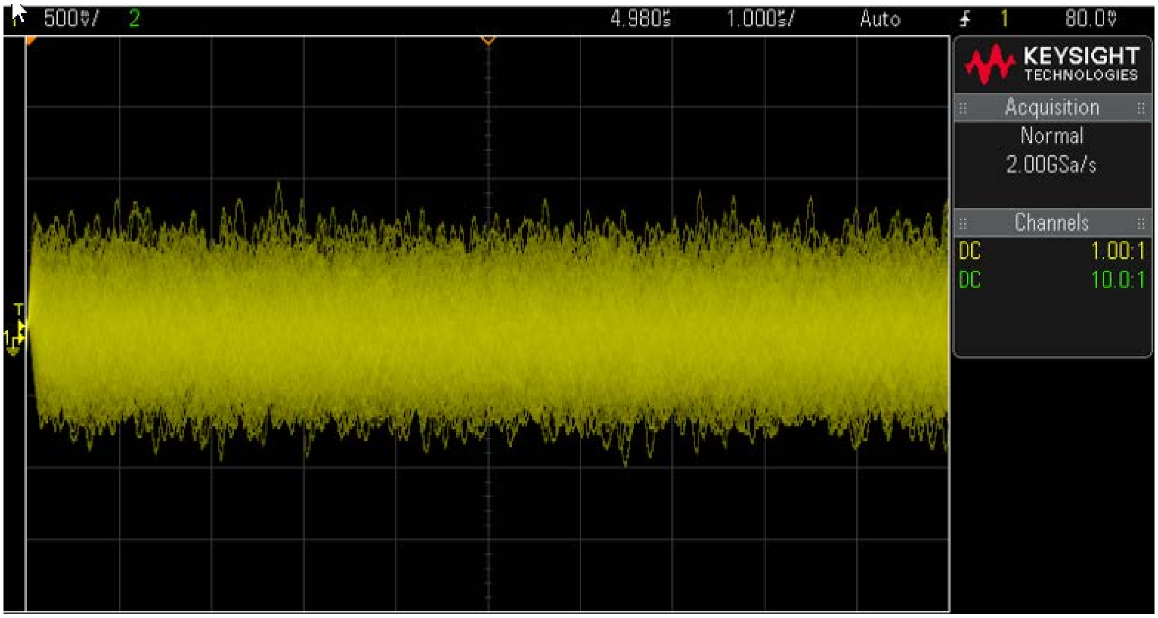
- Type to **Uniform**
- Amplitude to **500 mV**
- DC Offset to **0**
- Toggle LF Output **On**

5. Capture the signal on the oscilloscope



6. Set Type to **Gaussian**.

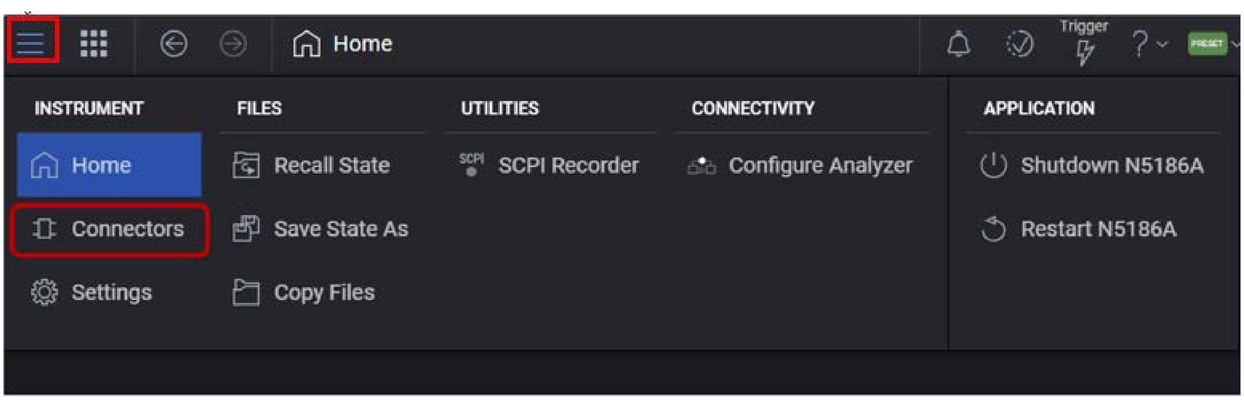
7. Capture the signal on the oscilloscope



Swept Function

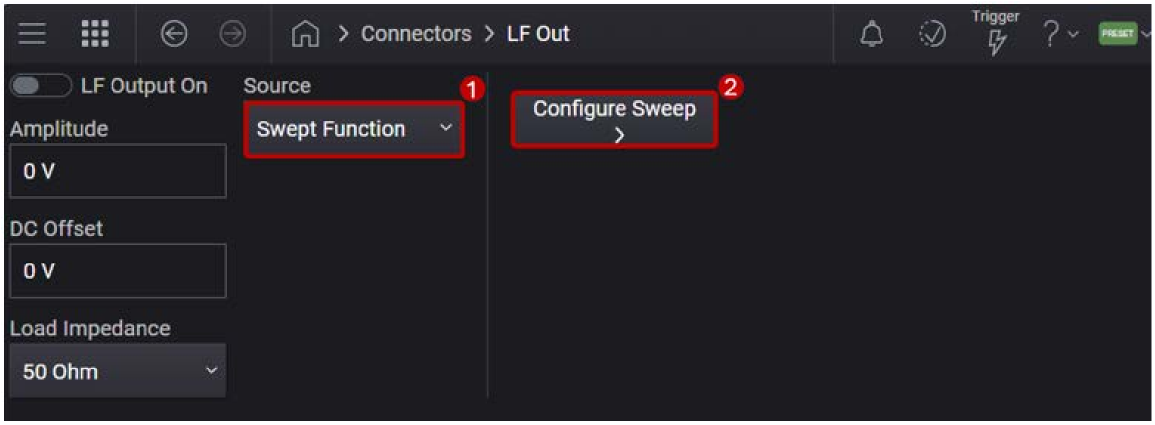
The Swept Function generator has a selectable start frequency, stop frequency, and sweep start to stop time as well as selectable sweep shape, sweep waveform shape, and trigger source. With a frequency range of 10 mHz to 10 MHz and a start-to-stop time range of 20 ns to 89 s. The Swept Function Generator is key in conducting frequency response testing for filters, amplifiers, and various other RF components. The Swept Function Generator can be routed to the LF port to observe it's behavior.

1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Select the **System** menu > **Connectors**.

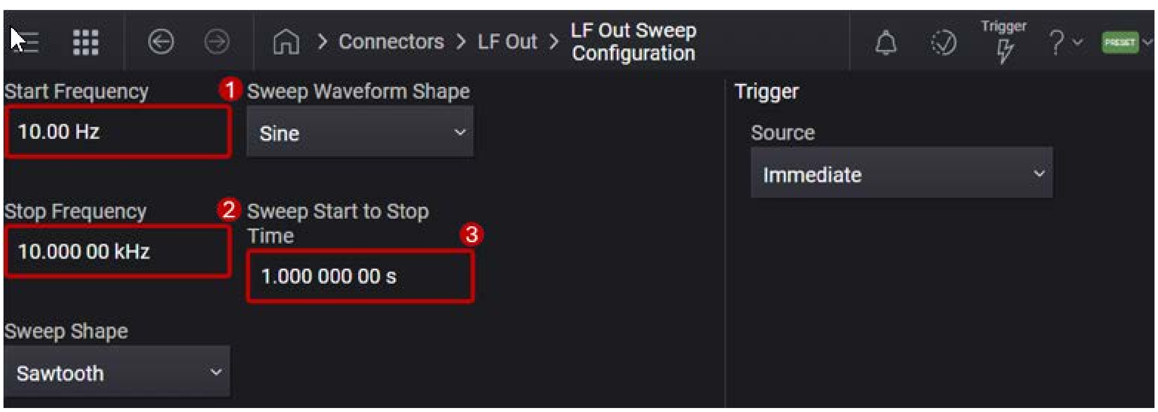


3. In the Connectors window, select **LF Out**.
4. In the LF Out window, set:

– Source to **Sweep Function**
– **Configure Sweep**

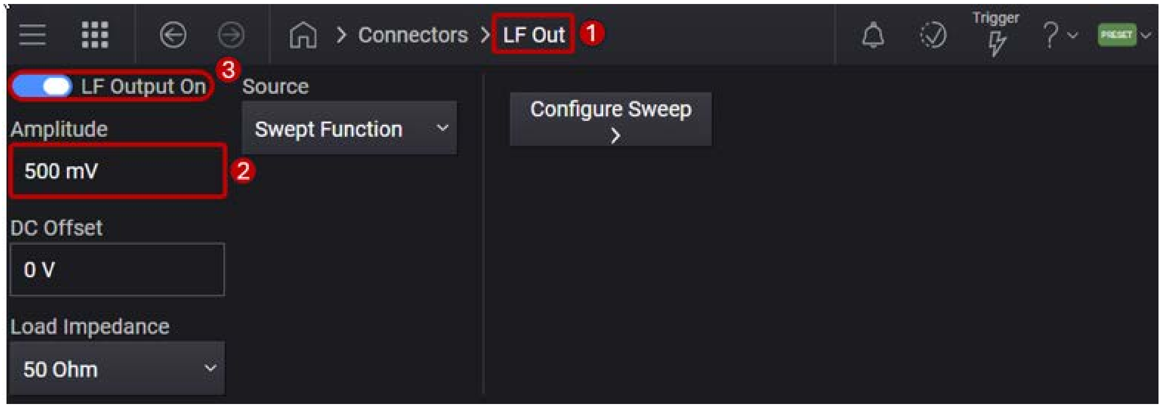


5. Set:
   – Start Frequency to **10 Hz**
   – Stop Frequency to **10 kHz**
   – Sweep Start to Stop Time to **1 s**

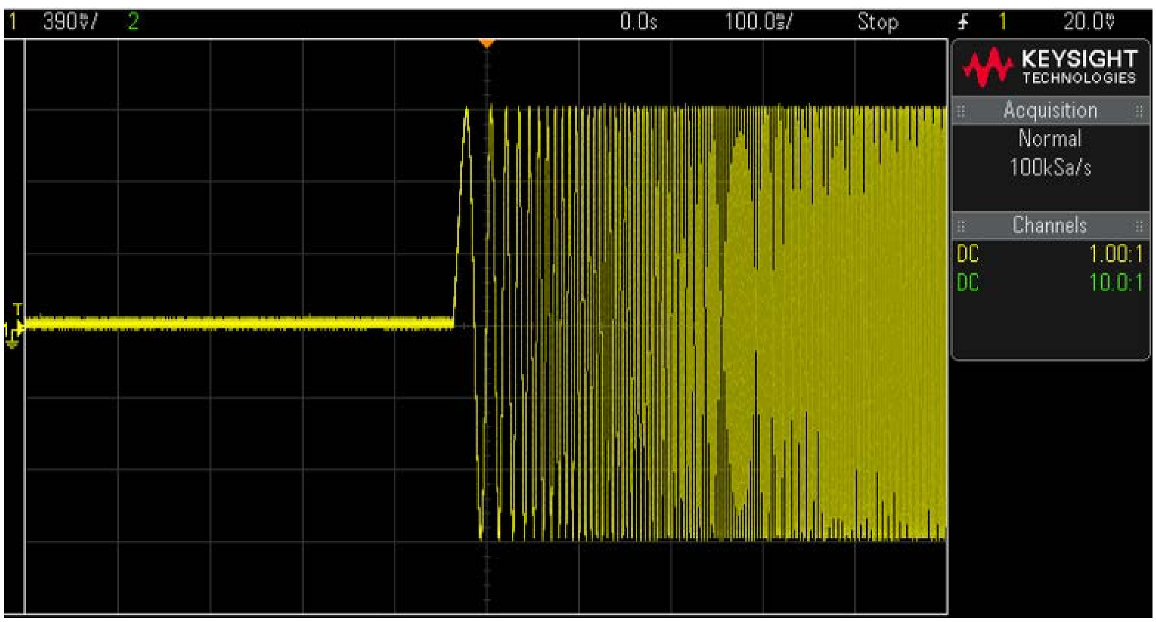


6. Select the **Back** Arrow and select:
   – **LF Out**
   – Amplitude to **500 mV**

– Toggle LF Output **On**



7. Capture the signal on the oscilloscope

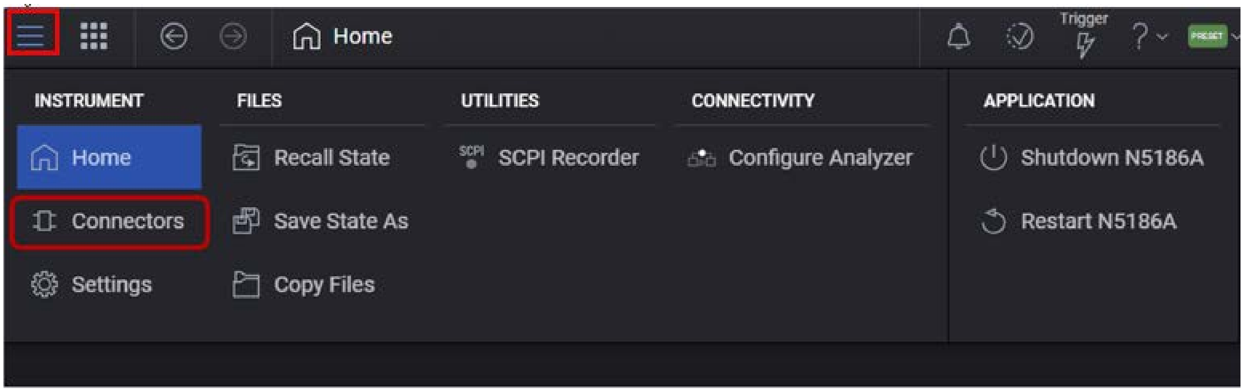


Sawtooth and Triangle Sweep Shapes

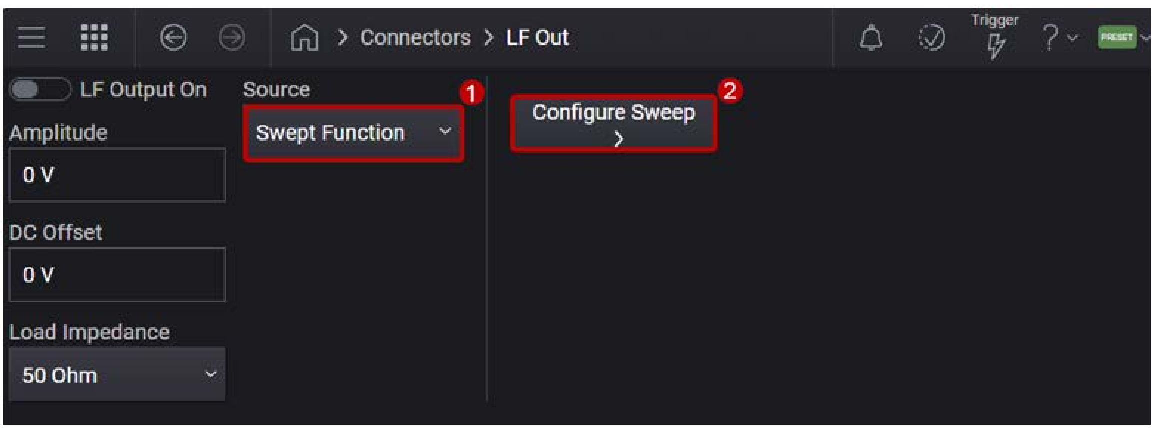
The Swept function generator has two selectable sweep shapes (Sawtooth and Triangle). The Sawtooth sweep shape is a linear sweep from start frequency to stop frequency. When the stop frequency is reached the function generator jumps back to the start frequency and repeats again. The Triangle waveform sweep shape starts at the start frequency then sweeps to the stop frequency, but when the stop frequency is reached the function generator sweeps back down in frequency until reaching the start frequency. This behavior is best seen on a spectrogram measurement.

1. Select **Preset** > **Preset** to set the instrument to a known state.

2. Select the **System** menu > **Connectors**.



3. In the Connectors window, select **LF Out**.
4. In the LF Out window, set:
   – Source to **Sweep Function**
   – **Configure Sweep**



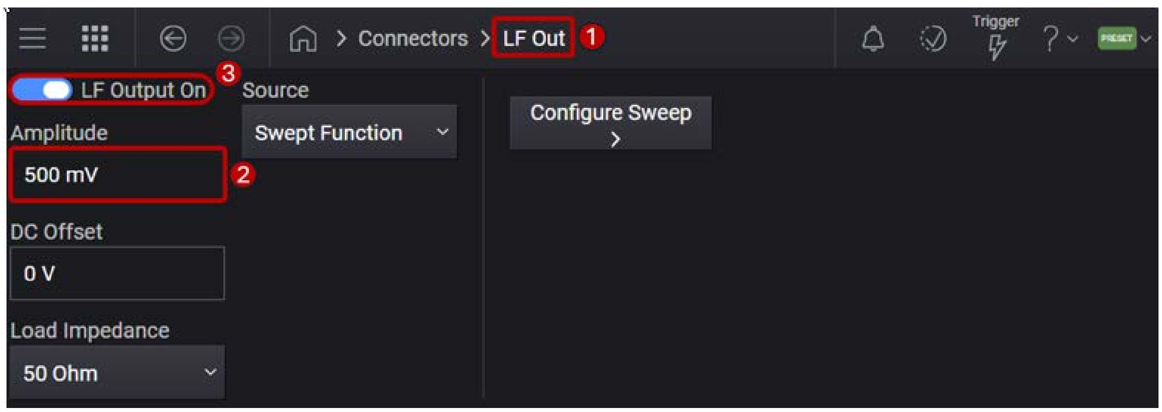
5. Set:
   – Start Frequency to **1 MHz**
   – Stop Frequency to **1.5 MHz**
   – Sweep Start to Stop Time to **1 s**

– Sweep Shape to **Sawtooth**

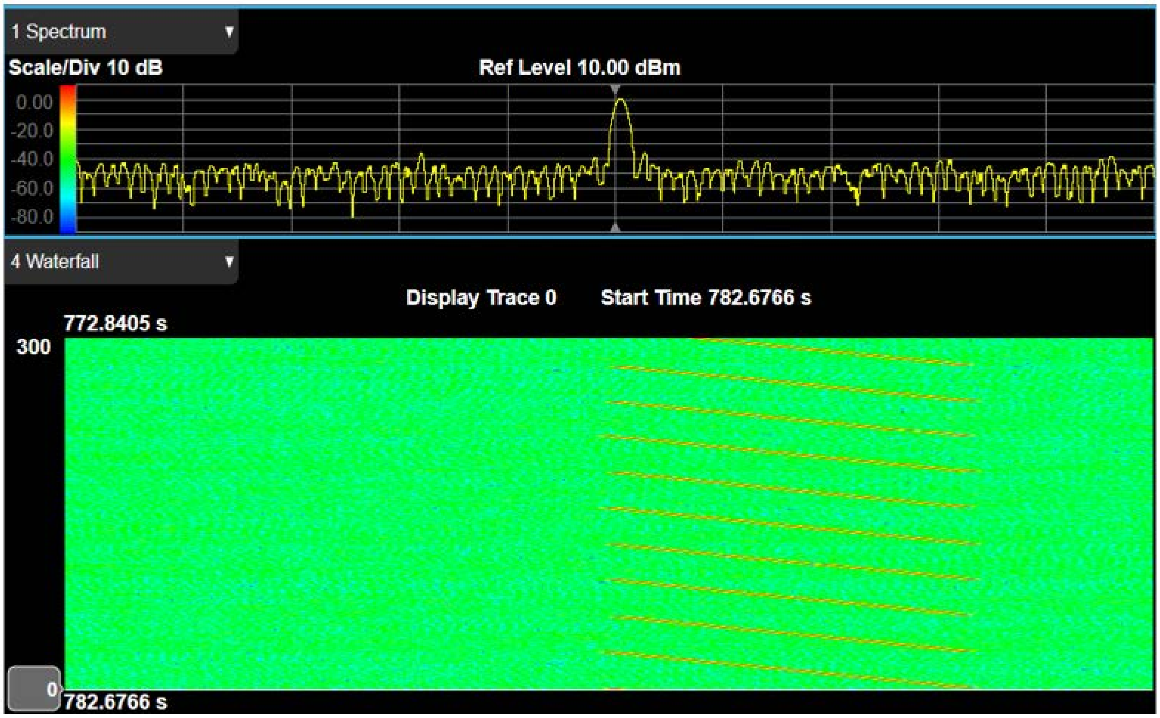
6. Select the **Back** Arrow and select:

   – Amplitude to **500 mV**

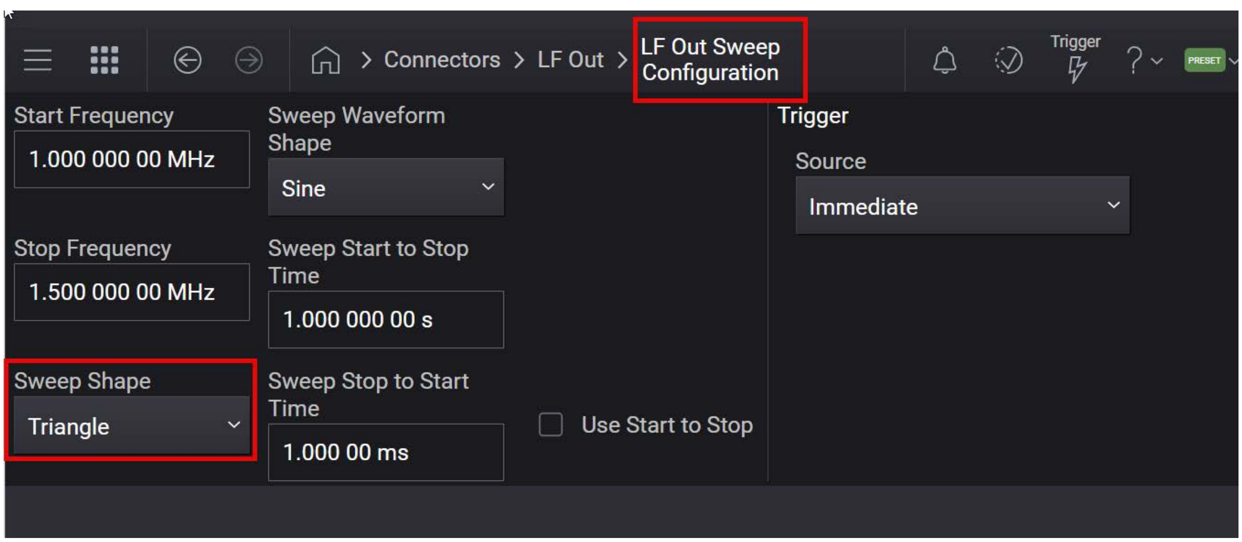
   – Toggle LF Output **On**



7. Capture the signal on a Spectrogram.

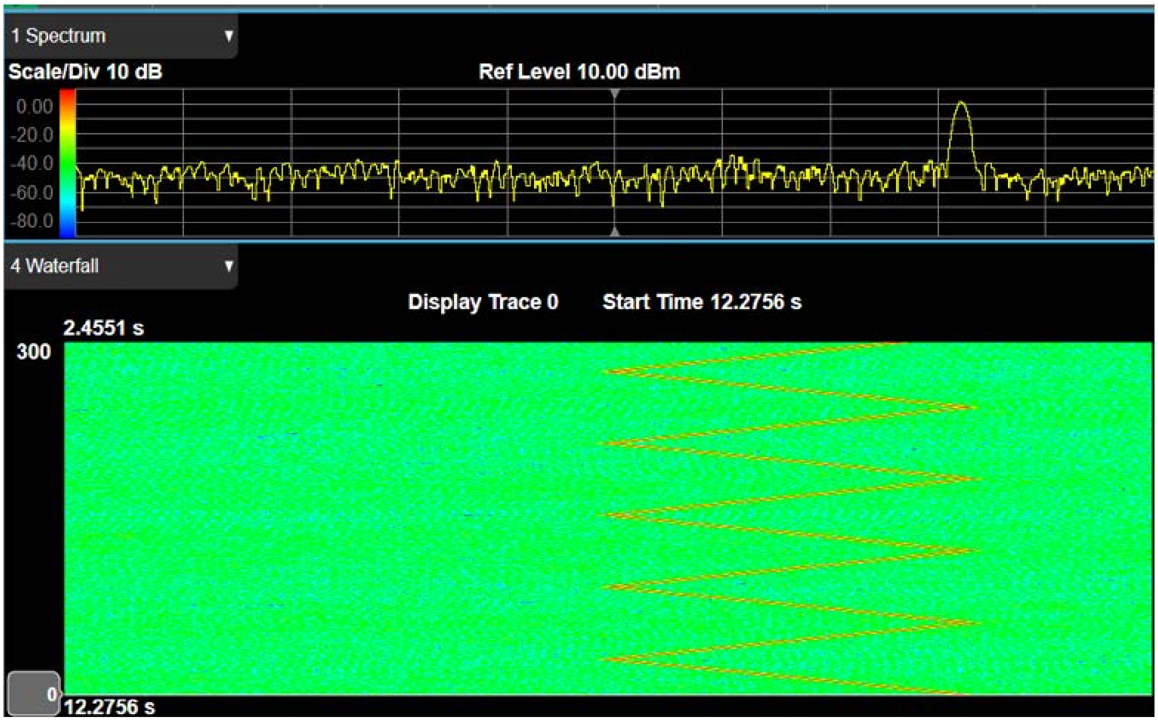


8. Select **Configure Sweep** > **Sweep Shape Triangle**.



9. Select the **Back** Arrow and Toggle LF Output **On**.

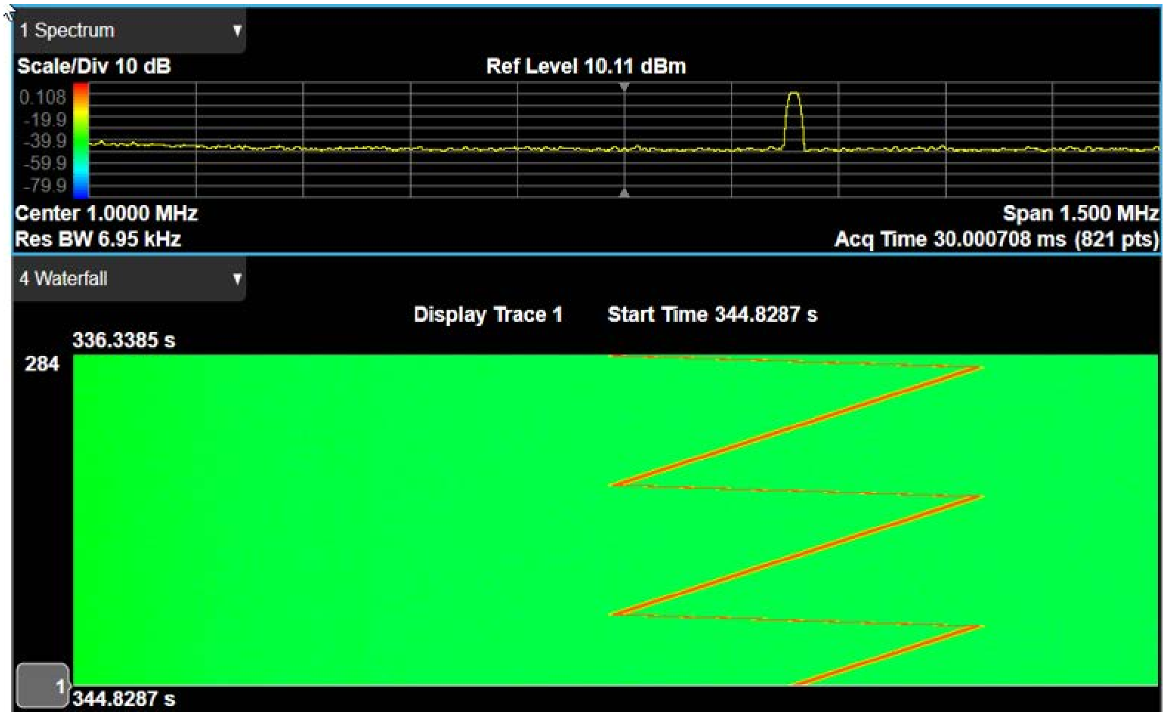
10. Capture the signal on the Spectrogram.



The Triangle Sweep shape has two Sweep Start to Stop Time inputs, one for sweep up and one for sweep down. By changing the sweep times to be unequal, the sweep shape that is seen on the spectrogram will become nonuniform.

11. In the LF Output Sweep Configuration window, set Sweep Start to Stop Time to **300 ms** and Sweep Start to Stop Time to **3s**.

12. Capture the signal on the Spectrogram.



Notice that the signal sweeps from a low to high frequency at a faster rate than from a high to low frequency.

Radio Frequency Modulation Option UNT

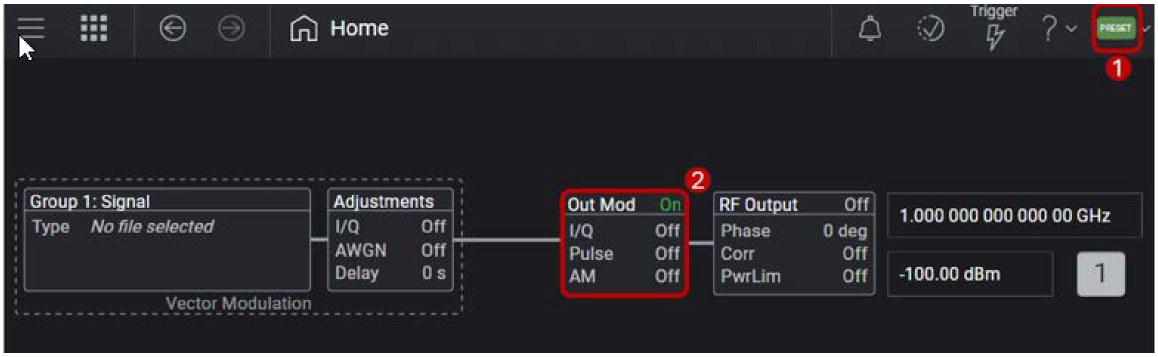
In the sections above the function generators were routed to the LF port to observe their operation individually. This section will demonstrate how Option 303 effects the RF signal at the RF port. The function generators are used to modulate the RF signal through amplitude and frequency/phase modulators (see Figure 1-2 on page 40). We can see how the modulators affect the original RF signal in both time and frequency domain using a signal analyzer and oscilloscope.

Amplitude Modulation

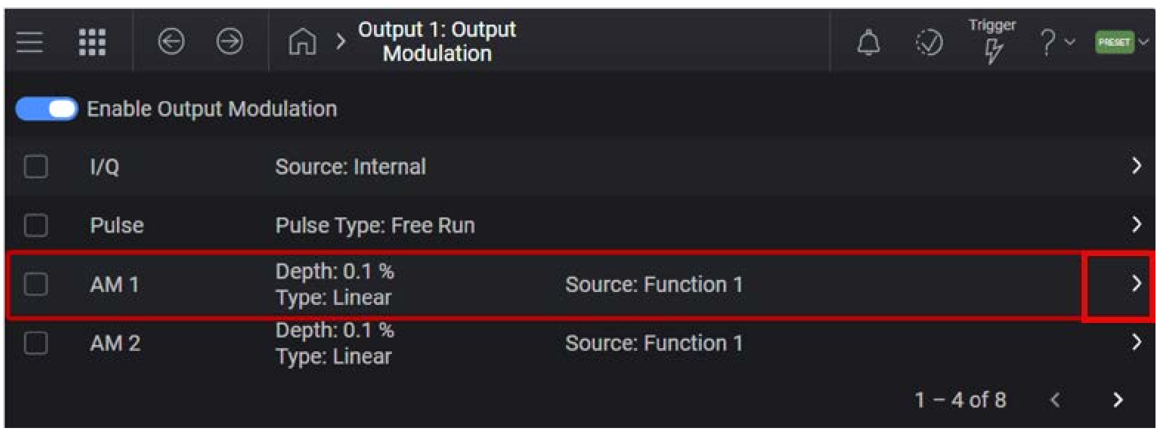
Using an oscilloscope, amplitude modulation can be observed in the time domain. The function generators produce the modulating signal, creating the envelope, while the RF signal serves as the carrier wave.

To apply amplitude modulation:

1. Select **Preset** > **Preset** to set the instrument to a known state and select the **Out Mod** block.

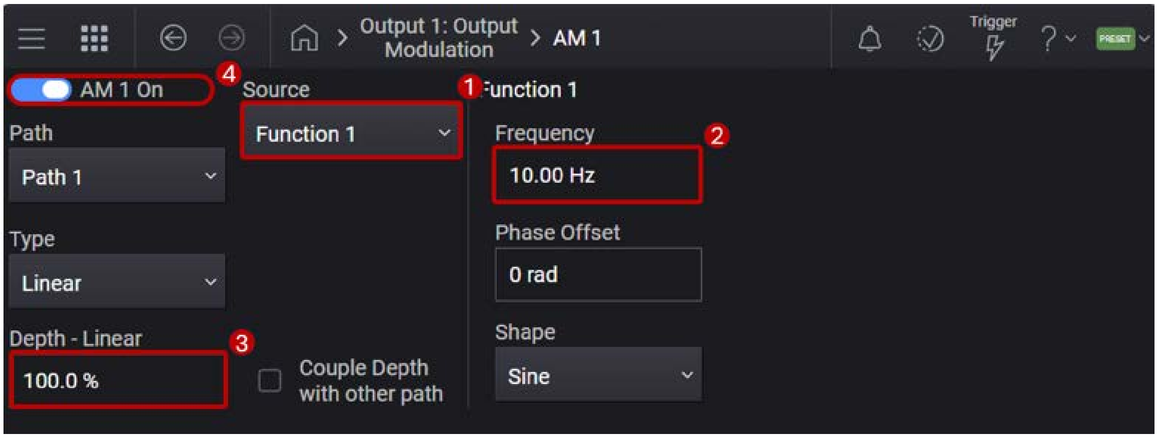


2. In the Output Mode window, select **AM1** arrow at the far left side of the window.



3. In the AM1 window, set:
   - Source to **Function 1**
   - Frequency to **10 Hz**
   - Depth to Linear to **100%**

– Toggle AM 1 **On**

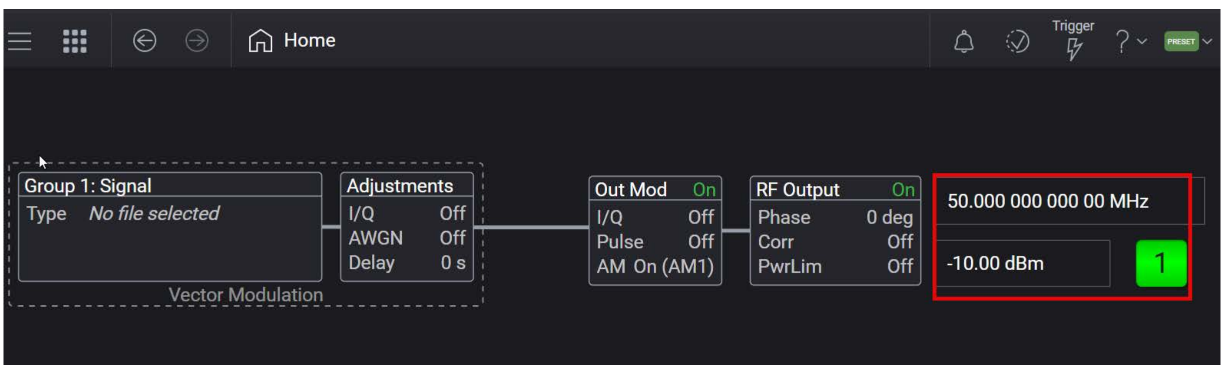


4. Select the **Home** icon and set:

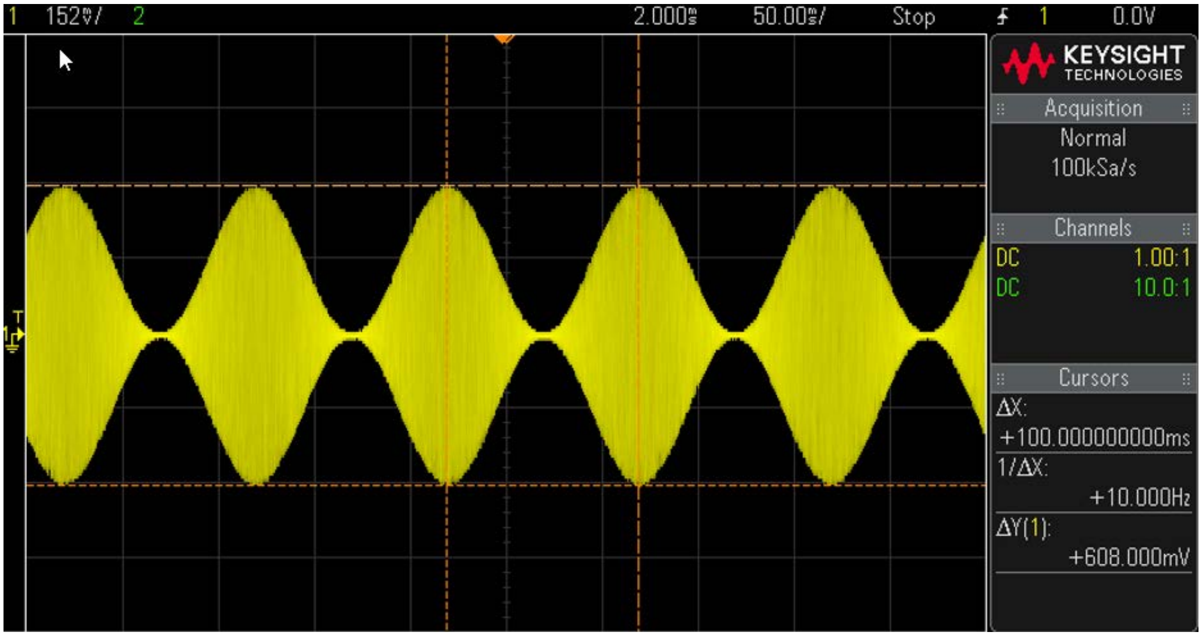
   – Frequency to **50 MHz**

   – Power to **-10 dBm**

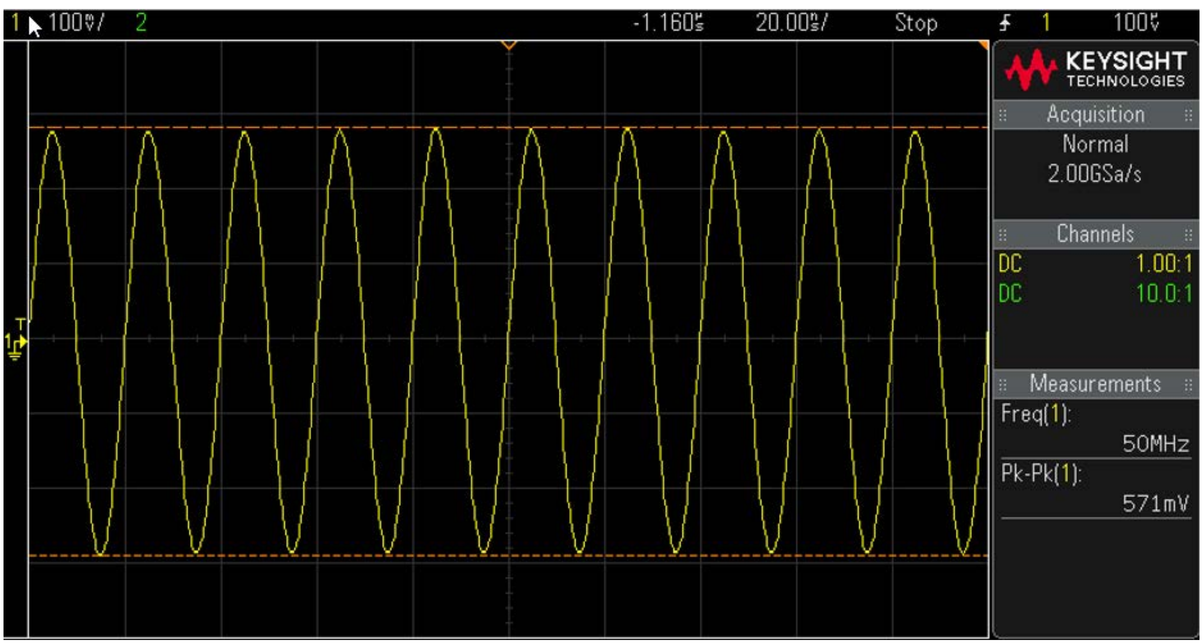
   – Toggle RF output **On**



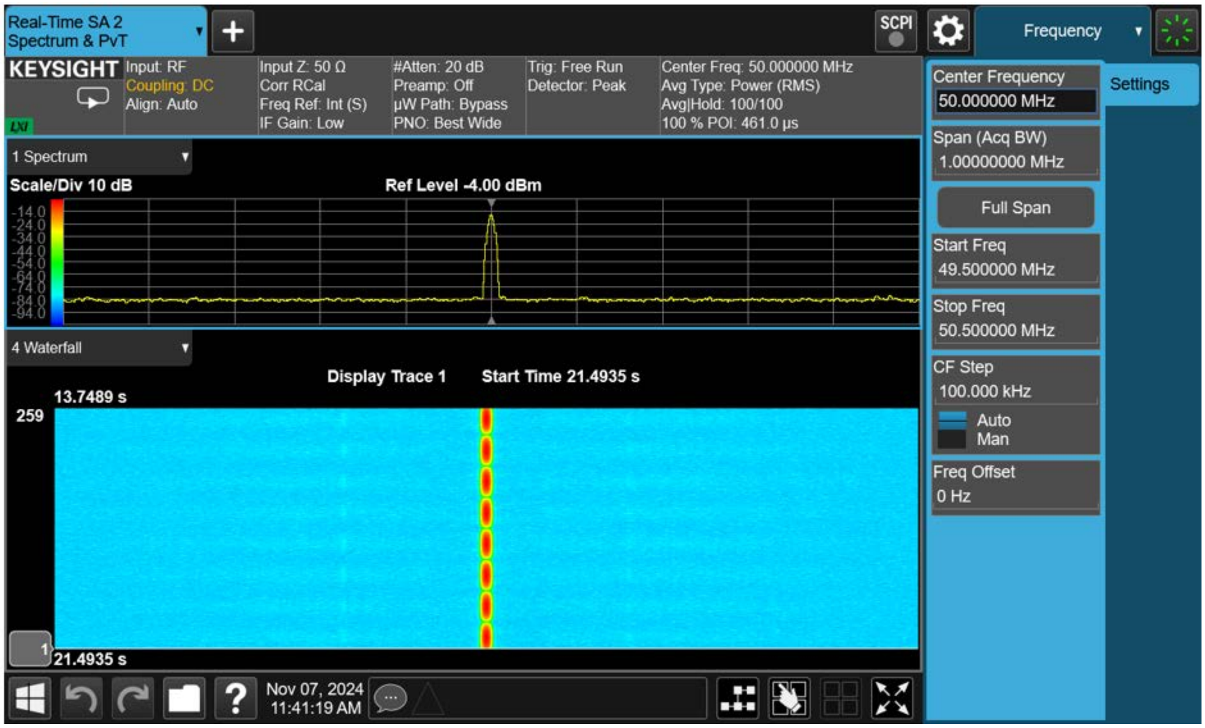
5. Capture the envelop on the oscilloscope. The shape of the function corresponds to the shape of the envelope. (In this example, the function shape is set to sine.)



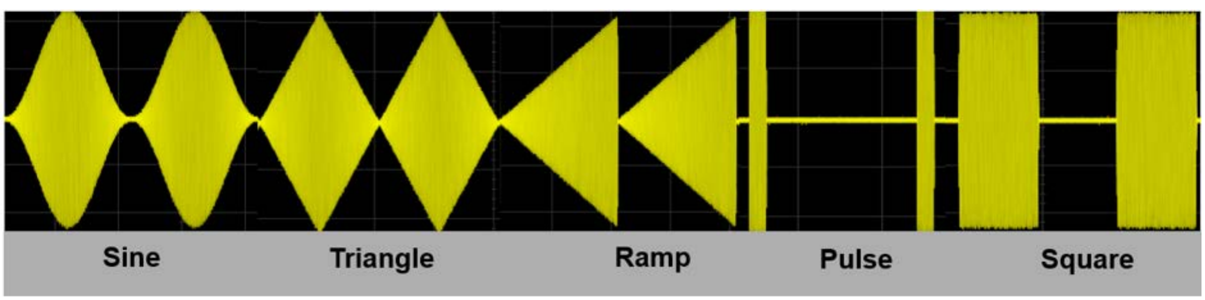
6. Capture the carrier on the oscilloscope.



You can also view the modulation on a spectrogram. The modulation can be visualized as varying intensity of the carrier frequency over time.



The shape of the function generator corresponds to the shape of the envelope when generating AM signals.

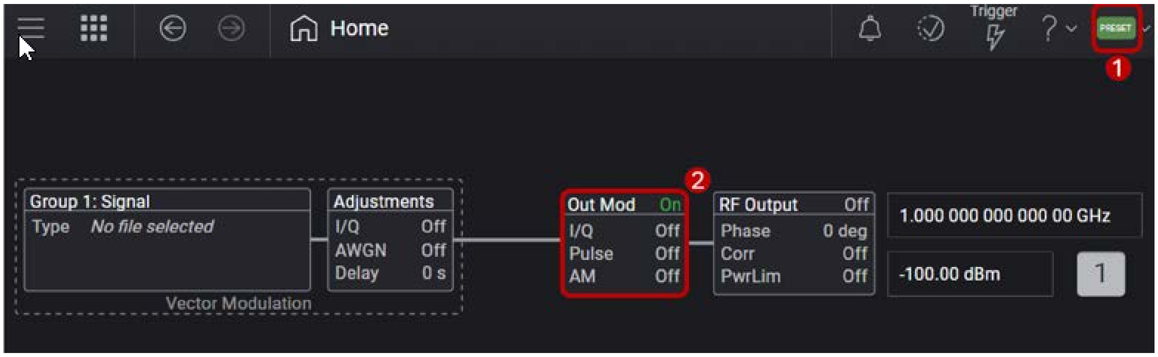


Frequency Modulation

Using a signal analyzer, frequency modulation can be observed using a spectrogram. The function generator produces the modulating signal, which varies the frequency of the RF signal.

To apply frequency modulation:

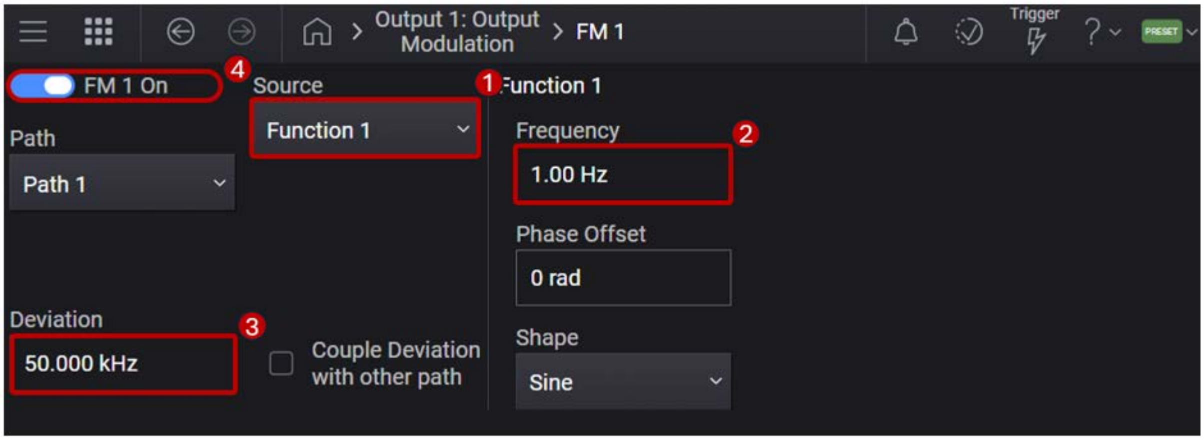
1. Select **Preset** > **Preset** to set the instrument to a known state and select the **Out Mod** block.



2. In the Output Mode window, select the right arrow at the bottom of the display to select choices 5-8, then select the **FM1** arrow at the far left side of the window.

3. In the FM1 window, set:
   - Source to **Function 1**
   - Frequency to **1 Hz**
   - Deviation to **50 kHz**

– Toggle FM 1 **On**

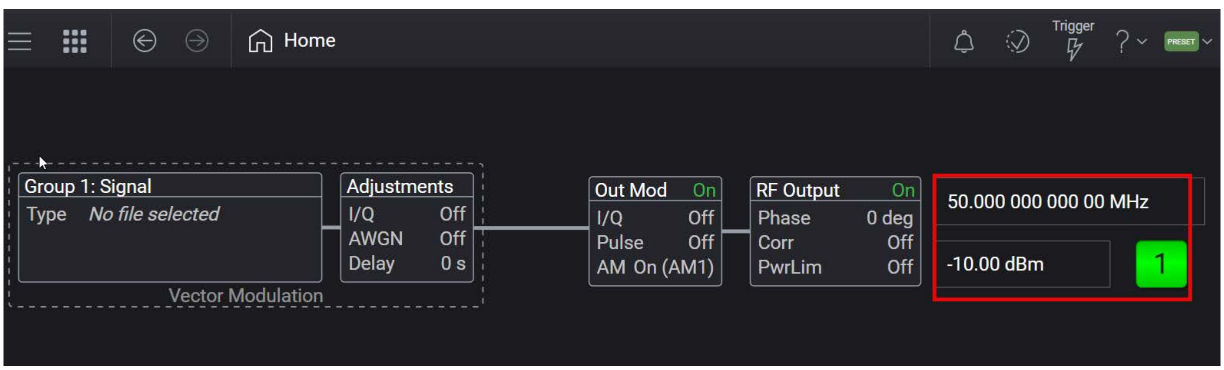


4. Select the **Home** icon and set:

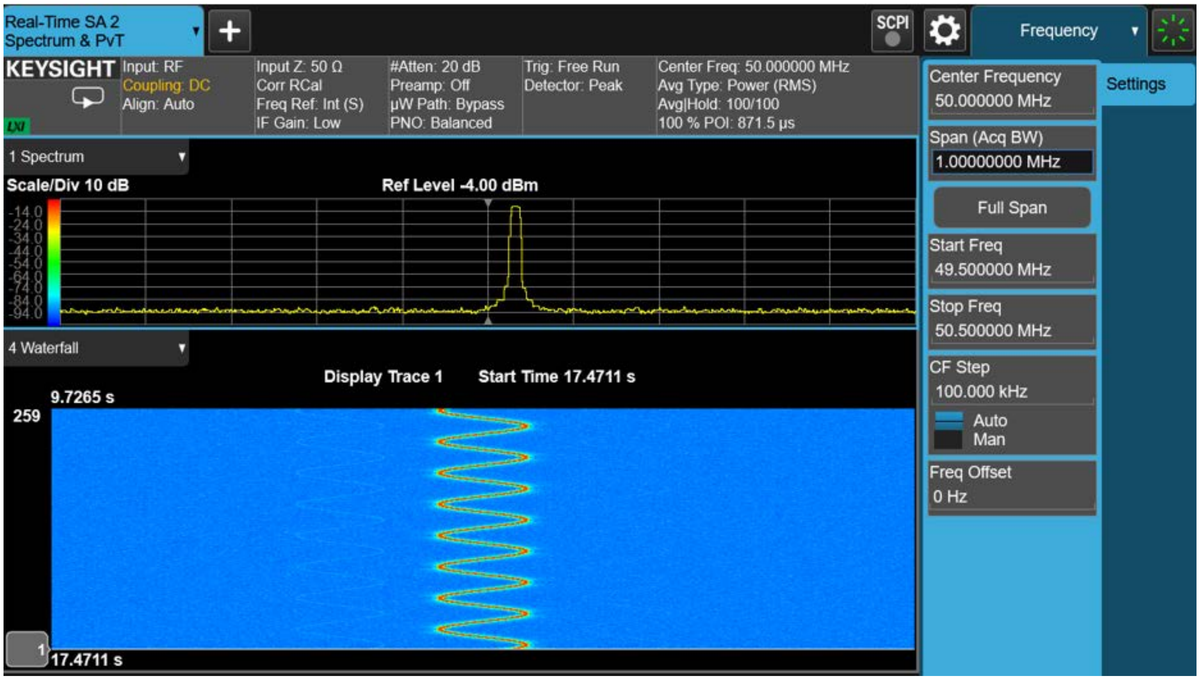
   – Frequency to **50 MHz**

   – Power to **-10 dBm**

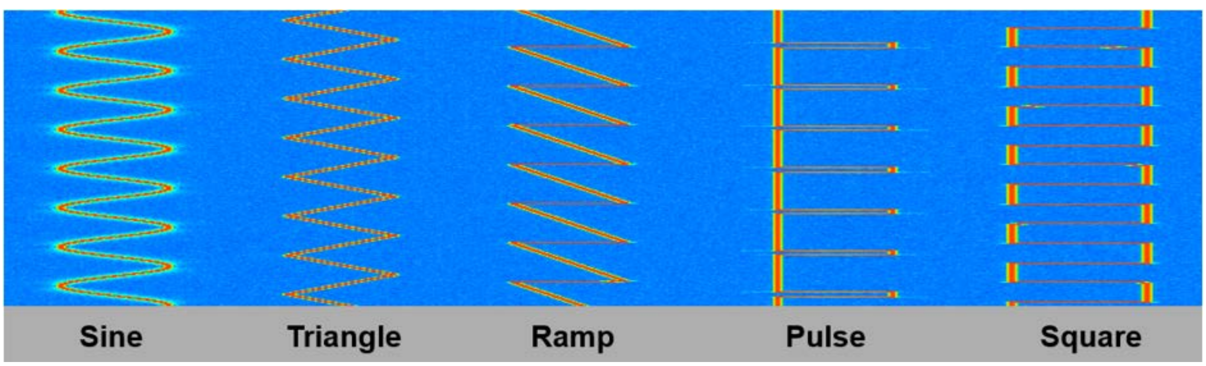
   – Toggle RF output **On**



5. Capture the signal on the Spectrogram.



The shape of the function generator corresponds to the shape of the frequency modulation.

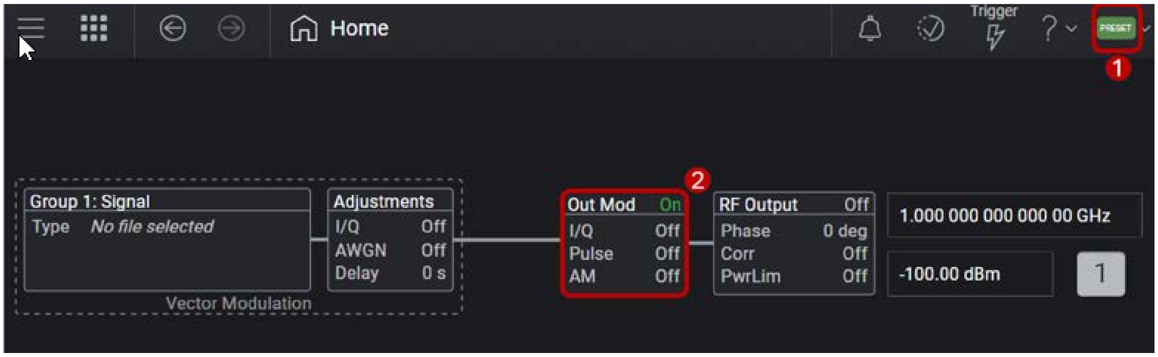


Phase Modulation

Phase Modulation can be visualized using an Oscilloscope in the time domain. The function generator produces the modulating signal, which varies the phase of the RF signal.

To apply phase modulation:

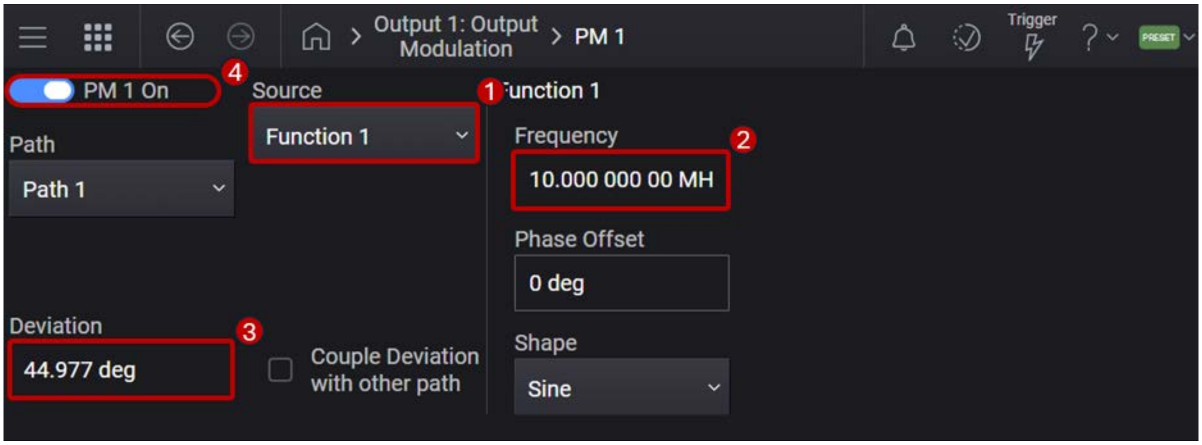
1. Select **Preset** > **Preset** to set the instrument to a known state and select the **Out Mod** block.



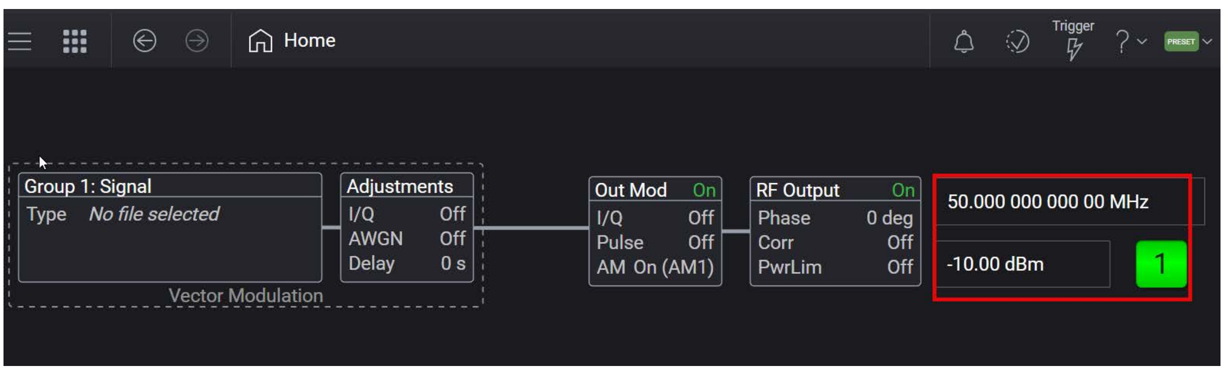
2. In the Output Mode window, select the right arrow at the bottom of the display to select choices 5-8, then select the **PM1** arrow at the far left side of the window.

3. In the PM1 window, set:
   – Source to **Function 1**
   – Frequency to **10 MHz**
   – Deviation to **45 deg**

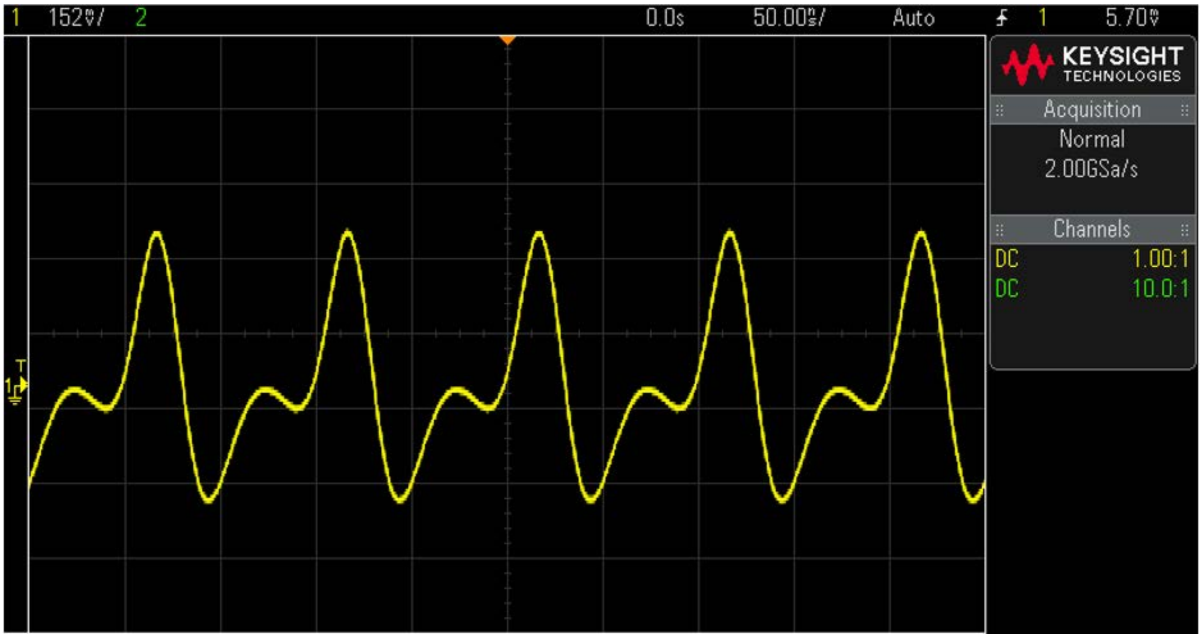
– Toggle PM 1 **On**



4. Select the **Home** icon and set:
   – Frequency to **50 MHz**
   – Power to **-10 dBm**
   – Toggle RF output **On**



5. Capture the signal on the Oscilloscope.



Applications

In many scenarios a RF communication system is subject to dynamic environments which can alter the characteristics of an ideal signal. In an ideal environment, the signal being generated and transmitted is the exact signal being received. Physically we know that this is not possible, the signal will be subject to some change. Therefore, a good communication system is resilient and can operate effectively within some range of impairments.

Consider an environment where signal strength fluctuates over time due to varying physical obstructions between the source and receiver. It would be inefficient and inconsistent to physically implement a RF environment to test your communication system. A more effective and repeatable test would be to simulate the conditions of such an environment. Using AM, we can simulate the impairment of varying signal strength. With selectable frequency, shape, and depth the AM modulator is capable of a wide range of simulated environments to support signal strength testing.

One of the design challenges of mobile communications systems comes from Doppler shift. As a transmitter and receiver move towards or away from one another, the signal will compress or stretch, effectively changing the perceived frequency. An effective way to simulate such an environment is by using the FM modulator. Using FM, we can simulate the impairment of varying frequency caused by Doppler shift. With selectable frequency deviation and deviation rate, the FM modulator can effectively simulate Doppler shift environments that mobile communication systems often encounter.

When in an environment that causes reflections, a wireless communication system will be subject to multipathing. Consider a communication system that operates in a major city. Large buildings made of concrete and glass windows create many reflections of the signal being sent. These reflections cause variation in phase with respect to the original signal. Using PM, we can simulate the impairment of phase variation caused by multipathing. With selectable phase deviation, deviation rate, and offset the PM modulator can effectively simulate a simple multipath environment caused by reflective surfaces.

Multifunction Generator Option 303 allows you to apply multiple impairments simultaneously. If needed, the function generators can be configured such that five impairments are applied at the same time. It is important to note that there are two paths per modulator, which means that no more than two functions can be applied to one modulation type. The FM/PM modulator can only do one modulation type at a time, meaning that PM and FM cannot run simultaneously. AM and FM or AM and PM can be summed, however.

Conclusion

Simulating RF environments using amplitude, frequency, and phase modulation provides a robust and repeatable method for testing communication systems. By leveraging these modulation techniques, engineers can effectively simulate real-world conditions such as fluctuating signal strength, Doppler shifts, and multipath reflections. This approach not only enhances the reliability of testing but also ensures that communication systems are resilient and capable of operating under various impairments. The Multifunction Generator Option 303 further extends this capability by allowing multiple impairments to be applied simultaneously, offering a comprehensive solution for thorough and efficient receiver testing. Through these simulation techniques, we can better prepare and design communication systems to perform reliably in dynamic and challenging environments.

2 Corrections

Corrections/De-embedding Using PathWave E7653APPC Software

De-embedding is used to remove the effects of test fixtures and cabling from the measurement results. De-embedding uses a model of the test fixture and mathematically removes the fixture characteristics (cables, connectors and other passive components) between the source and the device under test (DUT). Once the desired topology has been characterized, its effects can be removed from the output signal, moving the effective reference plane to the point at which the power sensor was connected.

Blocks can be added from supported file formats (.s2p, .csv, .uflat) or by direct measurement, using one of the supported power sensors (power meter, spectrum analyzer, or a network analyzer).

NOTE

The MXG must have the E7653APPC PathWave Automatic Channel Response Correction and S-parameter De-embedding license installed.

Adding Fixture Blocks using s2p Files

Amplitude and phase can be corrected by adding multiple s2p files as Fixture Blocks.

An s2p file (also known as a Touchstone file) is an ASCII text file used for documenting the n-port network parameter data and noise data of linear active devices, passive filters, passive devices, or interconnect networks. Each record contains 1 stimulus value and 4 S-parameters (total of 9 values)

The first line in the figure below (# GHz DB R 50) designates:

– (GHz) designates the frequency in Hz, kHz, MHz, or GHz

– (S) the measurements are in S parameters (rather than Y or Z)

– (DB) the values are given in decibel/angle. Instead of DB, you can have RI (real/imaginary) or MA (magnitude/angle)

– (50) the characteristic impedance is 50 ohms

```
!S2P File: Measurements: S11,S21,S12,S22:
# GHz S DB R 50
   2.5 -100 -100  10.0 -100  10.0 -100 -100 -100
   2.75 -100 -100   5.0 -100   5.0 -100 -100 -100
  3.0 -100 -100   0.0 -100   0.0 -100 -100 -100
  3.25 -100 -100  -5.0 -100  -5.0 -100 -100 -100
  3.5 -100 -100 -10.0 -100 -10.0 -100 -100 -100
```

NOTE

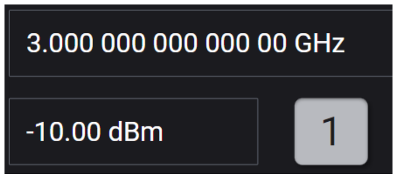
If there is not a first line header, the default format is GHz, S-parameters, and magnitude/angle.

1. Create s2p files in Notepad in the format shown above.

TIP An s2p example file is included on the MXG. Go to

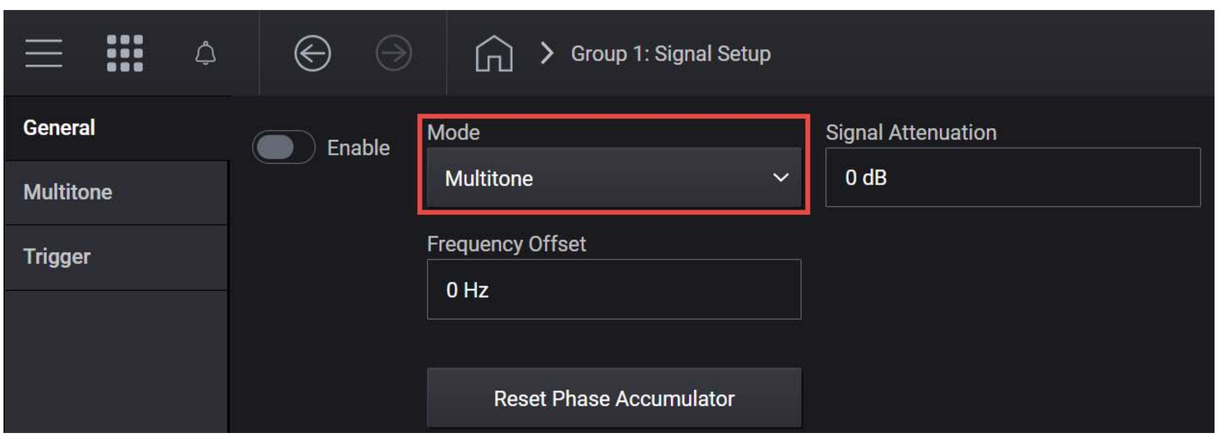
`/Examples/simpleAt3GHzInDB.s2p`

2. Select **Preset** > **Preset** to set the instrument to a known state.
3. In the MXG Output area, set the Frequency to **3 GHz** and **Power** to −10 dBm.



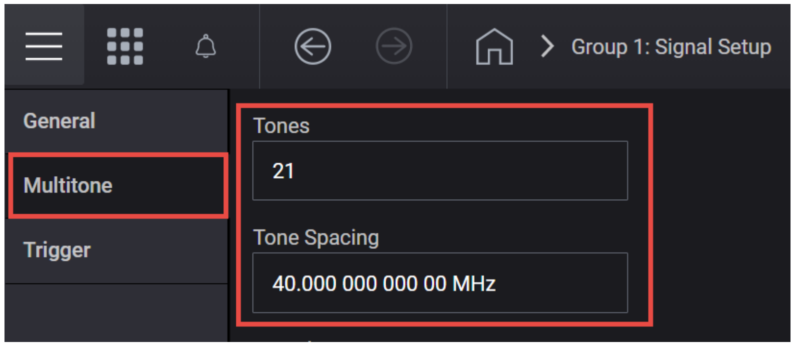
4. Select the **Group 1: Signals** block to open.

5. Select the **Mode** dropdown and select **Multitone**:

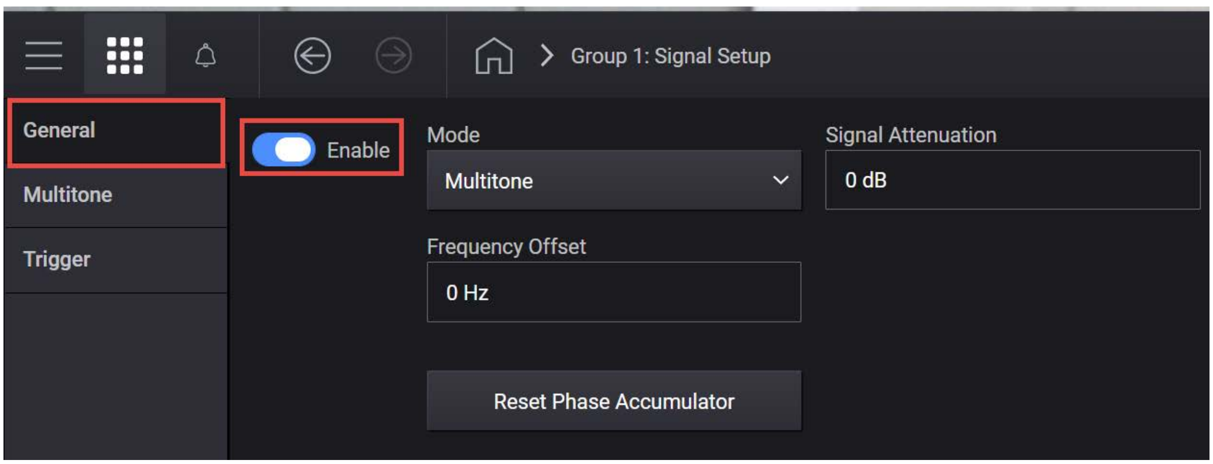


6. From the left pane, select **Multitone** and set:
   – Tones to **21** > **x1**

– Tone Spacing to **40 MHz**



7. Select the **General** tab > **Enable**.



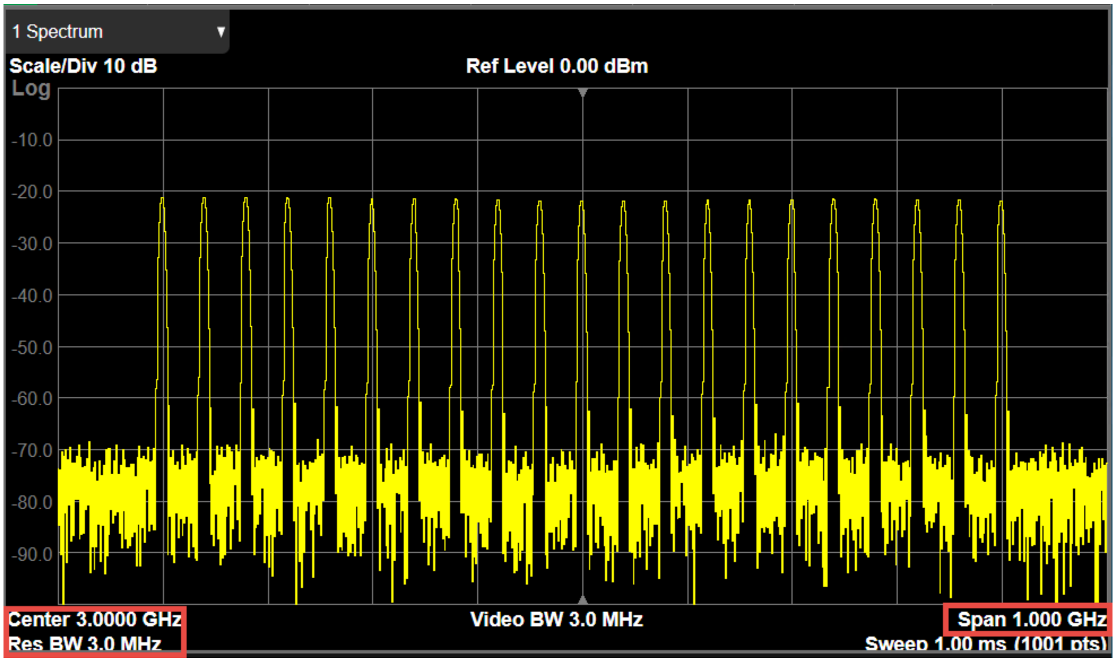
8. Close the Signal block by selecting the **Home** icon, and then select **RF Out** channel number to turn on.

9. On the X-Series Signal Analyzer spectrum analyzer in Spectrum Analyzer Mode:

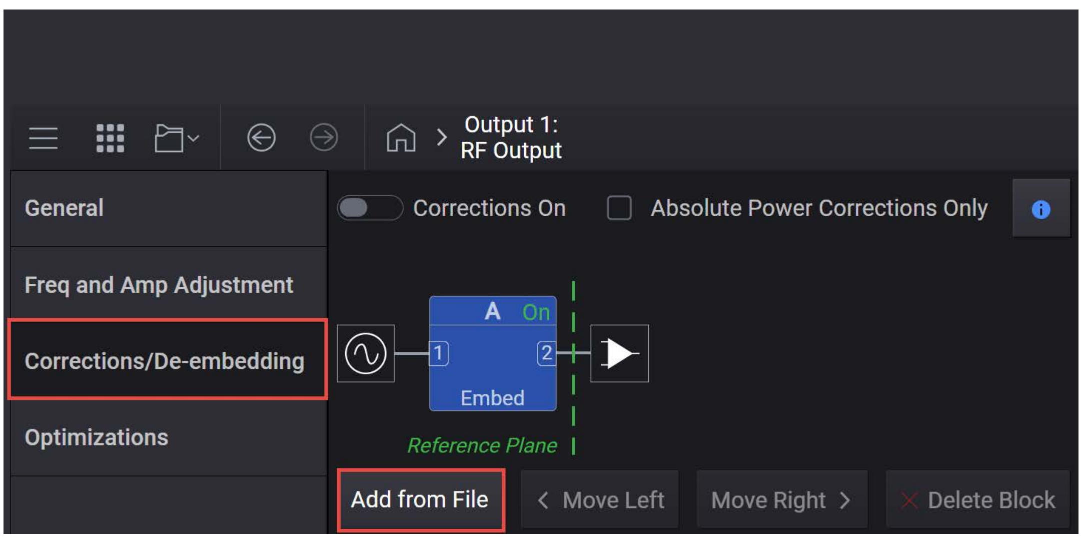
   – Select **Mode Preset** to set Spectrum Analyzer mode to a known state.

   – Set the Center to **3 GHz**

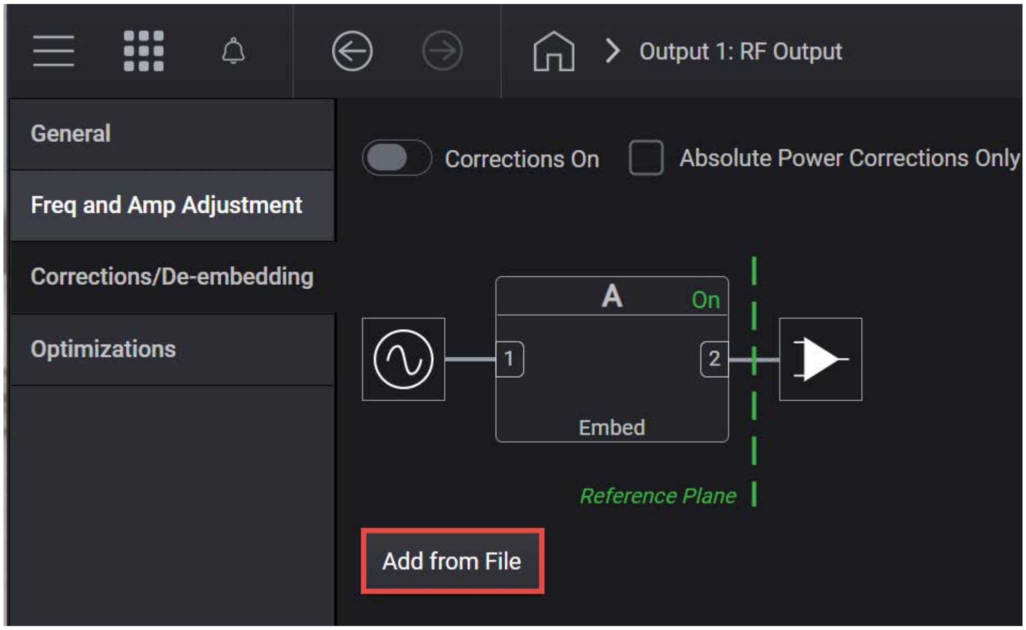
– Set Span to **1 GHz**



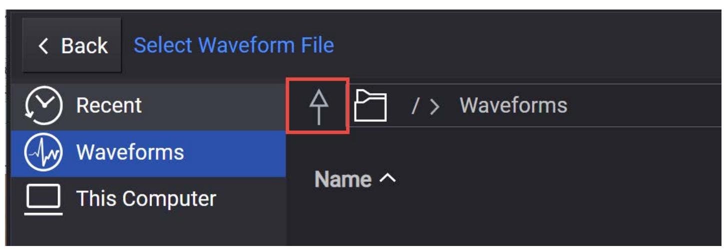
10. On the MXG, select the **RF Output** block > **Corrections/De-embedding**.



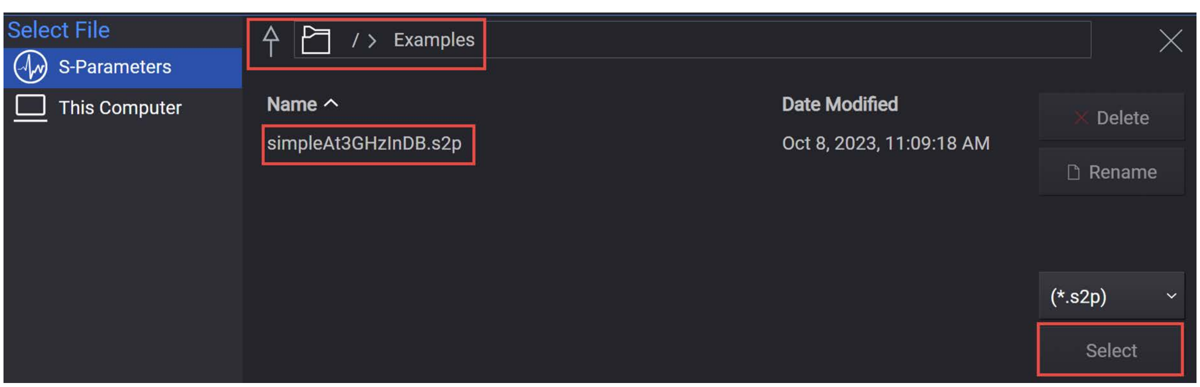
11. In the Corrections Setup dialog, select **Add from File**.



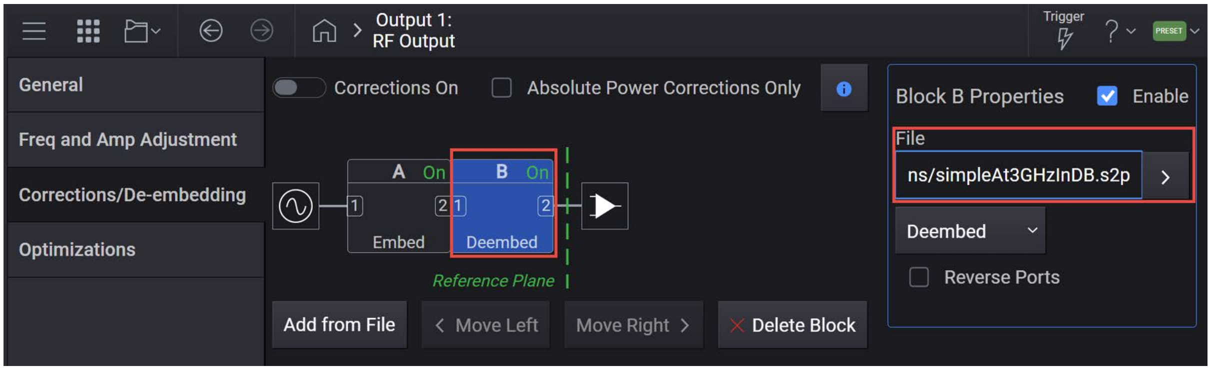
12. Select the **Up arrow** icon to access the Examples folder.



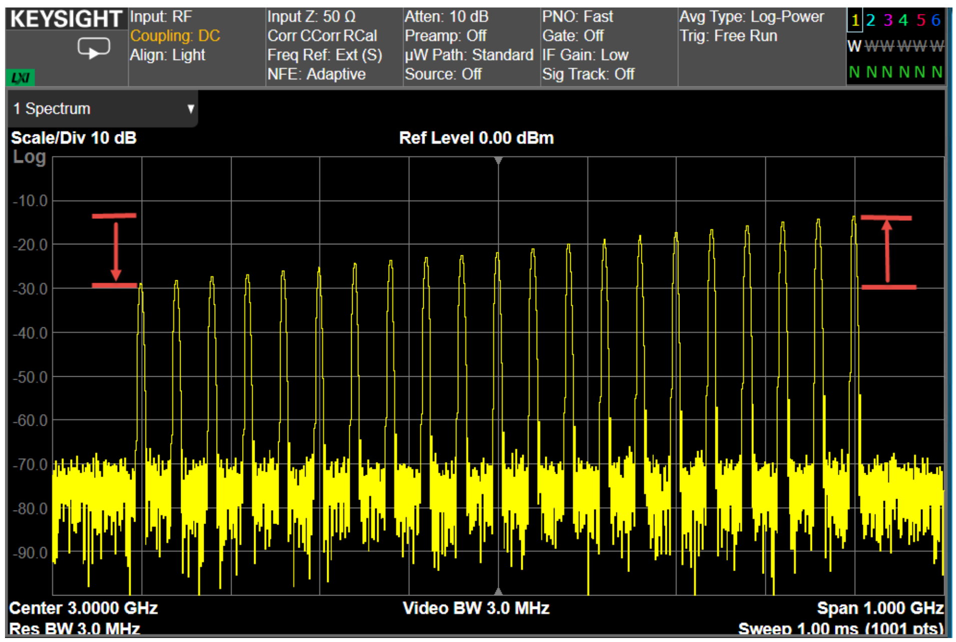
13. From the Examples folder select `simpleAt3GHzInDB.s2p`.



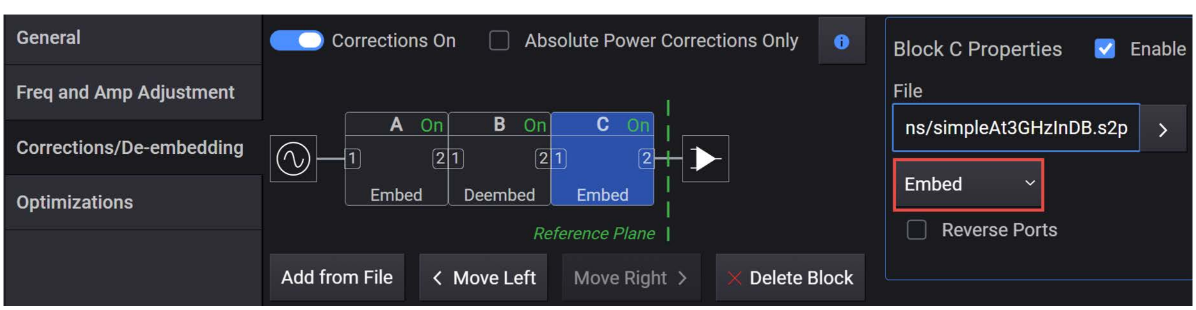
Notice that Block B is added in the Correction Setup diagram.



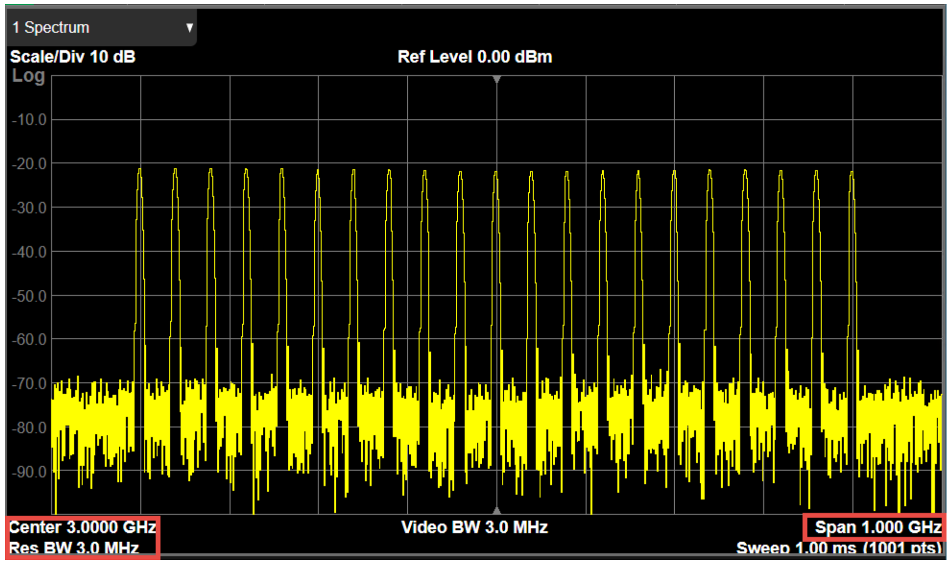
14. At the top of the display, turn **Corrections On**. View the results on the signal analyzer. Observe how the .s2p file has impacted the signal.



15. Add a third block using the same file name as shown in the steps above. Under Block C Properties, set to **Embed**.



View the results on the X-Series spectrum analyzer. Notice that the corrections are no longer shown. This is because the de-embedded corrections applied in Block B cancel the embedded corrections applied in Block C.



Using a Spectrum Analyzer to Make the Corrections Measurement

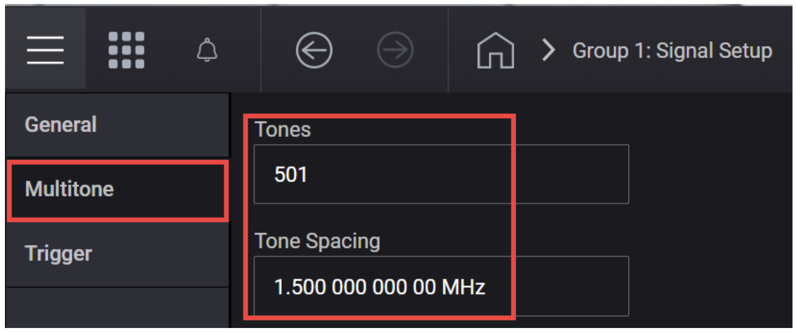
When using a spectrum analyzer, it must be locked to the MXG Frequency Reference. This is important because the power measurement can be inaccurate due to a narrow resolution bandwidth (RBW) used in the spectrum analyzer. Supported Keysight X-Series signal analyzers are:

– N9000A/B CXA
– N9010A/B EXA
– N9020A/B MXA
– N9021B MXA
– N9030A/B PXA
– N9032B PXA
– N9040B, N9041B, or N9042B UXA

On the MXG:

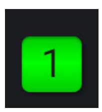
1. Connect the Ref Out to the N90x0A/B Ext Reference In.
2. Connect cable or DUT between the MXG RF Out and the signal analyzer RF in.
3. Select **Preset** > **Preset** to set the instrument to a known state.
4. Set the Frequency to **3 GHz** and Amplitude to **–10 dBm**.

5. Select the **Signal** block to open.
6. Select the **Mode** dropdown and select **Multitone**.
7. Select the **Multitone** tab from the left panel and then, configure the signal to have **501 Tones** with **1.5 MHz Tone Spacing.**



8. Select the **General** tab > **Enable**.
9. Select the **Home** icon and set RF Out to **On** by selecting the numbered channel indicator switch.

   This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel MXG.



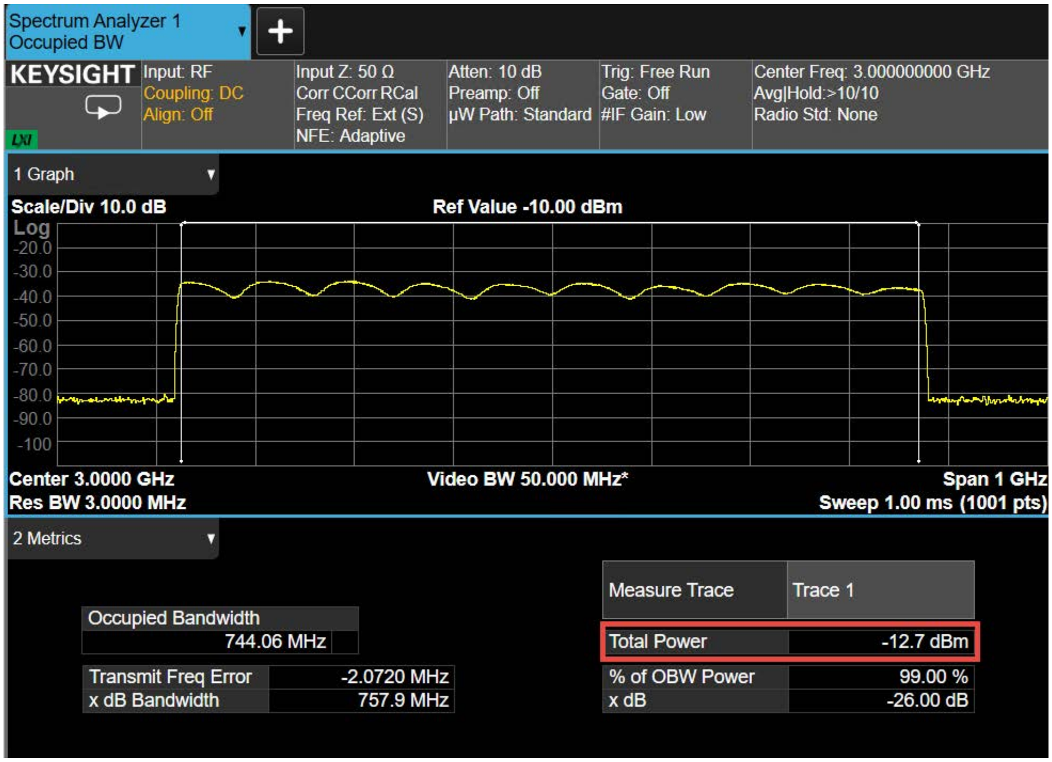
On the Signal Analyzer:

1. From the Menu Panel (on the top right of the display), select **Mode/Meas** > **Spectrum Analyzer** mode > **Occupied BW Measurement** > **OBW Results** View.

NOTE If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

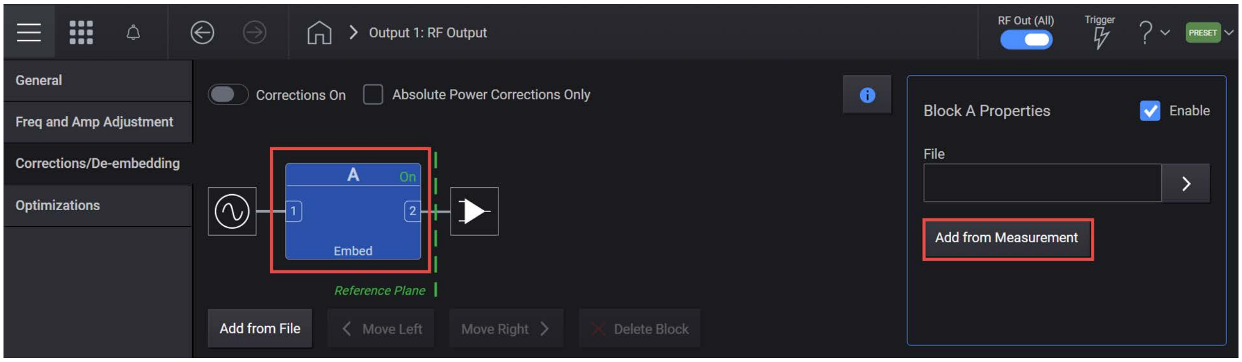
2. Set the Center Frequency to **3 GHz** and the Span to **1 GHz**.

   Observe how the fixturing is impacting this signal, including the flatness and the total power.

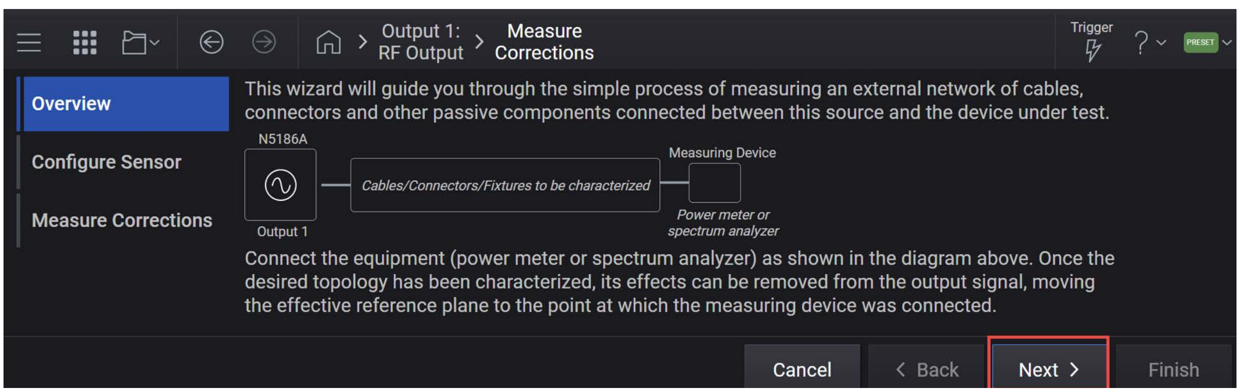

Spectrum Analyzer 1
Occupied BW
KEYSIGHT
Input: RF
Coupling: DC
Align: Off
Input Z: 50 Ω
Corr CCorr RCal
Freq Ref: Ext (S)
NFE: Adaptive
Atten: 10 dB
Preamp: Off
µW Path: Standard
Trig: Free Run
Gate: Off
#IF Gain: Low
Center Freq: 3.000000000 GHz
Avg|Hold:>10/10
Radio Std: None
1 Graph
Scale/Div 10.0 dB
Ref Value -10.00 dBm
Log
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100
Center 3.0000 GHz
Res BW 3.0000 MHz
Video BW 50.000 MHz*
Span 1 GHz
Sweep 1.00 ms (1001 pts)
2 Metrics
Occupied Bandwidth
744.06 MHz
Transmit Freq Error -2.0720 MHz
x dB Bandwidth 757.9 MHz
Measure Trace Trace 1
Total Power -12.7 dBm
% of OBW Power 99.00 %
x dB -26.00 dB

On the MXG:

1. Select the **RF Output** block > **Corrections/De-embedding** tab to open the Correction Setup.
2. Select **Block A** to highlight > **Add from Measurement** to open the Measure Corrections Block Wizard.

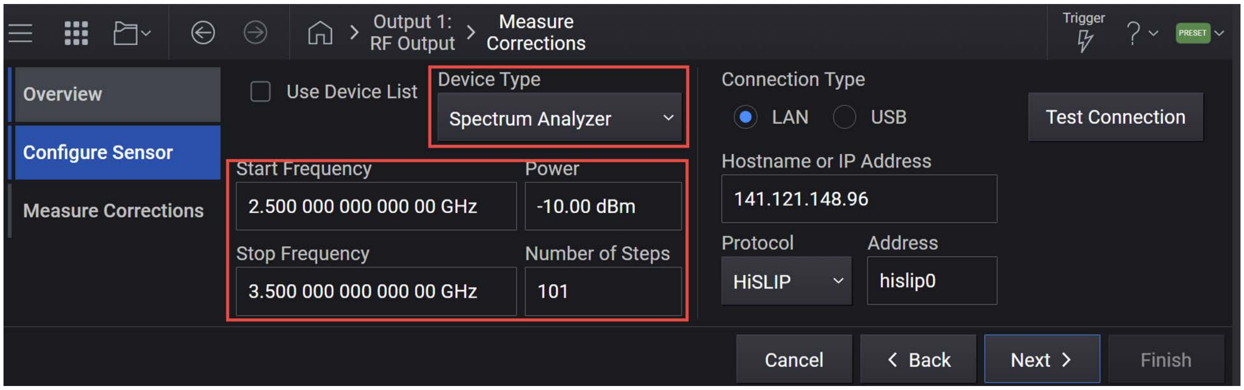


3. Connect the power sensor (in this case, the X-Series signal analyzer) as shown in the diagram below. After reading the overview, select **Next** to move to the Configure Sensor setup.

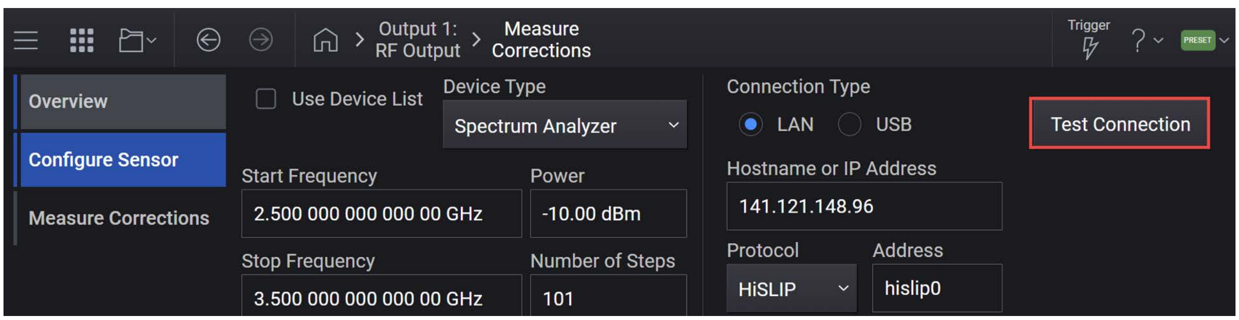


4. In the Configure Sensor setup, select the **Device Type** dropdown and select **Spectrum Analyzer**.
5. Set the Start and Stop Freq, Amplitude, and the Num Steps. For this example Start Freq **2.5 GHz**, Stop Freq **3.5 GHz**, Amplitude to the highest power used in your measurement (For this example, **-10 dBm**, which we

already set in the main window. If you change the value here, it will update the value in the main measurement window.) and Number of Steps to **101** > **x1**.

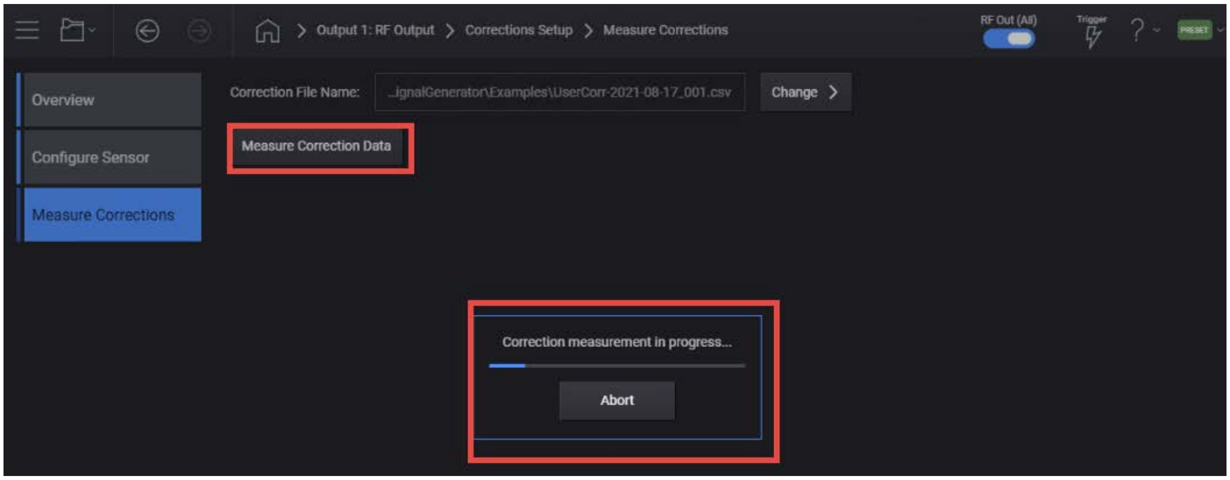


6. Set Connection Type to **LAN**, enter the LAN Address and set the Protocol parameters to **HiSLIP,** and then select **Test Connection**.



7. Once you are successfully connected, select **Next** to move to the Measure Corrections step.
8. Select **Measure Correction Data**.

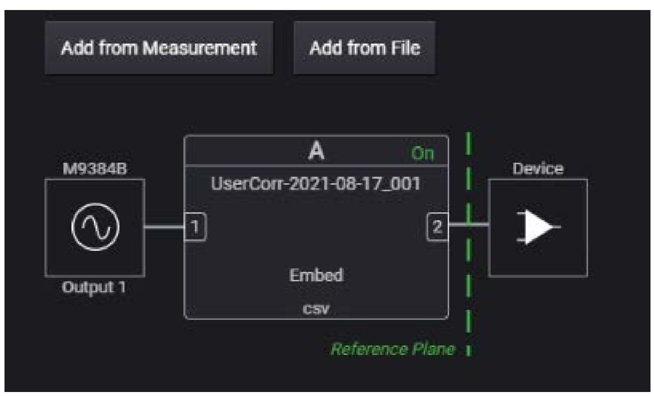
During the measurement, the MXG outputs a CW between the Start and Stop Frequencies for the specified number of steps and output power. It will take some time to measure all 101 points, and the progress is indicated by the blue bar. You can watch the signal analyzer as it steps through this process.



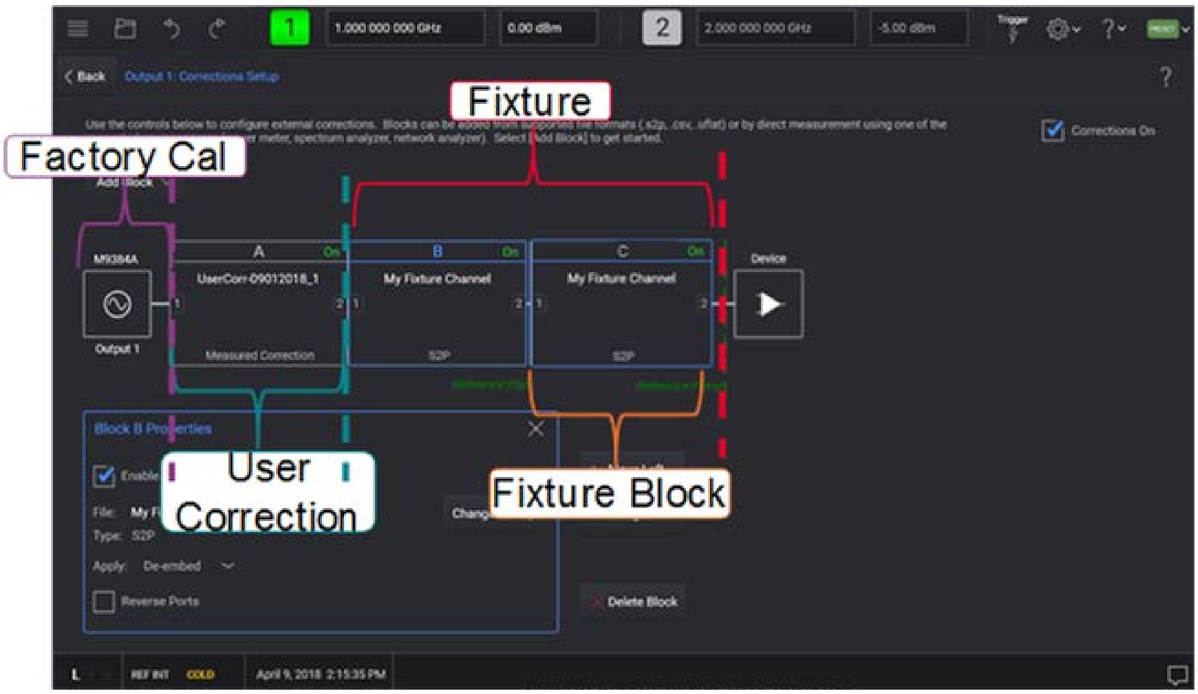
The measurement results are saved to a csv file using an automatically generated file name.

9. When the measurement is complete, select **Finish**, then set **Corrections On**.

   The output csv file is set to Block A.



Block A is dedicated for User Correction. The image below shows how blocks are assigned in the User Correction and Fixture block.



10. On the signal analyzer, **Restart** the (on the left corner of the user interface) measurement (because it is applying averaging). Observe how the measured corrections impacted the signal. You can easily toggle Corrections on and off on the MXG to see the difference.

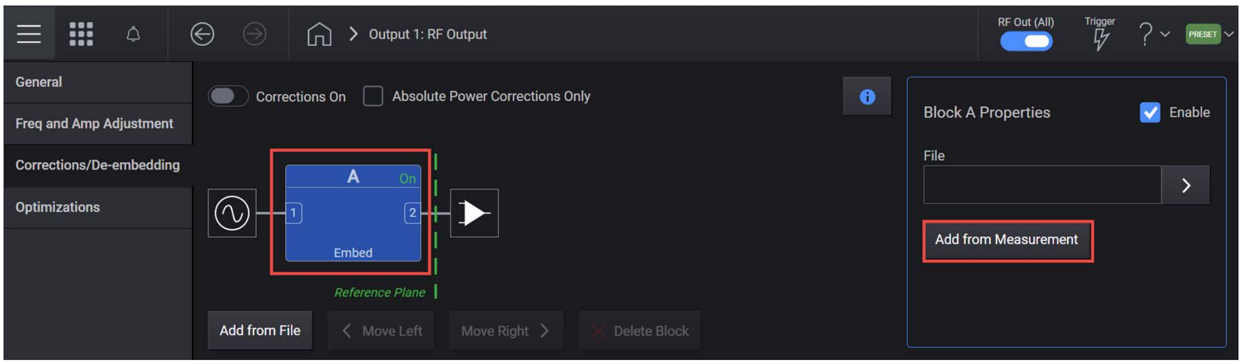
Using a Power Meter to Make the Corrections Measurement

The following USB power sensors can be used for the power measurement.

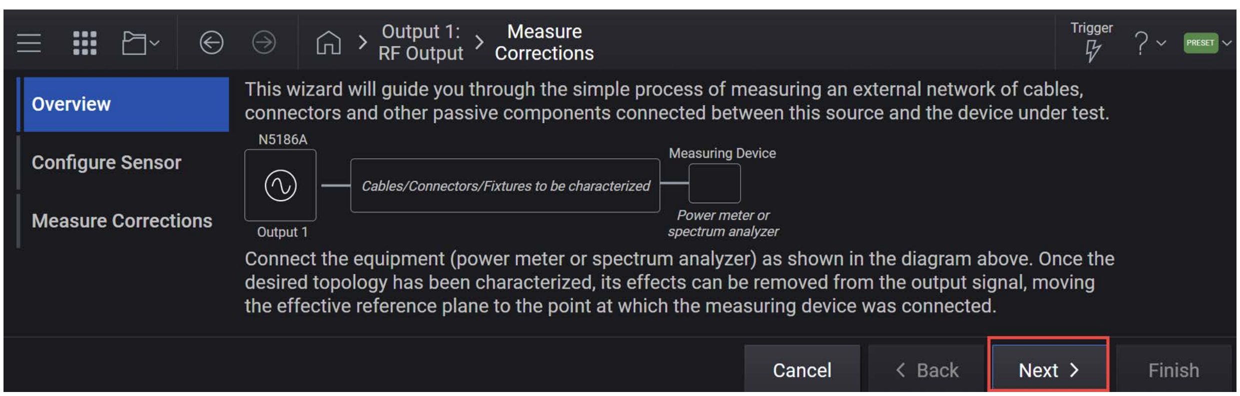
– U8487A-CFG007
– U8485A-CFG006
– U2000A
– U2001A
– U2002A
– U2004A
– U2000B
– U2001B
– U2000H
– U2001H
– U2002H

On the MXG:

1. Connect the MXG 10 MHz Out to the N90x0A/B Ext Reference In.
2. Select the **RF Output** block > **Corrections/De-embedding** tab to open the Correction Setup.
3. Select the **A block** (to highlight), then **Add from Measurement** to open the Measure Corrections Block Wizard.

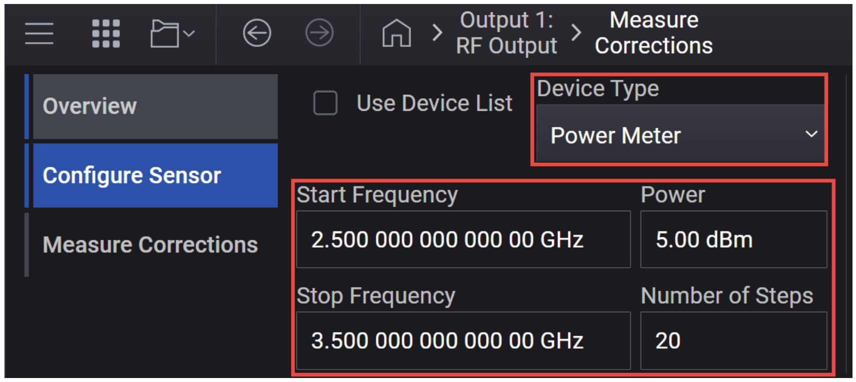


4. Connect the power sensor as shown in the diagram below then select **Next**.



5. Select **Next** to go to Configure Sensor dialog and select the **Power Measurement Device** dropdown > **Power Meter**.

6. Set the Start and Stop Freq, Amplitude, and the Num Steps. For this example Start Freq **2.5 GHz**, Stop Freq **3.5 GHz**, Amplitude to the highest power used in your measurement **5 dBm**, and Num Steps to **20**.

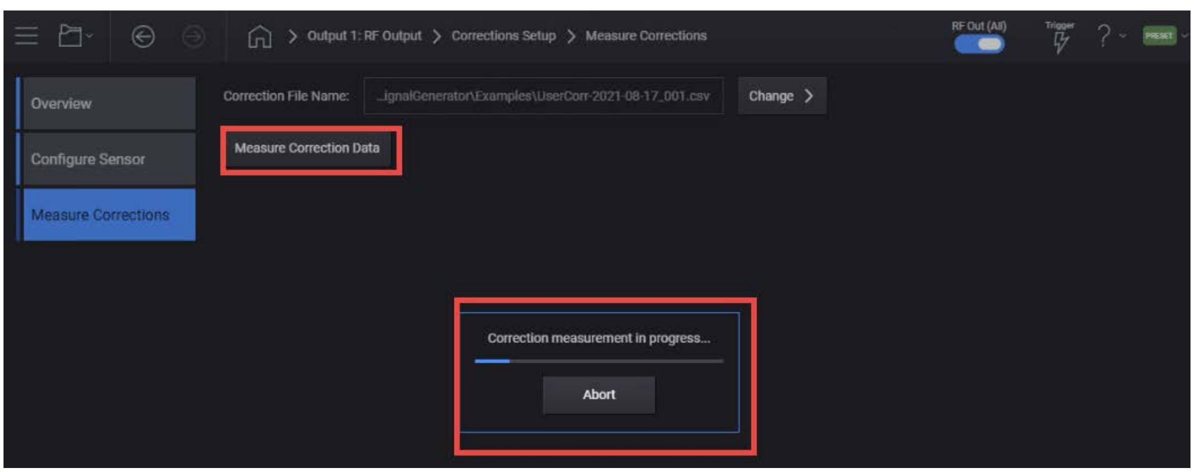


7. Select the Connection Type to **USB**, and then specify the Device and VISA Address.

8. Select **Test Connection** to verify connectivity, and then select **OK** then **Next** to continue.

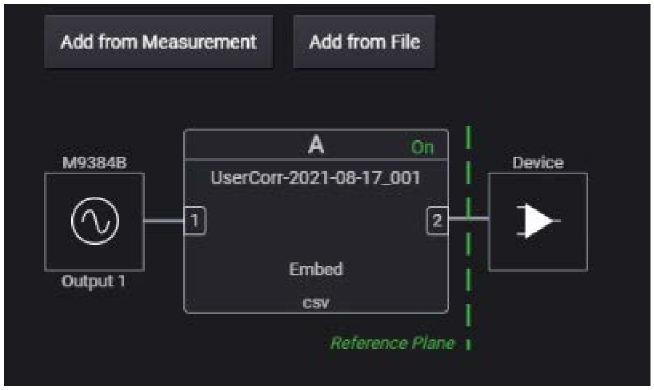
   You can also calibrate and zero out the power sensor before measuring corrections.

9. Select **Next** to go to the Measure Corrections dialog and select **Measure Correction Data**.

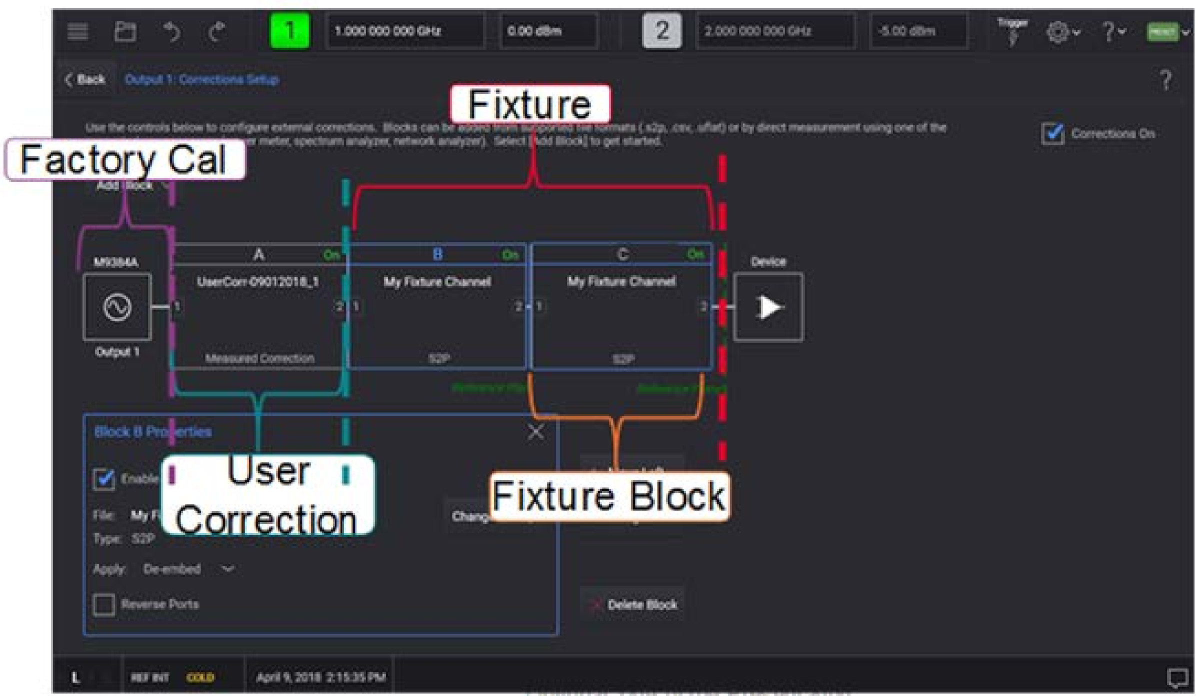


During the measurement, the MXG outputs a CW between the Start and Stop Frequencies for the specified number of steps and output power. The measurement results are saved to a csv file using an automatically generated file name.

10. Select **Finish**. The output csv file is set to Block A.



Block A is dedicated for User Correction. The image below shows how blocks are assigned in the User Correction and Fixture block.



11. Select **Corrections On** to apply.

Using the equivalent SCPI commands

Using a spectrum analyzer to make the corrections measurement

On the MXG:

`SYSTem:PRESet`

Set the power level to the highest level used in your measurement.

```
RF1:POWer:AMPLitude 5dBm
CORRection:PMDevice SANalyzer
CORRection:FLATness:STEP:STARt 5GHZ
CORRection:FLATness:STEP:STOP 7GHZ
CORRection:FLATness:STEP:POINts 20
CORRection:SANalyzer:COMMunicate:TYPE SOCKets
```

Set the LAN address and protocol parameters for your spectrum analyzer.

```
CORRection:SANalyzer:COMMunicate:LAN:IP "192.168.1.5"
CORRection:SANalyzer:COMMunicate:LAN:PORT 5025
CORRection:FLATness:CALibrate
CORRection ON
```

Using a power meter to make the corrections measurement.

On the MXG:

```
SYSTem:PRESet
RF1:POWer:AMPLitude 5dBm
CORRection:PMDevice PMETer
CORRection:FLATness:STEP:STARt 2.5GHZ
CORRection:FLATness:STEP:STOP 3.5GHZ
CORRection:FLATness:STEP:POINts 20
CORRection:SANalyzer:COMMunicate:TYPE USB
```

NOTE Use query `CORRection:PMETer:COMMunicate:USB:LIST?` for a list of all connected USB devices.

`CORRection:PMETer:COMMunicate:USB:DEVice “instr0”`

[Optional] `CORRection:PMETer:CALibrate`

[Optional] `CORRection:PMETer:ZERO`

`CORRection:FLATness:CALibrate`

```
CORRection ON
```

Adding fixture blocks using s2P files

On the MXG:

```
SYSTem:PRESet
RF1:FREQuency:CW 3GHZ
RF1:POWer:AMPLitude -20dBm
SIGNal1:MODE MTONe
SIGNal1:MTONe:ARB:NTON 21
SIGNal1:MTONe:ARB:FSP 100MHZ
SIGNal1 ON
RF1:OUTPut:STATe ON
```

For multi-channel instruments, set RF Out (all) to On.

```
RFALl:OUTPut ON
```

On the X-Series Signal Analyzer:

```
SYSTem:PRESet
FREQuency:CENTer 3GHZ
FREQuency:SPAN 1GHZ
```

On the MXG:

Set the path to the s2p data as block 2 (you can use 1 through 4).

```
CORRection:BLOCk2:FILE "FixtureChannel2"
CORRection:BLOCk2 ON
```

Add block C with the same file.

```
CORRection:BLOCk3:FILE "FixtureChannel2"
```

Change Block C to Embed.

```
CORRection:BLOCk3:APPLy EMBedding
CORRection:BLOCk3 ON
```

3 5G New Radio (NR) Measurements

This section includes the following topics:

5G Waveform, EVM, and ACP Analysis

The MXG enables 5G testing with a low error vector magnitude (EVM). The MXG has extremely good EVM at high power levels. However, not all signal analyzers can capture this low value. We will use the X-Series signal analyzer with the 5G NR X-Series application and the VSA software to observe EVM and adjacent channel power (ACP).

Setting Up Triggers on the Signal Analyzer using 5G NR Mode

NOTE Refer to "Equipment Setup" on page 9 for connecting the instruments.

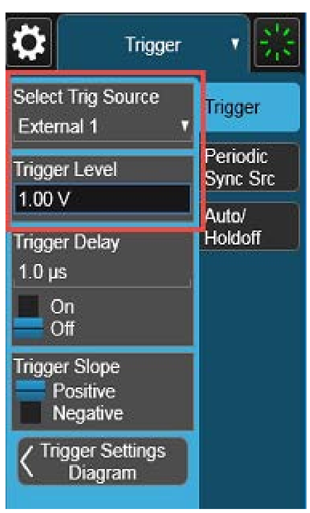
Setting Up Triggers on the X-Series Signal Analyzer

Using the graphical user interface

1. On the signal analyzer, select **Mode/Meas** > **5G NR & V2X** mode.

NOTE If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

2. Select **Mode Preset** to set 5G NR mode to a known state.
3. Select **Mode/Meas** > **5G NR V2X** Mode > **Modulation Analysis** Measurement.
4. From the Menu Panel (on the top right of the display), select **Trigger** and set Select Trigger Source to **External 1** and Trigger Level to **1 V**.



Using the equivalent SCPI commands

On the X-Series Signal Analyzer:

```
INSTrument:CONFigure:NR5G
```

```
SYSTem:PRESet
```

Change the current window to 5G NR Modulation Analysis Measurement Mode

```
INSTrument:CONFigure:NR5G:EVM
```

```
TRIGger:EVM:SOURce EXTernal1
```

```
TRIGger:EXTernal1:LEVel 1V
```

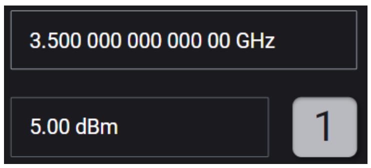
Setting Up a 1 CC 3.5 GHz EVM Measurement

NOTE

Ensure the equipment and triggers are properly configured. Refer to "Equipment Setup" on page 9 and "Setting Up Triggers on the Signal Analyzer using 5G NR Mode" on page 96.

On the MXG:

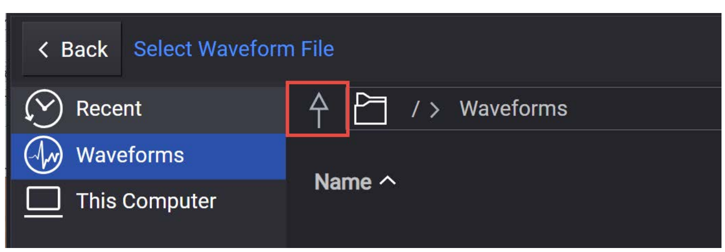
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. In the Output 1 area, set Frequency to **3.5 GHz** and Power to **5 dBm**.



3. Select **Group 1: Signals** block to open.

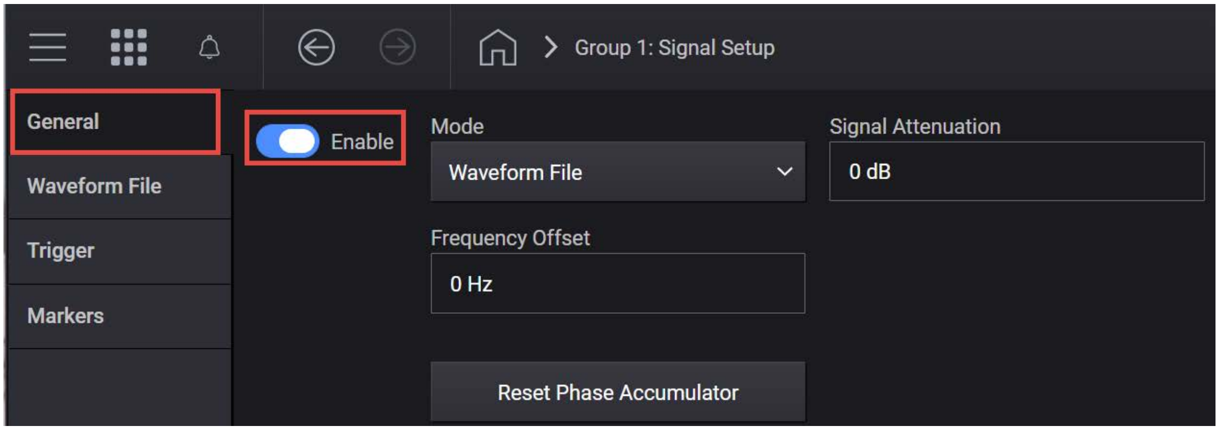
4. From the **Waveform** tab on the left side of the display, choose File **Select** to navigate to the **Waveforms** folder.

5. Select the **Up arrow** icon to access the Examples folder.

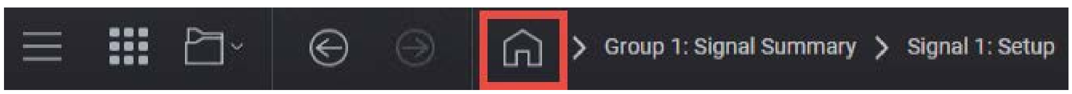


6. Open the Examples folder and highlight `5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC Punctured.wfm`, then **Select**.

7. Select the **General** tab > **Enable**.



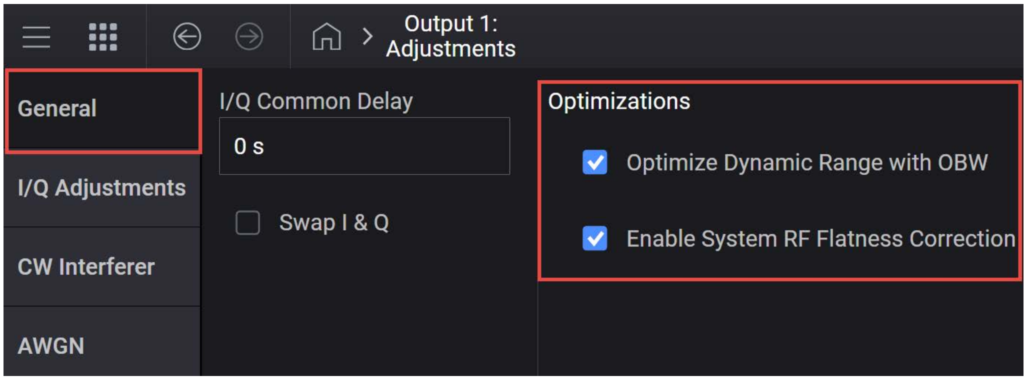
8. Close the Vector Modulation Signal Setup by selecting the **Home** icon at the top of the display.



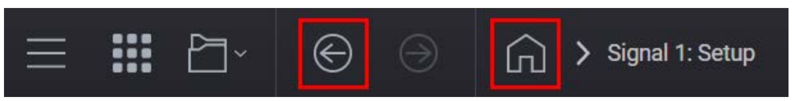
9. Select the **Adjustments** block and select **Optimize Dynamic Range with OBW** and **Enable System RF Flatness Correction.**

   Optimize Dynamic Range with OBW This setting filters the system RF flatness correction coefficients over the instantaneous bandwidth indicated in the waveform header (or in the "Occupied Bandwidth" settings area under the Signal block > Occupied Bandwidth setting). This has the potential to improve EVM performance by not having to correct for flatness errors outside the requested bandwidth. For example, if RF flatness correction was done at 960 MHz, but you are only interested in an 800 MHz section, then applying the correction flatness to that portion only can improve signal to noise ratio, and therefore EVM when there is a lot of hardware roll off.

   Enable System RF Flatness Correction - Disabling this function disables the factory calibrated RF channel flatness equalizer. Depending on the hardware channel response, this may hurt or improve the EVM. This is due to the dynamic range implications as it relates to signal to noise ratio. The greater the RF hardware variations in flatness, the greater the amount of correction is required, the greater the correction effectively reduces the number of resolution DAC bits that can be used, which degrades the signal to noise ratio and therefore potentially EVM. The trade-off is to balance between flatness and signal to noise ratio.

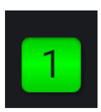


10. Close the Adjustments Setup by either selecting the Back or the Home icon at the top of the display.



11. Set RF Out to **On** by selecting the numbered channel indicator switch.

    This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel MXG.



12. **For multi-channel instruments only:** In the top right corner of the display, set RF Out (All) to **On** by selecting the switch.

NOTE

In order to turn on RF for any channel, both the RF Out for the specific channel (for example, Channel 1 or Channel 2), and RF Out All must be turned on.

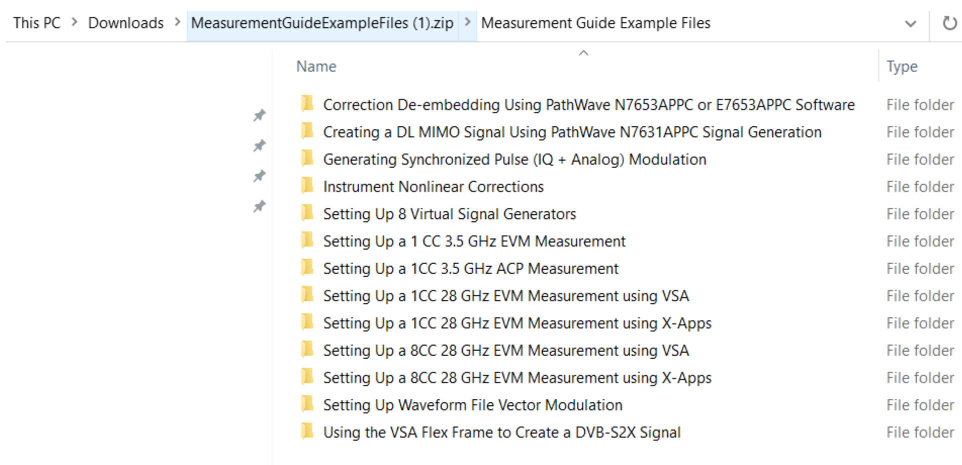
Demodulate the Waveform Using the X-Series Signal Analyzer Embedded Application

NOTE

You will need to copy the setup files to the X-Series Signal Analyzer or the PC running the VSA application. Go to:

https://www.keysight.com/us/en/lib/software-detail/instrument-firmware-software/measurement-guide-example-files.html

Select Download and wait for the zip file to finish downloading to your Downloads folder. This may take a few minutes as it is a 2 GB file. You will find the setup file(s) under the applicable Measurement name.



1. On the signal analyzer, select **Mode/Meas** > **5G NR & V2X** mode.

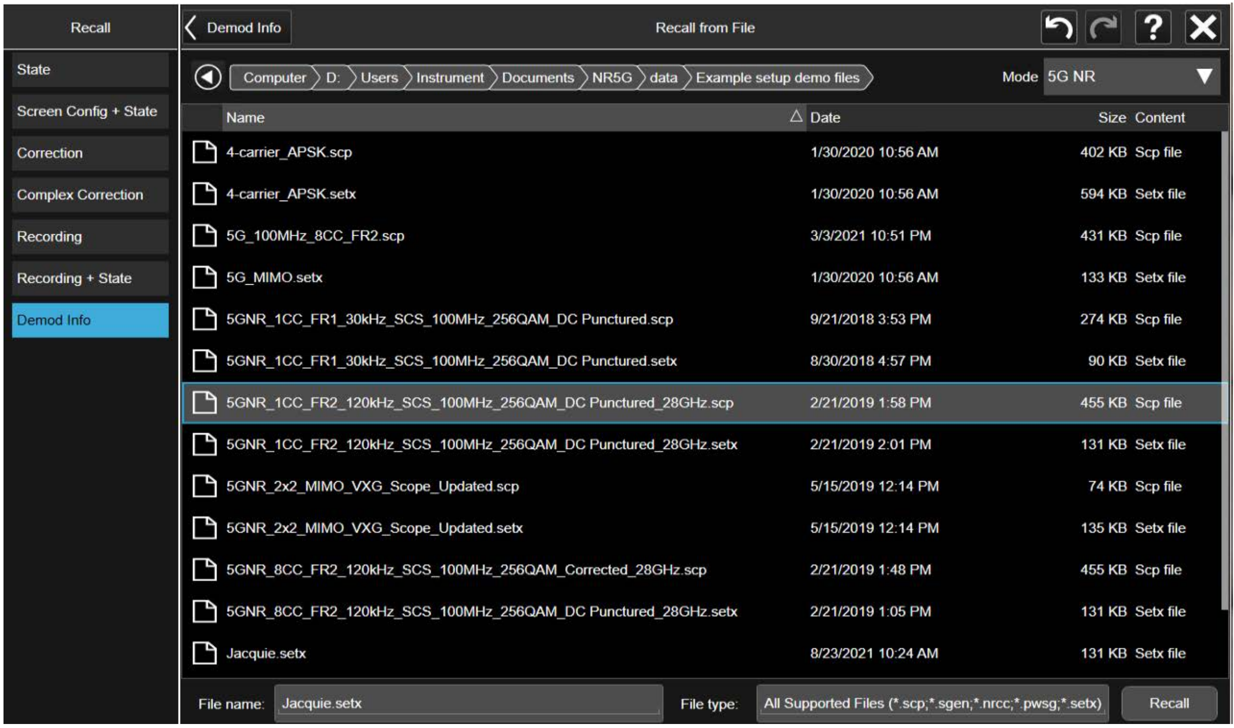
NOTE

If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

2. Select **Mode Preset** to set 5G NR mode to a known state.
3. Select **Mode/Meas** > **5G NR V2X** Mode > **Modulation Analysis** Measurement.
4. Select **Recall** (If accessing the signal analyzer remotely, select the Folder icon at the bottom of the display) **Demod Info** > Set Data Type to **CC Setup** > **Recall From** >

`5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC punctured_34.scp`

Recall



5. Select **Frequency** > **Carrier Reference Frequency** > **3.5 GHz**.
6. Select **Meas Setup** > **Advanced** tab > **Advanced Demod Setup** and ensure that RF for Phase Compensation Auto is *not* selected and the value is **0 Hz**. **Close** the Advanced Settings table.
7. Select the **Settings** tab > **Optimize EVM**.

   The Optimize EVM function automatically sets the combination of preamplification, mechanical and electronic attenuation, and IF gain based on the measured signal peak level.

   EVM should be less than 1%.


5G NR & V2X 1
Modulation Analysis
KEYSIGHT
Input: RF
Coupling: DC
Align: Light
Input Z: 50 Ω
Corr CCorr RCal
Freq Ref: Ext (S)
Atten: 24 dB
Preamp: Off
µW Path: Bypass
#PNO: Best Wide
Trig: Free Run
#IF Gain: 11 dB
Carrier Ref Freq: 3.500000000 GHz
CC Info: DL, 8 CCs, SISO
1 CC0-BWP1
IQ Meas Time
I-Q
-3.890
µ = 1: 30 kHz
3.890
2 CC0
Raw Main Time
Scale/Div 10.00 dB
Start: 0.00 ns
Stop: 22.00 ms
3 CC0
Spectrum
Scale/Div 10.00 dB Ref Value 0.00 dBm
Ctr: 3.500000000 GHz
Width: 110.6 MHz
Res BW: 100 Hz
4 Error Summary
CC0
Channel Power (Active / Total) 4.62 dBm / 4.62 dBm
EVM (RMS / Peak) 0.25 % / 1.39 %
Frequency Error (RMS / Worst) 83.7 mHz / 242.8 mHz
Symbol Clock Error -0.001 ppm
IQ Offset (SISO) -42.48 dB
Time Offset 5.812 ms
Sync Correlation 99.6 %
Sync Source SS Block
Magnitude Error 0.18 %
Phase Error 0.00 rad

Using the equivalent SCPI commands

On the MXG:

```
SYSTem:PRESet
RF1:FREQuency:CW 3.5GHZ
RF1:POWer:AMPLitude 5dBm
SIGNal1:MODE WAVeform
```

Navigate to the desired waveform file.

```
SIGNal1:WAVeform “/Examples/
5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC punctured.wfm”
SIGNal1 ON
IQO:CORR:OPT:DYN:RANG:OBW ON
RF1:OUTPut ON
```

For multi-channel instruments, set RF Out (all) to On.

```
RFALl:OUTPut ON
```

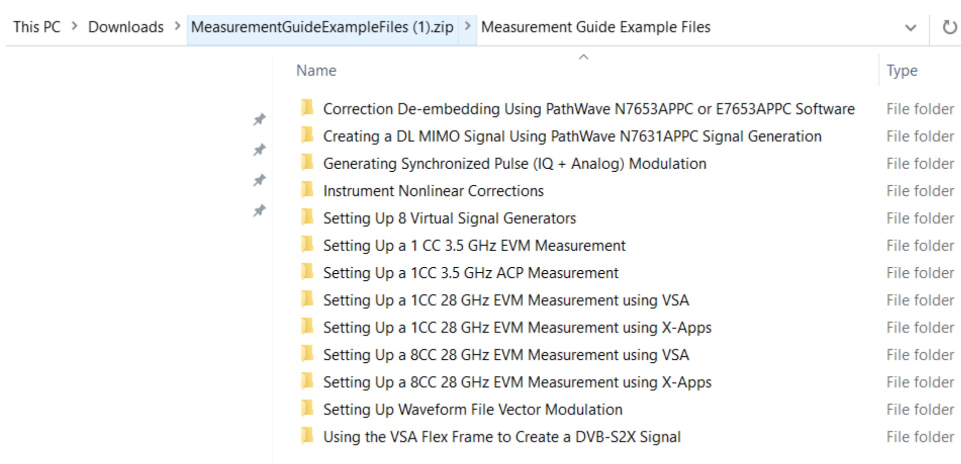
On the X-Series Signal Analyzer:

NOTE

You will need to copy the setup files to the X-Series Signal Analyzer or the PC running the VSA application. Go to:

https://www.keysight.com/us/en/lib/software-detail/instrument-firmware-software/measurement-guide-example-files.html

Select Download and wait for the zip file to finish downloading to your Downloads folder. This may take a few minutes as it is a 2 GB file. You will find the setup file(s) under the applicable Measurement name.



```
MMEMory:LOAD:EVM:SETup CC0,
“D:\Users\Instrument\Documents\NR5G\data\NR5GEvm\CarrierSetu
p\5GNR_1CC_FR1_30kHz SCS_100MHz_256QAM_DCpunctured.scp”

EVM:CCARrier0:TIME:LENGth:SEARch 10ms

EVM:CCARrier0:TIME:LENGth:RESult 2

EVM:CCARrier0:FRAMe:TRIGger ON

EVM:CCARrier0:DC:PUNCture ON

EVM:CCARrier0:PHASe:COMPensation:AUTO OFF

EVM:CCARrier0:PHASe:COMPensation:FREQuency 0 Hz

EVM:OPTimize
```

Demodulate the Waveform Using the 89601B VSA Software:

1. Open the VSA software by selecting **Mode Meas** > **Launch VSA**.

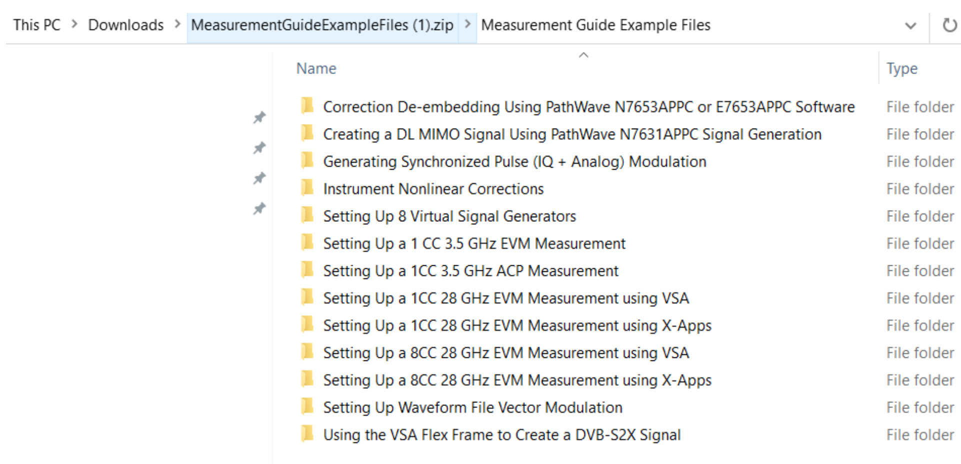
NOTE If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

2. From the menu bar, select **File** > **Preset** > **All** to set the VSA to a known state.

NOTE You will need to copy the setup files to the X-Series Signal Analyzer or the PC running the VSA application. Go to:

https://www.keysight.com/us/en/lib/software-detail/instrument-firmware-software/measurement-guide-example-files.html

Select Download and wait for the zip file to finish downloading to your Downloads folder. This may take a few minutes as it is a 2 GB file. You will find the setup file(s) under the applicable Measurement name.

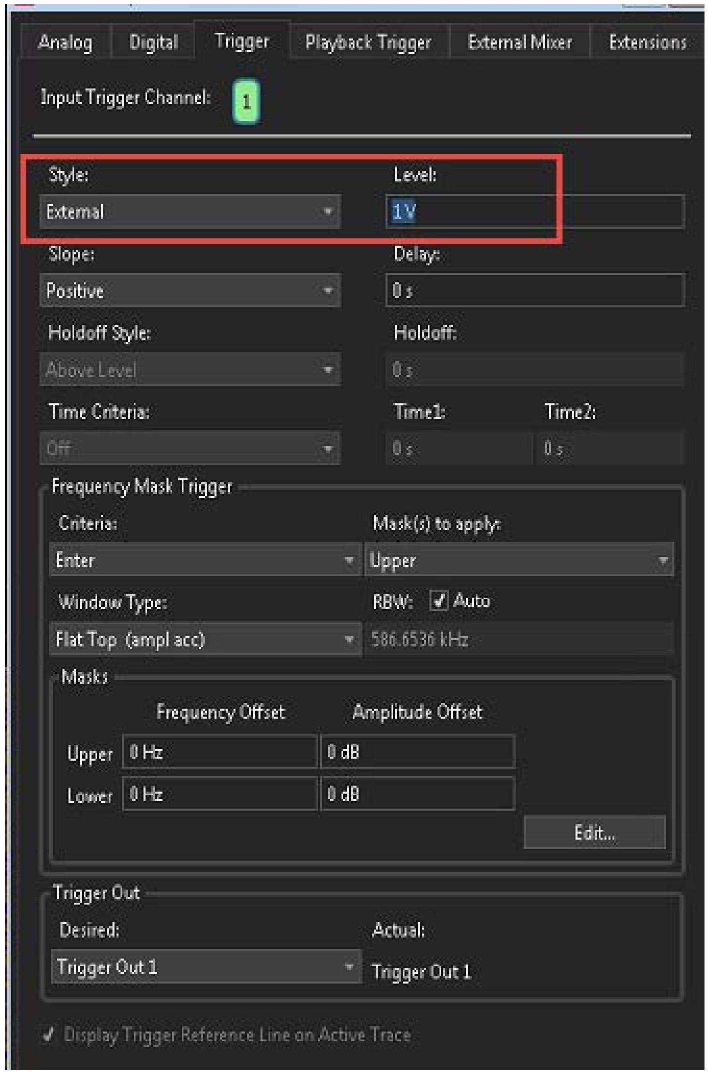


3. Select **File** > **Recall** > **Recall Setup** and navigate to `5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC punctured.setx`

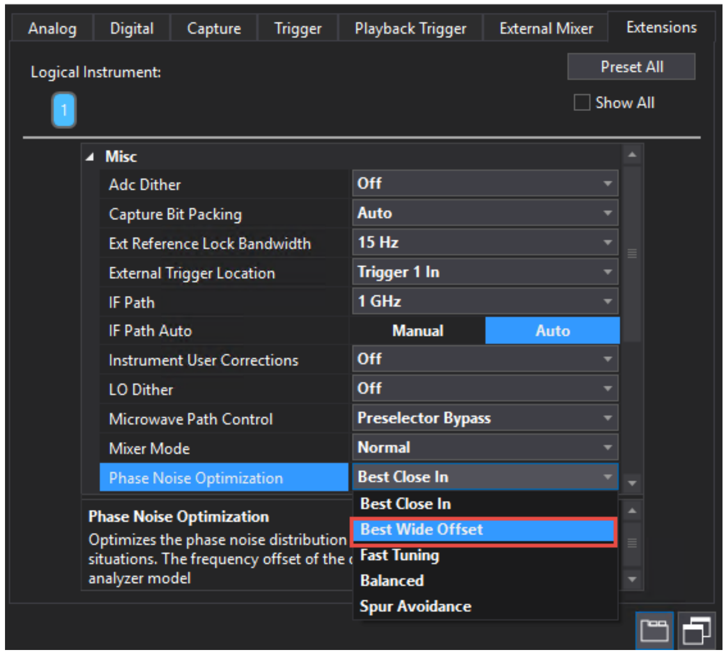
4. From the toolbar, select the **Pause** Icon. 

   Pausing the measurement will help speed up the setup time.

5. From the menu bar, select **Input** > **Trigger** and set Style to **External** and Level to **1.0 V**.



6. Select the **Extensions** tab and change the External Trigger location to **Trigger 1 In** (if using an N9040B with Option H1G, select Trigger 3) and Phase Noise Optimization to **Best Wide Offset**.

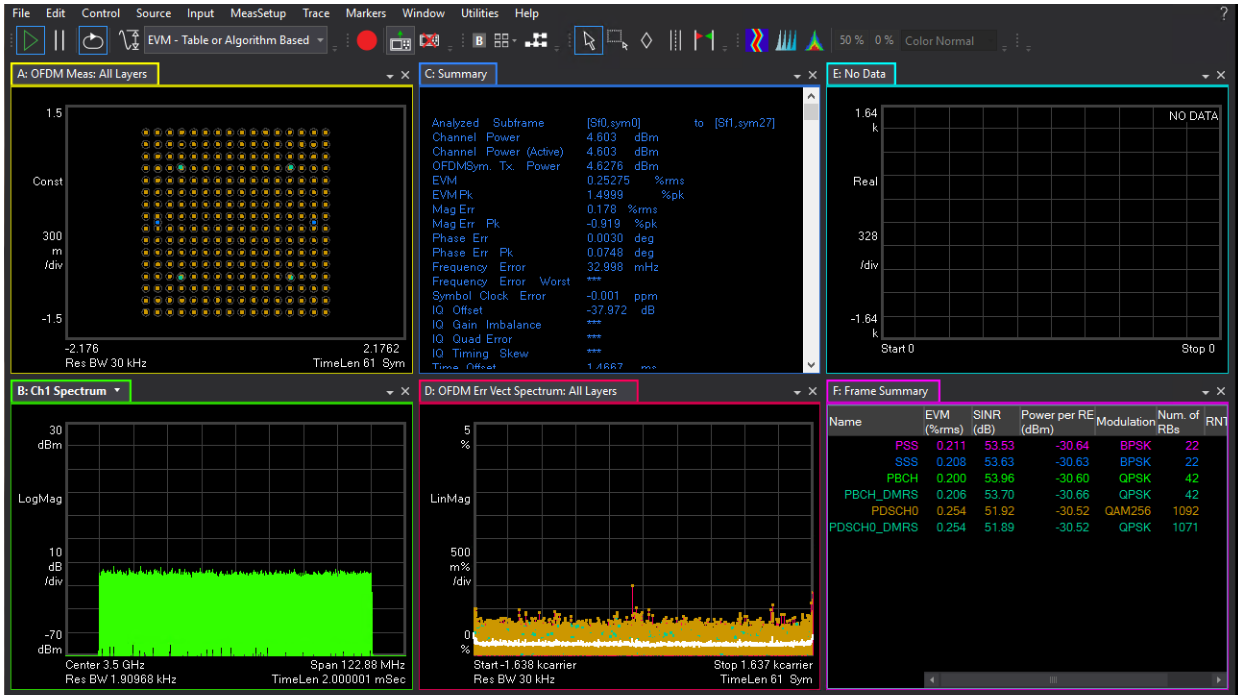


7. From the toolbar, select the **Auto-Rang**e dropdown and select **EVM-Table or Algorithm Based**.

   – EVM - Table or Algorithm Based performs EVM optimization based on prescribed table/algorithm instead of using EVM in the feedback loop. This method of EVM auto-range is normally faster than Meas Based Iteration, but may not achieve the most optimal setup for minimized EVM.

   – EVM - Meas Based Iteration has a feedback loop around the entire measurement, uses the measured EVM in the feedback loop, and tries to adjust hardware parameters to minimize the EVM. It is the slowest EVM auto-range method, but it should achieve the most optimal setup for good EVM.

8. Select the **Auto-Range** icon to run the measurement for EVM optimization. This may take a few minutes to complete.


File Edit Control Source Input MeasSetup Trace Markers Window Utilities Help
EVM - Table or Algorithm Based
A: OFDM Meas: All Layers
1.5
Const
300 m /div
-1.5
-2.176
2.1762
Res BW 30 kHz
TimeLen 61 Sym
C: Summary
Analyzed Subframe [Sf0,sym0] to [Sf1,sym27]
Channel Power 4.603 dBm
Channel Power (Active) 4.603 dBm
OFDMSym. Tx. Power 4.6276 dBm
EVM 0.25275 %rms
EVM Pk 1.4999 %pk
Mag Err 0.178 %rms
Mag Err Pk -0.919 %pk
Phase Err 0.0030 deg
Phase Err Pk 0.0748 deg
Frequency Error 32.998 mHz
Frequency Error Worst ***
Symbol Clock Error -0.001 ppm
IQ Offset -37.972 dB
IQ Gain Imbalance ***
IQ Quad Error ***
IQ Timing Skew ***
E: No Data
1.64 k
Real
328 /div
-1.64 k
NO DATA
Start 0
Stop 0
B: Ch1 Spectrum
30 dBm
LogMag
10 dB /div
-70 dBm
Center 3.5 GHz
Span 122.88 MHz
Res BW 1.90968 kHz
TimeLen 2.000001 mSec
D: OFDM Err Vect Spectrum: All Layers
5 %
LinMag
500 m% /div
0 %
Start -1.638 kcarrier
Stop 1.637 kcarrier
Res BW 30 kHz
TimeLen 61 Sym
F: Frame Summary
Name | EVM (%rms) | SINR (dB) | Power per RE (dBm) | Modulation | Num. of RBs
PSS 0.211 53.53 -30.64 BPSK 22
SSS 0.208 53.63 -30.63 BPSK 22
PBCH 0.200 53.96 -30.60 QPSK 42
PBCH_DMRS 0.206 53.70 -30.66 QPSK 42
PDSCH0 0.254 51.92 -30.52 QAM256 1092
PDSCH0_DMRS 0.254 51.89 -30.52 QPSK 1071

Using the equivalent SCPI commands

On the X-Series Signal Analyzer:

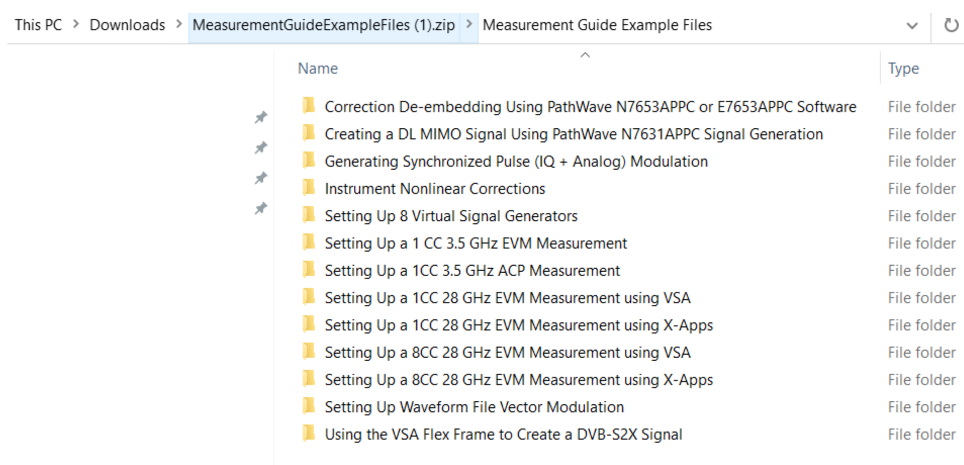
`INSTrument:SELect VSA89601`

NOTE

You will need to copy the setup files to the X-Series Signal Analyzer or the PC running the VSA application. Go to:

https://www.keysight.com/us/en/lib/software-detail/instrument-firmware-software/measurement-guide-example-files.html

Select Download and wait for the zip file to finish downloading to your Downloads folder. This may take a few minutes as it is a 2 GB file. You will find the setup file(s) under the applicable Measurement name.




```
SYSTem:PRESet
```

```
MMEMory:LOAD
"D:Users\Instrument\Documentts\NR5G\data\NR5GEvm\Carrier
Setup\5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC
punctured.setx"
```

```
INITiate:PAUSe
```

```
INPut:TRIGger:STYle "EXTERNAL"
```

```
INPut:TRIGger:LEVel:EXTernal 1V
```

```
INPut:EXTension:PARameters:SET "ExtTriggerLoc", 2
```

```
INPut:EXTension:PARameters:SET "PhaseNoiseOptDualLoop", 1
```

Set the 5G NR Demod Result Length to 10 Subframes:

```
NR5G:RLENgth 10
```

```
NR5G:SUBFrame:INTerval 2
```

Set the Acquisition Mode to “Frame Trigger is Present”

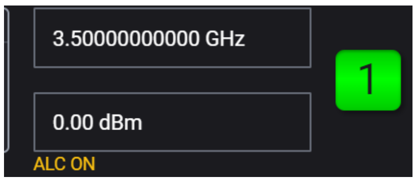
```
nr5g:FRAMe:TRIGger:ENABled 1
```

Setting Up a 1 CC 3.5 GHz ACP Measurement

NOTE Ensure the equipment and triggers are properly configured. Refer to "Equipment Setup" on page 9 and "Setting Up Triggers on the Signal Analyzer using 5G NR Mode" on page 96.

Setup the MXG:

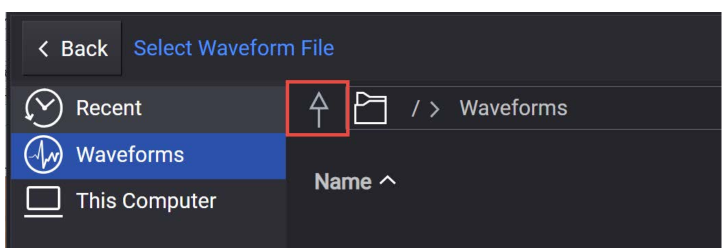
1. Select **Preset > Preset** to set the MXG to a known state.
2. Set Frequency to **3.5 GHz** and Amplitude to **0 dBm**.



3. Select **Group 1: Signals** block to open.

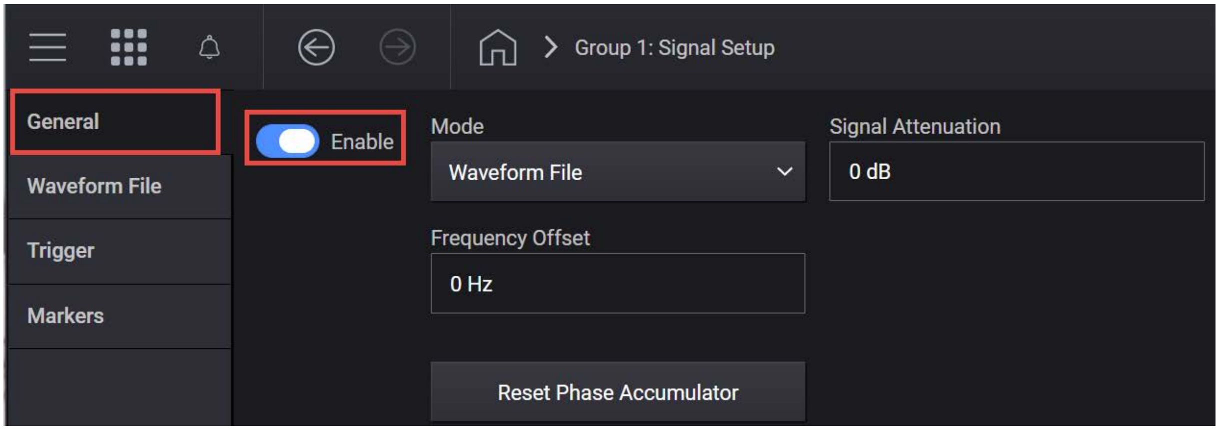
4. From the Waveform tab on the left side of the display, choose File **Select** to navigate to the **Waveforms** folder.

5. Select the **Up arrow** icon to access the Examples folder.

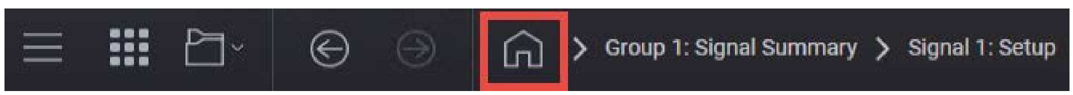


6. Open the Examples folder and highlight `5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC Punctured.wfm`, then **Select**.

7. Select the **General** tab > **Enable**.

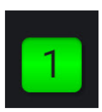


8. Close the Vector Modulation Signal Setup by selecting the **Home** icon at the top of the display.

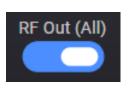


9. Set RF Out to **On** by selecting the numbered channel indicator switch.

This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel MXG.



10.For multi-channel instruments only: In the top right corner of the display, set RF Out (All) to **On** by selecting the switch.



NOTE

In order to turn on RF for any channel, both the RF Out for the specific channel (for example, Channel 1 or Channel 2), and RF Out All must be turned on.

On the X-Series Signal Analyzer:

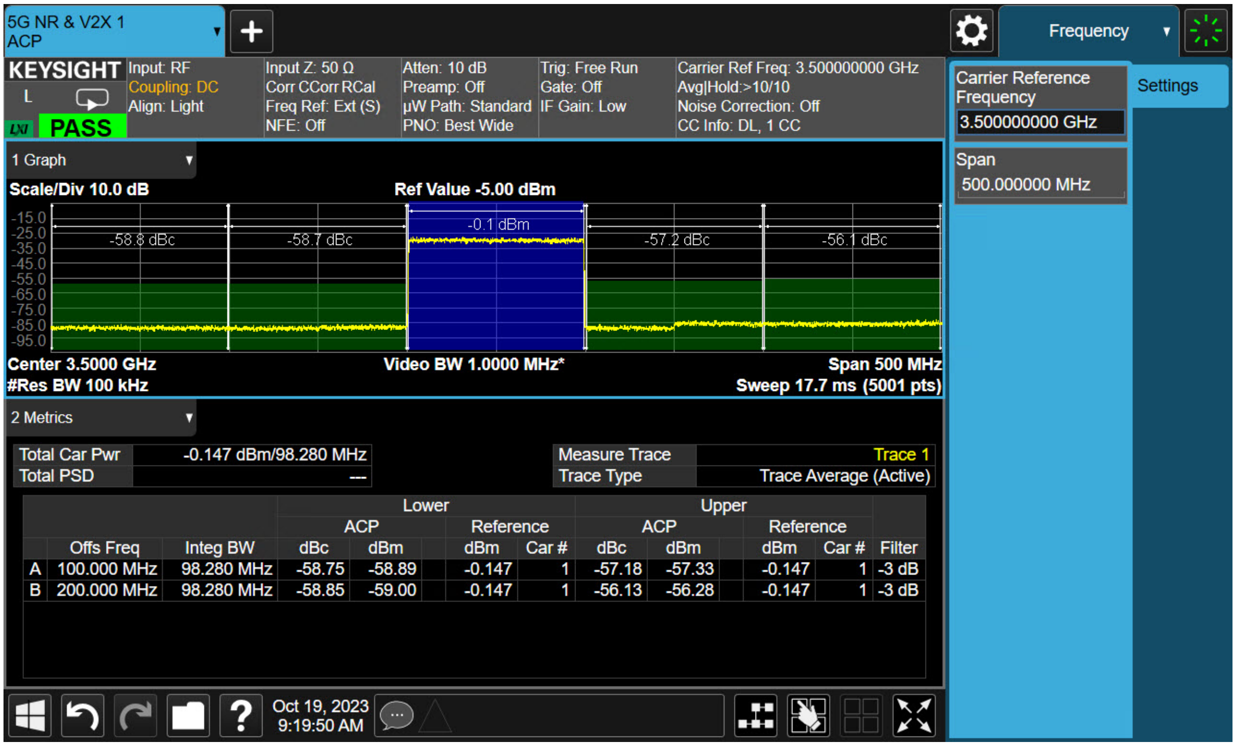
1. Select **Mode Preset** to set 5G NR V2X mode to a known state.

2. Select **Mode/Meas** > **5G NR & V2X** Mode > **ACP** Measurement.

NOTE

If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

3. Select **Frequency** and set Carrier Reference Frequency to **3.5 GHz**.


5G NR & V2X 1
ACP
Frequency
KEYSIGHT
PASS
Input: RF
Coupling: DC
Align: Light
Input Z: 50 Ω
Corr CCorr RCal
Freq Ref: Ext (S)
NFE: Off
Atten: 10 dB
Preamp: Off
µW Path: Standard
PNO: Best Wide
Trig: Free Run
Gate: Off
IF Gain: Low
Carrier Ref Freq: 3.500000000 GHz
Avg|Hold:>10/10
Noise Correction: Off
CC Info: DL, 1 CC
Carrier Reference Frequency
3.500000000 GHz
Span
500.000000 MHz
Settings
1 Graph
Scale/Div 10.0 dB
Ref Value -5.00 dBm
-58.8 dBc
-58.7 dBc
-0.1 dBm
-57.2 dBc
-56.1 dBc
Center 3.5000 GHz
#Res BW 100 kHz
Video BW 1.0000 MHz*
Span 500 MHz
Sweep 17.7 ms (5001 pts)
2 Metrics
Total Car Pwr -0.147 dBm/98.280 MHz
Total PSD ---
Measure Trace Trace 1
Trace Type Trace Average (Active)
Lower
Upper
ACP
Reference
Offs Freq
Integ BW
dBc
dBm
Car #
Filter
A 100.000 MHz 98.280 MHz -58.75 -58.89 -0.147 1 -57.18 -57.33 -0.147 1 -3 dB
B 200.000 MHz 98.280 MHz -58.85 -59.00 -0.147 1 -56.13 -56.28 -0.147 1 -3 dB
Oct 19, 2023
9:19:50 AM

Using the equivalent SCPI commands

On the MXG:

```
SYSTem:PRESet
RF1:FREQuency:CW 3.5GHZ
RF1:POWer:AMPLitude 0dBm
SIGNal1:MODE WAVeform
SIGNal1:WAVeform
"/Examples/5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DCPunctured.
wfm"
SIGNal1 ON
DM:OPTimization:CHANnel ACP
RF1:OUTPut ON
```

For multi-channel instruments, set RF Out (all) to On.

```
RFALl:OUTPut ON
```

On the X-Series Signal Analyzer:

```
SYSTem:PRESet
INSTrument:CONFigure: NR5G:ACP
CCARrier:REFerence 3.5GHZ
ACPower:CORRection:NOISe ON
```

4 Other X-Series Signal Analyzer Measurements

KEYSIGHT TECHNOLOGIES

Using the X-Series Analyzer's SCPI Recorder Function

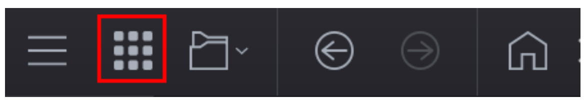
The SCPI Recorder feature allows you to view active recording content, and edit the content. Right-click or touch and hold on any UI control to display a menu allowing you to record the SCPI associated with the control. You can also record a series of commands. These commands can be viewed and edited directly, or you can also play, save/recall for future use.

For this example, we will generate a simple 5G NR 100 MHz signal.

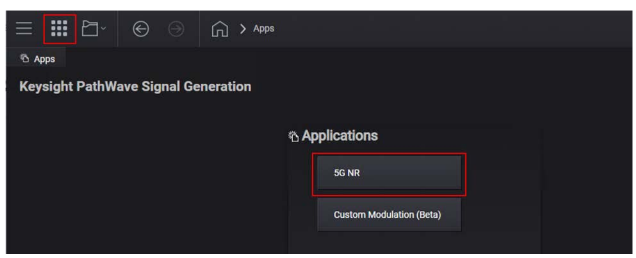
Using the graphical user interface

On the MXG:

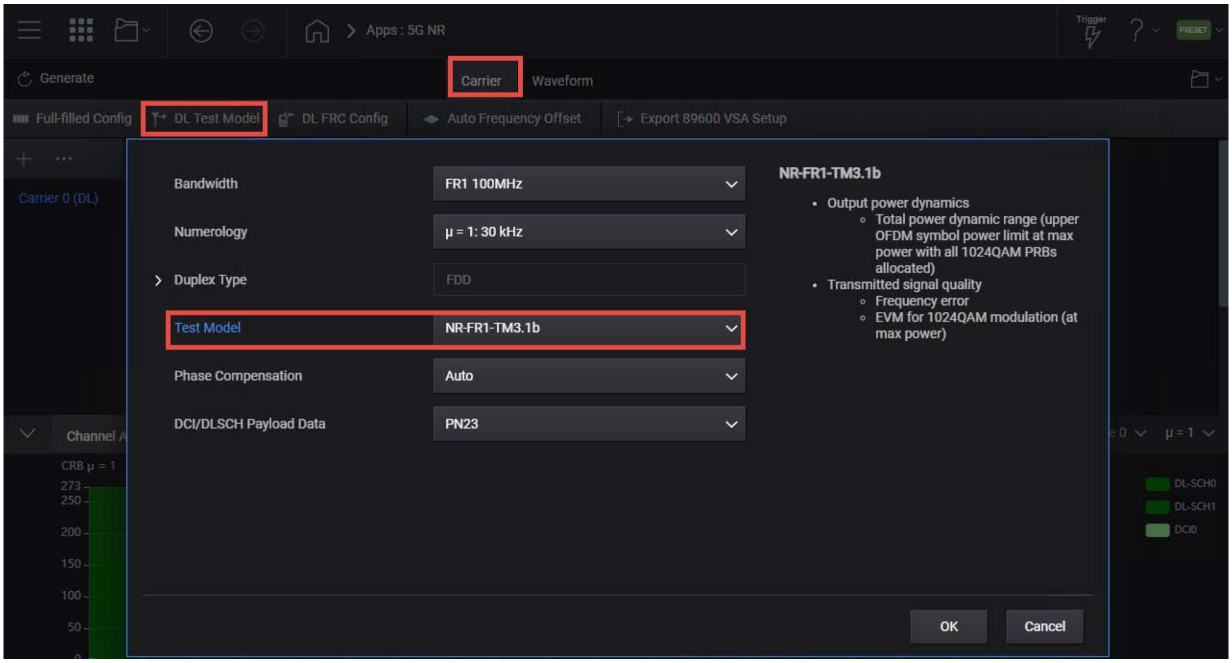
1. Select **Preset** > **Preset** to set the VXG to a known state.
2. In the Output area, set Frequency to **3.5 GHz** and Power to **0 dBm**.
3. Select the **Radio Apps** block to open the mode selection panel.



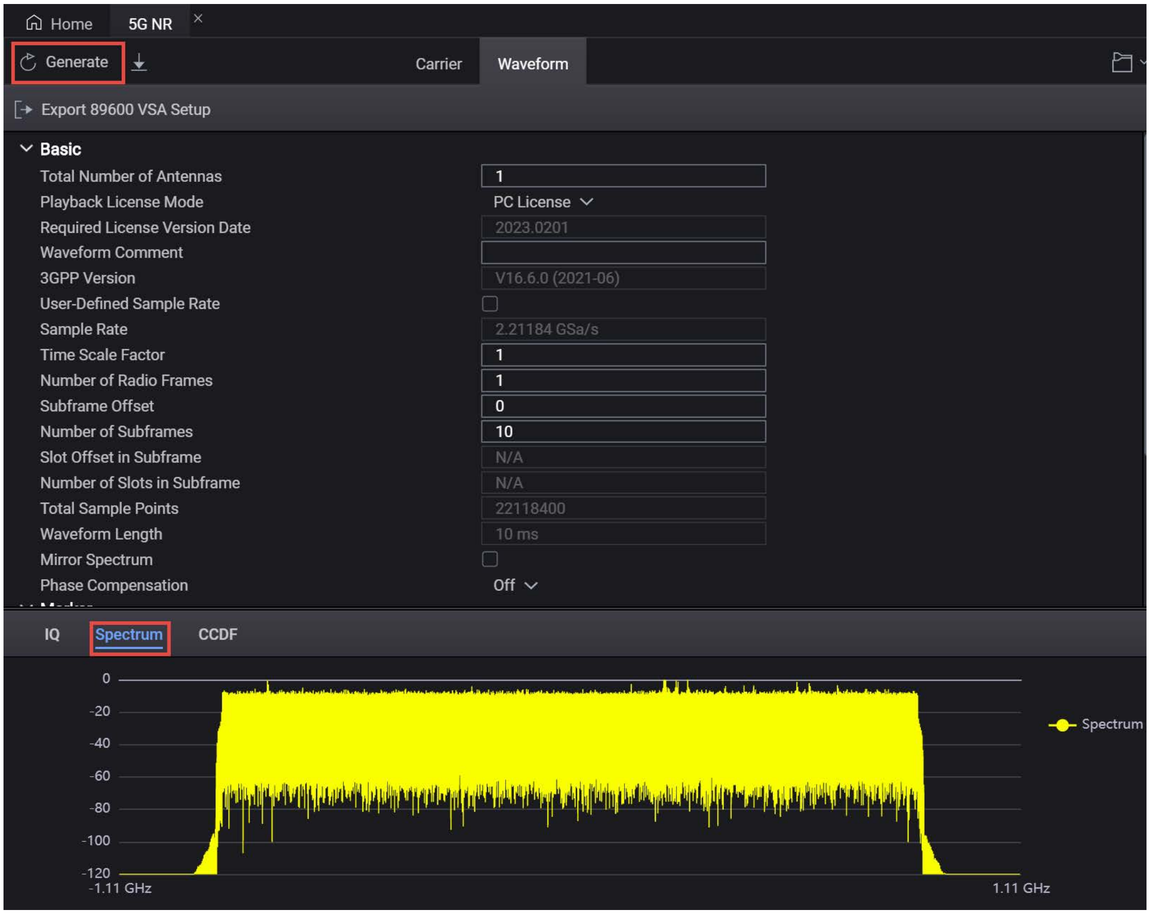
4. Select **5G NR**.



5. Select the **Carrier** tab > **DL Test Model** and set Test Model to **NR-FR1-TM3.1b**, leave the remain settings at their default values, and select **OK**.

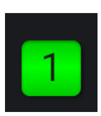


6. Select the **Waveform** tab, then **Generate** to generate the Waveform, and then select **Home** to exit the setup panel.



7. Set RF Out to **On** by selecting the numbered channel indicator switch.

   This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel VXG.



On the X-Series Signal Analyzer:

1. Select **Mode/Meas** > **5G NR &V2X** Mode > **OK**.

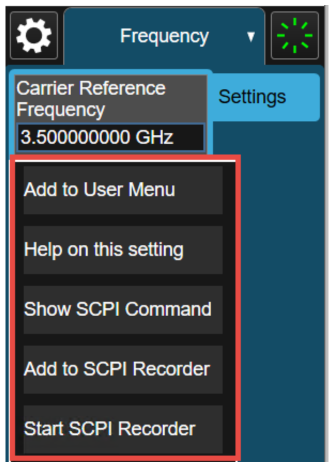
NOTE If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top left of the display) to open the Mode/Measurement/View Selector window.

2. Select **Mode Preset** to set Spectrum Analyzer 5G NR mode to a known state.

3. From the Menu Panel (or the Screen tab), select **Mode/Meas** > **5G NR & V2X** Mode > **Modulation Analysis** Measurement > **OK**.

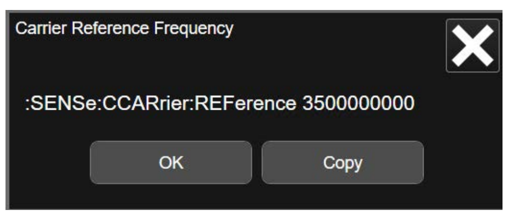
4. Select **Frequency** and set Carrier Reference Frequency to **3.5 GHz**.

   – Touch and hold the **Carrier Reference Frequency** function for at least one second on the touch screen or if using a mouse pointer and right click to open the menu.



   – Select **Show SCPI Command**.

   The SCPI command for this function is displayed in the dialog box.



   Select Copy to copy the current SCPI command string for further use.

   If you use Windows Remote Desktop or a VNC viewer with clipboard synchronization enabled, you can copy the SCPI command into the clipboard. This makes SCPI commands available on the fly via a simple copy/paste operation.

   – Select **Help on this setting** to open the SCPI syntax document page.

You will see the background information for that setting including allowed values, SCPI command and examples, and other useful information.

Carrier Reference Frequency

The parameter sets the reference frequency of all the carriers. The center frequencies of carriers are defined as offset frequency from this value.

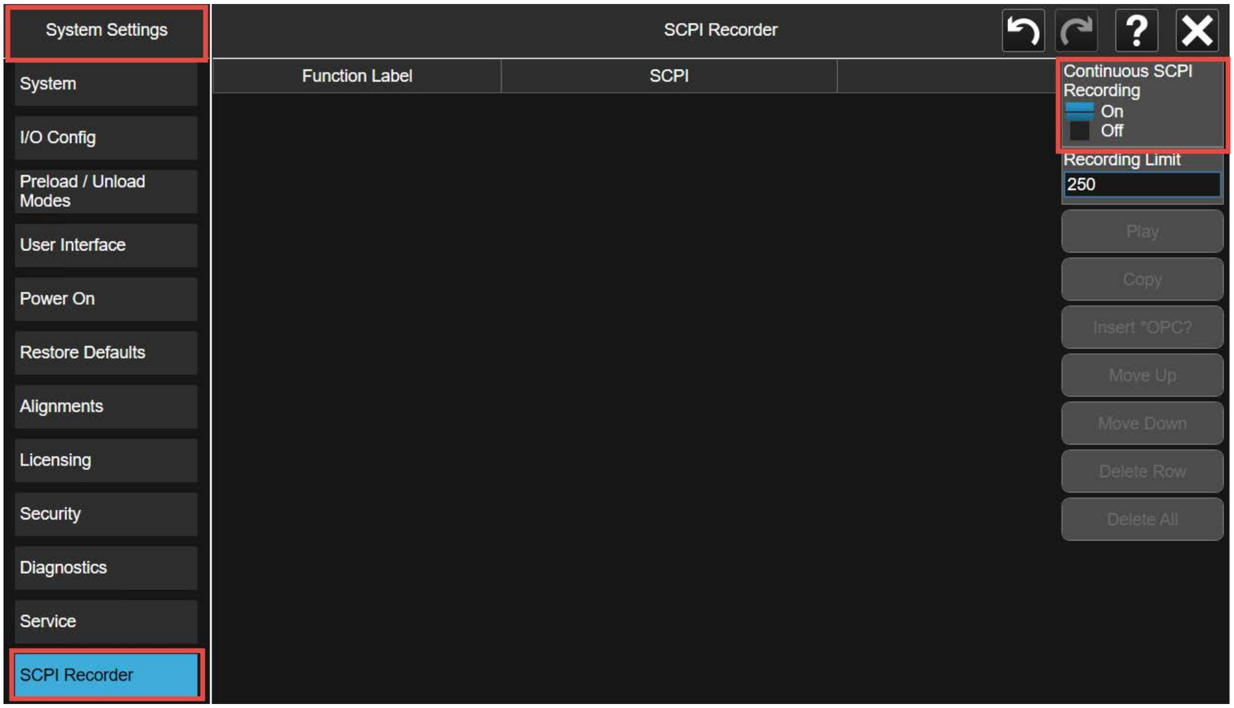
Remote Command	`[:SENSe]:CCARrier:REFerence <freq>` `[:SENSe]:CCARrier:REFerence?`
Example	`:CCAR:REF 2GHz` `:CCAR:REF?`
Preset	1 GHz
State Saved	Saved in instrument state
Min	Depends on instrument minimum center frequency. Same as Center Frequency
Max	Depends on instrument maximum center frequency. Same as Center Frequency

To Start Continuous SCPI Recording:

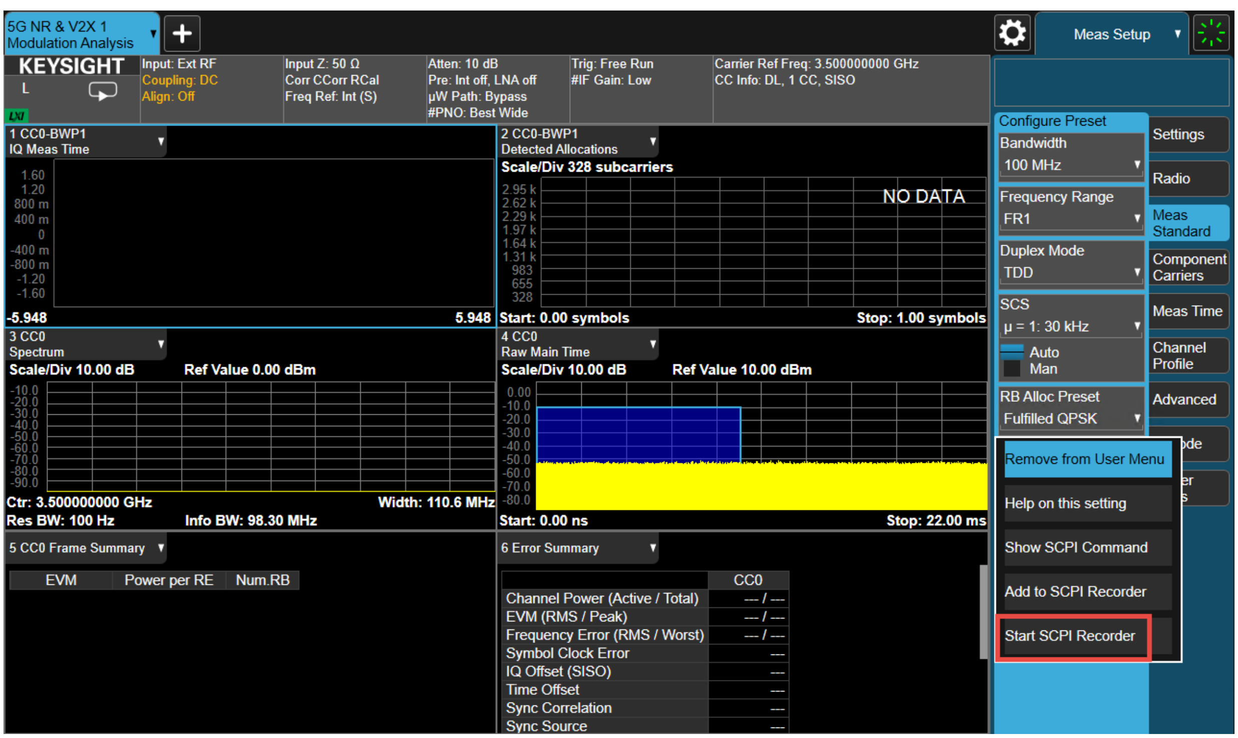
The SCPI Recorder supports an automatic mode of operation. In this mode, a series of manual operations can be added to the list automatically without any further user activity. You can start the recording process by enabling the Continuous SCPI Recording, then disable it to stop recording after completing all configuration steps. This is normally the best choice for fast and convenient SCPI list recording.

There are two ways to start continuous SCPI recording:

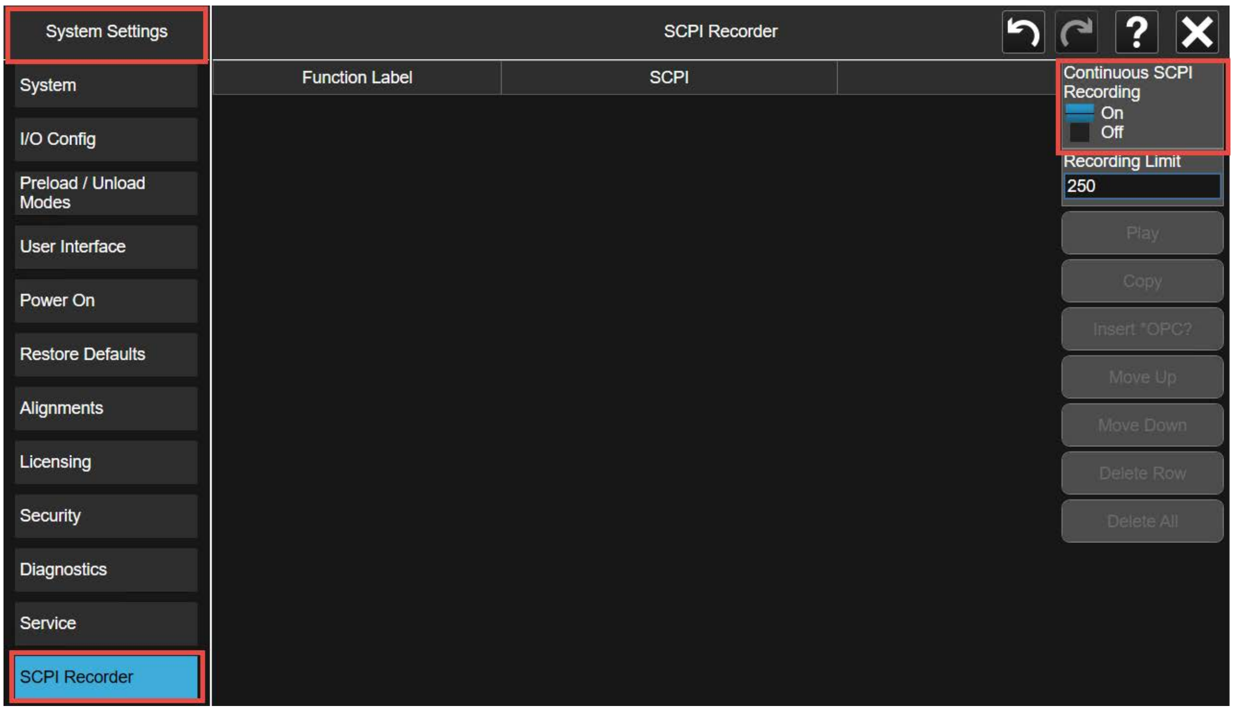
- From the System Settings > SCPI Recorder.



- From the context sensitive menu of the function key.



1. Select **Mode Preset** to set 5G NR V2X mode to a known state.
2. For this example, select the **System Settings** icon (Gear wheel on top right of the display) > **SCPI Recorder** > **Continuous SCPI Recording On**. Close the System Settings window by selecting the "X" at the top of the window.



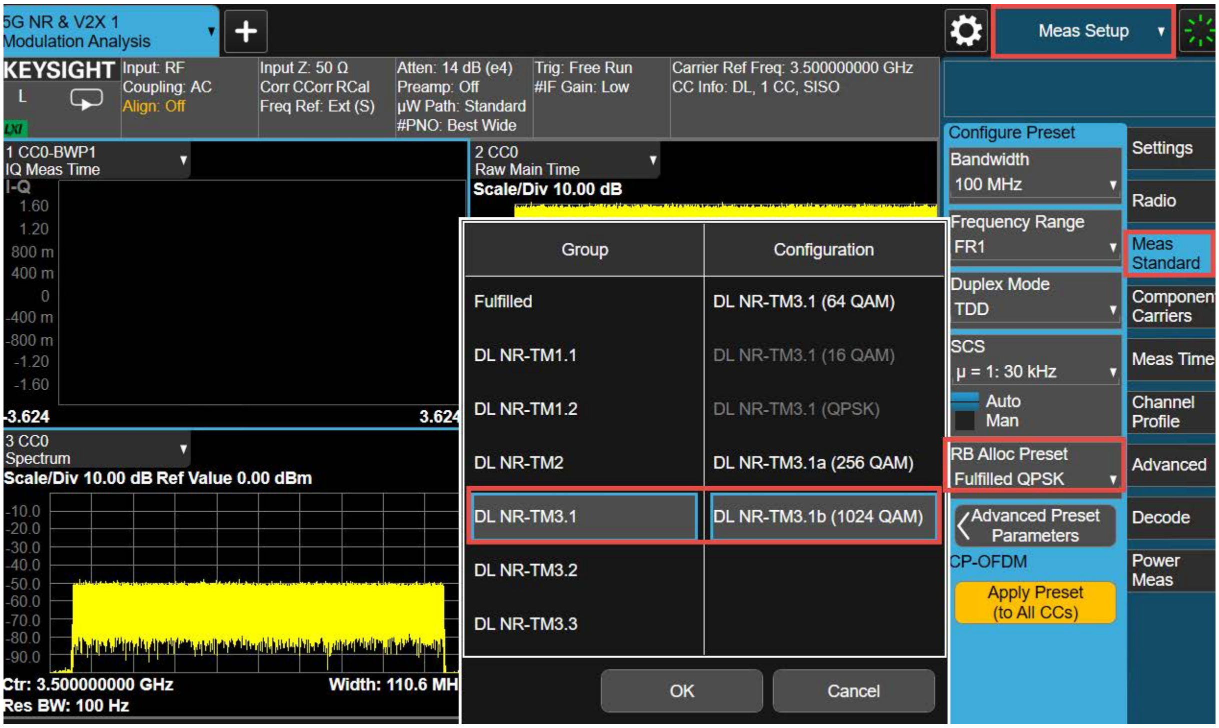
3. Select **Mode/Meas** > **5G NR &V2X** Mode > **Modulation Analysis** Measurement > **Normal** View > **OK**.

NOTE

If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top left of the display) to open the Mode/Measurement/View Selector window.

4. Select **Frequency** > **Carrier Reference Frequency** and set to **3.5 GHz**.

5. Select **Meas Setup** > **Meas Standard** > **RB Alloc Preset** > **DL NR-TM3.1** > **DL NR-TM3.1b (1024QAM)** > **OK.**

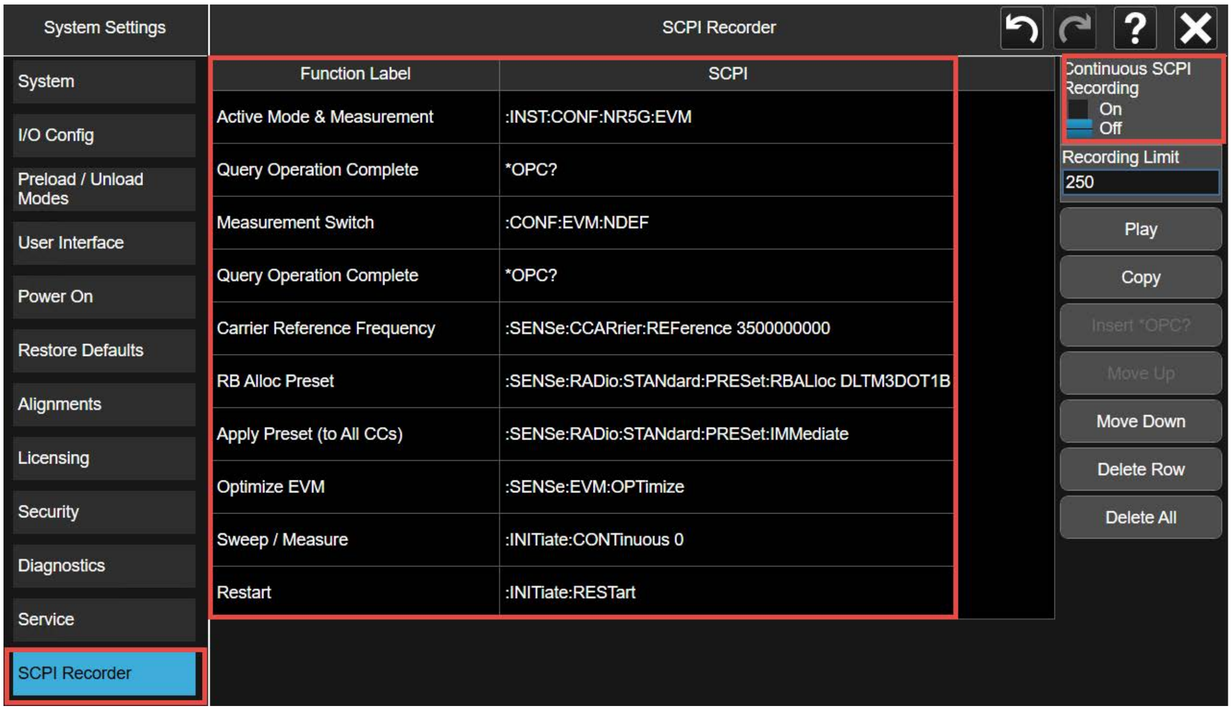


6. Select **Apply Preset (to All CCs).**

7. Select the **Settings** side tab and select **Optimize EVM**.

8. Select **Sweep** > **Sweep/Meas to Single** > **Restart**.

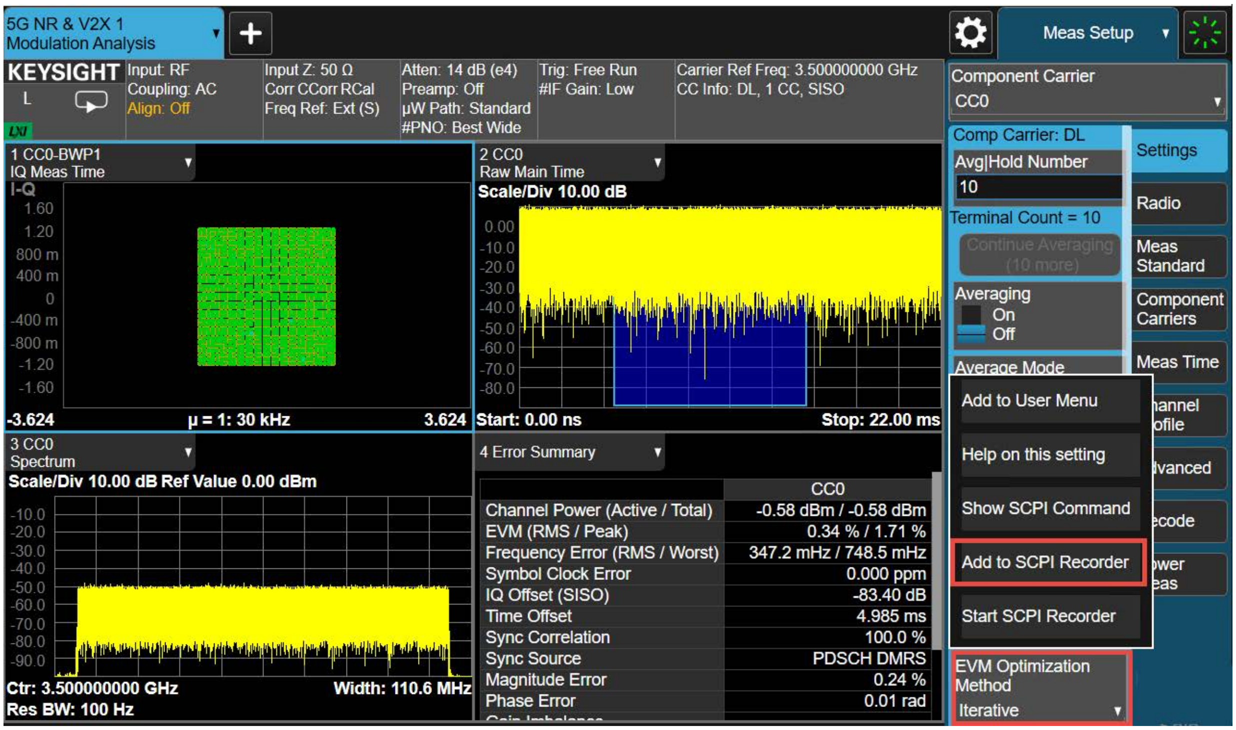
9. Select the **System Settings** icon (Gear wheel on top right of the display) > **SCPI Recorder** > **Continuous SCPI Recording Off.** Close the System Settings window by selecting the "X".



Manual Recording, Edit, Save and Play Functions

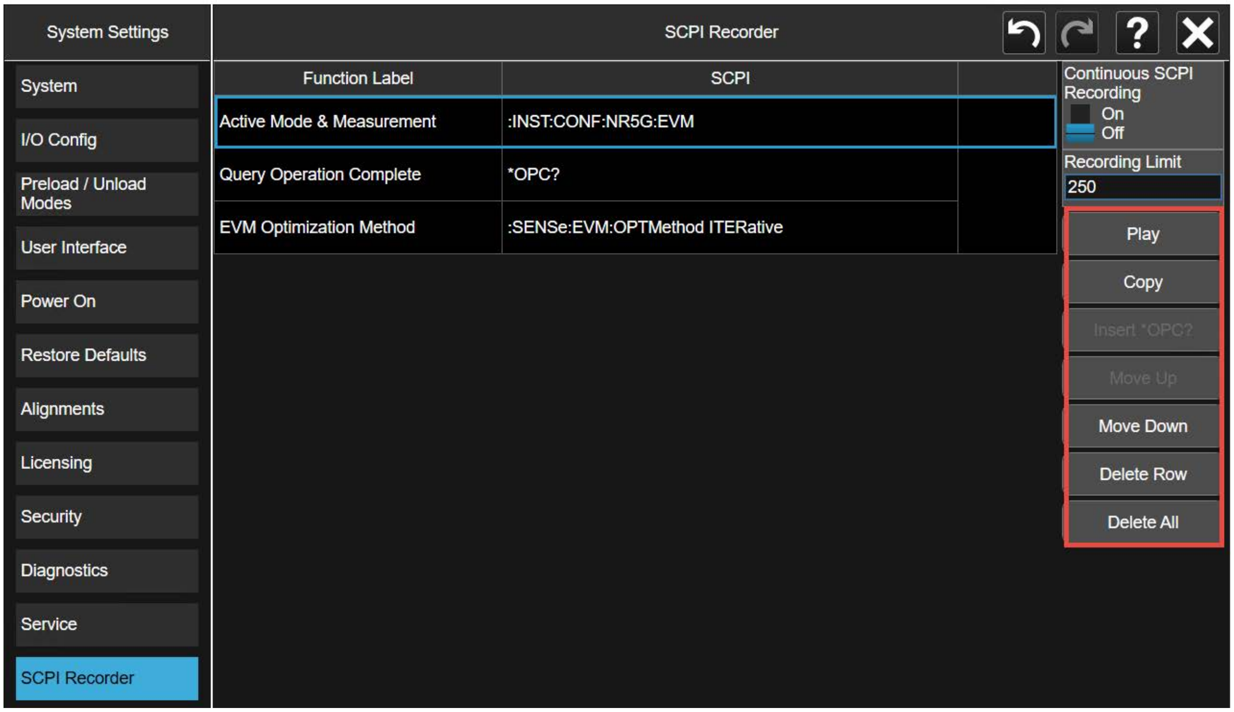
The SCPI Recorder supports manual recording of a list consisting of SCPI commands comprising any number of parameter variations when Continuous SCPI Recording is off. In this mode, the user can decide which SCPI commands should be added to the SCPI list. This mode of recording is helpful if a certain configuration must be figured out, and you only want to record the final, correct settings and not every variation or keystroke.

1. Touch and hold the any function for at least one second on the touch screen or if using a mouse pointer and right click to open the menu and select **Add to SCPI Recorder**. For this is example we will change EVM Optimization Method to Iterative.

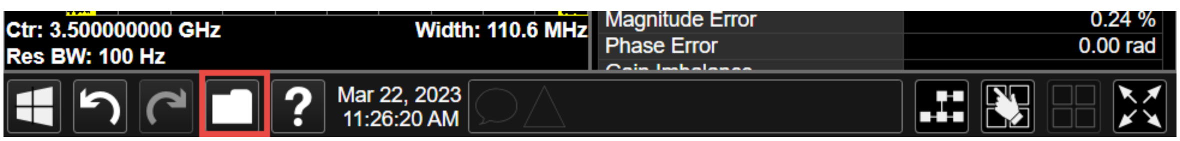


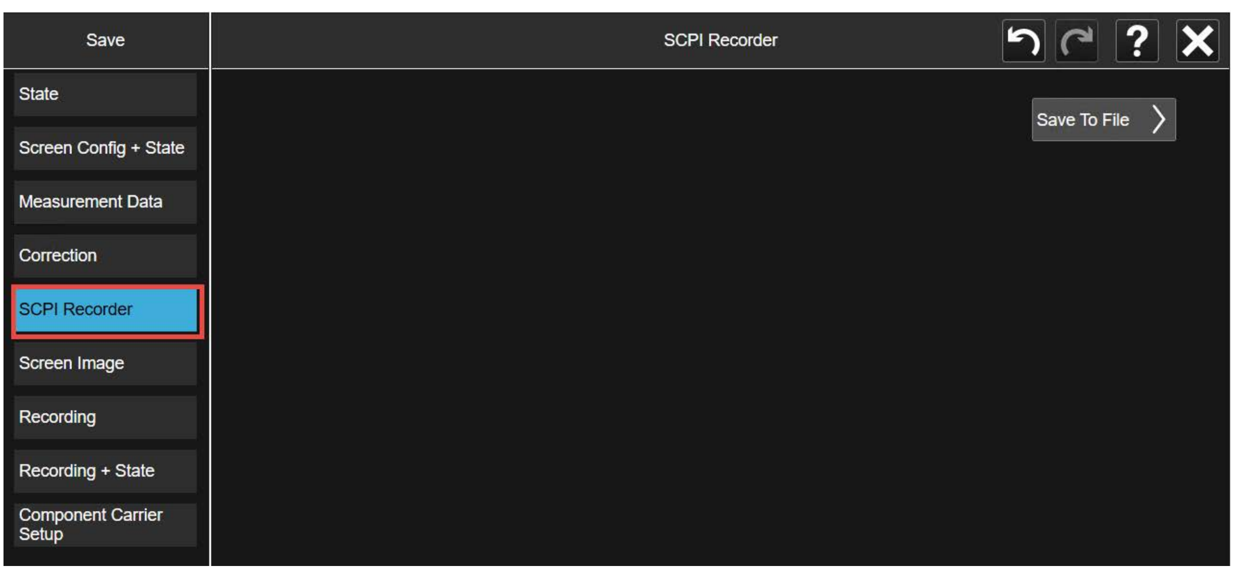
2. To view the newly added command, go to **System Settings** icon (Gear wheel on top right of the display) > **SCPI Recorder**.

From the SCPI Recorder provides several operations to edit the SCPI list you created. You can Play, Copy, Move Up or Down the selected SCPI command, Delete the command, or Delete All the commands.



The recorded SCPI list can be exported as a script file in .TXT format via the Save/Recall function at the bottom of the main window.

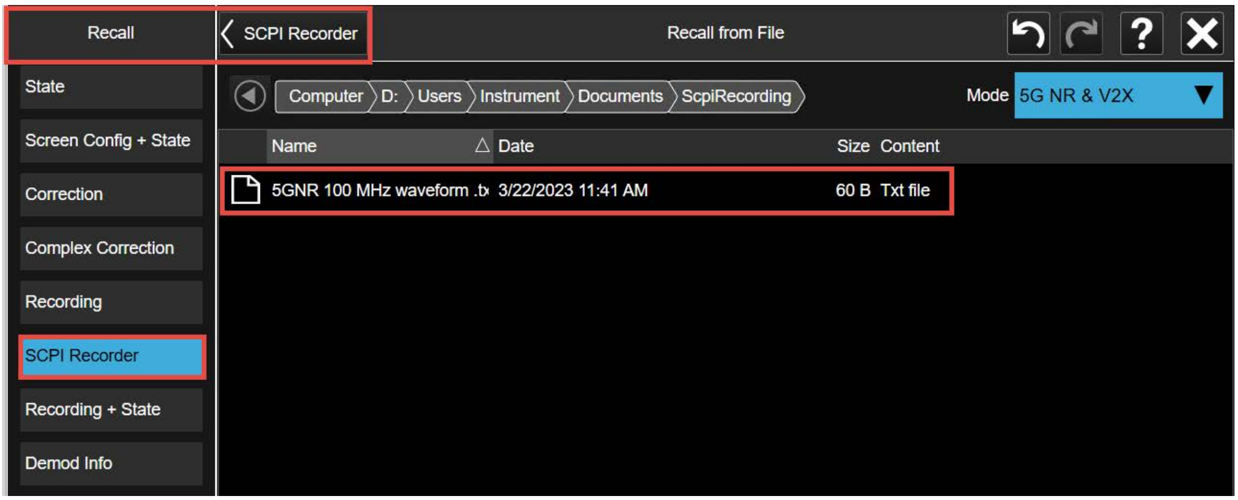




There are two ways to playback SCPI commands. One is recalling from a script file. And another one is pressing the 'Play' button in 'SCPI Recorder' tab view.

Recalling SCPI script file allows you to play back a series of operations in the same or another instrument, which helps you setup complex measurement scenarios quickly and easily.

To recall the SCPI recording, go to Save/Recall and navigate to the saved file.



Using Real-time Spectrogram Streaming (Option RRT) for N9032B and N9042B

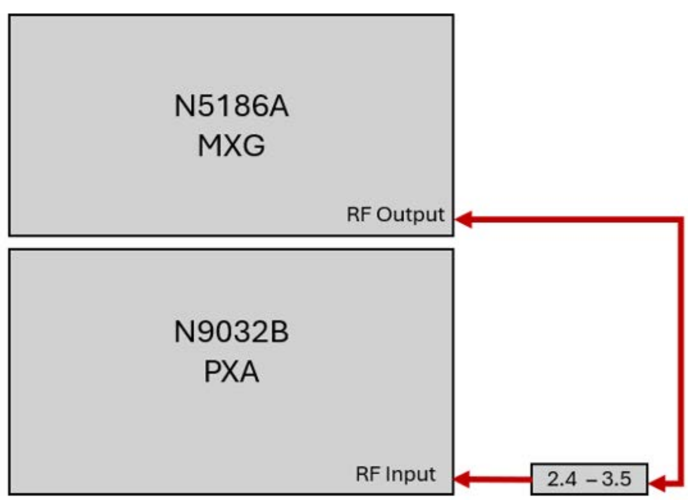
Overview

Real-time Spectrogram Streaming combines the high-speed capture capabilities of RTSA equipped analyzers with the convenient flexibility of post-processing, allowing you to set their desired measurement parameters such as: center frequency, span, and acquisition time and then stream the resulting gapless spectrogram data to binary files. This improves the storage capacity of captured slices by 8x. The saved binary files can be used for customized post-processing. A MATLAB program (RTSA viewer) is provided to introduce users to post process analysis of the saved binary files. In this procedure you will learn how to set up Real-time Spectrogram Streaming and how to use the Rtsa viewer to view your captured spectrogram slices.

Equipment:

– N5186A MXG or M9484C VXG
– N9032B PXA or N9042B UXA with Option RRT
– 3.5 mm female to female cable
– For a mmWave signal analyzer, 2.4 mm female to 3.5 mm male adaptor

For a μWave signal analyzer, Type N male to 3.5 mm female



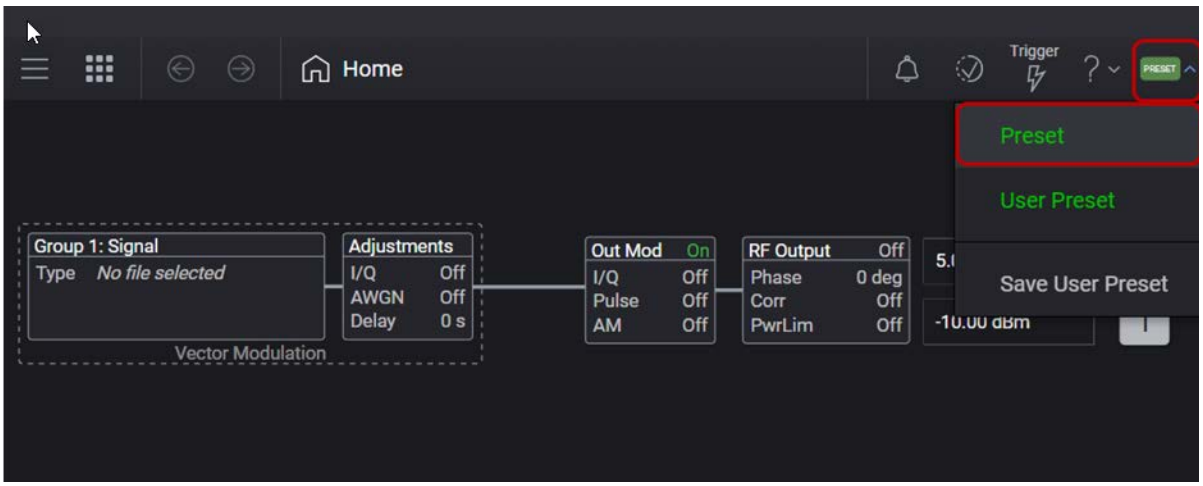
Using the 3.5 mm cable and the 3.5 mm to 2.4 mm (or Type N) adaptor, connect the MXG/VXG RF output to the RF input of the PXA/UXA.

On the MXG/VXG Signal Generator:

Start by generating a sweeping frequency modulated signal for its distinctive formation in the spectrogram screen. Note: This is purely an example for simplicity and demonstrative purposes.

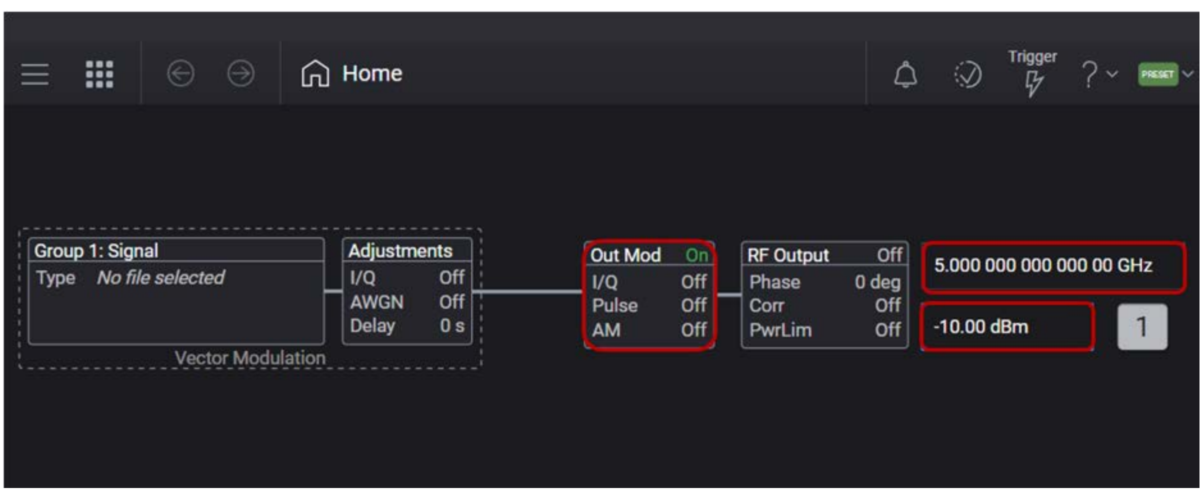
NOTE This is purely an example for simplicity and demonstrative purposes. This process can be used for other signals such as 5G NR and WLAN.

1. Select **Preset** > **Preset** to set the instrument to a known state.



2. Set Frequency to **5 GHz** and Power to **-10 dBm**.

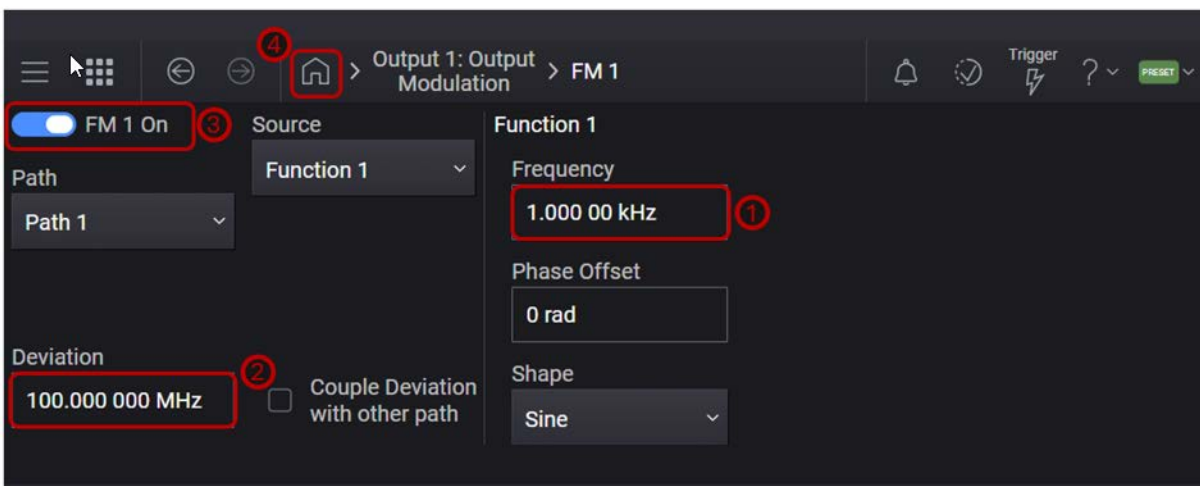
   These values are coupled to CW Frequency and Total Power (RMS) in the corresponding RF Output Block.



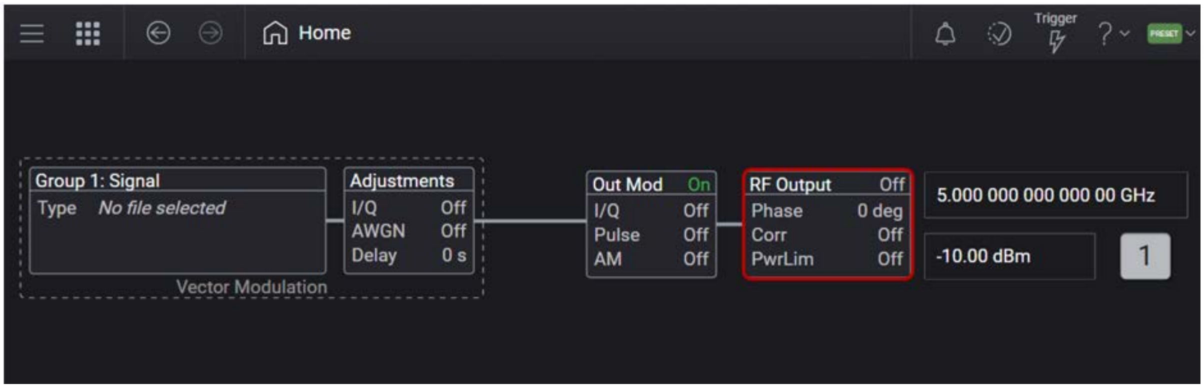
3. Select the **Out Mod** block to open.

4. In the Output Mode window, select the right arrow at the bottom of the display to select choices **5-8**, then select the **FM 1** arrow at the far left side of the window.

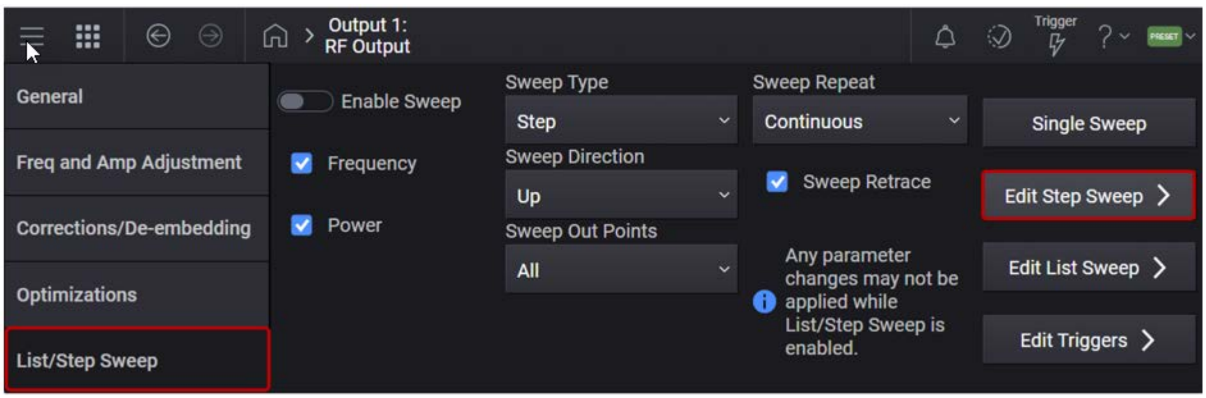
5. In the Output Modulation FM 1 window, set:
   - Frequency to **1 kHz**
   - Deviation to **100 MHz**
   - Toggle **FM 1 on**
   - select the **Home** icon at the top of the screen



6. Select the **RF Output** block.

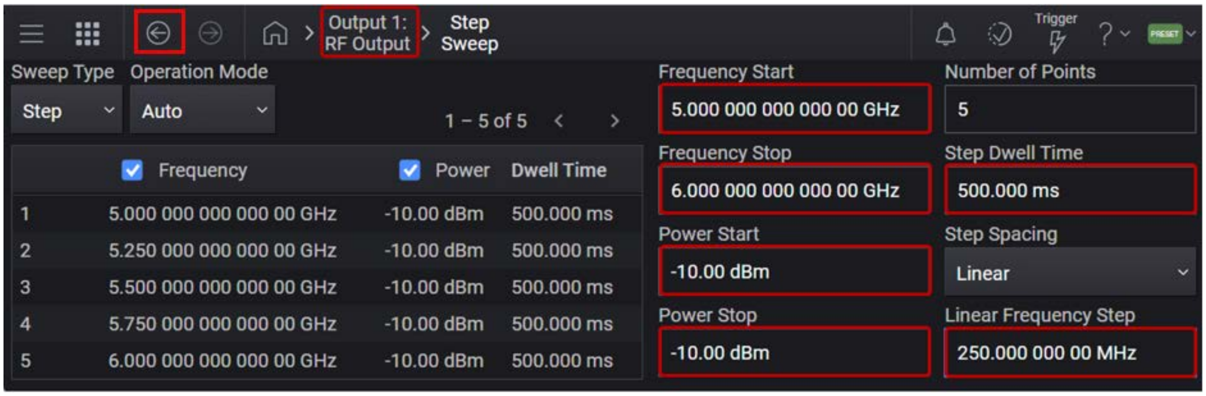


7. In the RF Output block, set:
   – **List/Step Sweep** tab
   – **Edit Step Sweep**

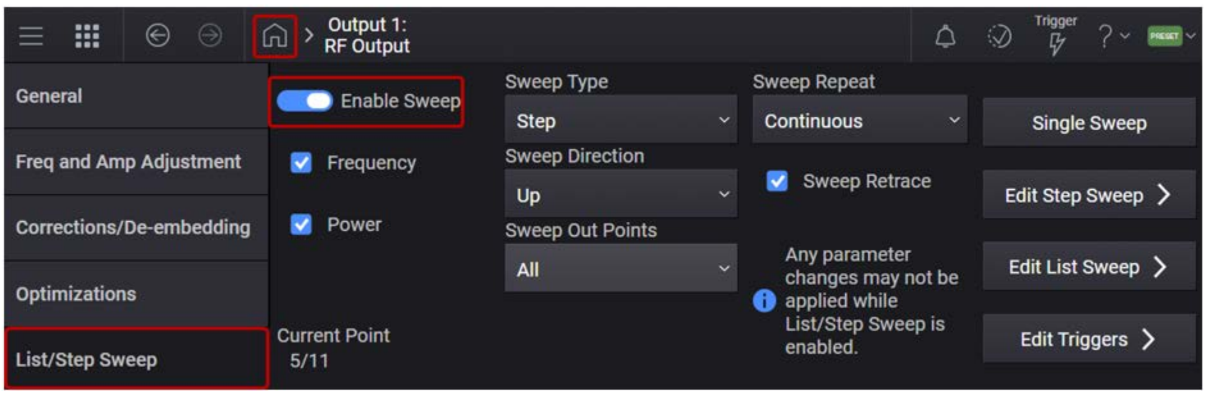


8. In the Step Sweep window, set:
   – Frequency Start to **5 GHz**
   – Frequency Stop to **6 GHz**
   – Power Start to **-10 dBm**
   – Step Dwell Time to **500 ms**
   – Linear Frequency Step to **250 MHz**

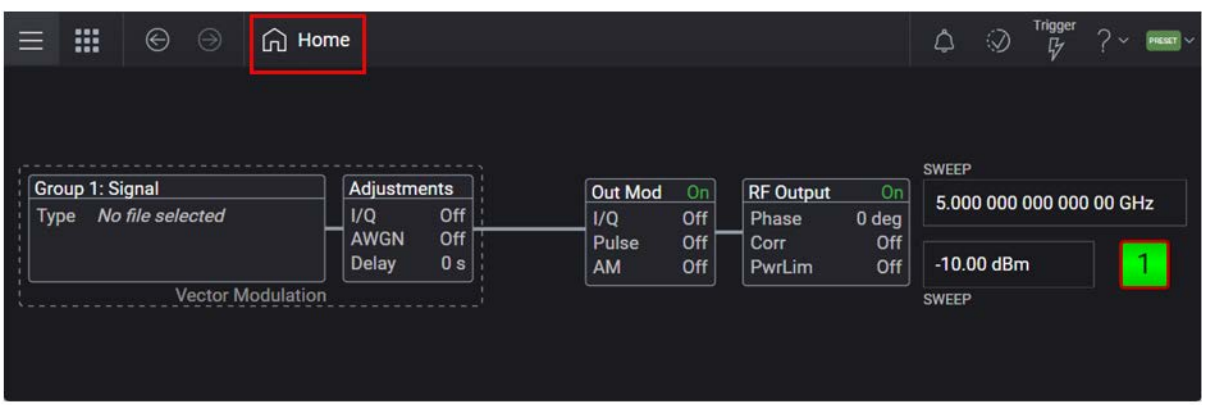
– select the **Back** arrow to return to Output 1: RF Output.



9. Select **List/Step Sweep** >toggle **Enable Sweep** to turn on.



10. Select the **Home** Icon and turn **RF Output On**.



On the PXA or UXA Signal Analyzer:

Now that the signal has been created, we can use RTSA with Option RRT to capture the signal into bin files.

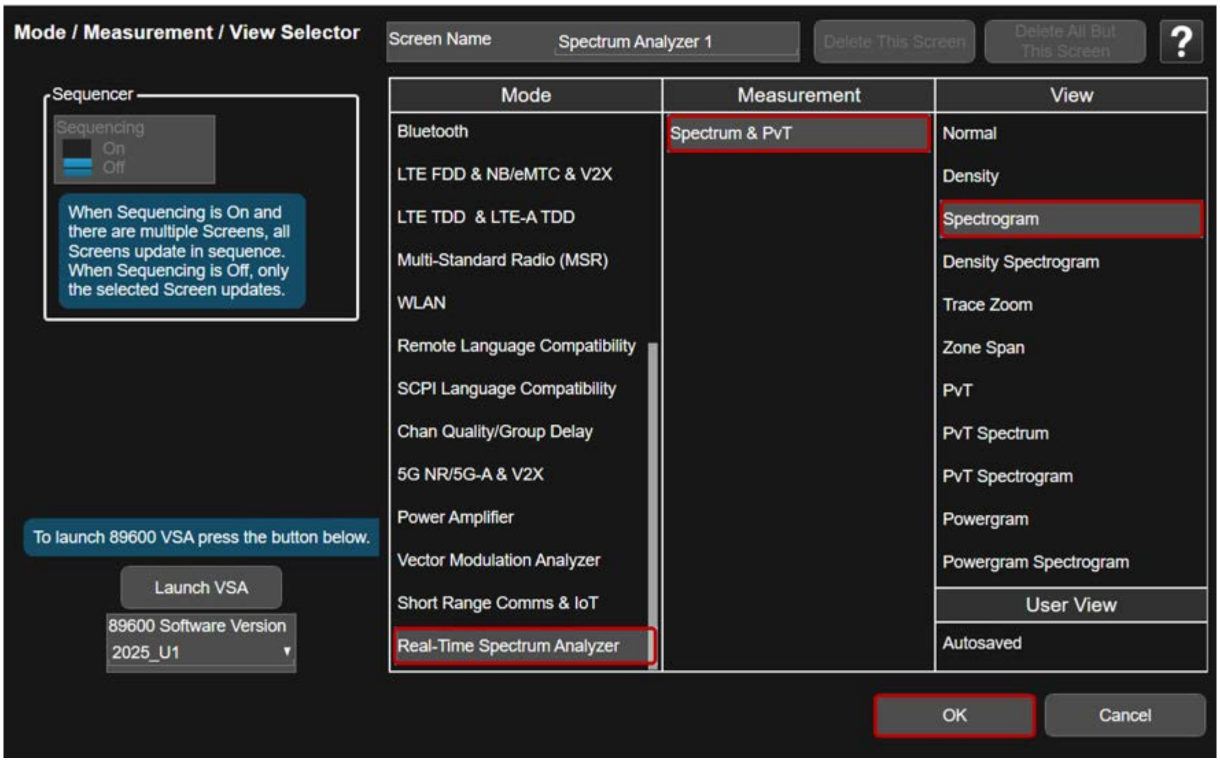
1. Select **Mode/Meas** > **Real-Time Spectrum Analyzer** Mode > **Spectrum & PvT** Measurement.

NOTE

If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

2. Select **Mode Preset** to set Real-time Spectrum Analyzer mode to a known state.

3. Select **Mode/Meas** > **Real-Time Spectrum Analyzer** Mode > **Spectrum & PvT** Measurement > **Spectrogram** View.

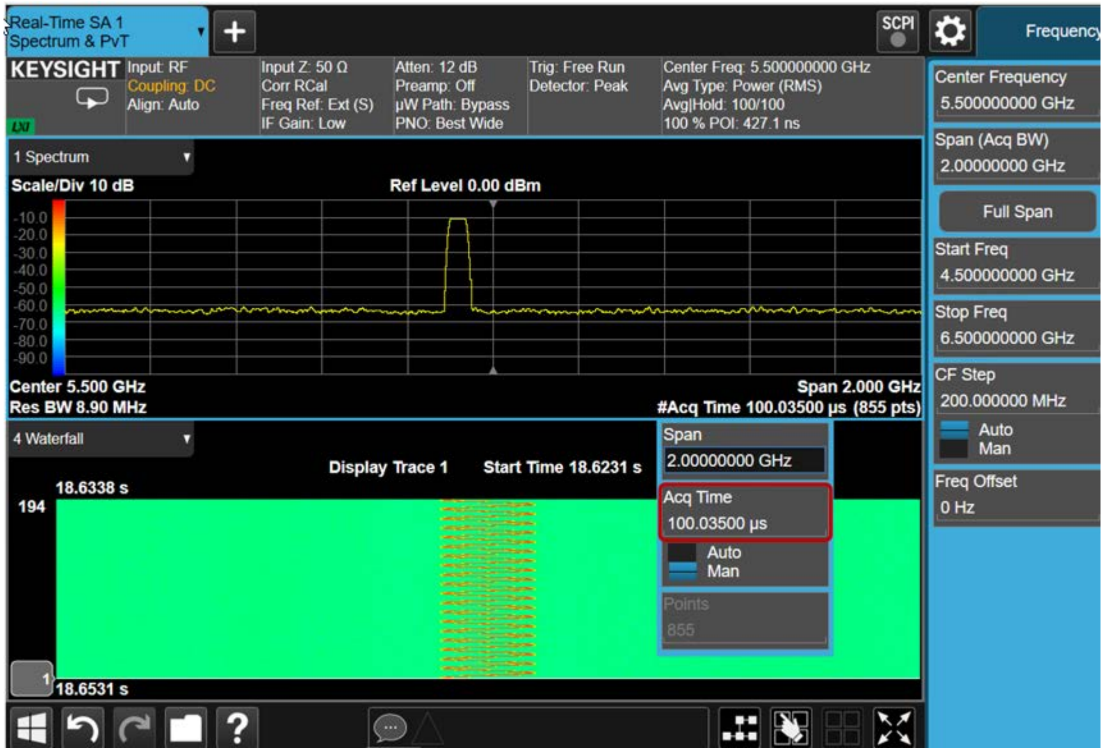


4. Select **Frequency** and set Center Frequency to **5.5 GHz** and Span to **2 GHz**.

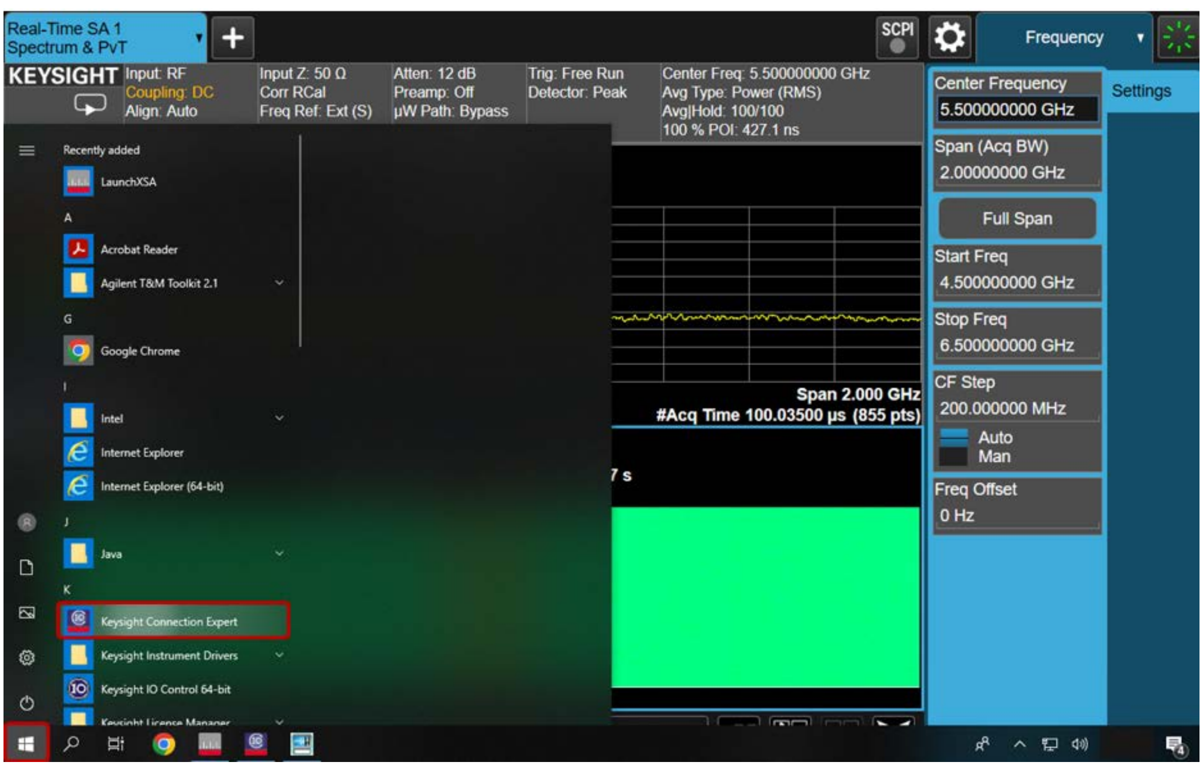
Notice the acquisition time is preset to 30 ms and how changing the acquisition time affects the spectrogram.

5. On the lower right area of the Spectrum window, select **Acq Time** and change to **100µs.**

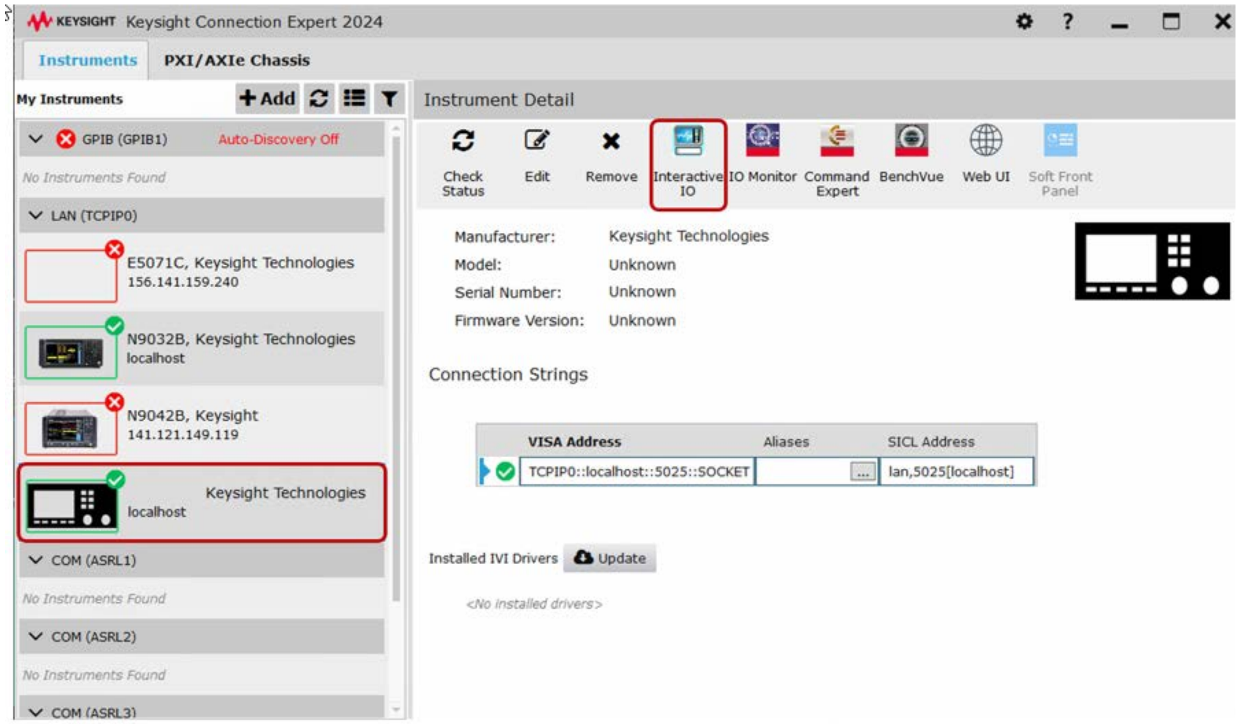
Notice how the FM signal is now resolved.



6. At the bottom of the display, select the **Windows** icon > **Keysight Connection Expert**.



7. In the Keysight Connection Expert window's left pane, select **Keysight Technologies localhost** and then **Interactive IO**.



8. In the **Command** area, type in the following commands:

   – `STR:TYPE FINite` > **Send Command**

   – `STR:TYPE?` > **Send Command**

   – `STR:LENGth 100,000` > **Send Command**

   – `STR:LENGth?` > **Send Command**

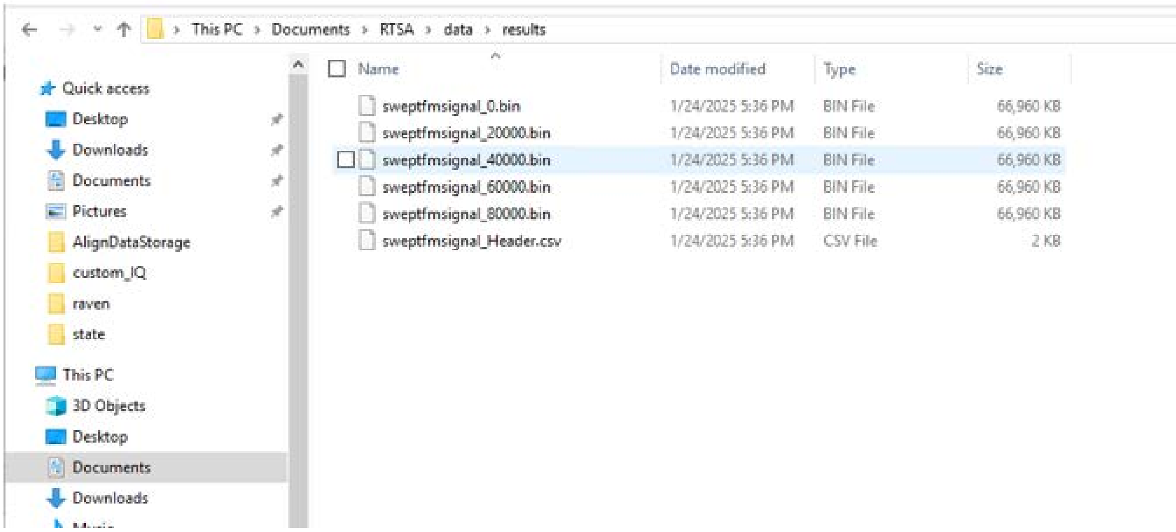
   – `STR:FNAMe "sweptfmsignal"` > **Send Command**

   – `STR:FNAMe?` > **Send Command**

   – `STR:STARt` > **Send Command**

   Once the Start command is sent, the analyzer will execute the number of iterations and store the resulting bin file in Documents > RTSA > data > results.

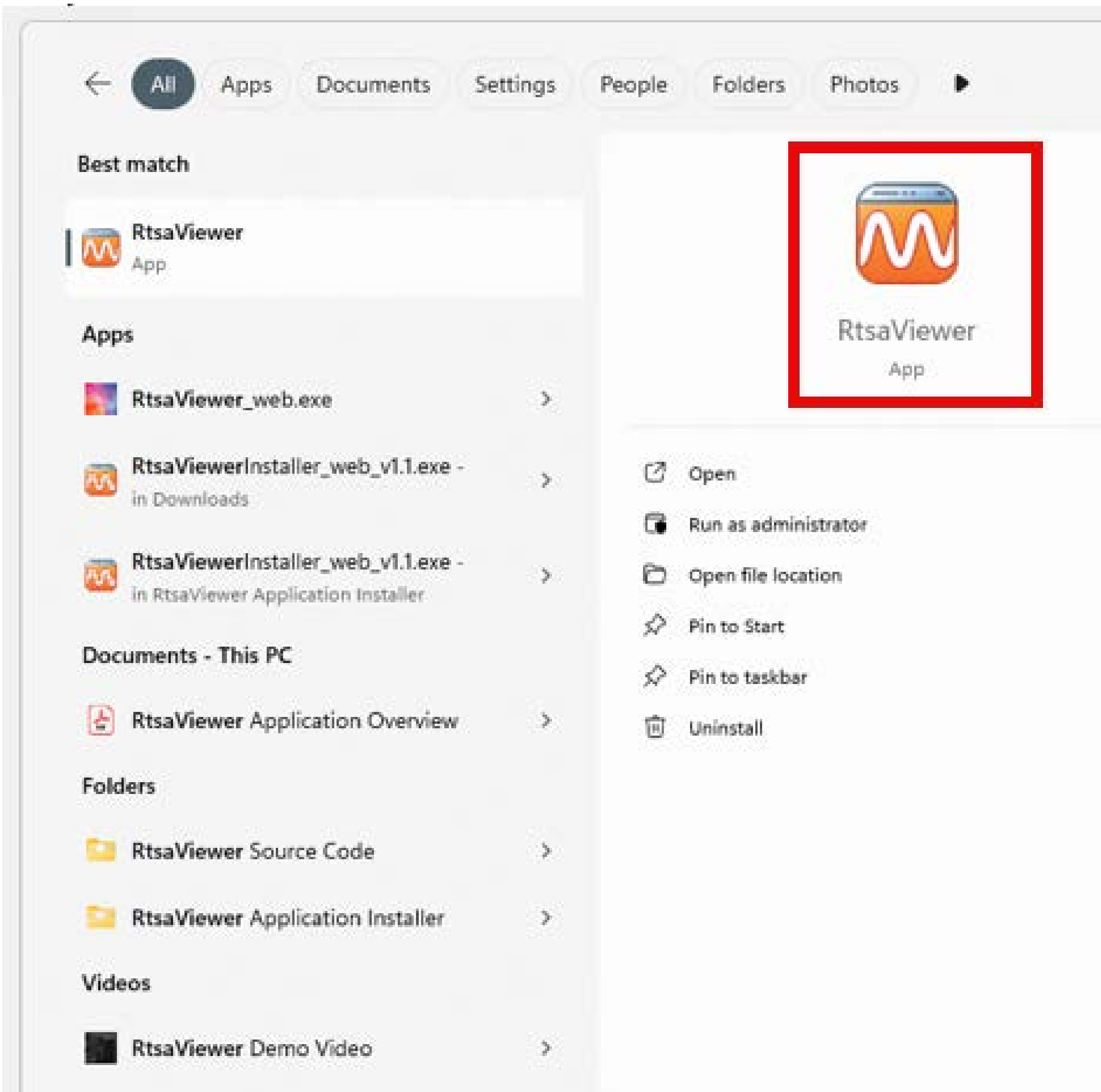
9. From the bottom of the X-series app, select **Windows File Explorer** and navigate to **Documents** > **RTSA** > **data** >**results**.



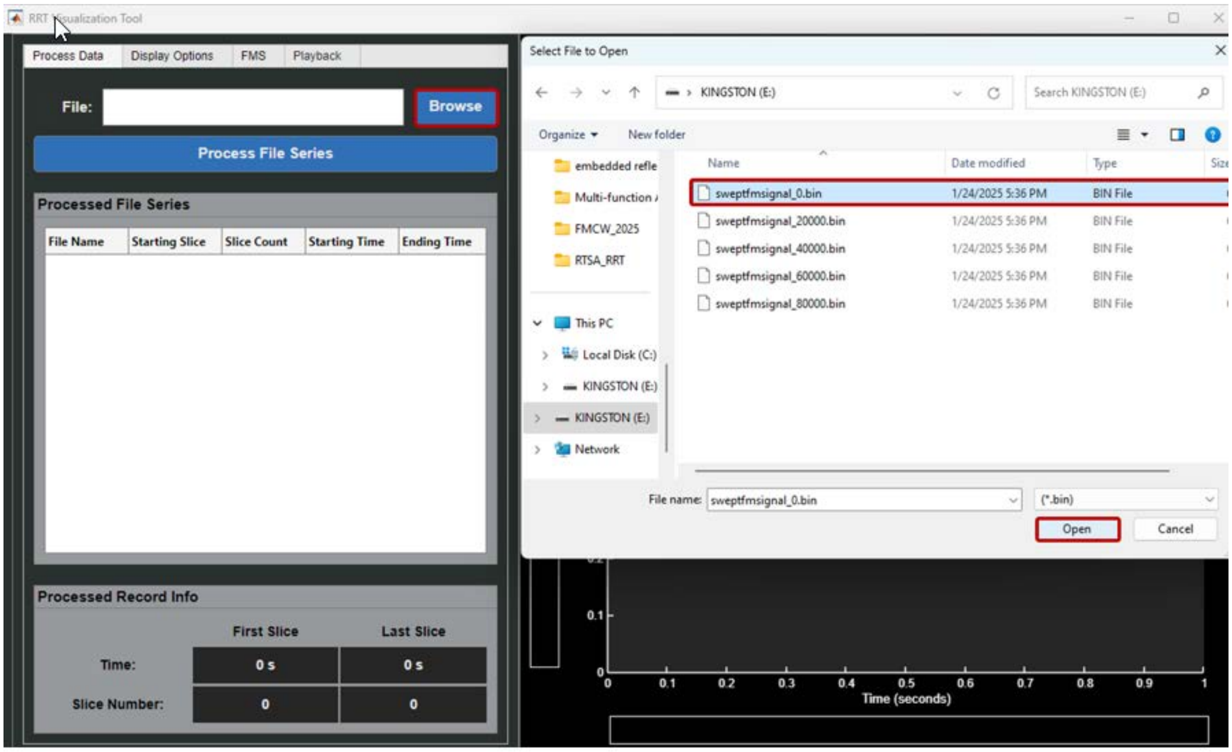
These bin files can now be uploaded to the RtsaViewer for processing and analysis. You can open RtsaViewer locally on the analyzer or transfer the files to another PC equipped with the RtsaViewer.

Using the Rtsa Viewer

1. In the Windows search bar, type `RtsaViewer` and **Open** the application.



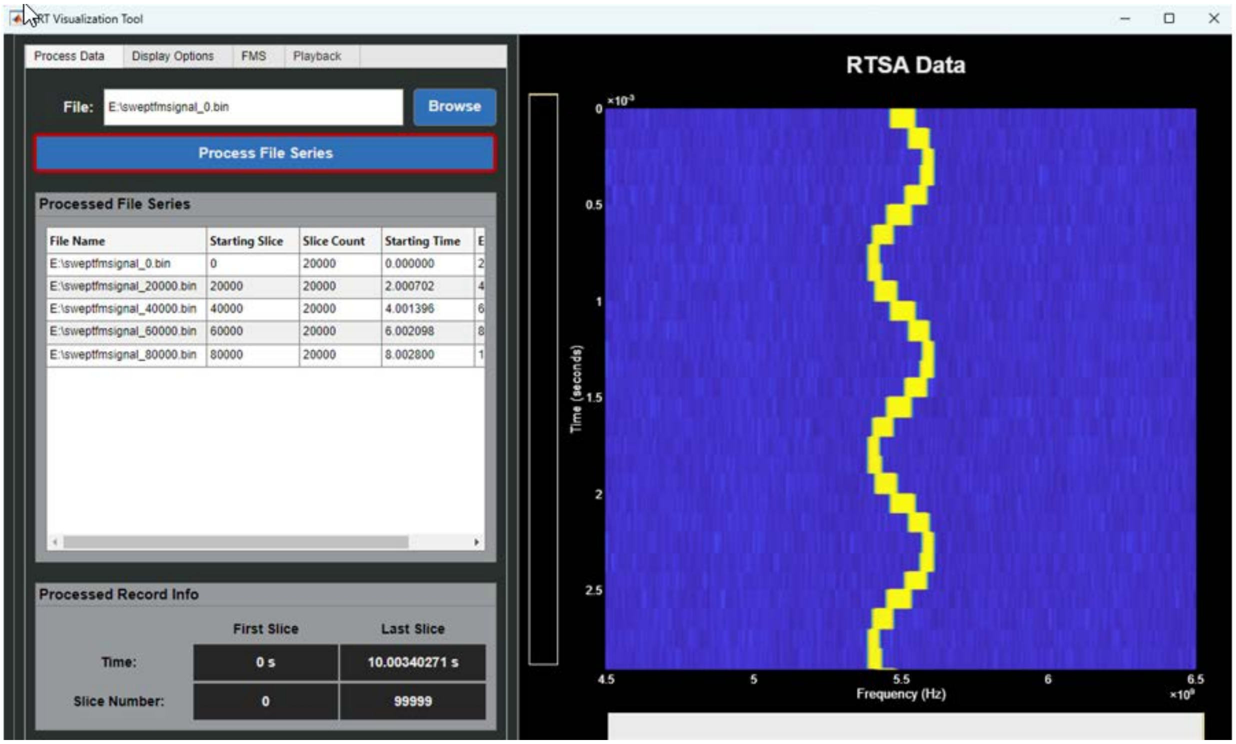
2. In the RtsaViewer, select **Browse** and navigate to your bin files. (Documents > RTSA > data >results). Select `sweptfmsignal_0.bin` > **Open**.



NOTE

The RRT Visualization Tool window may be hidden by the X-apps display. If you cannot see the visualization tool, select **Alt** > **Tab** to position it in front of the X-apps display.

3. Select **Process File Series** to generate the file table.



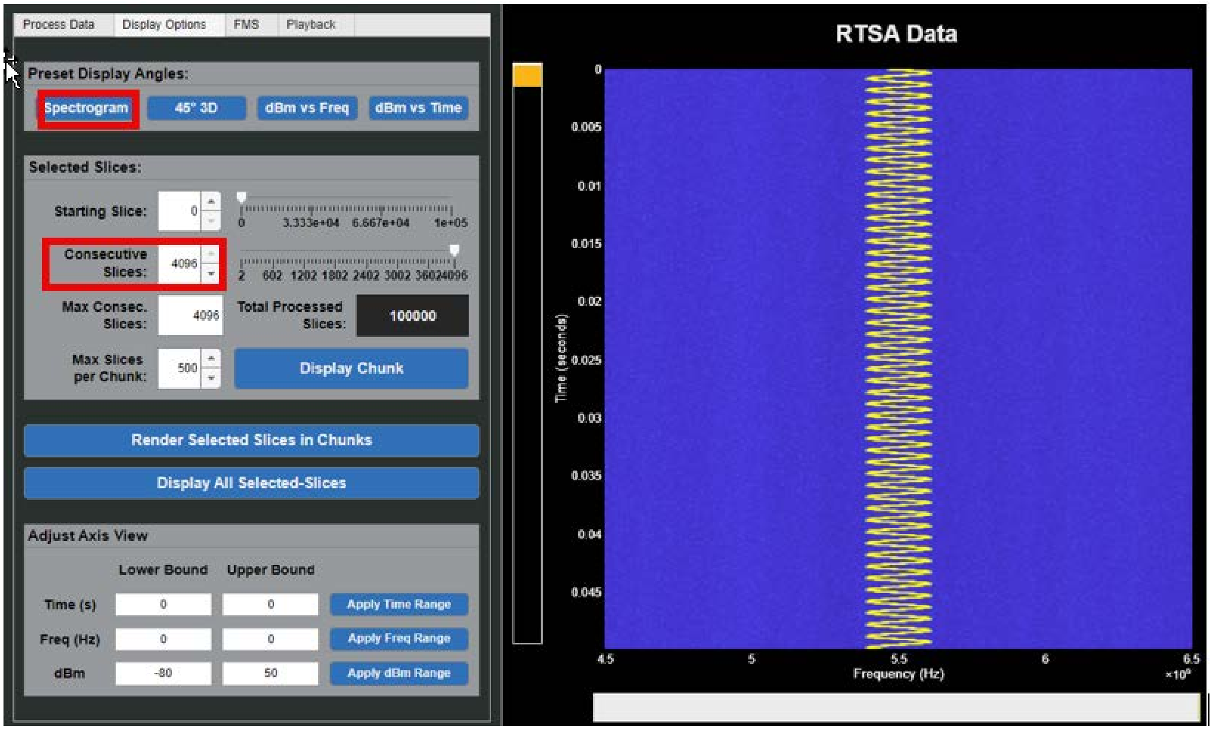
4. Select **Display Options** and set Consecutive Slices to **4096** to view the sames displays as shown in the pictures below.

Display Option Settings

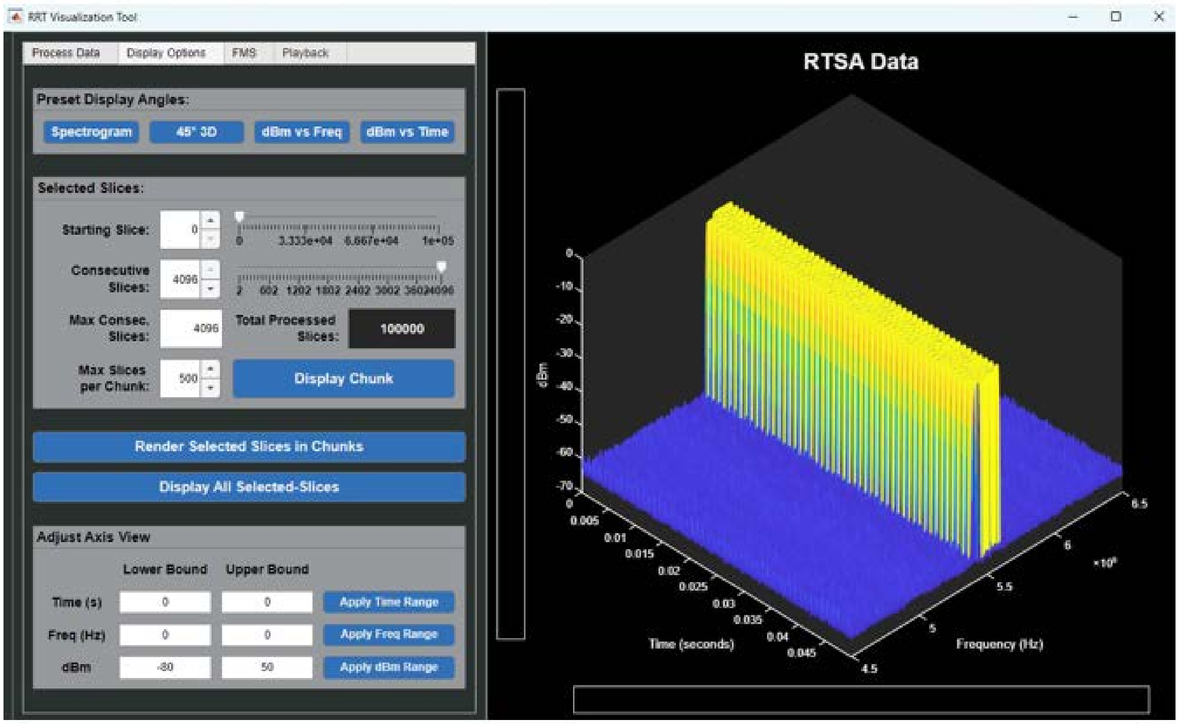
The **Display Options** tab contains settings to customize the display.

Preset Display Angles Area

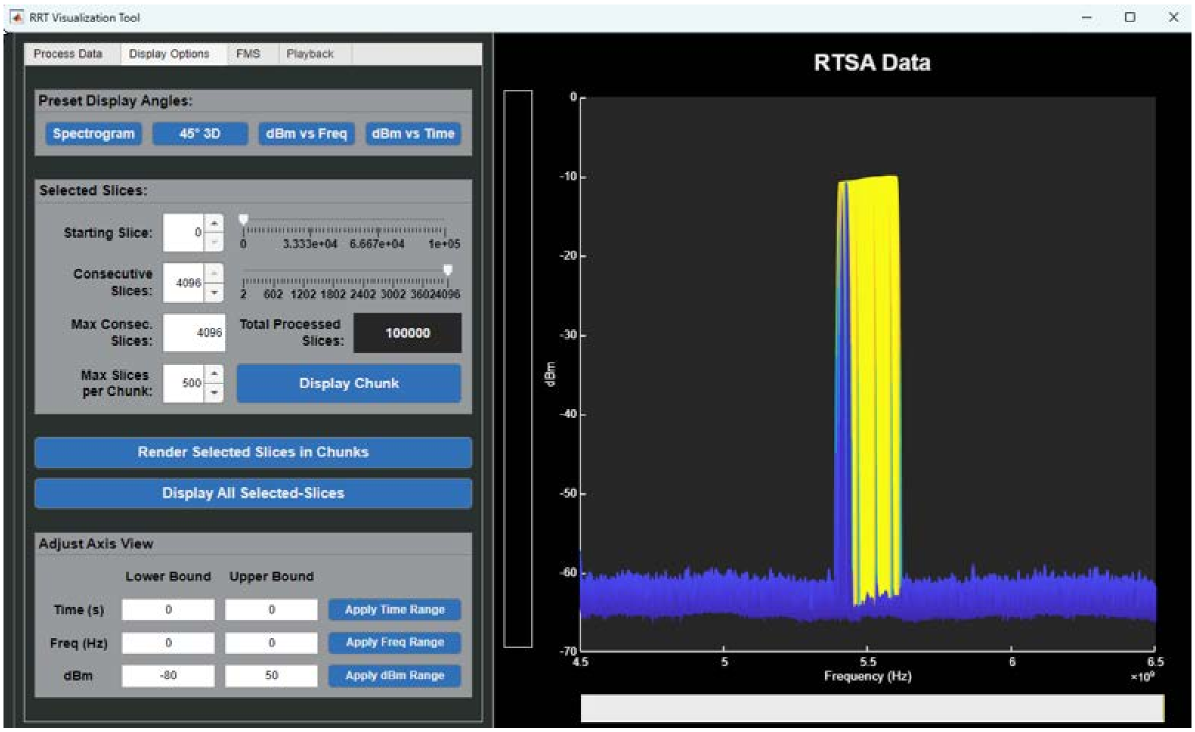
– **Spectrogram View** - plots the selected slices with axes of time in seconds and frequency in Hz.



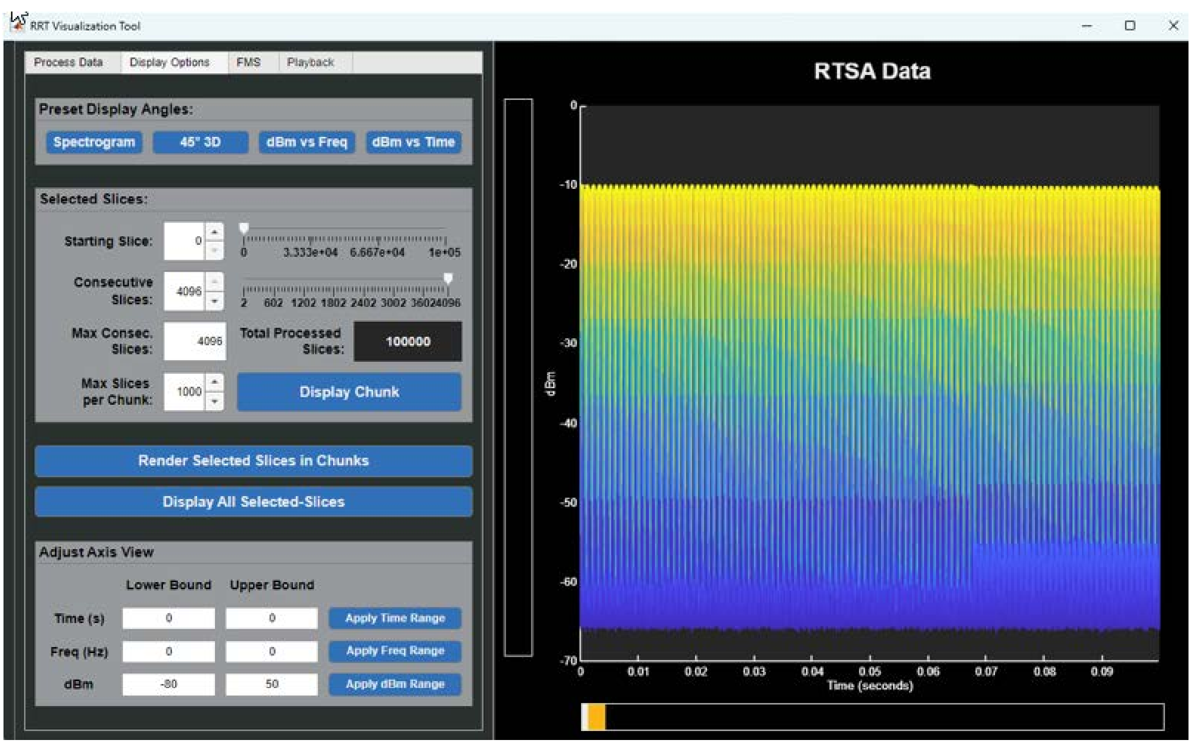
– **45° 3D View** - plots the selected slices on a 45-degree rotated, three-dimensional plot with axes of power in dBm, time in seconds, and frequency in Hz.



– **dBm vs Freq View** – plots the selected slices with axes of power in dBm and frequency in Hz, showing the power distributed over the spectrum.

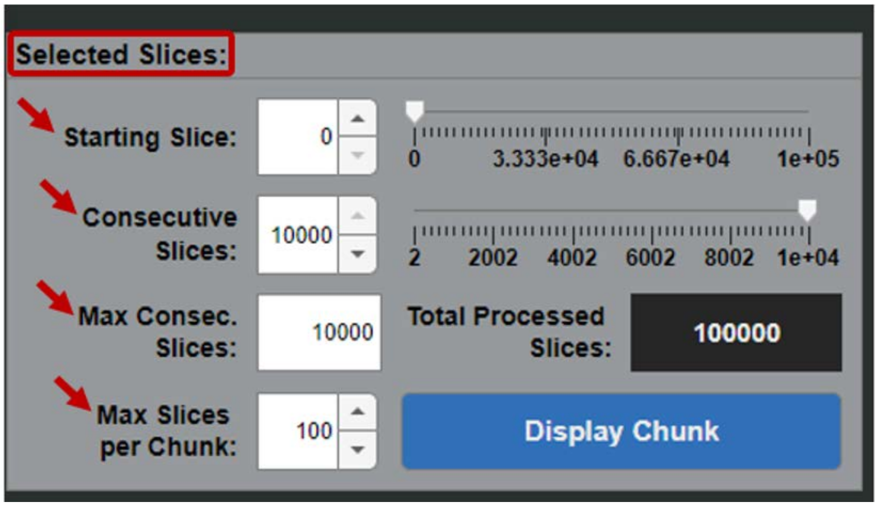


– **dBm vs Time View** – plots power in dBm over time in seconds.



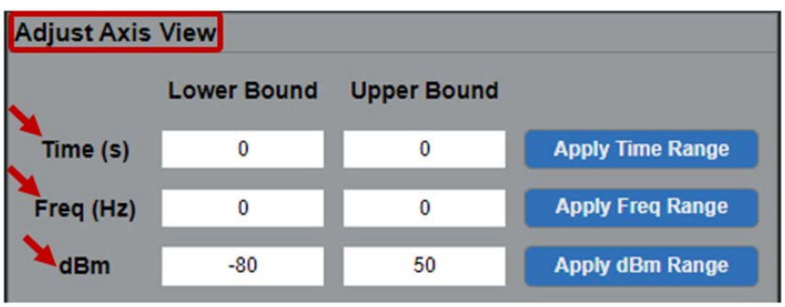
Selected Slices Area

The Selected Slices menu has adjustable settings including Starting Slice, Consecutive Slices, Max Consecutive Slices, and Max Slices per Chunk. Adjusting these settings allows for complete control of the signal slices you want to view.



Adjust Axis View

The Adjust Axis View can be used to alter the Axis of the viewable plot in time, frequency, and power without affecting the Selectable Slices settings.



FMS Tab

The FMS tab allows you to isolate signals by specifying corner bounds of an upper mask, then selecting **Run FMS**. Any signal considered inside the mask will be shown in the **Frequency Mask "Search" hits** table. While the upper mask includes a default of 4 bounds, mask bounds may be added or removed by right clicking the Upper Mask Settings table.

To render and display specific events, highlight the FMS hit you wish to see plotted. The example program's display will update to render the capture portion including the signal that triggered the mask (not the isolated signal passing over the mask alone).

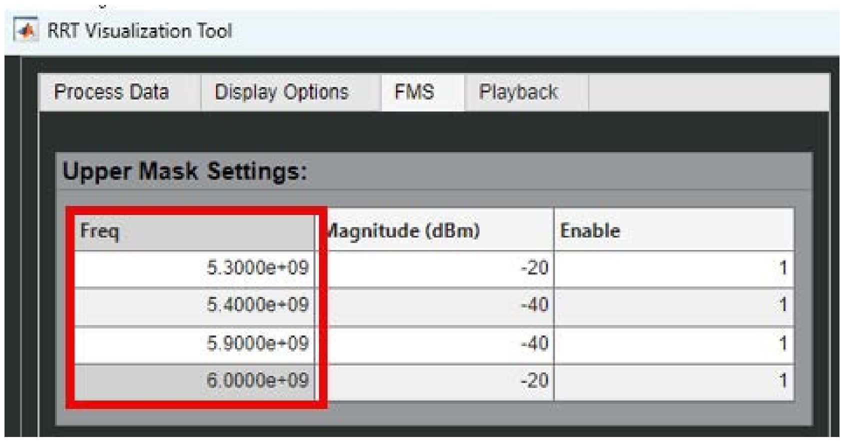
Additionally, at the bottom of the FMS tab, the Display of the Selected Event can be customized between three display options:

– **Beginning** shows the moment the signal entered the mask.

– **Ending** shows the moment the signal left the mask.

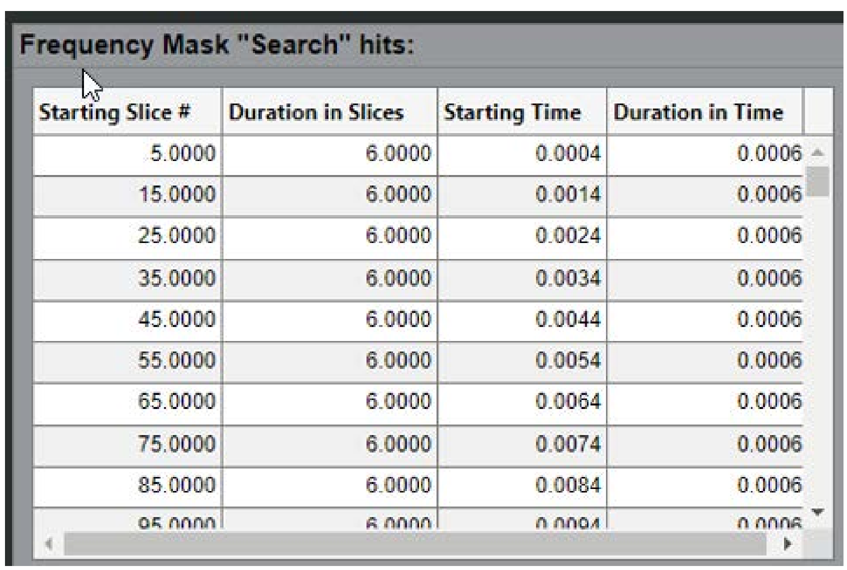
– **Entire** shows the full duration between when the signal entered and exited the upper mask

1. Set the Frequencies to **5.3 GHz**, **5.4 GHz**, **5.9 GHz**, and **6.0 GHz**.



Freq	Magnitude (dBm)	Enable
5.3000e+09	-20	1
5.4000e+09	-40	1
5.9000e+09	-40	1
6.0000e+09	-20	1

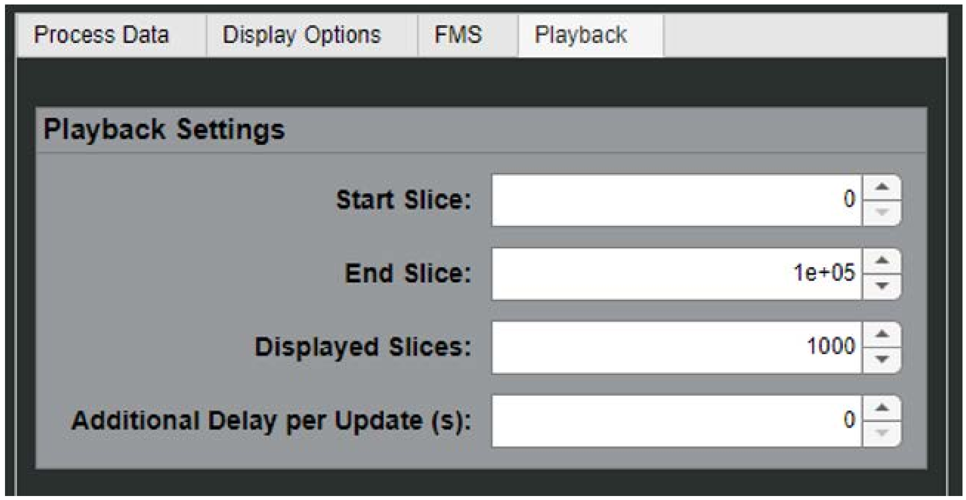
2. Check for signals that are found using the mask.



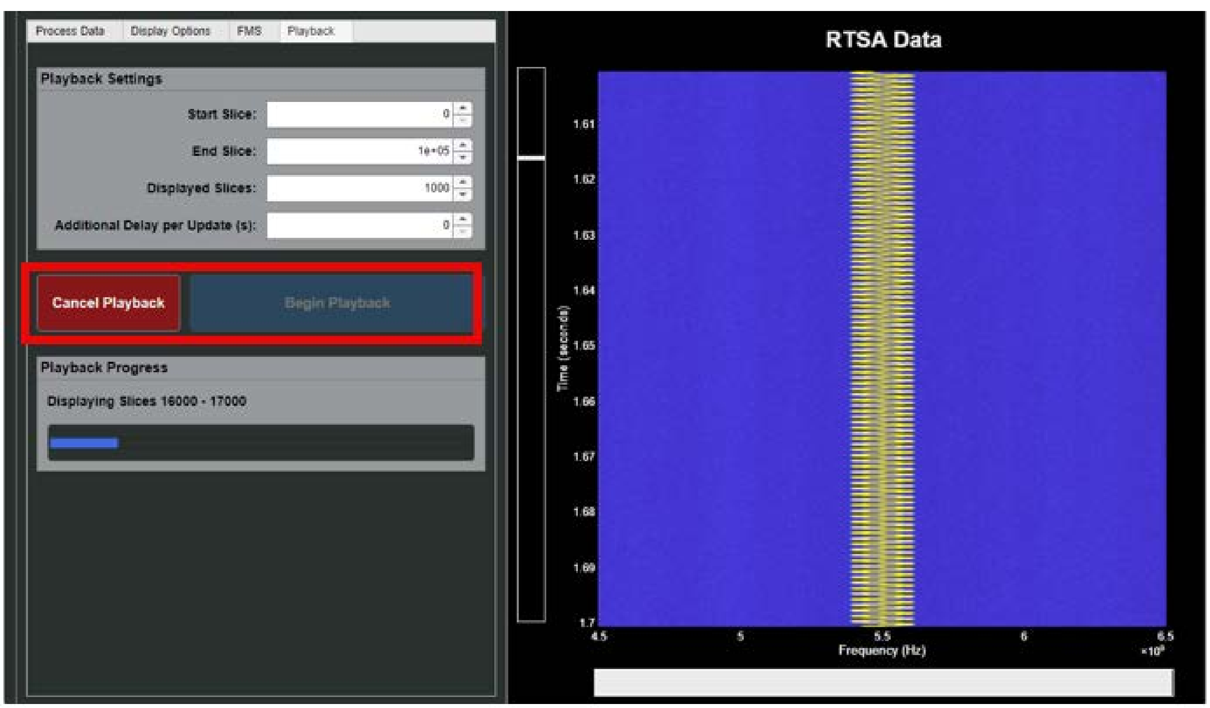
Starting Slice #	Duration in Slices	Starting Time	Duration in Time
5.0000	6.0000	0.0004	0.0006
15.0000	6.0000	0.0014	0.0006
25.0000	6.0000	0.0024	0.0006
35.0000	6.0000	0.0034	0.0006
45.0000	6.0000	0.0044	0.0006
55.0000	6.0000	0.0054	0.0006
65.0000	6.0000	0.0064	0.0006
75.0000	6.0000	0.0074	0.0006
85.0000	6.0000	0.0084	0.0006

Playback Tab

The Playback tab provides you with a quicker method for visually parsing data. Given a specified start and end slice within the uploaded capture, displayed slices (at a time), and desired additional delay per update in seconds, the playback feature will scroll through the provided range, rendering and displaying Displayed Slices on the axes at a given time. This screen will then show for some latency + the desired additional delay before updating to the next screen; unlike rendered displays generated through Display Options, rendering is cleared the moment it leaves the display.



To begin Playback, select the **Begin Playback**. Playback will continue until completion, regardless of the tab you may be on. If for any reason you wish to stop the playback, select **Cancel Playback**, which is only available during an active playback. You may monitor the playback's progress relative to your uploaded capture through the loading bar.



Try using the tabs and settings to get a feel for the RTSA Viewer application.

Conclusion

Option RRT allows you to record RTSA spectrogram slices for post capture processing. The option comes with an example program (RTSA viewer) that extracts the spectrogram data from the bin files that are created from recording. You can create your own applications or build off of RTSA viewer to perform in depth signal processing.

Additional Resources

Application note: Real-Time-Spectrogram-Streaming.pdf

5 Custom Modulation Measurements

This section includes the following topics:

– "Using PathWave E7608APPC to Create a Waveform File then Automatically Configure the Analyzer to View the Results" on page 150
– "Using the N5186A MXG as an Embedded Reflectometer" on page 156

Using PathWave E7608APPC to Create a Waveform File then Automatically Configure the Analyzer to View the Results

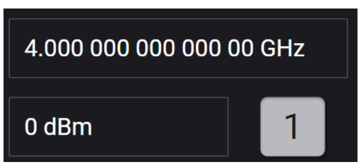
PathWave software tools can be used to create, download, and playback waveforms through the MXG.

This example shows you how to create and analyze a 16QAM using the embedded PathWave software and then automatically configure the analyzer to make the measurement.

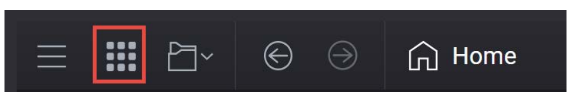
NOTE	The MXG must have the E7608APPC Custom Modulation license installed and Signal Analyzer Version 2023 A.36.xx or later.

On the MXG:

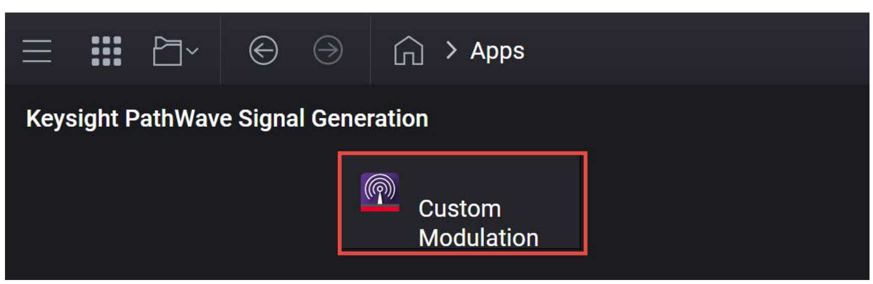
1. Select **Preset** > **Preset** to set the MXG to a known state.
2. In the Output area, set Frequency to **4 GHz** and Power to **0 dBm**.



3. Select the **Apps** block to open the mode selection panel.

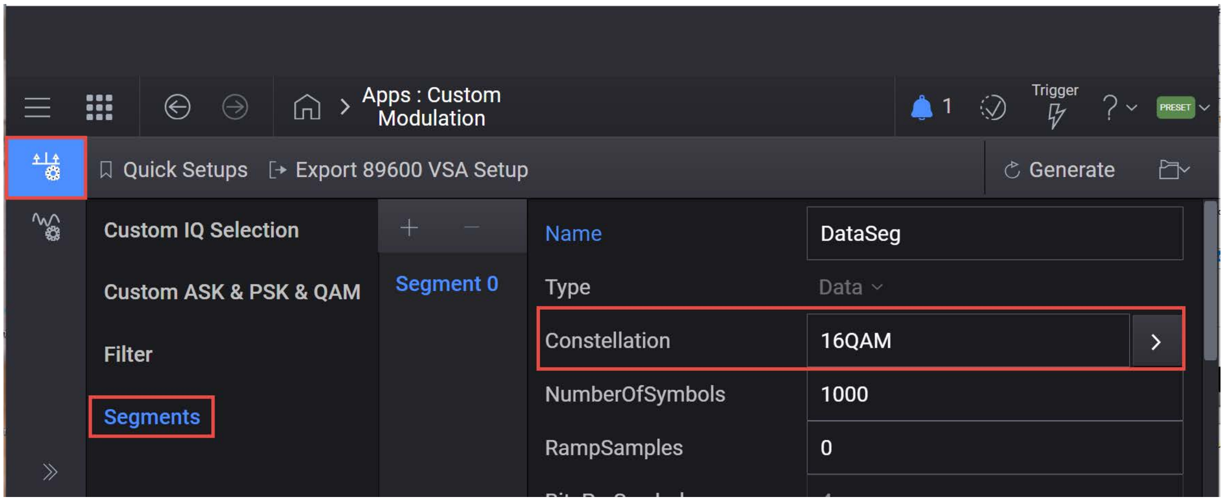


4. Select **Custom Modulation** to enter the custom modulation application.

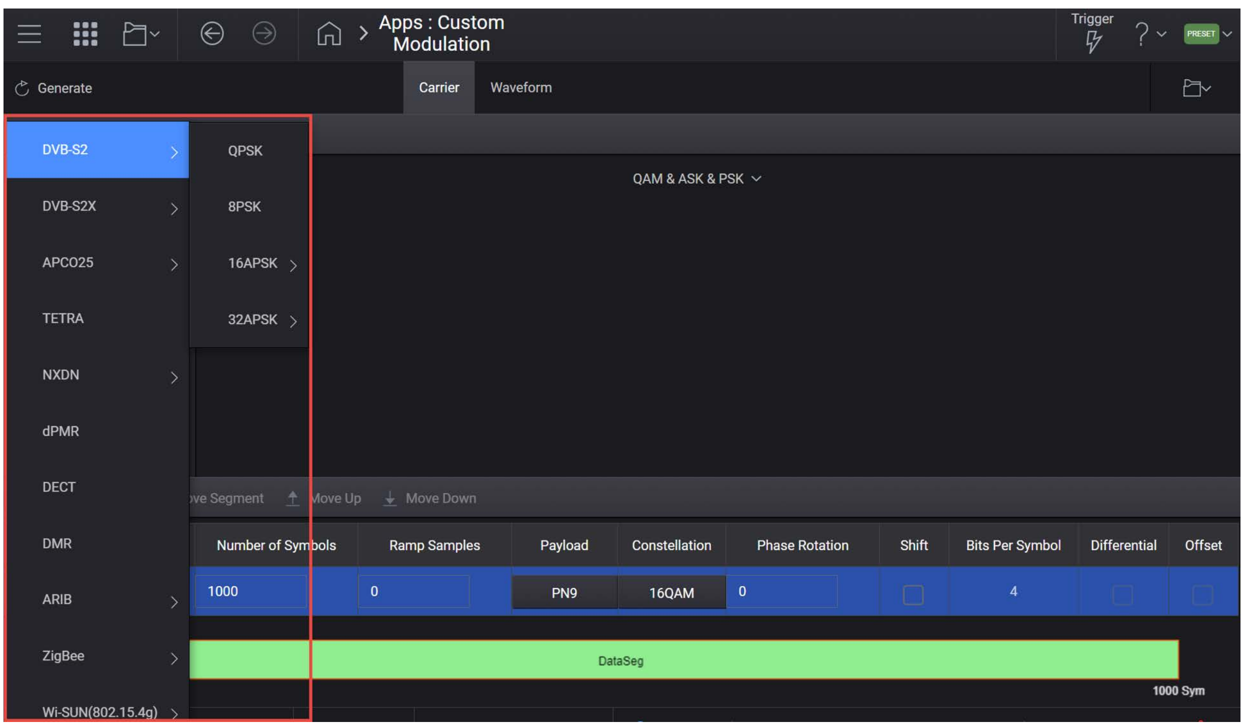


5. In the Custom Modulation setup, select the **Carrier** tab.

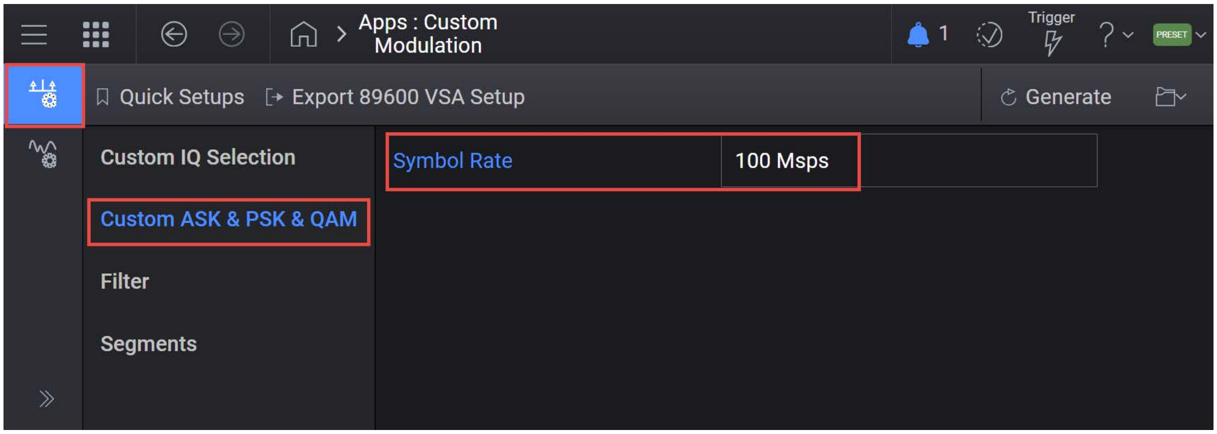
We will use the default 16QAM constellation for this example.



TIP Use Quick Setups for convenient saving and loading of common configurations. Quick Setups are factory supplied configurations and cannot be deleted by users.

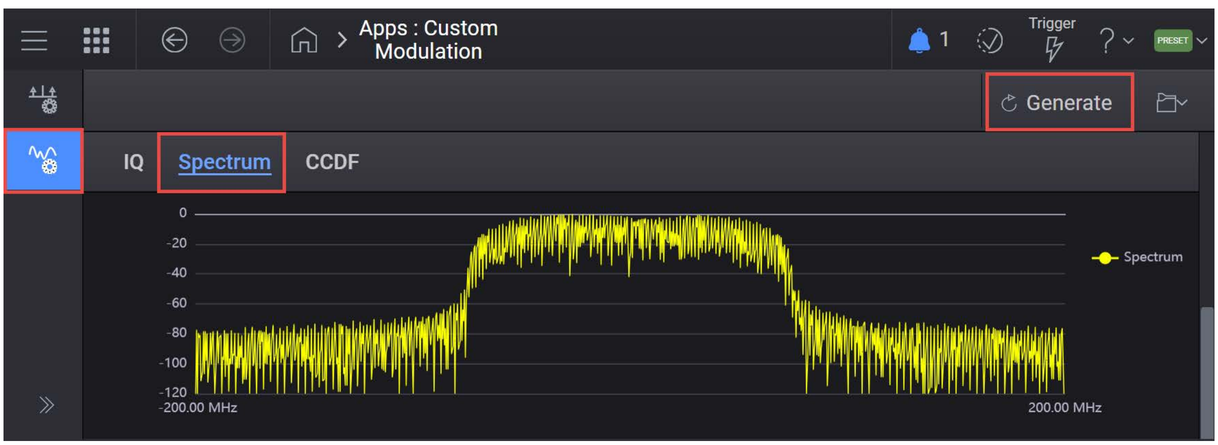


6. In the left pane, select **Custom ASK & PSK & QAM** and set Symbol Rate to **100 Msps**.



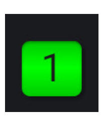
7. Select the **Waveform** tab > **Generate**.

   Scroll down to the bottom half of the display and select **Spectrum** to view the Waveform.



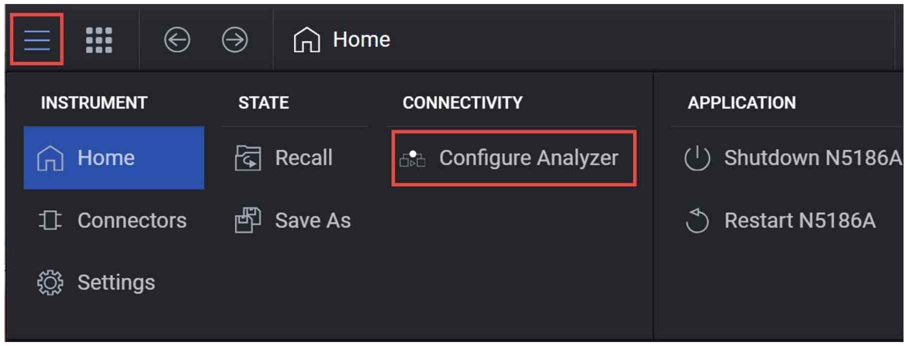
8. Select the **Home** icon and set RF Out to **On** by selecting the numbered channel indicator switch.

   This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel MXG.

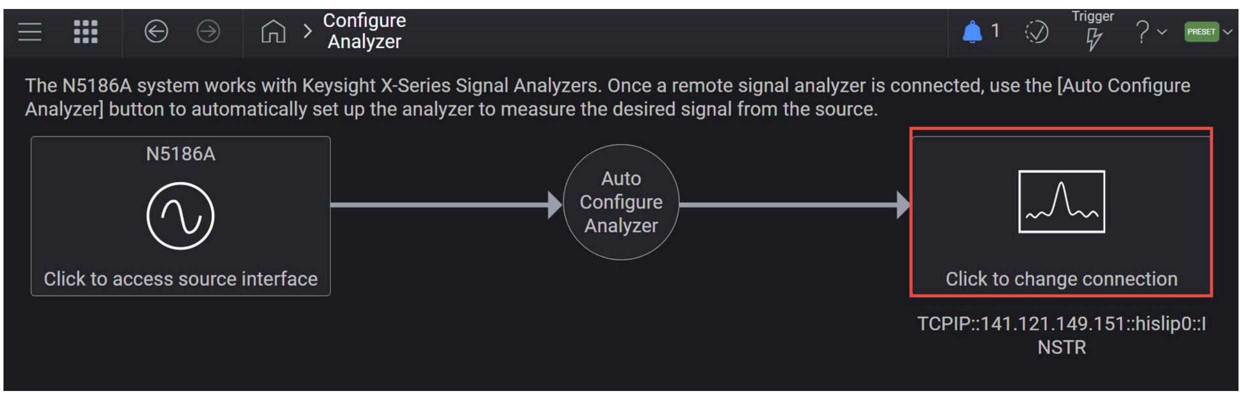


Setup Auto Configure Analyzer

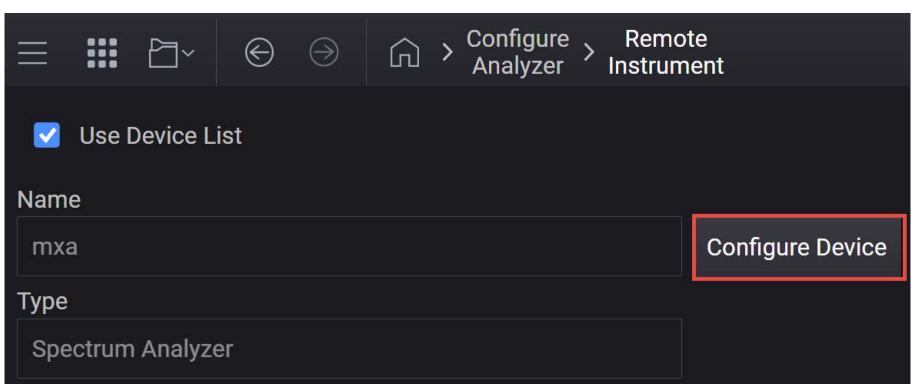
1. Select the System menu (triple bar tab at the top left of the window) and select **Configure Analyzer**.



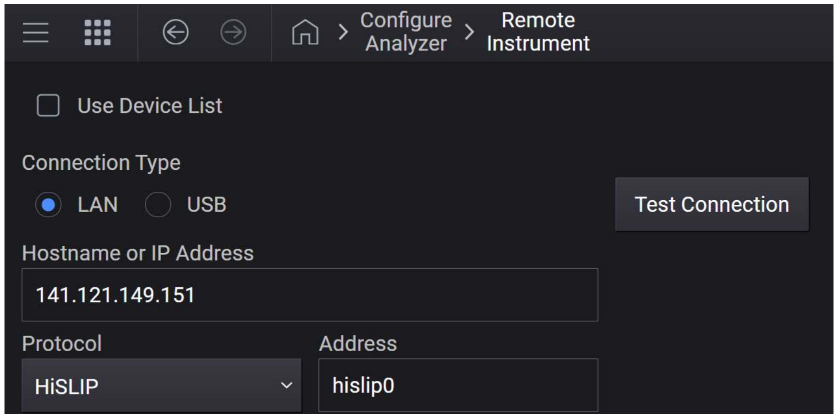
2. In the Configure Analyzer setup, click on the Remote Signal Analyzer block (on far right) to setup the communication channel to the Keysight X-Series Signal Analyzer.



3. Select the **Use Device List** checkbox > **Configure Device**



Alternatively, you can just enter the device information for a one time use. The Use Device List allows you to set up more than one Spectrum Analyzer to be used for a channel's Auto Configuration.



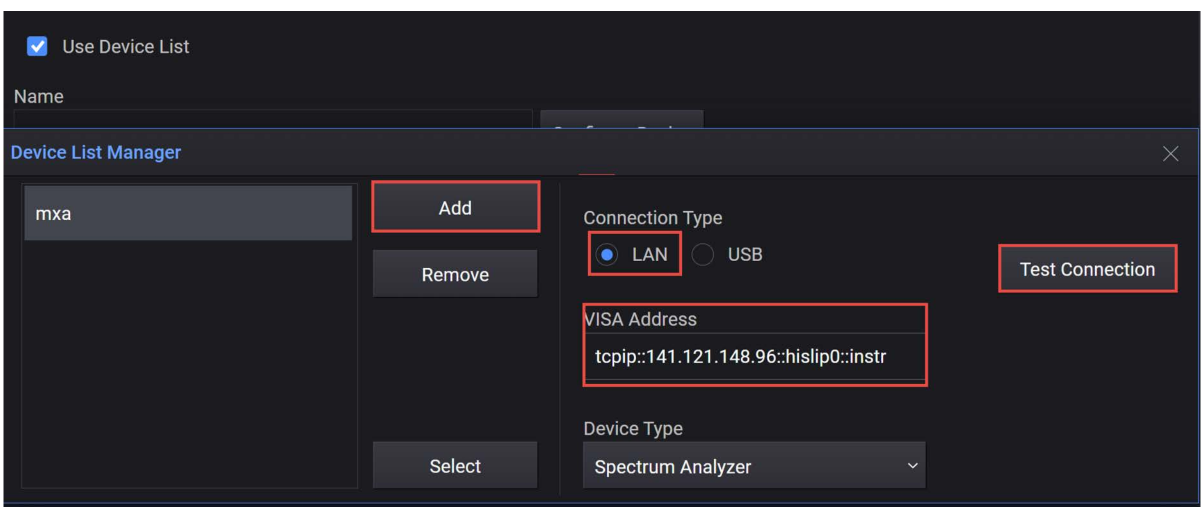
4. In the Device List Manager, select **Add** and enter a name for your X-Series Signal Analyzer:

   – Set Connection Type to **LAN**

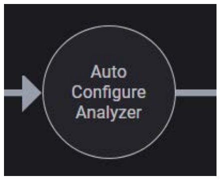
   – Enter the VISA Address of the analyzer.

   – Test Connection

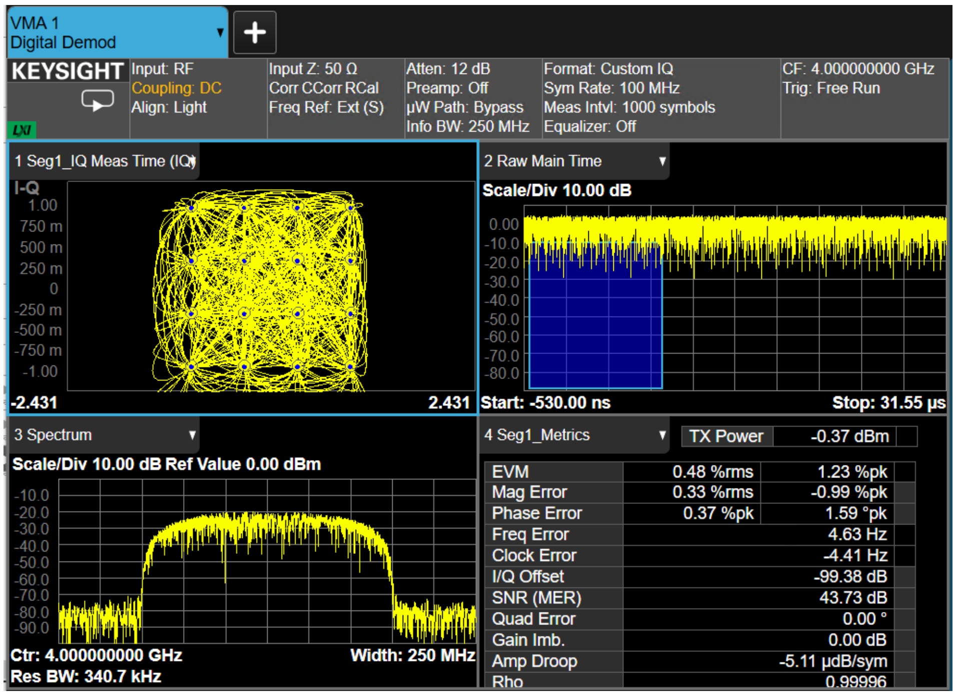
   Select the Info icon (Bell shaped icon at top right of the display) to view the connection status.



5. Select the Back Arrow and select **Auto Configure Analyzer** to send the MXG settings to the analyzer.



6. View the results on the signal analyzer.



Using the N5186A MXG as an Embedded Reflectometer

Traditionally Keysight signal generators, such as the N5182B MXG, have automatic level control (ALC) which works great for RMS power across time and temperature. The ALC is a closed loop system with feedback from a power detector. A challenge with this approach is maintaining amplitude accuracy when the generated signal is wide-band and or high crest factor. The ALC does not compensate for phase flatness or delay. Keysight's N5186A MXG implements a new approach that guarantees amplitude accuracy by aligning across frequency and temperature along with advanced temperature control compensation. Compensation includes amplitude, phase, and delay.

A common source of linear error is caused by mismatch of the fixture and device under test (DUT). By default, the reference plane is at the test port of the MXG and assumes a 50 ohm load is connected, which in many cases is not how the test is set up. The effect of linear error affects absolute amplitude accuracy, amplitude frequency response (flatness), phase frequency response (phase dispersion or deviation from linear phase), and IQ impairments. By using the N5186A's embedded reflectometer, the reference plane can be moved from the source's RF output to the input of the DUT while also generating a match corrected signal. The embedded reflectometer supports features such as fixture characterization, DUT S11 measurements, corrections/fixture de-embedding, and DUT match correction (by generating a match corrected wave). This measurement example will provide detailed steps and features of the embedded reflectometer for N5186A MXG.

NOTE **The MXG must have the E7608APPC Custom Modulation license installed and Signal Analyzer Version 2024 A.38.xx or later.**

Test Setup

Definitions

– **DUT Input**: Targeted plane that the user desires to stimulate the DUT.

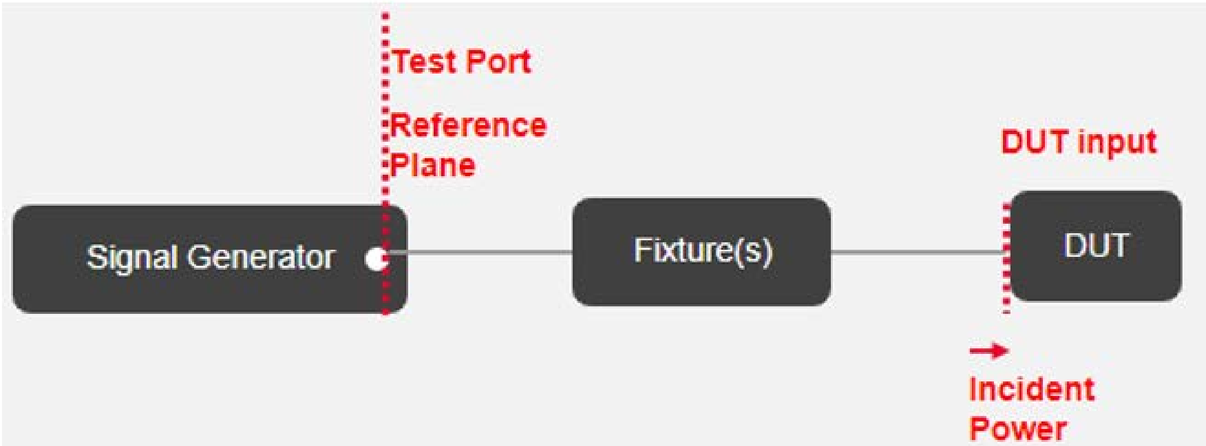
– **Reference Plane**: The endpoint for the MXG’s calibration.

– **Fixtures**: All electrical components in the signal path between the DUT and the MXG.

– **Incident Power [dBm]:** The incident power the user desires to stimulate the DUT.

In general, a DUT is connected to a fixture that is connected to the test port of the MXG.

Figure 5-1 Block diagram of general test setup when connecting a DUT to an MXG



Materials

	Material	Part Number	Quantity
1	MXG	N5186A MXG - (Any channel configuration is acceptable)	1
2	Signal Analyzer	N9032B PXA - (Any Keysight Signal Analyzer is acceptable)	1
3	ECal Module	N7555A - (See "Supported ECal Modules" on page 161)	1
4	DUT	Mini Circuits ZX60-83LN-S+	1
5	RF Attenuator	Mini Circuits 15542 6 dB	1
6	3.5 mm Coax Cable	Any quality male-to-male connector is acceptable	2
7	USB 5 V Connector	Used to power the DUT	1

Figure 5-2 Number 1 on material list: N5186A MXG (Any channel configuration is acceptable)

Figure 5-3 Number 2 on material list: N9032B PXA (Any Keysight Signal Analyzer is acceptable)

Figure 5-4 Number 3 on material list: N7555A ECal Module (See “Supported ECal Modules” on page 161)

Figure 5-5 Number 4 on material list: Mini Circuits ZX60-83LN-S+

Figure 5-6 Number 5 on material list: Mini Circuits 15542 (6 dB attenuator)

Figure 5-7 Number 6 on material list: SMA 3.5mm male to male coaxial cable

Figure 5-8 Number 7 on material list: USB powered 5V connector

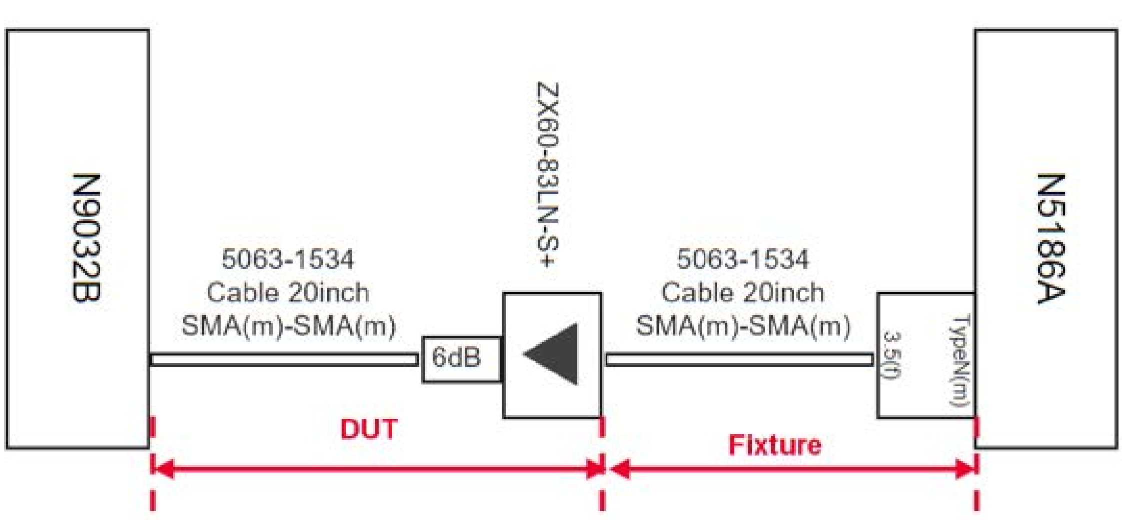
Supported ECal Modules

	Model	Description
N755xA Series 2-port Economy ECal modules		
	N7550A	DC to 4 GHz
	N7551A	DC to 6.5 GHz
	N7552A	DC to 9 GHz
	N7553A	DC to 14 GHz
	N7554A	DC to 18 GHz
	N7555A	DC to 26.5 GHz
8509xD Series 2-ports RF ECal module		
	85091D	DC/300 kHz to 9 GHz
	85092D	DC/300 kHz to 9 GHz
	85093D	DC/300 kHz to 9 GHz
	85094D	DC/300 kHz to 9 GHz
	85096D	DC/300 kHz to 9 GHz
	85098D	DC/300 kHz to 7.5 GHz
	85099D	DC/300 kHz to 6 GHz
8509xC Series 2-ports RF ECal module		
	85091C	300 kHz to 9 GHz
	85092C	300 kHz to 9 GHz
	85093C	300 kHz to 9 GHz
	85096C	300 kHz to 3 GHz
	85098C	300 kHz to 7.5 GHz
	85099C	300 kHz to 3 GHz
N469xD Series 2-ports Microwave ECal module		
	N4690D	DC/300 kHz to 18 GHz
	N4691D	DC/300 kHz to 26.5 GHz
	N4692D	DC/10 MHz to 40 GHz
	N4693D	DC/10 MHz to 50 GHz
	N4694D	DC/10 MHz to 67 GHz
	N4696D	DC/300 kHz to 18 GHz
N443xD Series 4-ports ECal modules		
	N4431D	DC to 13.5 GHz
	N4432D	DC/300 kHz to 18 GHz
	N4433D	DC /300 kHz to 26.5 GHz

Configure the Test Setup

Part 1

Begin setting up the equipment to take the first measurement, measuring the DUT without fixturing or calibration.



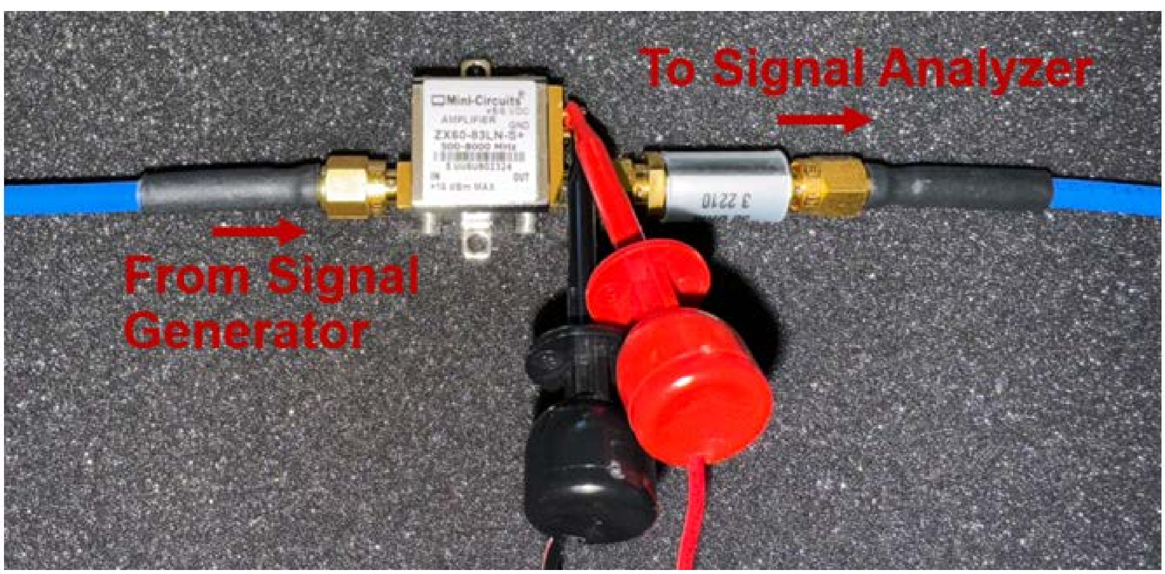
Setup the DUT:

CAUTION To prevent shorting and damage to DUT, ensure USB 5V connector is unplugged when attaching power and ground clips to DUT.

1. Connect the 6 dB attenuator to the DUT's output port.

2. Attach the red clip to the +5 VDC pin and the black clop to the GND pin.

3. Connect the MXG RF output to the input port of the DUT. Connect the signal analyzer RF input to the other side of the attenuator. The figure below shows the RF connection to the MXG and the signal analyzer.



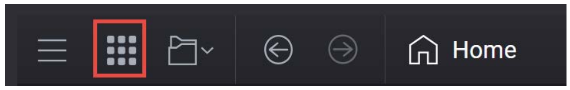
4. Connect the USB 5V to any of the available USB ports on either the analyzer or generator.

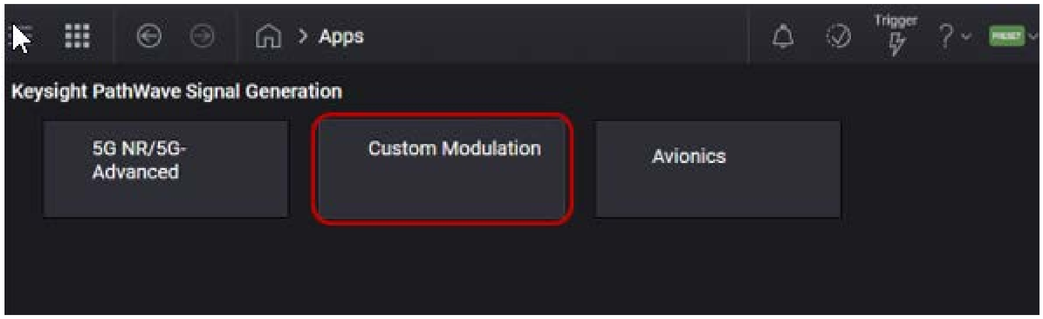
Generate the Signal:

The signal used in this demonstration is a 500 Msps symbol rate, 4096 Symbol, 16 QAM signal.

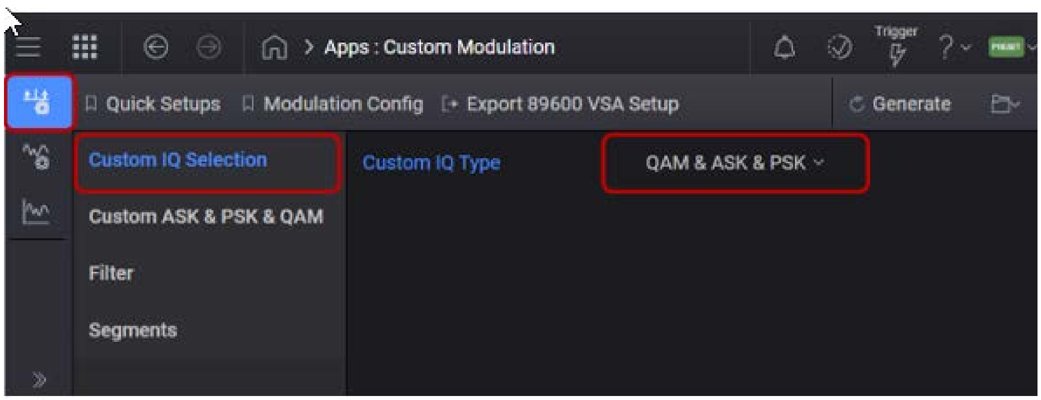
1. On the MXG, select **Preset** > **Preset** to set the instrument to a known state.

2. On the MXG select the **Apps** menu > **Custom Modulation.**

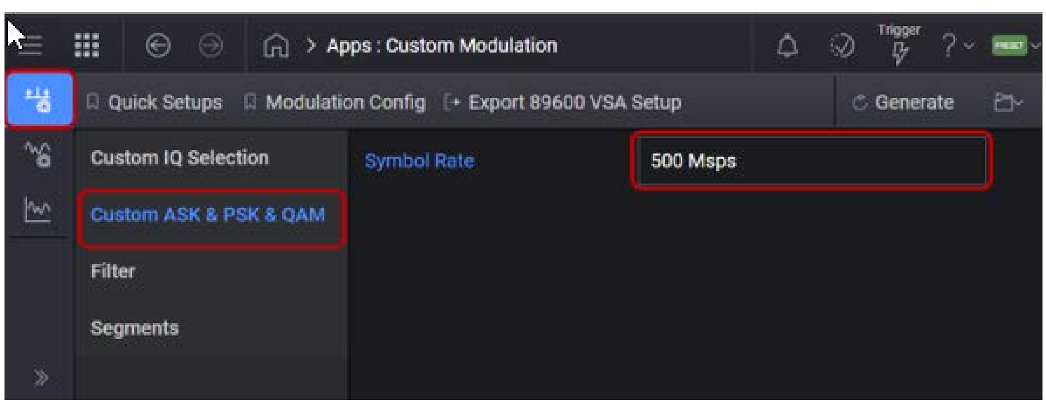




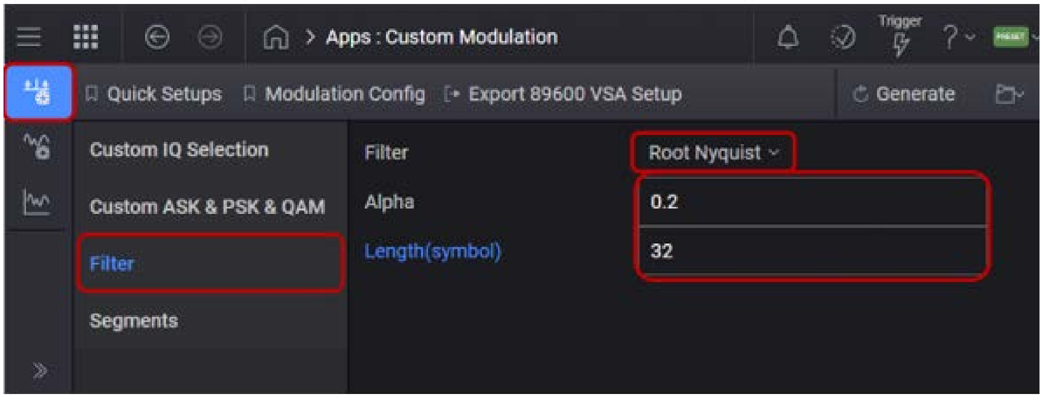
3. In the **Carrier** menu (left pane) select **Custom IQ Selection** > **Custom IQ Type** > **QAM & ASK & PSK.**



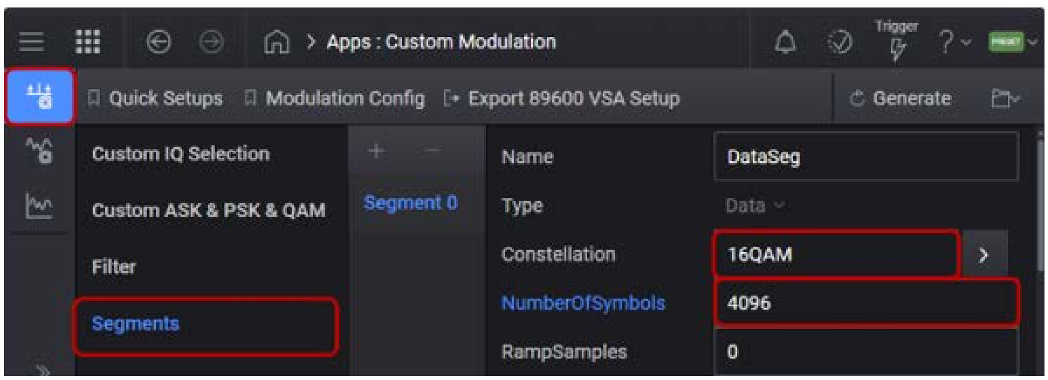
4. Select **Custom ASK & PSK & QAM** > **Symbol Rate** to **500 Msps**.



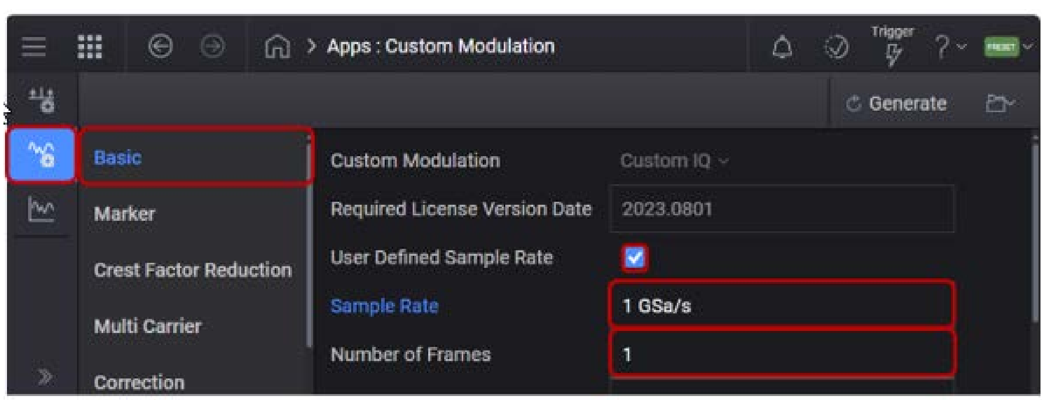
5. Select the **Filter** tab > set Filter to **Root Nyquist** > Alpha **0.2** > Length (symbol) **32**.



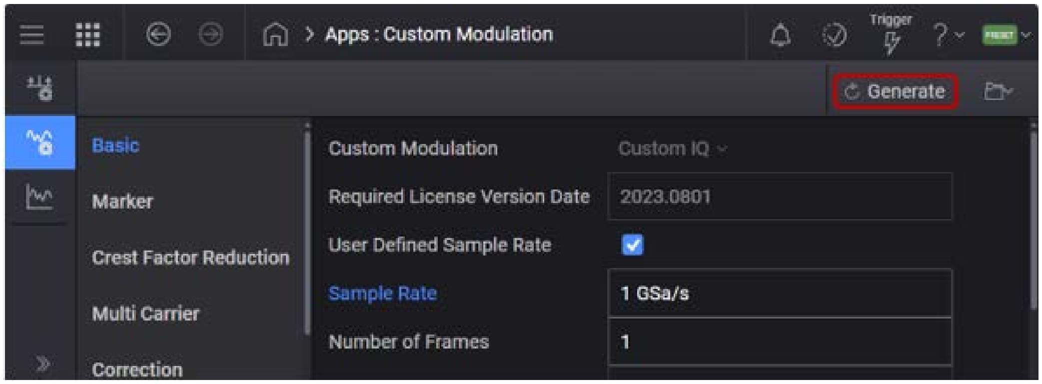
6. Select **Segments** > Constellation **16QAM** > NumberOfSymbols **4096**.



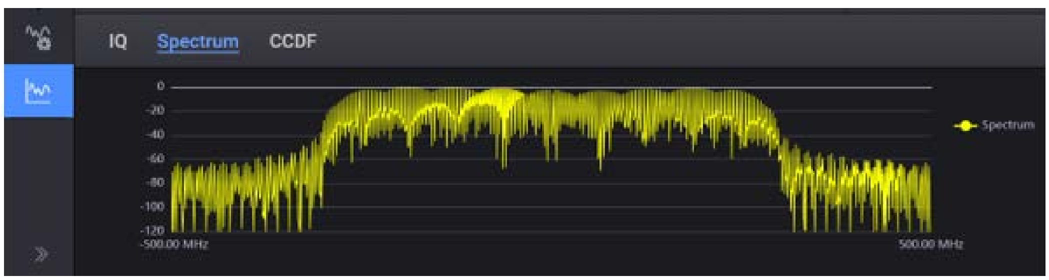
7. Select the **Waveform** menu (left pane) and select:
   - **Basic** tab
   - Enable **User Defined Sample Ratio**
   - Sample Rate to **1 GSa/s**
   - Number of Frames to **1**



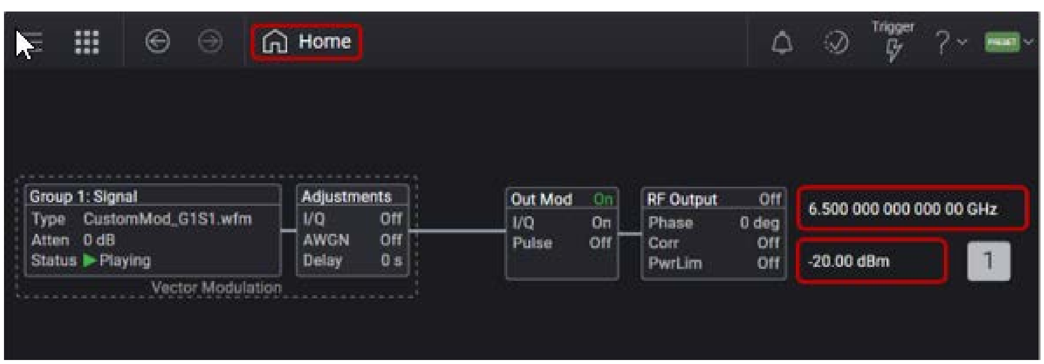
Select **Generate**.



8. Scroll down to the bottom half of the display and select **Spectrum** to view the Waveform.

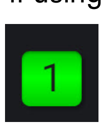


9. Select the **Home** icon and set Frequency to **6.5 GHz** and Power to **-20 dBm**.



10. Set RF Out to **On** by selecting the numbered channel indicator switch.

This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel MXG.

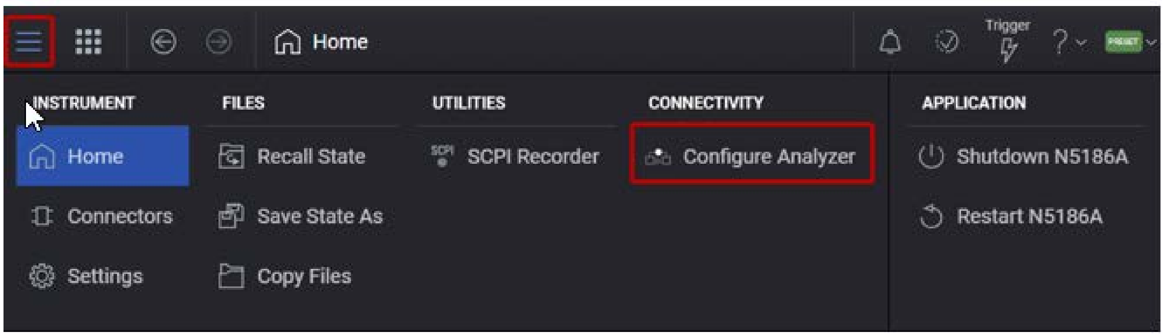


Set up the Signal Analyzer:

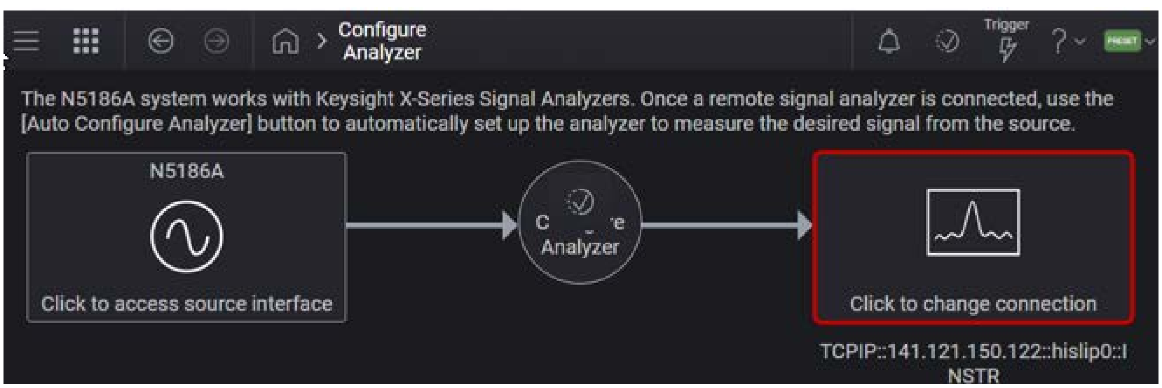
To characterize the DUT we need to demodulate the signal we are sending through it.

The following steps can be done quickly by taking advantage of the Configure Analyzer function on the MXG. The MXG and Signal Analyzer must be on the same LAN network to use the Configure Analyzer function to work. If this criterion is met, follow these three steps to quickly configure your Signal Analyzer.

1. Select the **System** menu > **Configure Analyzer**.

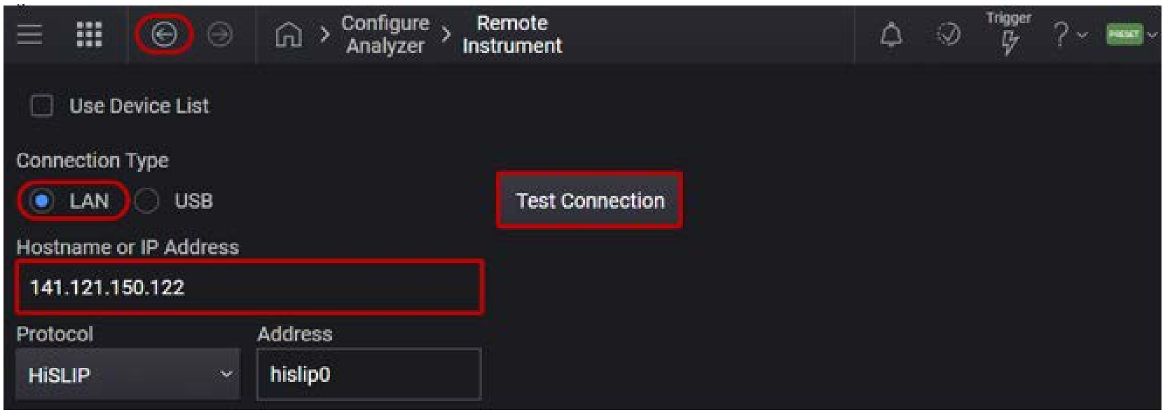


2. Select **Click to change connection.**

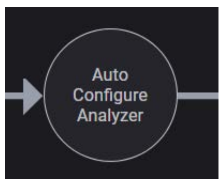


3. In the Remote Instrument window,
   - set Connection Type to **LAN**
   - Enter the **IP address** of the signal analyzer
   - select **Test Connection** to verify proper connection

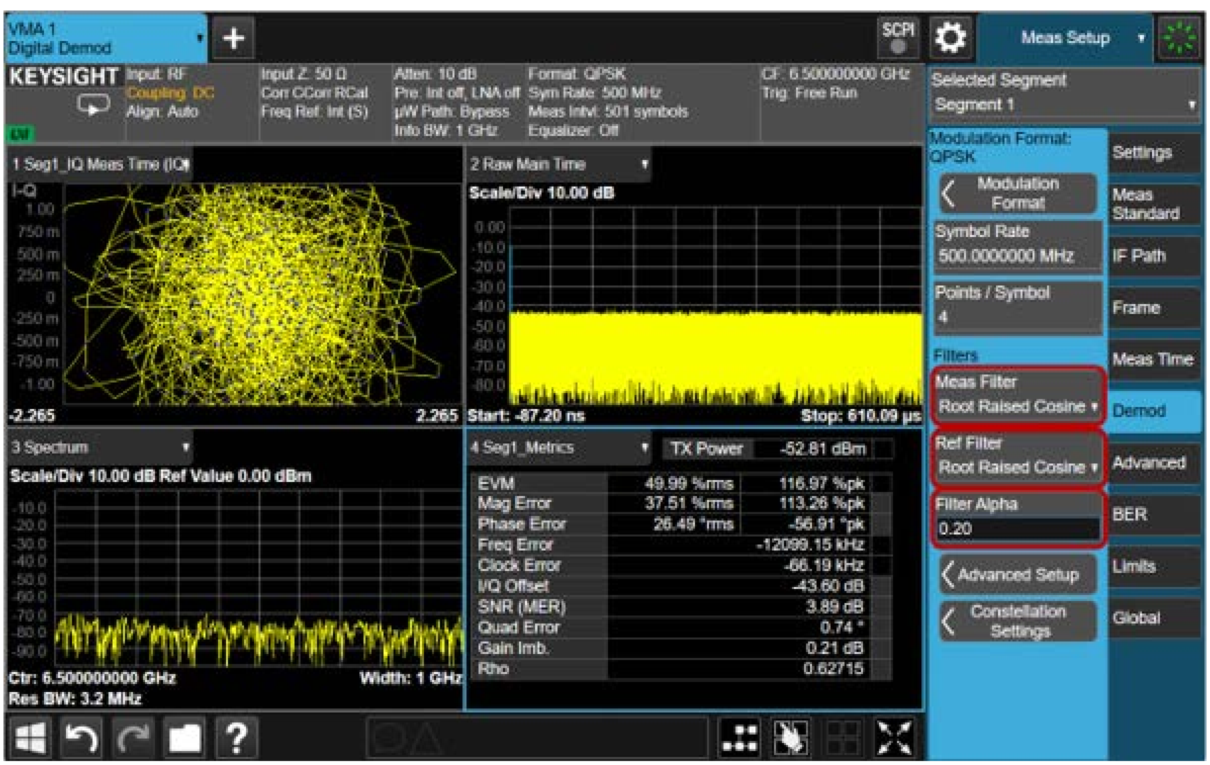
– select the navigation button (left arrow) to return to the Configure Analyzer window.



4. Select **Auto Configure Analyzer** to send the MXG settings to the analyzer.



5. View the results on the signal analyzer.



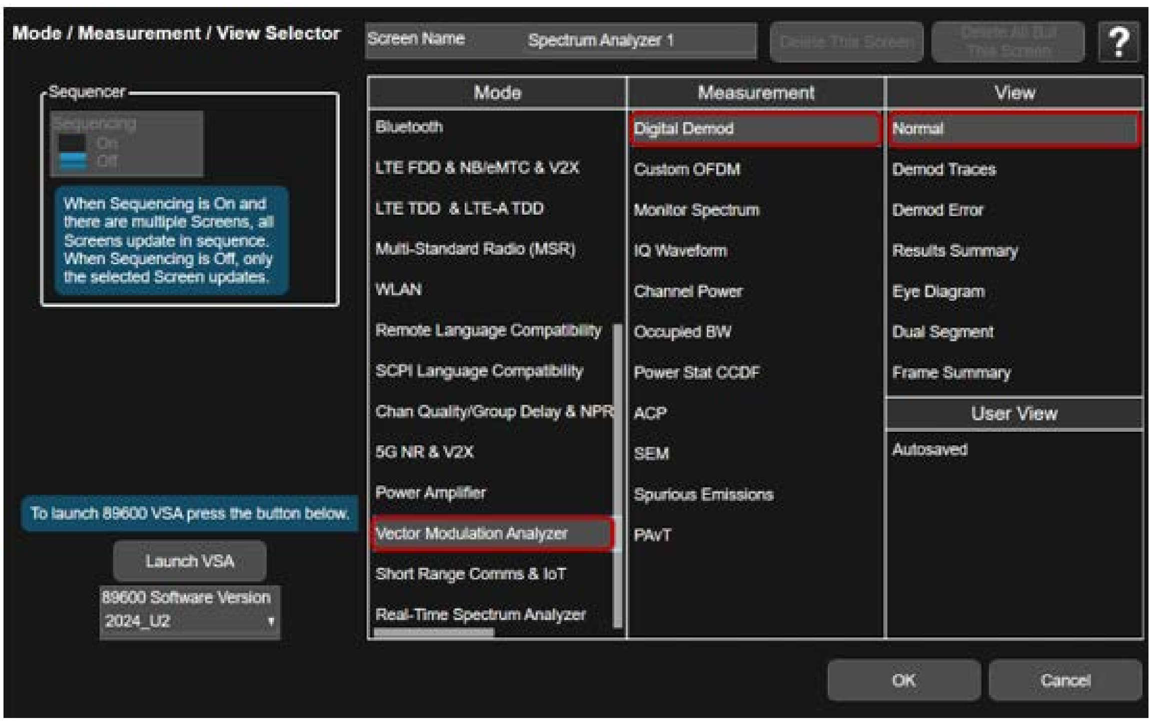
Manually Configure the Signal Analyzer

When not using Auto Configuration, follow these steps to manually configure the Signal Analyzer.

1. From the Menu Panel (on the top right of the display), select **Mode/Meas** > **Vector Modulation Analyzer** mode > **Digital Demod** > **OK**.

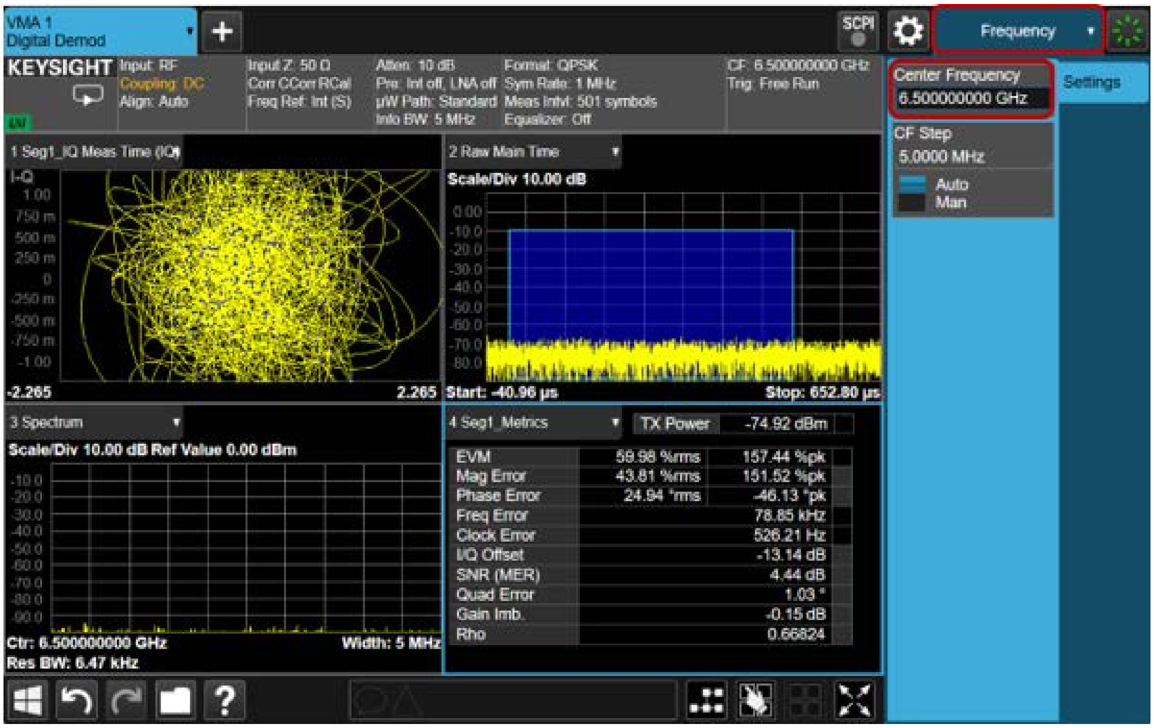
NOTE

If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

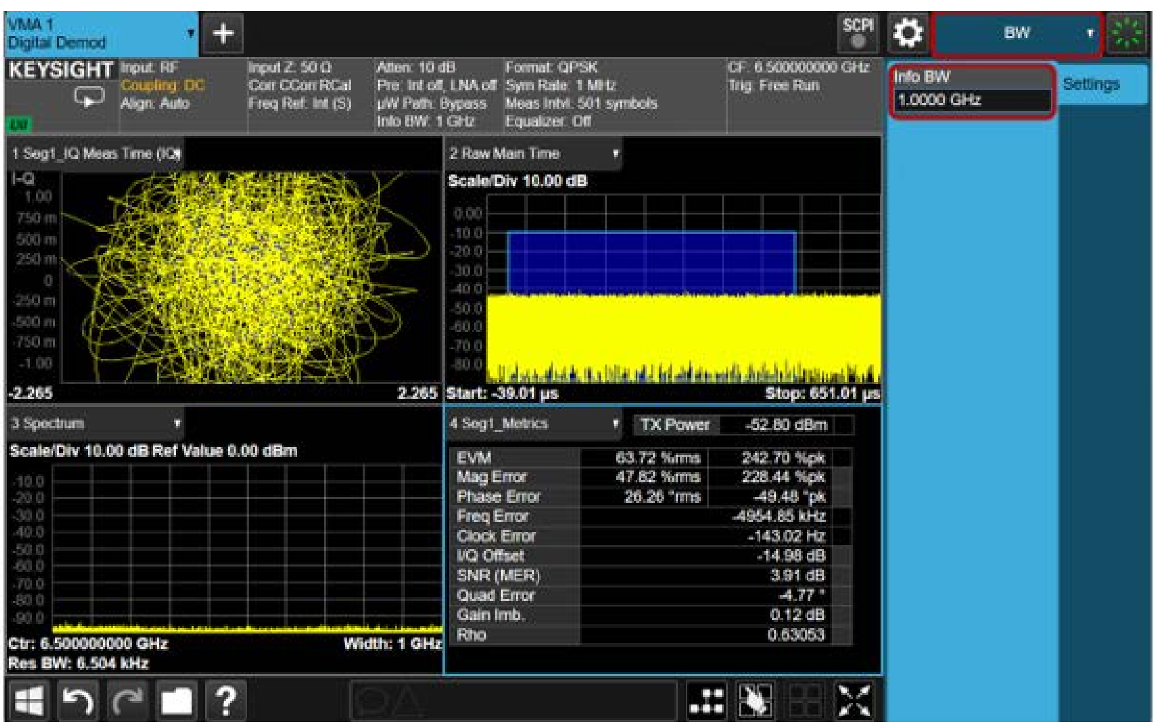


2. Select **Mode Preset** to set the Vector Modulation Analyzer mode to a known state.

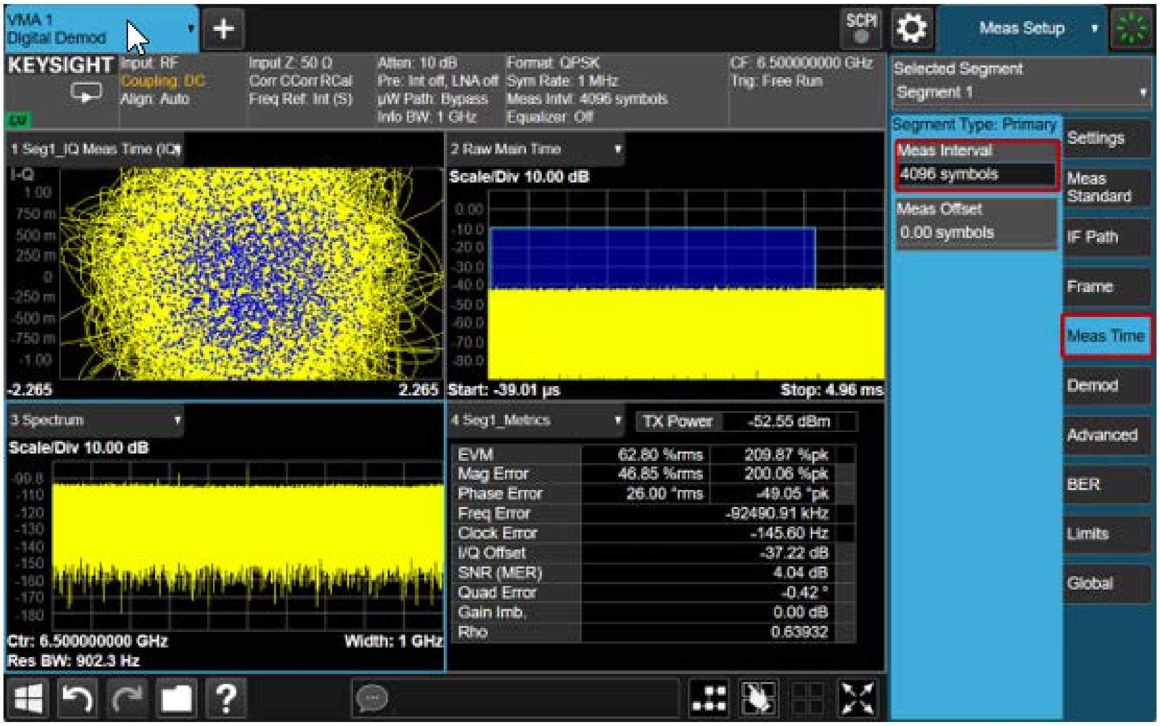
3. Select **Frequency** and set Center Frequency to **6.5 GHz**.



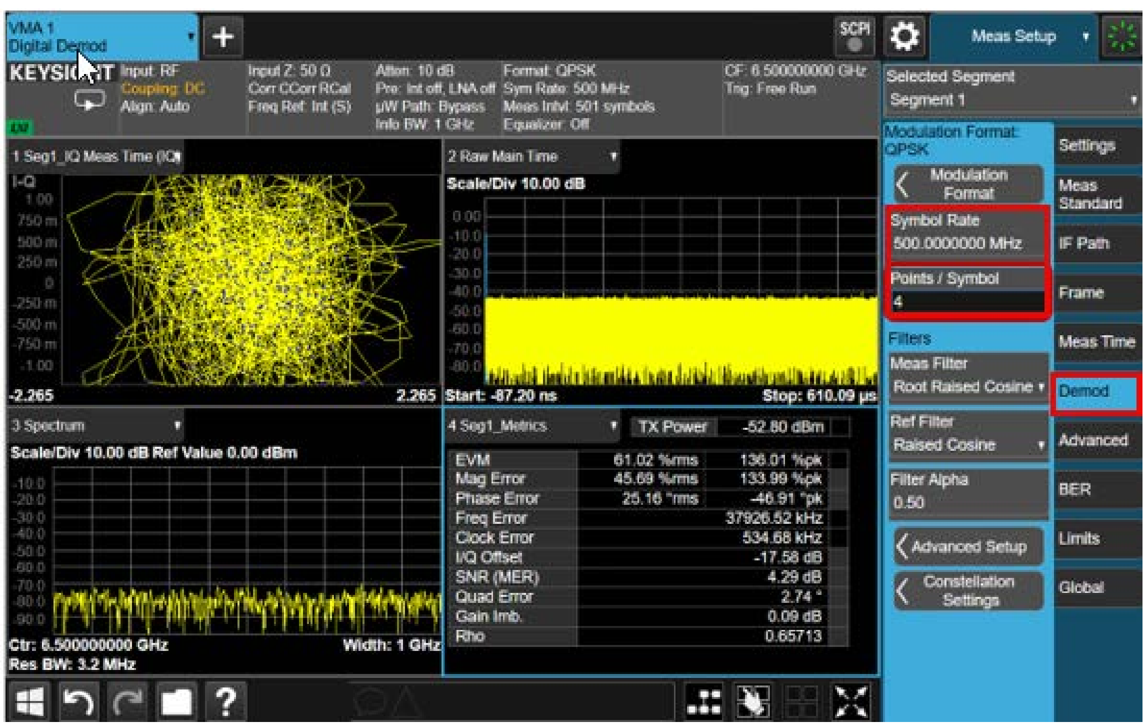
4. Select **BW** > and set Info BW to **1 GHz**.



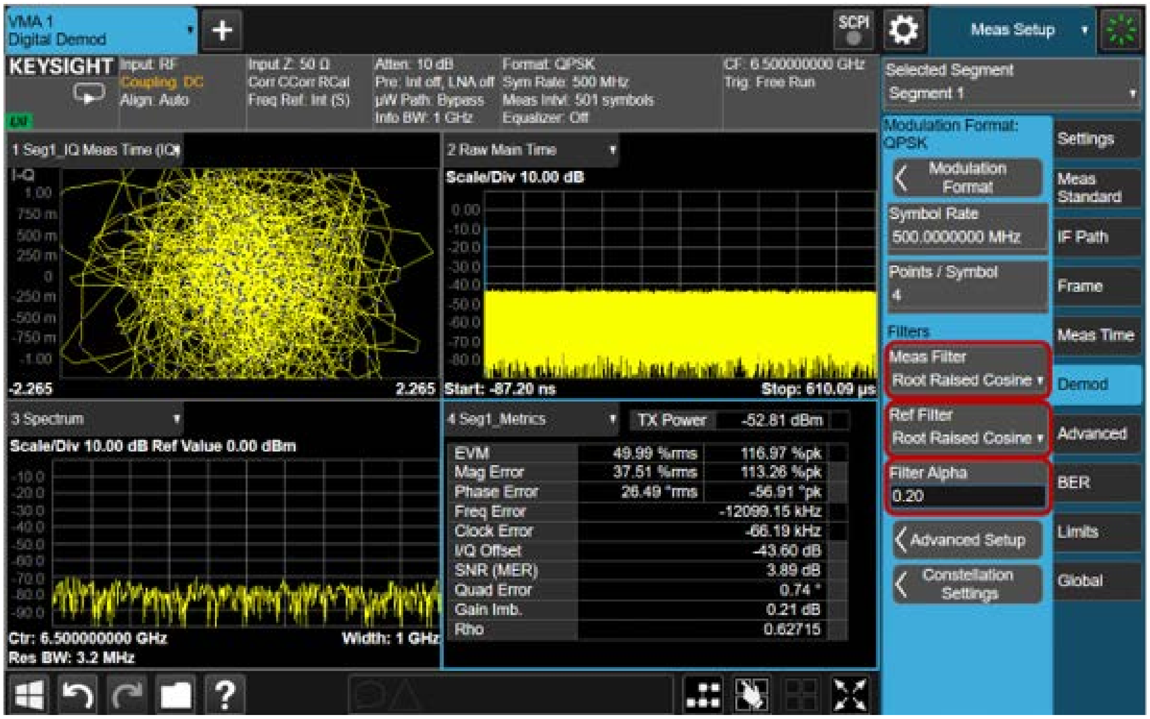
5. Select **Meas Setup** > **Meas Time** > set Meas Interval to **4096 symbols.**



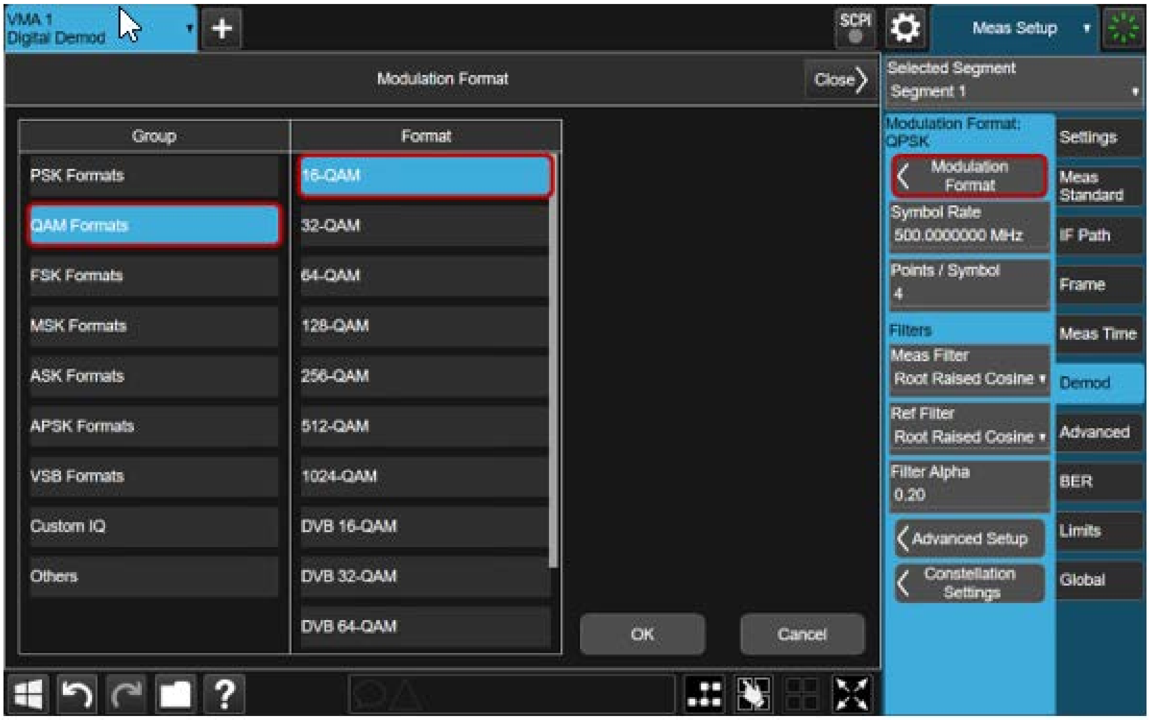
6. Select **Meas Setup** > **Demod** > set Symbol Rate to **500 MHz** and Points/Symbol to **4.**



7. Set Meas Filter to **Root Raised Cosine** > Ref Filter to **Root Raised Cosine** > Filter Alpha to **0.2**.



8. Select **Modulation Format** to open the Modulation Format window and then select **QAM Formats** > **16 QAM**. Select **OK** to close the Modulation Format window.

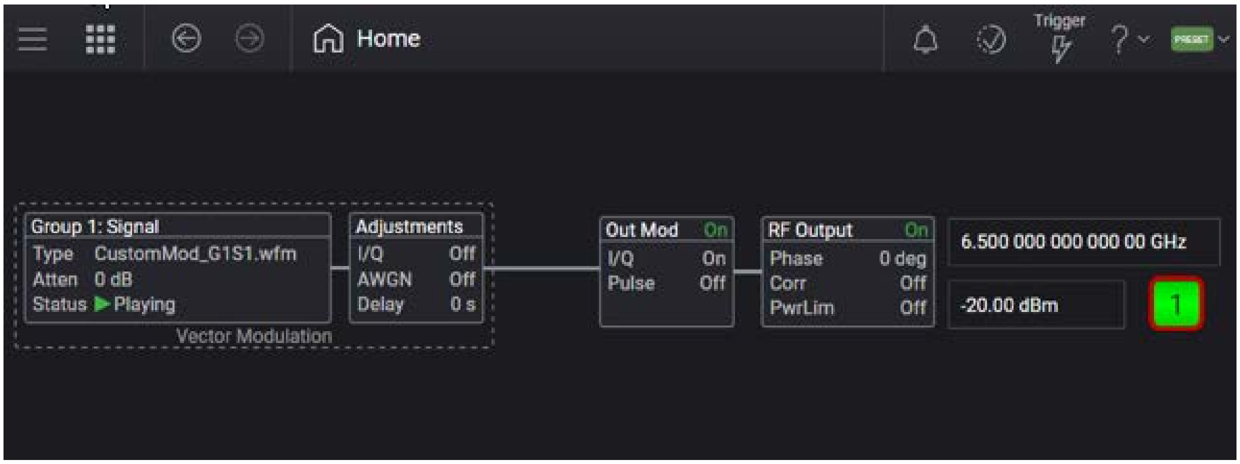


Take the DUT Measurement

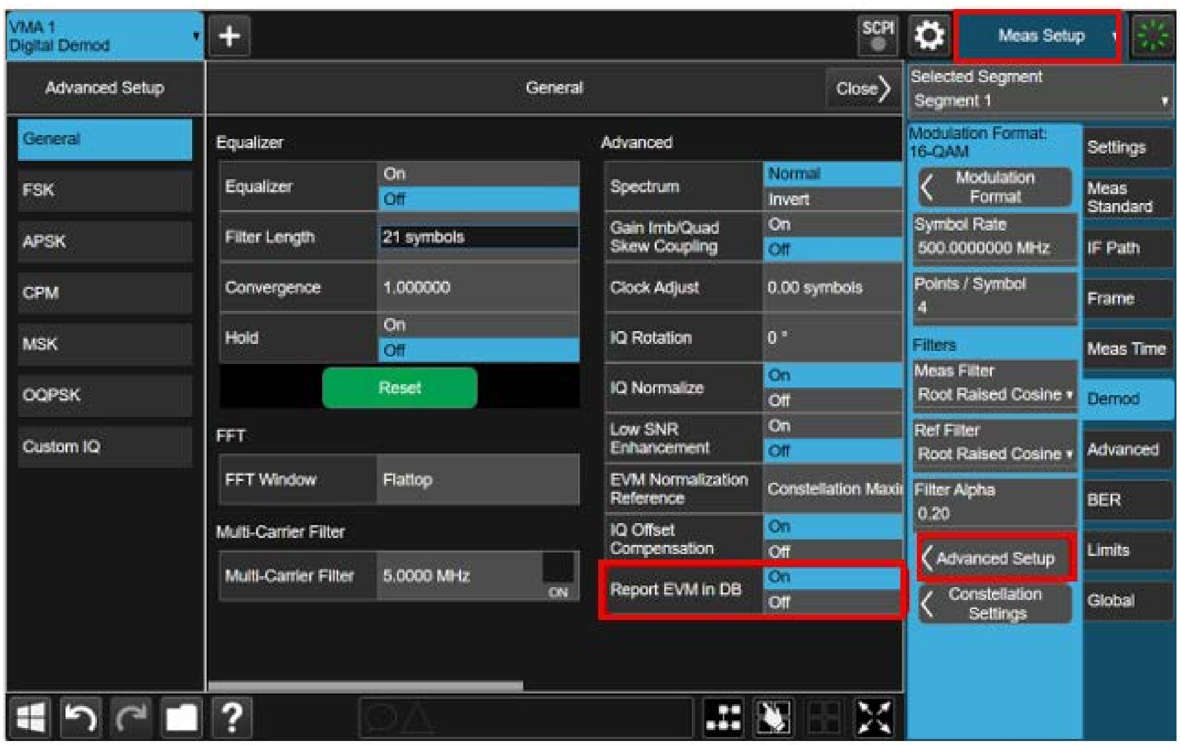
Now that the source is set up to demodulate the 16QAM signal, you can measure the unequalized EVM in dB and channel response in both phase and magnitude. This will give a baseline for how the DUT preforms without fixturing and calibration.

1. On the **MXG**, set RF Out to **On** by selecting the numbered channel indicator switch.

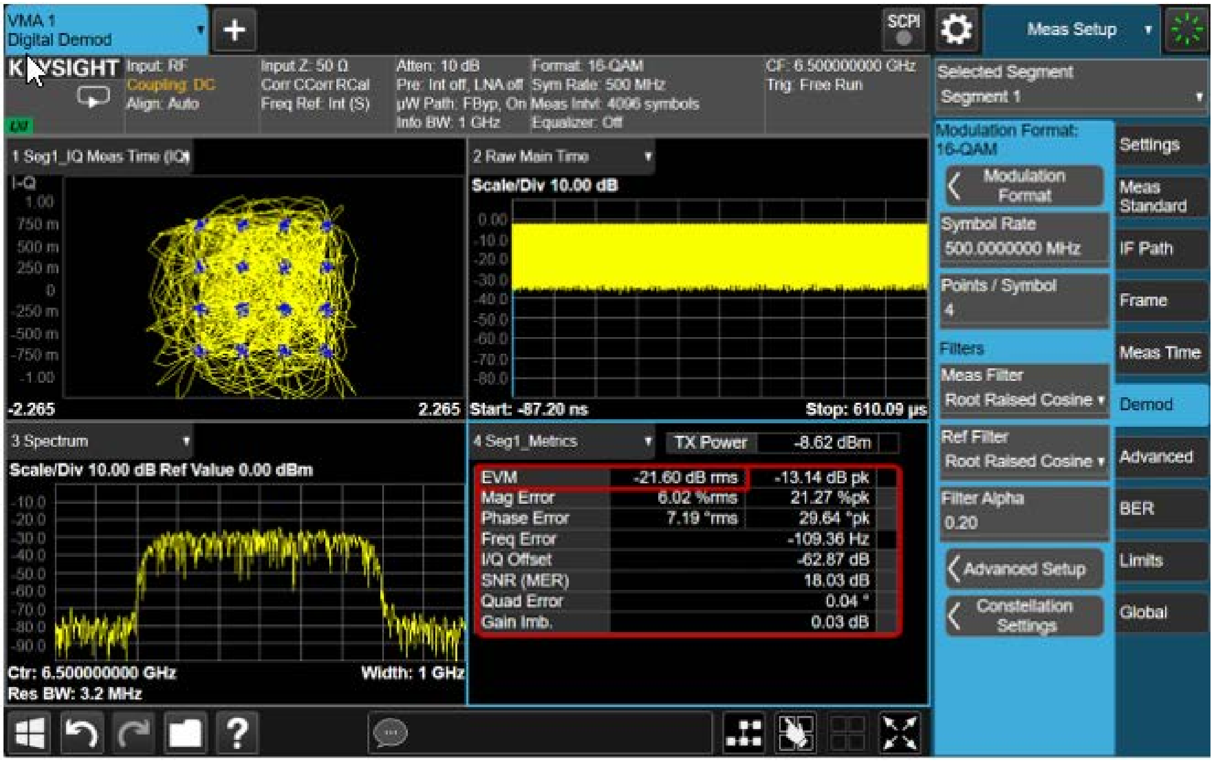
This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel MXG.



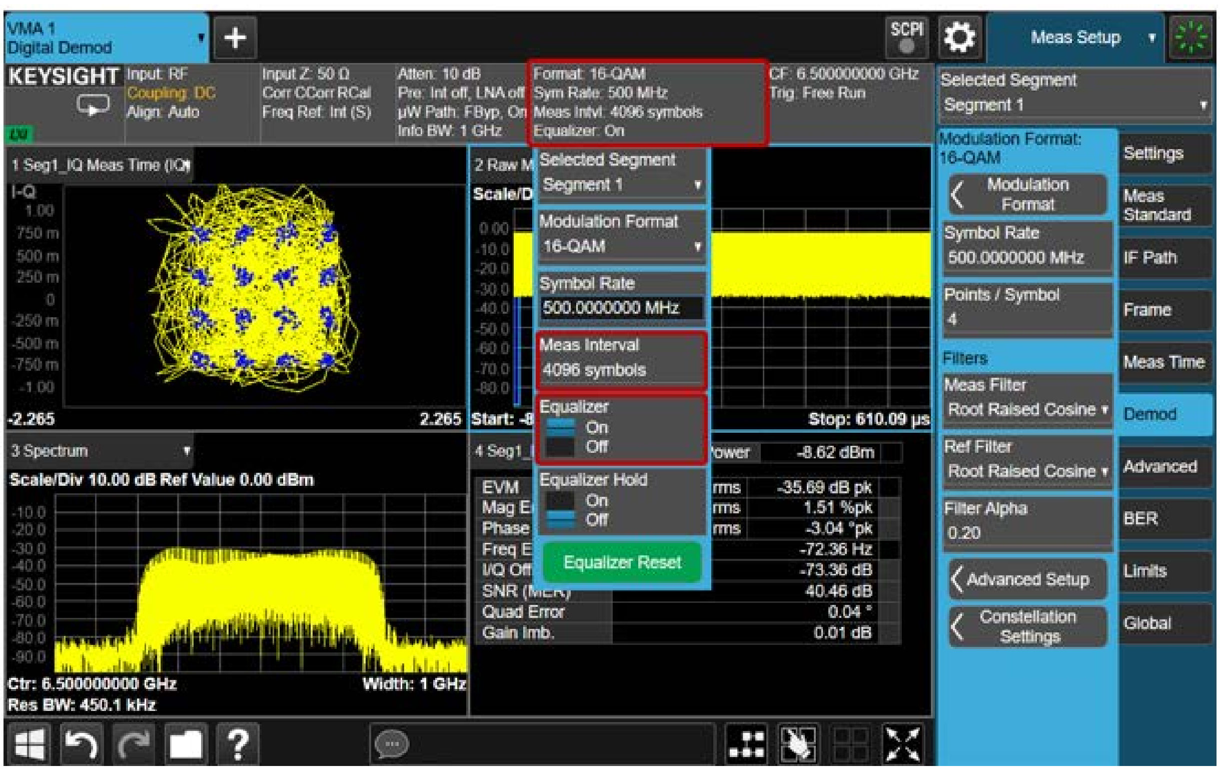
2. On the Signal Analyzer, select **Meas Setup** > **Demod** tab > **Advanced Setup** and set Report **EVM DB to On**. **Close** the Advanced Setup Window.



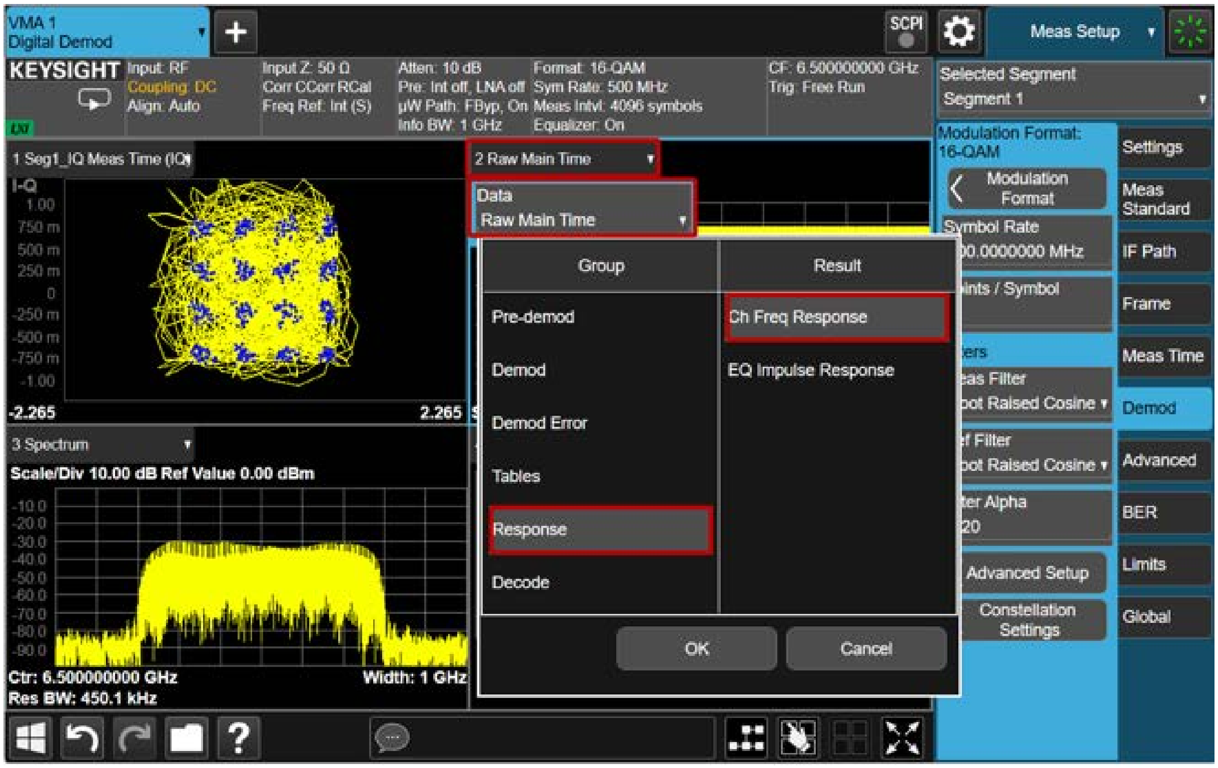
3. Record the EVM in dB. For this example, 21.60 dB rms.



4. At the top of the display, select the **Equalizer** menu and toggle Equalizer **On**. The Meas Interval was already set to 4096 in a previous step.



5. On Measurement window 2 (top right), select the dropdown and select **Data** > **Response** > **Ch Freq Response** > **OK**.

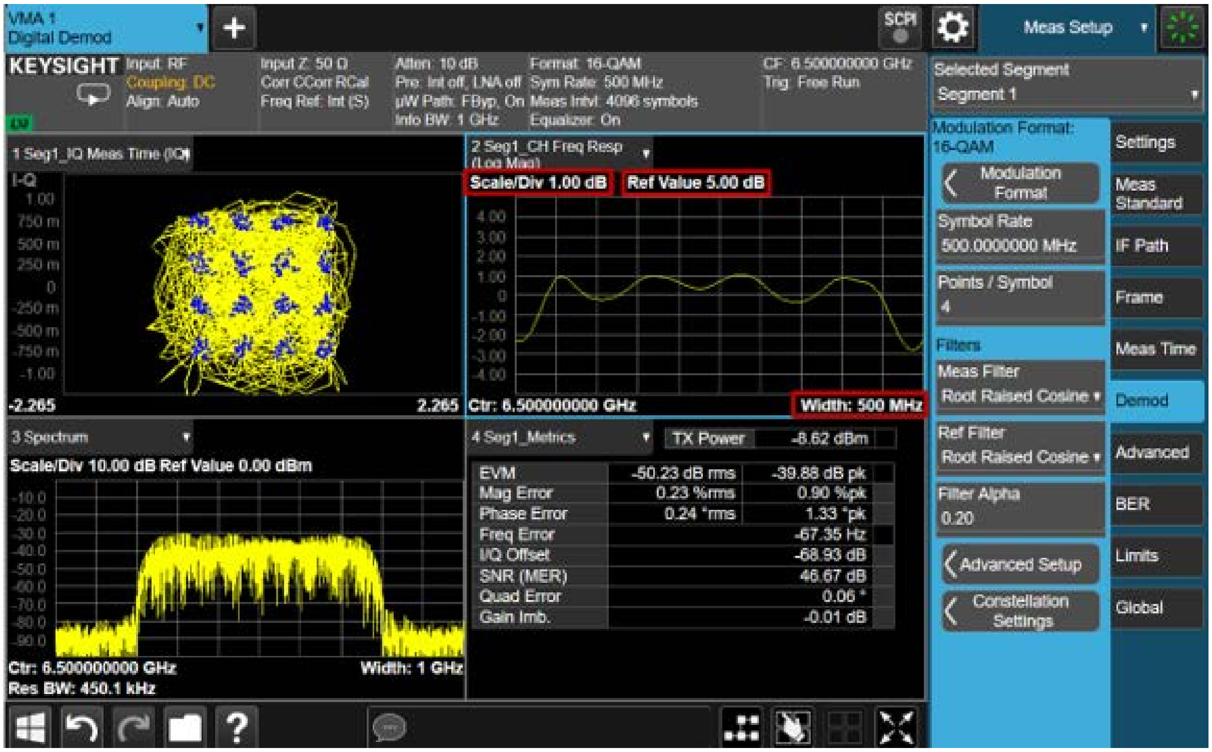


6. On Measurement window 2, set.

   – Scale/Div to **1.00 dB**

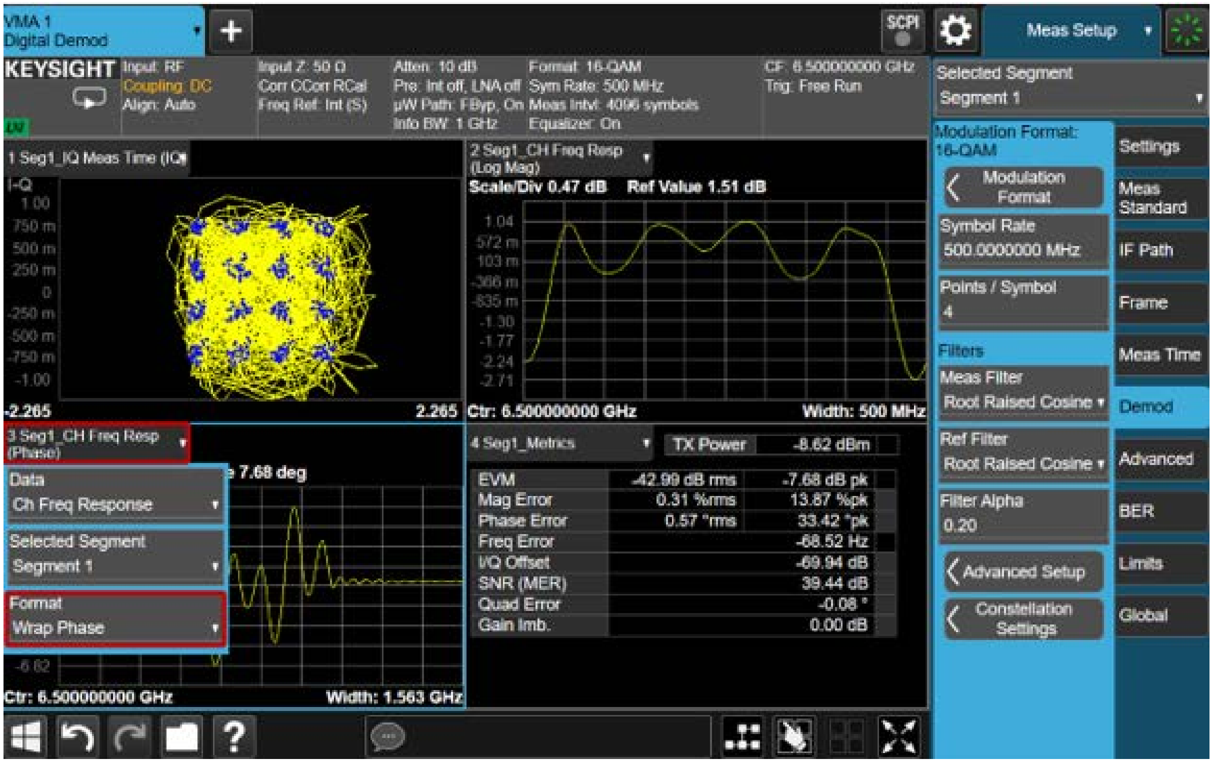
   – Ref Value to **5.00 dB**

– Width to **500.000 MHz**



7. Select Measurement window 3 (bottom left) dropdown menu and select **Data** > **Response** > **Ch Freq Response** > **OK.**

8. On Measurement Window 3, select **Format** > **Wrap Phase** to measure the phase response in Measurement window 3.

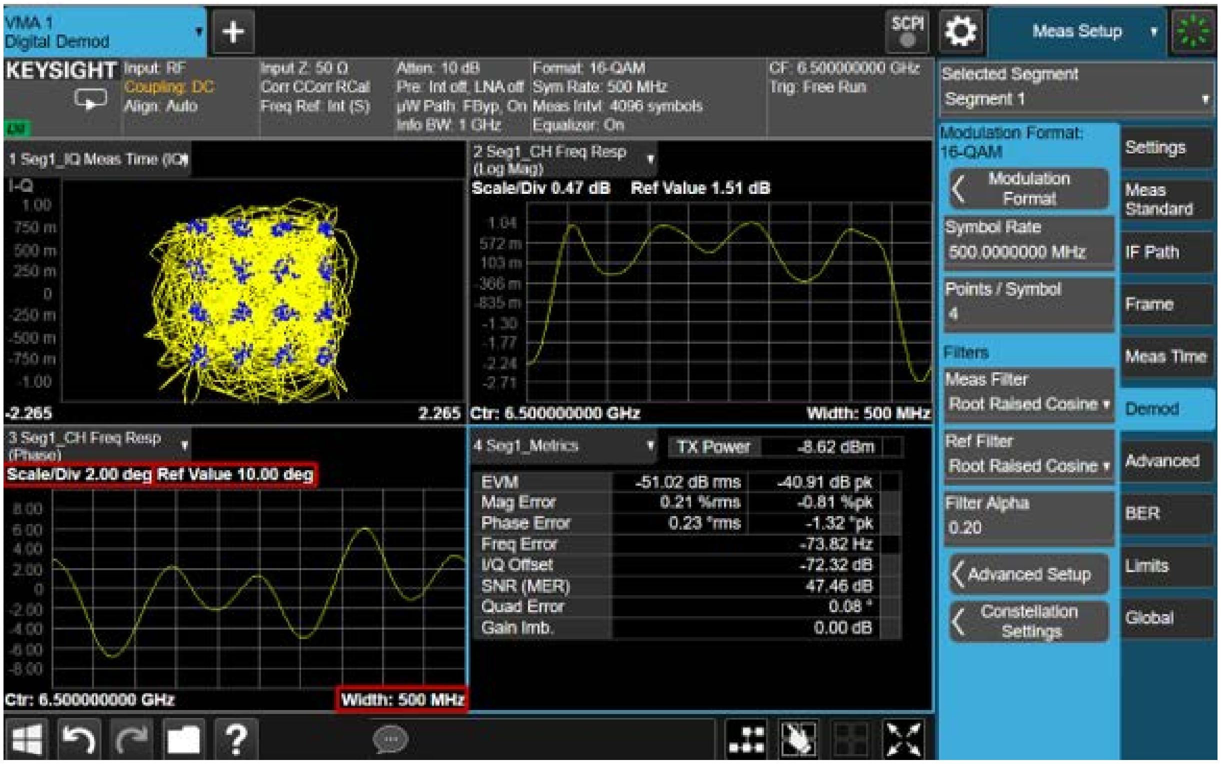


9. On Measurement Window 3, set:

   – Scale/Div to **2.00 deg**

   – Ref Value to **10.00 deg**

– Width to **500 MHz**



Part 2

Use the ECal module to de-embed the cable or test fixture.

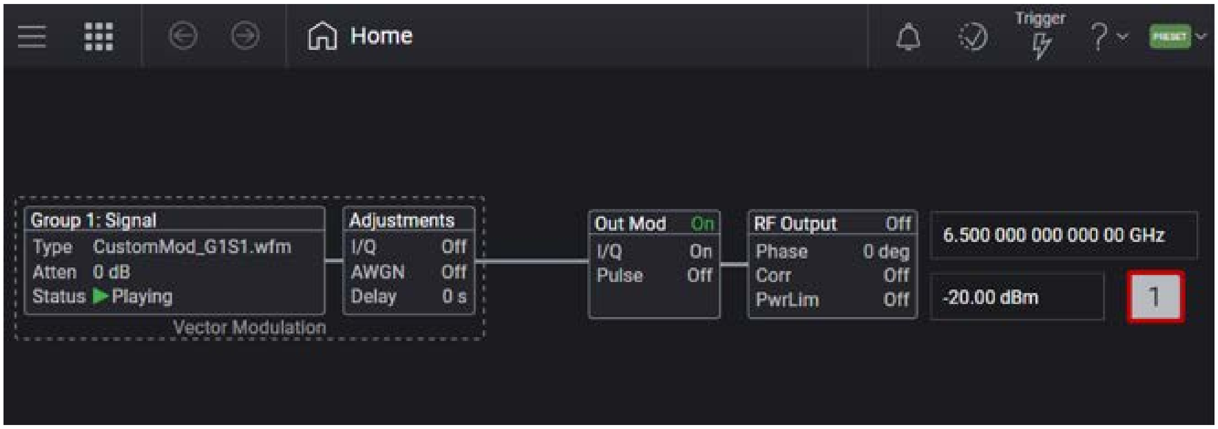
CAUTION

– Do not set the power over ECal's damage levels. Refer to the data sheet for your specific ECal module.

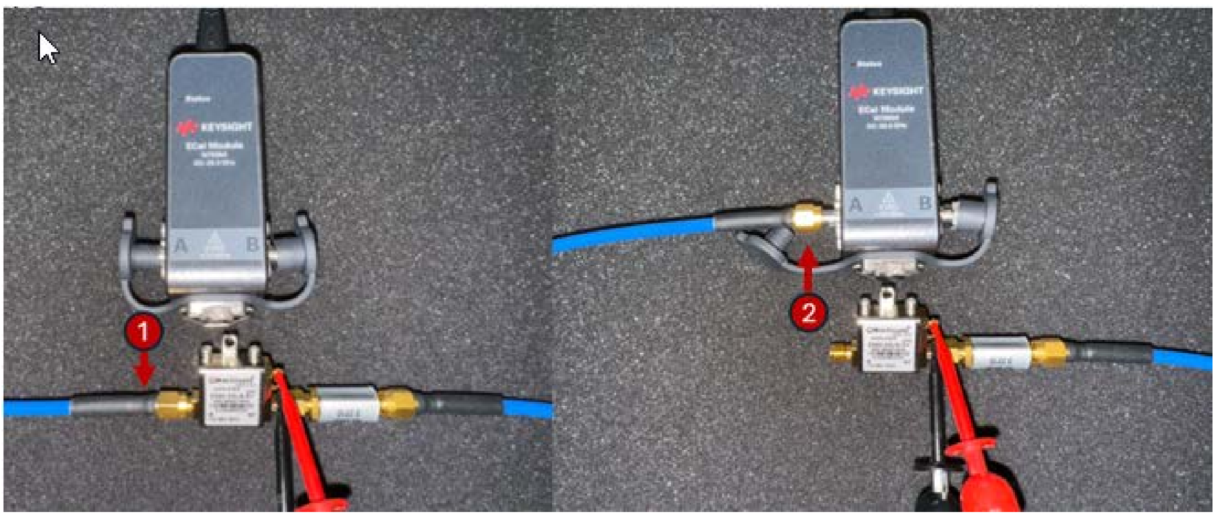
Characterize the Fixture

To characterize the fixture, an ECal module is used to generate an .s2p file of the fixture.

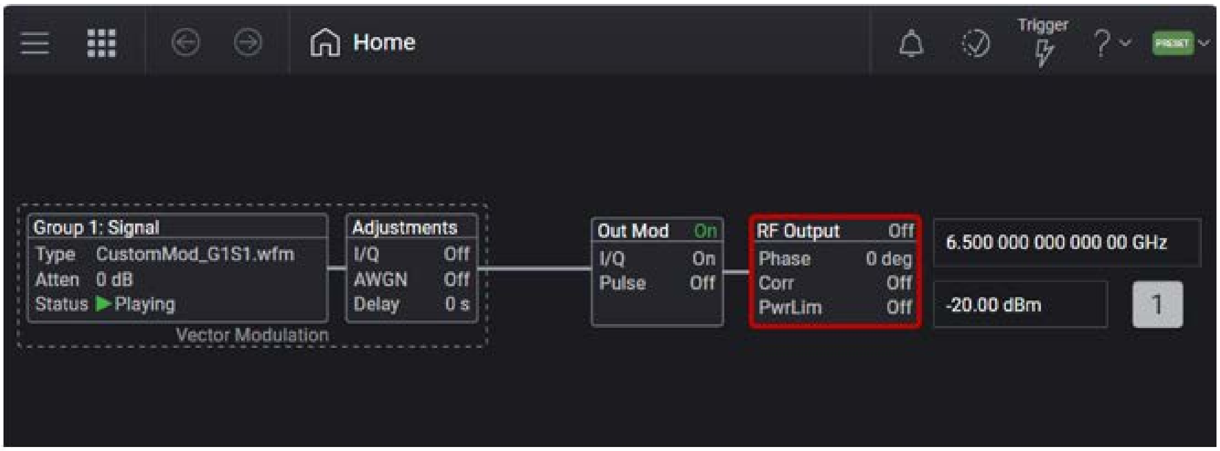
1. On the MXG, turn RF Output **Off**.



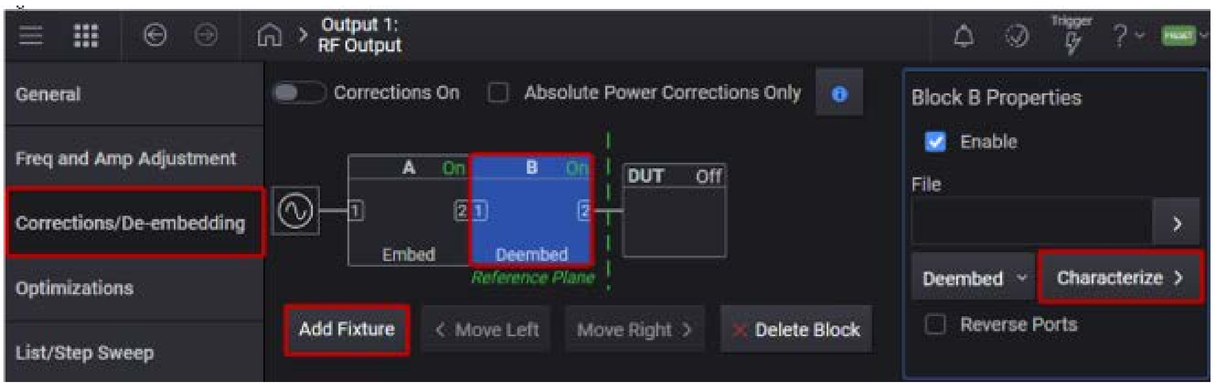
2. Disconnect the input of the DUT and connect the same fixture to Port A of the ECal module.



3. Select the **RF Output** block to open.



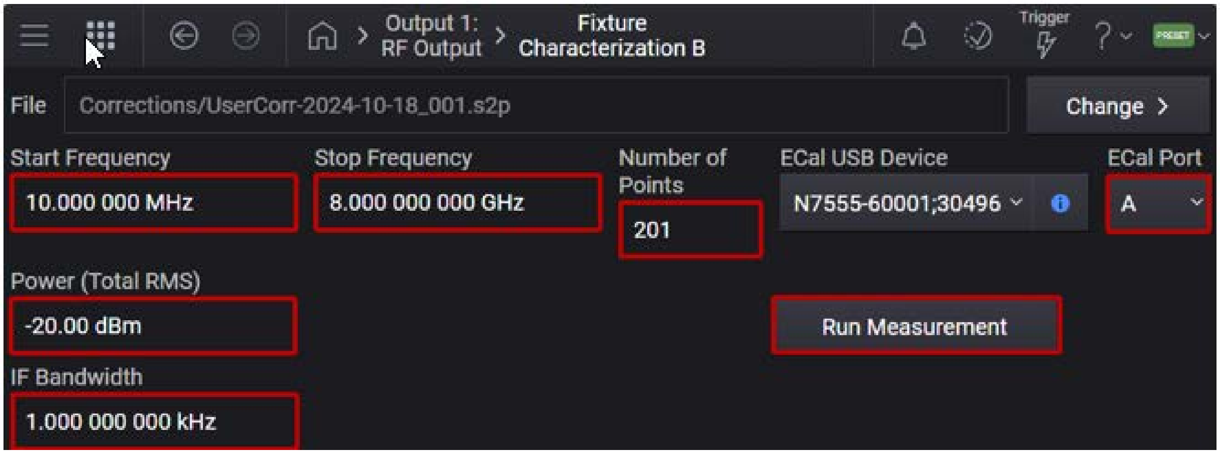
4. In the RF Output dialog box, select the **Corrections/De-embedding** tab > **Add Fixture** > **Block B** > **Characterize.**



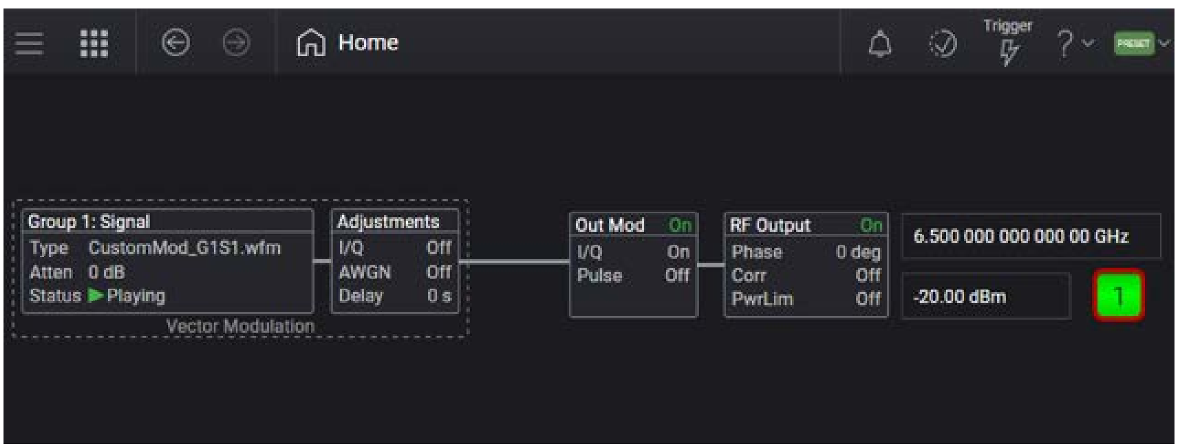
5. Set:

- Start Frequency to **10 MHz**
- Stop Frequency to **8 GHz**
- Number of Points to **201**
- ECal Port to **A**
- Power (Total RMS) to **-20 dBm**
- IF Bandwidth to **1 kHz**

– **Run Measurement**

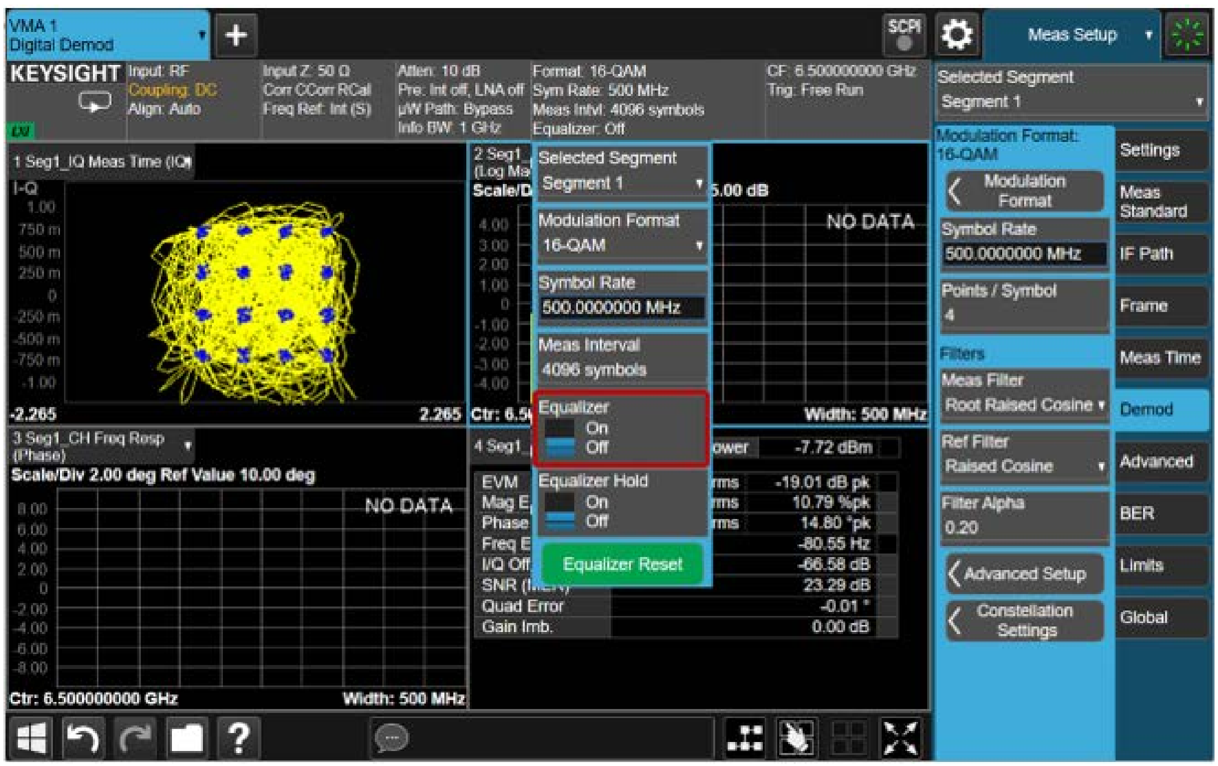


6. When the measurement is complete, Disconnect the fixture from the ECal module and connect the fixture back to the input of the DUT.
7. Select the Home icon and turn RF **On**.

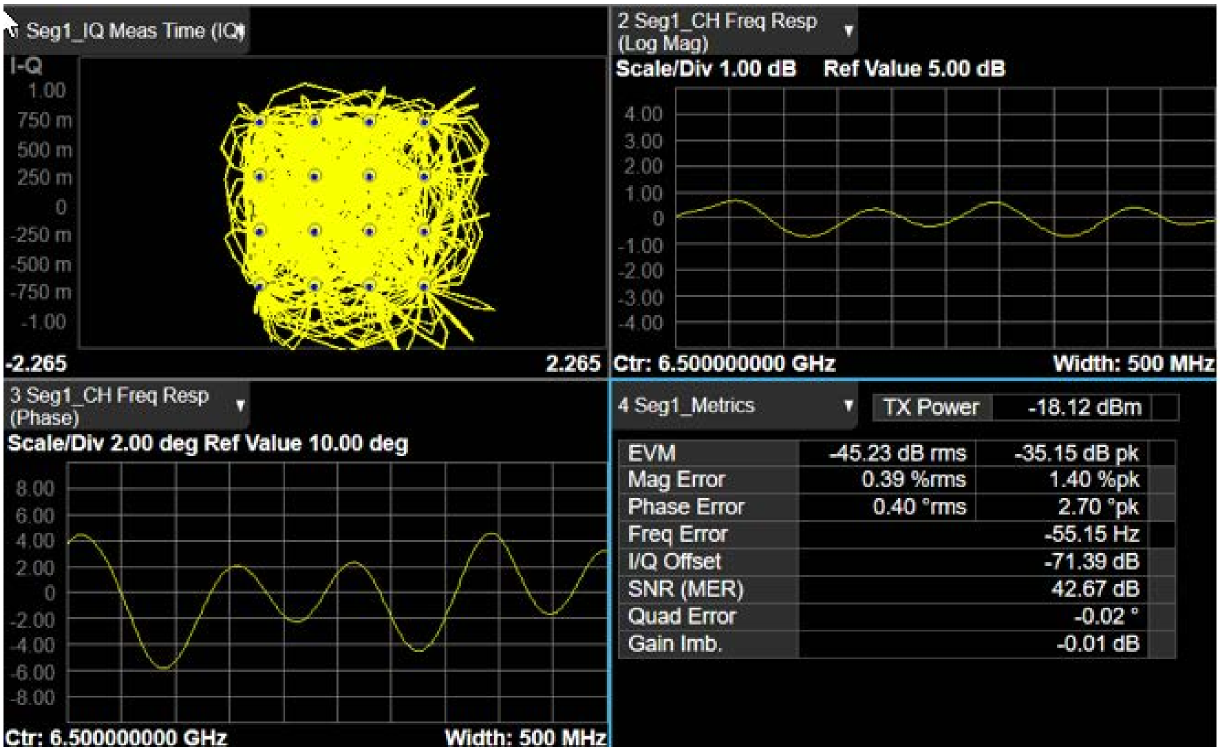


8. Select the **RF Output** block > **Corrections/De-embedding** tab > Corrections **On** > **Enable**.

9. On the Signal Analyzer, at the top of the display, select the **Equalizer** menu and toggle Equalizer **Off** to take and unequalized measurement of the EVM with fixture de-embedding enabled.



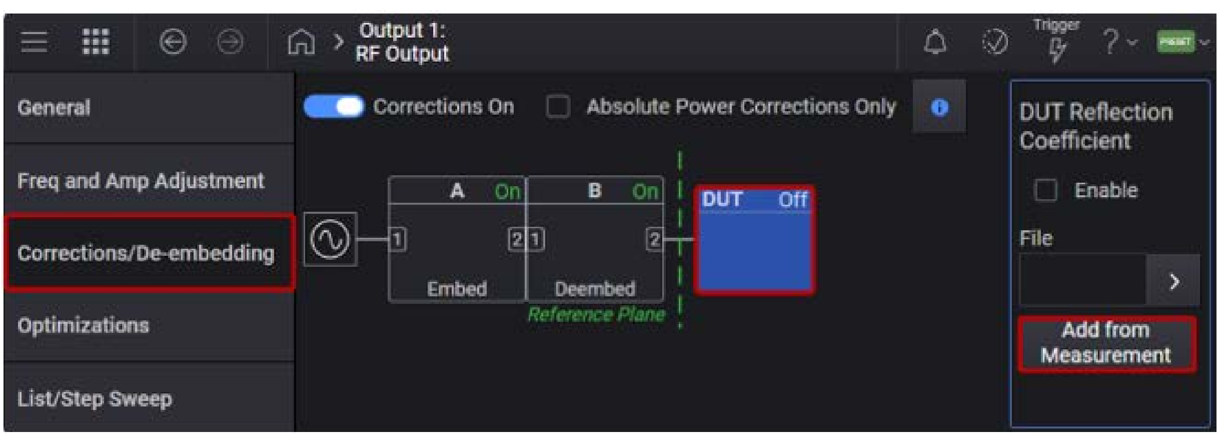
10. Toggle the Equalizer to **On** and select **Equalizer Reset** to take the equalized measurement.



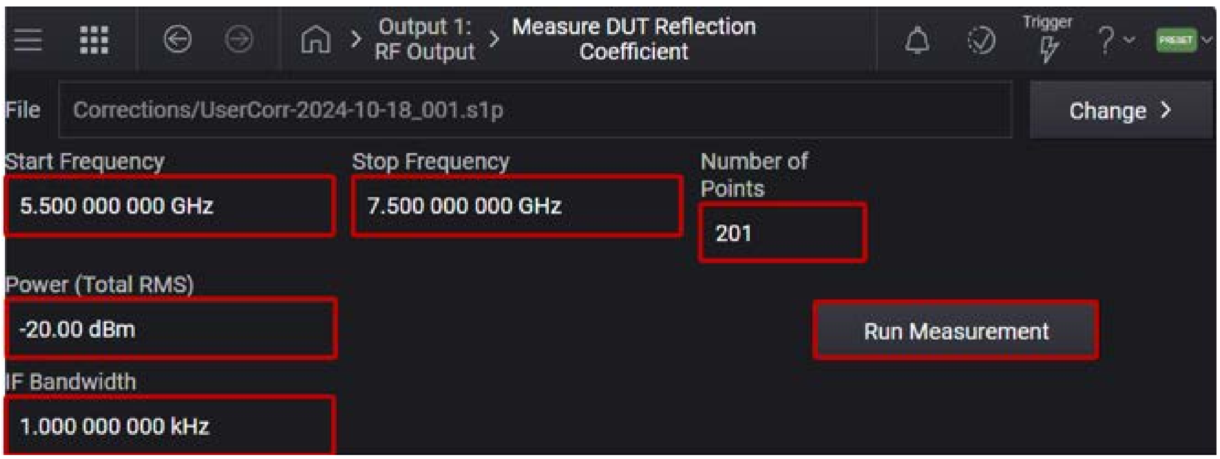
Generate an 1.s1p File

Start by generating an .s1p file using embedded reflectometer to enable DUT match correction and take unequalized EVM measurements and channel response for magnitude and phase. Compare results to the two previous DUT measurements.

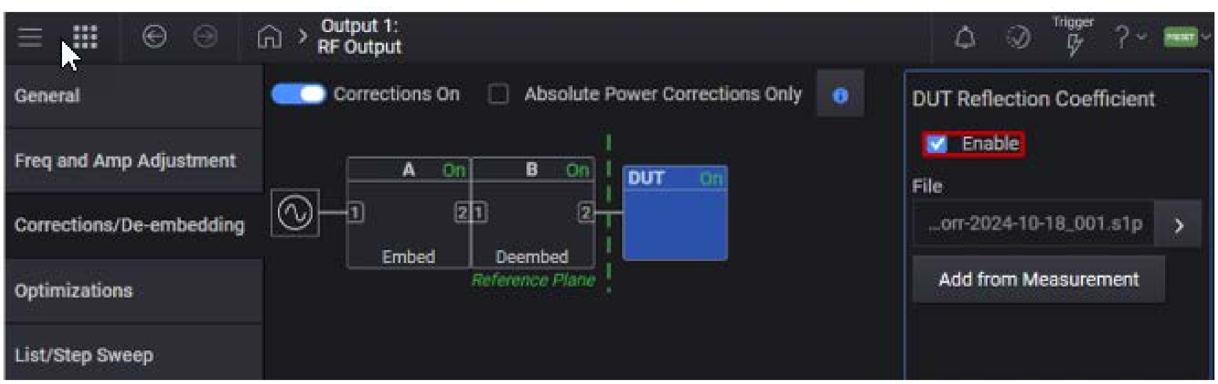
1. On the MXG, select **RF Output** block > **Corrections/De-embedding** tab > **DUT** block > **Add from Measurement.**



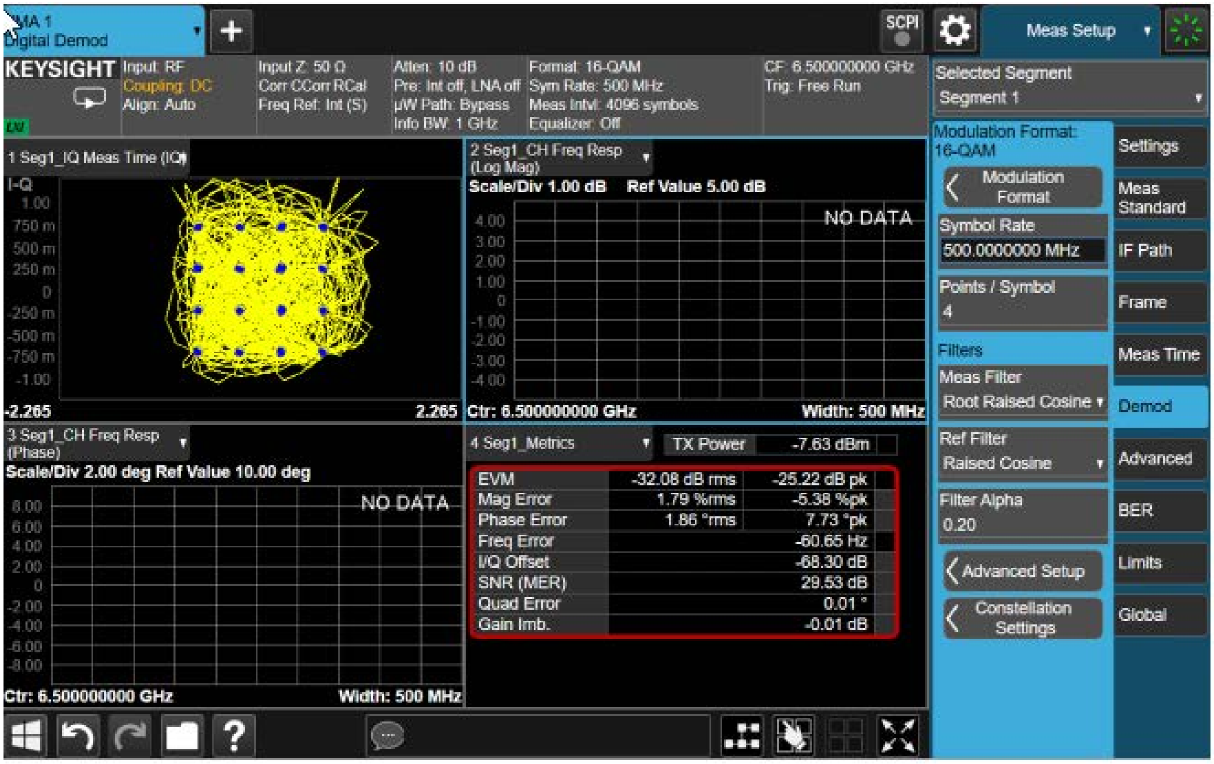
2. To generate the .s1p file, set:
   - Start Frequency to **5.5 GHz**
   - Stop Frequency to **7.5 GHz**
   - Number of Points to **201**
   - Power (Total RMS) to **-20 dBm**
   - IF Bandwidth to **1 kHz**
   - **Run Measurement**



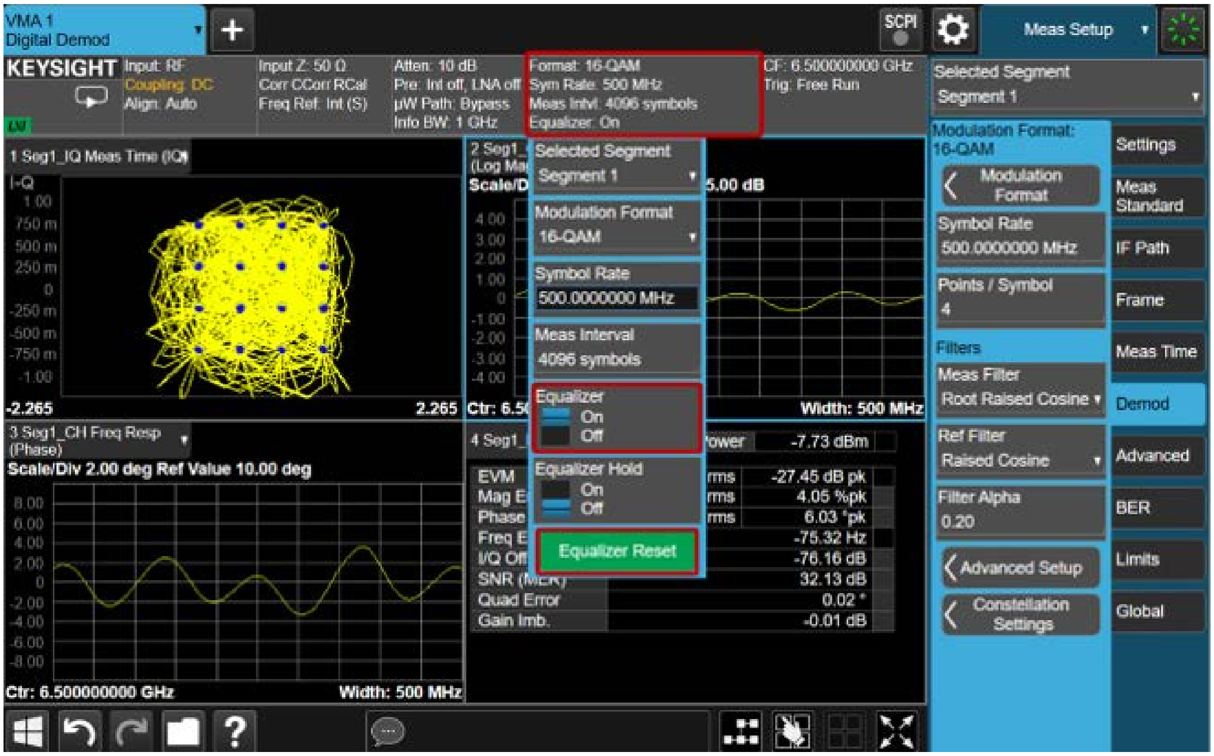
3. Select the **Back** arrow icon to return to the previous window and ensure **Enable** is selected.

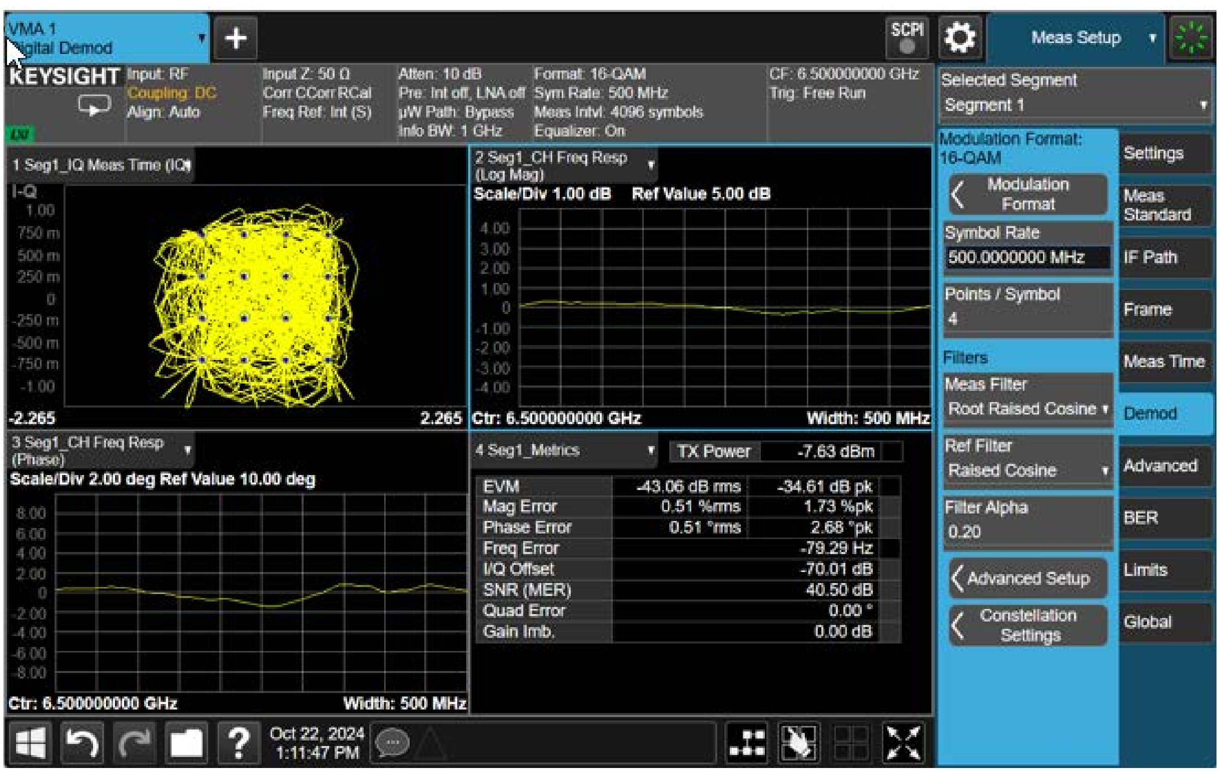


4. Take an unequalized measurement of the EVM with fixture de-embedding and DUT match corrections enabled.



5. Toggle the Equalizer to **On** and select **Equalizer Reset** to take the equalized measurement.





Summary

The embedded reflectometer allows easy fixture characterization without the use of a Vector Network Analyzer. By characterizing the fixture, corrections can be applied to move the reference plane to the input of the DUT. The embedded reflectometer can also be used to preform DUT match correction. By making an S11 measurement, the reflection can be characterized and therefore corrected, allowing for better channel response. In this demonstration you can see the increase in performance in real time. In this particular setup the measured unequalized EVM goes from -21.60 dB rms to -25.84 dB rms when characterizing the fixture and applying corrections. A further increase in performance can be seen from preforming DUT match correction. In this example, the unequalized EVM goes down to -32.08 dB rms. With both correction types applied the unequalized EVM improves by 10.48 dB rms. This increase in performance is also embodied in the channel response. The channel response in magnitude and phase goes from 3 dB peak-to-peak for magnitude and 10 degrees peak-to-peak for phase to ~1 dB peak-to-peak for magnitude and ~3 degrees peak-to -peak for phase after applying corrections. Using the embedded reflectometer to characterize a fixture and a DUT improves station-to-station reproducibility allowing for greater confidence in test results.

KEYSIGHT TECHNOLOGIES

Edition 1, February 2025

N5186-90003

www.keysight.com