
VXG Signal Generator and X-Series Signal Analyzers

M9484C VXG Vector Signal Generator
N9042B, N9041B, N9040B, N9032B, N9030B,
and N9021B Signal Analyzers

This manual provides documentation for the M9484C and X-Series Signal Analyzers running the Microsoft Windows 10 operating system.

Notices

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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/M9484C/m9484c.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>

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Overview

The M9484C VXG Vector Signal Generator provides frequency coverage from 9 kHz to 54 GHz, with up to 2.5 GHz RF modulation bandwidth per channel using an internal baseband generator, and up to 5 GHz RF modulation bandwidth with channel bonding.

The measurement examples use an X-Series Signal Analyzer to view the results. A few measurement examples require an N9042B signal analyzer and is called out in those specific measurement examples. For information on using the X-Series Signal Analyzer multi-touch user interface, refer to the Online Help.

CAUTION

Please refer to the VXG data sheet and X-Series Signal Analyzer data sheet to ensure your measurement setup has adequate power.

<https://www.keysight.com/us/en/product/M9484C/m9484c.html>

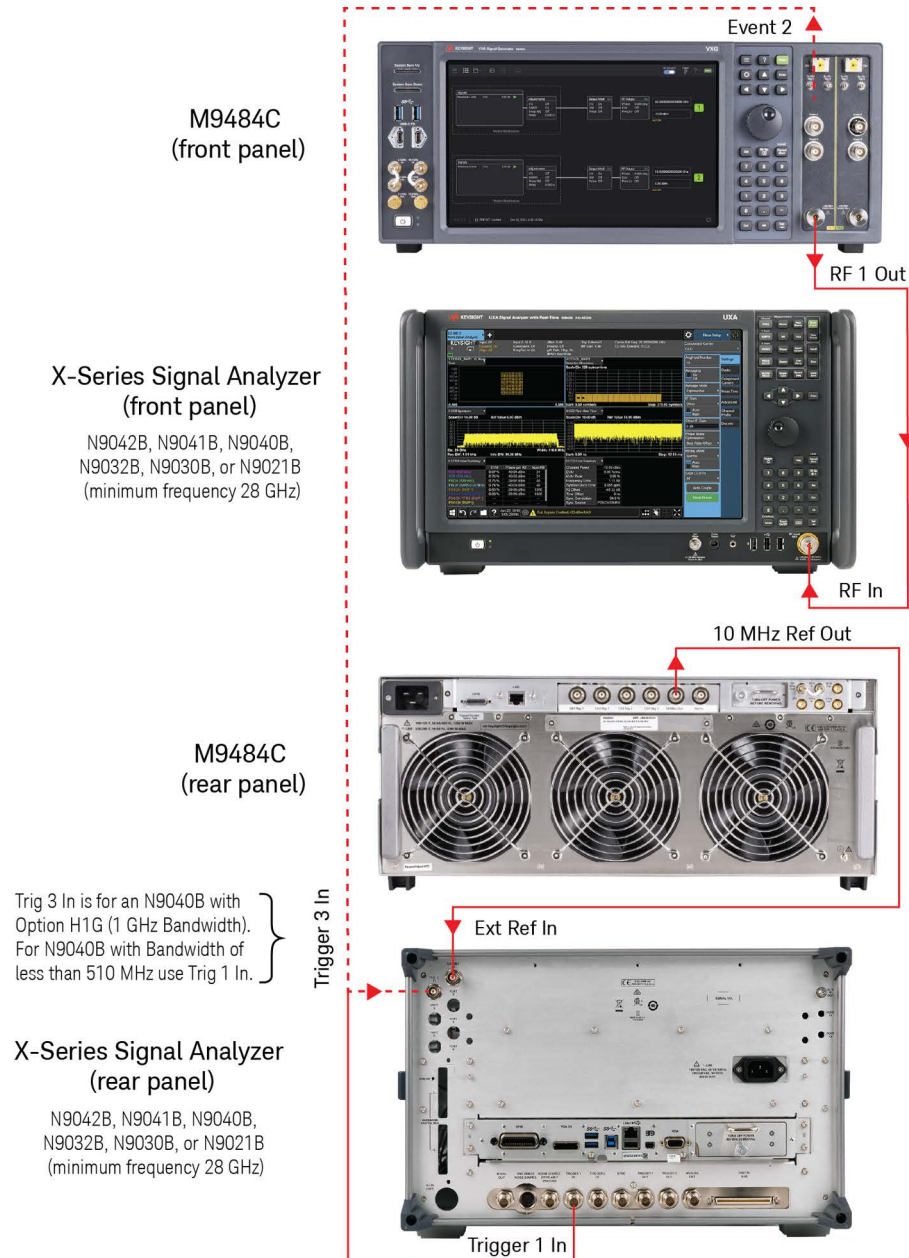
NOTE

The software versions used in this measurement guide are:

- VXG: A.11.01
 - X-Series Spectrum Analyzers/N9085EM0E: A.34.xx or later
 - 89601 VSA: Version 2023 or later
-

Equipment Setup

- M9484C front panel RF 1 Out to X-Series Signal Analyzer front panel RF In
- M9484C front panel Event 2 to X-Series Signal Analyzer rear panel Trig 1 In
Trig 3 In is used for an N9040B with Option H1G (1 GHz Bandwidth). For N9040B with Bandwidth 510 MHz or less, use Trig 1 In.
- M9484C rear panel 10 MHz Ref Out to X-Series Signal Analyzer rear panel Ext Ref In



m9484c2x_series.png

Required Software

- M9484C
 - N7631APPC - 5GNR
 - N7608APPC - Custom Modulation
 - N7605APOC - 3GPP Real Time/Fading
 - PathWave Automatic Channel Response Correction and S-parameter De-embedding (N7653APPC)

Setting Up Triggers on the X-Series Signal Analyzer

1. From the X-Series 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 drop-down on the top right, select **Trigger** and set Trigger Source to **Free Run**.



Basic Measurements

Generating a Continuous Waveform (CW)

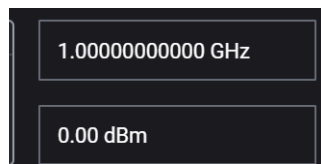
This procedure will demonstrate the amplitude and frequency accuracy of the VXG at RF and μ W frequencies.

NOTE

Ensure the equipment and triggers are properly configured. Refer to [“Equipment Setup” on page 11](#) and [“Setting Up Triggers on the X-Series Signal Analyzer” on page 13](#).

On the VXG:

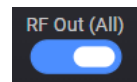
1. Select **Preset > Preset** to set the instrument to a known state.
2. In the Output area, set Frequency to **1 GHz** and Power to **0 dBm**.
These values are coupled to CW Frequency and Total Power (RMS) in the corresponding RF Output Block.



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 VXG.



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

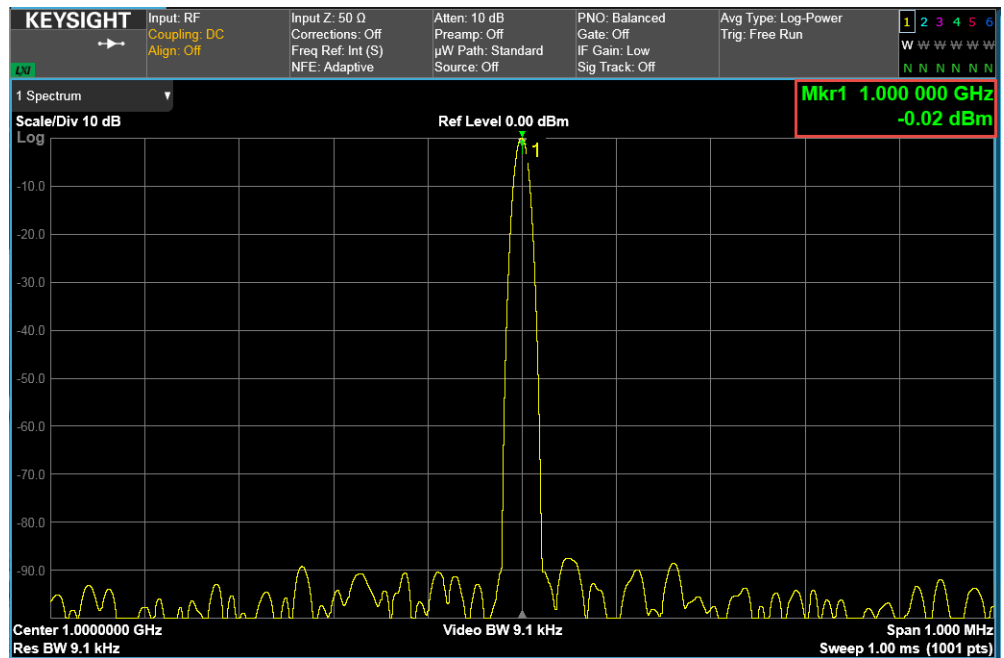
In order to turn on RF for any channel, both the RF Out for the specific channel (for example, Channel 1 or Channel 2), and RF Out All must be turned on.

On the X-Series 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.



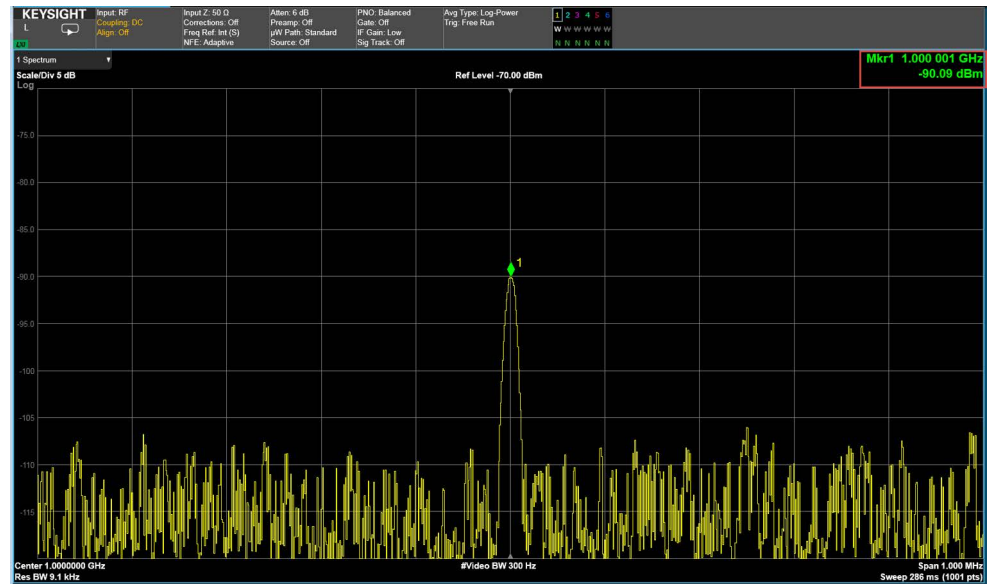
On the VXG:

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

On the X-Series 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 VXG at low power levels.



On the VXG:

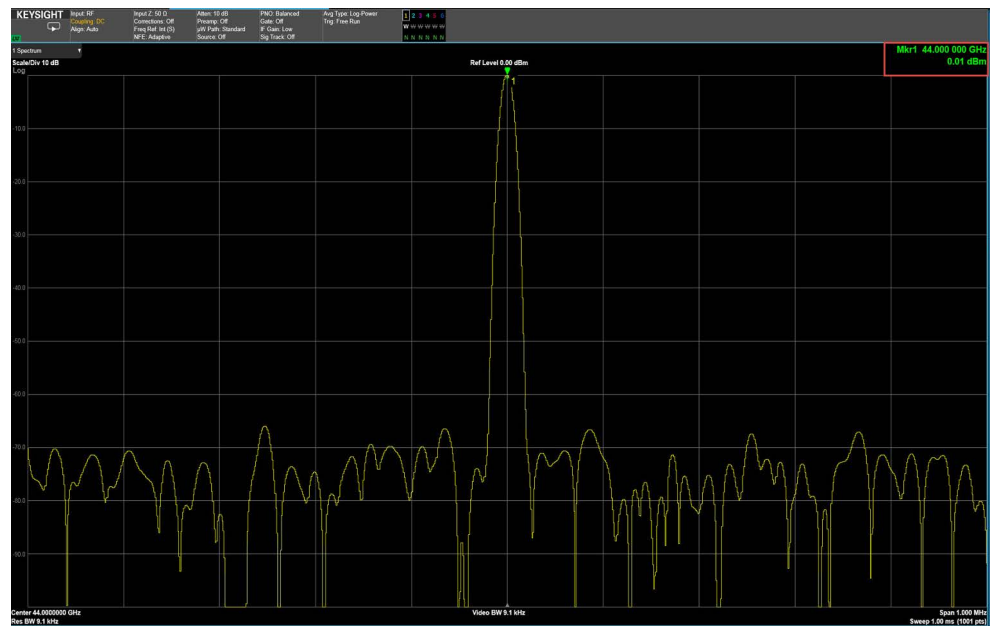
1. Set Frequency to **44 GHz** and Power to **0 dBm**.

On the X-Series Signal Analyzer:

1. Select **Frequency** and set Center Frequency to **44 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**.

M9484C VXG Basic Measurements

Basic Measurements



Observe the frequency and amplitude accuracy at high frequency levels.

Using the equivalent SCPI commands

Creating a CW signal on Channel 1.

On the VXG:

```
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 X-Series Signal Analyzer:

```
FREQuency:CENTer 1GHZ
```

```
FREQuency:SPAN 1MHZ
```

```
CALCulate:MARKer1:MAXimum
```

On the VXG:

```
RF1:FREQuency:CW 1GHZ
```

```
RF1:POWer:AMPLitude -90dBm
```

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

On the X-Series Signal Analyzer:

```
DISPlay:WINDow1:TRACe:Y:RLEVel -70
```

```
DISPlay:WINDow1:TRACe:Y:PDIVision 5
```

```
BWIDth:VIDeo 300Hz
```

```
CALCulate:MARKer1:MAXimum
```

On the VXG:

```
RF1:FREQuency:CW 44GHZ
```

```
RF1:POWer:AMPLitude 0dBm
```

On the X-Series Signal Analyzer:

```
FREQuency:CENTer 44GHZ
```

```
DISPlay:WINDow1:TRACe:Y:RLEVel 0
```

```
DISPlay:WINDow1:TRACe:Y:PDIVision 10
```

```
BANDwidth:VIDeo:AUTO ON
```

```
CALCulate:MARKer1:MAXimum
```

Generating Amplitude Modulation

NOTE

The VXG must have the N7642APPC PathWave Signal Generation for IQ Based AM, FM, Phase license installed.

NOTE

Ensure the equipment and triggers are properly configured. Refer to [“Equipment Setup” on page 11](#) and [“Setting Up Triggers on the X-Series Signal Analyzer” on page 13](#).

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

On the VXG:

1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Set Frequency to **20 GHz** and Amplitude to **0 dBm**.
3. Select the **Signal** block.



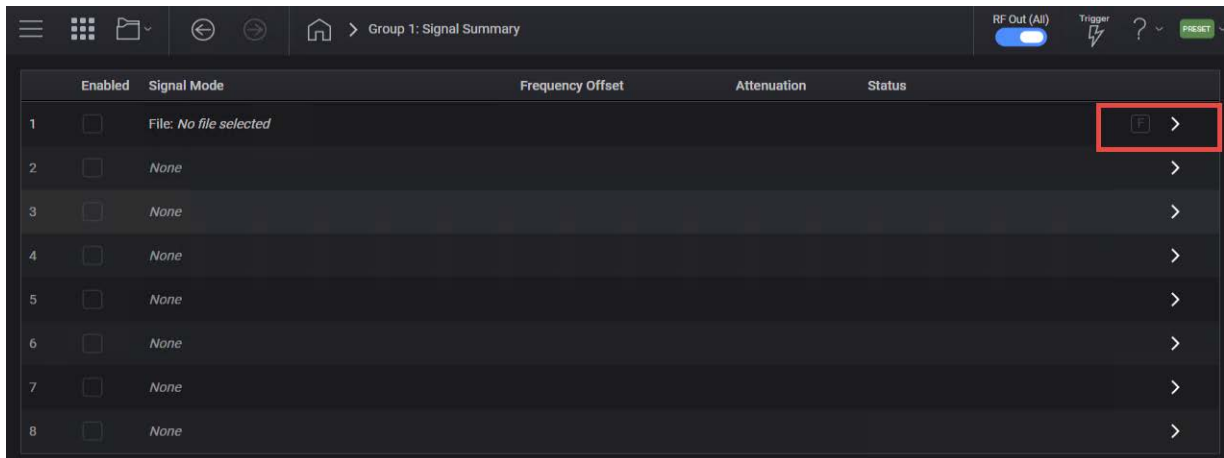
4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

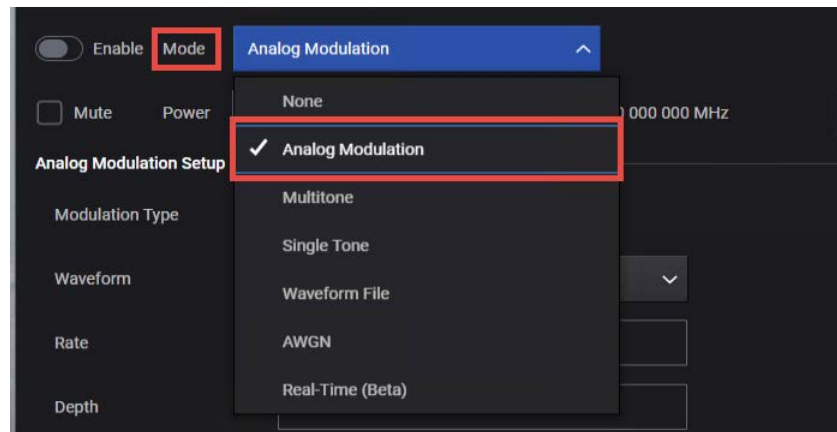
This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.

M9484C VXG Basic Measurements

Basic Measurements



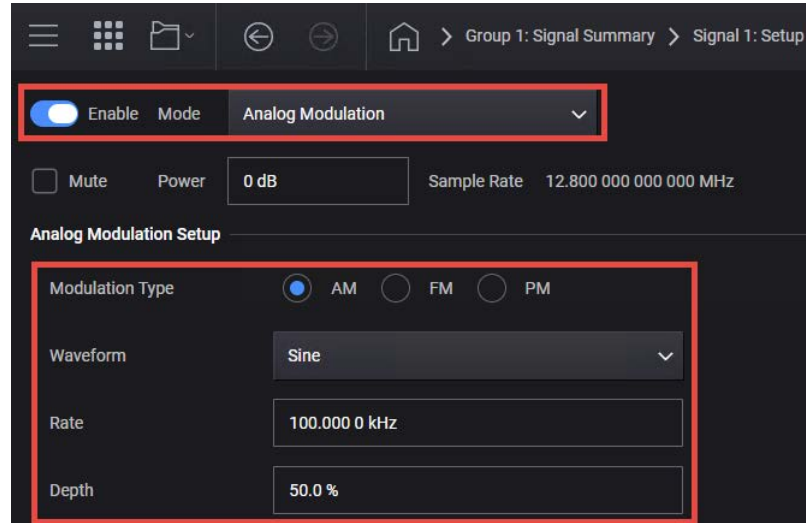
5. In the Mode dropdown, select Analog Modulation.



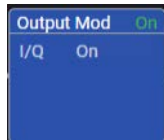
6. In the Analog Modulation Signal Setup:

- Set Modulation Type to **AM**.
- Set Waveform to **Sine**.
- Set Rate to **100 kHz**.
- Set Depth to **50%**.

e. Select **Enable Vector Modulation Signal.**



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.

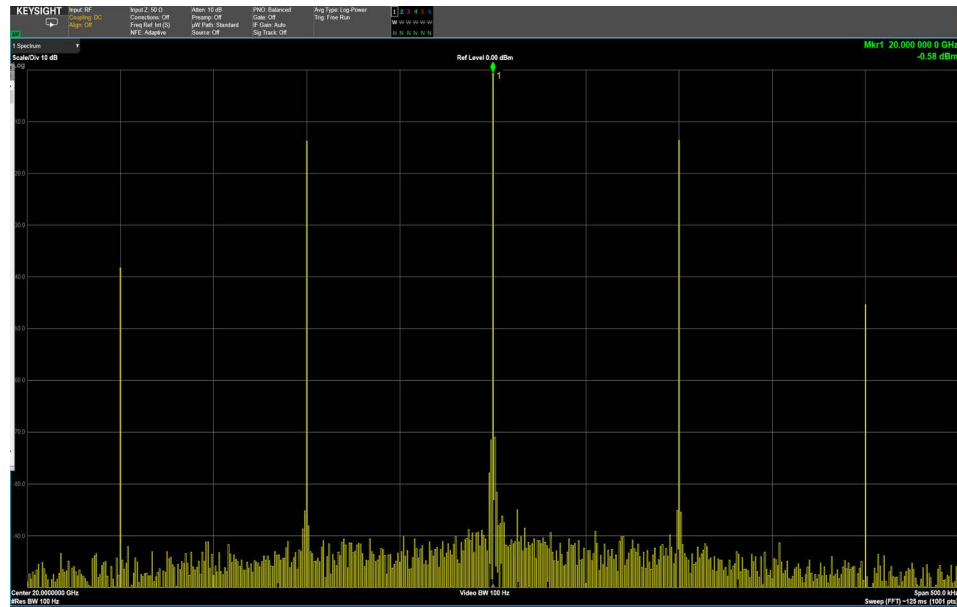
This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel VXG.



On the X-Series Signal Analyzer:

1. Select **Mode Preset** to set Spectrum Analyzer mode to a known state.
2. Select **Frequency** and set Center Frequency to **20 GHz** and Span to **500 kHz**.

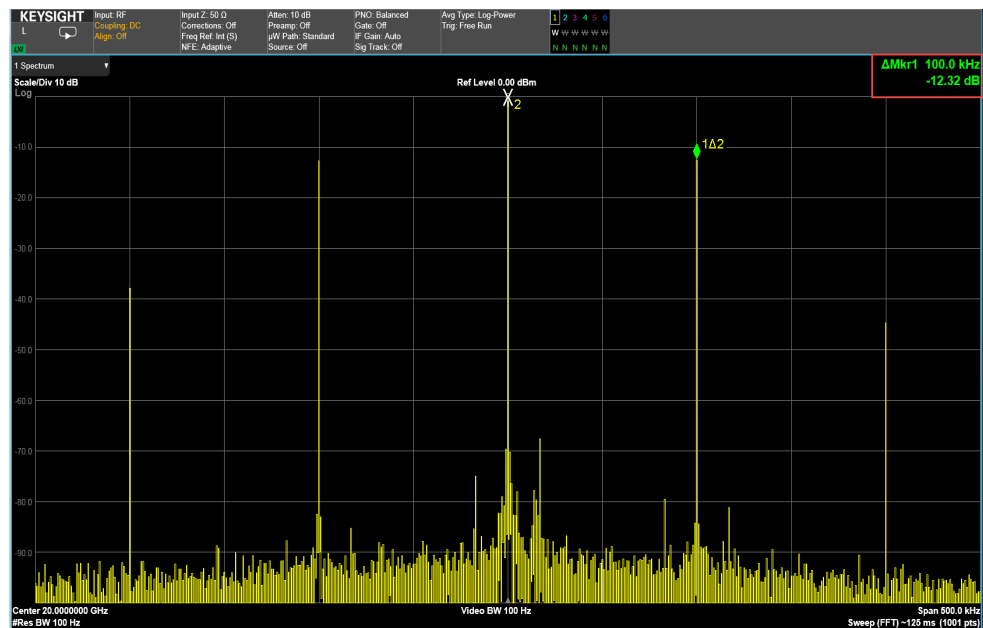
3. Select **BW** and set Res BW to 100 Hz.



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 VXG:

```
SYSTem:PRESet  
RF1:FREQuency:CW 20GHZ  
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 X-Series Signal Analyzer:

```
FREQuency:CENTer 20GHZ  
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?
```

Generating Frequency Modulation

NOTE

The VXG must have the N7642APPC PathWave Signal Generation for IQ Based AM, FM, Phase license installed.

NOTE

Ensure the equipment and triggers are properly configured. Refer to [“Equipment Setup” on page 11](#) and [“Setting Up Triggers on the X-Series Signal Analyzer” on page 13](#).

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

On the VXG:

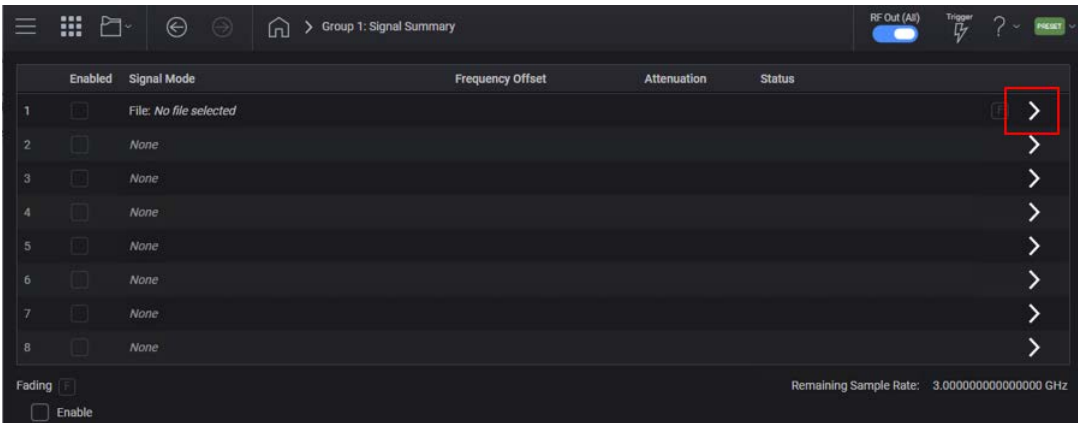
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Set Frequency to **20 GHz** and Amplitude to **0 dBm**.
3. Select the **Signal** block.



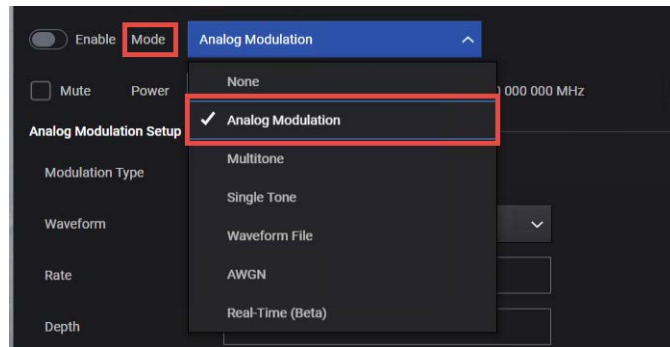
4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

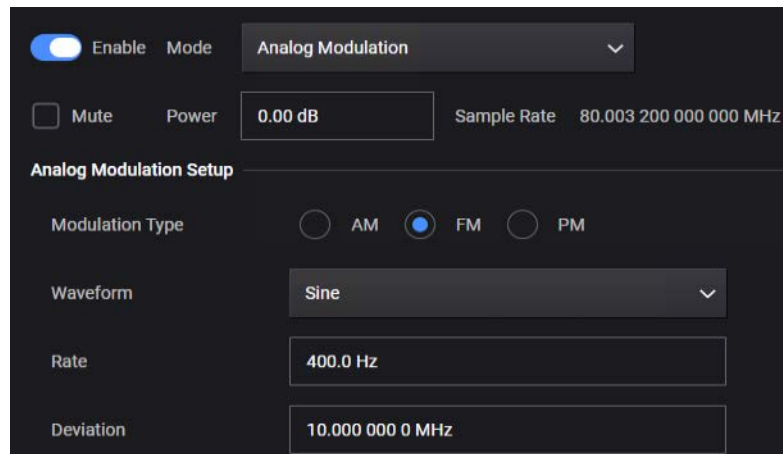
This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.



5. In the Mode dropdown, select **Analog Modulation**.



- a. Set Modulation Type to **FM**.
- b. Set Waveform to **Sine**.
- c. Set Rate to **400 Hz**.
- d. Set Deviation to **10 MHz**.
- e. Select **Enable** Vector Modulation Signal



6. Close the Vector Modulation Signal Setup by either selecting the Back button or the Home icon at the top of the display.



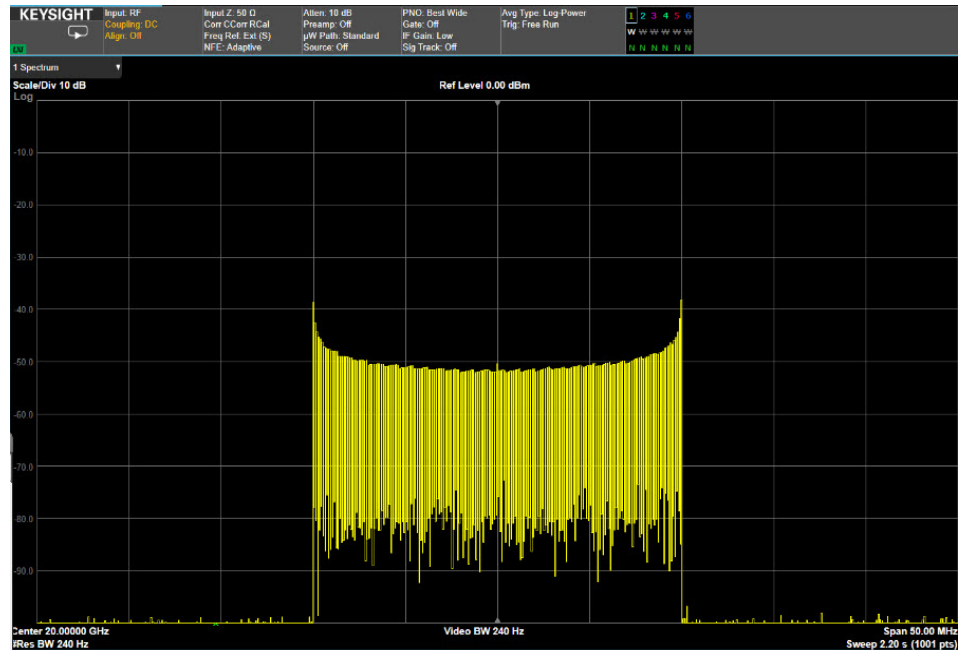
7. Set RF Out to **On** by selecting the numbered channel indicator switch.

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 Preset** to set Spectrum Analyzer mode to a known state.
2. Select **Frequency** and set Center Frequency to **20 GHz** and Span to **50 MHz**.
3. Select **BW** and set Res BW to **240 Hz**.



Using the equivalent SCPI commands

On the VXG:

```
SYSTem:PRESet  
RF1:FREQuency:CW 20GHZ  
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 X-Series Signal Analyzer:

```
FREQuency:CENTer 20GHZ  
FREQuency:SPAN 50MHZ  
ACPower:BANDwidth 240 Hz
```

Generating Phase Modulation

NOTE

The VXG must have the N7642APPC PathWave Signal Generation for IQ Based AM, FM, 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 11](#) and [“Setting Up Triggers on the X-Series Signal Analyzer” on page 13](#).

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

On the VXG:

1. Select **Preset > Preset** to set the instrument to a known state.
2. Set Frequency to **20 GHz** and Amplitude to **0 dBm**.
3. Select the **Signal** block to open.



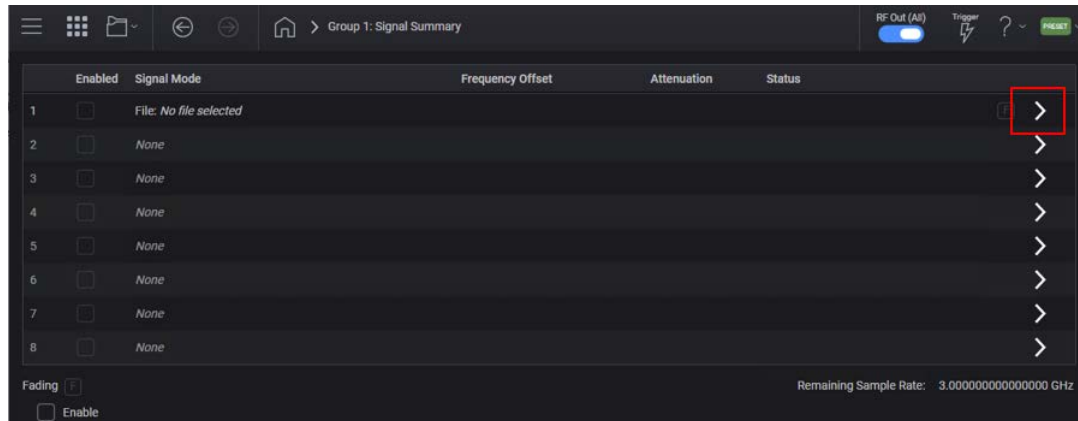
4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.

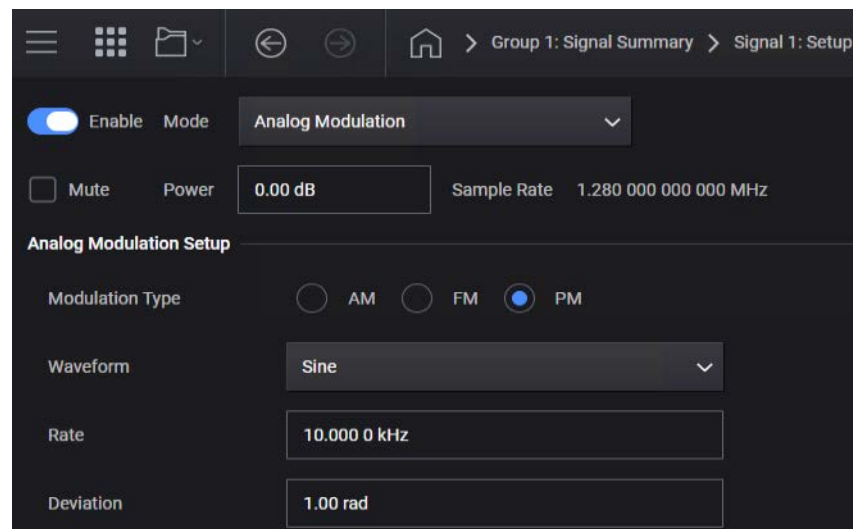
M9484C VXG Basic Measurements

Basic Measurements



5. In the Analog Modulation Signal Setup:

- a. Set Modulation Type to **PM**.
- b. Set Waveform to **Sine**.
- c. Set Rate to **10 kHz**.
- d. Set Deviation to **1 rad**.
- e. Select **Enable** Vector Modulation Signal.



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



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. From the Menu Panel (on the top right of the display), select **Mode/Meas > Analog Demod** 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 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.

4. Select **Frequency** and set Center Frequency to **20 GHz**.



Using the equivalent SCPI commands

On the VXG:

```
SYSTem:PRESet  
RF1:FREQuency:CW 20GHZ  
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 X-Series Signal Analyzer:

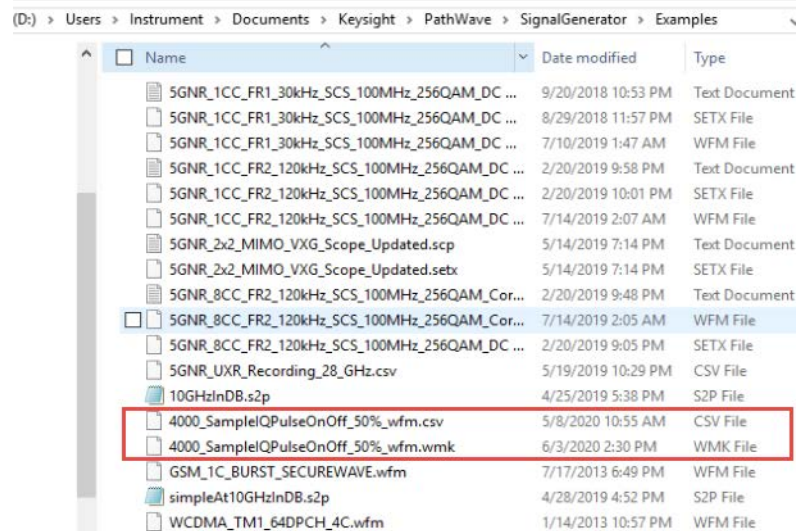
```
INSTrument:CONFIgure:ADEMOD:PM  
SYSTem:PRESet  
DISPlay:VIEW:ADVanced:SElect "QUAD"  
FREQuency:CENTer 20GHZ
```

Generating Synchronized Pulse (IQ + Analog) Modulation

NOTE

Ensure the equipment and triggers are properly configured. Refer to [“Equipment Setup” on page 11](#) and [“Setting Up Triggers on the X-Series Signal Analyzer” on page 13](#).

You will need to create your own ASCII text marker file and a binary file with the exact same name. Both files must be stored in the same file folder. For this example, we will use example files that have been stored on the VXG.



On the VXG:

1. Select **Preset > Preset** to set the instrument to a known state.
2. Set the Frequency to **1 GHz** and Power to **0.0 dBm**.
3. Select the **Signal** block to open.



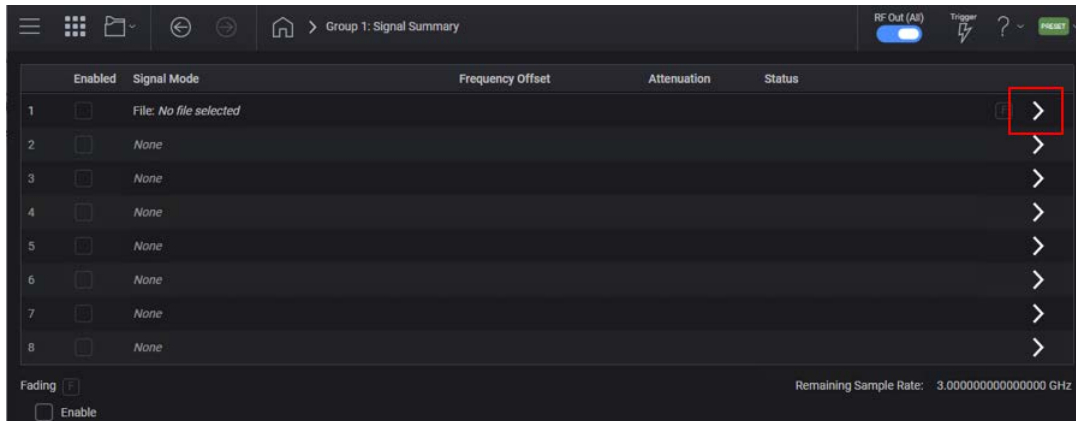
4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

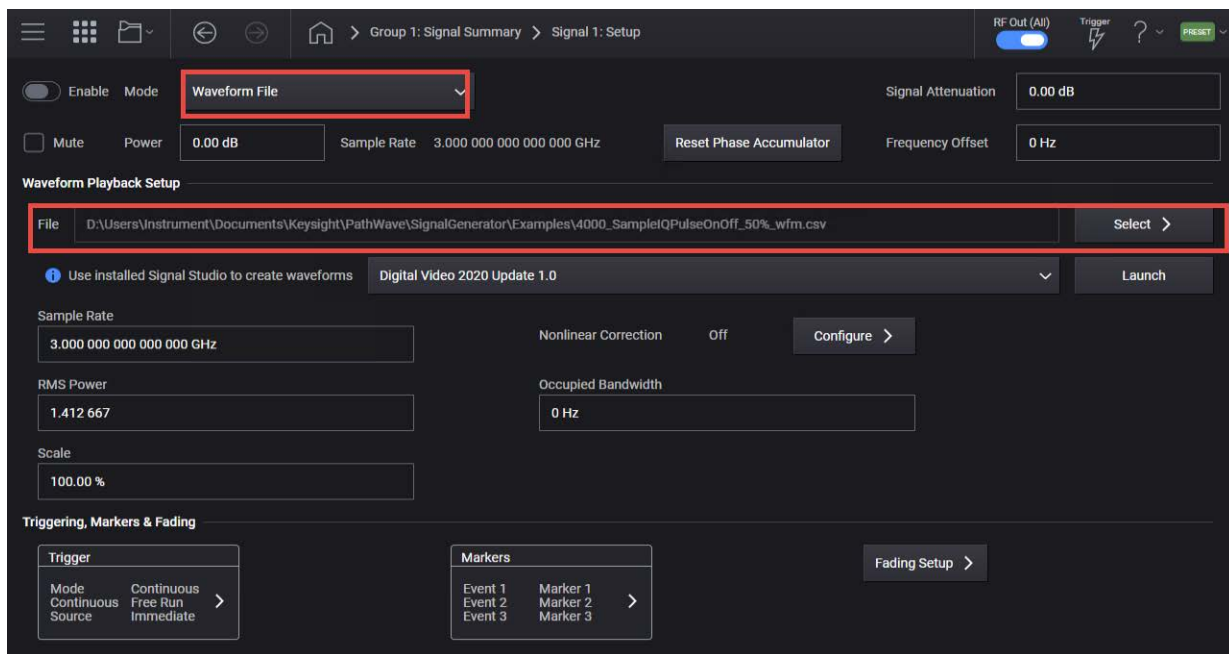
This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.

M9484C VXG Basic Measurements

Basic Measurements



5. Select the **Mode** drop-down and select **Waveform File**.



6. In the Waveform Setup area, use File **Select** to navigate to:

D:\Users\Instrument\Documents\Keysight\PathWave
SignalGenerator\Examples

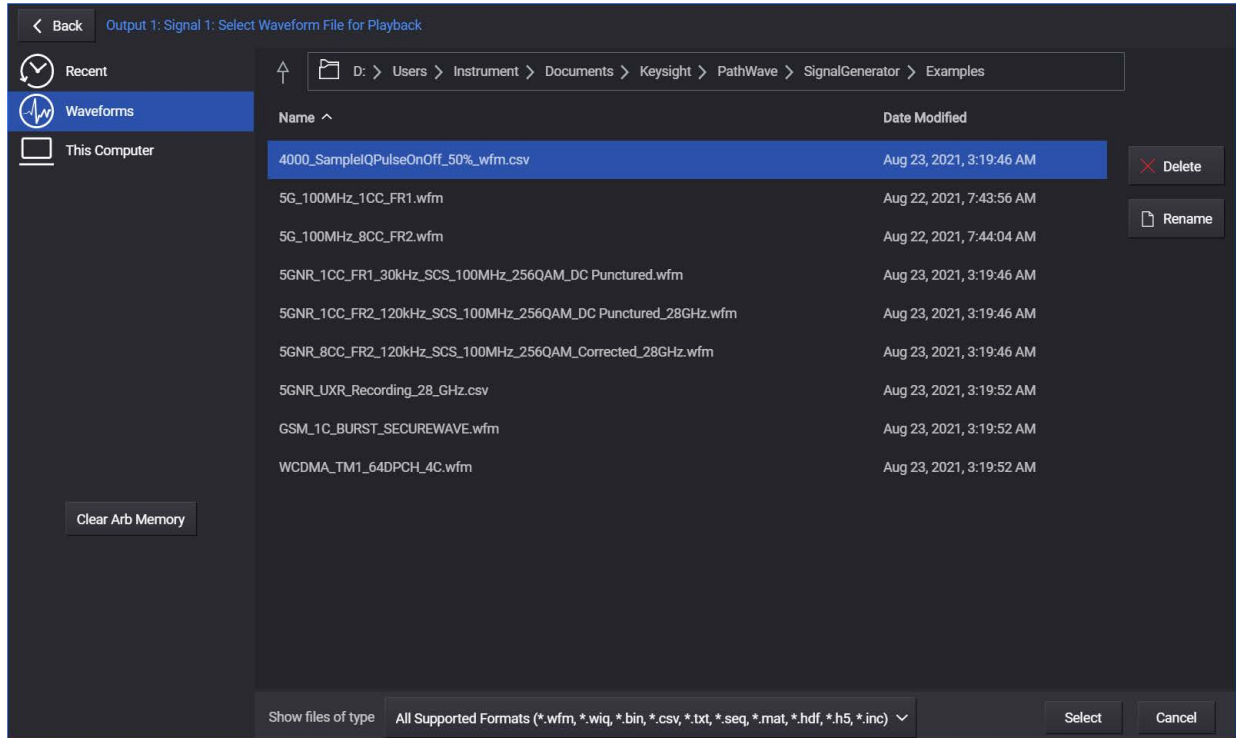
and choose

M9484C VXG Basic Measurements

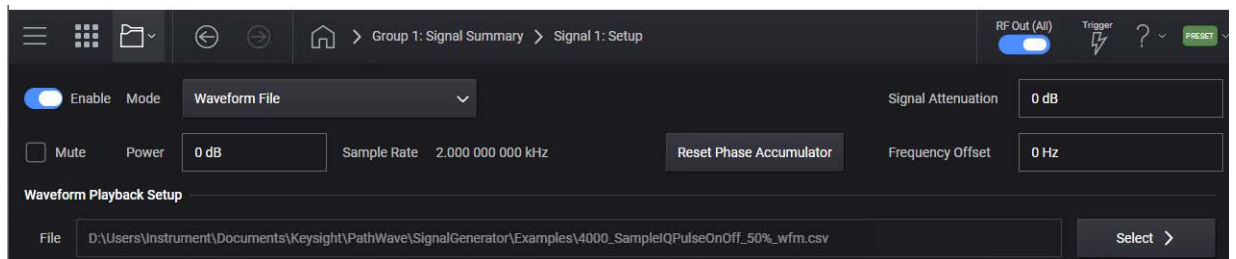
Basic Measurements

4000_SampleQPulseOnOff_50%_wfm.csv

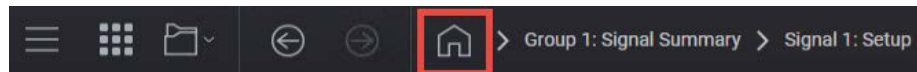
then **Select**.



- Set the Sample Rate to **2 kHz** and select **Enable** Vector Modulation Signal.

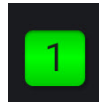


- Close the Vector Modulation Signal Setup by selecting the **Home** icon at the top of the display.



- 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.



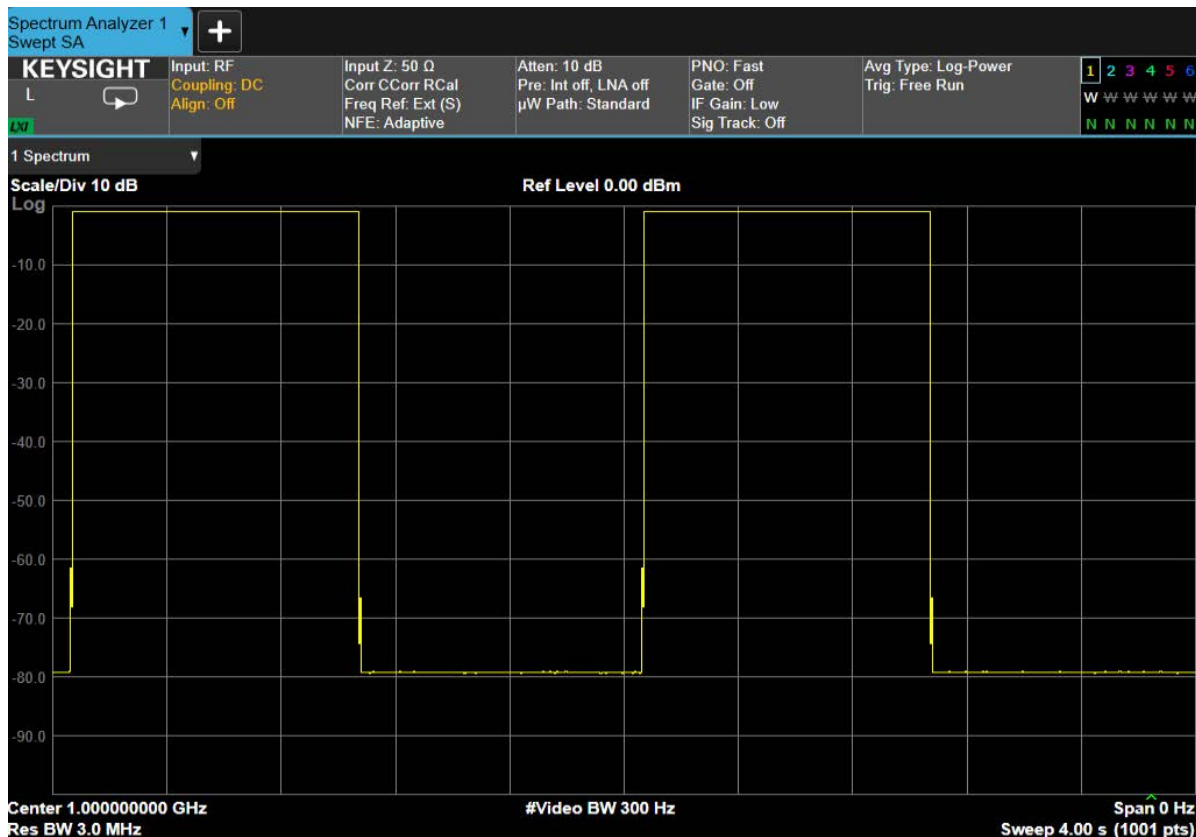
On the X-Series Signal Analyzer:

1. From the Menu Panel (on the top right of the display), select **Mode/Meas** > **Spectrum Analyzer** mode > **Swept SA** Measurement > **Normal 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 **1.0 GHz** and Span to **0 Hz**.
4. Select **BW** and set the Video BW to **300 Hz**.
5. Select **Sweep** and set the Sweep Time to **4.0 s**.



Generating 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 VXG must have the N7621APPC PathWave Signal Generation for Multitone license installed.

NOTE

Ensure the equipment and triggers are properly configured. Refer to [“Equipment Setup” on page 11](#) and [“Setting Up Triggers on the X-Series Signal Analyzer” on page 13](#).

On the VXG:

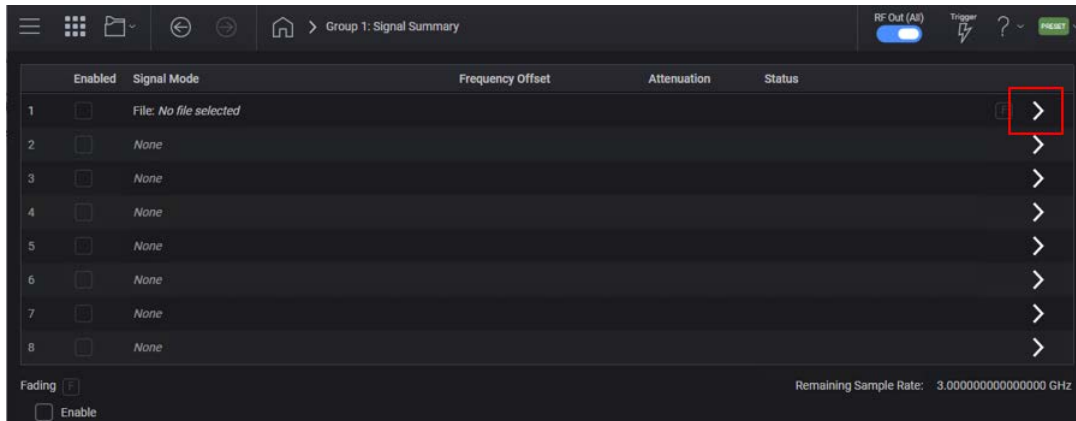
1. Select **Preset > Preset** to set the instrument to a known state.
2. Set Frequency to **20 GHz** and Amplitude to **-10 dBm**.
3. Select the **Signal** block to open.



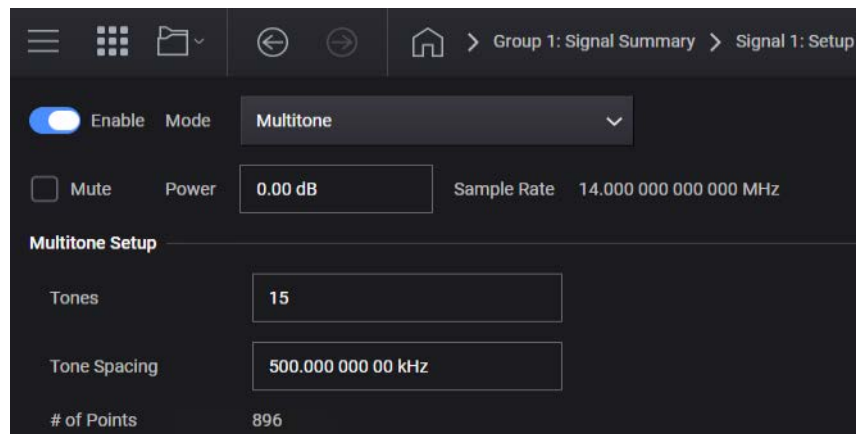
4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

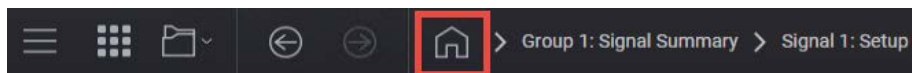
This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.



5. In the Mode dropdown:
 - a. Set Vector Modulation Signal Mode to **Multitone**.
 - b. Set Tones to **15**.
 - c. Set Tone Spacing to **500 kHz**.



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

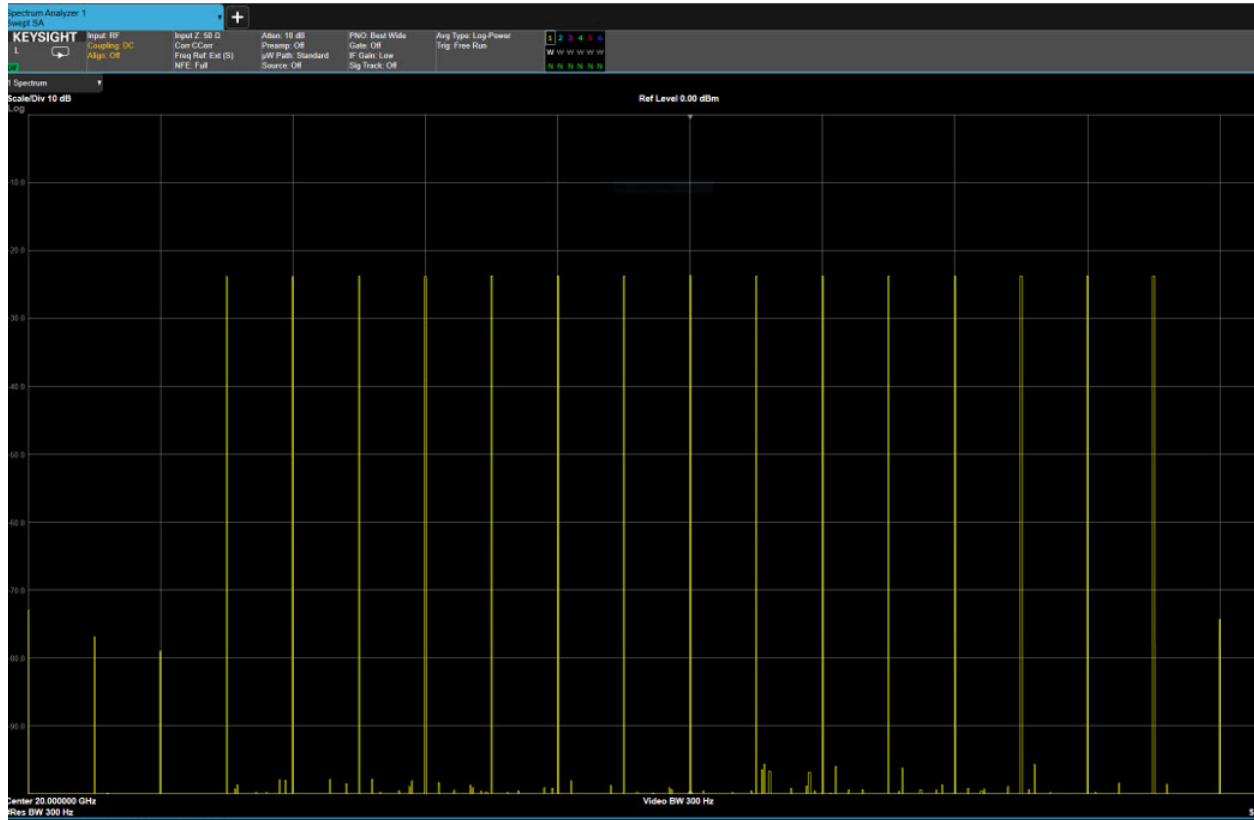


8. Set RF Out to **On** by selecting the numbered channel indicator switch.
This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel VXG.



On the X-Series Signal Analyzer:

1. Select **Mode Preset** to set Spectrum Analyzer mode to a known state.
 2. Select **Frequency** and set Center Frequency to **20 GHz** and Span to **10 MHz**.
 3. Select **BW** and set Res BW to **300 Hz** and Video BW to **300 Hz**.
- Observe the 15 tones.



Using the equivalent SCPI commands

On the VXG:

SYSTem:PRESet

RF1:FREQuency:CW 20GHZ

RF1:POWer:AMPLitude -10dBm

SIGNal1:MODE MTONes

SIGNal1:MTONE:ARB:NTON 15

SIGNal1:MTONE:ARB:FSP 500KHZ

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:

Change to Spectrum Analyzer mode, Swept SA measurement.

INSTrument:CONFigure:SA:SAN

DISPlay:VIEW:ADVanced:SElect "NORMAL"

FREQuency:CENTer 20GHZ

FREQuency:SPAN 10MHZ

Setting Up Waveform File Vector Modulation

In this section, we will load a GSM and a LTE waveform into the VXG to demonstrate the accuracy of the VXG's vector modulation using error vector magnitude (EVM) measurement applications available on the X-Series Signal Analyzer.

The VXG 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 11](#) and [“Setting Up Triggers on the X-Series Signal Analyzer” on page 13](#).

On the VXG:

1. Select **Preset > Preset** to set the instrument to a known state.
2. Set Frequency to **20 GHz** and Amplitude to **0 dBm**.
3. Select the **Group 1: Signals** block to open.



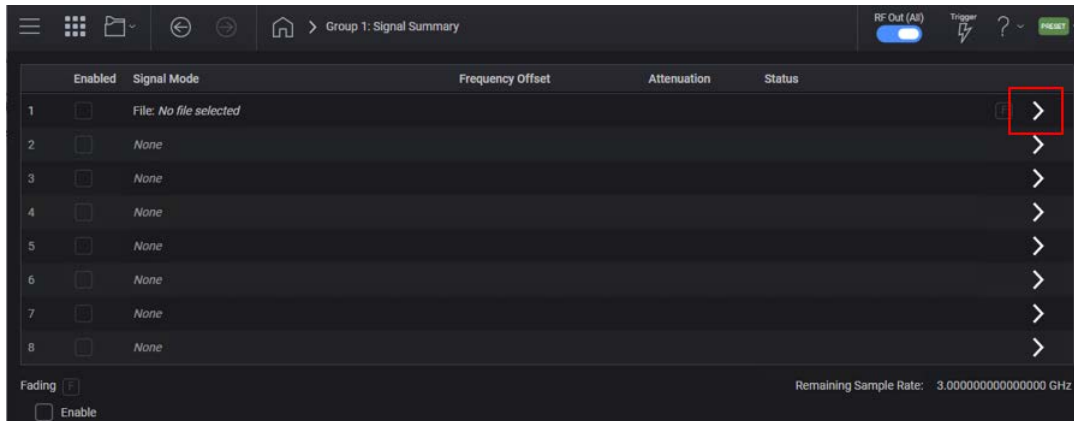
4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.

M9484C VXG Basic Measurements

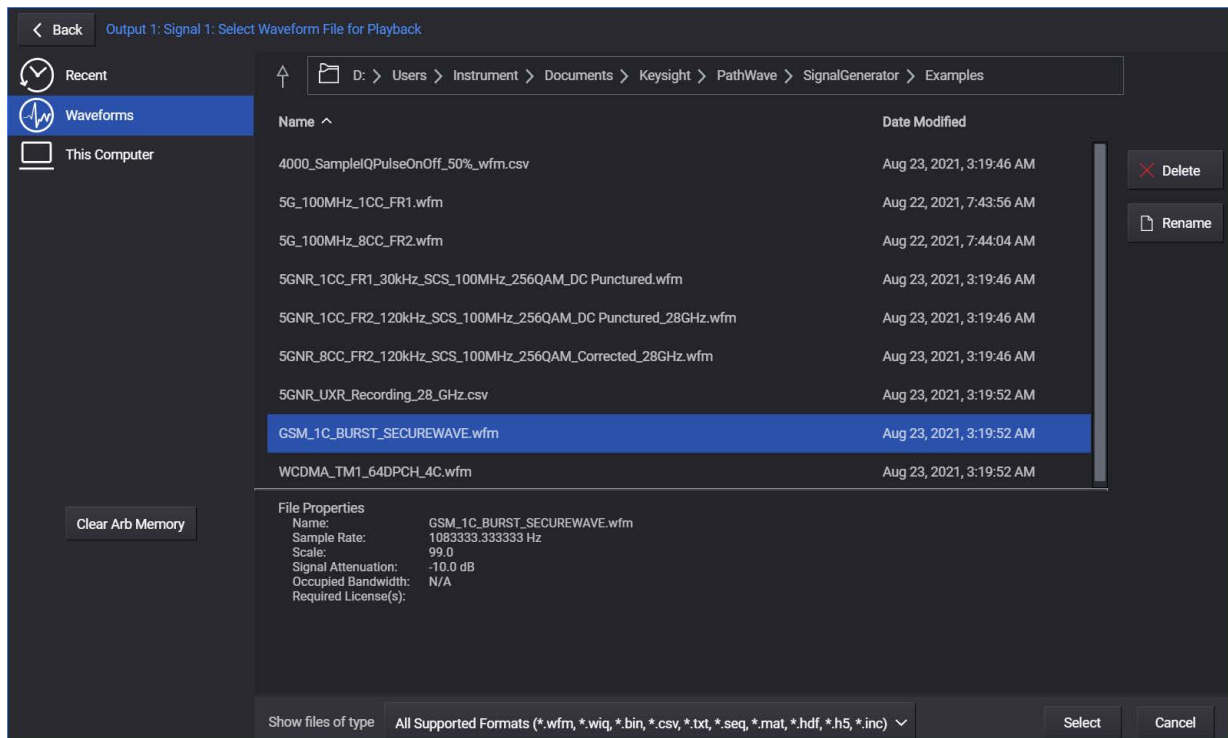
Basic Measurements



5. In the Vector Modulation Signal Setup:

- a. Select the **Mode** dropdown and set to **Waveform File**.
- b. Use **File Select** to navigate to:

D:\Users\Instrument\Documents\Keysight\PathWave
SignalGenerator\Examples



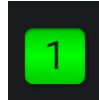
- c. Highlight **GSM_1C_BURST_SECUREWAVE.wfm**, then **Select**.
- d. Select **Enable** Vector Modulation Signal.

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



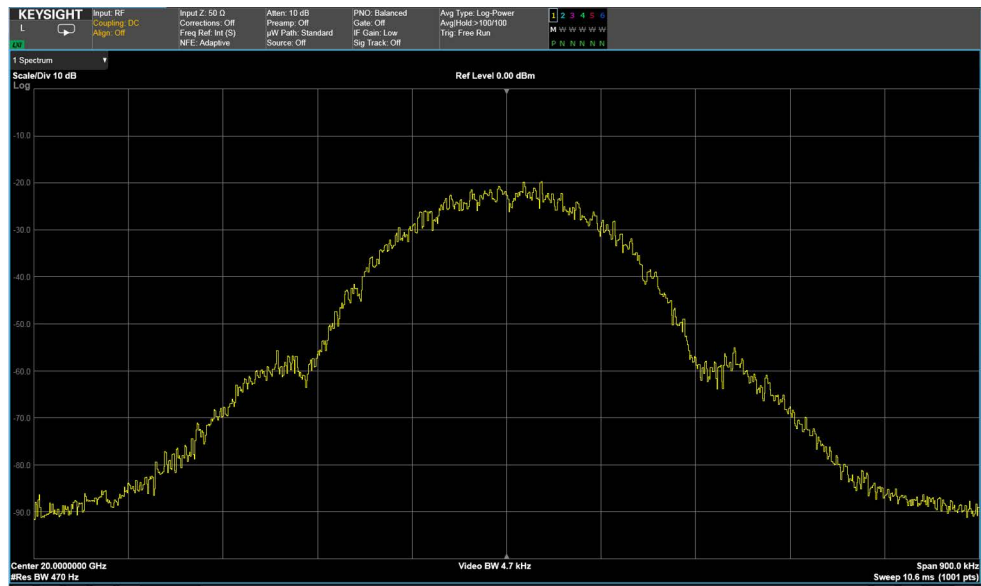
- Set RF Out to **On** by selecting the numbered channel indicator switch.

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:

- Select **Mode Preset** to set Spectrum Analyzer mode to a known state.
- Select **Frequency** and set Center Frequency to **20 GHz** and Span to **900 kHz**.
- Select **BW** and set Res BW to **470 Hz**.
- Select **Trace** and set Trace Type to **Max Hold**.
- Observe the GSM signal.



On the VXG:

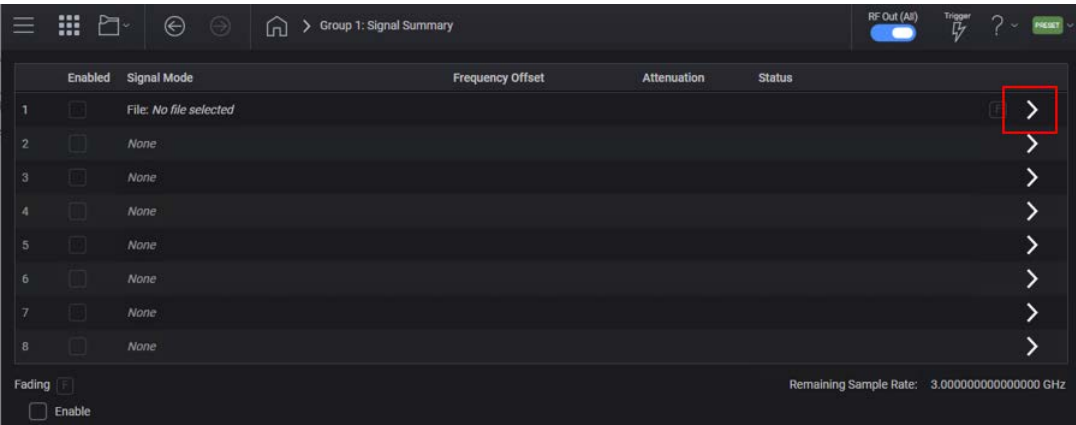
1. Select the **Group 1: Signals** block to open.



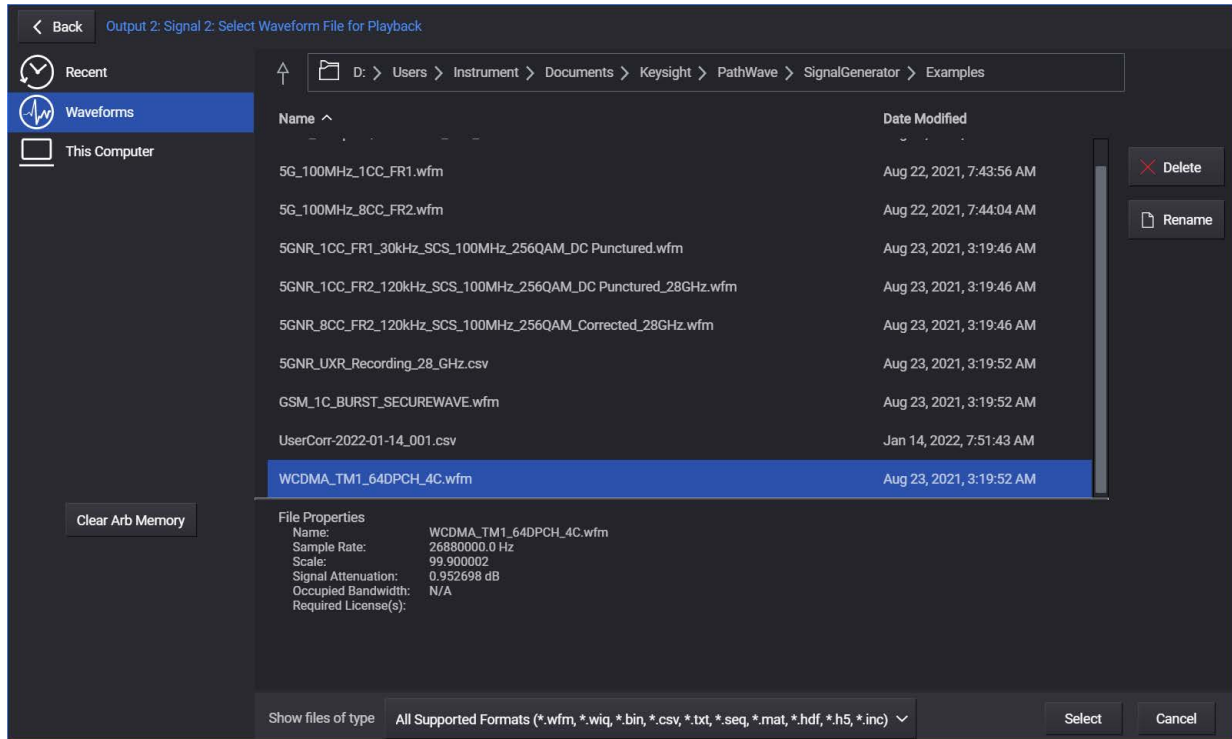
2. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.



3. Use File **Select** to navigate to:
D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

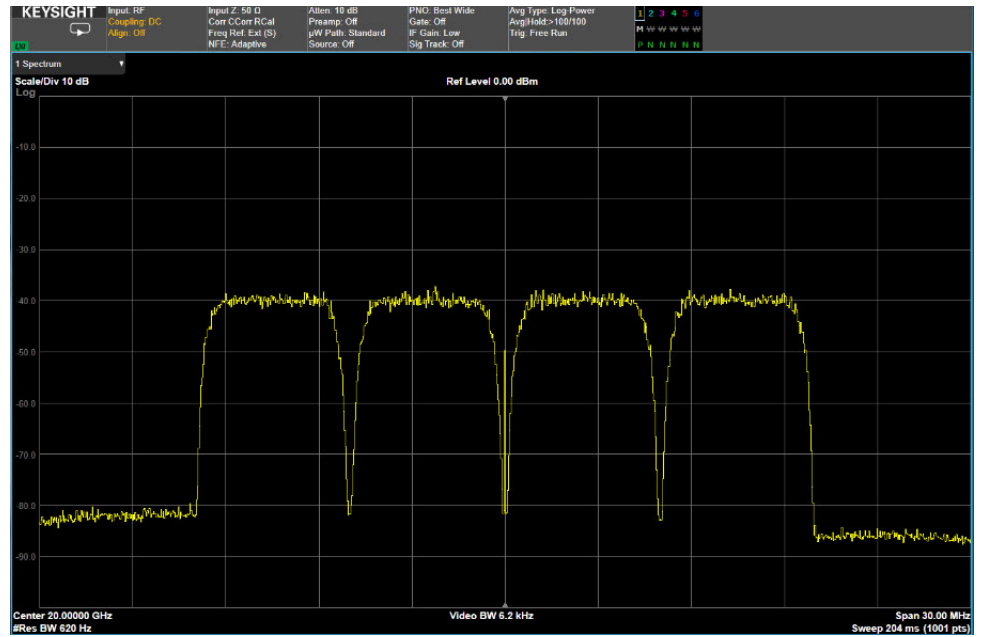


4. Set the file extension to All Files (*.*), highlight WCDMA_TM1_64DPCH_4C.wfm, then **Select**.
5. Ensure that **Enable** Vector Modulation Signal is selected.
6. Ensure that **RF Out** is on.

On the X-Series Signal Analyzer:

1. Select **BW** and set Res BW to **620 Hz**.
2. Select **Frequency** and set Span to **30 MHz**.

3. Observe the LTE signal.



Using the equivalent SCPI commands

On the VXG:

SYSTem:PRESet

RF1:FREQuency:CW 20GHZ

RF1:POWer:AMPLitude 0dBm

SIGNal1:MODE WAVeform

SIGN1:WAV " D:\Users\Instrument\Documents\Demo
Waveforms\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 X-Series Signal Analyzer:

FREQuency:CENTer 20GHZ

FREQuency:SPAN 900KHZ

ACPower:BANDwidth 470 Hz

DISPlay:TXPower:WINDow1:TRACe:MAXHold ON

On the VXG:

SIGN1:WAV " D:\Users\Instrument\Documents\Demo
Waveforms\WDCMA_TM1_64DPCH_4C.wfm"

SIGNal1 ON

RF1:OUTPut:STATe ON

On the X-Series Signal Analyzer:

ACPower:BANDwidth 620 Hz

FREQuency:SPAN 30MHZ

2 Corrections

- “Corrections/De-embedding Using PathWave N7653APPC Software” on page 48
 - “Using a Spectrum Analyzer to Make the Corrections Measurement” on page 54
 - “Using a Power Meter to Make the Corrections Measurement” on page 61
 - “Adding Fixture Blocks using s2p Files” on page 48
- “Instrument Nonlinear Correction” on page 68
 - “Setting Up an INC 1CC 4 GHz, 10 dBm EVM Measurement” on page 68
 - “Setting Up an INC 8CC 28 GHz, 10 dBm EVM Measurement” on page 79

Corrections/De-embedding Using PathWave N7653APPC Software

De-embedding is used to remove the effects of the 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 VXG must have the N7653APPC 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
 9.0 -100 -100 10.0 -100 10.0 -100 -100 -100
 9.5 -100 -100 5.0 -100 5.0 -100 -100 -100
10.0 -100 -100 0.0 -100 0.0 -100 -100 -100
10.5 -100 -100 -5.0 -100 -5.0 -100 -100 -100
11.0 -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.

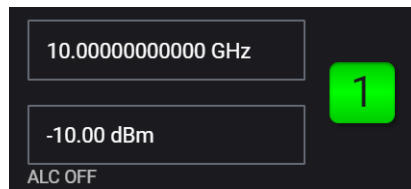
1. Create s2p files in Notepad in the format shown above.

TIP

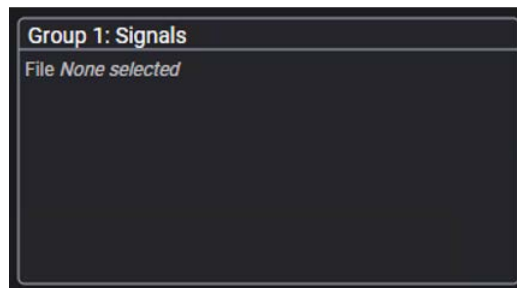
An s2p example file is included on the VXG. Go to

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples\simpleAt10GHzInDB.s2p

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



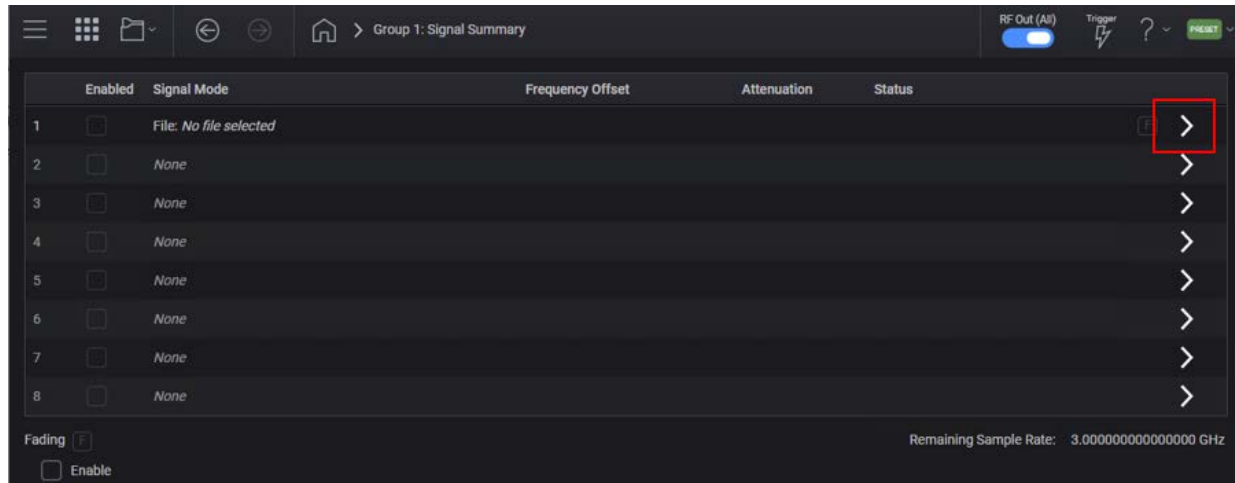
4. Select the **Group 1: Signals** block to open.



5. Select the arrow for Signal 1 to open the Signal Setup window.

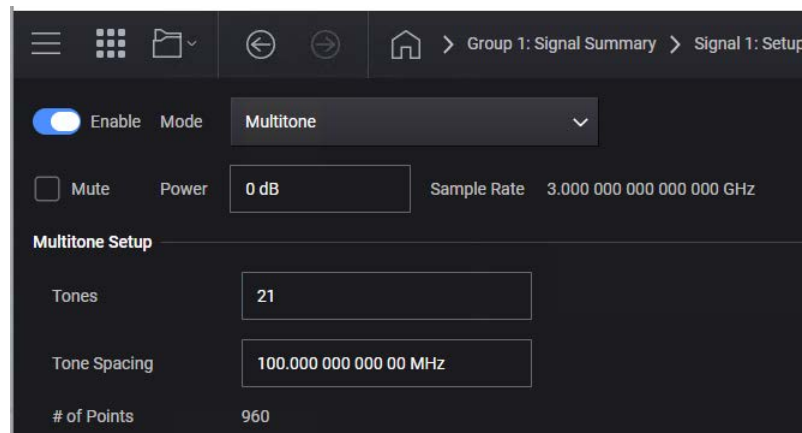
NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.



6. Select the **Mode** dropdown and set:

- Vector Modulation Signal Mode to **Multitone**
- Tones to **21**
- Tone Spacing to **100 MHz**
- Select **Enable** Vector Modulation Signal

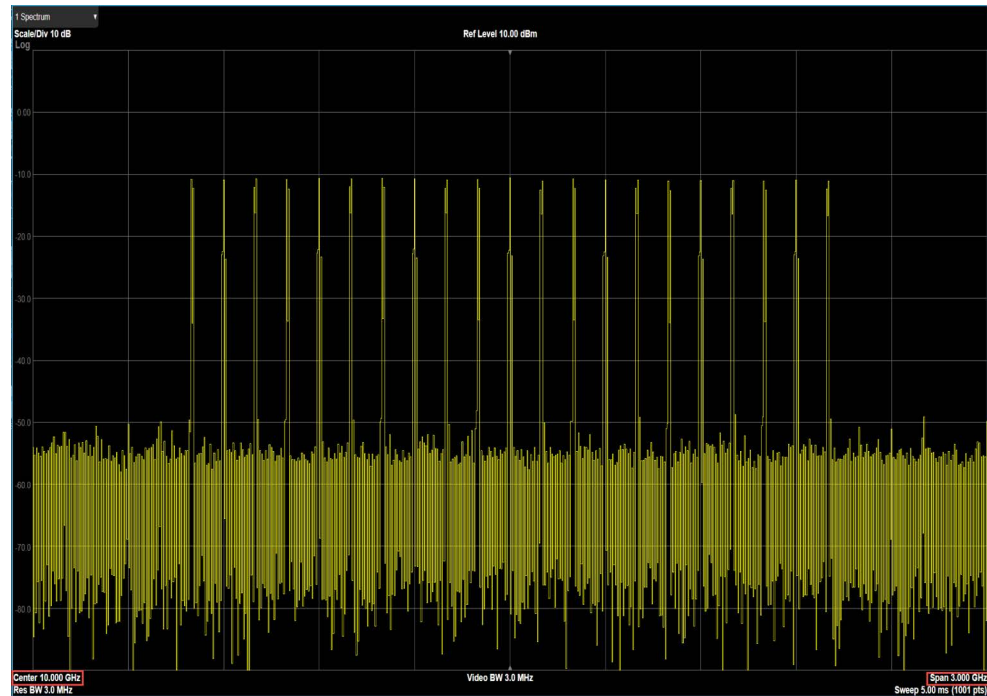


7. Close the Signal block by selecting the **Home** icon, and then select **RF Out** to turn on.

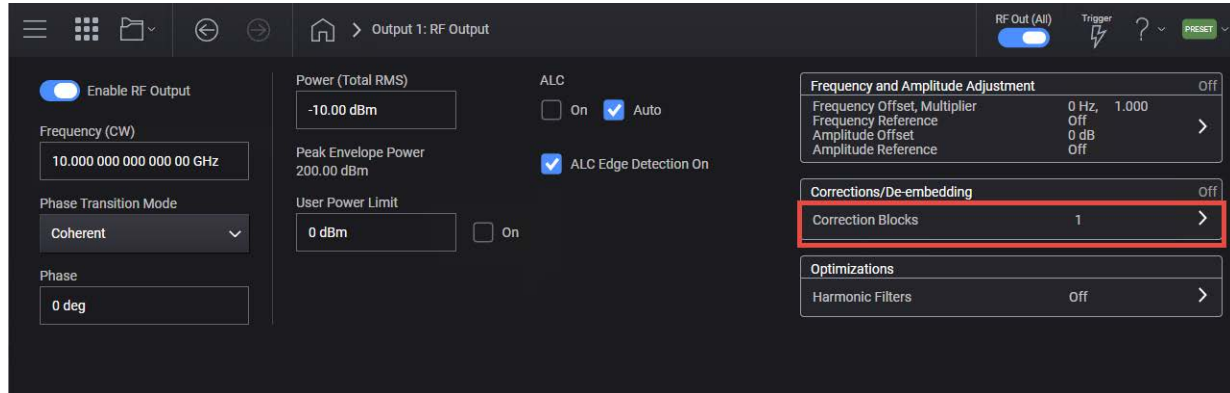
8. On the X-Series Signal Analyzer spectrum analyzer in Spectrum Analyzer Mode:

- Select **Mode Preset** to set Spectrum Analyzer mode to a known state.
- Set the Center to **10 GHz**

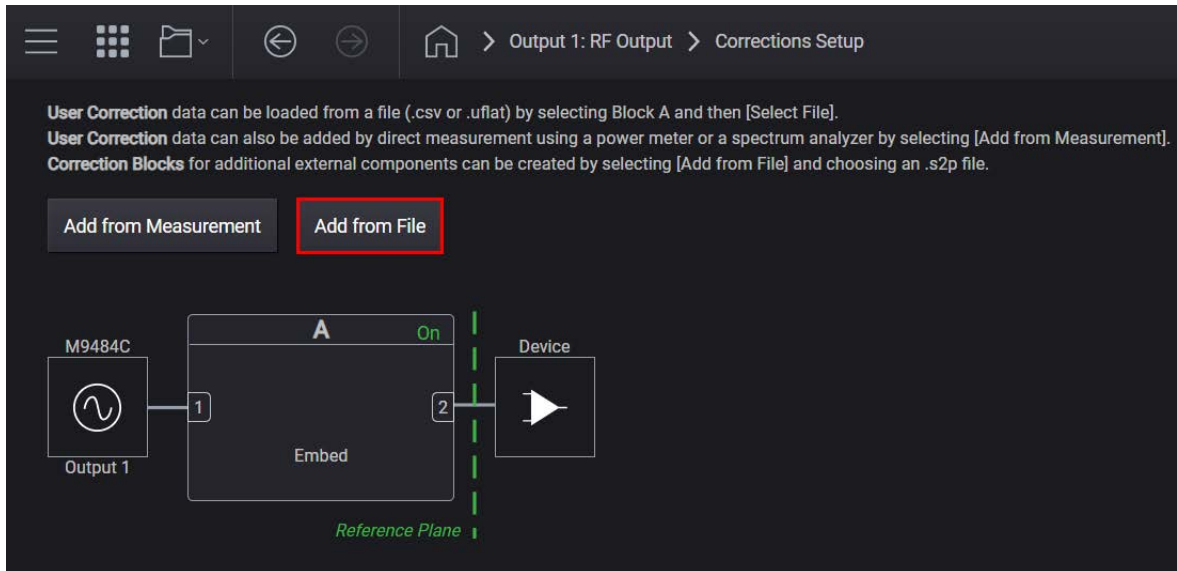
- Set Span to **3 GHz**



9. On the VXG, select the **RF Output** block > **Corrections/De-embedding**.



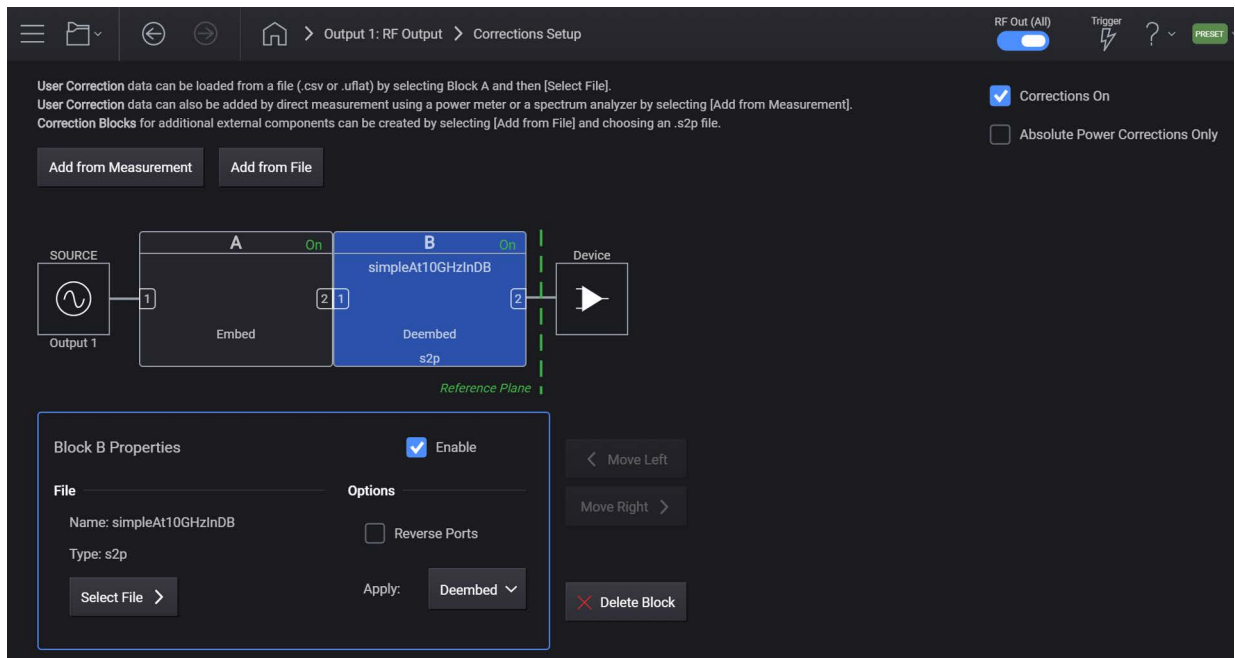
10. In the Corrections Setup dialog, select **Add from File**.



11. Navigate and select the s2p file and then **Select**.

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples\simpleAt10GHzInDB.s2p

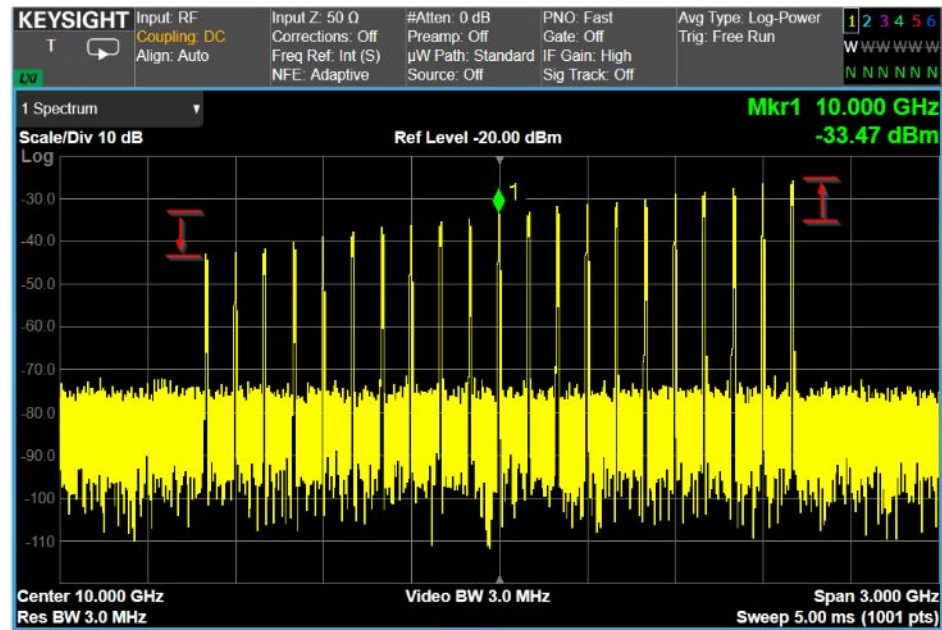
Notice that Block B is added in the Correction Setup diagram.



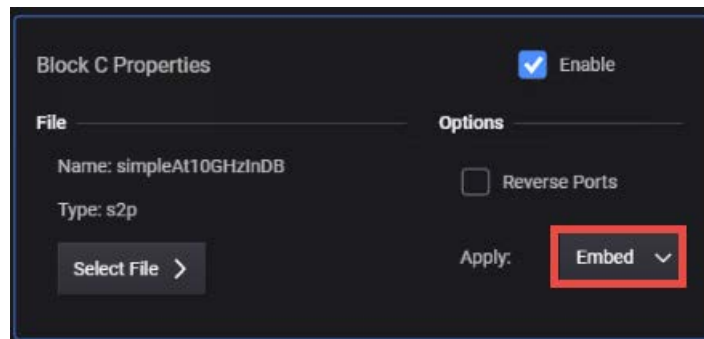
Corrections

Corrections/De-embedding Using PathWave N7653APPC Software

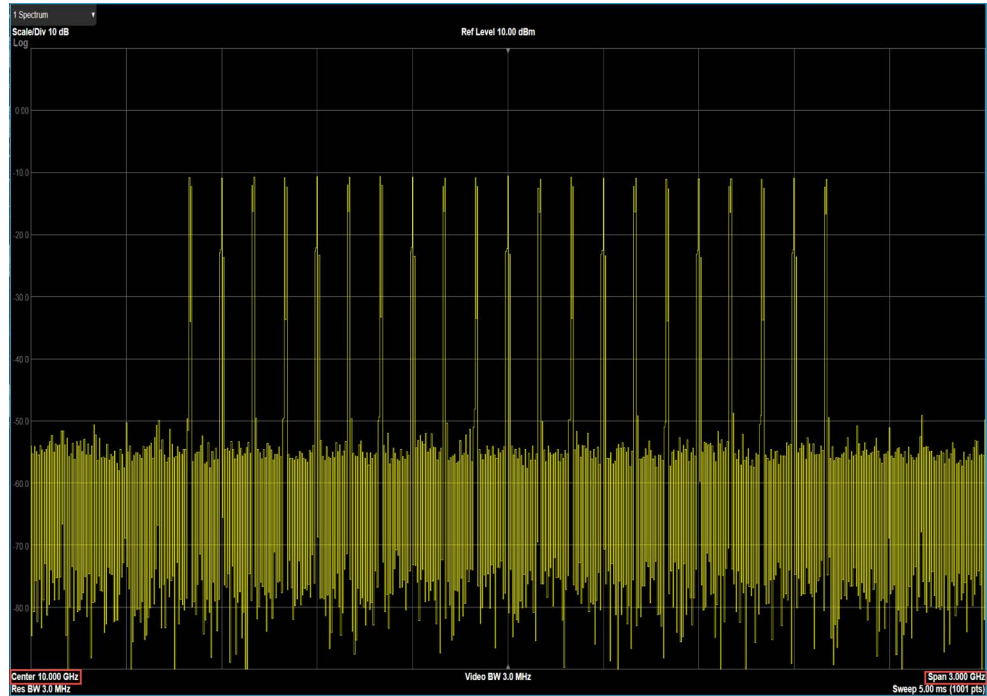
12. Turn **Corrections On**. View the results on the signal analyzer. Observe how the .s2p file has impacted the signal.



13. 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 VXG 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
- N9030A/B PXA
- N9040B and N9041B UXA

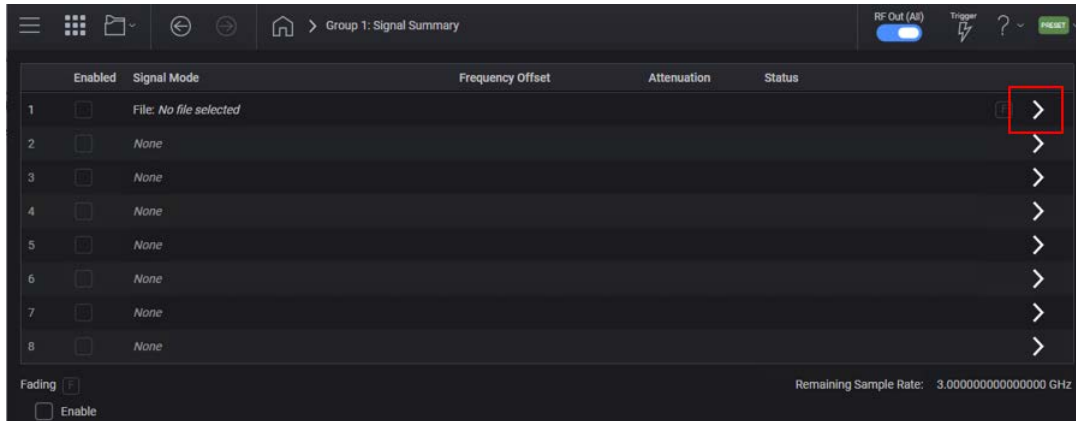
On the VXG:

1. Connect the VXG 10 MHz Out to the N90x0A/B Ext Reference In.
2. Connect cable or DUT between the VXG 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 **12 GHz** and Amplitude to **-10 dBm**.

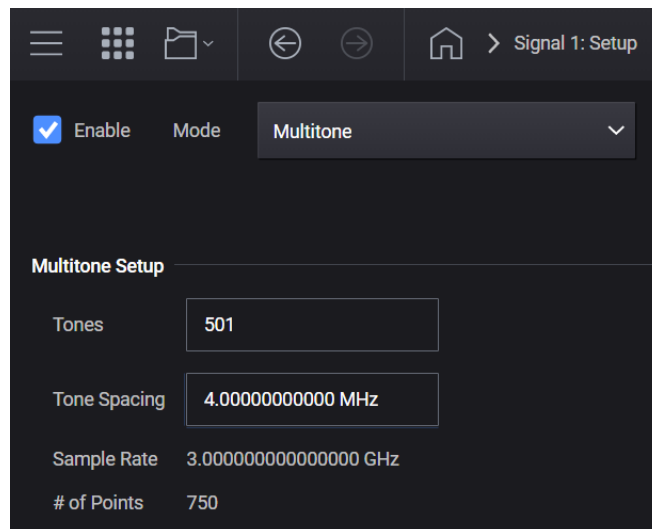
5. Select the **Signal** block to open.
6. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.



7. Select the **Mode** dropdown and select **Multitone**.
8. Configure the signal to have **501 Tones** with **4 MHz Tone Spacing**, then select **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 VXG.



On the Signal Analyzer:

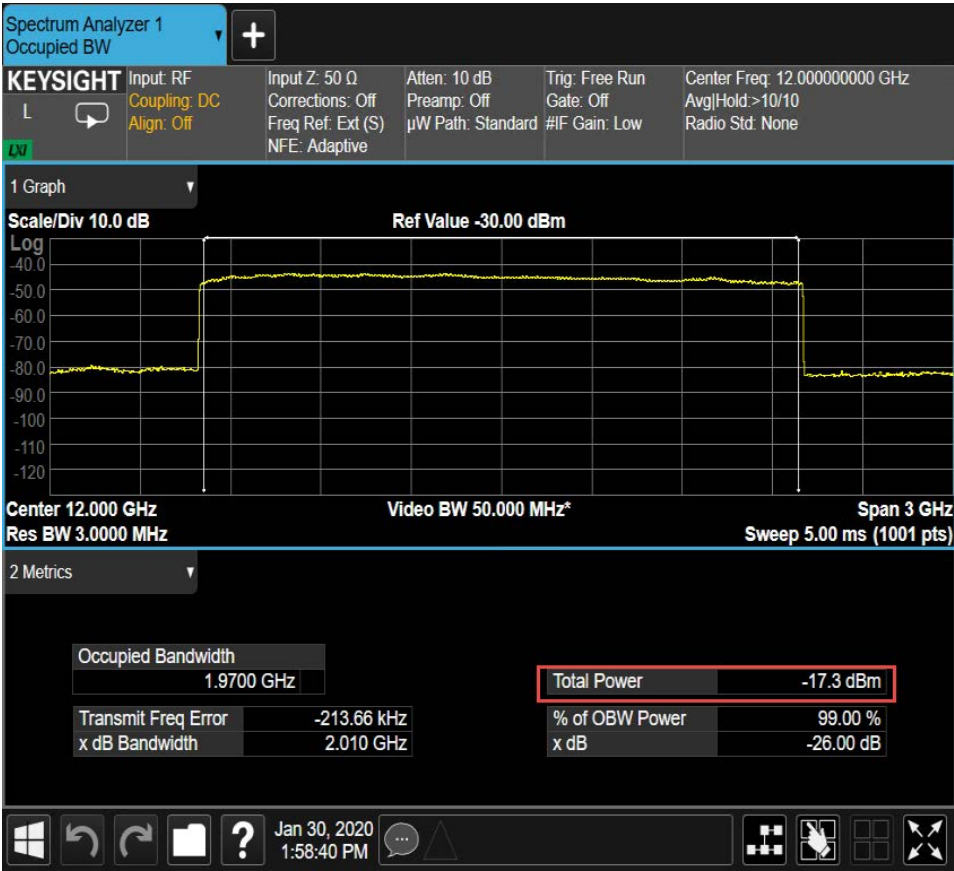
- 1. From the Menu Panel (on the top right of the display), select **Mode/Meas > Spectrum Analyzer mode > Occupied BW Measurement > OBW Results View.**

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.

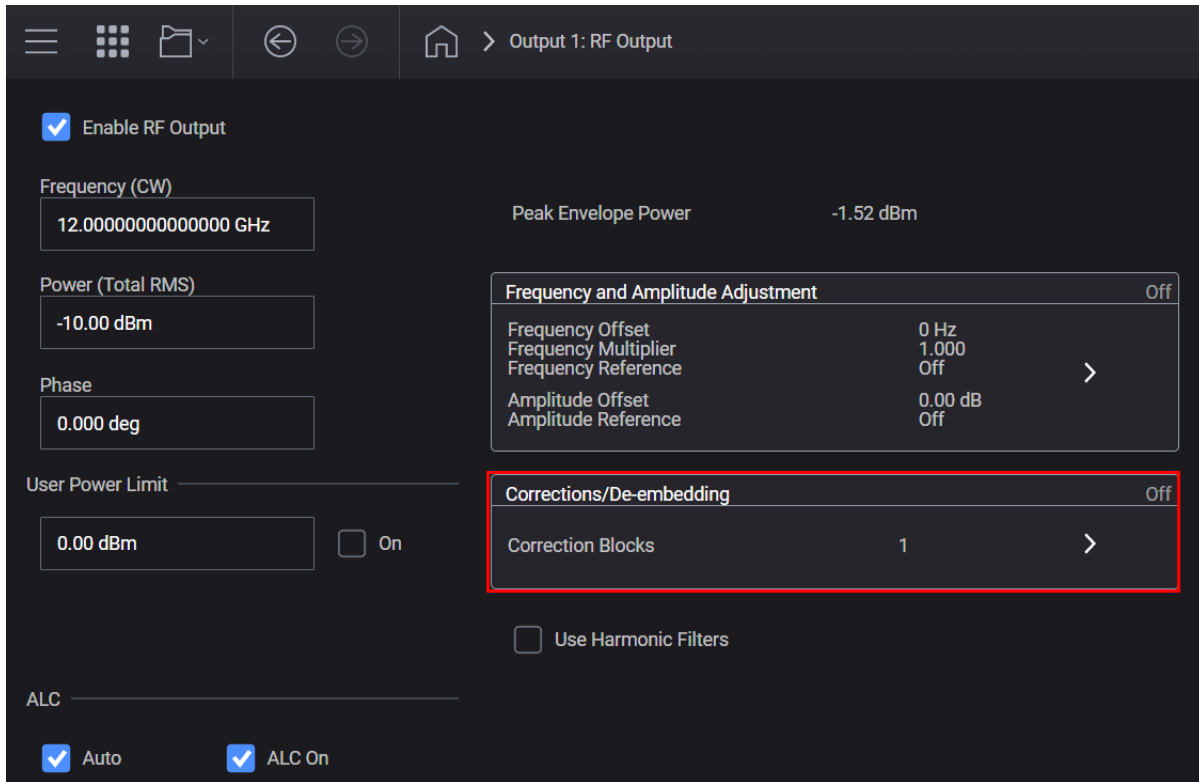
- 2. Set the Center Frequency to **12 GHz** and the Span to **3 GHz**.

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

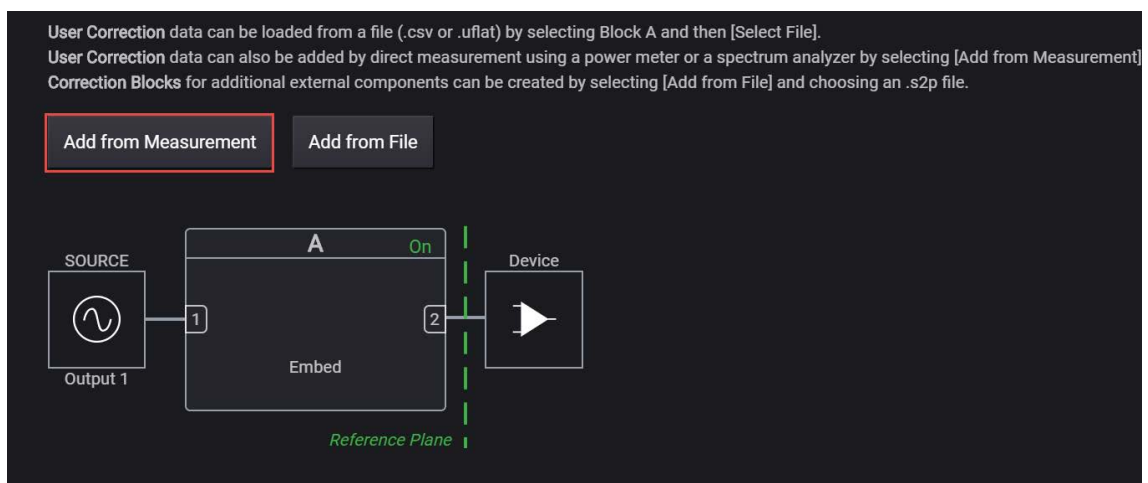


On the VXG:

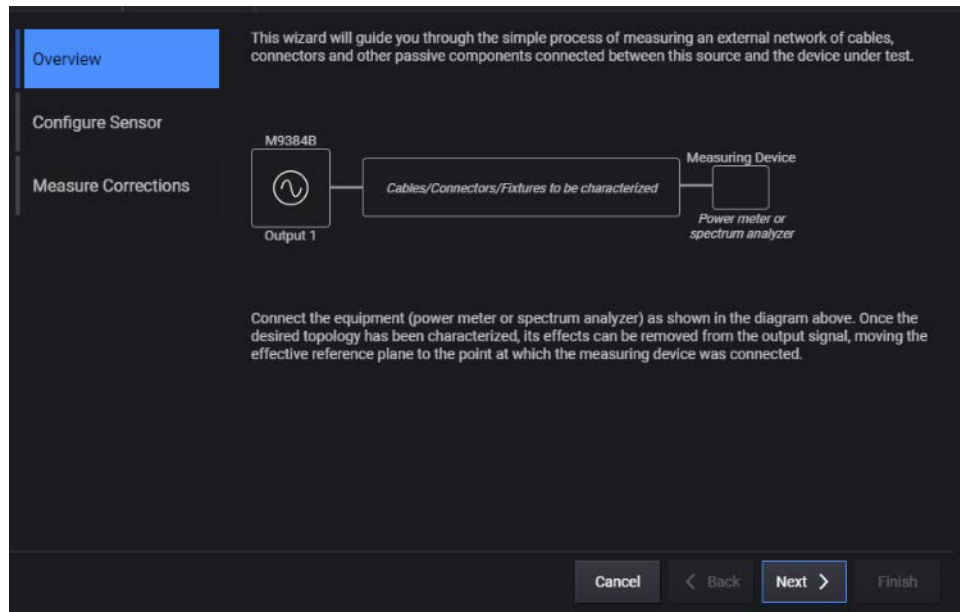
1. Select the **RF Output** block > **Corrections/De-embedding** block to open the Correction Setup.



2. Select **Add from Measurement** to open the Measure Corrections Block Wizard.



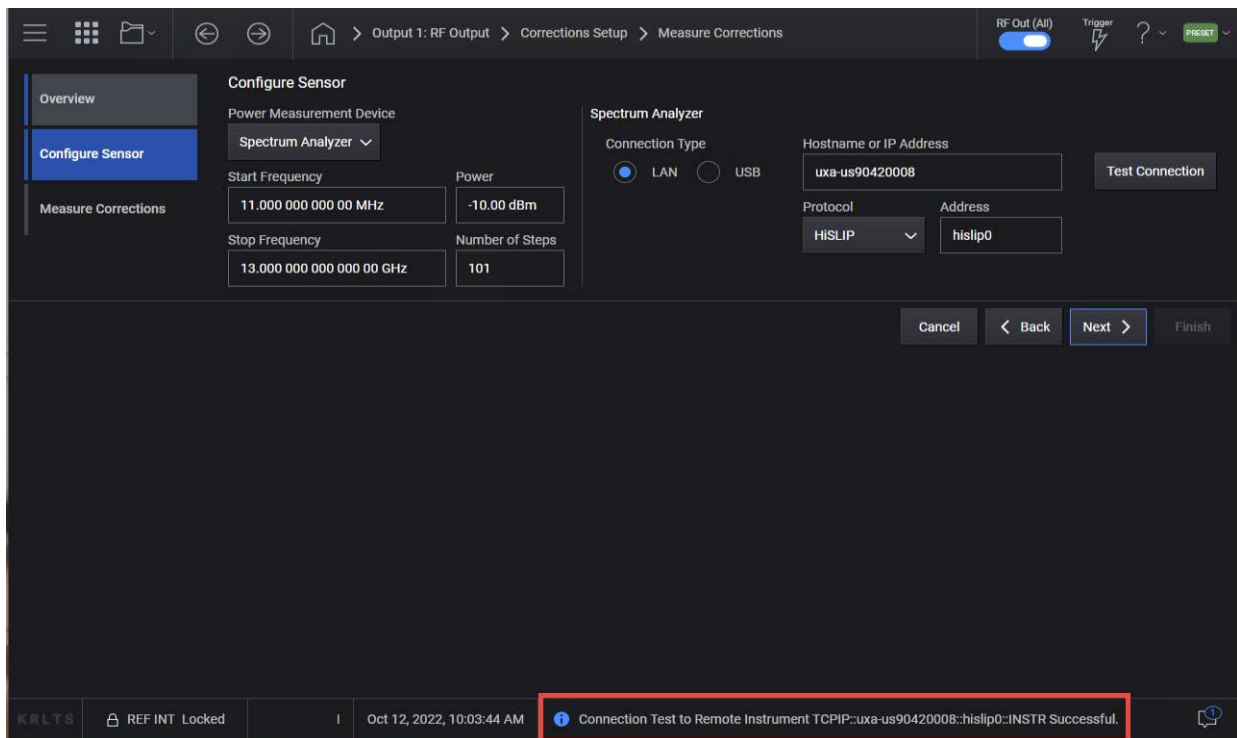
3. Connect the power sensor (in this case, the X-Series signal analyzer) as shown in the diagram below. After reading the overview, select **Next** to move to the Configure Sensor setup.



4. In the Configure Sensor setup, select the **Power Measurement Device** dropdown and select **Spectrum Analyzer**.
5. Set the Start and Stop Freq, Amplitude, and the Num Steps. For this example Start Freq **11 GHz**, Stop Freq **13 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**.

The screenshot shows the 'Configure Sensor' setup window in the PathWave N7653APPC software. The window has a sidebar with 'Overview', 'Configure Sensor', and 'Measure Corrections'. The 'Configure Sensor' section is active. It contains a 'Power Measurement Device' dropdown menu set to 'Spectrum Analyzer'. Below this, there are four input fields: 'Start Frequency' (11.000 000 000 00 MHz), 'Power' (-10.00 dBm), 'Stop Frequency' (13.000 000 000 00 GHz), and 'Number of Steps' (101). These four fields are highlighted with a red rectangle. To the right of these fields is a 'Spectrum Analyzer' section with 'Connection Type' (LAN selected), 'Hostname or IP Address' (empty), 'Protocol' (HISLIP), and 'Address' (hislip0). There is a 'Test Connection' button. At the bottom right, there are buttons for 'Cancel', '< Back', 'Next >', and 'Finish'.

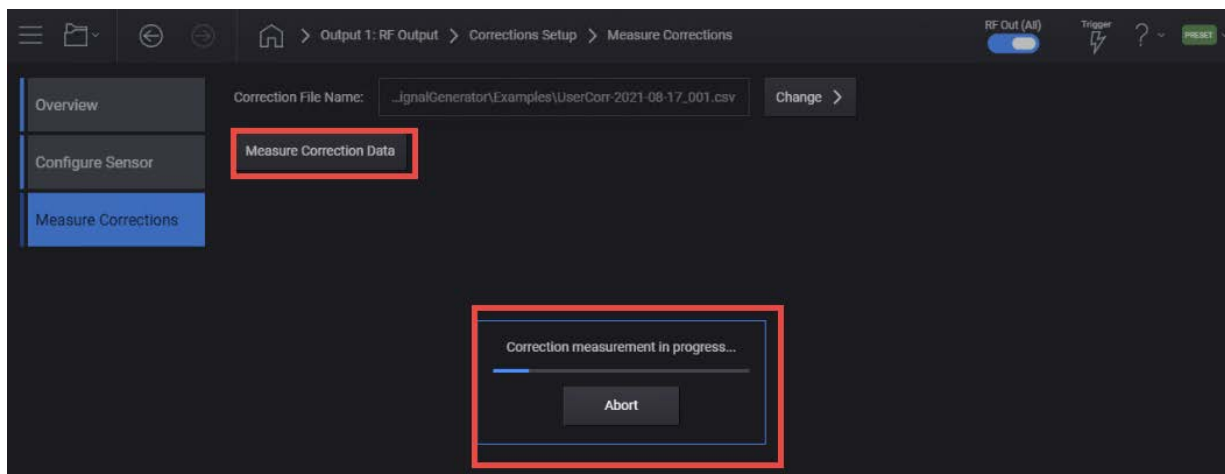
- Set Connection Type to **LAN**, enter the LAN Address and set the Protocol parameters to **HiSLIP**, and then select **Test Connection**.



- Once you are successfully connected, select **Next** to move to the Measure Corrections step.

- Select **Measure Correction Data**.

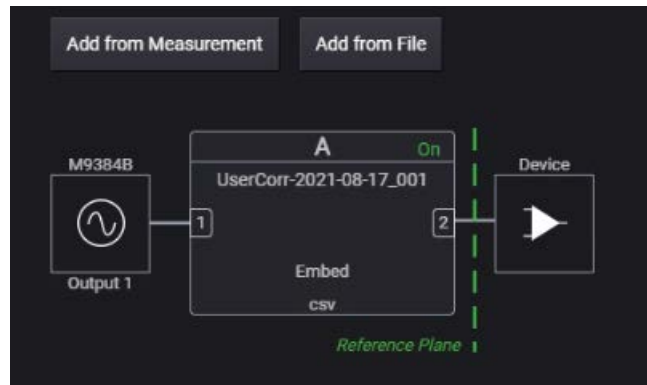
During the measurement, the VXG outputs a CW between the Start and Stop Frequencies for the specified number of steps and output power. It will take some time to measure all 101 points, and the progress is indicated by the blue bar. You can watch the signal analyzer as it steps through this process.



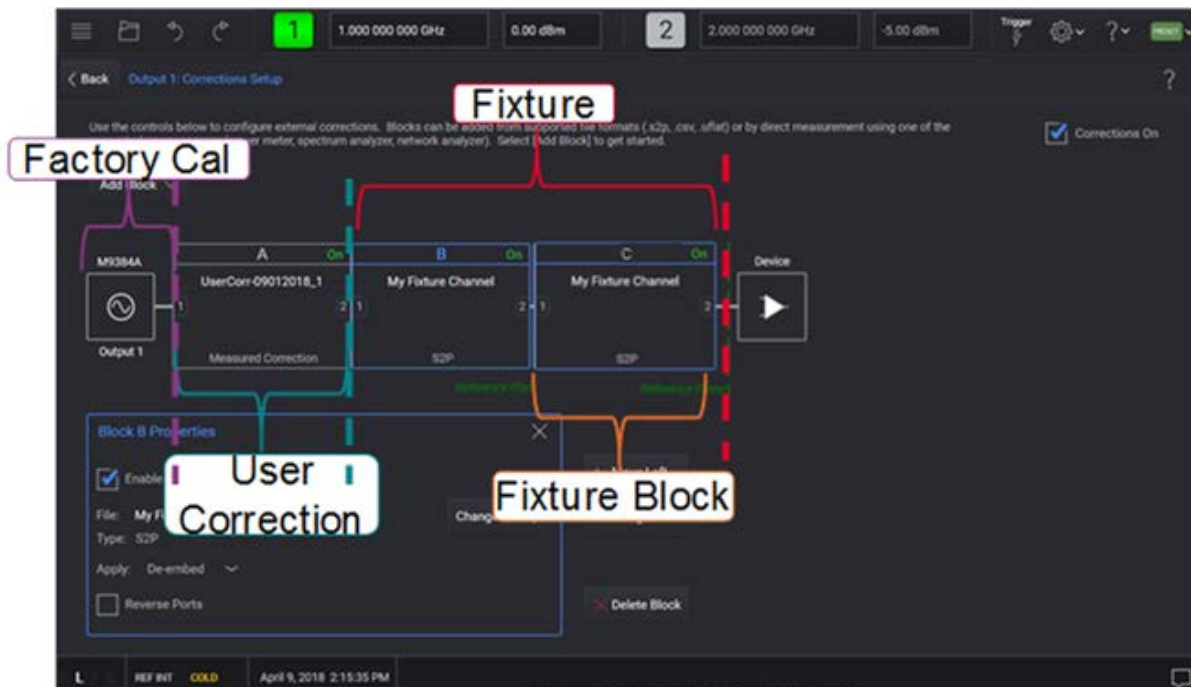
The measurement results are saved to a csv file using an automatically generated file name.

- When the measurement is complete, select **Finish**, then select **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.



- 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 VXG to see the difference.

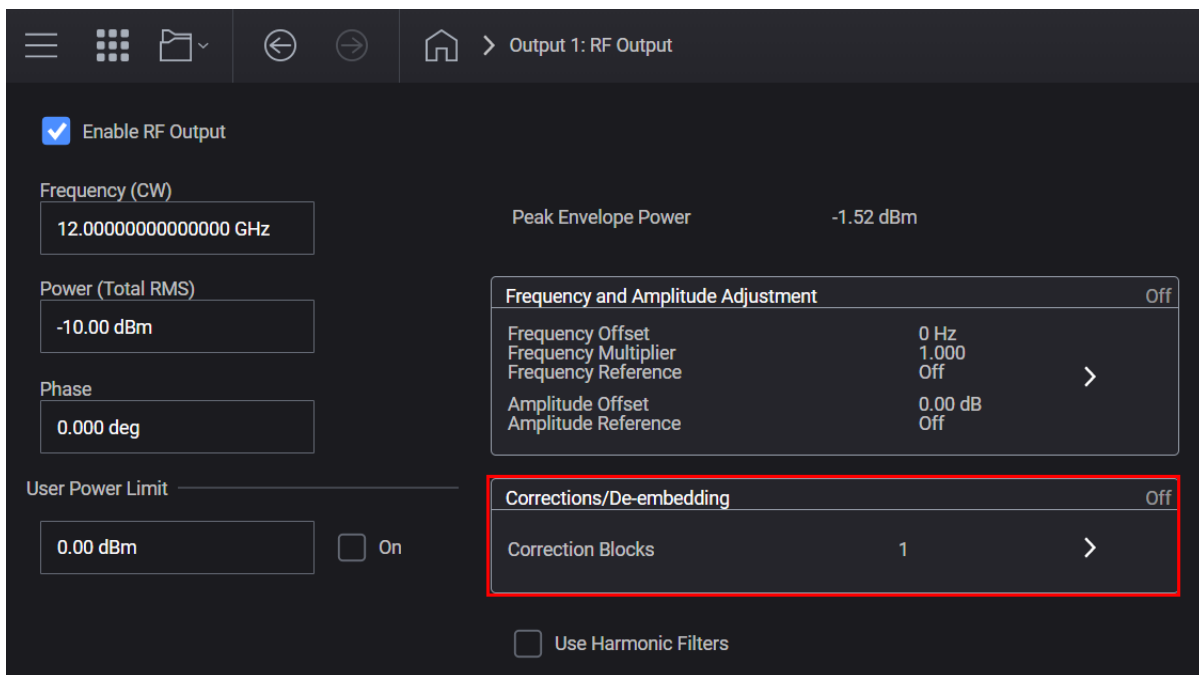
Using a Power Meter to Make the Corrections Measurement

A power meter can also be used at the power measurement device. The following USB power sensors are supported:

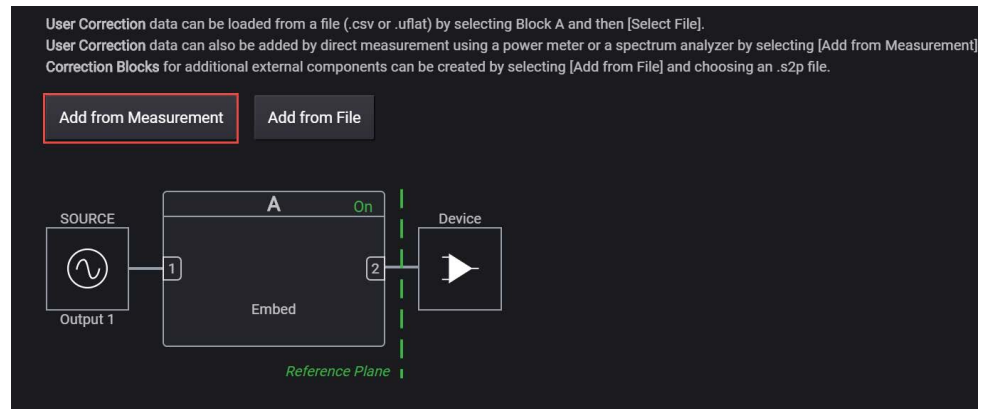
- U8487A-CFG007
- U8485A-CFG006
- U2000A
- U2001A
- U2002A
- U2004A
- U2000B
- U2001B
- U2000H
- U2001H
- U2002H

On the VXG:

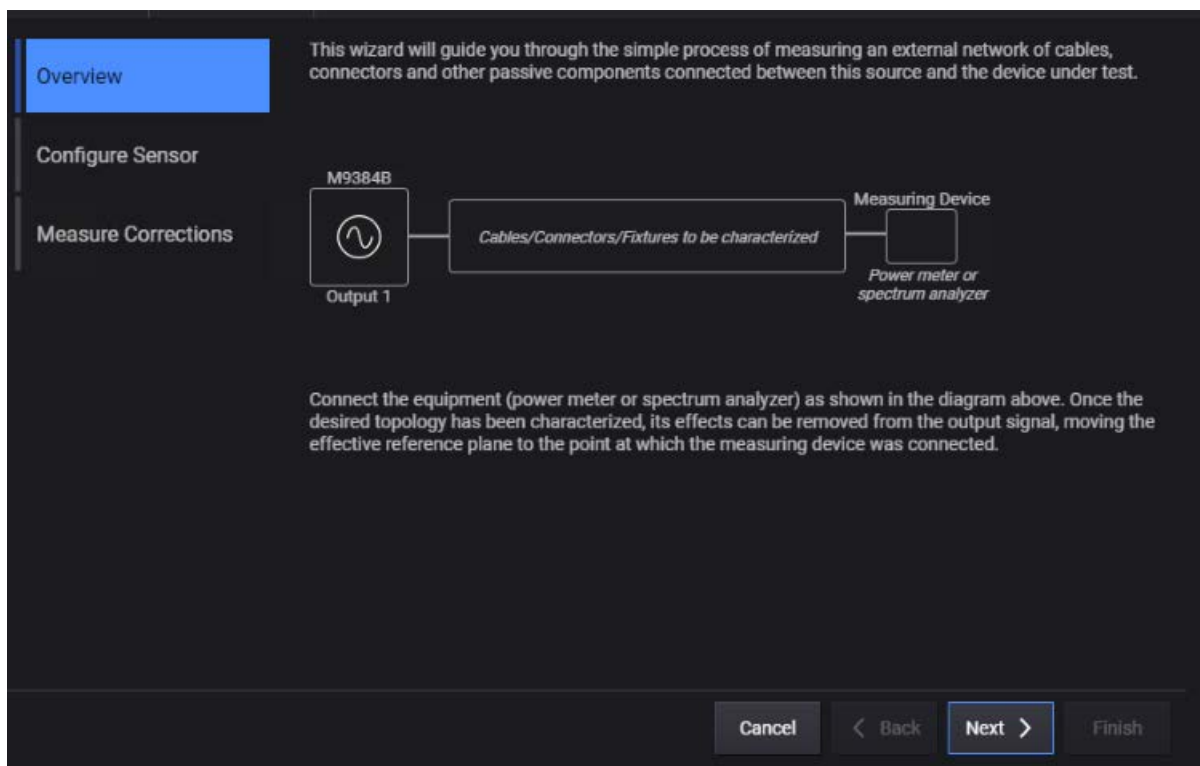
1. Connect the VXG 10 MHz Out to the N90x0A/B Ext Reference In.
2. Select the **RF Output** block > **Corrections/De-embedding** block to open the Correction Setup.



3. Select **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**.

The screenshot shows the 'Configure Sensor' dialog with three tabs: 'Overview', 'Configure Sensor', and 'Measure Corrections'. The 'Configure Sensor' tab is active. At the top, 'Power Measurement Device' is set to 'Power Meter'. Below this, the 'Start Frequency' is 11.0000000000 GHz, 'Stop Frequency' is 30.0000000000 GHz, 'Number of Steps' is 20, and 'Power' is 5.00 dBm.

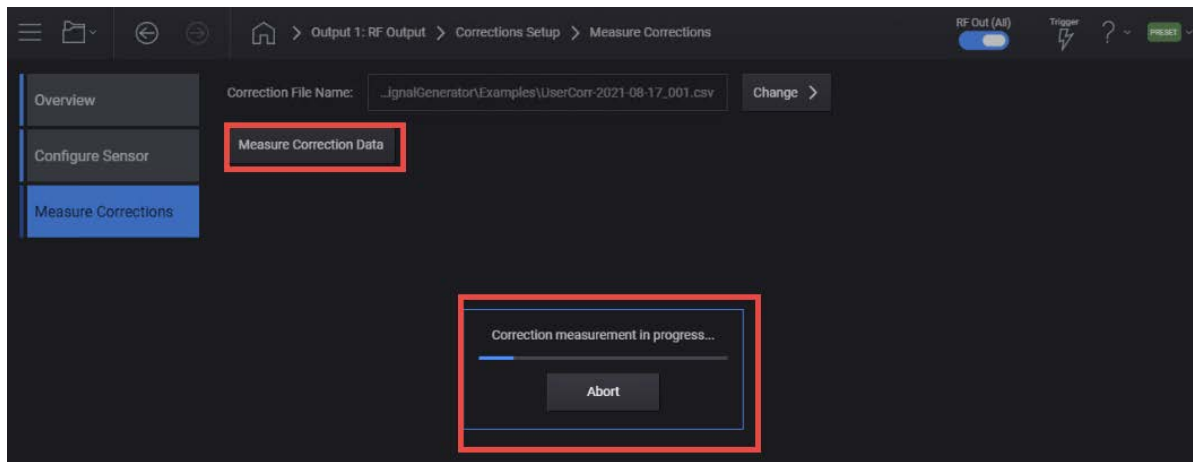
6. Set the Start and Stop Freq, Amplitude, and the Num Steps. For this example Start Freq **26 GHz**, Stop Freq **30 GHz**, Amplitude to the highest power used in your measurement **5 dBm**, and Num Steps to **20**.

This screenshot shows the 'Configure Sensor' dialog with the 'Power Meter' configuration. The 'Start Frequency' is now 26.0000000000 GHz, 'Stop Frequency' is 30.0000000000 GHz, 'Number of Steps' is 20, and 'Power' is 5.00 dBm. Below these fields, the 'Power Meter' section is expanded, showing 'Connection Type' with 'LAN' and 'USB' options (USB is selected), a 'Device' dropdown set to 'Select Device...', and buttons for 'Test Connection', 'Calibrate Sensor', and 'Zero Sensor'. At the bottom, there are 'Cancel', '< Back', 'Next >', and 'Finish' buttons.

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.

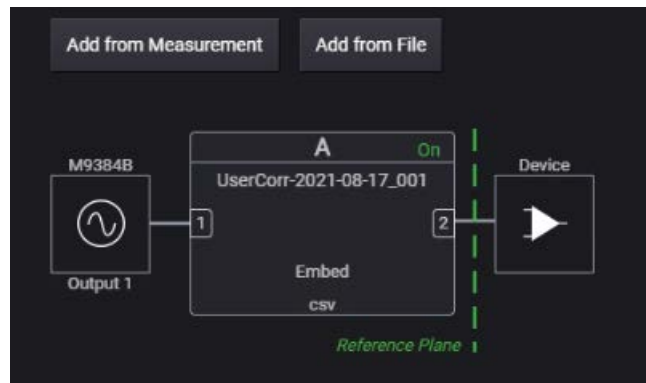
You can also calibrate and zero out the power sensor before measuring corrections.

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



During the measurement, the VXG 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.

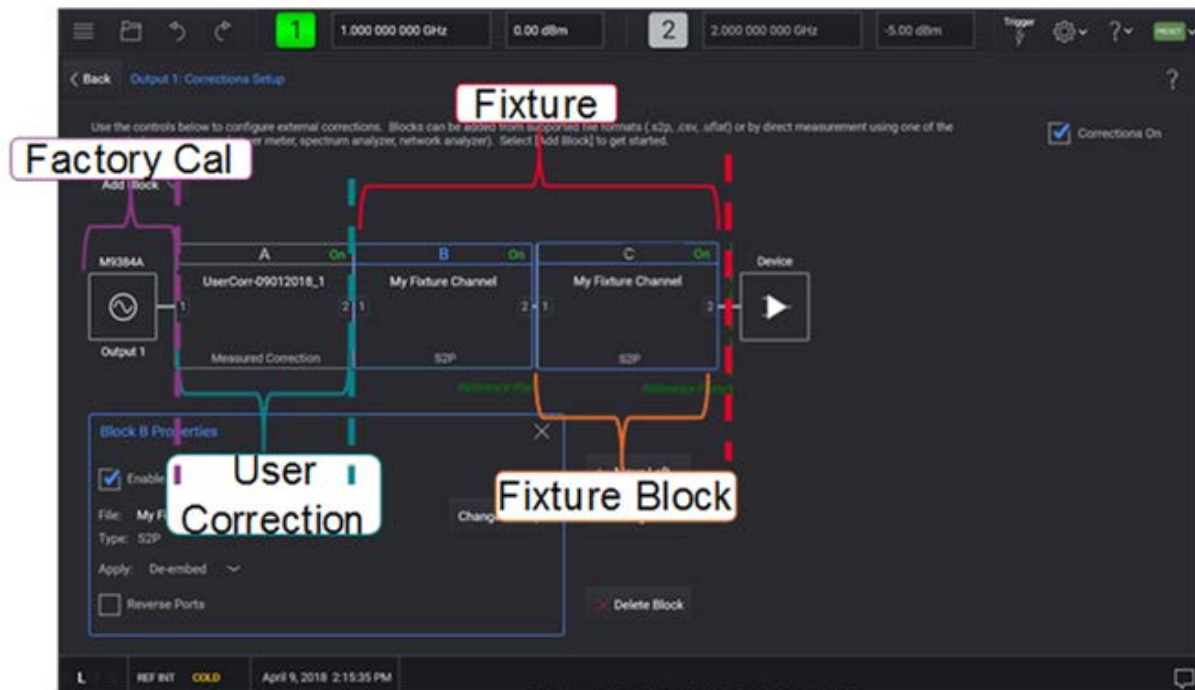
10. Select **Finish**. The output csv file is set to Block A.



Corrections

Corrections/De-embedding Using PathWave N7653APPC Software

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 VXG:

```
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 26GHZ
```

```
CORRection:FLATness:STEP:STOP 30GHZ
```

```
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 VXG:

```
SYSTem:PRESet
```

```
RF1:POWer:AMPLitude 5dBm
```

```
CORRection:PMDevice PMETer
```

```
CORRection:FLATness:STEP:START 26GHZ
```

```
CORRection:FLATness:STEP:STOP 30GHZ
```

```
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 VXG:

SYSTem:PRESet

RF1:FREQuency:CW 10GHZ

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.

RFAL1:OUTPut ON

On the X-Series Signal Analyzer:

SYSTem:PRESet

FREQuency:CENTer 10GHZ

FREQuency:SPAN 3GHZ

On the VXG:

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.

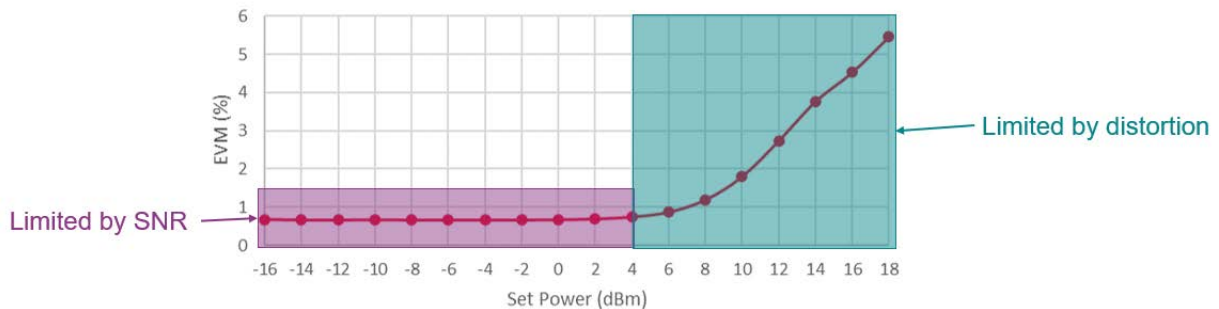
CORRection:BLOCK3:APPLY EMBedding

CORRection:BLOCK3 ON

Instrument Nonlinear Correction

Instrument Nonlinear Correction (INC) is a digital pre-distortion (DPD) based correction using a Keysight signal analyzer (N9042B, N9040B, or N9030B) to compensate for nonlinearities in the VXG. INC is useful in reducing EVM (and other metrics impacted distortion) at high power levels and extending the range of the power with linear output of the VXG. INC is a point correction valid for a given frequency/power/waveform combination and can be used for EVM and ACP measurements at high power levels (>5 dB). The VXG must have the N7653APPC PathWave automatic channel response correction and S-parameter de-embedding license installed.

Instrument nonlinear corrections compensate for nonlinearities in the VXG. Improvement to EVM will only be seen at power levels where distortion is the limiting factor. INC will not improve EVM in the area where signal to noise ratio (SNR) is the limiting factor.

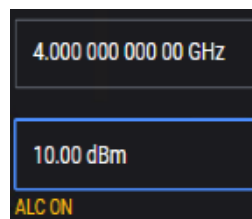


Setting Up an INC 1CC 4 GHz, 10 dBm EVM Measurement

On the VXG:

In order to compare before and after correction results, we will start by making an EVM measurement without applying corrections.

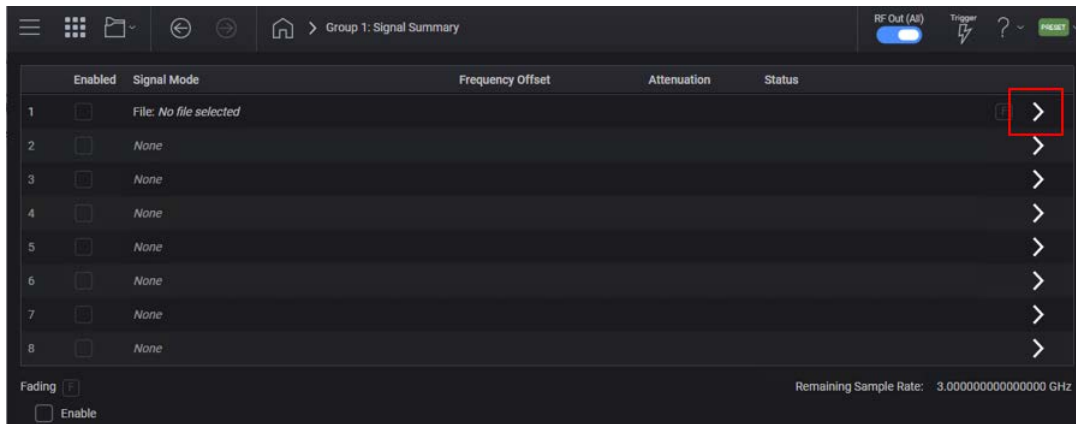
1. Select **Preset > Preset** to set the instrument to a known state.
2. In the Output area, set Frequency to **4 GHz** and Power to **10 dBm**.



3. Select the **Signal** block to open the Vector Modulation Signal Setup panel.



4. Select the arrow for Signal 1 to open the Signal Setup window.



NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.

5. In the Waveform Playback Setup area, use File **Select** to navigate to:

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

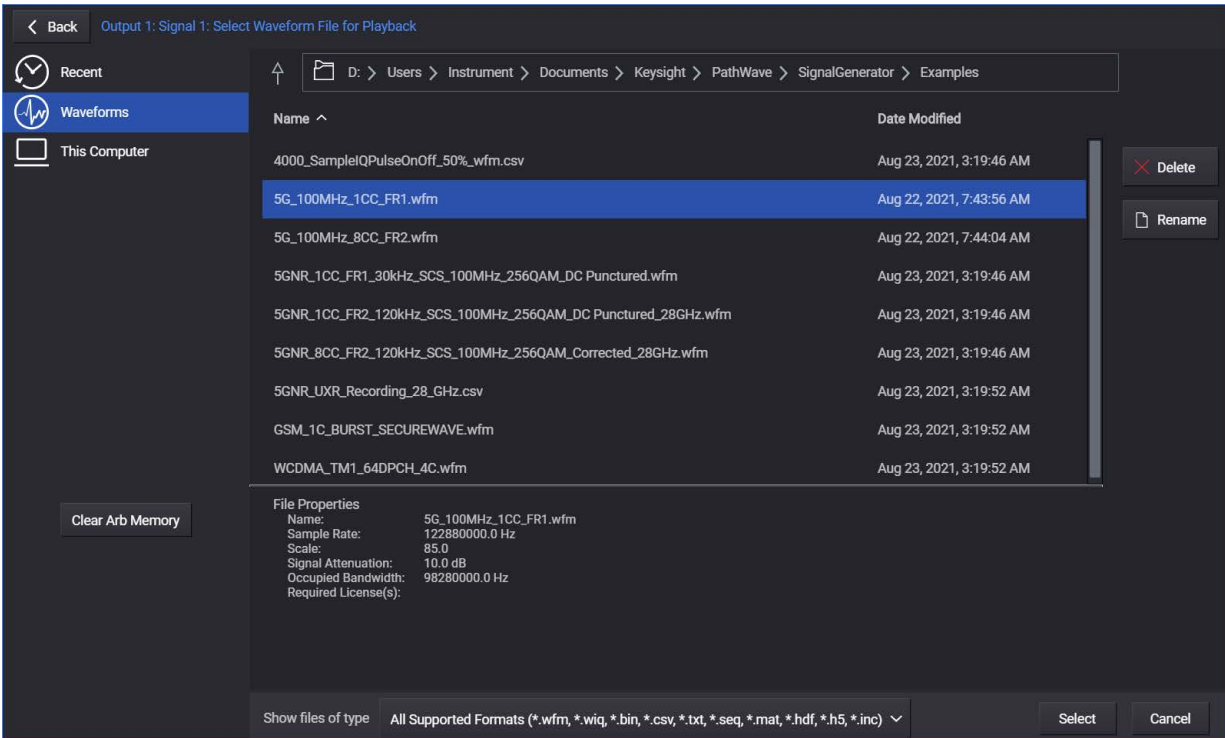
and choose

Corrections

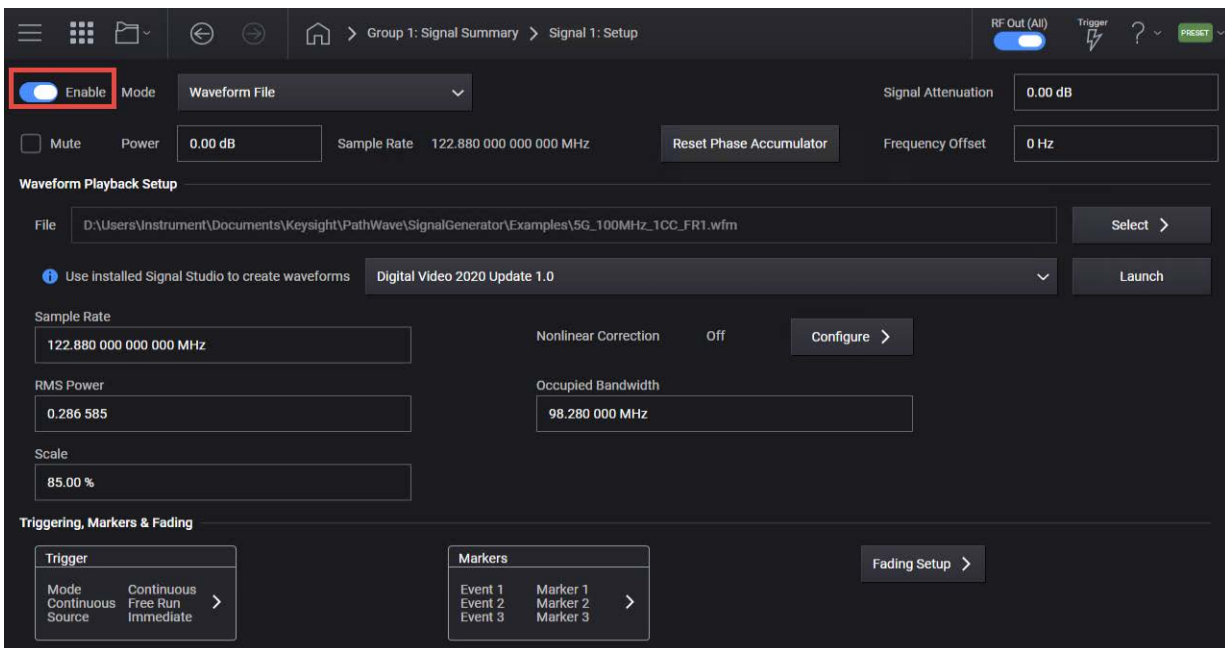
Instrument Nonlinear Correction

5G_100MHz_1CC_FR1.wfm

then **Select**.



6. Select **Enable** Vector Modulation Signal.



7. Select the **Home** icon and set RF Out to **On**.

On the UXA:

1. From the X-Series Signal Analyzer Menu Panel (on the top right of the display), 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 of the display) to open the Mode/Measurement/View Selector window.

2. Select **Mode Preset** to set Spectrum Analyzer 5G NR & V2X mode to a known state.
3. From the X-Series Signal Analyzer Menu Panel (on the top right of the display), select **Mode/Meas > 5GNR Mode > Modulation Analysis Measurement > OK**.

NOTE

All example waveforms and setup files are located on the VXG at:

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

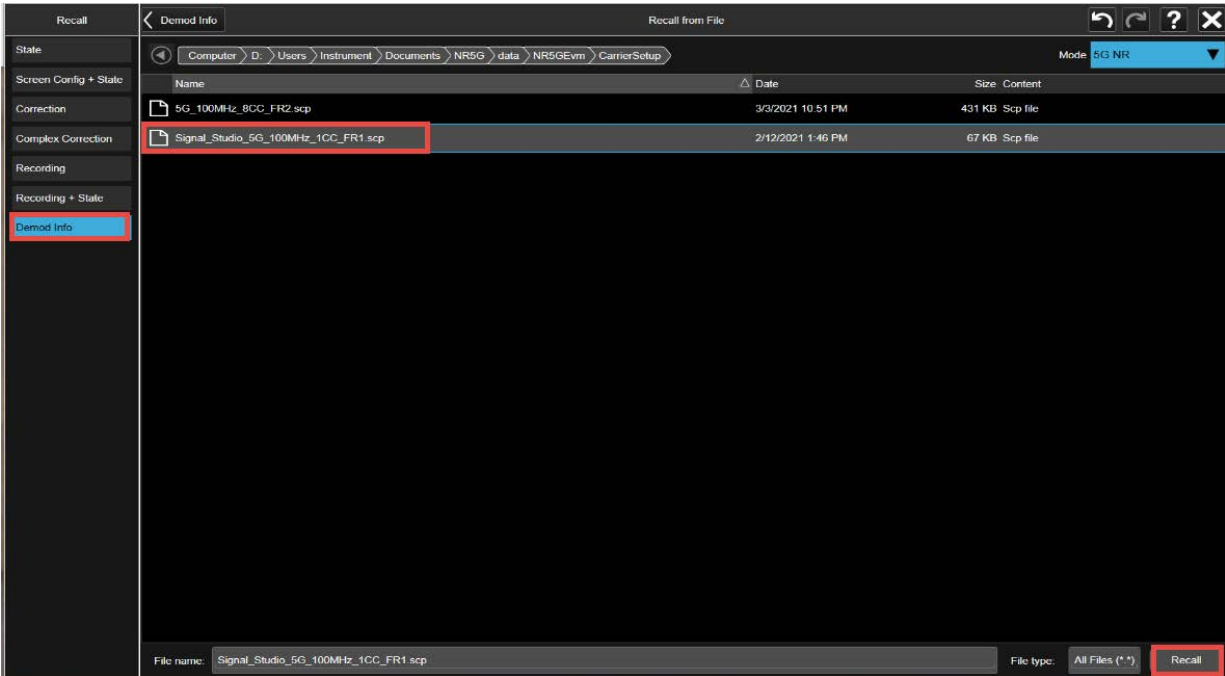
You will need to copy over the setup files to the X-Series Signal Analyzer or the PC running the VSA application.

4. Select **Recall** (If accessing the X-Series Signal Analyzer remotely, select the Folder icon at the bottom of the display) **Demod Info > Data Type set to CC Setup > Recall From >**

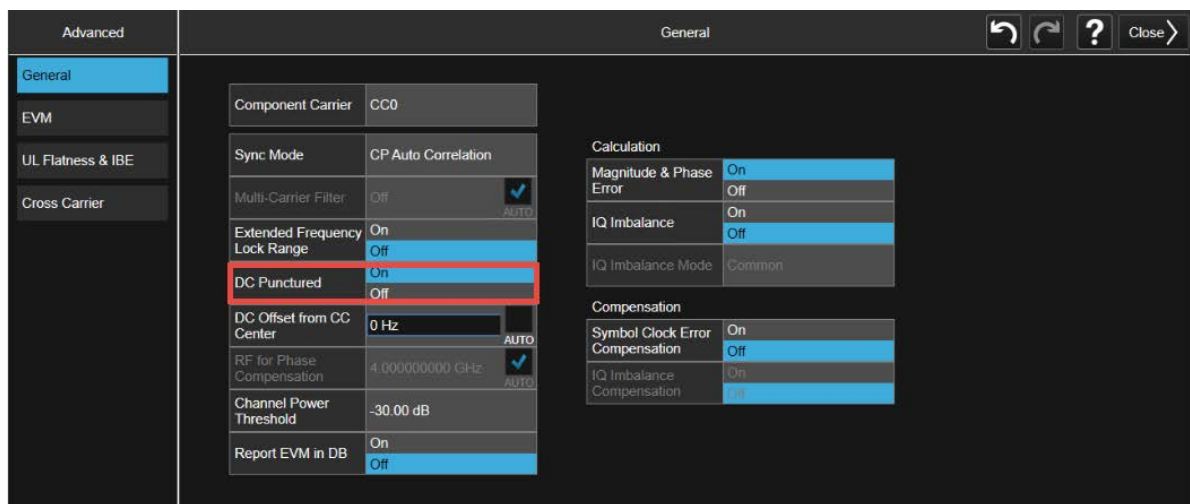
Corrections Instrument Nonlinear Correction

Signal Studio_5G_100 MHz_1CC_FR1.scp

Recall

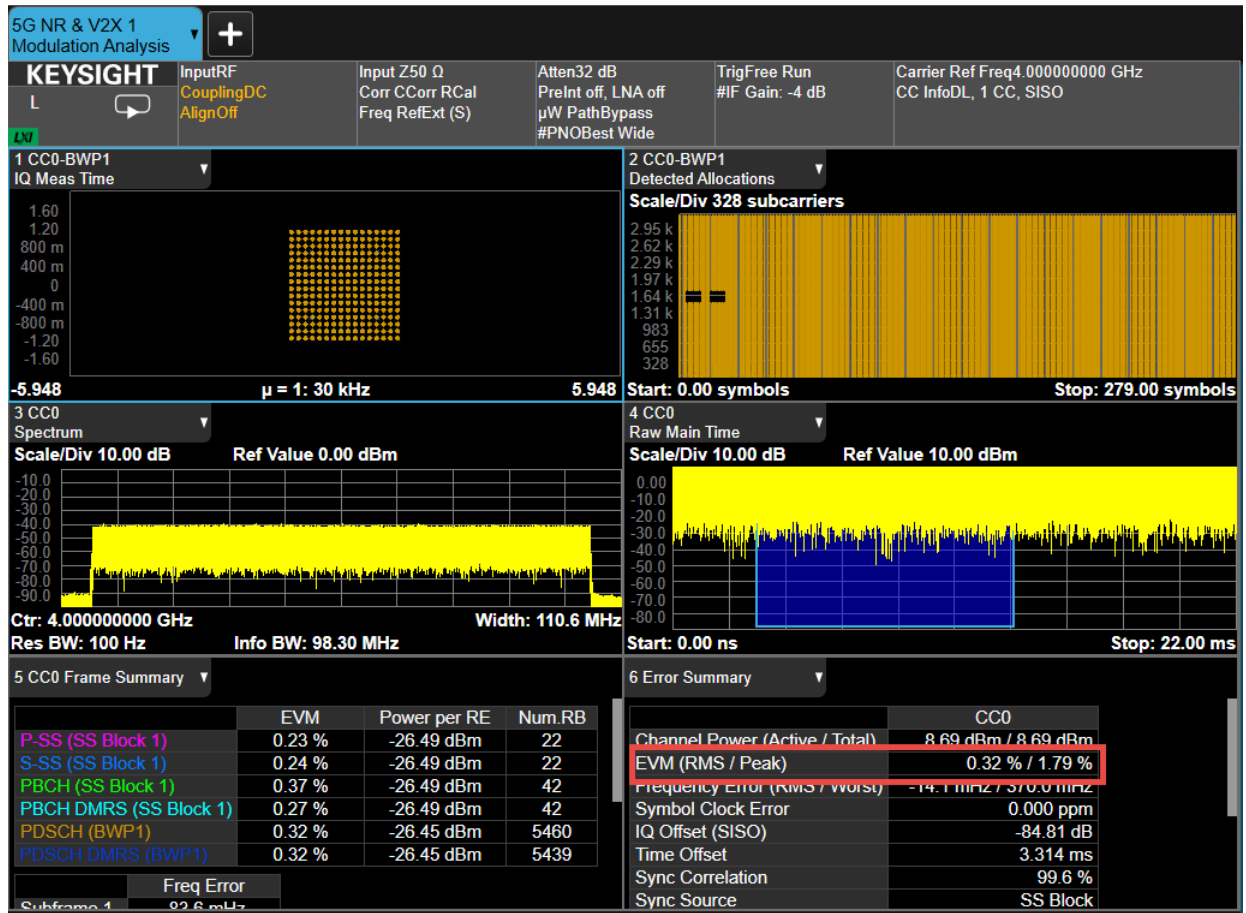


5. The Signal Studio_5G_100 MHz_1CC_FR1.scp file automatically sets the Carrier Frequency to 4 GHz.
6. From the Main menu, select **Meas Setup > Advanced tab > Advanced Demod Setup** and set DC Punctured to **On**, then **Close** the Advanced Demod Setup window.



7. In the Meas Setup window, select the **Settings** tab > **Optimize EVM**.
Record the results. For this example EVM is 0.32% and EVM Peak is 1.79%

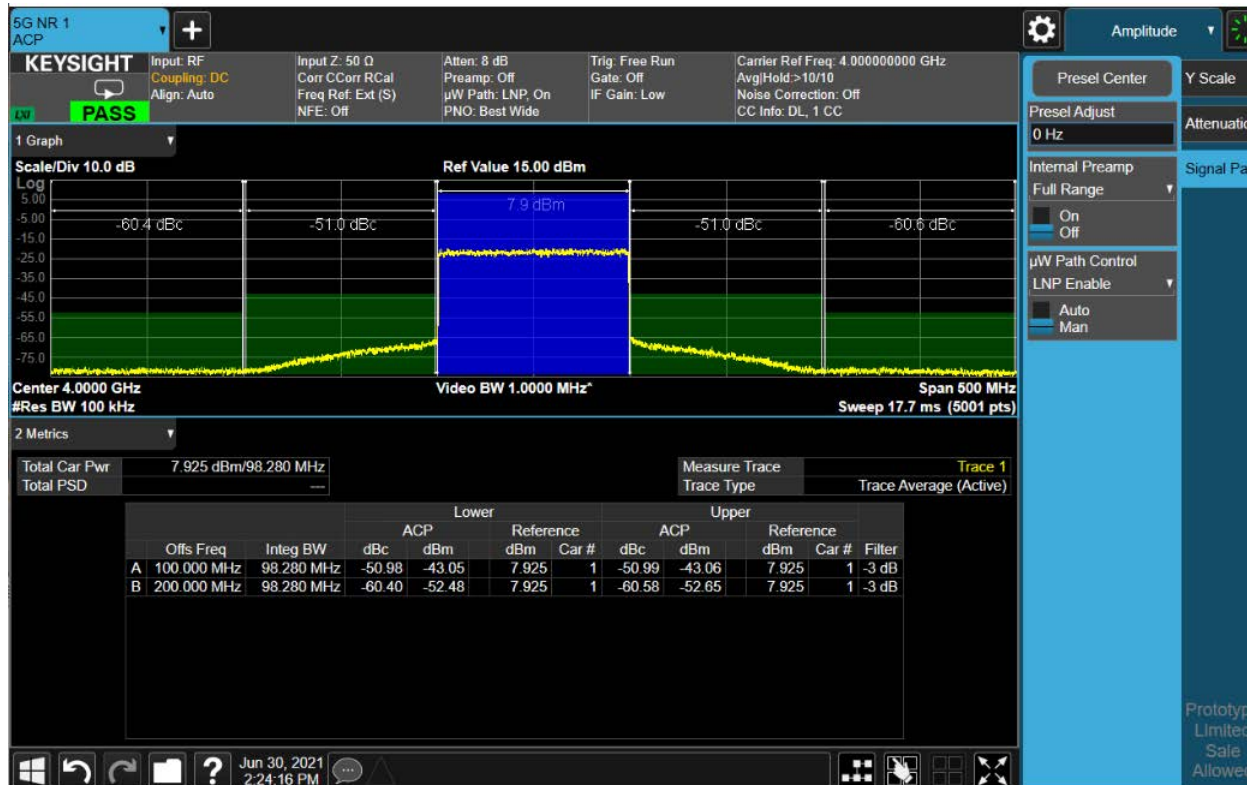
Corrections Instrument Nonlinear Correction



To Measure ACP:

- Select **Mode/Meas > 5GNR & V2X Mode > ACP > OK.**
- Select **Amplitude > Signal Path** tab > and set μ W Path Control to **Low Noise Path Enable.**

Record the results for the Lower and Upper ACP results. For this example -50.9 dBc (lower) and -50.9(upper).

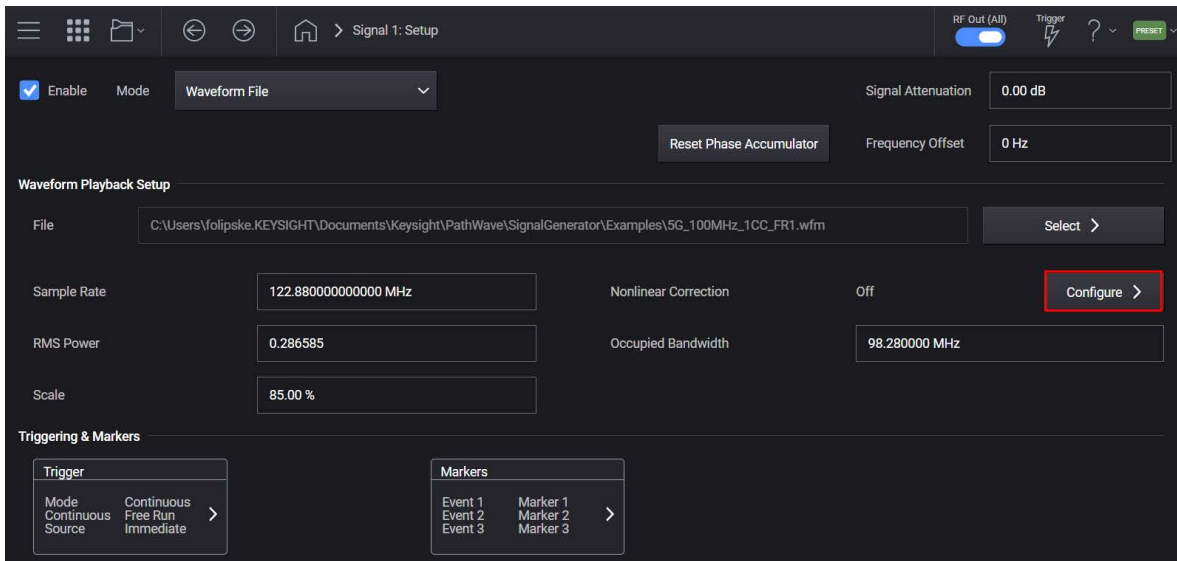


- Select **Mode/Meas > 5GNR & V2X > Modulation Analysis > OK.**

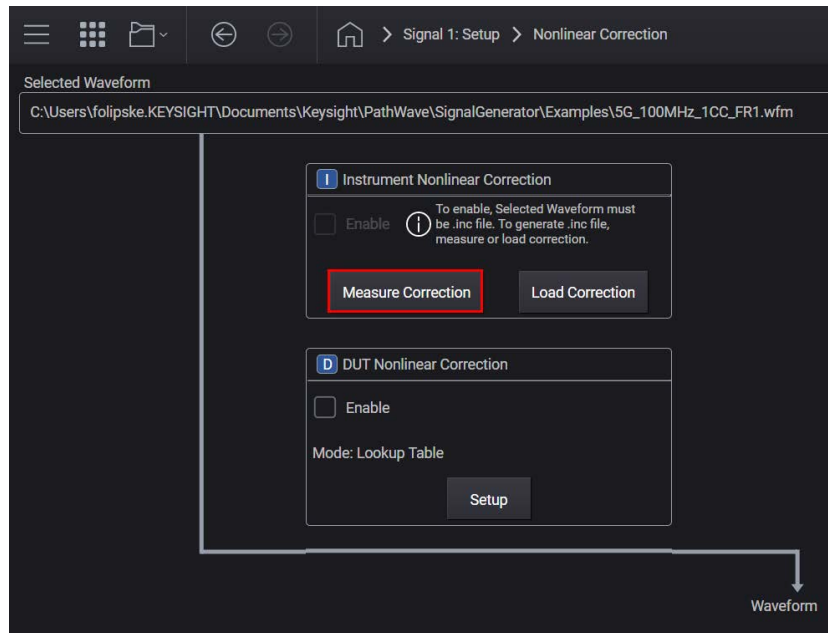
On the VXG:

Corrections Instrument Nonlinear Correction

1. Open the Signal block and select **Configure** to open the Nonlinear Correction Setup.



2. In the Instrument Nonlinear Correction area, select **Measure Correction** to open the Instrument Nonlinear Calibration screen.

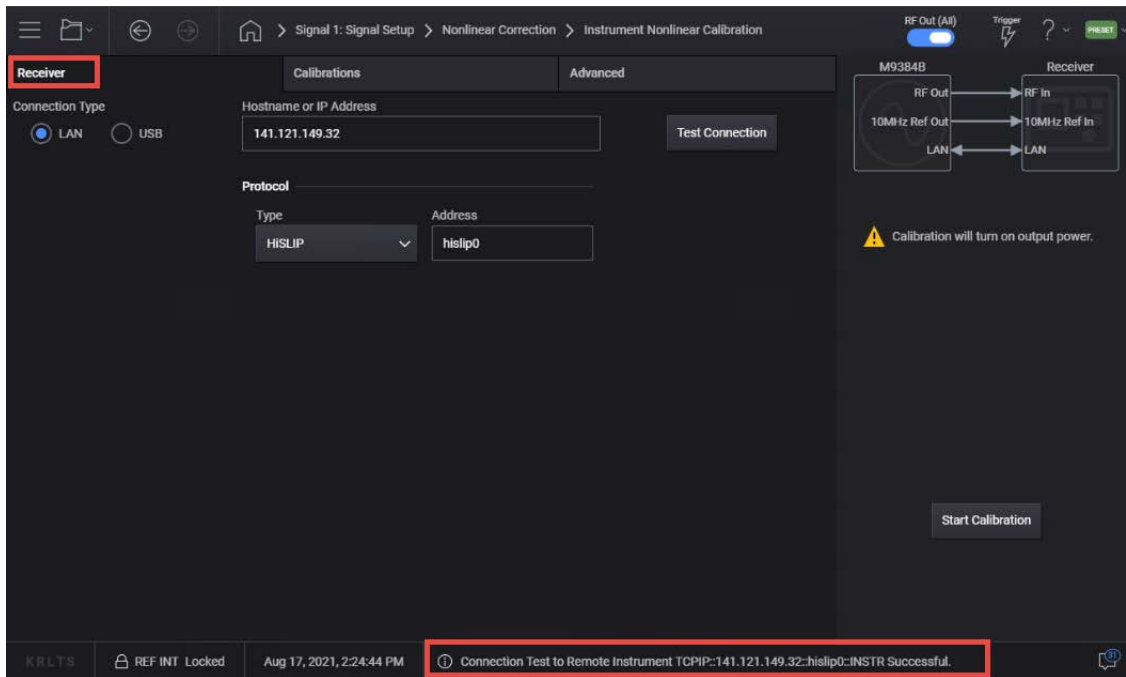


3. Under the Receiver tab (opened by default), enter your connection information and test the connection. For this example, select **LAN** as the Connection Type > Enter the IP address for you signal analyzer (for this example, 141.121.149.32) as the Hostname > **Test Connection**.

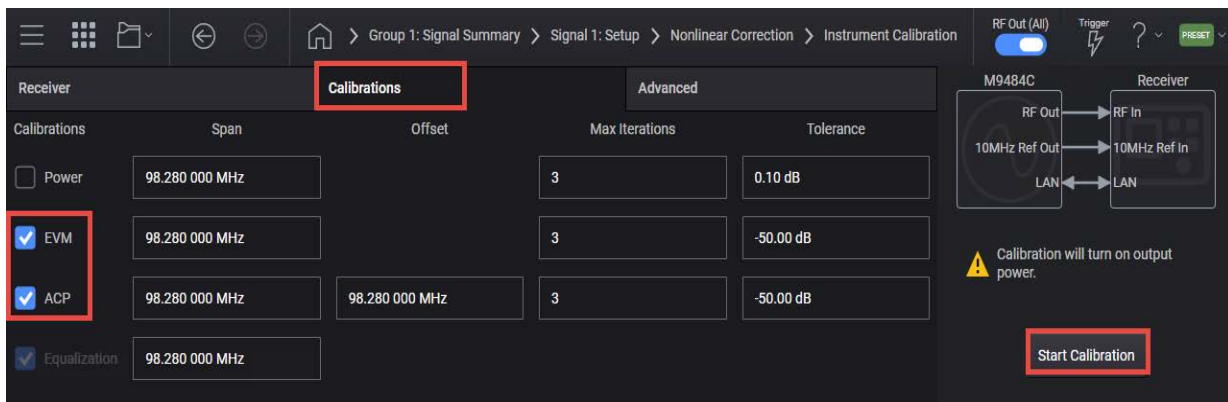
Corrections

Instrument Nonlinear Correction

The Connection status will be displayed in the Notifications area at the bottom of the main window.

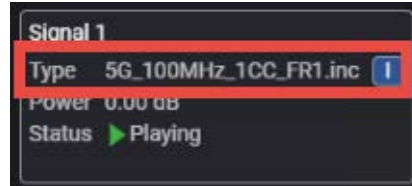


4. Select the **Calibrations** tab and select **EVM** and **ACP** for the Calibrations, then **Start Calibration**.



Corrections Instrument Nonlinear Correction

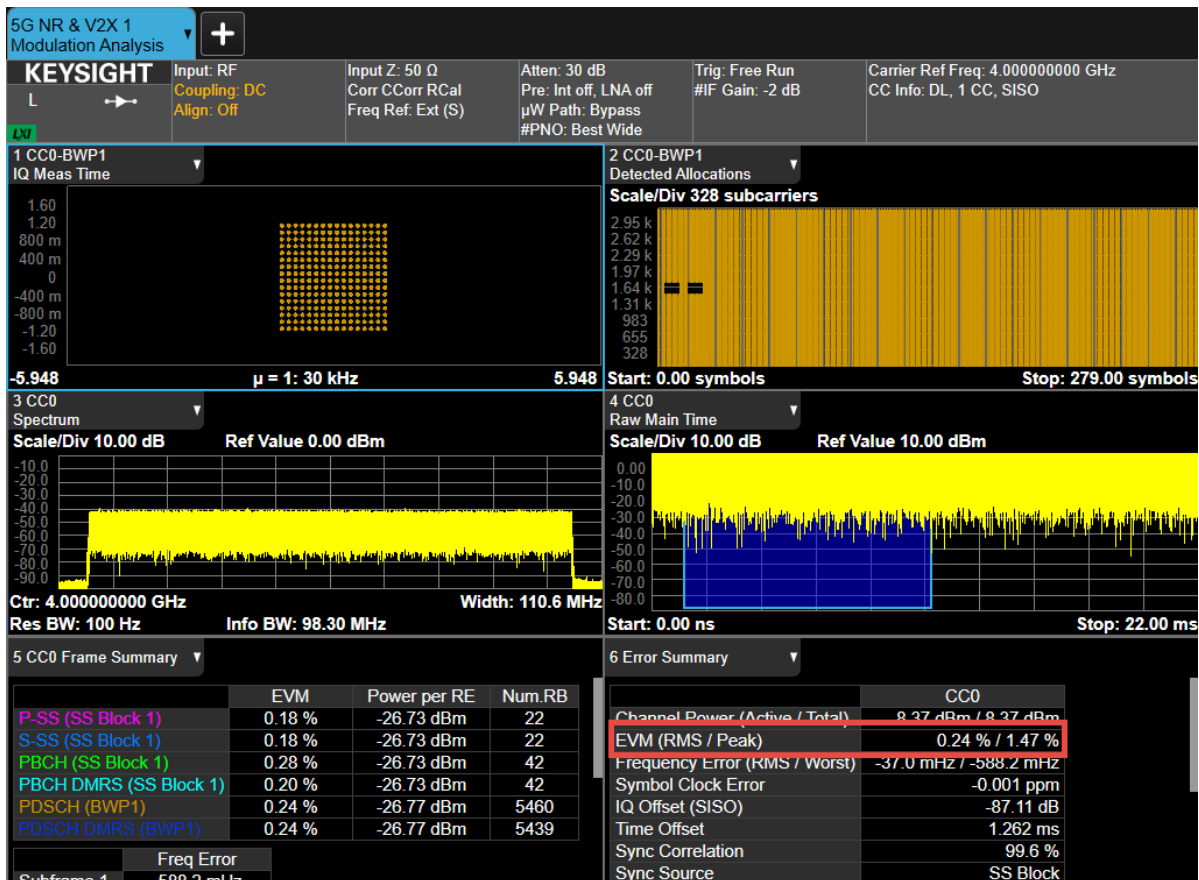
The calibration will take a few minutes to complete. Once done, the INC file will be created and it will automatically be used in place of the .wfm file originally loaded. An "I" will be displayed in the Signal block indicating this status.



On the UXA:

1. Select **Optimize EVM**.

Note the changes to EVM RMS and EVM Peak values. For this example EVM RMS is 0.24% (before 0.32%) and EVM Peak is 1.47% (before 1.79%).

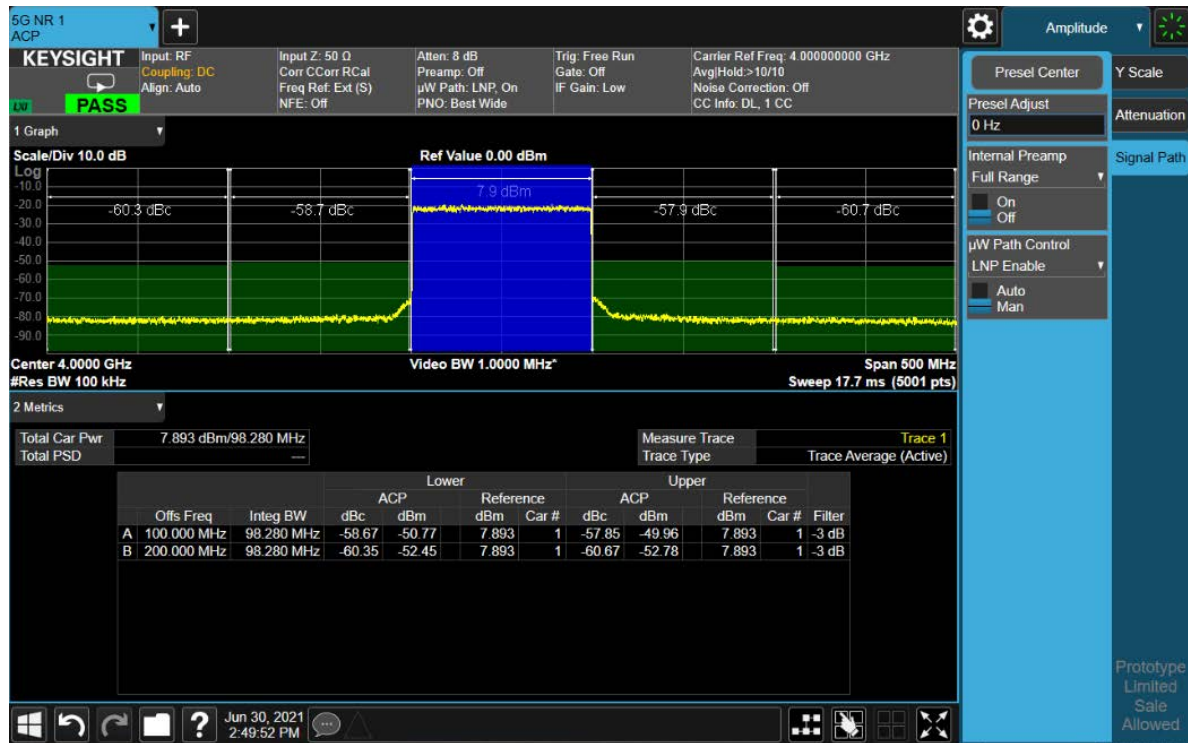


To Measure ACP:

- Select Mode/Meas > **5G NR & V2X Mode** > **ACP** > **OK**.
- Select Amplitude > **Signal Path** tab > and set μ W Path Control to **Low Noise Path Enable**.

Corrections Instrument Nonlinear Correction

Note the changes to the Lower and Upper ACP values. For this example Lower -58.67 dBc (before -50.9 dBc) and Upper -57.85 dBc (before -50.9).

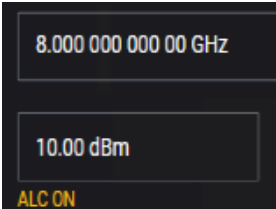


Setting Up an INC 8CC 28 GHz, 10 dBm EVM Measurement

On the VXG:

In order to compare before and after correction results, we will start by making an EVM measurement without applying corrections.

1. Select **Preset > Preset** to set the instrument to a know state.
2. In the Output area, set Frequency to **28 GHz** and Power to **10 dBm**.



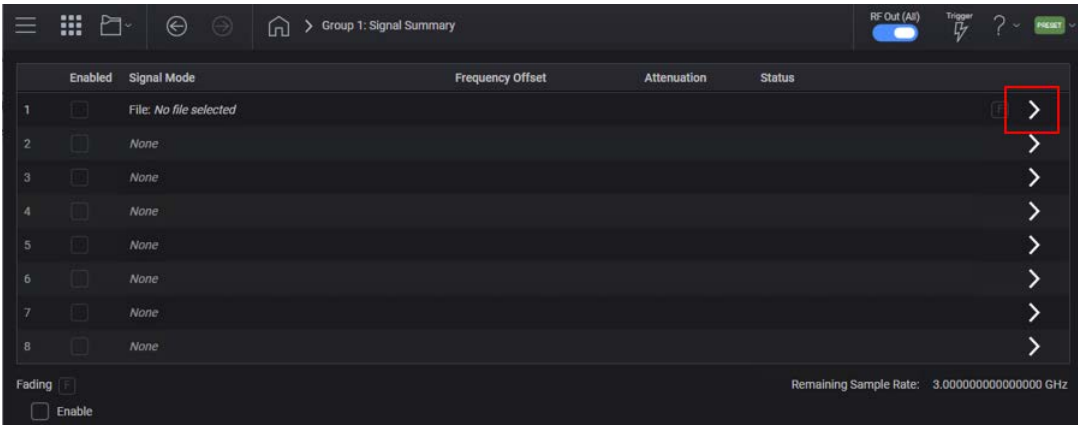
3. Select the **Group 1: Signals** block to open.



4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.

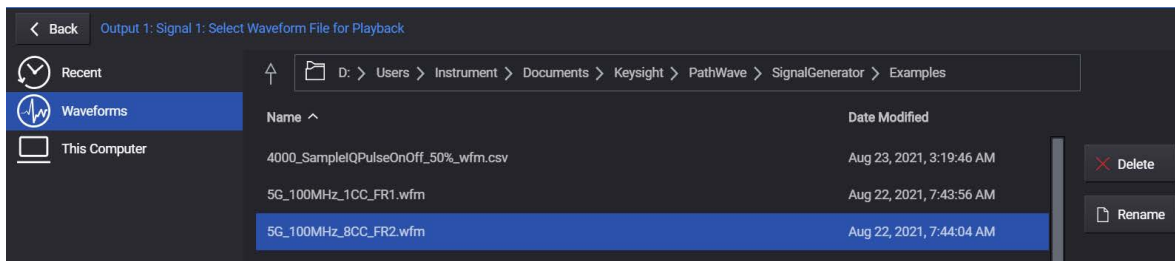


5. In the Vector Modulation Setup, set Mode to **Waveform File**.
6. In the Waveform Playback Setup area, use File **Select** to navigate to:

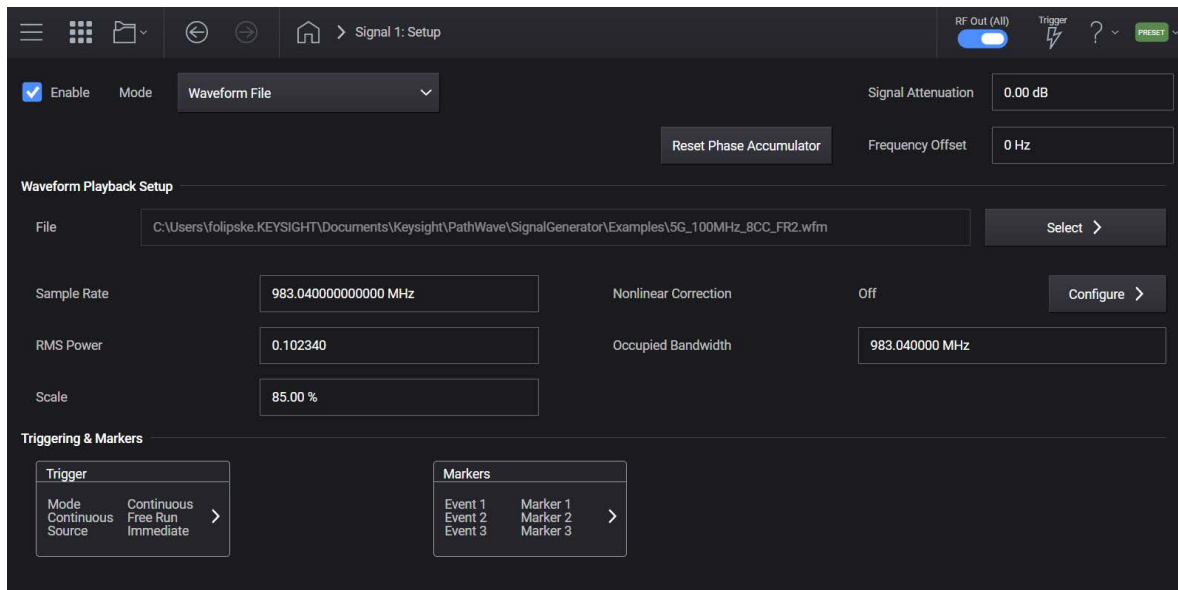
D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

5G_100MHz_8cc_FR2.wfm

then **Select**.



7. Select **Enable** Vector Modulation Signal and close the Signal block.



8. Set RF Out to On.

On the UXA:

1. From the X-Series Signal Analyzer Menu Panel (on the top right of the display), select **Mode/Meas > 5GNR & V2X Mode > 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 Spectrum Analyzer 5GNR mode to a known state.
3. From the X-Series Signal Analyzer Menu Panel (on the top right of the display), select **Mode/Meas > 5GNR & V2X Mode > Modulation Analysis Measurement > OK**.

NOTE

All example waveforms and setup files are located on the VXG at:

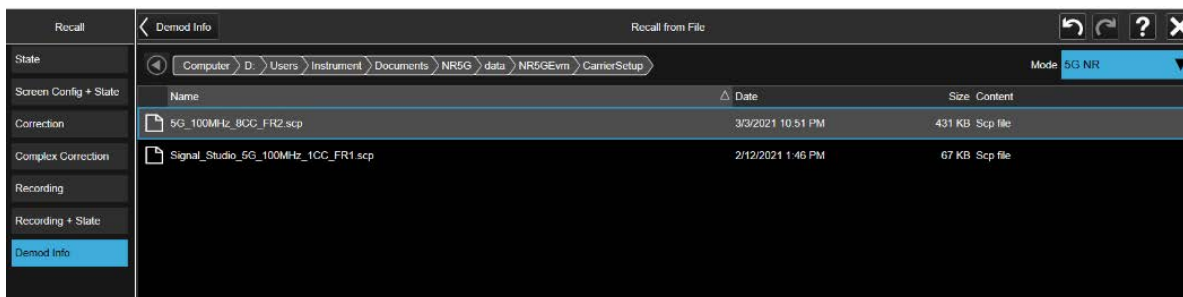
D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

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

4. Select **Recall** (If accessing the X-Series Signal Analyzer remotely, select the Folder icon at the bottom of the display) **Demod Info > Set Data Type to CC Setup > Recall From >**

5G_100 MHz_8CC_FR2.scp

Recall



5. The .scp file automatically sets the Carrier Frequency to 28 GHz.
6. Select **Meas Setup > Advanced tab > Advanced Demod Setup** and set DC Punctured to **On**, then **Close** the Advanced Demod Setup window.
7. Select the **Sweep > Single Sweep**.
8. Select **Meas Setup > Settings tab > Optimize EVM**.

It will take a couple of minutes for the UXA to measure all 8 carriers.
Record the results.

Corrections Instrument Nonlinear Correction

For this example CC0 EVM RMS is 6.21%, EVM Peak is 27.33% and for CC7 EVM RMS is 4.51% and EVM Peak is 15.75%



To Measure ACP:

- Select Mode/Meas > 5G NR & V2X Mode > ACP > OK.
- Select Amplitude > Signal Path tab > and set μW Path Control to LNP (Low Noise Path) Enable.
- Select Sweep > Restart to take a new sweep.

Corrections Instrument Nonlinear Correction

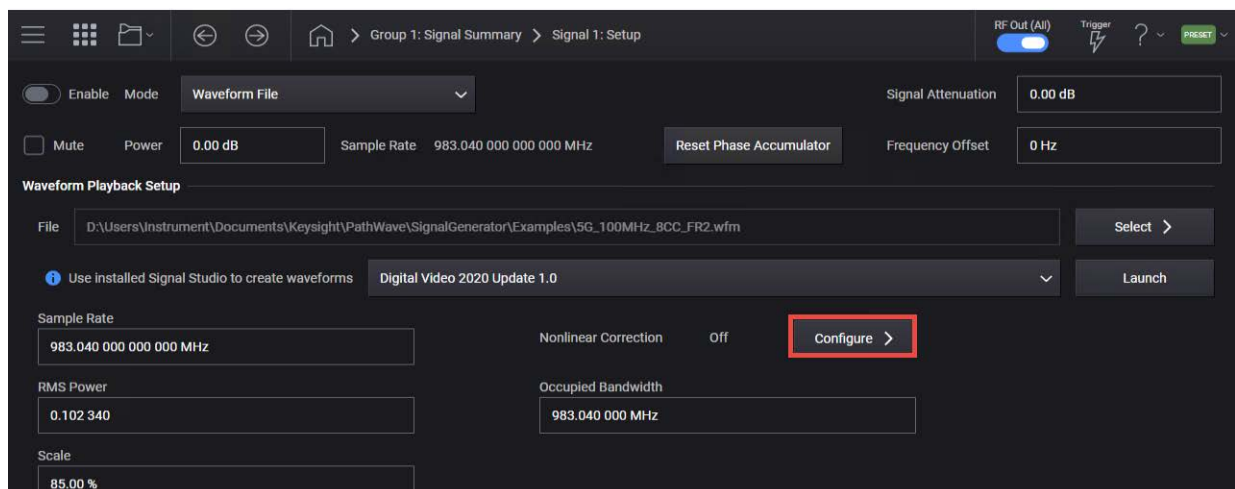
Note the values of the Lower and Upper ACP. For this example Lower, at 100 MHz offset is -26.7 dBc and Upper -27.06 dBc.



d. Select Mode/Meas > 5GNR & V2X > Modulation Analysis > OK.

On the VXG:

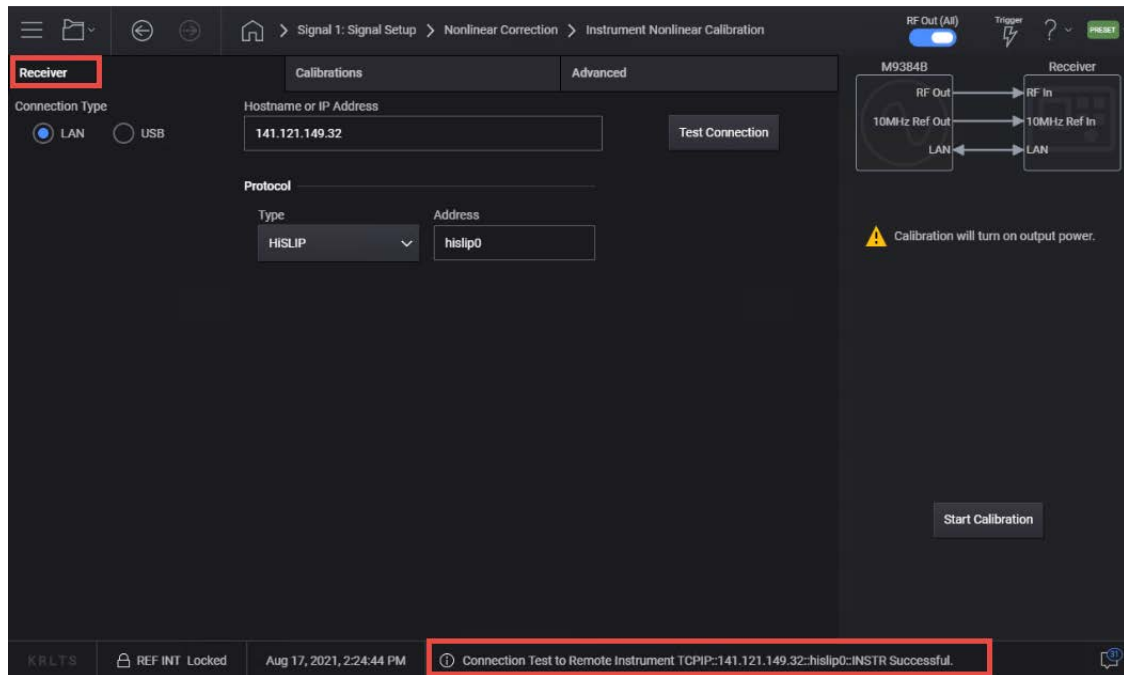
1. In the Signal block and select **Configure** to open the Nonlinear Correction Setup.



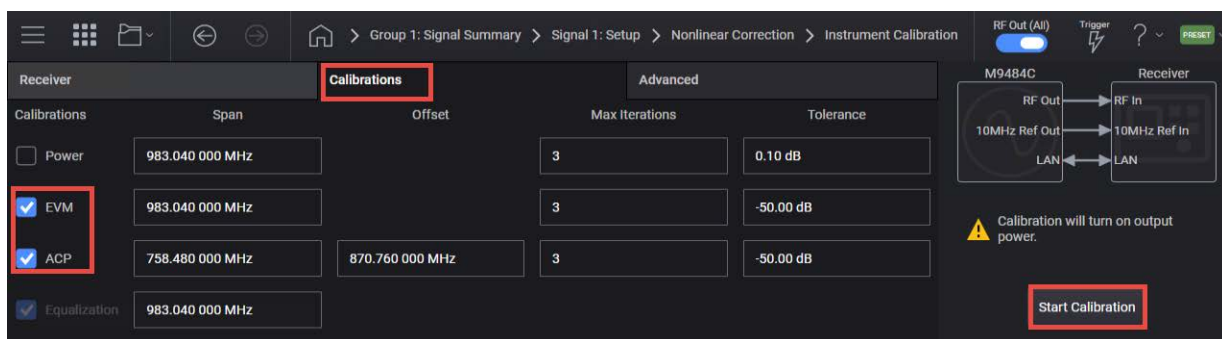
2. In the Instrument Nonlinear Correction area, select **Measure Correction** to open the Instrument Nonlinear Calibration screen.

3. Under the Receiver tab (opened by default), enter your connection information and test the connection. For this example, select **LAN** as the Connection Type > Enter the IP address for your signal analyzer (for this example, 141.121.149.32) as the Hostname > **Test Connection**.

The Connection status will be displayed in the Notifications area at the bottom of the main window.



4. Select the **Calibrations** tab and select **EVM** and **ACP** for the Calibrations, then **Start Calibration**.



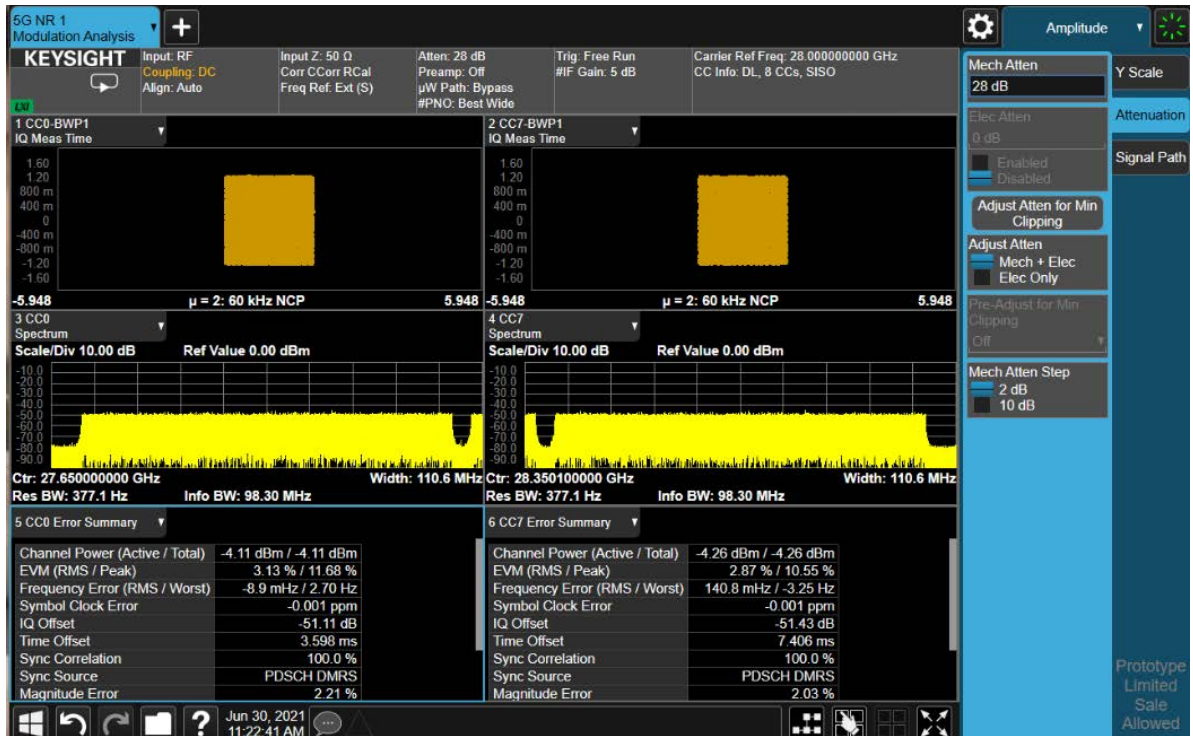
On the UXA:

1. Select the **Sweep > Restart**.
2. Select **Optimize EVM**.

Note the changes to EVM RMS and EVM Peak values.

Corrections Instrument Nonlinear Correction

For this example CC0 EVM RMS went from 6.21% to 3.13%, EVM Peak went from 27.33% to 11.68% and for CC7 EVM RMS went from 4.51% to 2.87% and EVM Peak went from 15.75% to 10.55%.



To Measure ACP:

- Select Mode/Meas > 5GNR & V2X Mode > ACP > OK.
- Select Amplitude > Signal Path tab > and set μW Path Control to LNP (Low Noise Path) Enable.
- Select Sweep > Restart to take a new sweep.

Corrections
Instrument Nonlinear Correction

Note the changes to the Lower and Upper ACP values. For this example Lower, at 100 MHz offset is -32.27 (before -26.7 dBc) and Upper -31.15 (before -27.06 dBc).



3 Advanced Measurements

- “Channel Bonding” on page 88
 - “Generating a Multi-Carrier DVB-S2X Signal for Satellite TV” on page 89
 - “Generating a Wide Band QPSK” on page 103
 - “Generating a 5G NR Waveform” on page 113
- “Setting Up 8 Virtual Signal Generators” on page 124
- “Using the VSA Flex Frame to Create a DVB-S2X Signal” on page 135
- “Creating & Analyzing a 5G NR DL 2x2 MIMO Measurement Using Two UXAs” on page 173

Channel Bonding

Data requirements are pushing bandwidths and modulation complexity across many global industries.

- Global data consumption is growing
- IoT drives new data consumption
- Autonomous vehicles require data links
- Satellite networks need to provide 5G backbone in 5G Non-Terrestrial Networks (NTN)
- New applications generate new sources of data intelligence

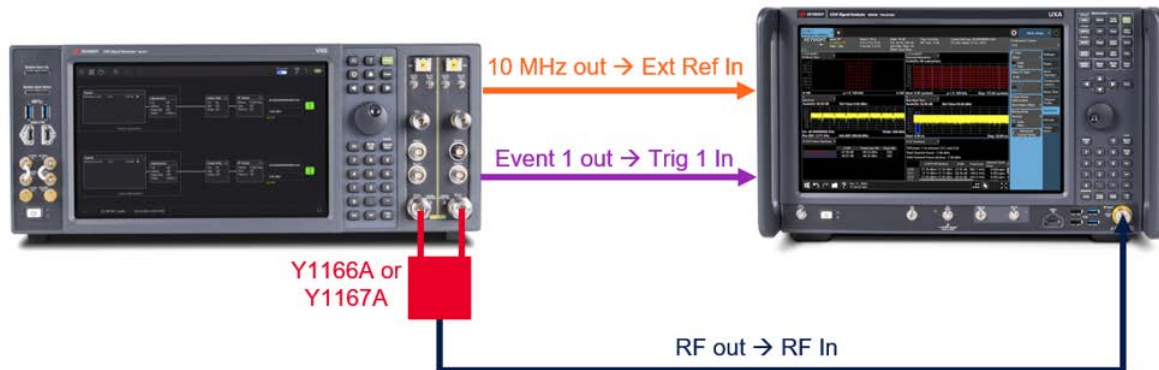
The following three examples are showing

- **“Generating a Multi-Carrier DVB-S2X Signal for Satellite TV” on page 89**
- **“Generating a Wide Band QPSK” on page 103**
- **“Generating a 5G NR Waveform” on page 113**

For this measurement example, we are using the following equipment:

- M9484C with options
 - Two channels (M9484C-001 and 002)
 - RF bandwidth of 2.5 GHz per channel (M9484C-R25)
 - Channel bonding, 5 GHz (M9484C-CB5 and M9484C-PCH)
 - PathWave Signal Generation for Custom Modulation (N7608APPC)
 - PathWave Automatic Channel Response Correction and S-parameter De-embedding (N7653APPC)
- Accessories
 - Channel Bonding Combiner kit (Y1166A or Y1167A, frequency dependent)
- N9042B UXA
 - Analysis bandwidth of 4 GHz (N9042B-R40)
 - 89600 PathWave Vector Signal Analysis software, VSA

Figure 3-1 Channel Bonding Setup

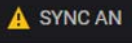


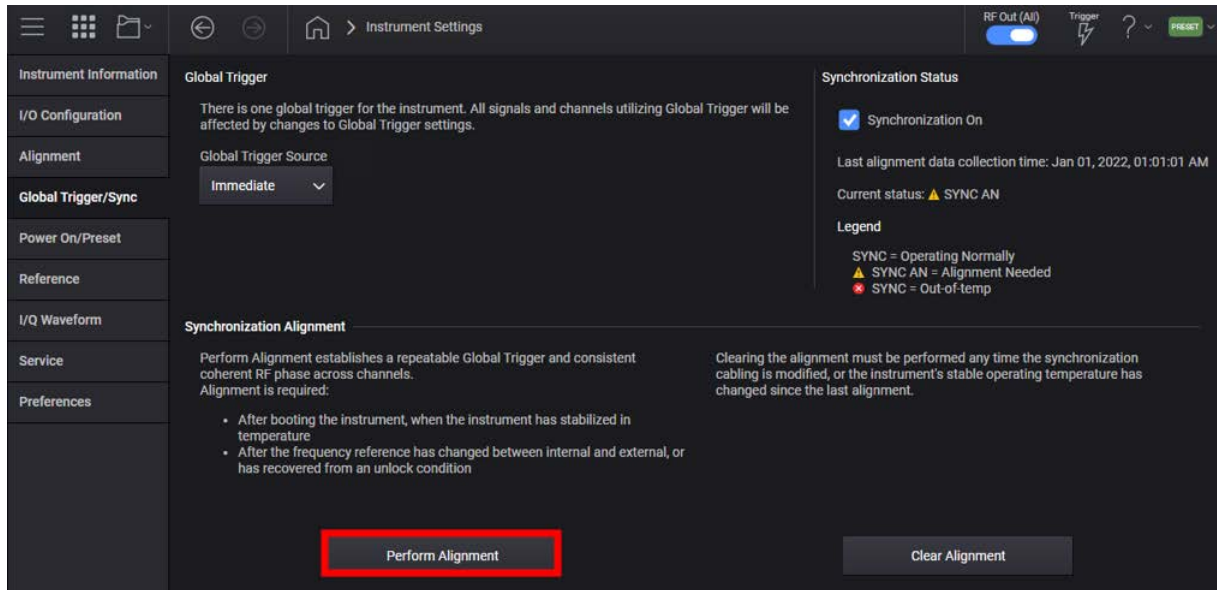
Generating a Multi-Carrier DVB-S2X Signal for Satellite TV

DVB-S2X is a digital satellite television broadcast standard. Channel bonding can be used for UHDTV services where statistical multiplexing is used to allow many television channels can use the same bandwidth. Other applications include Direct to Home (DTH), Digital Satellite News Gathering (DSNG) and professional VSAT.

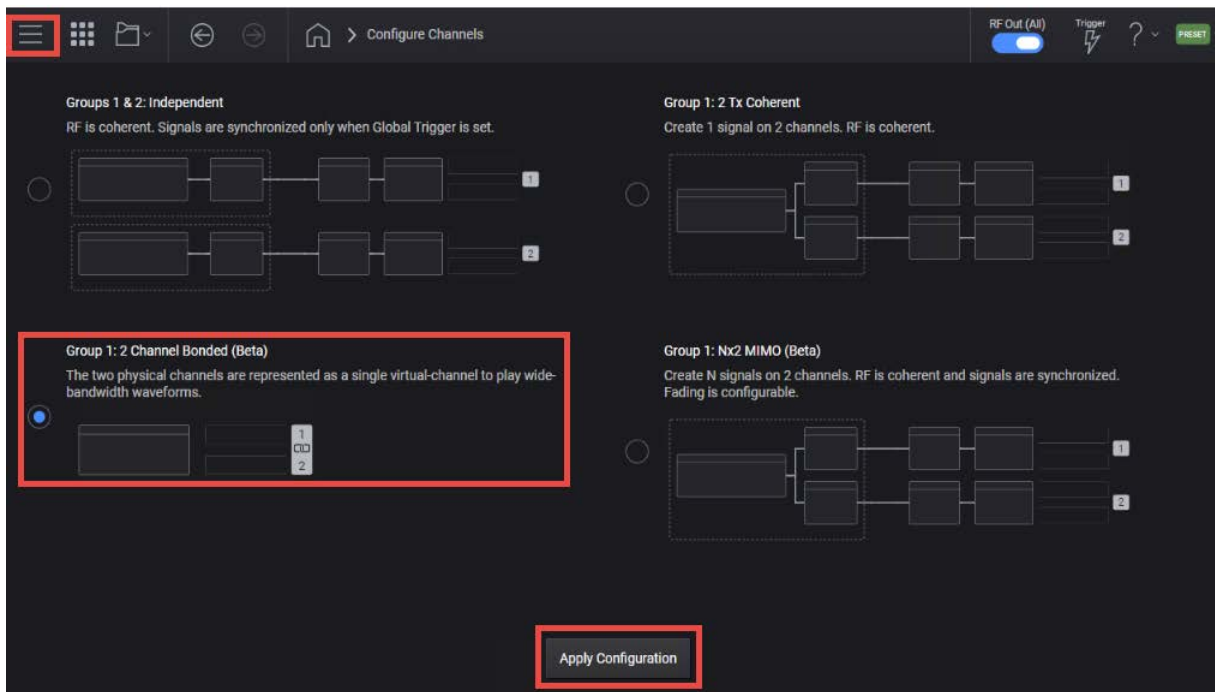
On the VXG:

1. Connect the equipment as shown above.
2. Select **Preset > Preset** to set the VXG to a known state.

If a Synchronization Alignment is required, indicated by  in the bottom left corner, tap or click the warning message and choose **Perform Alignment** before proceeding.

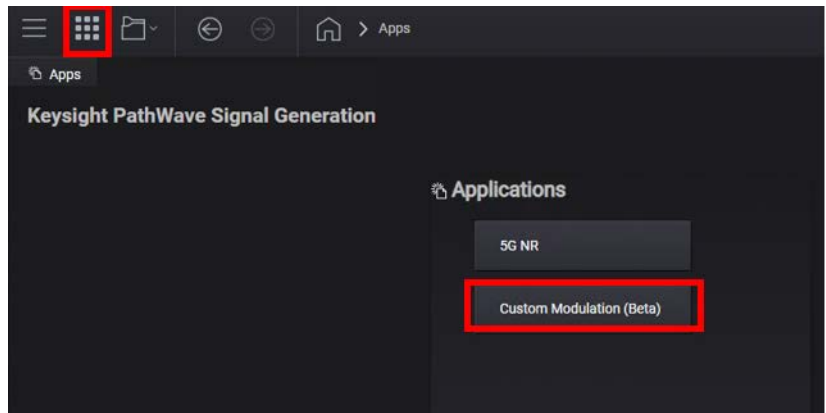


3. Select the System menu (triple bar tab at the top left of the window), and then select **Configure Channels** > **Group 1:2 Channel Bonded** > **Apply Configuration**.



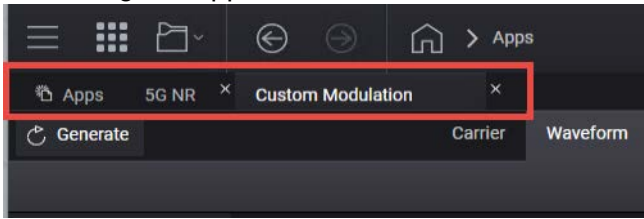
4. Set the Center Frequency to **12 GHz** and Power to **0 dBm**.

5. Select the **Apps** block to open, then select **Custom Modulation**.

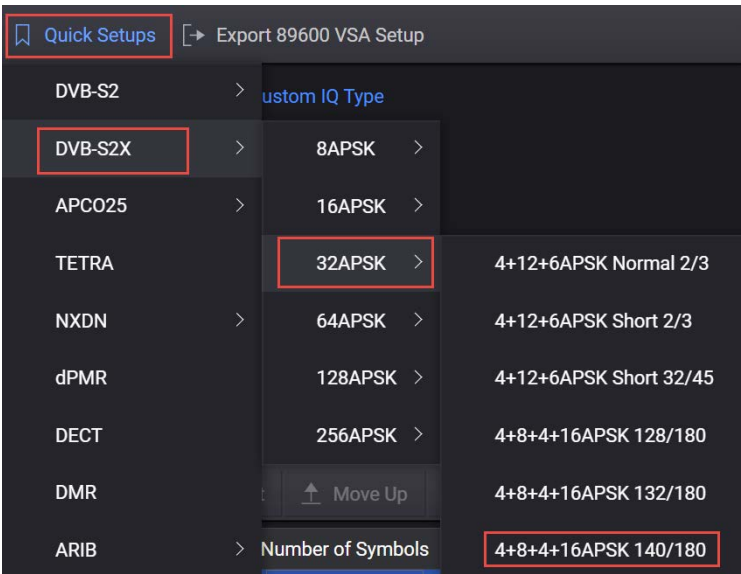


NOTE

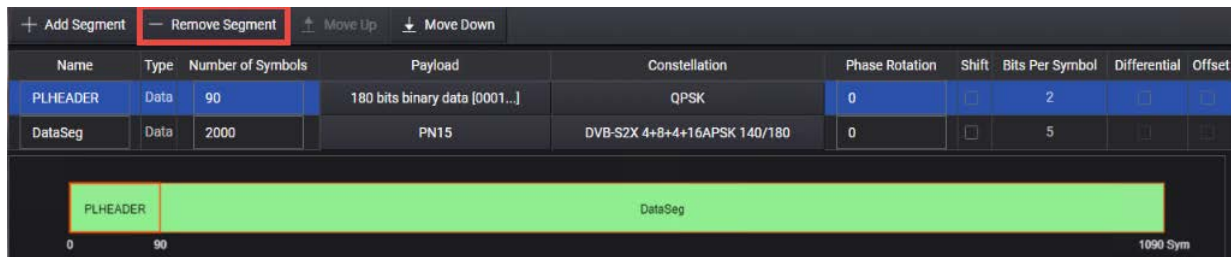
If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



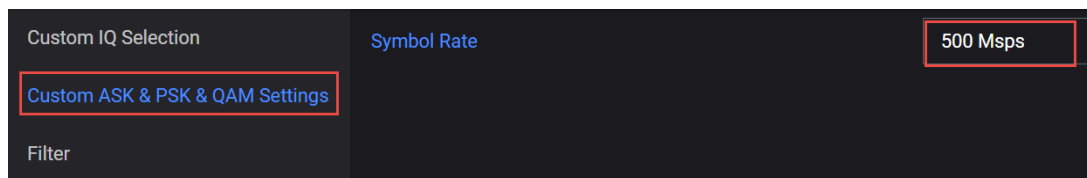
6. In the Custom Modulation setup, select the **Carrier** tab > **Quick Setups** > **DVB-S2X** > **32APSK** > **4+8+4+16APSK 140/180**.



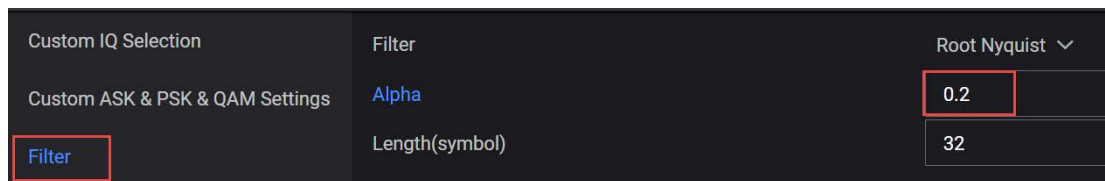
7. From the bottom pane, select **Remove Segment** to remove the Header. This will simplify the demonstration.



8. From the left pane, select **Custom ASK & PSK & QAM Settings** and set the Symbol Rate to **500 Msps** per channel.

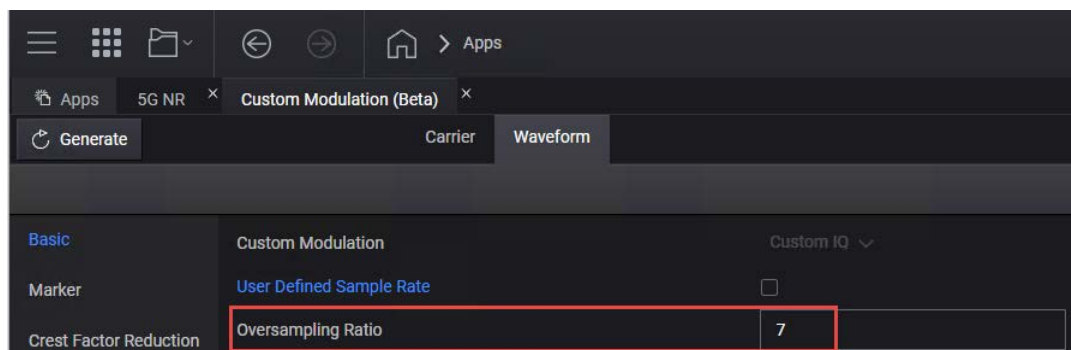


9. Select **Filter** > Alpha to **0.2**.



10. Select the **Waveform** tab > **Basic** > Oversampling Ratio to **7 x** multiplier which provides a span of 3.5 GHz.

Each channel is 2.56 GHz for a combined sample rate of 5.12 GHz. This could be set by entering 5.12 GHz as the User Defined Sample Rate however; for Multi-carrier it is best to set the Oversampling Ratio.



11. From the left pane, select **Multi Carrier** and select **Multicarrier Enabled**.

12. Open the **Frequency Offsets** setup screen. For Carrier Index 0, set the Frequency Offset to **-1200 MHz**, then select **Add Rows**.

Frequency Offsets

+ Add — Remove ✕ Clear + Add Rows

Carrier Index	Frequency Offset (MHz)	Power Offset (dB)
0	-1200	0

13. Enter the 1st Frequency Offset of **-600 MHz**, # of Carriers **4**, and Carrier Spacing **600 MHz**. Select **Add**.

Frequency Offsets

+ Add — Remove ✕ Clear + Add Rows

1st Frequency Offset: -600 MHz

of Carriers: 4

Carrier Spacing: 600 MHz

Add

Carrier Index	Frequency Offset (MHz)	Power Offset (dB)
0	-1200	0

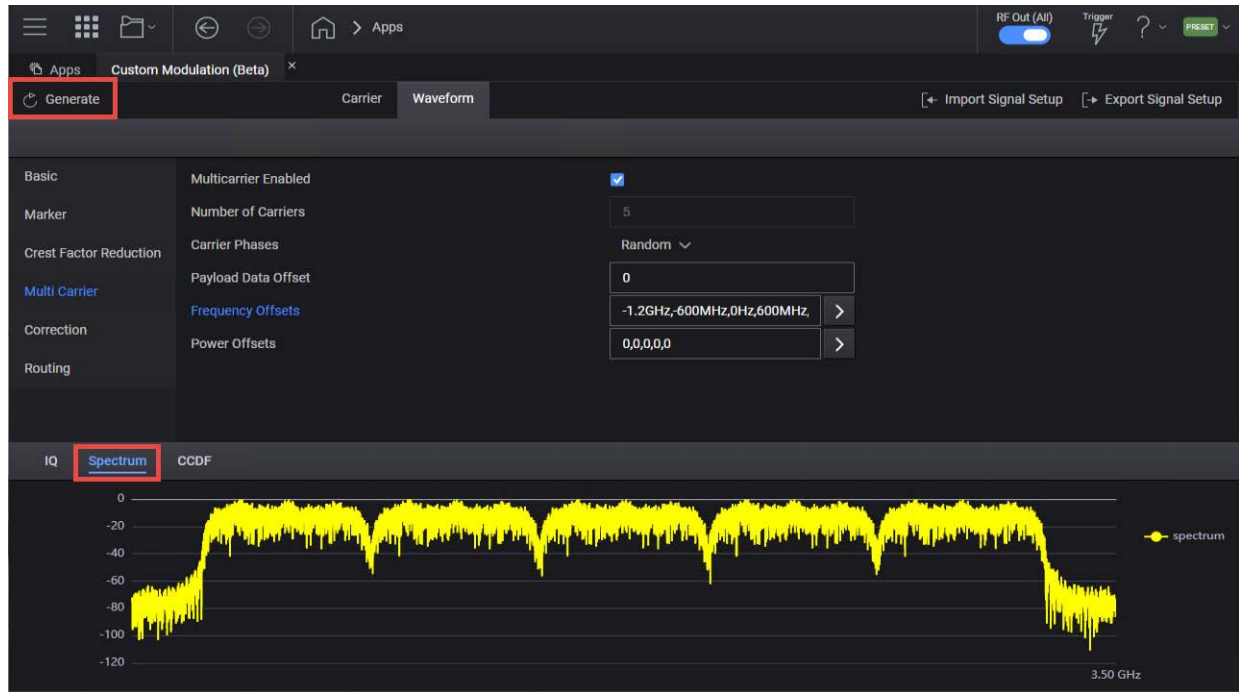
All five carriers will be setup. Select **OK** to close the Frequency Offsets dialog.

Frequency Offsets

+ Add — Remove ✕ Clear + Add Rows

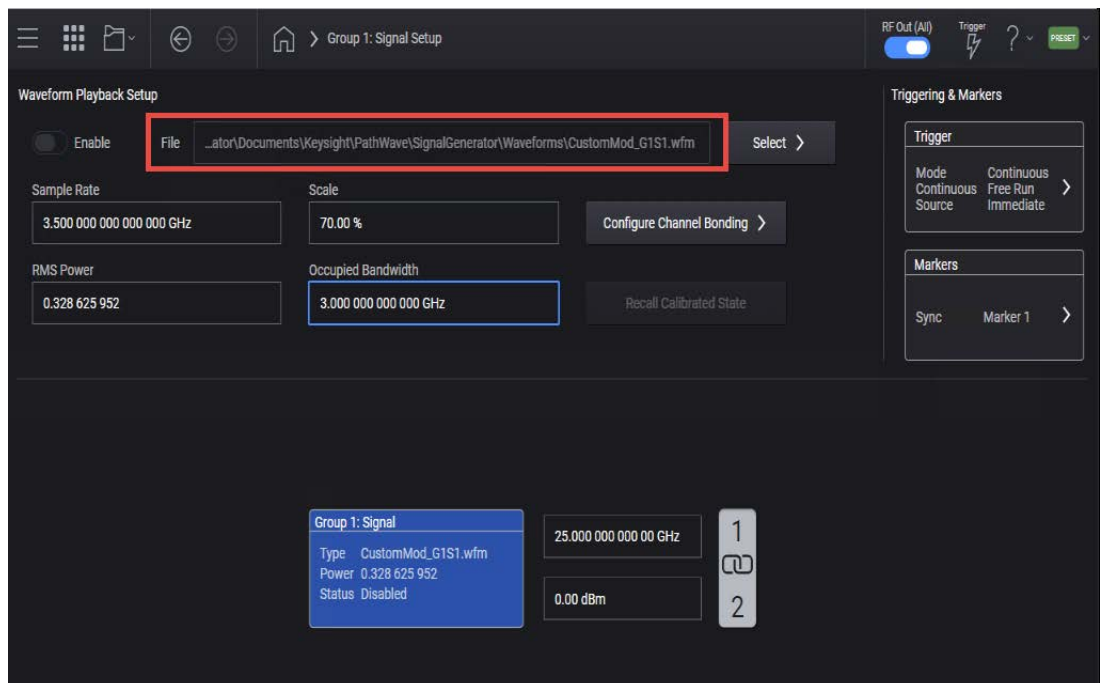
Carrier Index	Frequency Offset (MHz)	Power Offset (dB)
0	-1200	0
1	-600	0
2	0	0
3	600	0
4	1200	0

14. **Generate** the waveform and select the **Spectrum** tab from the bottom pane to ensure the resulting waveform is correct.

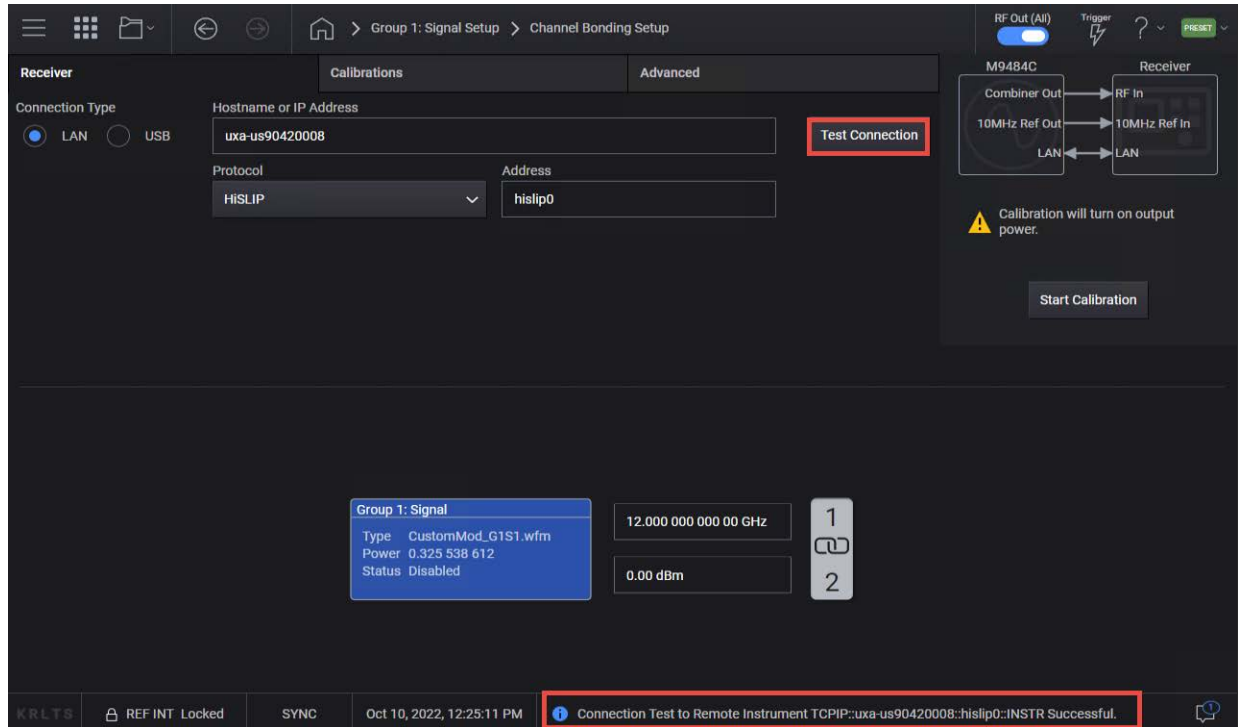


15. Select the **Home** icon to return to the main window and then select the **Signal Block** to open.

16. In the Signal Setup dialog box, notice that new custom modulation file is already selected (`CustomMod_G1S1.wfm`). Set the Occupied Bandwidth to **3 GHz**.



17. Select **Configure Channel Bonding** and configure the Hostname or IP address for the UXA, then **Test Connection**. Ensure that you have successfully connected to the UXA, a message will be displayed in the Status area at the bottom of the display.

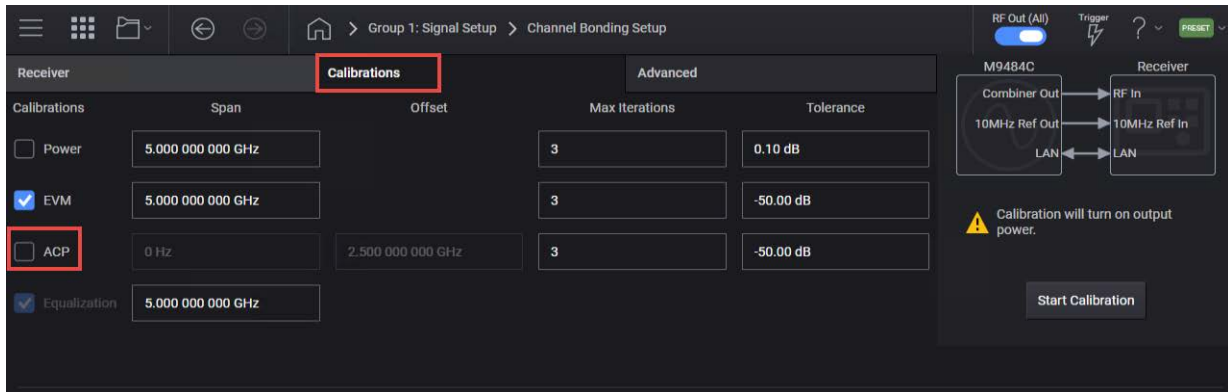


18. Select the **Calibrations** tab and clear the **ACP** calibration.

In some cases it is not possible (or necessary) to improve the ACP of the bonded waveform. In these cases, it is best to disable it.

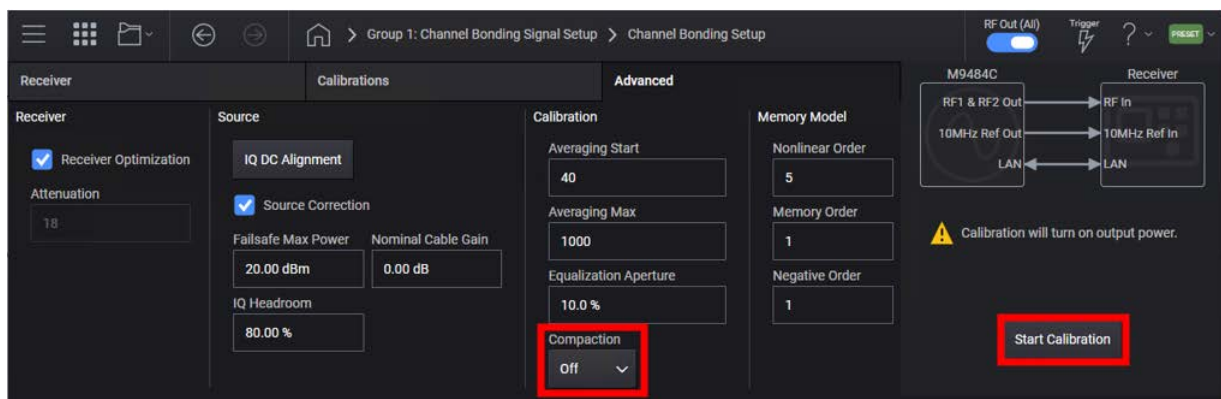
- If the ACP cannot be improved, in some cases, the highest fidelity bonded waveform will result from Bonding with ACP disabled.
- ACP increases the time it takes to perform Bonding, and if the receiver does not have sufficient analysis bandwidth to cover the ACP regions + modulated bandwidth of the waveform, then frequency-stitching will be performed and this will further increase the Bonding time.
- With ACP enabled, the resulting signal will typically have significantly increased bandwidth, sample rate, and number of samples (as compared to a Bonded signal with ACP disabled).

- Note that the available ACP region bandwidth is limited by the bandwidth of the source, so if the available source bonded-bandwidth is 5 GHz, and the bonded waveform is 5 GHz, then there is no available BW for performing an ACP calibration.



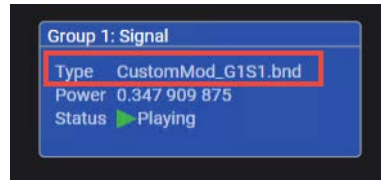
19. Select the **Advanced tab and set **Compaction Off**, then **Start Calibration**.**

When the waveform length is short enough, compaction is not needed. However, for 5G signals (which tend to be relatively long and have a lot of IQ samples), the calibration time can be long (without compaction). So for signals with lots of IQ samples, the suggestion is to use compaction as this will reduce the calibration time. The calibration takes a few minutes to complete. However, the highest fidelity bonded waveform may result without compaction. How much compaction to use can be optimized (none, automatic, or a specified compaction level) by experimenting with the different settings.



The calibration takes a few minutes to complete.

Notice that the CustomMod_G1S1.bnd waveform is now playing.

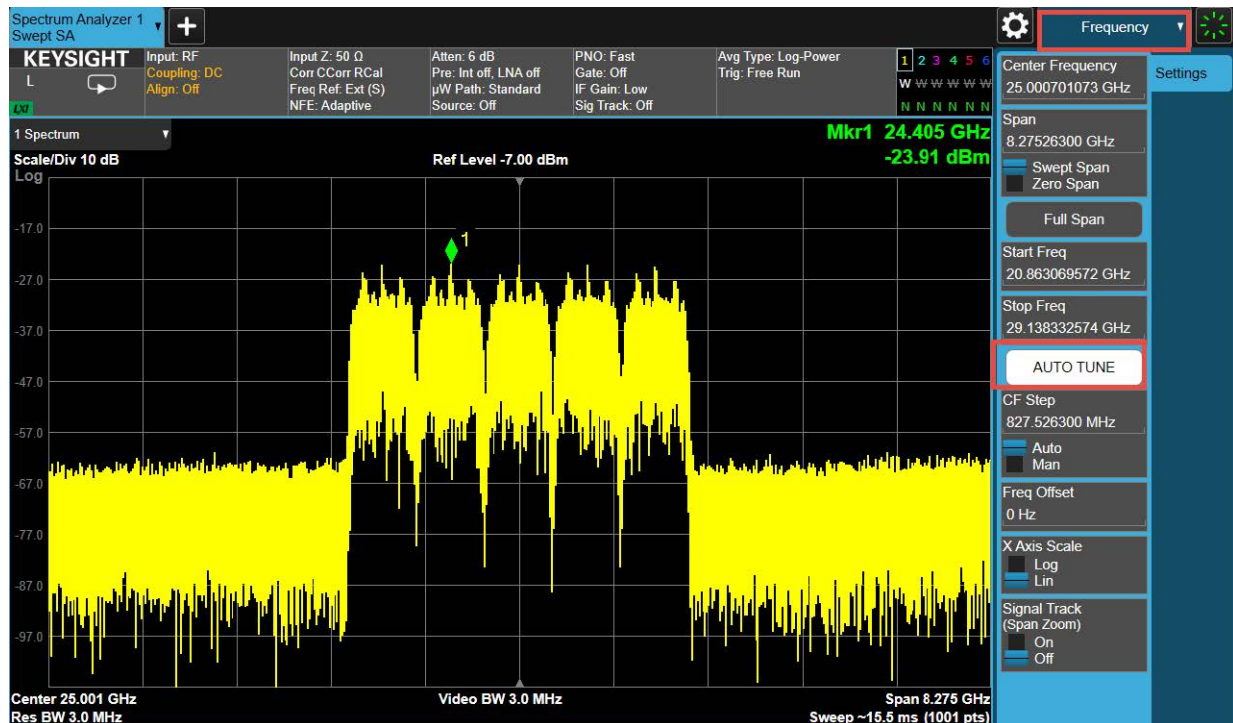


On the Signal Analyzer:

1. Select **Frequency** > **Auto Tune** to observe the spectrum.

NOTE

Ensure that signal analyzer is set to Spectrum Analyzer mode > Swept SA Measurement > View Normal.



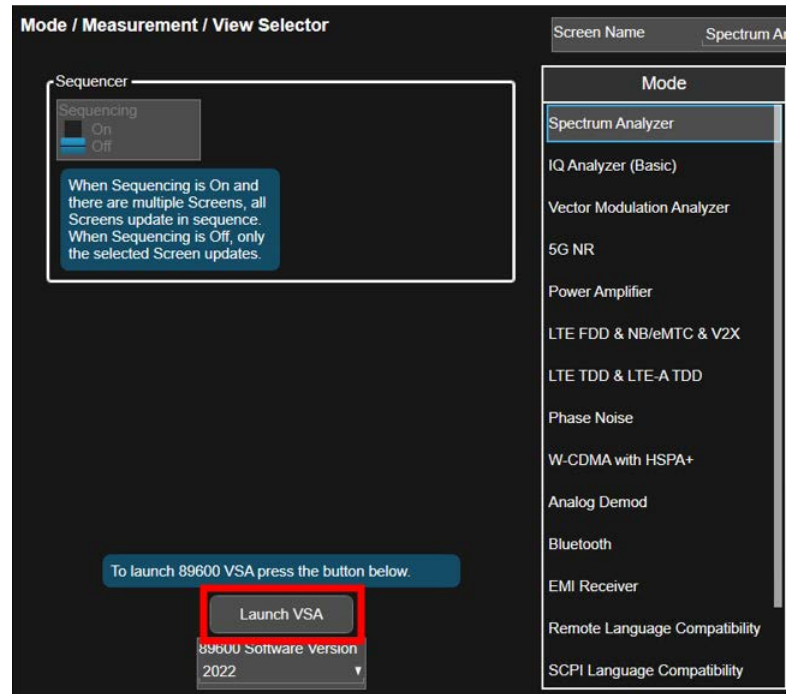
2. Open the VSA software by selecting **Mode Meas** > **Launch VSA**.

NOTE

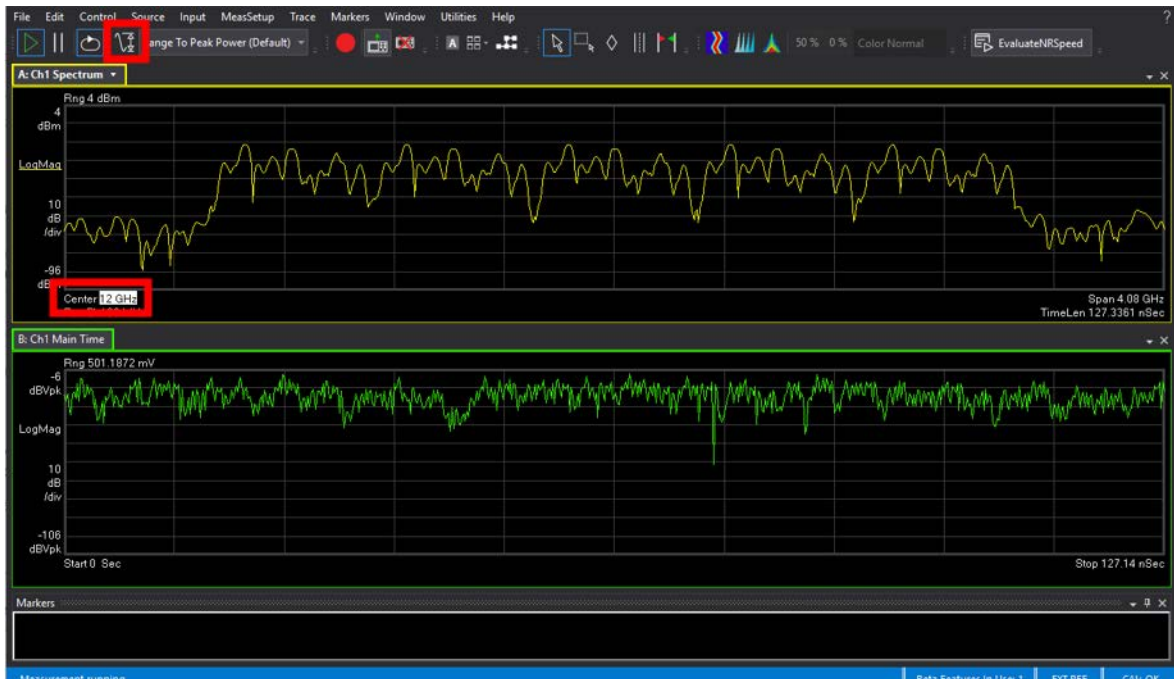
If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top left of the display) to open the Mode/Measurement/View Selector window.

Advanced Measurements

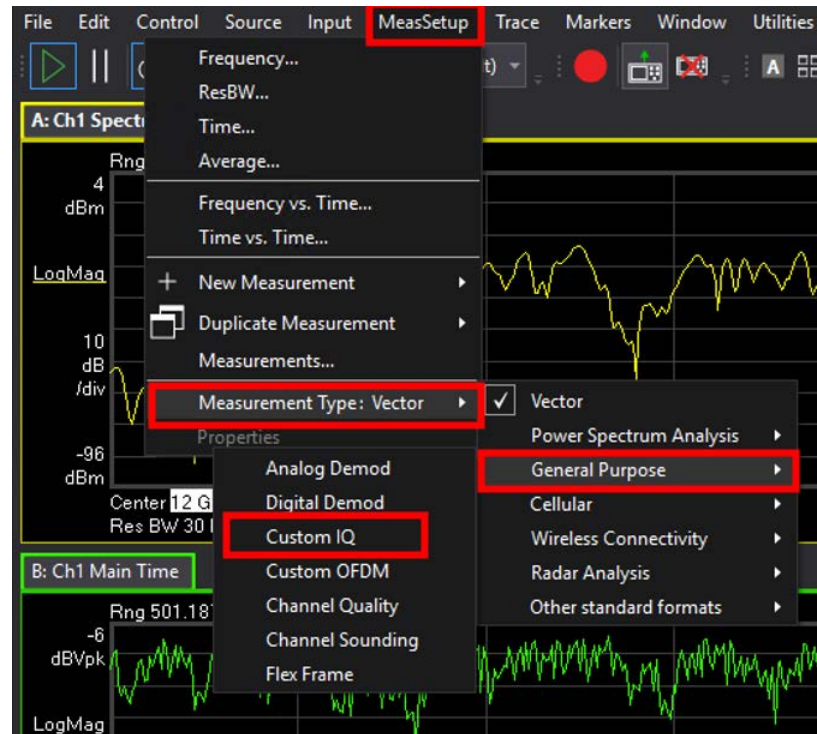
Channel Bonding



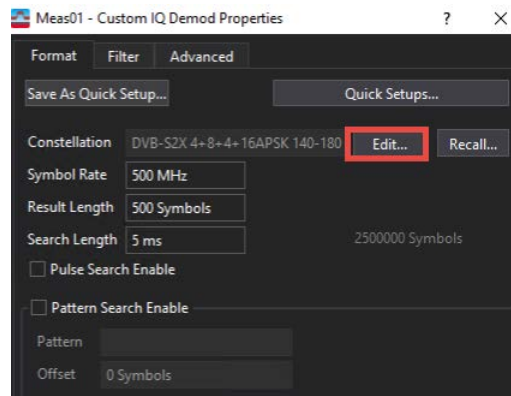
3. In the Spectrum window, select **Center frequency** and set to **12 GHz**, then select **Auto-range**.



4. From the menu bars, select **MeasSetup > Measurement Type: Vector > General Purpose > Custom IQ**.

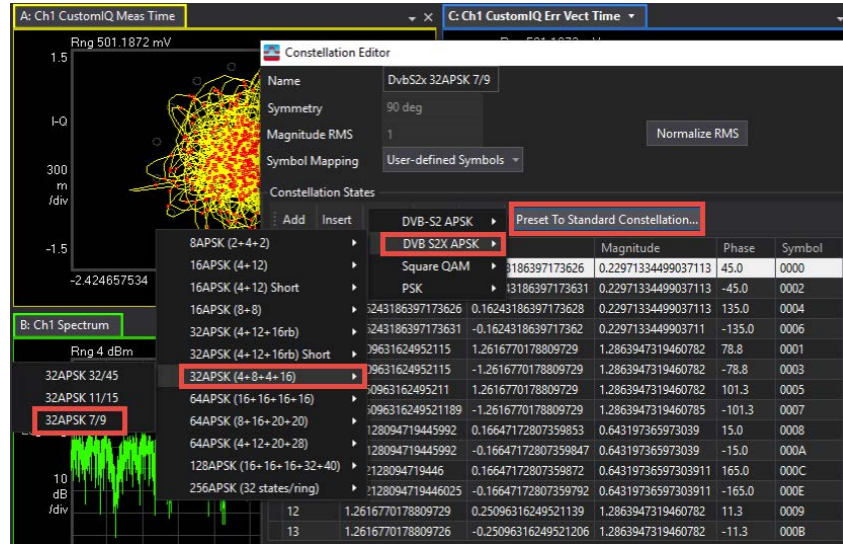


5. Select **MeasSetup > Custom IQ Demod Properties**.
- a. In the **Format** tab, select **Constellation Edit**.



- b. Select **Preset to Standard Constellation > DVB S2X APSK > 32APSK (4+8+4+16) > 32APSK 7/9**. This is equivalent to the 4+8+4+16APSK 140/180 setting we chose in the Custom Modulation setup.

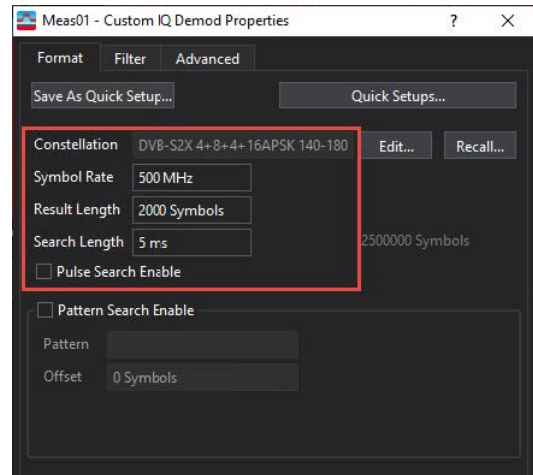
c. Select **OK** to close the Constellation Edit dialog.



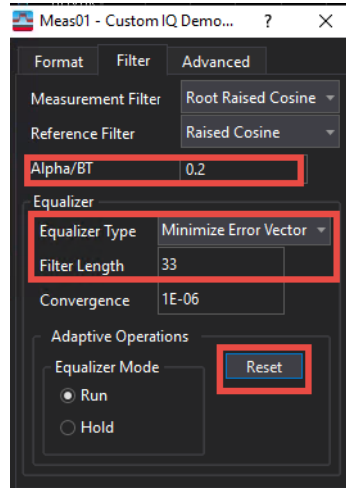
d. Turn off **Pulse Search Enable** (checkbox cleared).

e. Set the Result Length to **2000 Symbols**.

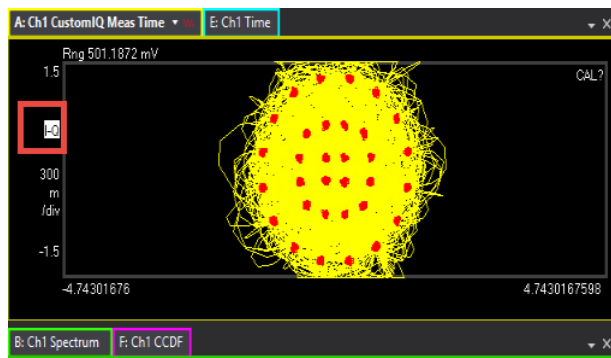
f. Set the Symbol Rate to **500 MHz**. The Result Length and Symbol Rate will adjust the resolution bandwidth to better define the waveform.



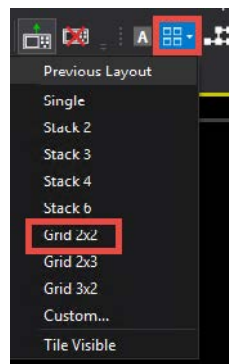
- g. Select the **Filter** tab and set Alpha/BT to **0.2**, Filter Length to **33**, and Equalizer Type to **Minimize EVM**. Close the Custom IQ Demod Properties window and notice the center carrier is now being demodulated.



6. In the CustomIQMeas Time window, click on **I-Q** and change to **Constellation**, if desired.

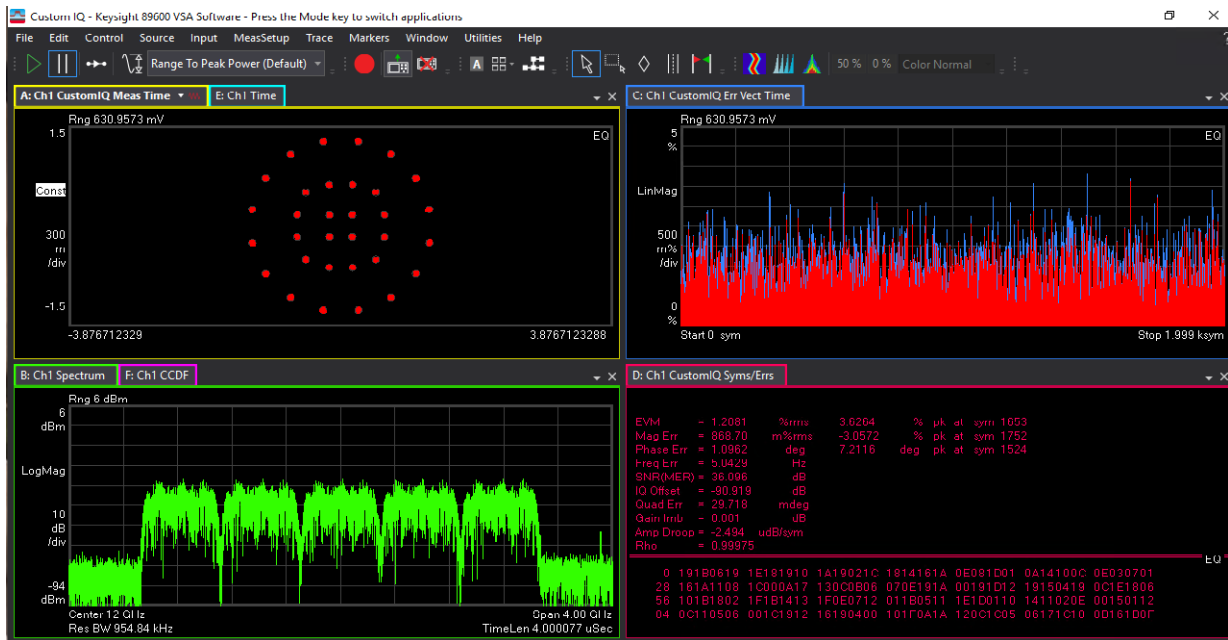


7. Change the window layout to Grid 2x2.



Advanced Measurements Channel Bonding

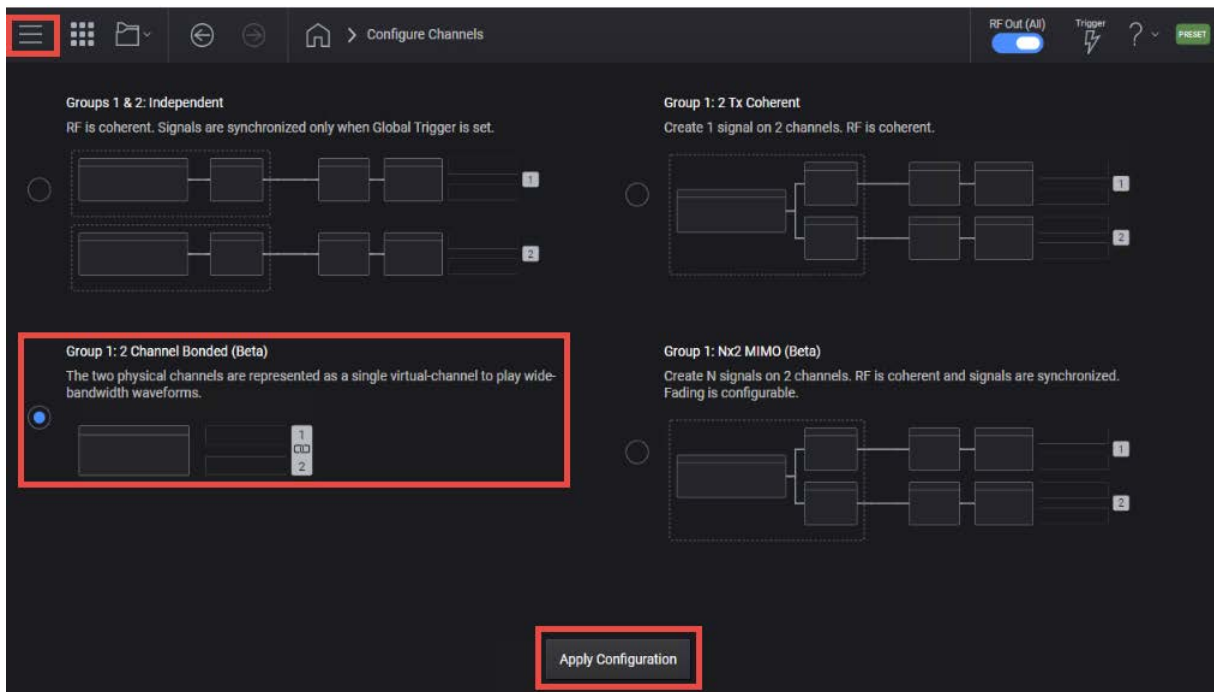
- Note the measured EVM value in the CustomIQSyms/Errs window. For this example, 1.2%rms.



Generating a Wide Band QPSK

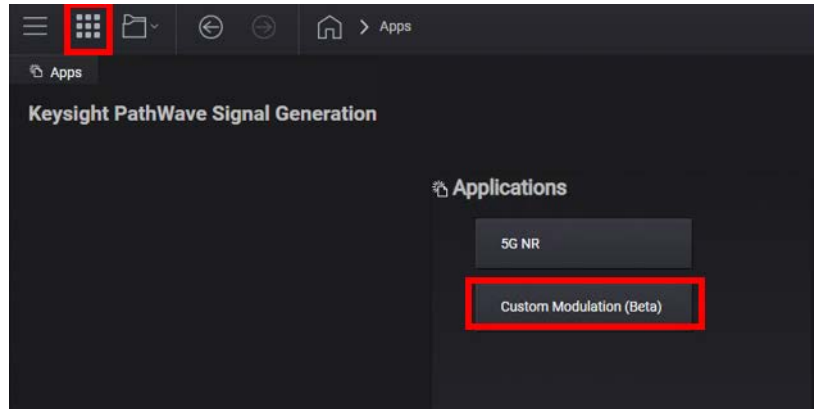
On the VXG:

1. Connect the equipment as shown in **Figure 3-1** on page 89.
2. Select **Preset > Preset** to set the VXG to a known state.
3. Select the System menu (triple bar tab at the top left of the window), and then select **Configure Channels > Group 1:2 Channel Bonded > Apply Configuration**.



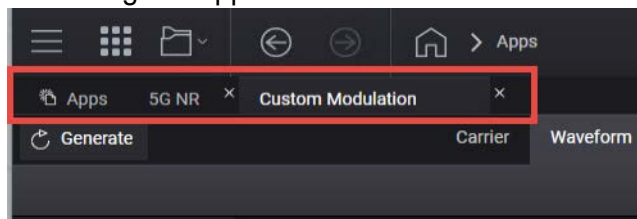
4. Set the Center Frequency to **12 GHz** and Power to **0 dBm**.

5. Select the **Apps** block to open, then select **Custom Modulation**.

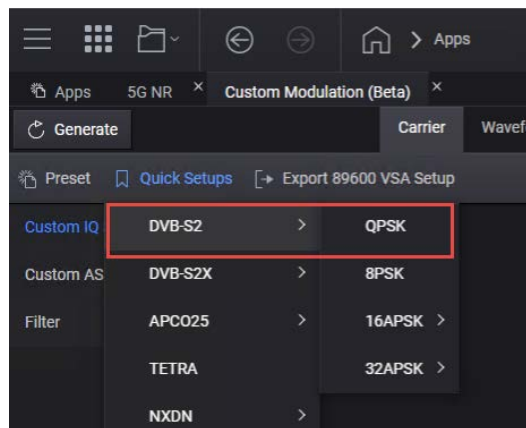


NOTE

If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



6. In the Custom Modulation setup, select the **Carrier** tab > **Quick Setups** > **DVB-S2** > **QPSK**.



7. From the bottom pane, select **Remove Segment** to remove the Header. This will simplify the demonstration.

8. From the left pane, select **Custom ASK & PSK & QAM Settings** and set the Symbol Rate to **3 Gsps** per channel.

Custom IQ Selection	Symbol Rate	3 Gsps
Custom ASK & PSK & QAM Settings		
Filter		

9. Select **Filter** > Alpha to **0.2**.

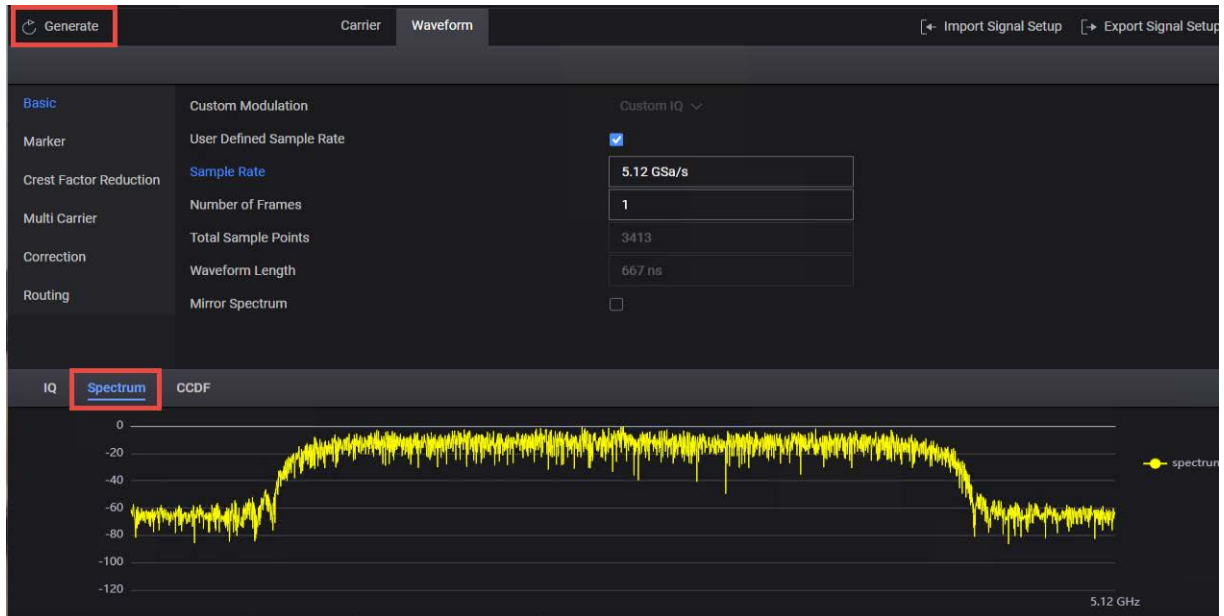
Custom IQ Selection	Filter	Root Nyquist
Custom ASK & PSK & QAM Settings	Alpha	0.2
Filter	Length(symbol)	32

10. Select the **Waveform** tab > **Basic** > Select **User Defined Sample Rate** and set Sample Rate to **5.12 GSa/s**.

Each channel is 2.56 GHz for a combined sample rate of 5.12 GHz.

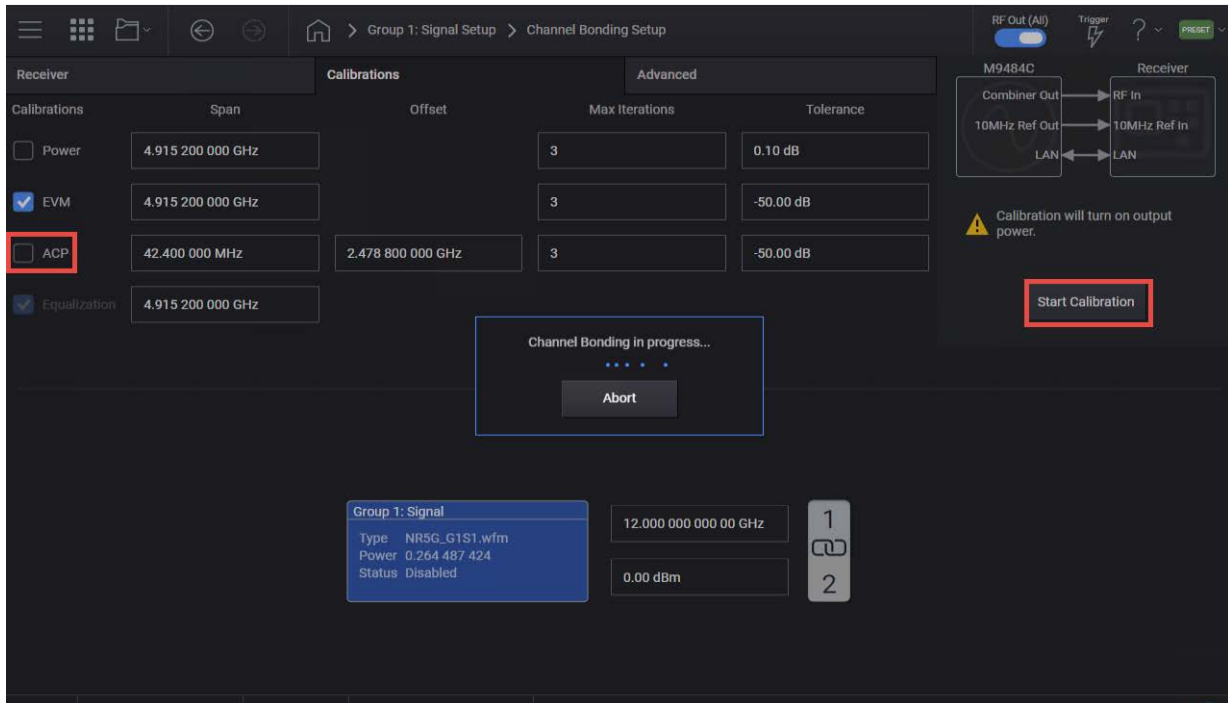
Apps	5G NR	Custom Modulation (Beta)
Generate	Carrier	Waveform
Basic	Custom Modulation	Custom IQ
Marker	User Defined Sample Rate	<input checked="" type="checkbox"/>
Crest Factor Reduction	Sample Rate	5.12 GSa/s

11. **Generate** the waveform and select the **Spectrum** tab from the bottom pane.



12. Select the **Home** icon to return to the main window and then select the **Signal Block** to open.
13. In the Signal Setup dialog box, notice that new custom modulation file is already selected (`CustomMod_G1S1.wfm`).
14. Set the Occupied Bandwidth to **3.6 GHz** (or 1.2×3 GHz) and the Sample Rate to **5.12 GHz** Samples per second.
15. Select **Configure Channel Bonding** and configure the Hostname or IP address for the UXA, then **Test Connection**. Ensure that you have successfully connected to the UXA.

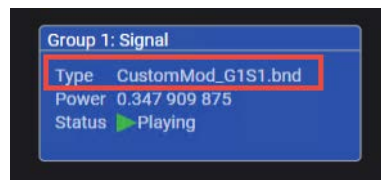
16. Select the **Calibrations** tab and clear the **ACP** calibration.



17. Select **Start Calibration**.

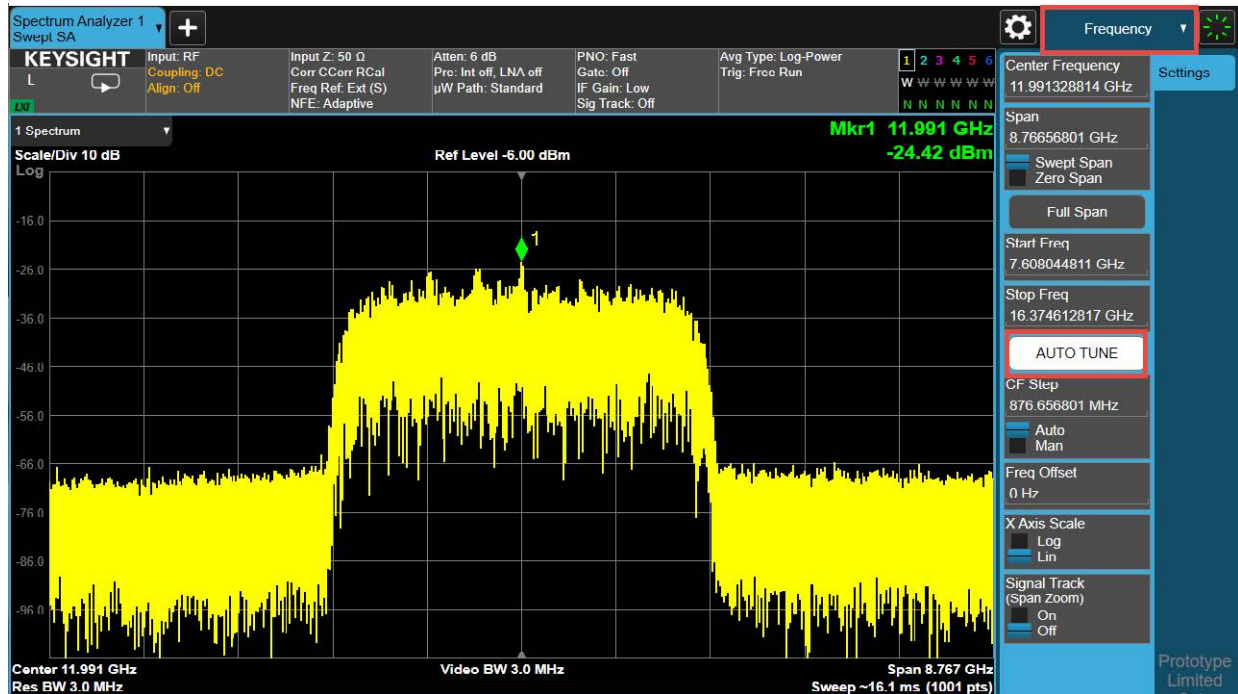
The calibration takes a few minutes to complete. Note that the VXG displays an `Invalid file selection` message. This is because the VXG no longer sees the .wfm waveform instead the newly calibrated waveform has a .bnd file extension.

Notice that the CustomMod_G1S1.bnd waveform is now playing.



On the Signal Analyzer:

1. Select **Frequency** > **Auto Tune** to observe the spectrum.



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

NOTE

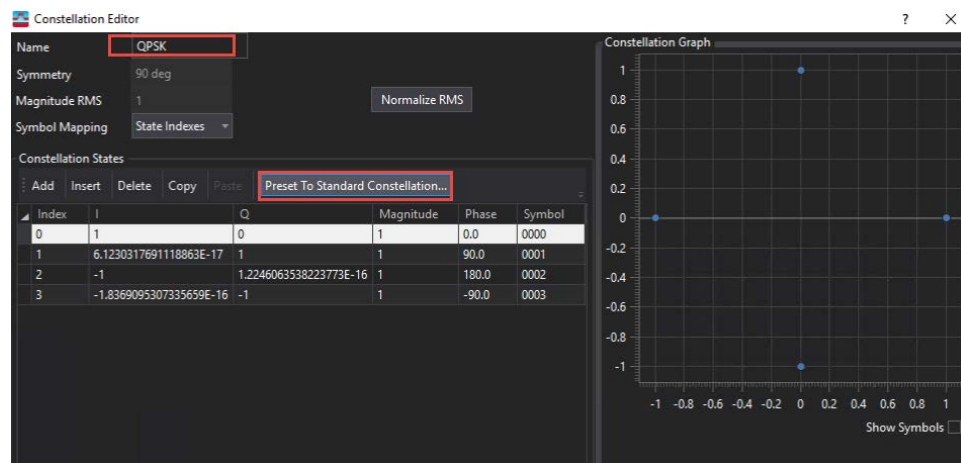
If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top left of the display) to open the Mode/Measurement/View Selector window.

Advanced Measurements Channel Bonding

3. In the Spectrum window, set the Center Frequency to **12 GHz** and **Auto-range**.

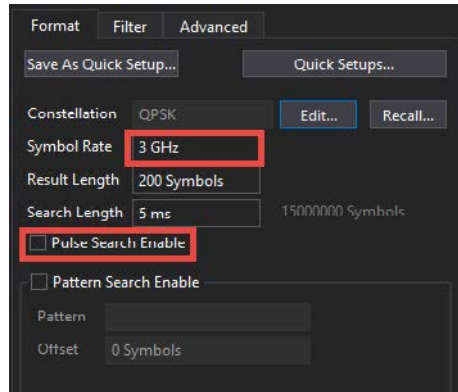


4. From the menu bar, select **MeasSetup > Measurement Type > General Purpose > Custom IQ**.
5. From the menu bar, select **MeasSetup > Custom IQ Demod Properties**.
 - a. Select the **Format** tab and select **Constellation Edit**.
 - b. Select **Preset to Standard Constellation > PSK > QPSK**.
 - c. Select **OK** to close the Constellation Edit dialog.

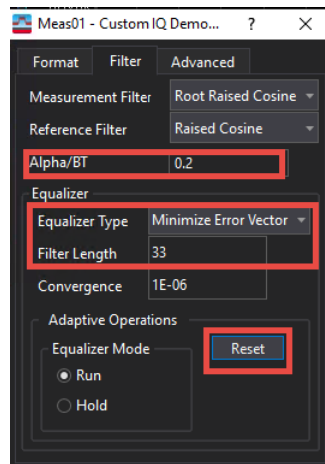


- d. Turn off **Pulse Search Enable** (checkbox cleared).

e. Set the Symbol Rate to **3 GHz**.



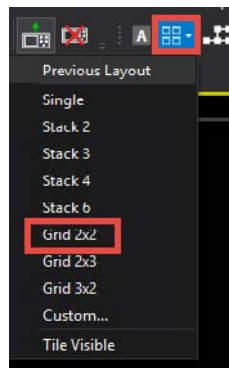
f. Select the **Filter** tab and set Alpha/BT to **0.2**, Filter Length to **33**, Equalizer Type to **Minimize Error Vector**, and **Reset** the Filter.



6. View the results.

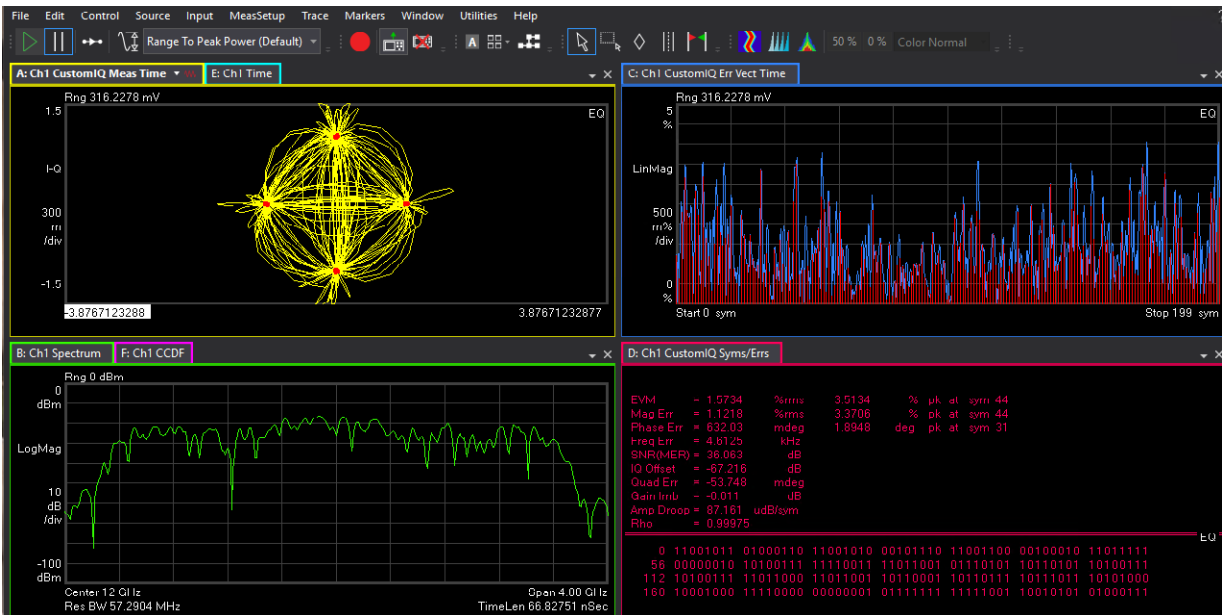


7. In the menu bar, select the **Trace Layout** icon and select the **Grid 2 x 2** format.



This allows you to view more measurement details like the EVM results, which for this example is ~1.6 %rms.

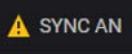
Advanced Measurements Channel Bonding

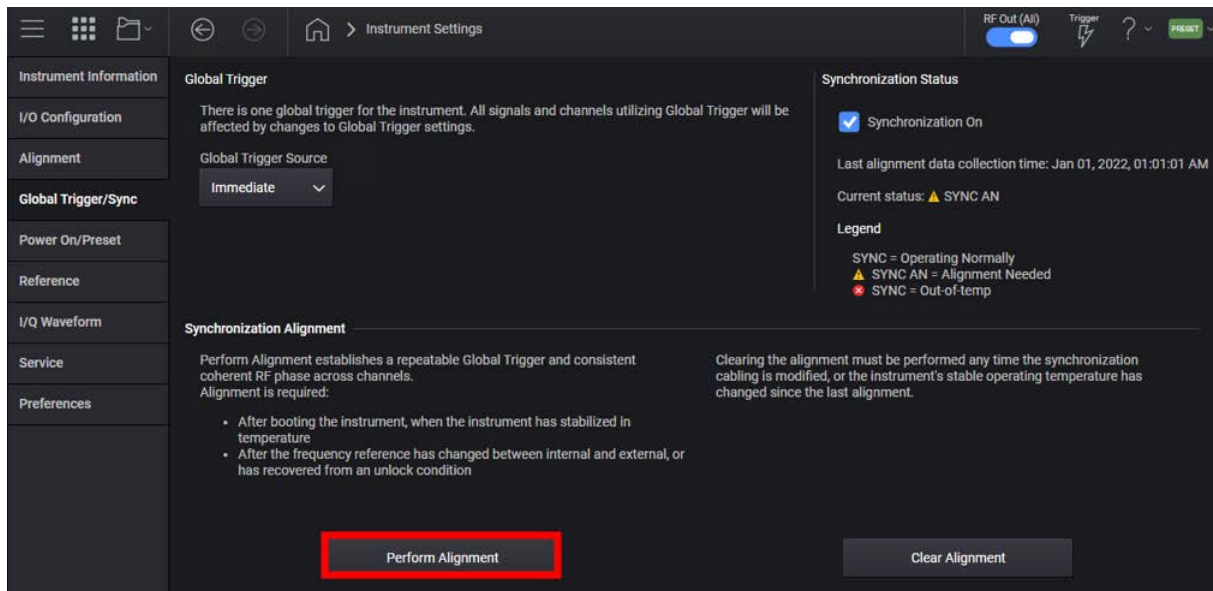


Generating a 5G NR Waveform

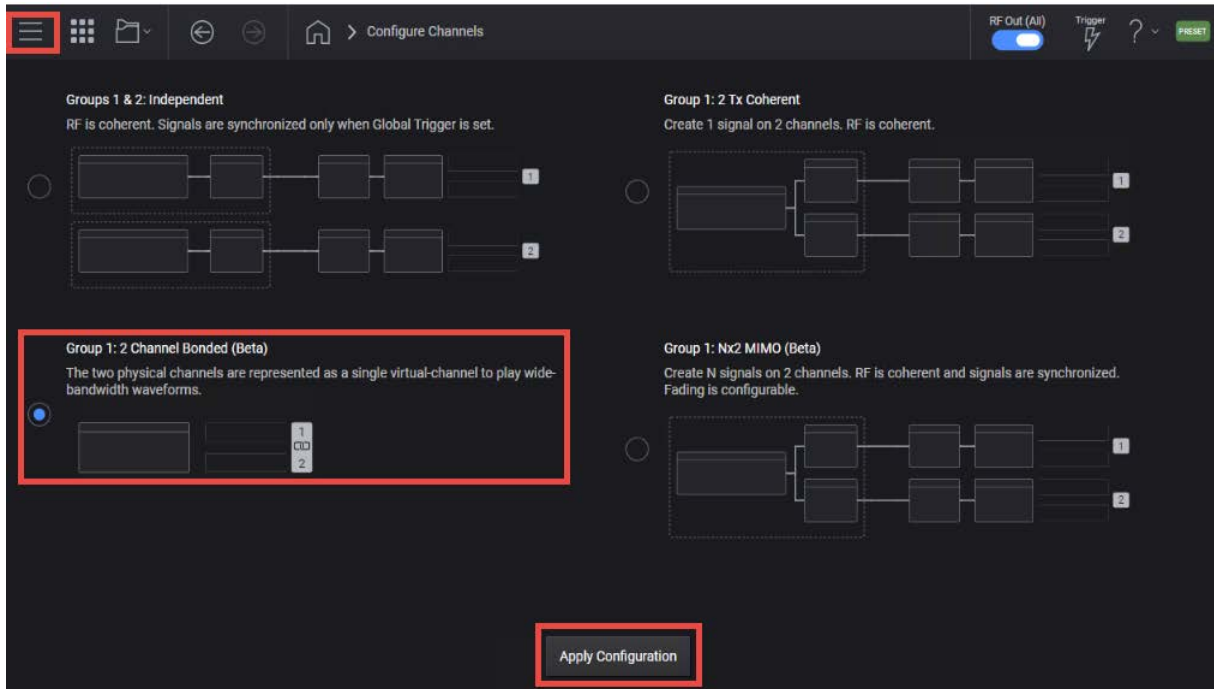
On the VXG:

1. Connect the equipment as shown in **Figure 3-1** on page 89.
2. Select **Preset > Preset** to set the VXG to a known state.

If a Synchronization Alignment is required, indicated by  in the bottom left corner, tap or click the warning message and choose **Perform Alignment** before proceeding.

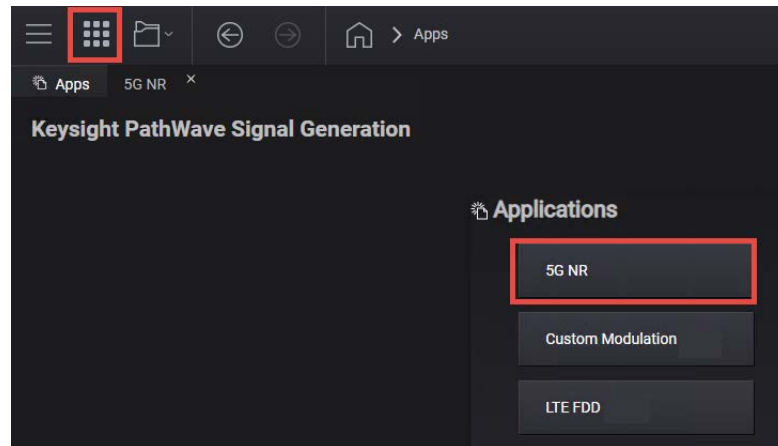


3. Select the System menu (triple bar tab at the top left of the window), and then select **Configure Channels** > **Group 1:2 Channel Bonded** > **Apply Configuration**.



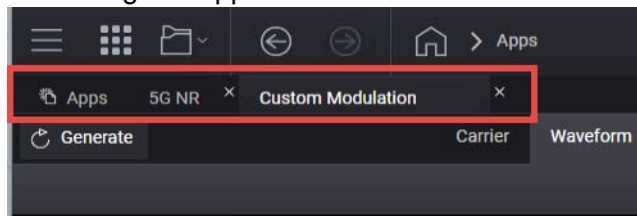
4. Set the Center Frequency to **12 GHz** and Power to **0 dBm**.

5. Select the **Apps** block to open, then select **5G NR**.



NOTE

If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



6. Select the **Carrier** tab.

7. Select **Full-Filled Config** and set Bandwidth to **FR2 400 MHz**, and then select **OK**.

Full Filled Configurations is a great place to start creating your waveform. You can select FR, bandwidth, and modulation format with a fully allocated PDSCH data channel. This would represent a spectrally correct

signal that is typically used in power amplifier measurements. You can modify the RB allocations and Slot allocations if fully allocated data channels are not desired.

Downlink Test Model (Base Station Tx Test based on 38.141 v17.5.0)

Bandwidth	FR2 400MHz
Numerology	$\mu = 3$: 120 kHz
> Duplex Type	TDD
Test Model	NR-FR2-TM1.1
Number of Layers	1
Phase Compensation	Off
DCI/DLSCH Payload Data	PN23

8. Select **DL Test Model** to open. set Bandwidth to **FR2 400 MHz** and set Phase Compensation to **Off**, and then select **OK**.

DL Test Model

9. Select the Waveform Tab, and set the Time Scale Factor to 10.

Carrier Waveform

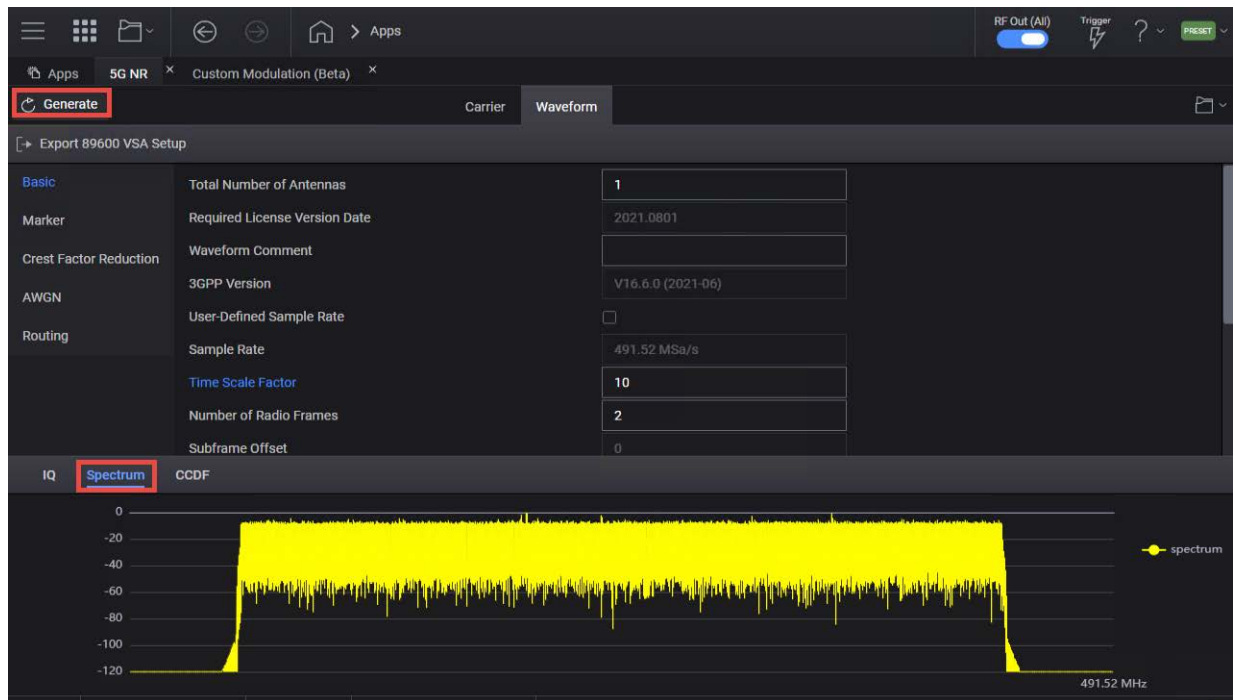
Capability

Waveform Playback

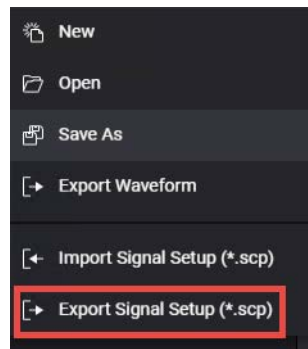
Total Number of Antennas	1
Required License Version Date	2021.0801
3GPP Version	V16.6.0 (2021-06)
User-Defined Sample Rate	<input type="checkbox"/>
Sample Rate	491.52 MSa/s
Time Scale Factor	10
Number of Radio Frames	2
Subframe Offset	0

CCDF

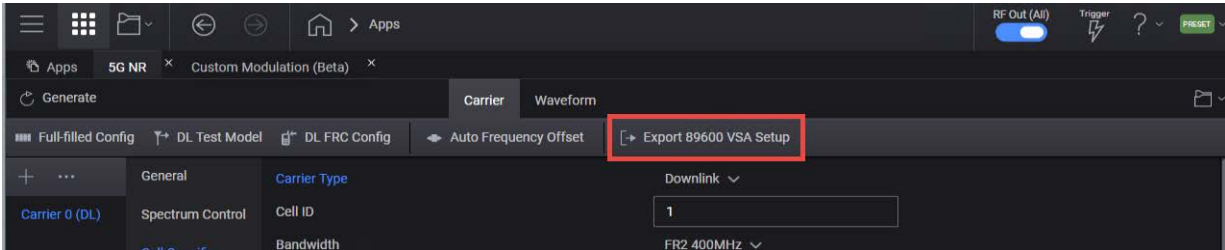
10. **Generate** the waveform and select the **Spectrum** tab from the bottom pane. The waveform will take a moment to finish generating.



11. Select the folder icon in the right corner of the display, and select **Export Signal Setup (*.scp)** file. In the File Name field, create a name for the setup file, then select **Enter**. Note the location where you saved this file as you will need to copy it to the UX.



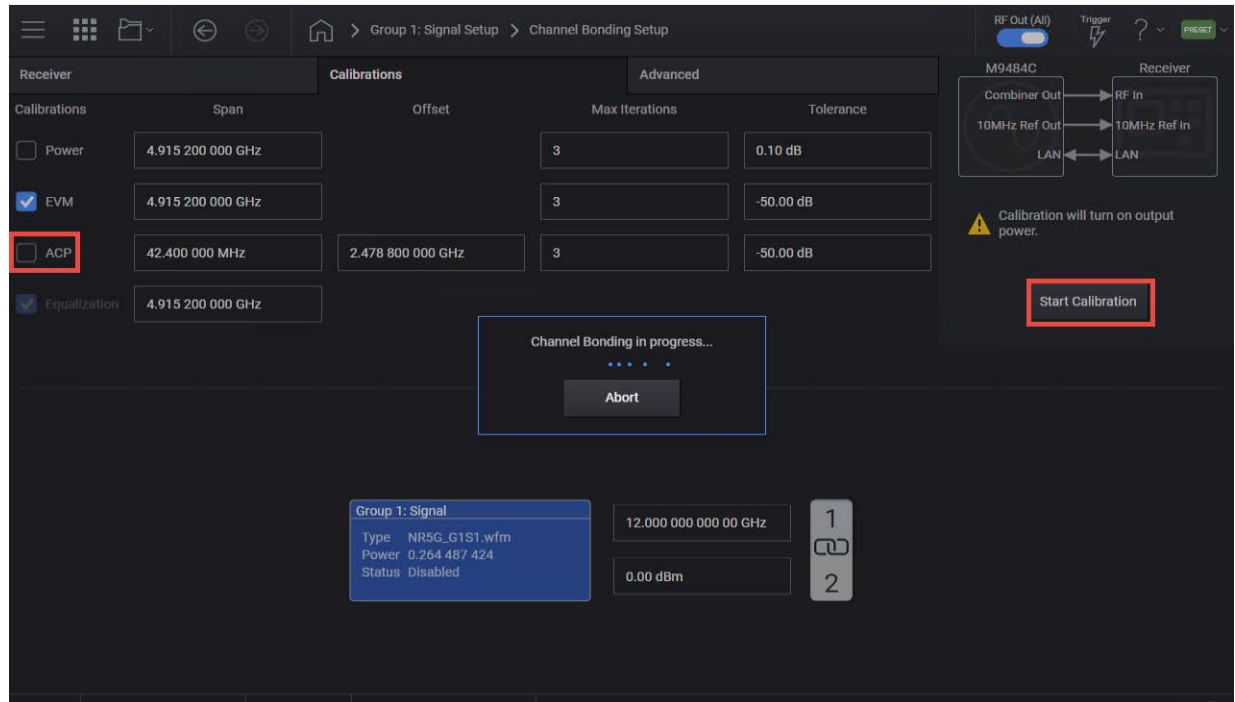
12. Select the **Carrier** tab and select **Export 89600 VSA Setup**. In the File Name field, create a name for the setup file, then select **Enter**. Note the location where you saved this file as you will need to copy it to the UXA.



To copy the two setup files to the UXA:

- Select the **System** menu icon (triple bar), then **Switch to Windows**.
 - Select the **Windows** icon (bottom left corner), open **File Explorer** and navigate to the setup files and **Copy** both files.
 - On the UXA, select the **Windows** icon, open **File Explorer** and **Save** the two setup files.
 - On the VXG, select the PathWave SG icon in the Desktop to restore the PathWave application.
13. Select the **Home** icon to return to the main window and then select the **Signal Block** to open.
14. In the Signal Setup dialog box, notice that new custom modulation file is already selected (NR5G_G1S1.wfm).
15. Select **Configure Channel Bonding** and configure the Hostname or IP address for the UXA, then **Test Connection**. Ensure that you have successfully connected to the UXA.

16. Select the **Calibrations tab and clear the **ACP** calibration, then select **Start Calibration**.**



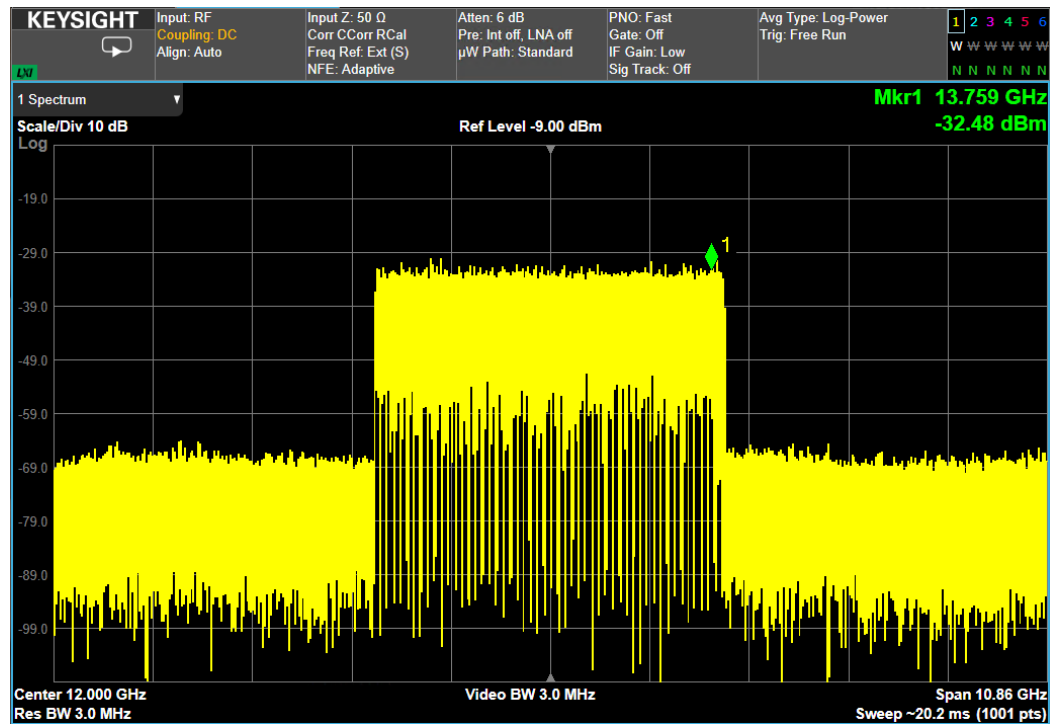
On the Signal Analyzer:

Below are two methods for viewing the results of the 5G NR wideband waveform.

- Using X-Apps 5G NR & V2X Modulation mode Modulation Analysis measurement
- Using 89600 VSA

Using X-Apps 5G NR & V2X 1 Mode

1. Select **Frequency > Auto Tune** to observe the channel bonded signal.



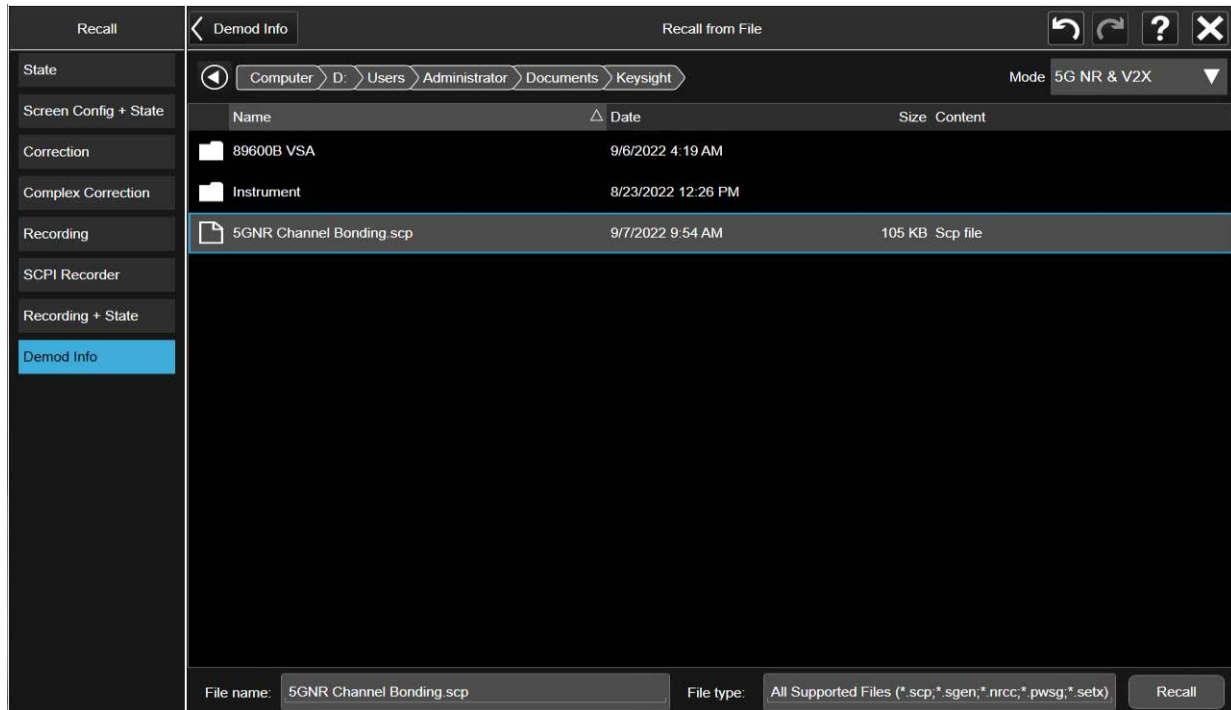
2. From the N9042B select **Mode/Meas > 5G NR & V2X Mode > OK**.

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.

3. Select **Mode Preset** to set Spectrum Analyzer 5G NR mode to a known state.
4. From the N9042B Menu Panel (or the Screen tab), select **Mode/Meas > 5G NR & V2X Mode > Modulation Analysis Measurement > OK**.
5. Select **Recall** (If accessing the N9042B remotely, select the Folder icon at the bottom of the display) **Demod Info > Data Type set to CC Setup > Recall From**.

6. Navigate to the .scp file you created in **step 11** above and select **Recall**.



7. From the Menu Panel, select **Meas Setup** > **Settings** tab > **Optimize EVM**. For this example, the EVM RMS is ~1.9%.



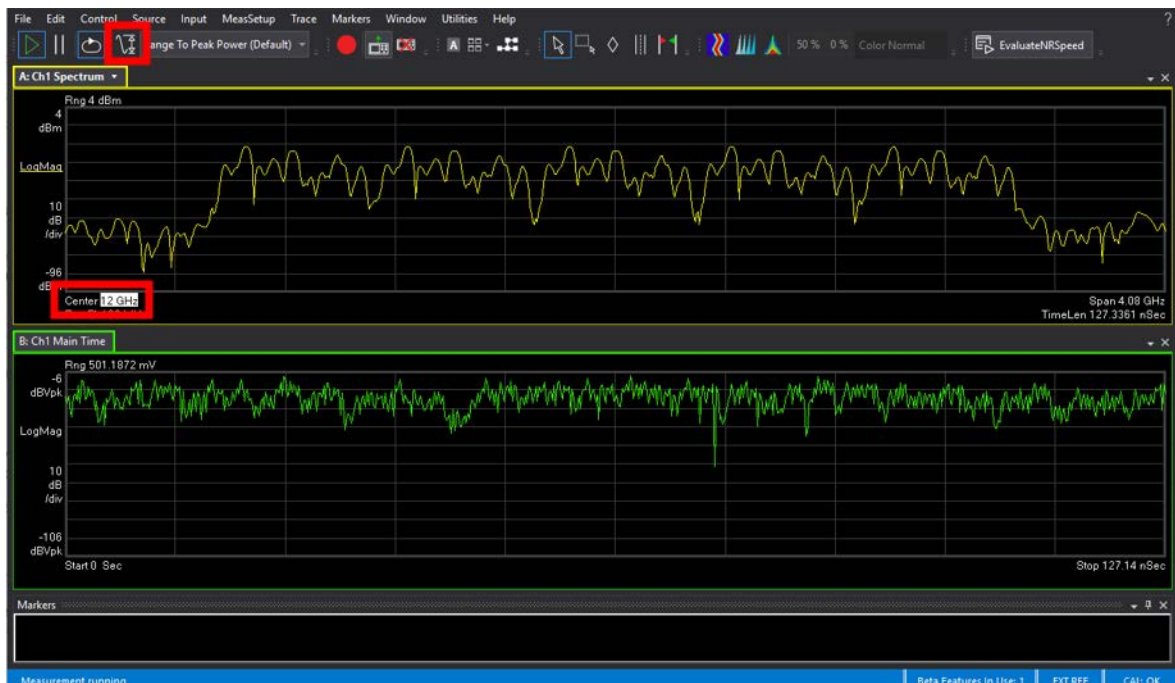
Using 89600 VSA

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 left of the display) to open the Mode/Measurement/View Selector window.

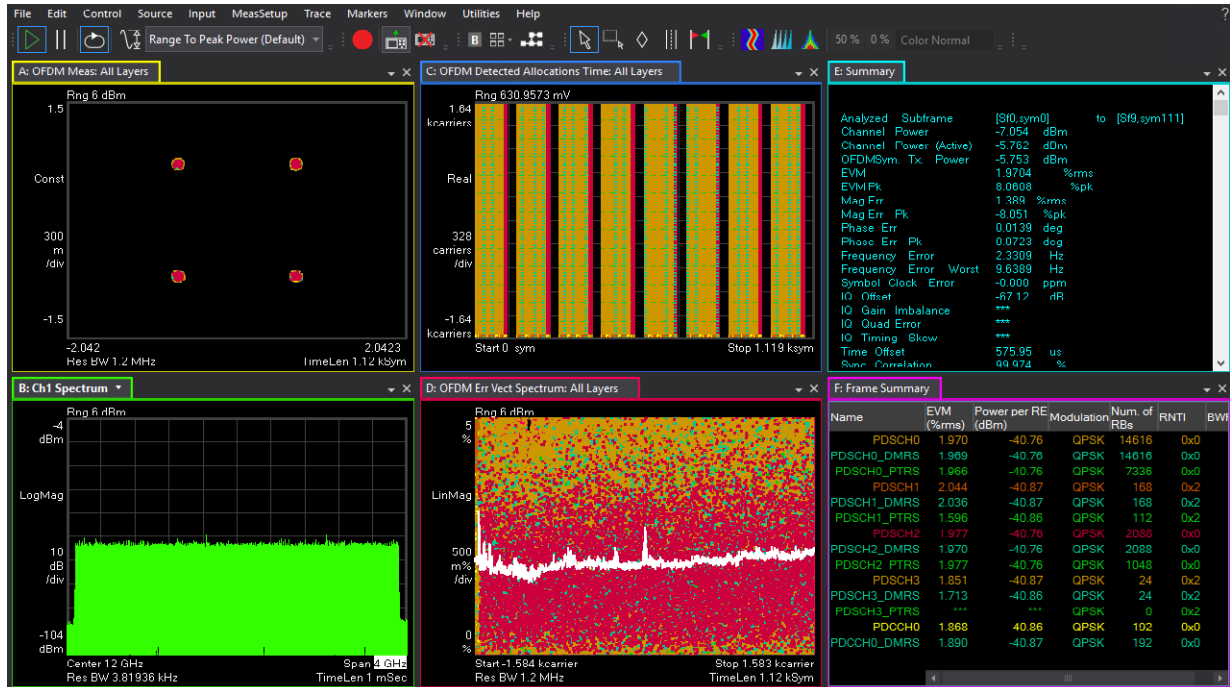
2. In the Spectrum window, set the Center Frequency to **12 GHz** and **Auto-range**.



3. From the menu bar, select **File > Recall Setup > Recall** and select the .setx file you copied over from the VXG.
4. From the menu bar, select **MeasSetup > 5G NR Demod Properties > Time** tab and set Time Scale Factor to **10**. Close the Demod Properties windows and observe the results.

Advanced Measurements Channel Bonding

- In the Spectrum window, set the Span to **4 GHz**, then select the Auto-range icon at the top of the display.



In this example, the EVM is ~2%

Setting Up 8 Virtual Signal Generators

The M9484C Option 8SG provides eight virtual signal generators (multiple IQ paths to RF) allowing you to emulate up to 8 signals simultaneously with one channel. This feature is most beneficial in receiver design and test applications in which the current implementation often involves RF combining of multiple signal generators due to dynamic range limitations. 8SG can simplify device characterization where multi-carrier or multi-radio access technology signals are required.

NOTE

The VXG must have Option M9484C-8SG (8 virtual signal generators) installed.

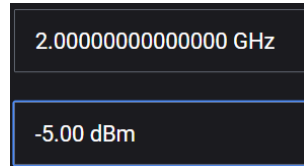


For this example we will use the following equipment:

- M9484C VXG
 - RF bandwidth of 2.5 GHz per channel (M9484C-R25)
 - 8 Virtual Signal Generators (M9484C-8SG)
 - N7631APPC PathWave Signal Generation for 5G NR measurement application
- X-Series Signal Analyzer
 - N9085EMOE 5G NR Measurement application

On the VXG:

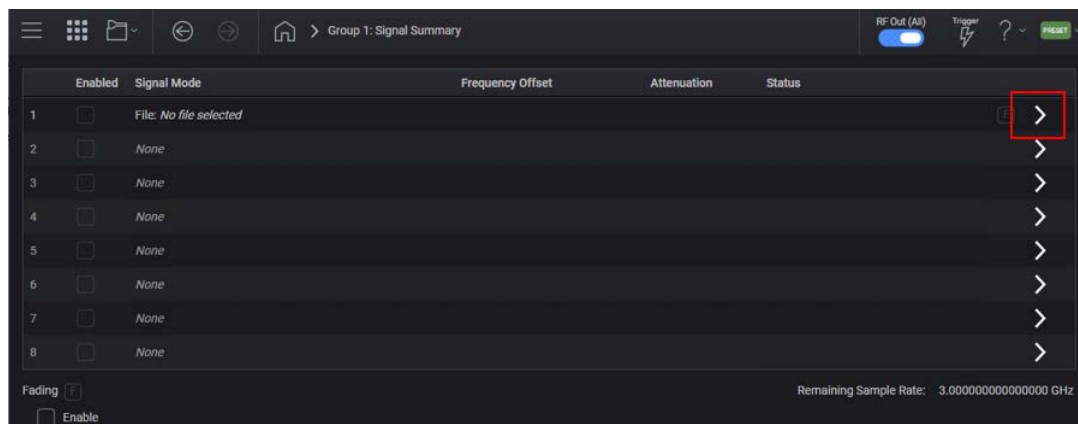
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. In the Output area for Channel 1, set Frequency to **2 GHz** and Power to **-5 dBm**.



3. Select **Group 1 Signal** block to open.



4. Select the arrow for Signal 1 to open the Signal Setup window.



5. Select the **Mode** drop down menu and select **Waveform File**.
6. In the Waveform Playback Setup area, use File **Select** to navigate to:

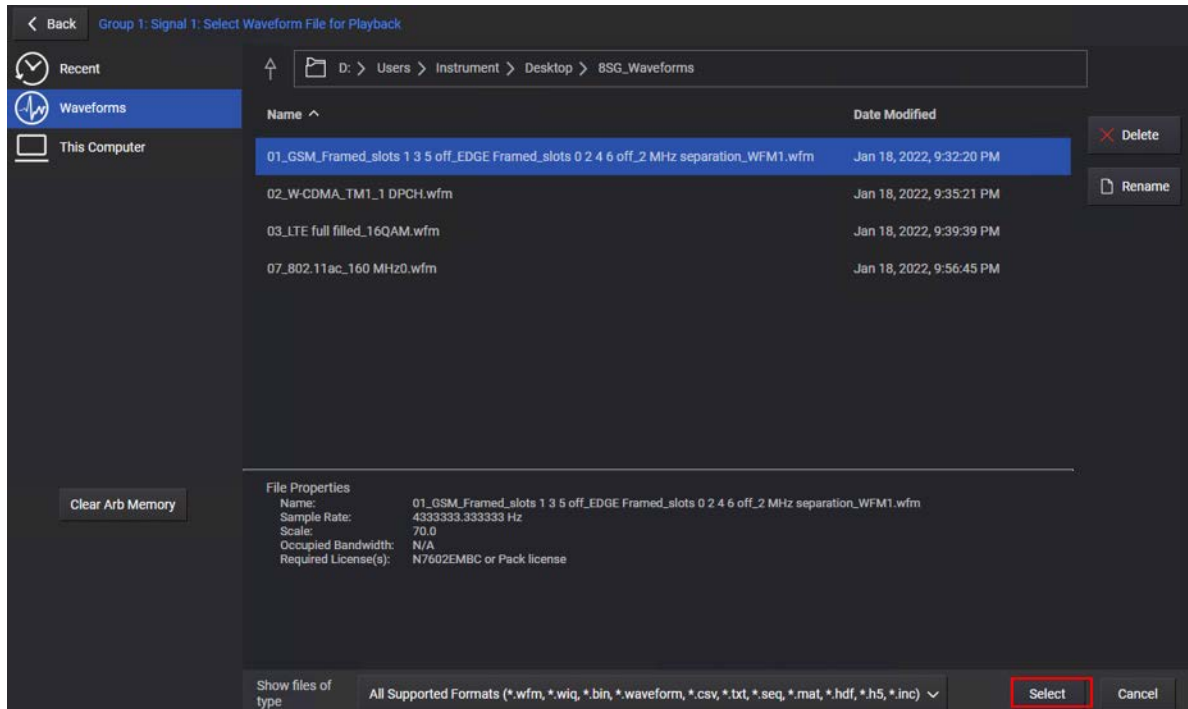
D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

and choose

01_GSM_Framed_slots 1 3 5 off_EDGE Framed_slots 0 2 4 6 off_2MHz

separation_WFM1.wfm

then **Select**.



NOTE

Whenever you enable a particular waveform file that is not currently enabled in another IQ path, it uploads prior to playback. If the file is already enabled in one or more other IQ paths, an upload does not occur and the waveform plays directly.

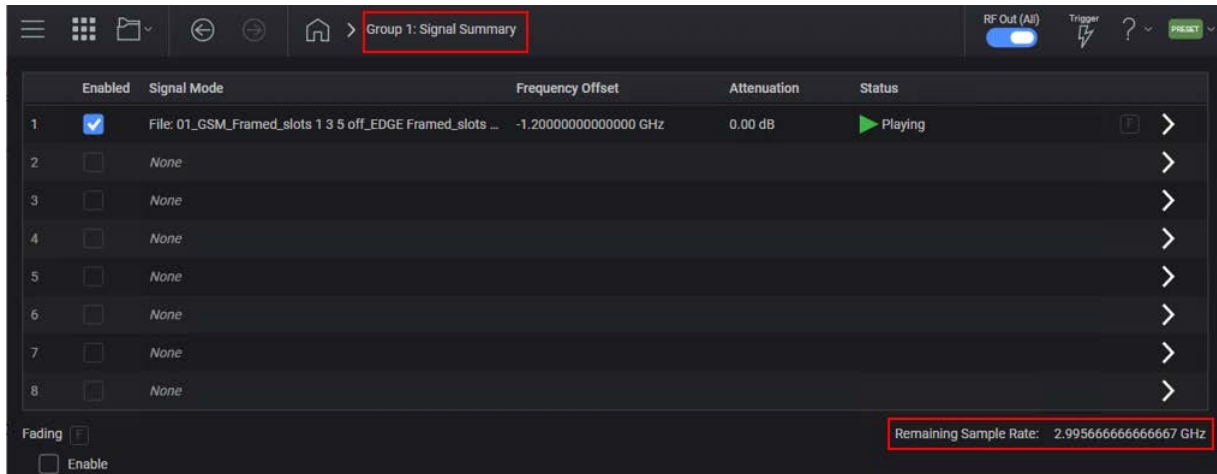
If you update the IQ data for a particular waveform file, you must first disable the IQ paths where the old version of the same file is being used so that it uploads, replacing the old data.

7. Set the Frequency Offset to the desired value. For this example **-1.2 GHz**.

The Frequency Offset is the distance from the channel's RF center frequency (set in step 2) to the center frequency of the signal. You can adjust the signal attenuation for each signal to allow scaling the signal down without disrupting the output.

8. Select **Enable** to turn on Signal Mode.
9. From the Menu/Tool & Navigation bar, select **Group 1: Signal Summary**.

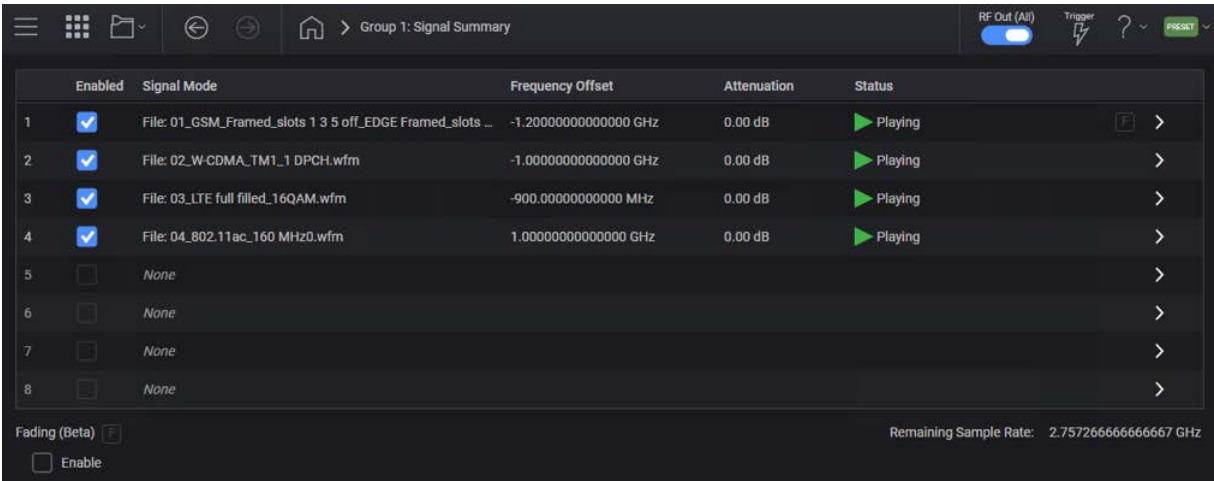
Notice the Remaining Sample Rate has decreased from 3.0 GHz to 2.9956 GHz now that Signal 1 is consuming 4.333 MHz.



10. Repeat step **step 4** through **step 9** for Signal 2, Signal 3, and Signal 4 with the following changes.

- Signal 2
 - Waveform:
D:\Users\Instrument\Documents\Keysight\PathWave\SignalGenerator\Examples\02_W-CDMA_TM1_1 DPCH.wfm
 - Frequency Offset: **-1.0 GHz**
- Signal 3
 - Waveform:
D:\Users\Instrument\Documents\Keysight\PathWave\SignalGenerator\Examples\03_LTE full filled_16QAM.wfm
 - Frequency Offset: **-900 MHz**
- Signal 4
 - Waveform:
D:\Users\Instrument\Documents\Keysight\PathWave\SignalGenerator\Examples\04_802.11ac_160 MHz0.wfm

– Frequency Offset: 1.0 GHz

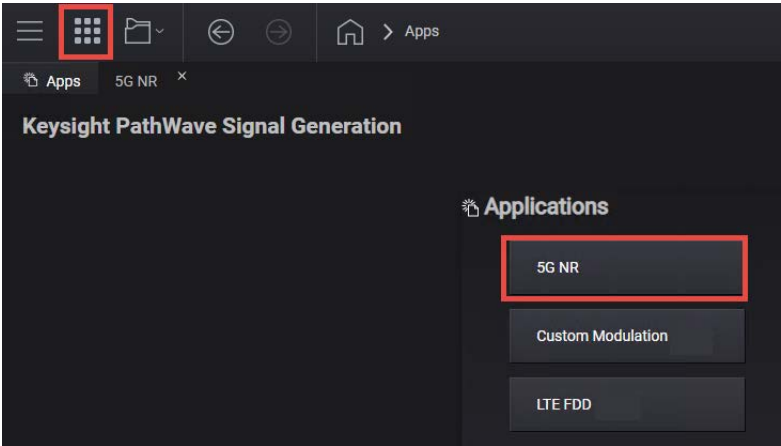


	Enabled	Signal Mode	Frequency Offset	Attenuation	Status
1	<input checked="" type="checkbox"/>	File: 01_GSM_Framed_slots 1 3 5 off_EDGE Framed_slots ...	-1.20000000000000 GHz	0.00 dB	▶ Playing
2	<input checked="" type="checkbox"/>	File: 02_W-CDMA_TM1_1 DPCH.wfm	-1.00000000000000 GHz	0.00 dB	▶ Playing
3	<input checked="" type="checkbox"/>	File: 03_LTE full filled_16QAM.wfm	-900.000000000000 MHz	0.00 dB	▶ Playing
4	<input checked="" type="checkbox"/>	File: 04_802.11ac_160 MHz0.wfm	1.00000000000000 GHz	0.00 dB	▶ Playing
5	<input type="checkbox"/>	None			
6	<input type="checkbox"/>	None			
7	<input type="checkbox"/>	None			
8	<input type="checkbox"/>	None			

Fading (Beta) ☐ Enable

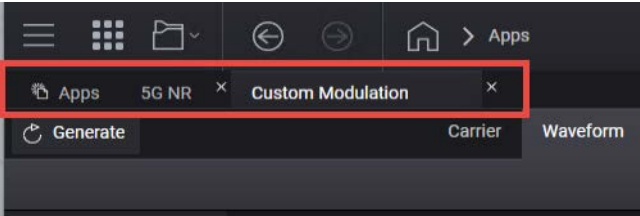
Remaining Sample Rate: 2.75726666666667 GHz

11. Signals 5 -7 will be configured using the embedded PathWave Signal Generation for 5G NR (N7631APPC). Select the **Radio Apps** icon in the top left of the window, and then select **5G NR**.



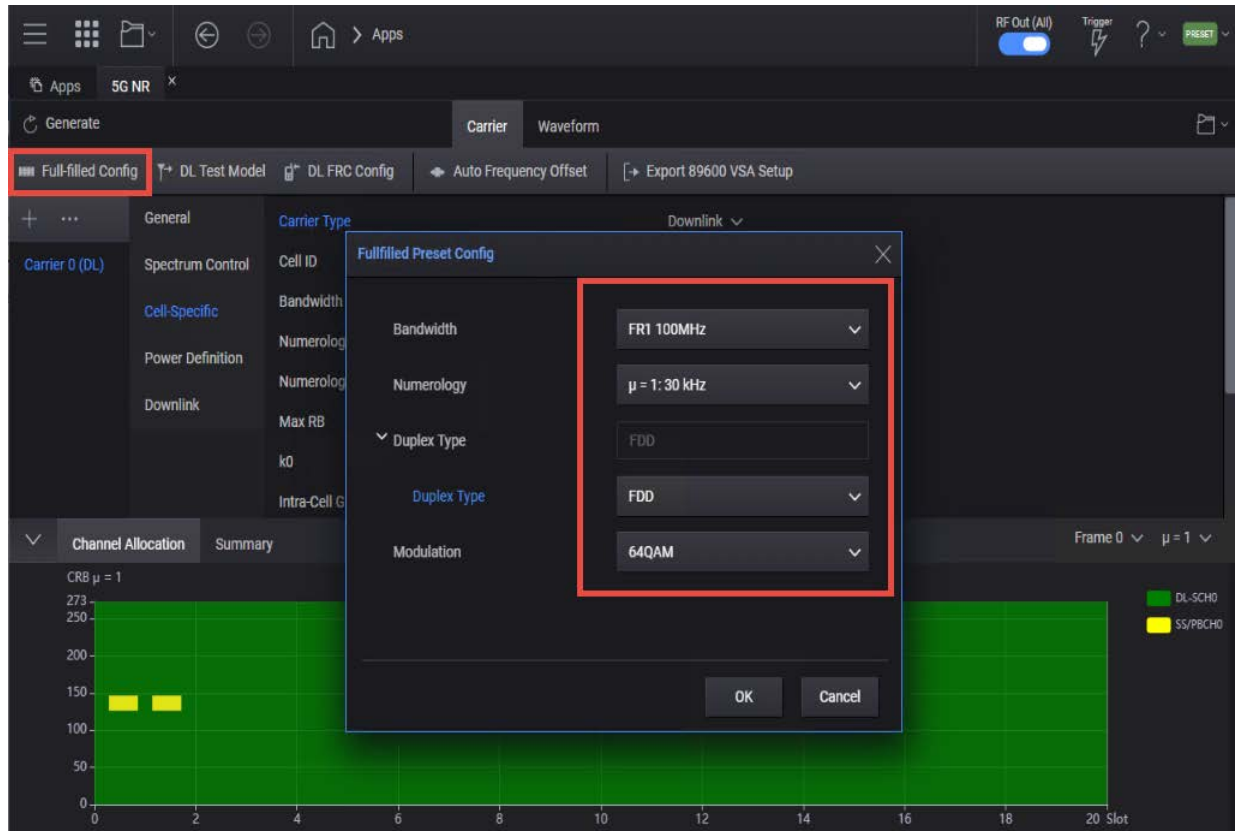
NOTE

If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.

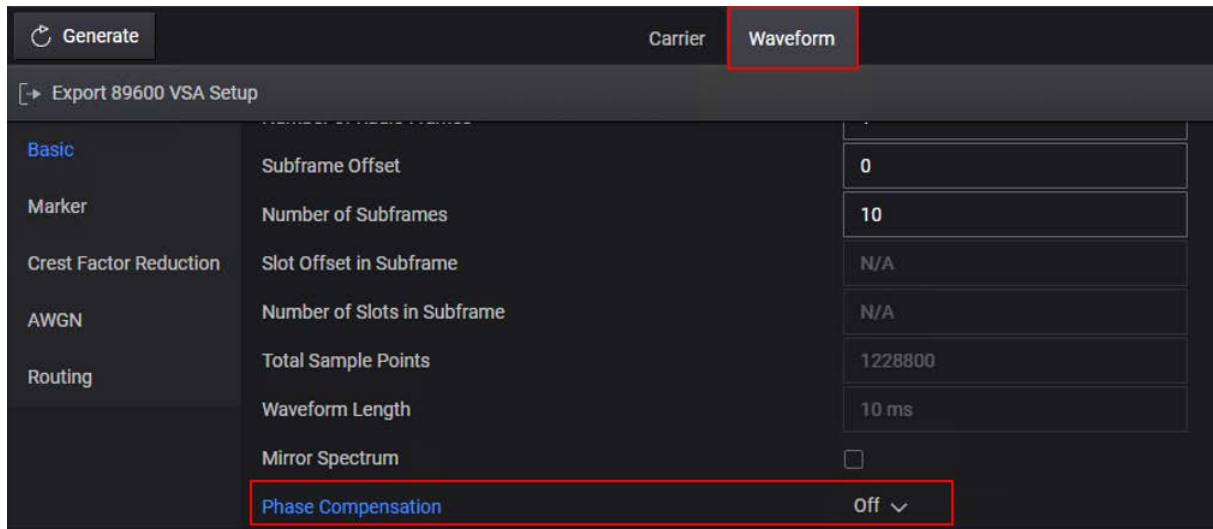


12. To create signal 5, select the **Carrier** tab > **Full-filled Config** and set

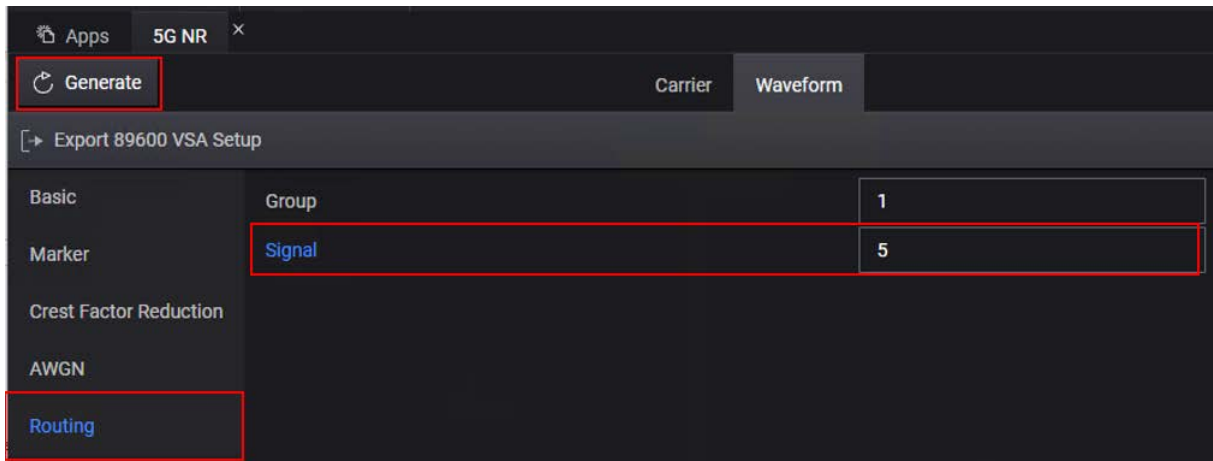
- Bandwidth to **FR1 100 MHz**
- Duplex Type to **FDD**
- Modulation to **64QAM**, then select **OK**



13. Select the **Waveform** tab and scroll down to turn Phase Compensation **Off**. This will allow the waveform to be offset in frequency without needing to be re-generated.



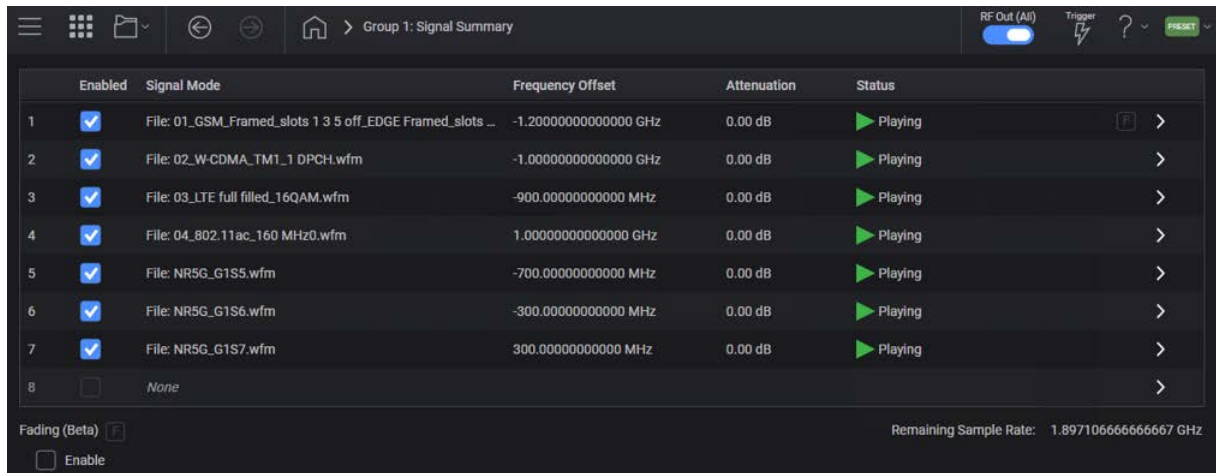
14. From the left pane, select the **Routing** tab, set the signal number to **5**, and then **Generate**.



15. To create signal 6, select the **Carrier** tab > **Full-filled Config** and set Bandwidth to **FR2 200 MHz**.
16. Select the **Waveform** tab, then from the left pane, select the **Routing** tab, set the signal number to **6**, and then **Generate**.
17. To create signal 7, select the **Carrier** tab > **Full-filled Config** and set Bandwidth to **FR2 400 MHz**.
18. Select the **Waveform** tab, then from the left pane, select the **Routing** tab, set the signal number to **7**, and then **Generate**.

19. Return to Group 1: Signal Summary by selecting the **Home** icon > **Group1: Signals** and set the Frequency Offset for each of the newly generated 5G NR signals as follows:

- Signal 5 to -700 MHz
- Signal 6 to -300 MHz
- Signal 7 to 300 MHz



20. Select the arrow for Signal 8.

21. Select the **Mode** drop down and select **AWGN**. Set Channel Bandwidth to **1.5 GHz** and Frequency Offset to **-200 MHz**.

Advanced Measurements

Setting Up 8 Virtual Signal Generators

Notice that if the default Channel Bandwidth setting of 2.5 GHz was used, the Enable checkbox is greyed out. This is because these settings result in a total Sample Rate of > 3.0 GHz for this Group. Reducing the Channel Bandwidth such that the AWGN Sample Rate is less than the Remaining Sample Rate shown in the previous step allows for the Enable box to be selected (checked).

The screenshot shows the 'Signal 8: Setup' window. The 'Enable' checkbox is greyed out. The 'Channel Bandwidth' is set to 2.500 000 000 GHz. The 'Sample Rate' is 3.000 000 000 000 GHz. A warning message at the bottom states: 'Settings conflict; Sample rate exceeds the remaining sample rate. Signal has been turned off.'

AWGN Setup

Parameter	Value
Channel Bandwidth	2.500 000 000 GHz
Flat Bandwidth	2.500 000 000 GHz
Bandwidth Ratio	1.000
Power Control Mode	Total
Total Power	-5.00 dBm
Channel Noise Power	-5.97 dBm

Diagram: Power vs. Frequency. The diagram shows a trapezoidal power spectrum. The 'Channel Bandwidth' is the width of the flat top. The 'Flat Bandwidth' is the total width of the spectrum. The 'Channel Noise' is the area under the flat top. The 'Total' is the area under the entire spectrum.

The screenshot shows the 'Signal 8: Setup' window. The 'Enable' checkbox is now checked. The 'Channel Bandwidth' is reduced to 1.500 000 000 GHz. The 'Sample Rate' is 1.800 000 000 000 GHz. The 'Frequency Offset' is -200.000 000 MHz.

AWGN Setup

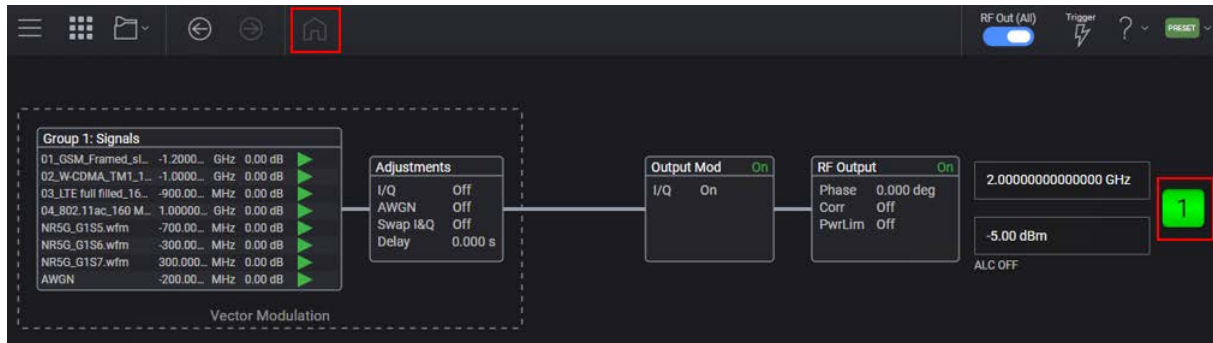
Parameter	Value
Channel Bandwidth	1.500 000 000 GHz
Flat Bandwidth	1.500 000 000 GHz
Bandwidth Ratio	1.000
Power Control Mode	Total
Total Power	-5.00 dBm
Channel Noise Power	-5.97 dBm

Diagram: Power vs. Frequency. The diagram shows a trapezoidal power spectrum. The 'Channel Bandwidth' is the width of the flat top. The 'Flat Bandwidth' is the total width of the spectrum. The 'Channel Noise' is the area under the flat top. The 'Total' is the area under the entire spectrum.

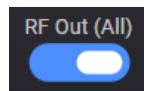
22. Select **Enable** to turn on Signal Mode for the AWGN signal.

- 23.** 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 VXG.



- 24.** 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:

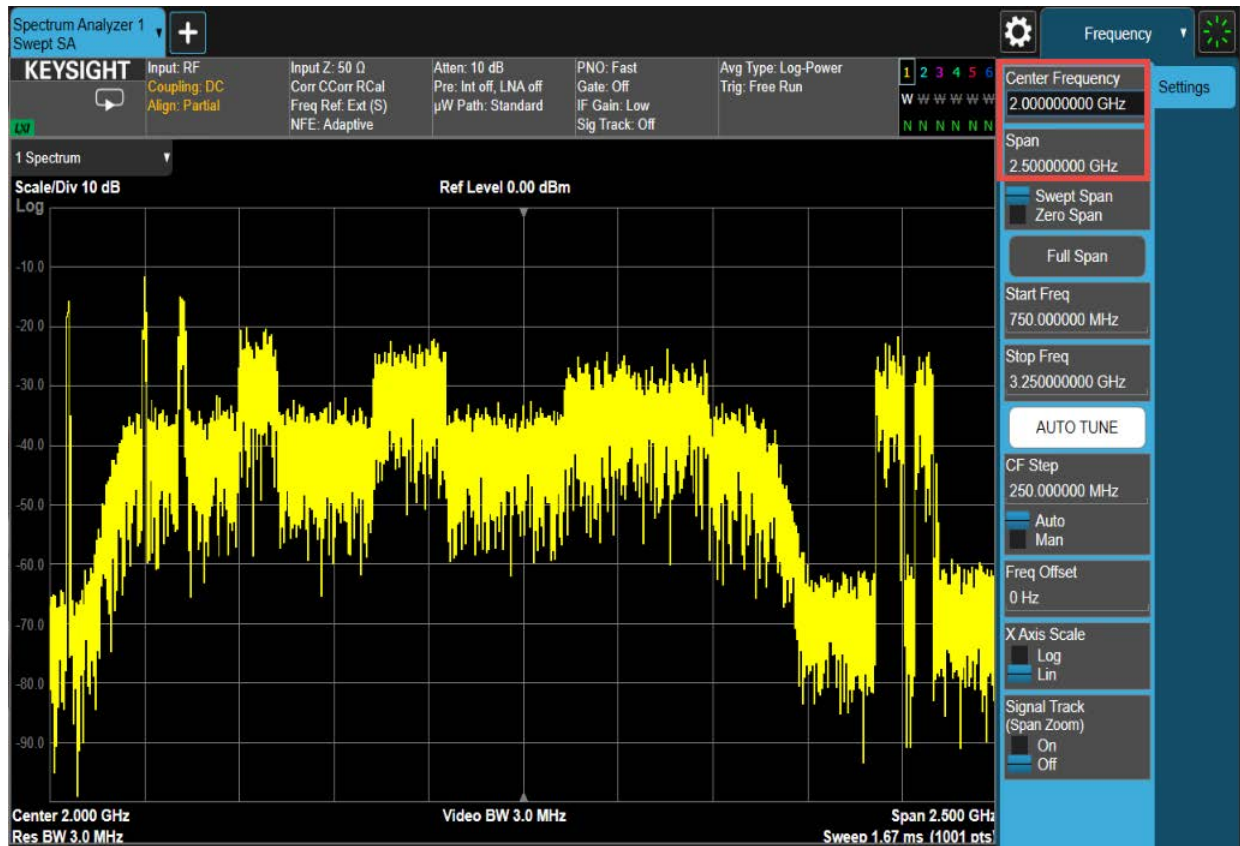
1. Select **Mode/Meas** > **Spectrum Analyzer Mode** > **Swept SA Measurement**.

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 the spectrum analyzer to a known state.

3. Adjust the center frequency and span to view all of the signals around the RF center frequency. For this example, set the Center Frequency to **2 GHz** and Span to **2.5 GHz**.



4. Adjust the Resolution Bandwidth and Video Bandwidth as needed.
5. Now that 8 waveforms are playing, try some of the following experiments to see how different settings impact the signals.
 - Toggle the Enable checkbox for various signals.
 - Adjust the Frequency Offset of various signals. Note that signals can overlap.
 - Set up a Channel Power measurement on the Signal Analyzer. Observe how changing different signal settings (relative power, attenuation, mute, enable, etc.) either impact or do not impact Total Channel Power.
 - Use the Auto Configure Analyzer feature to demodulate one of the 5G NR signals. Note, the center frequency will need to be manually adjusted on the Signal Analyzer to match the Frequency Offset of the signal set on the VXG.
 - Change Trigger and/or Marker settings.

Using the VSA Flex Frame to Create a DVB-S2X Signal

The Flex Frame extension (89601AYAC) for the 89600 VSA software provides a means of creating complex frames to demodulate and analyze advanced custom IQ signals.

A frame can contain a combination of flexible elements, or allocations. Each allocation can be a Preamble, Pilot, Data or an Idle period. Allocations have configurable payload PN sequence and modulation type.

As you build the flexible frame in the Frame Definition tab, an Allocation Summary panel displays the order of each assembled frame part and allocation, and shows how the total number of symbols are distributed across the frame.

There are two parts to this example.

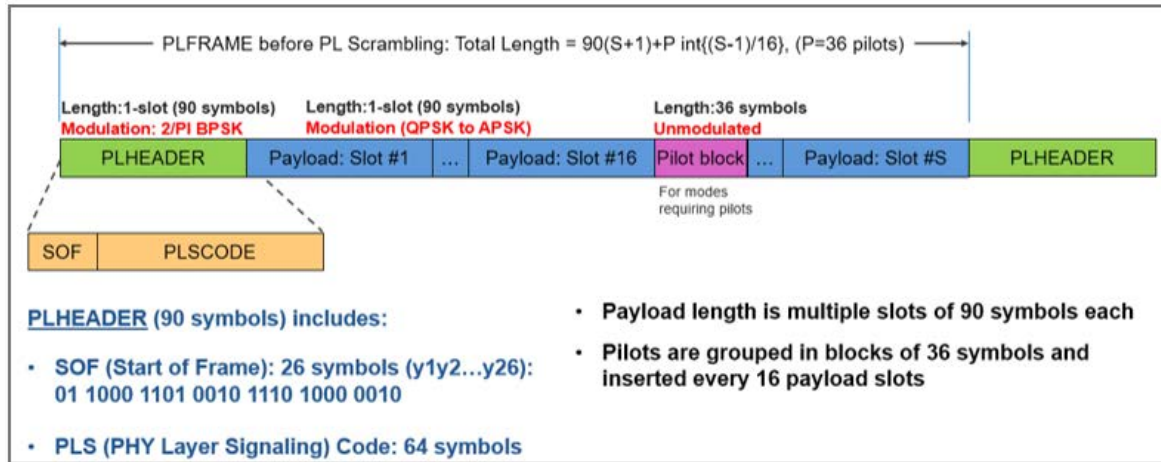
The first example uses N7623C Signal Studio for Digital Video. The N7623C generates a fully coded, full-standard compliant DVB-S2X waveform. Then, we will use VSA Flex Frame to demod the signal.

The second example uses PathWave N7608C Custom Modulation. Since the N7623C cannot provide an uncoded signal, we will use the N7608C to uncoded the signal to perform a Bit Error Rate (BER) measurement.

For this example, we will use the following equipment:

- N7623C Signal Studio for Digital Video (Software release 2020 Update 1.0 or higher)
- N7608C Signal Studio for Custom Modulation (Software release 2021 or higher)
- 89600 VSA Digital Demodulation Analysis, Flex Frame Measurement (Software release VSA 2022 or higher)

DVB-S2X PHY Layer Framing



256 APSK modulation is used in this demo guide. The coding rate is represented differently between Signal Studio for Digital Video (N7623C), Signal Studio for Custom modulation (N7608C), and VSA Flex Frame (89601AYAC). N7608C and 89601AYAC use “Implementation MODCOD” name and N7623C uses “Canonical MODCOD” name.

In this example, we will use a coding rate of 32/45 in the N7623C which corresponds to 128/180 in the N7608C and VSA.

N7623C Signal Studio for Digital Modulation	N7608C Signal Studio for Custom Modulation	89601AYAC Flex Frame
256APSK 29/45	256APSK 116/180	256APSK 116/180
256APSK 2/3	256APSK 20/30	Not supported
256APSK 31/45	256APSK 124/180	256APSK 124/180
256APSK 32/45	256APSK 128/180	256APSK 128/180
256APSK 11/15	256APSK 22/30	Not supported
256APSK 3/4	256APSK 135/180	256APSK 135/180

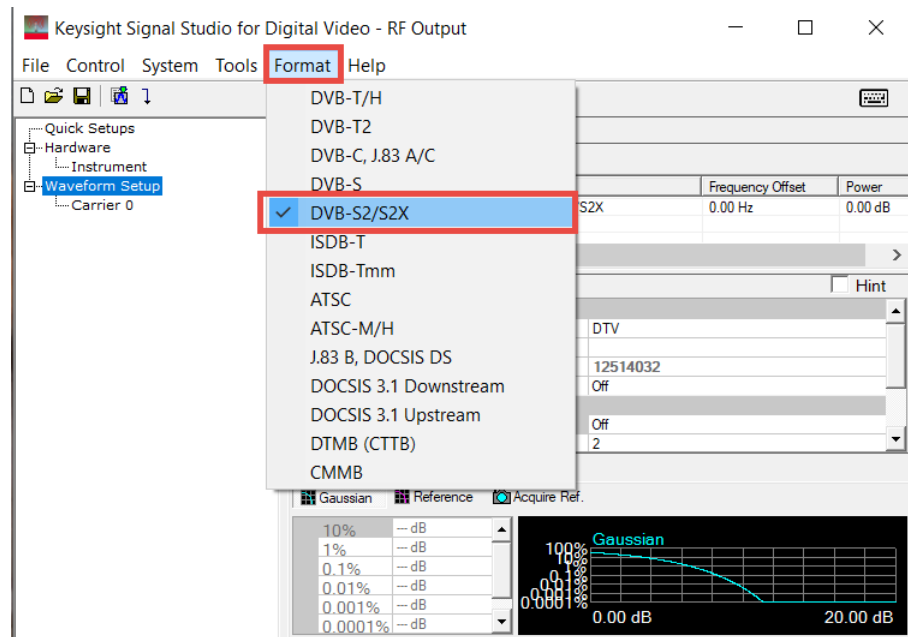
Part 1: Generating a DVB-S2X Waveform Using N7623C Signal Studio for Digital Modulation

NOTE

DVB-S2 and DVB-S2X operate in Ku band (10–14 GHz) and Ka band (18–30 GHz). This example uses a sub-6GHz hardware thus using a center frequency of 4.5 GHz. Modify the frequency based on the hardware you are using.

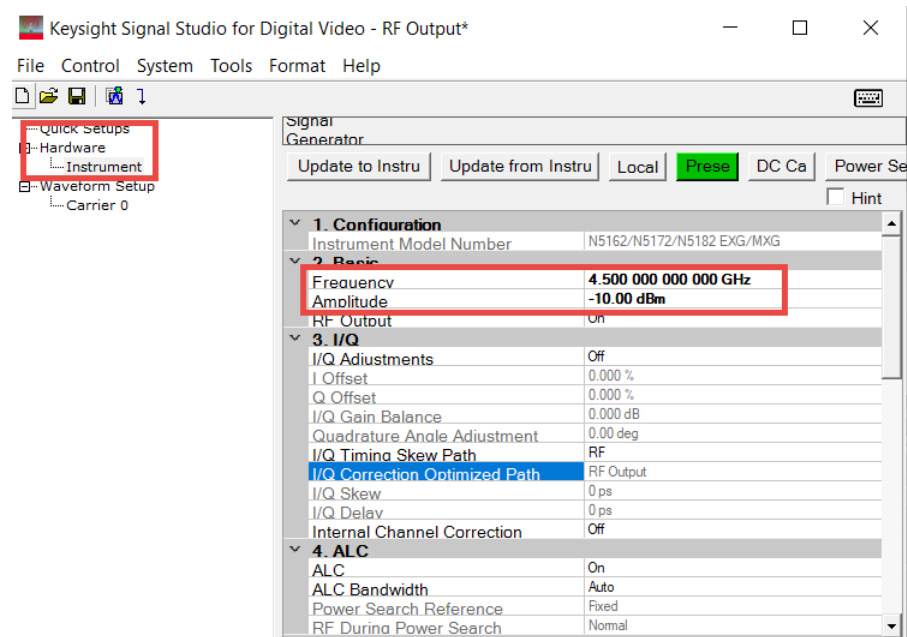
Setting Up the Waveform in Signal Studio for Digital Video

1. From the main menu, select **Format > DVB-S2/S2X**.



2. From the left panel, select **Quick Setups > Hardware > Instrument**.

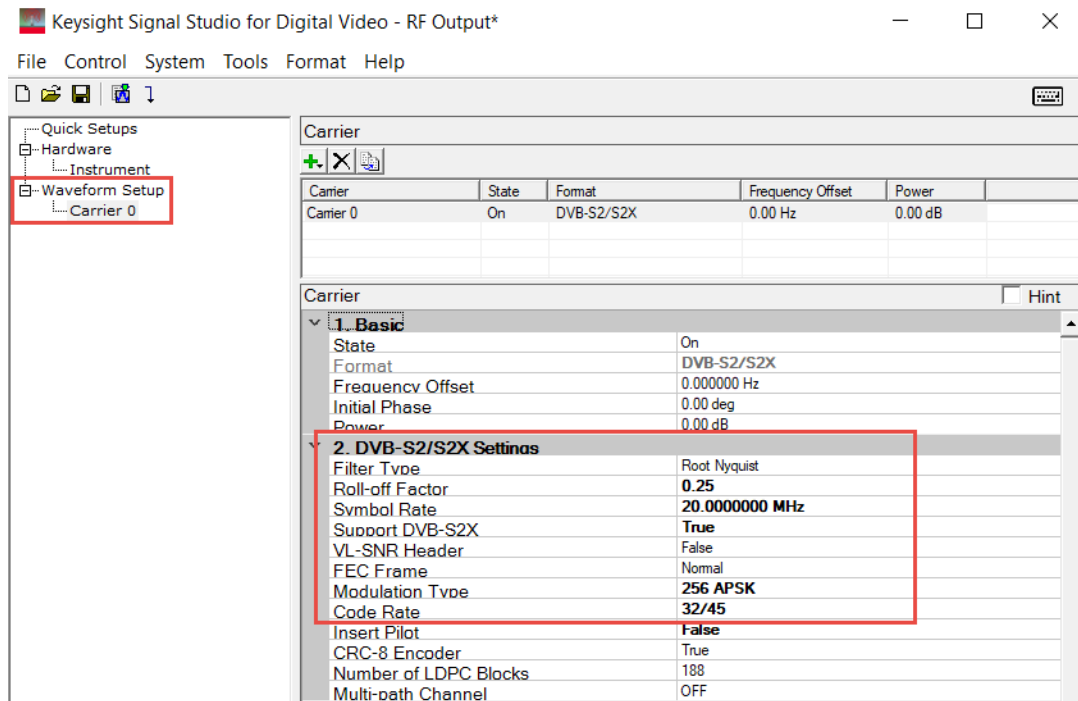
3. Set the Frequency to 4.5 GHz and the Amplitude to -10 dBm.



4. Under **Waveform Setup**, select **Carrier** and configure the DVB-S2/S2X signal to the following parameters.

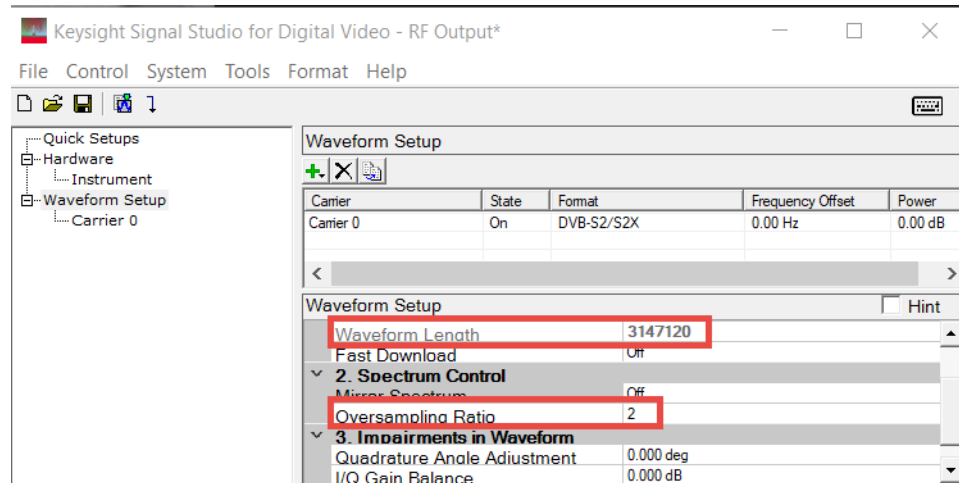
- Roll of Factor to **0.25**
- Symbol Rate to **20 MHz**
- Support DVB-S2X to **True**
- Modulation Type to **256 APSK**
- Code Rate to **32/45**

This is equivalent to MODCOD 256APSK 128/180 in the VSA.



5. In the **Waveform Setup** window, set the Oversampling Ratio to 2.

This results in a Waveform Length of 3147120. We will use this length when configuring the signal in VSA Flex Frame.



6. From the **Control** menu, select **Generate**.

NOTE

Depending on the signal generator you are using, the steps for downloading the waveform may be different. If this is the case, go to File > Export Waveform Data and Save the file. Then load it onto the your signal generator.

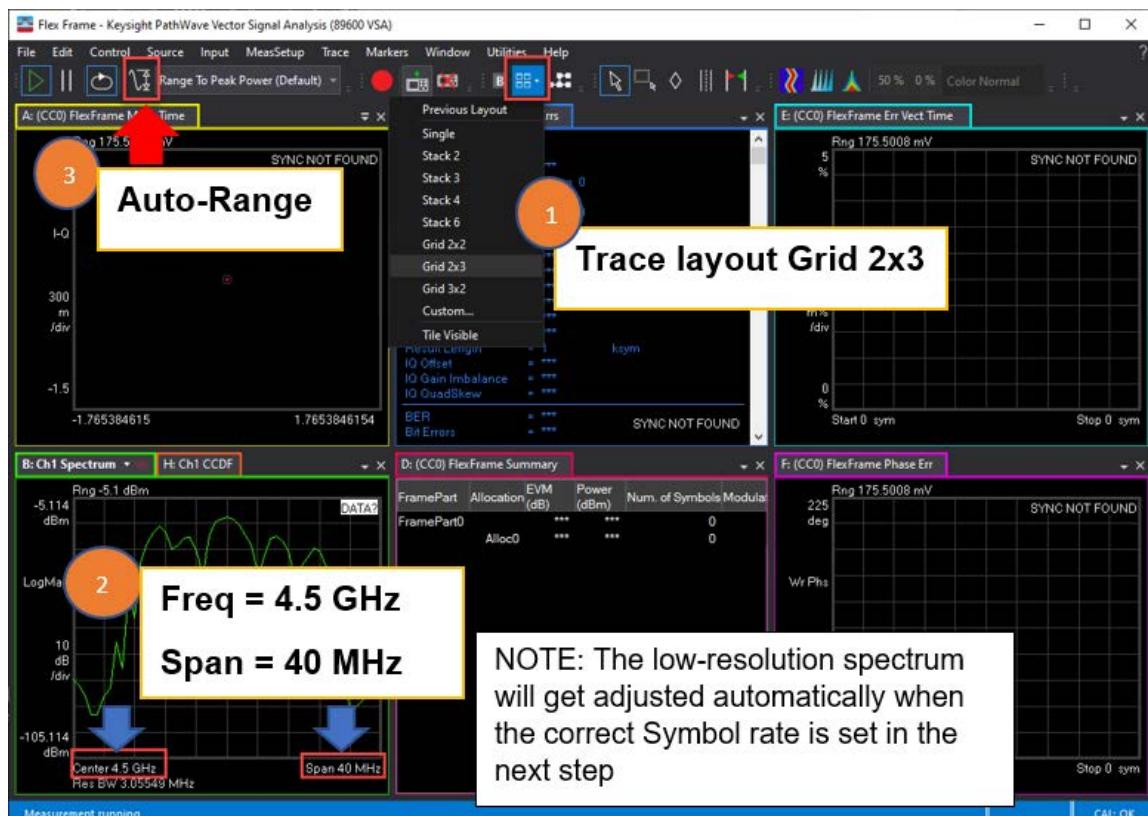
7. Select **Control** menu > **Download** to download it to your Signal Generator.

Setting up and Analyzing the Signal Using VSA Flex Frame

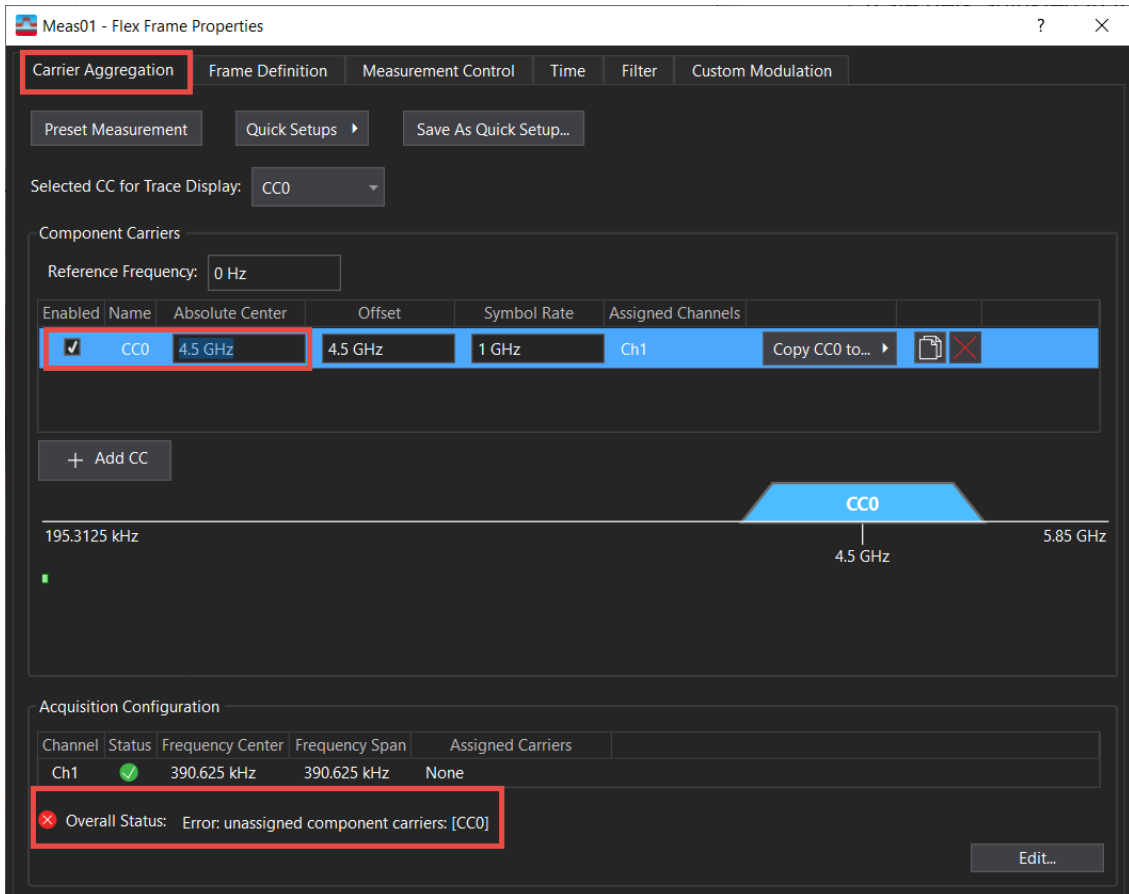
NOTE

Changing settings on the VSA can take longer to take affect than expected. Wait to change the next setting until the previous setting has been updated.

1. From the VSA menu bar, select **MeasSetup** > **Measurement Type** > **General Purpose** > **Flex Frame**.
2. Set the correct frequency, span, and input range. For this example, set:
 - Change the Trace Layout Grid to 2 x 3.
 - Change Trace B to **Ch1 Spectrum**, and set Center Frequency to **4.5 GHz**
 - Span to **40 MHz**
 - Autorange

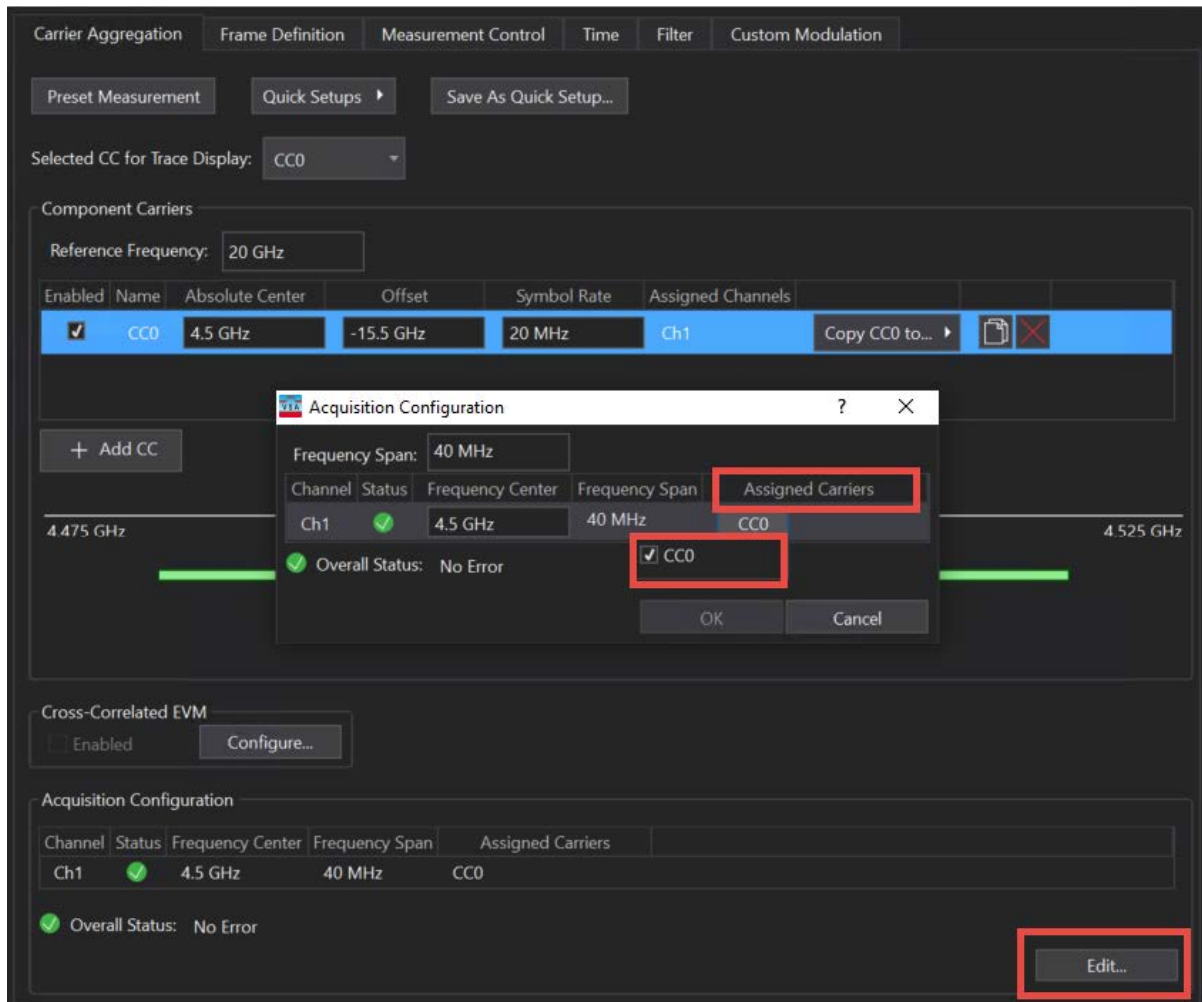


3. Select **MeasSetup > Flex Frame Properties > Carrier Aggregation** tab, then set CCO Absolute Center frequency to **4.5 GHz**.



The Symbol Rate error will be resolved once the Symbol Rate gets adjusted in **step 5**.

4. At the bottom right portion of the display, select **Edit**, then select the **Assigned Carriers** drop down and select **CC0**.

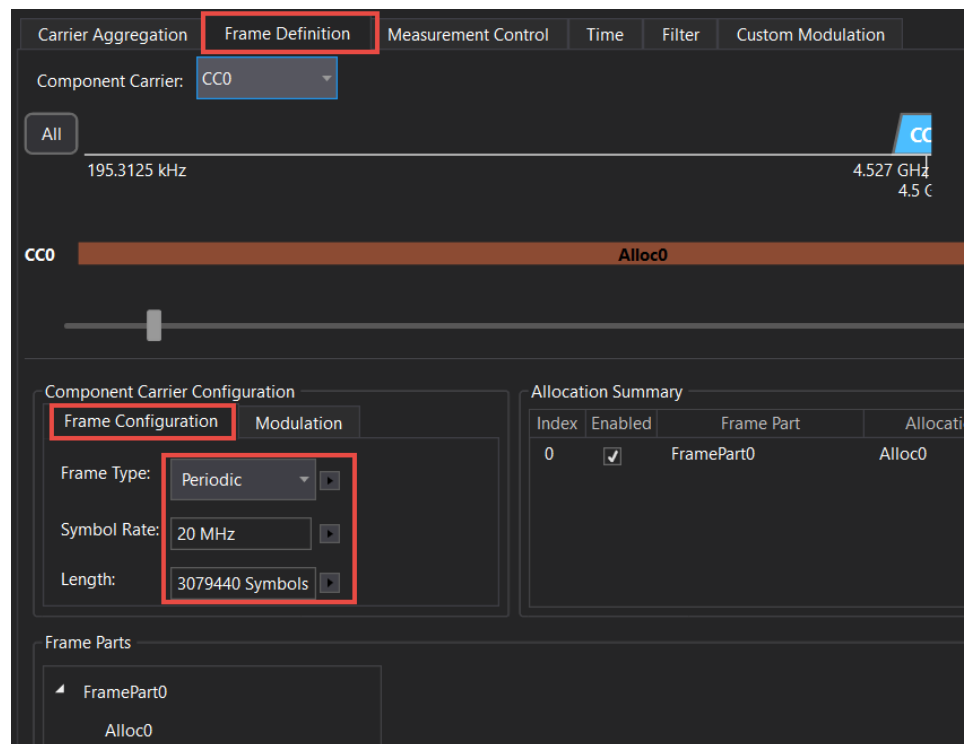


5. In the Flex Frame Properties window, select the **Frame Definition** tab and set:

- Frame Type to **Periodic**
- Symbol Rate to **20 MHz**
- Length to **3147120 Symbols**

To match the waveform length in Signal Studio.

For a bursted signal, Frame Type is set to Burst, and the frame length can be automatically set based on the detected burst length.



6. In the Component Carrier Configuration area, select the **Modulation** tab and set Preferred Bit to Symbol Mapping to **Default**.

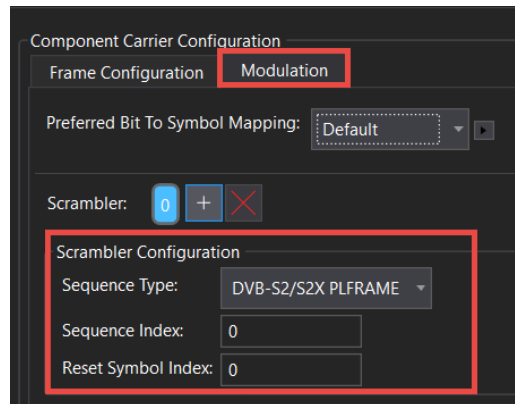
When testing a DUT, if the bit mapping into constellation point is as defined by DVB-S2X, DVB-RCS2 or 802.11ad/ay standard, selecting the correct standard under "Bit To Symbol Mapping" is required for accurate Tx BER measurement. When using Signal Studio, leave it as Default.

Constellation mapping definition between VSA Flex Frame and N7608C Signal Studio is not aligned. VSA comes with a set of bit mappings (.txt file) to recall into the N7608C and this is required for successful demodulation. You can find it under: C:\Program Files\Keysight\<version>\89600 VSA Software\Help\Signals\FlexFrame.

7. Set the Sequence Type to **DVB-S2/S2X PLFRAME**.

This selects the scrambling method as described in section 5.5.4 of EN 302.301-1.

8. Set both Sequence Index and Reset Symbol to 0.



Configure the Preamble (PLHEADER)



PLHEADER (90 symbols) includes:

- **SOF (Start of Frame): 26 symbols (y1y2...y26):**
01 1000 1101 0010 1110 1000 0010

9. Select the **Frame Configuration** tab and configure the Start of Frame Index (SOF), 26 symbols long:

- In the Frame Parts area, select **Alloc0**.
- In the Configuration area, set
 - Name to **SOF**
 - Type to **Preamble**
 - Sequence to **Custom**
 - Modulation to **DVB-S2/S2X $\pi/2$ BPSK**
 - Enter the 26 symbols
01100011010010111010000010
(011 000 110 100 101 110 100 000 10)
- In the Location area,
 - Clear the End of Frame checkbox

- Start Symbol to **0**
- Total Length to **26**

Note that Scrambling is not applied to Preamble.

The screenshot displays the VSA Flex Frame configuration interface. On the left, the 'Frame Parts' panel shows a list with 'Alloc0' highlighted. Below this are buttons for 'Add Frame Part', 'Remove Frame Part', 'Add Allocation', and 'Remove Allocation'. The main 'Configuration' panel is divided into several sections: 'Configuration' (Enabled: checked, Name: Alloc0, Type: Preamble, Power Boost: 0 dB), 'Payload' (Sequence: Custom, Custom Sequence Type: Bit Sequence, Modulation: DVB-S2/S2X $\pi/2$ BPSK, Include in BER Calculations: unchecked, Autodetect Bit Sequence Offset: unchecked, and a bit sequence field containing '01100011010010111010000010'), 'Scrambling' (Enabled: unchecked, Scrambler ID: 0), and 'Location' (Start Symbol: 0, Last Symbol: 25, Symbol Index: 25, Total Length: 26 Symbols, End of Frame: unchecked, Repeat Pattern: unchecked, Repetition Parameters: Active Symbols: 0, Repeat every: 1 Symbols).

Configure the PLS (PHY Layer Signaling) Code 64 symbols long

10. In the Frame Parts area:

- Select **Add Allocation**

11. In the Configuration area, set:

- Name to **PLSCODE**
- Type to **Preamble**
- Sequence to **Unknown**
- Modulation to **DVB-S2/S2X $\pi/2$ BPSK**

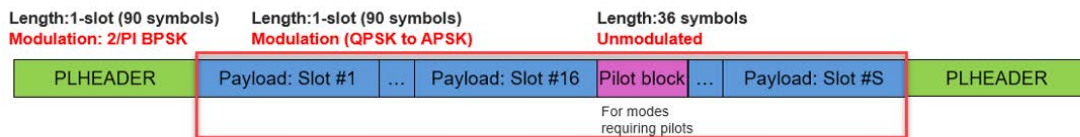
Notice that Scrambling is not applied to Preamble.

12. In the Location area, set:

- Clear the End of Frame checkbox
- Start Symbol to **26**

- Total Length to **64 Symbols**

Configure the Payload



- Payload length is multiple slots of 90 symbols each
- Pilots are grouped in blocks of 36 symbols and inserted every 16 payload slots

13. In the Frame Part area, select **Add Allocation**.

14. In the Configuration area:

- Name to **Data**
- Type to **Data**
- Sequence to **Unknown**
- Modulation to **DVB-S2/S2X APSK**
Notice that Scrambling is not applied to Preamble.
- MODCOD to **256APSK Normal 128/180**
- Scrambling to **Enabled**

15. In the Location area, set:

- Start Symbol to **90**
- Last Symbol to **End of Frame**
- Select **Repeat Pattern**
- Set Active Symbols to **0:1439**

Before the Pilot block, there are 16 payload slots, each 90 symbols long resulting in 1440 active symbols.

- Repeat every to **1476 Symbols**

The 1440 payload symbols are followed by a 36-symbols Pilot block resulting in a total of 1476 symbols. This will repeat until the end of the frame length.

The screenshot shows the 'Frame Parts' configuration window. On the left, a tree view shows 'FramePart0' with sub-items 'Alloc0', 'PLSCODE', and 'Alloc2', and 'FramePart1' with 'Data'. Below this are buttons for 'Add Frame Part', 'Remove Frame Part', 'Add Allocation', and 'Remove Allocation'. The 'Add Allocation' button is highlighted with a red box. The main area is divided into 'Configuration' and 'Location' sections. In the 'Configuration' section, 'Name' is set to 'Data', 'Type' is 'Data', 'Power Boost' is '0 dB', 'Sequence' is 'Unknown', 'Modulation' is 'DVB-S2/S2X APSK', and 'MODCOD' is '256APSK Normal 128/180'. The 'Scrambling' section has 'Enabled' checked and 'Scrambler ID' set to '0'. In the 'Location' section, 'Start Symbol' is '90', 'Last Symbol' is 'End of Frame', 'Repeat Pattern' is checked, 'Active Symbols' is '0:1439', and 'Repeat every' is '1476 Symbols'. Several fields and checkboxes are highlighted with red boxes.

Configure the Pilot

16. In the Frame Part area, select Add Allocation.

17. In the Configuration area:

- Name to **Pilot**
- Type to **Pilot**
- Sequence to **Unknown**
- Modulation to **QPSK**

Pilots are unmodulated, but they are identified by
 $I=Q=1/\sqrt{2}$

- Scrambling to **Enabled**

18. In the Location area, set:

- Start Symbol to **90**
- Last Symbol, select **End of Frame**
- Select **Repeat Pattern**
- Set Active Symbols to **1440:1475**

Pilot is 36 symbols long following a 1440 symbols long payload.

- Repeat every to **1476 Symbols**

The 1440 payload symbols are followed by a 36-symbols Pilot block resulting in a total of 1476 symbols. This will repeat until the end of the frame length.

The screenshot shows the 'Frame Parts' configuration window. On the left, a tree view shows 'FramePart0' with sub-items 'Alloc0', 'PLSCODE', and 'Pilot' (selected), and 'FramePart1' with 'Data'. Below this are buttons: 'Add Frame Part', 'Remove Frame Part', 'Add Allocation' (highlighted with a red box), and 'Remove Allocation'. The main area has two tabs: 'Configuration' and 'Location'. The 'Configuration' tab is active, showing: 'Enabled' (checked), 'Name' (Pilot), 'Type' (Pilot), 'Power Boost' (0 dB), 'Payload' (Sequence: Unknown, Modulation: QPSK), 'Scrambling' (checked), and 'Scrambler ID' (0). The 'Location' tab is also visible, showing: 'Start Symbol' (90), 'Last Symbol' (End of Frame), 'Repeat Pattern' (checked), 'Active Symbols' (1440:1475), and 'Repeat every' (1476 Symbols). Several fields and checkboxes are highlighted with red boxes.

Configure Synchronization and Equalization

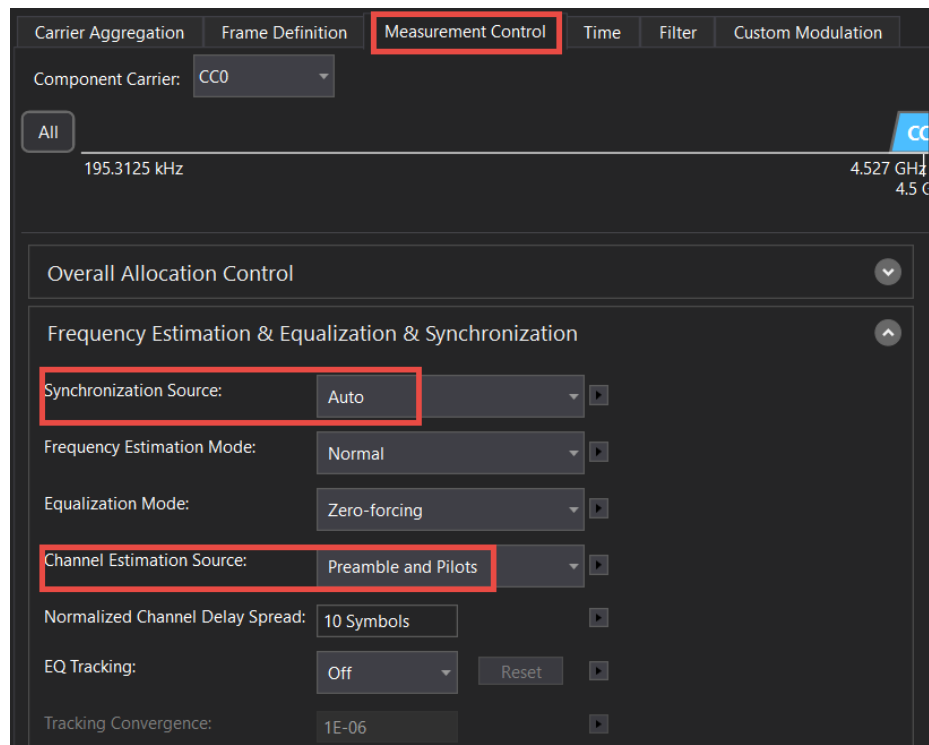
19. Select the **Measurement Control** tab, and set:

- Synchronization Source to **Auto**

By default, SOF is used for synchronization. This can be changed to "Customized" to add additional frame parts for synchronization.

- Channel Estimation Source to **Preamble and Pilots**

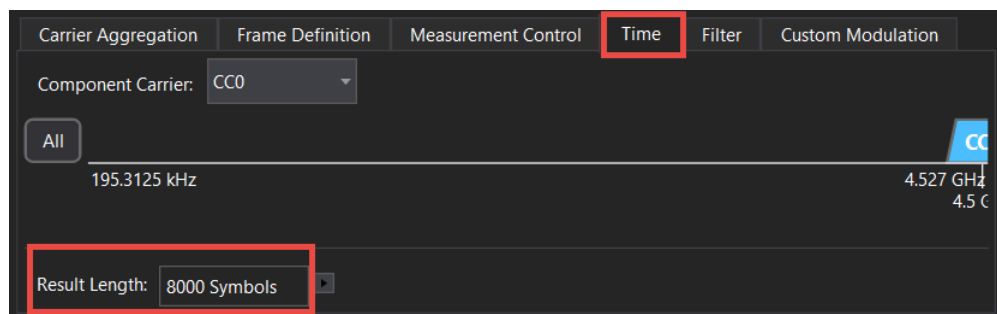
Equalization is off by default. You can choose the different frame parts for channel estimation and equalization.



Configure the Analysis Region

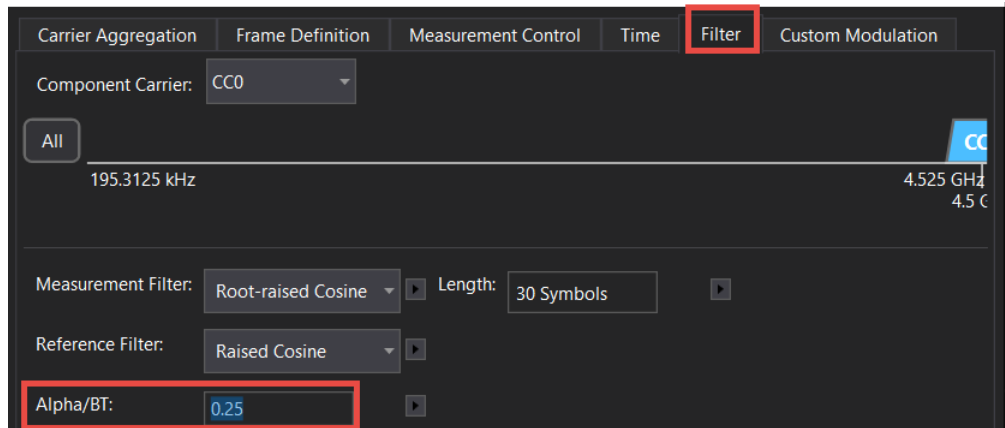
20. Select the Time tab, set the Result Length to 8000 Symbols.

Setting the result length to \leq the waveform length when oversampling ratio of 1, provides the best performance. In Signal Studio, when oversampling ratio is set to 1, the waveform length is 8370. Using a result length of ≤ 8370 symbols provides the best EVM performance.



Configure the RRC filter

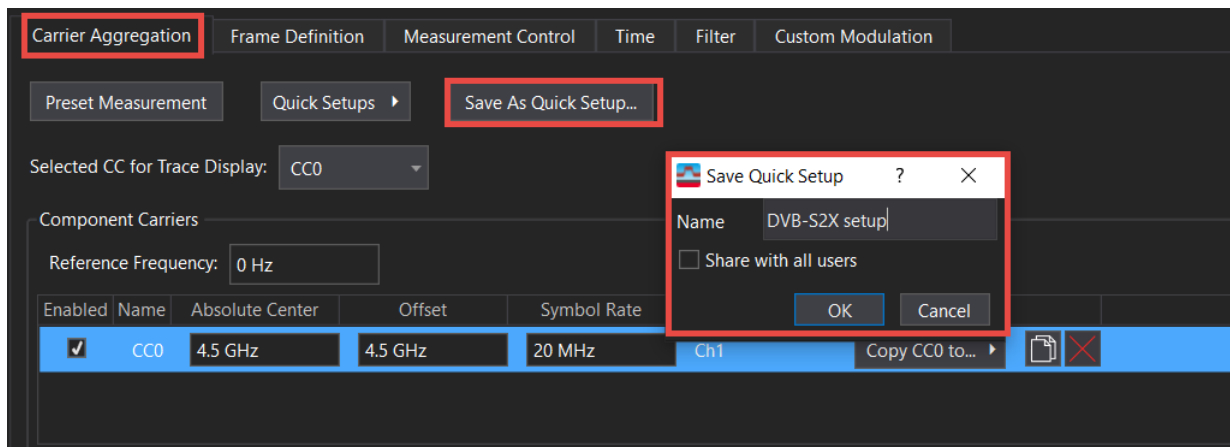
21. In the **Filter** tab, set Alpha/BT: to 0.25.



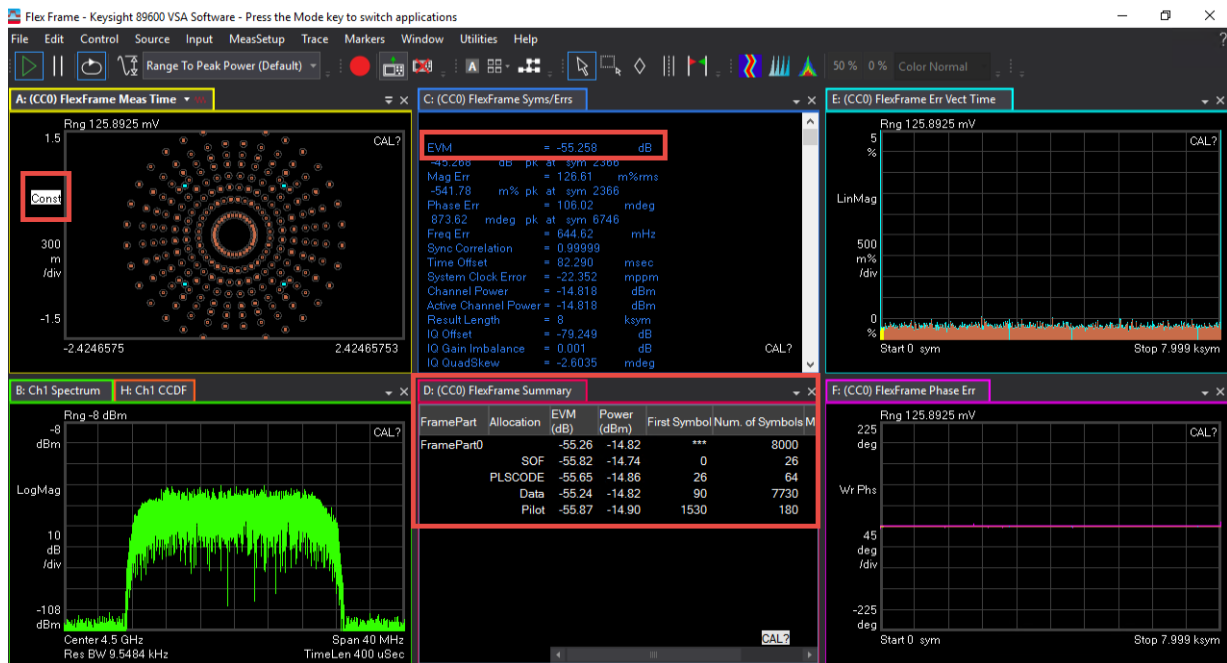
Save the Configuration as a Quick Setup

22. In the **Carrier Aggregation** tab, select **Save As Quick Setup**.

This saves the measurement settings for future use. Select **Share with all users** if you want to share with other users on the PC running the VSA software.



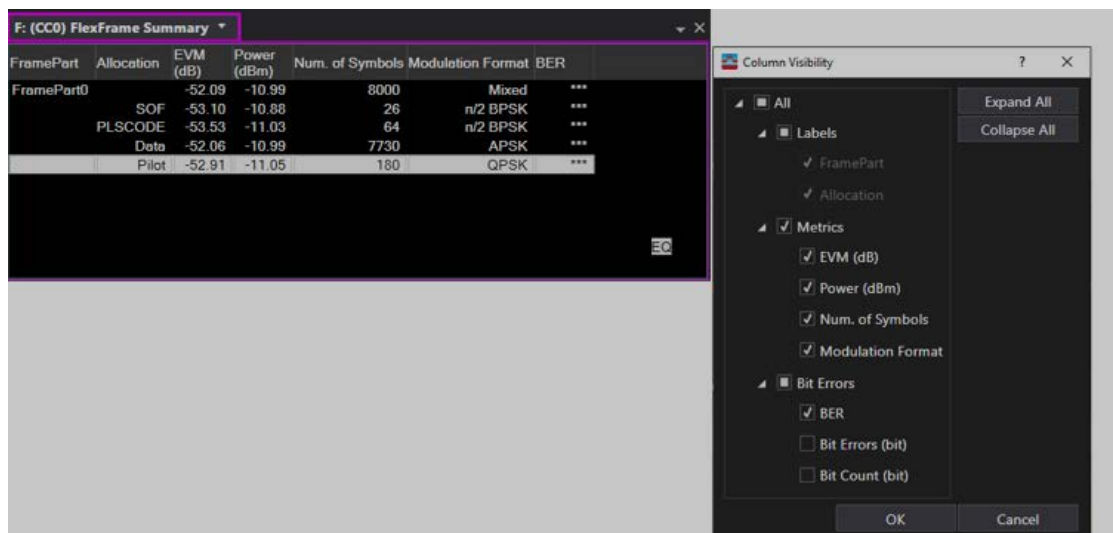
23. Close the Properties window and change Trace A to a Constellation Diagram, then view the results.



You should see a successful demodulation with very low EVM. Multiple traces and tables are available including Error Vector Spectrum, Error Vector Time, demod, and BER Bits.

The FlexFrame Summary table is a type of Matrix Table that provides sortable rows by column, selectable column visibility, and copy/paste and export functionality to share rows of content or complete tables to applications like email, text editing or spreadsheet programs.

Right click the column header to display the menu.



Advanced Measurements

Using the VSA Flex Frame to Create a DVB-S2X Signal

FlexFrame Summary always displays the EVM of each active segment. Flex Frame Syms/Errs table shows composite EVM of segment(s) selected under Measurement Control -> Include EVM. By default, it shows all segments.

C: (CC0) FlexFrame Syms/Errs

EVM	=	-55.947	dB	-24.768	dB	pk	at	sym	7314
Magn Err	=	132.57	m%rms	608.37	m%	pk	at	sym	7314
Phase Err	=	107.98	mdeg	738.58	mdeg	pk	at	sym	4986
Freq Err	=	942.74	uHz						
Sync Correlation	=	0.99998							
Time Offset	=	212.74	uSec						
System Clock Error	=	-14.992	ppm						
Channel Power	=	-10.998	dBm						
Active Channel Power	=	-10.995	dBm						
Result Length	=	8	ksym						
IQ Offset	=	-59.135	dB						
IQ Gain Imbalance	=	0.002	dB						
IQ QuadSkew	=	-11.108	mdeg						
BER	=	***							
Bit Errors	=	***							
Bit Count	=	***							

D: (CC0) FlexFrame Summary

FramePart	Allocation	EVM (dB)	Power (dBm)	Num. of Symbols	Modulation Format	BER
FramePart0		-54.86	-10.99	8000	Mixed	***
	SOF	-55.55	-10.88	26	n/2 BPSK	***
	PLSCODE	-56.12	-11.03	64	n/2 BPSK	***
	Data	-54.84	-10.99	7730	APSK	***
	Pilot	-55.57	-11.05	180	QPSK	***

FlexFrame Properties - Measurement Control

Frame Part	Allocation	Type	Include in EVM	Calculate BER	Synchronization	Chan Estimation
FramePart0	SOF	Preamble	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
FramePart0	PLSCODE	Preamble	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
FramePart0	Data	Data	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
FramePart0	Pilot	Pilot	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Part 2: Generating a DVB-S2X Waveform Using the N7608APPC Signal Studio for Custom Modulation

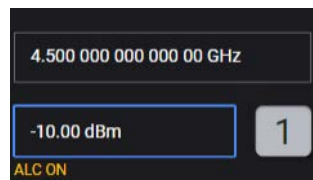
For this example, we will use the embedded N7608APPC application on the M9484C VXG.

NOTE

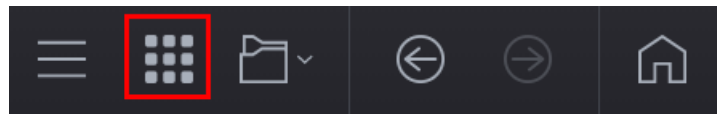
The VXG must have the N7608APPC Signal Generation for Custom Modulation license installed. You can also use N7608C Signal Studio for Custom Modulation

Setting Up the Waveform in PathWave Custom Modulation

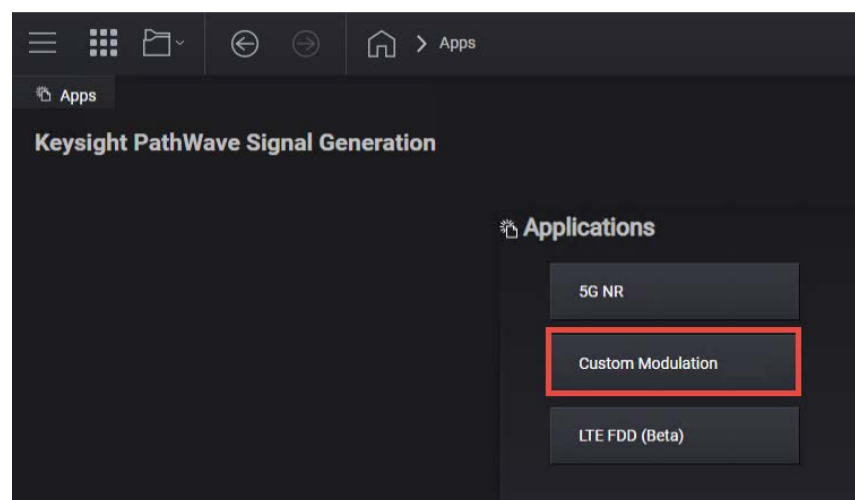
1. On the VXG, select **Preset > Preset** to set the VXG to a known state.
2. In the Output area, set Frequency to **4.5 GHz** and Power to **-10 dBm**.



3. Select the **Radio Apps** block to open the Vector Modulation Signal Setup panel.

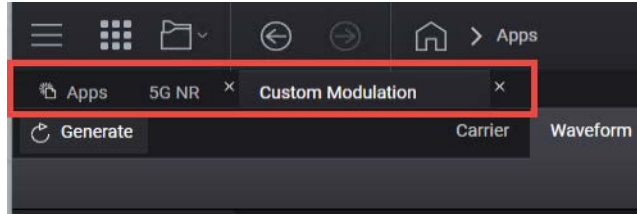


4. Select **Custom Modulation** to enter Custom Modulation Signal Mode.

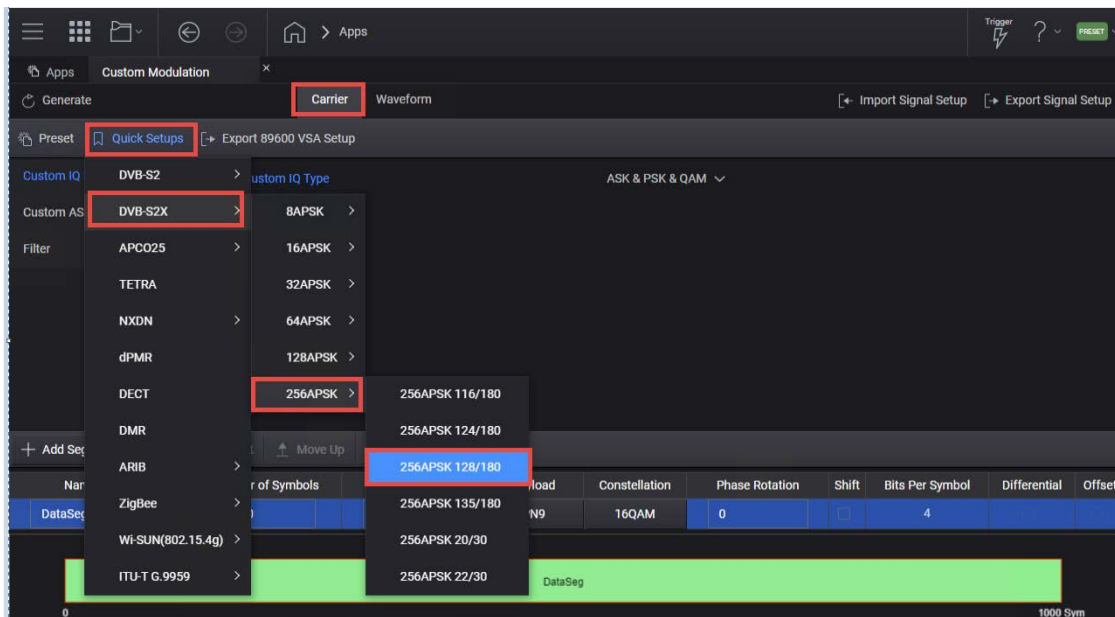


NOTE

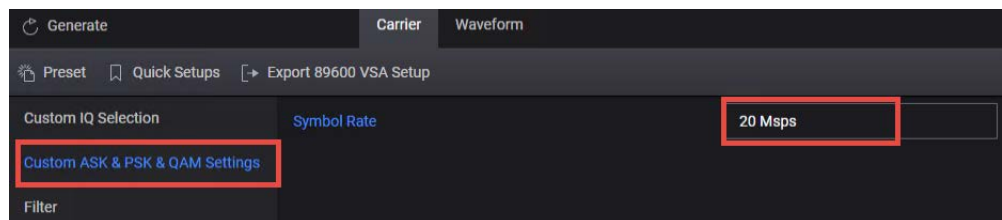
If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



5. In the Custom Modulation setup, select the **Carrier** tab > **Quick Setups** > **DVB-S2X** > **256APSK** > **256APSK 128/180**.



6. From the left pane, select **Custom ASK & PSK & QAM Settings** and set the Symbol Rate to **20 Msps** per channel.



7. Select **Filter** > Alpha to **0.25**.

Filter length is 32 symbols, which we will set this value in the VSA.



Configure the PLHEADER (Preamble)

In Part 1, the PLHEADER using $\pi/2$ -BPSK modulation is split into two: SOF (Start of Frame) of 26 symbols and PLS (PHY Layer Signaling) of 64 symbols for a total of 90 symbols. The N7608C by default uses a single segment for PLHEADER with 90 symbols using QPSK modulation and provides a payload of 180 symbols. For the purpose of this example, we will merge the two. You can split the PLHEADER into two by adding a segment and provide a payload of

Advanced Measurements

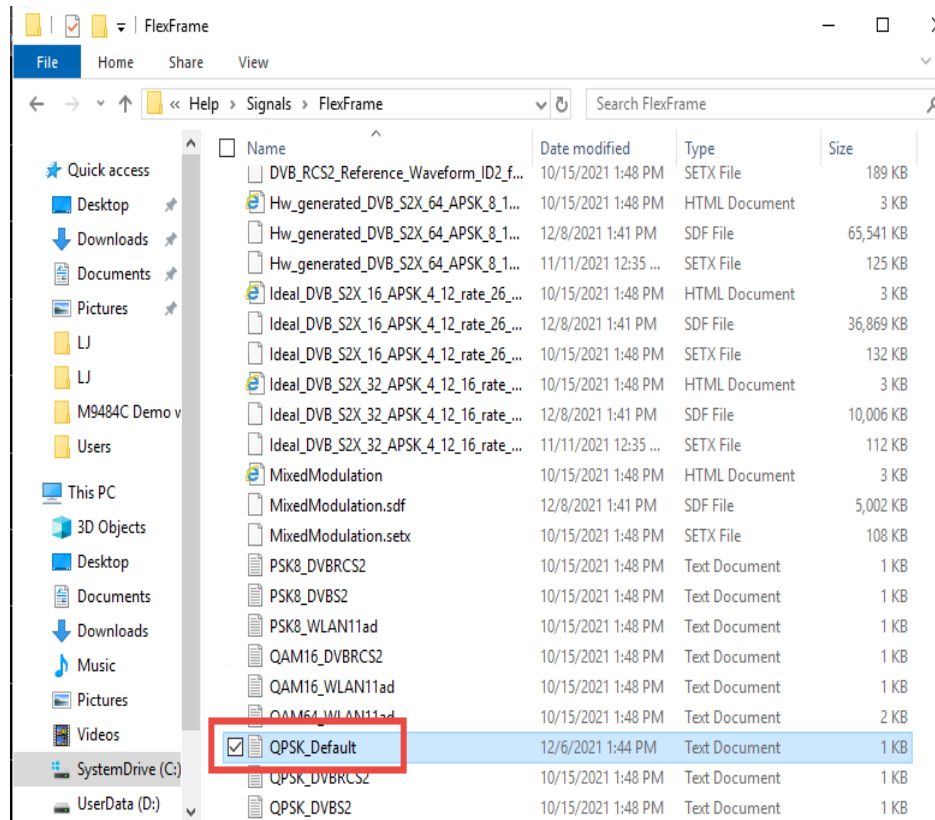
Using the VSA Flex Frame to Create a DVB-S2X Signal

52 symbols for the SOF. Since N7608C doesn't support $\pi/2$ -BPSK modulation, it uses QPSK so it would require a payload of 52 symbols for the SOF, instead of the 26-symbols used in Part 1.

NOTE

Default constellation symbol mappings of VSA Flex Frame and N7608C/APPC do not match. VSA provides .txt files to load into the N7608C/APPC to match the mapping. These .txt files are in the VSA installer under:

C:\Program Files\Keysight\<version>\89600 VSA Software\Help\Signals\FlexFrame.



NOTE

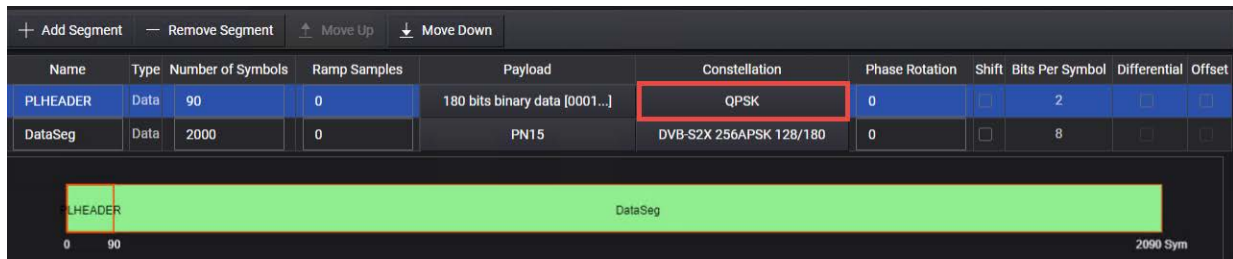
For the convenience of this demonstration, the QPSK text file has already been copied onto the VXG.

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples\QPSK_Default_for FlexFrame Example

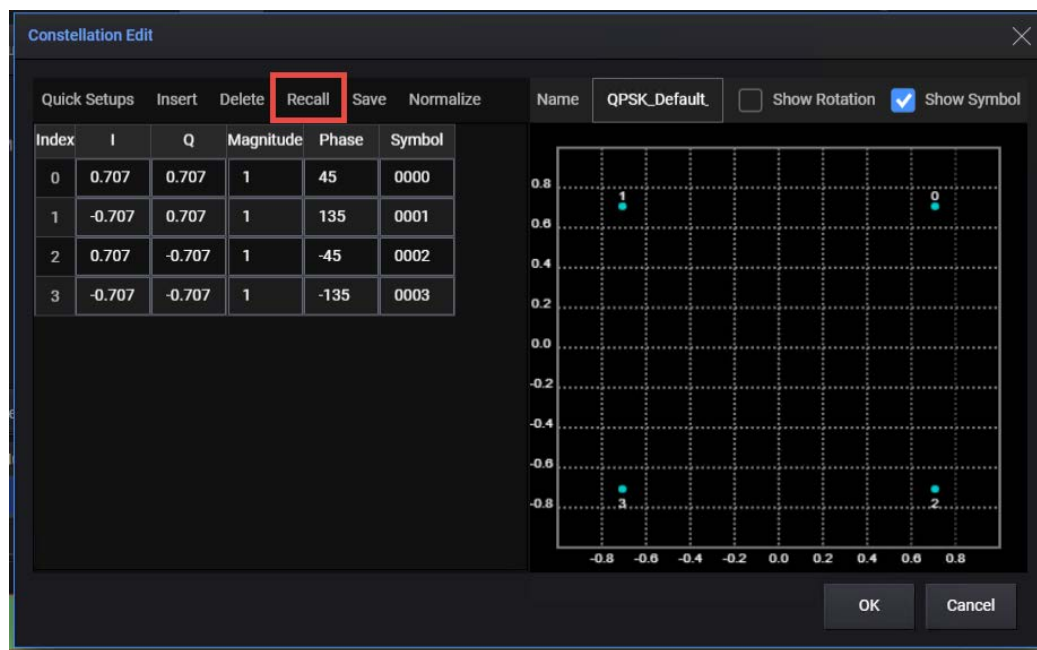
Advanced Measurements

Using the VSA Flex Frame to Create a DVB-S2X Signal

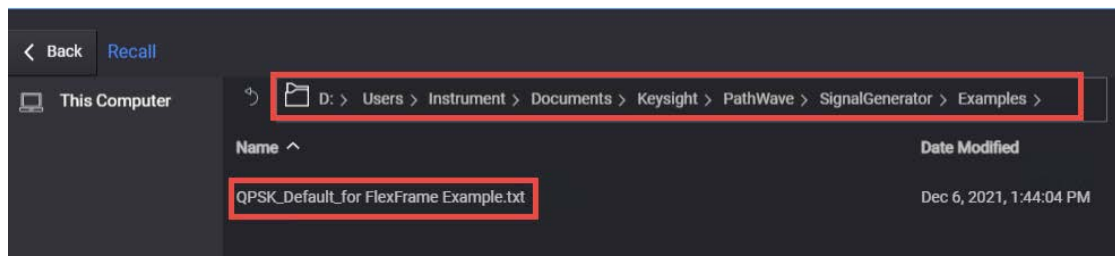
8. From the bottom pane, select the PLHEADER row > **QPSK** constellation to open the Constellation Edit window.



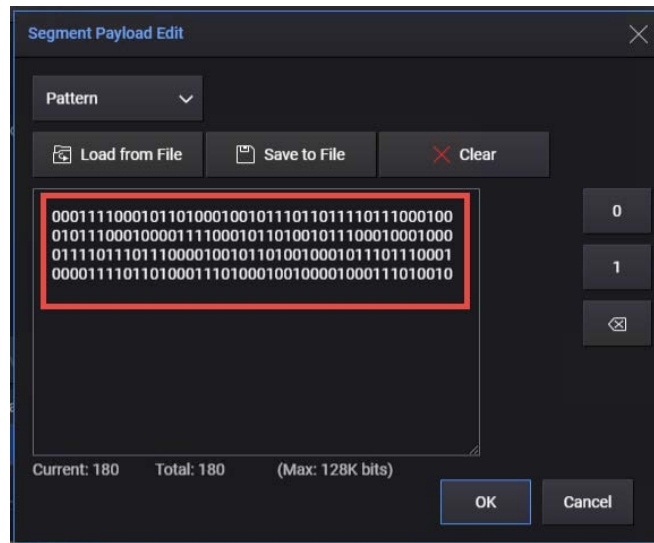
9. In the Constellation Edit dialog, select **Recall**.



10. Navigate to the text file and choose **Select**. Select **OK** to Close the Constellation Edit dialog.



11. In the PLHEADER row, under Payload, select **180 bits binary data [0001...]** to open the Segment Payload Edit dialog. Select and copy the 180 symbols. These will be pasted in to the VSA for synchronization.



12. To configure the Payload, from the DataSeq row, set the Number of Symbols to **1440**.

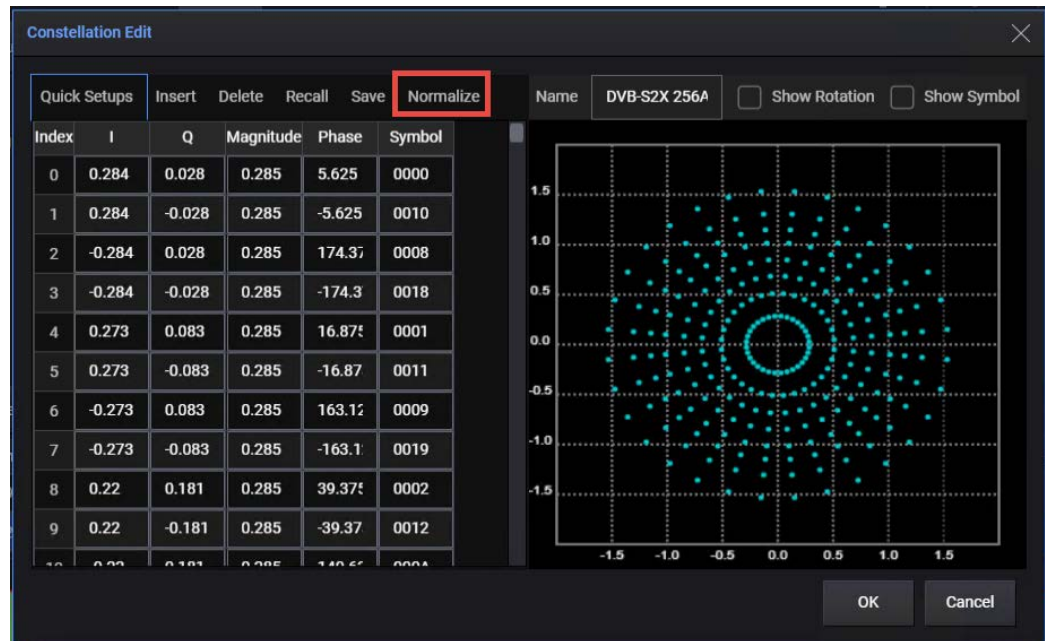
Name	Type	Number of Symbols	Ramp Samples	Payload	Constellation	Phase Rotation	Shift	Bits Per Symbol	Differential	Offset
PLHEADER	Data	90	0	180 bits binary data [0001...]	QPSK_Default_for FlexFrame Example	0	<input type="checkbox"/>	2	<input type="checkbox"/>	<input type="checkbox"/>
DataSeq	Data	1440	0	PN15	DVB-S2X 256APSK 128/180	0	<input type="checkbox"/>	8	<input type="checkbox"/>	<input type="checkbox"/>

Use 16 payload slots (90 symbols/slot) for the radio frame. These are the slots prior to Pilot. Pilots are optional and not generated (See part 1 of this demo guide for a frame with pilot segment).

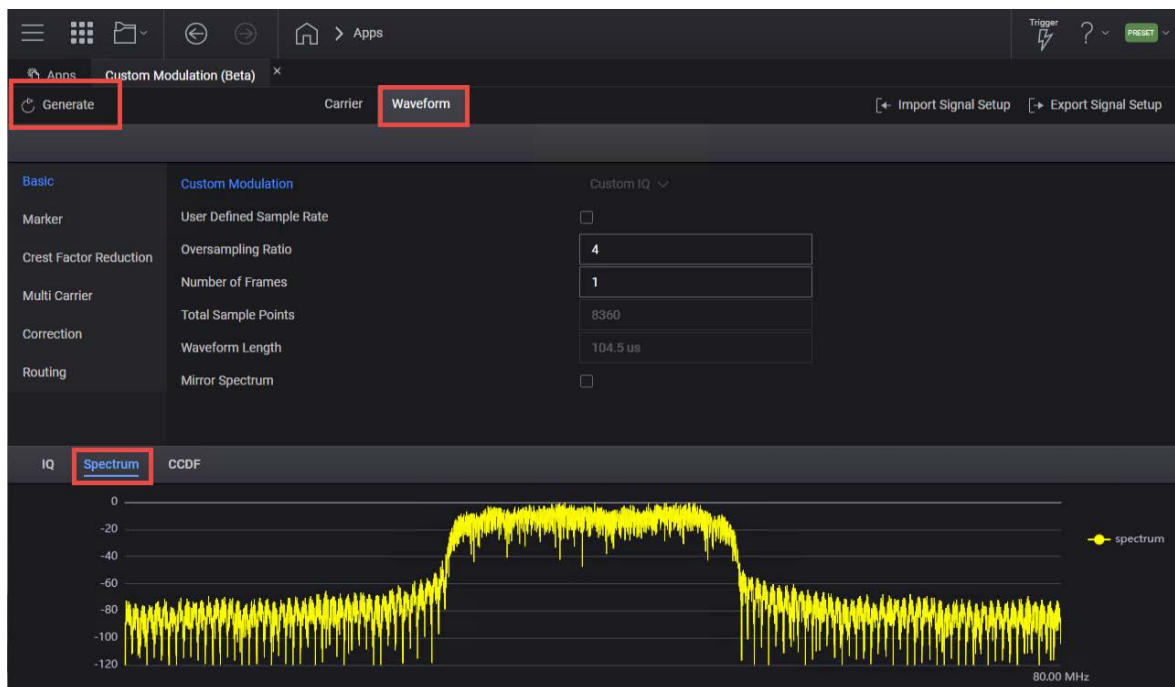
13. In the DataSeq row, under the Constellation area, select **DVB-S2X256APSK 128/180** to open the Constellation editor, and then select **Normalize**.

Advanced Measurements
Using the VSA Flex Frame to Create a DVB-S2X Signal

It is a good idea to normalize the power. Difference power levels between data and preamble can result in high EVM.

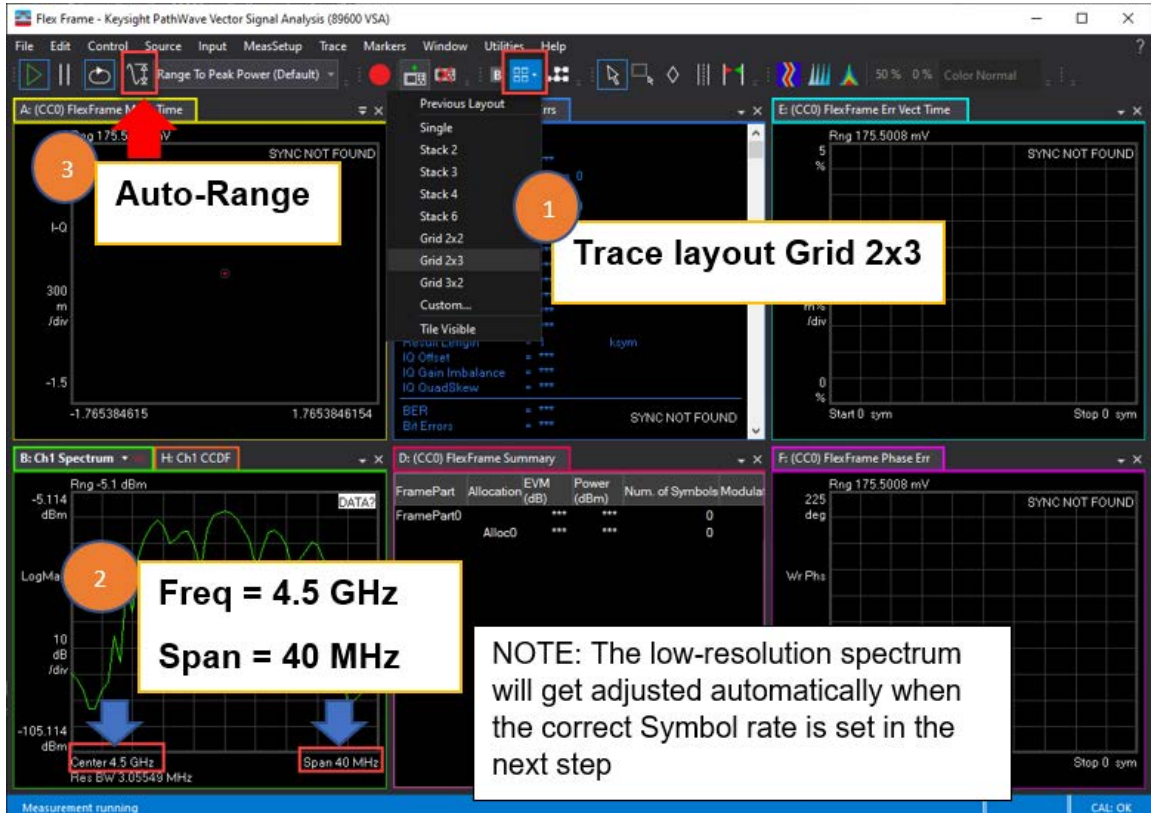


14. Close the Constellation editor and select **Generate** to generate the waveform. To view the Generated waveform, select the **Waveform** tab and select **Spectrum**.



2. Set the correct frequency, span, and input range. For this example, set:

- Change the Trace Layout Grid to 2 x 3.
- Change Trace B to **Ch1 Spectrum**, and set Center Frequency to **4.5 GHz**
- Span to **40 MHz**
- Autorange



3. Select **MeasSetup** > **Flex Frame Properties** > **Carrier Aggregation** tab, then set CCO Absolute Center frequency to **4.5 GHz**.

Carrier Aggregation | Frame Definition | Measurement Control | Time | Filter | Custom Modulation

Preset Measurement | Quick Setups ▶ | Save As Quick Setup...

Selected CC for Trace Display: CC0 ▼

Component Carriers

Reference Frequency: 20 GHz

Enabled	Name	Absolute Center	Offset	Symbol Rate	Assigned Channels	
<input checked="" type="checkbox"/>	CC0	4.5 GHz	-15.5 GHz	1 GHz	Ch1	Copy CC0 to... ▶

+ Add CC

Frequency Diagram: 3.15 GHz | 4.5 GHz (CC0) | 5.85 GHz

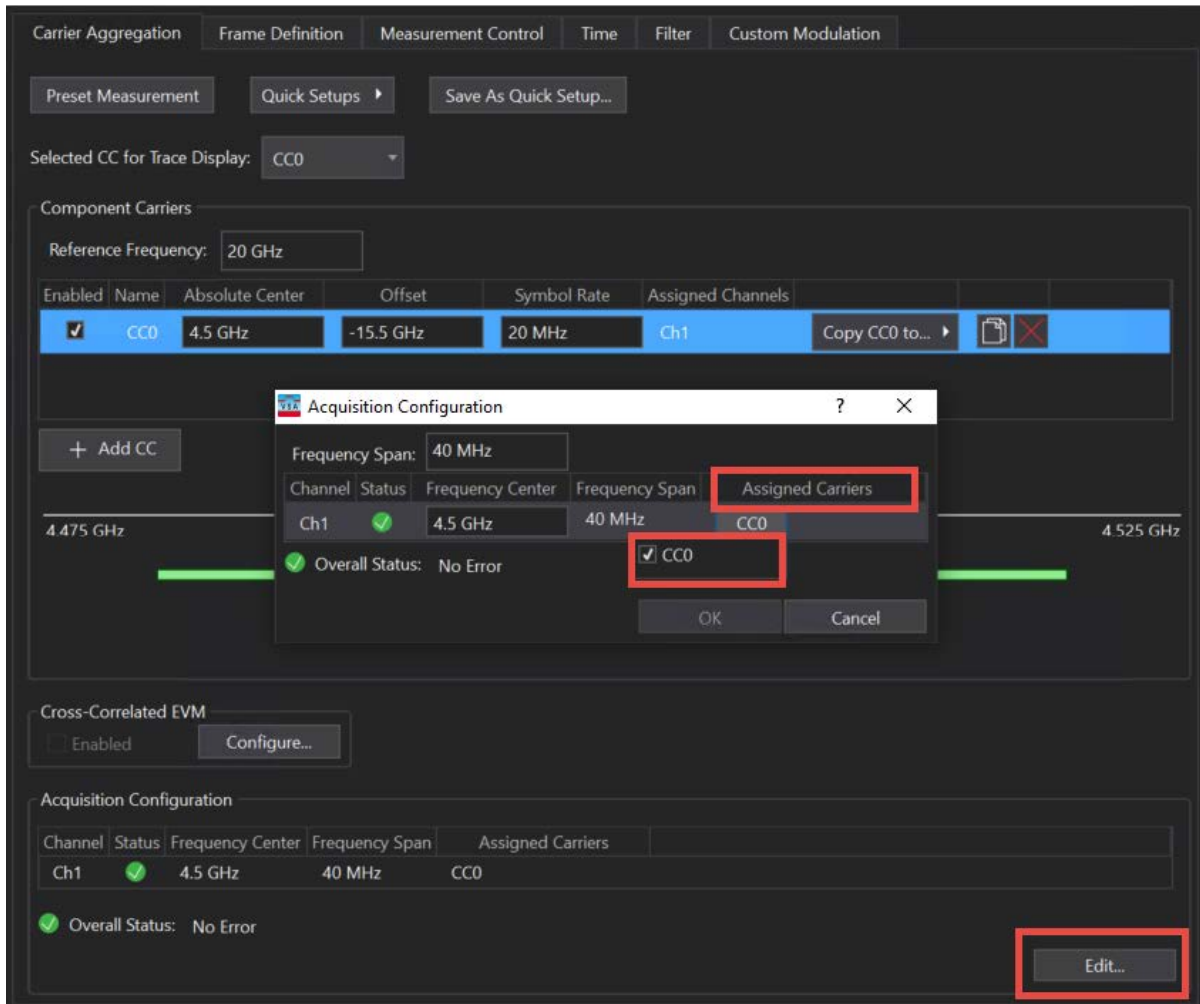
Cross-Correlated EVM
☐ Enabled | Configure...

Acquisition Configuration

Channel	Status	Frequency Center	Frequency Span	Assigned Carriers
Ch1		4.5 GHz	40 MHz	CC0

Overall Status: Error: CC0 bandwidth (Symbol Rate) not entirely captured within Ch1 bandwidth. Edit...

4. At the bottom right portion of the display, select **Edit**, then select the Assigned Carriers drop down and select **CC0**.

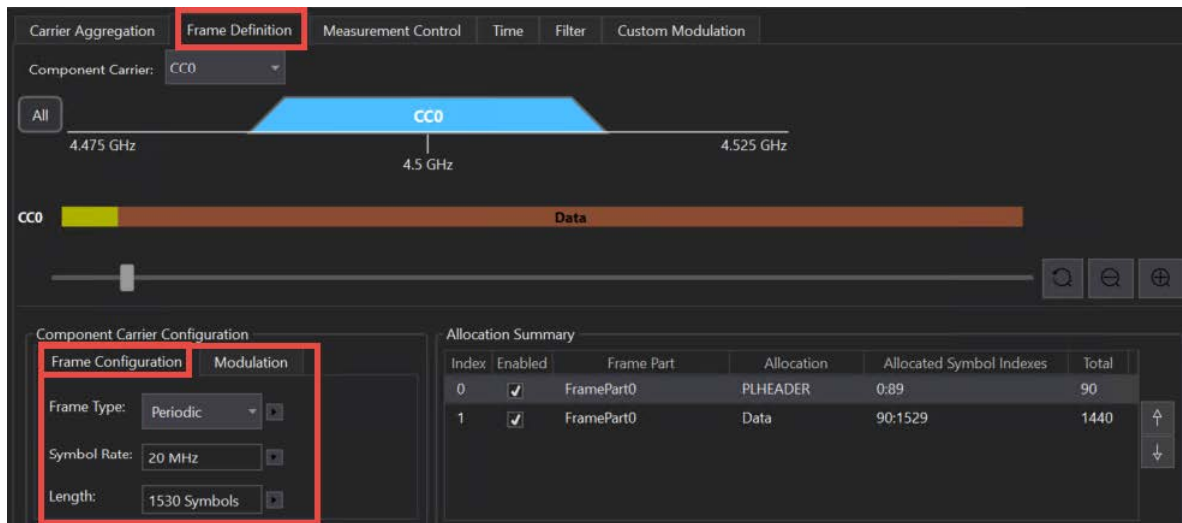


5. In the Flex Frame Properties window, select the **Frame Definition** tab and set:

- Frame Type to **Periodic**
- Symbol Rate to **20 MHz**
- Length to **1530 Symbols**

This is 90 symbols of PLHEADER plus 1430 symbols of data.

For a bursted signal, Frame Type is set to Burst, and the frame length can be automatically set based on the detected burst length.



Configure the Preamble (PLHEADER)

6. Configure the Start of Frame Index (Preamble), 90 symbols long:

- In the Frame Parts area, select **Alloc0**.
- In the Configuration area, set
 - Name to **PLHEADER**
 - Type to **Preamble**
 - Sequence to **Custom**
 - Modulation to **QPSK**
 - Enter the 180 symbols you copied over from the Custom Modulation PLHEADER Payload setup in **step 11**.
- In the Location area,
 - Clear the End of Frame checkbox
 - Start Symbol to **0**

- Total Length to **90**

The screenshot shows the 'Frame Parts' configuration window. On the left, 'FramePart0' is selected, and 'PLHEADER' is highlighted. The main area is divided into three sections: Configuration, Location, and Scrambling. The Configuration section is highlighted with a red box and contains the following settings: Enabled (checked), Name (PLHEADER), Type (Preamble), Power Boost (0 dB), Sequence (Custom), Custom Sequence Type (Bit Sequence), Modulation (QPSK), Include in BER Calculations (unchecked), and Autodetect Bit Sequence Offset (unchecked). Below these settings is a text box containing a 6-line bit sequence. The Location section is also highlighted with a red box and contains: Start Symbol (0), Last Symbol (89), Symbol Index (89), Total Length (90 Symbols), and End of Frame (unchecked). The Scrambling section at the bottom has Scrambling Enabled (unchecked) and Scrambler ID (0). At the bottom left, there are buttons for 'Add Frame Part', 'Remove Frame Part', 'Add Allocation', and 'Remove Allocation'.

7. Configure the Payload 1440 symbols long:
 - In the Frame Parts area:
 - Select **Add Allocation**
8. In the Configuration area, set:
 - Name to **Data**
 - Type to **Data**
 - Sequence to **PN15**
 - Modulation to **DVB-S2/S2X APSK**
 - MODCOD to **256APSK Normal 128/180**
 - Select **Include in BER Calculations**
 - Select **Autodetect Bit Sequence Offset**
9. In the Location area, set:
 - Start Symbol to **90**

– Last Symbol to **End of Frame**

Index	Enabled	Frame Part	Allocation	Allocated Symbol Indexes	Total
0	<input checked="" type="checkbox"/>	FramePart0	PLHEADER	0:89	90
1	<input checked="" type="checkbox"/>	FramePart0	Data	90:1529	1440

Configuration	Location
Enabled: <input checked="" type="checkbox"/>	Start Symbol: 90
Name: Data	Last Symbol: 90
Type: Data	Symbol Index: 90
Power Boost: 0 dB	- or -
Payload: PN15	Total Length: 1 Symbols
Modulation: DVB-S2/S2X APSK	<input checked="" type="checkbox"/> End of Frame
MODCOD: 25bAPSK Normal 128/180	<input type="checkbox"/> Repeat Pattern
<input checked="" type="checkbox"/> Include in BER Calculations	Repetition Parameters
<input checked="" type="checkbox"/> Autodetect Bit Sequence Offset	Active Symbols: 0
<input type="checkbox"/> Scrambling	Repeat every: 1 Symbols
Scrambler ID: 0	

TIP

Include in BER Calculations: BER is supported if the allocation's payload sequence is either a PN type or a Custom bit sequence.

Autodetect Bit Sequence Offset: Supported when the segment(s) is not used for synchronization.

If not selected (unchecked), demodulator assumes the bit sequence starts at the beginning of the allocation.

If selected, demodulator finds the best match to the bit sequence.

Configure Synchronization and Equalization

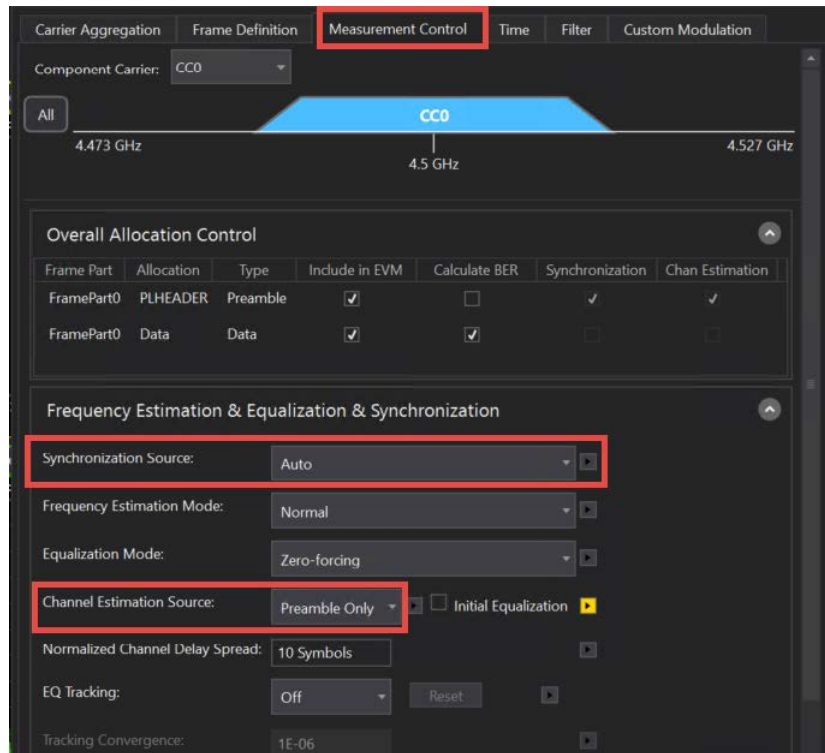
10. Select the **Measurement Control** tab, and set:

- Synchronization Source to **Auto**

By default, PLHEADER is used for synchronization. This can be changed to "Customized" to also include the Data segment for synchronization. Calculated BER must be cleared (unchecked) from Data before selecting if for Synchronization.

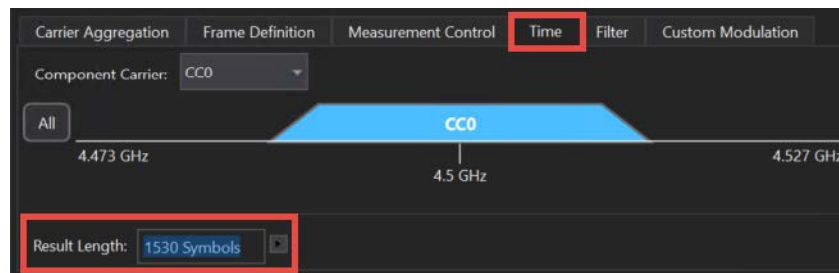
- Channel Estimation Source to **Preamble Only**

Equalization is off by default. You can choose the different frame parts for channel estimation and equalization.



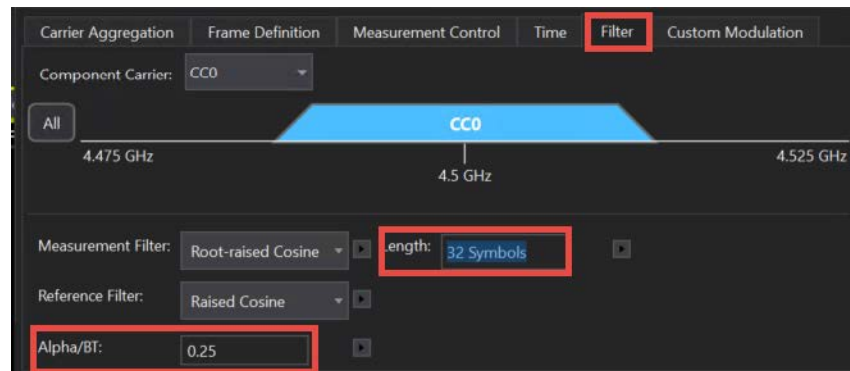
Configure the Analysis Region

11. Select the **Time** tab, set the Result Length to **1530 Symbols**.
90 for the preamble plus 1440 for the data.



Configure the RRC filter

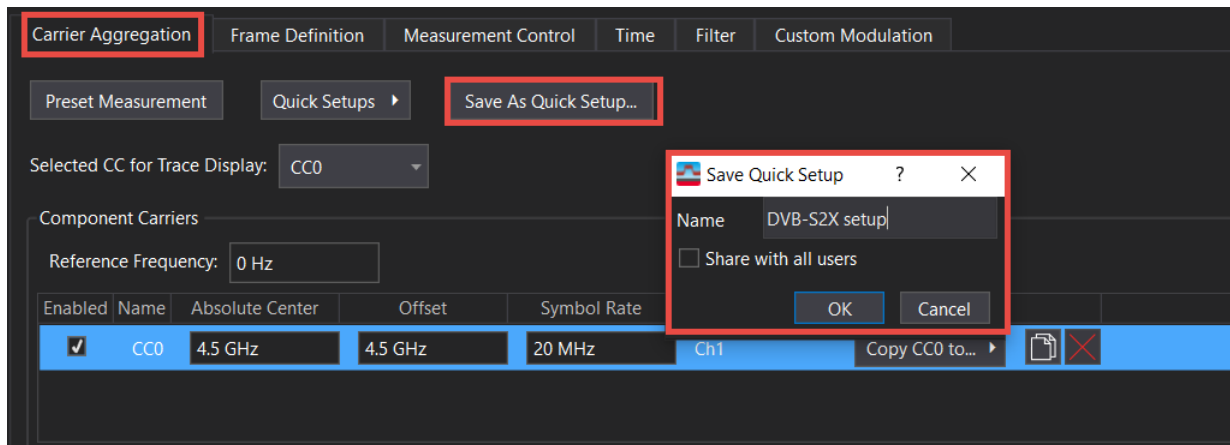
12. In the **Filter** tab, set Alpha/BT: to **0.25** and Length to **32 Symbols**.



Save the Configuration as a Quick Setup

13. In the **Carrier Aggregation** tab, select **Save As Quick Setup**.

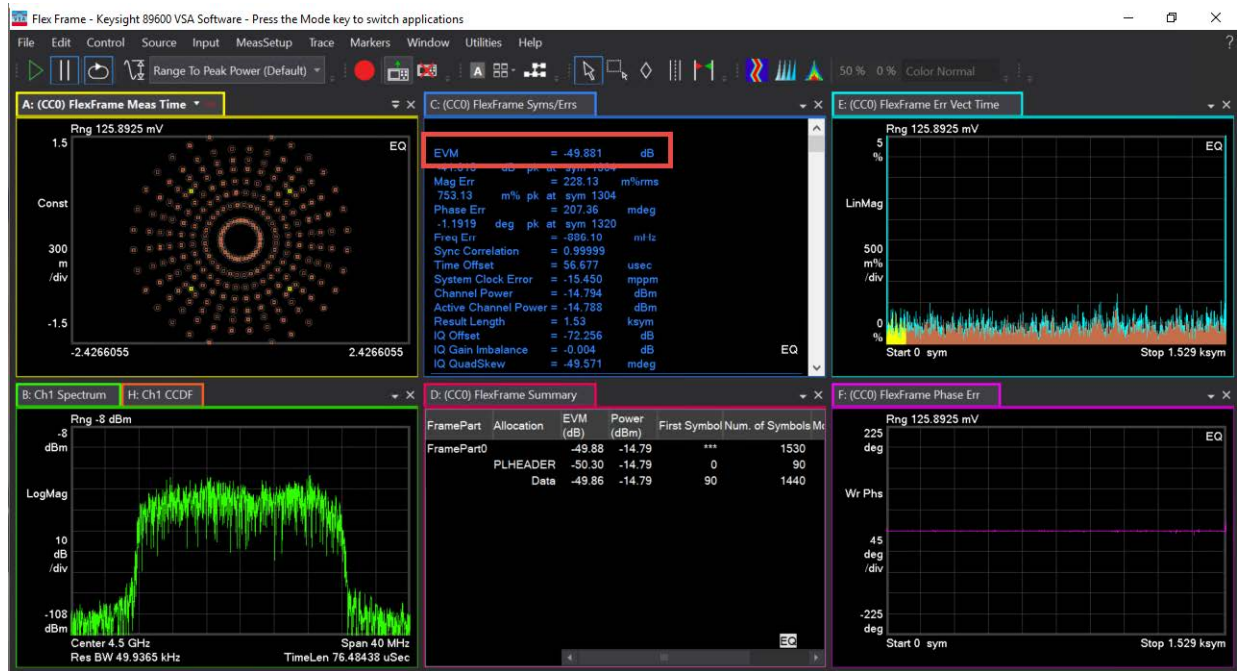
This saves the measurement settings for future use. Select **Share with all users** if you want to share with other users on the PC running the VSA software.



Advanced Measurements

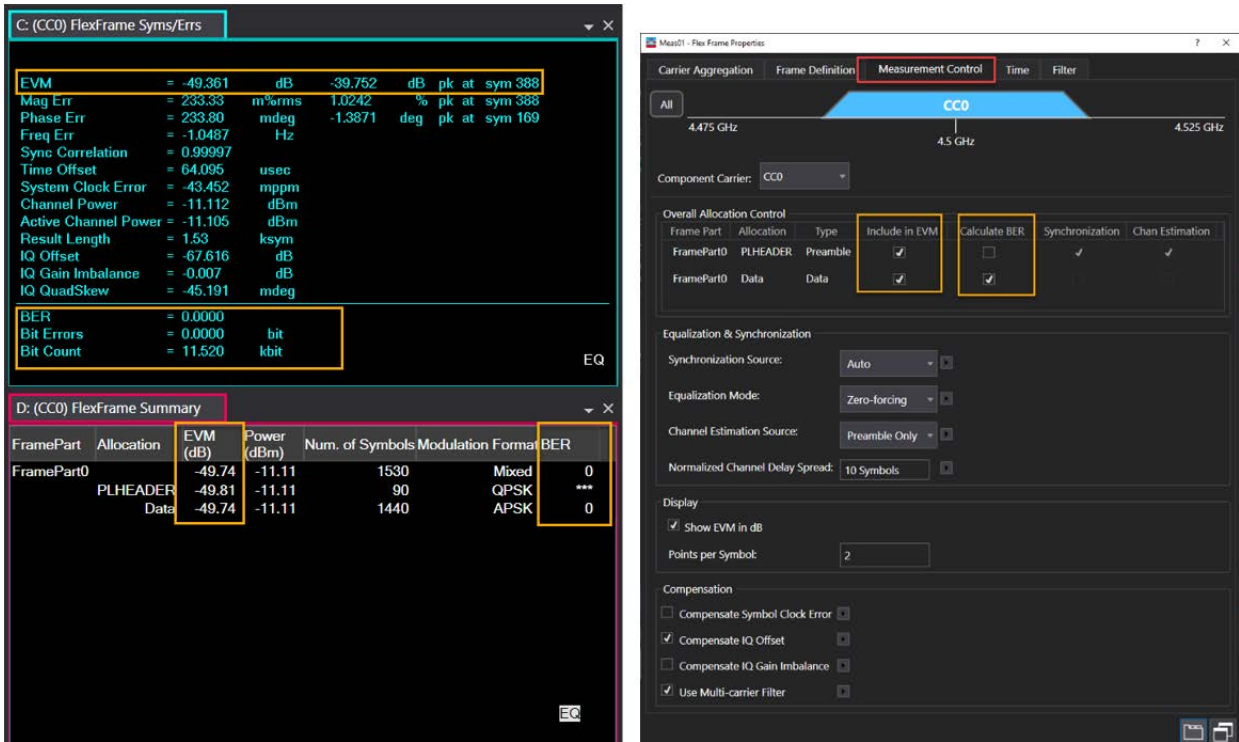
Using the VSA Flex Frame to Create a DVB-S2X Signal

14. Close the Properties window and change Trace A to a Constellation Diagram, then view the results.



You should see a successful demodulation with very low EVM. Multiple traces and tables are available including Error Vector Spectrum, Error Vector Time, demod, and BER Bits.

The FlexFrame Summary table always displays EVM of each active segment. However, "Flex Frame Syms/Errs" Table shows composite EVM of segment(s) selected under Measurement Control -> Include EVM. By default, it is all segments.

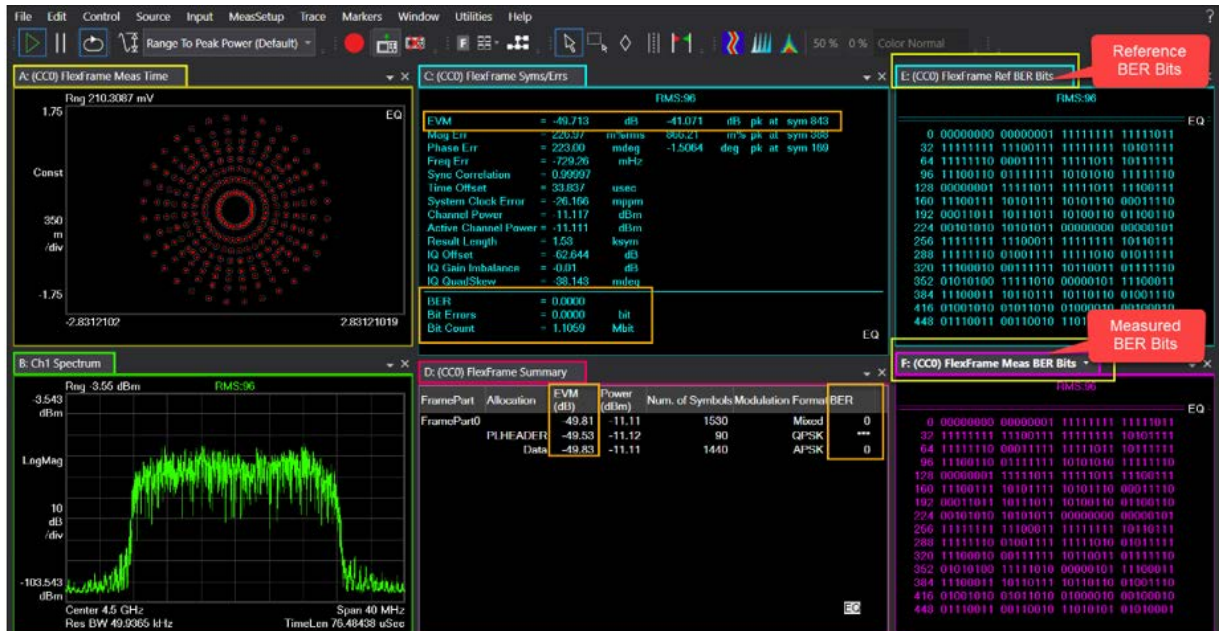


TxBER/RawBER is returned for the Data segment. NOTE: BER is supported if the allocation's payload sequence is either a PN type or a Custom bit sequence. Reference and measured bits are returned.

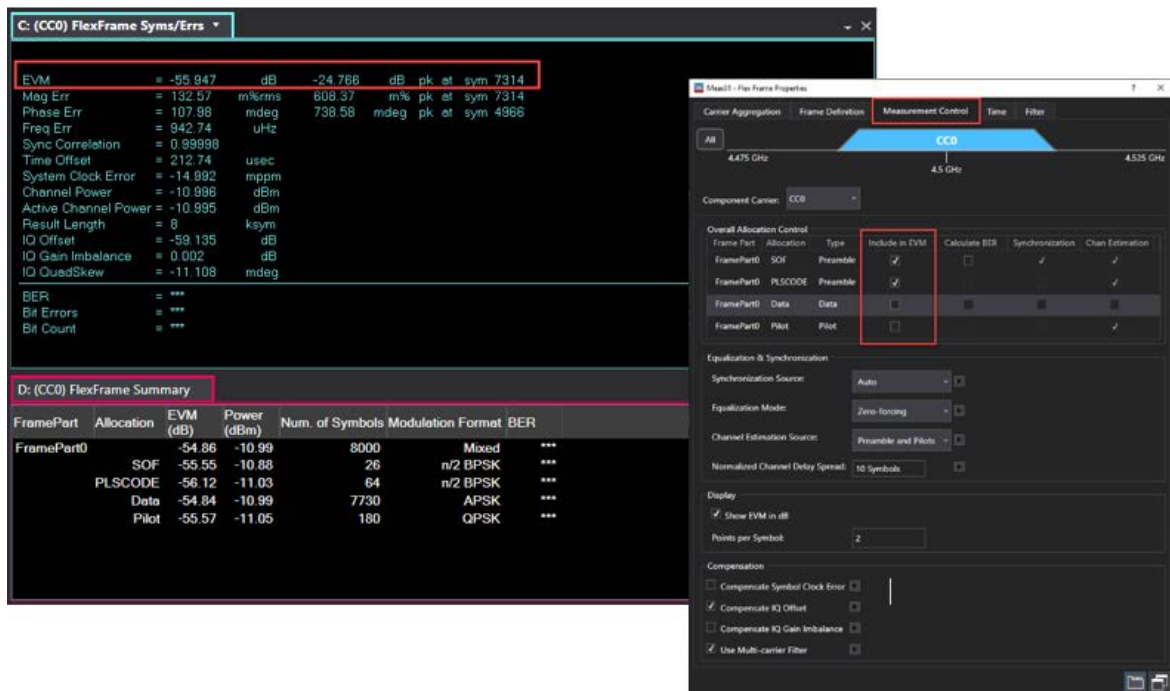
- BER is expressed as a ratio and calculated as Bit Errors/Bit Count.
- Turn On averaging to accumulate bit count.
- Recording with 0% overlap gives gap free BER data (limited by memory).

Advanced Measurements

Using the VSA Flex Frame to Create a DVB-S2X Signal



FlexFrame Summary always displays the EVM of each active segment. Flex Frame Syms/Errs table shows composite EVM of segment(s) selected under Measurement Control -> Include EVM. By default, it shows all segments.



FlexFrame Summary table is a type of Matrix Table that provides sortable rows by column, selectable column visibility, and copy/paste and export functionality to share rows of content or complete tables to applications like email, text editing or spreadsheet programs. Right click the column header to display the menu.

F: (CC0) FlexFrame Summary

FramePart	Allocation	EVM (dB)	Power (dBm)	Num. of Symbols	Modulation Format	BER
FramePart0		-52.09	-10.99	8000	Mixed	***
	SOF	-53.10	-10.88	26	n/2 BPSK	***
	PLSCODE	-53.53	-11.03	64	n/2 BPSK	***
	Data	-52.06	-10.99	7730	APSK	***
	Pilot	-52.91	-11.05	180	QPSK	***

Column Visibility

All

Expand All

Collapse All

Labels

FramePart

Allocation

Metrics

EVM (dB)

Power (dBm)

Num. of Symbols

Modulation Format

Bit Errors

BER

Bit Errors (bit)

Bit Count (bit)

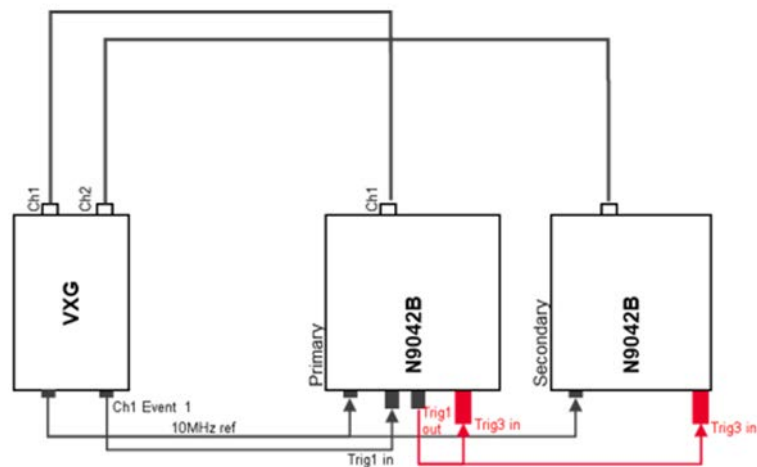
OK

Cancel

Creating & Analyzing a 5G NR DL 2x2 MIMO Measurement Using Two UXAs

We will create a 5G NR MIMO signal using a VXG with PathWave Signal Generation, and then analyze it with using both the X-Series 5G NR measurement application and the 89600 VSA software.

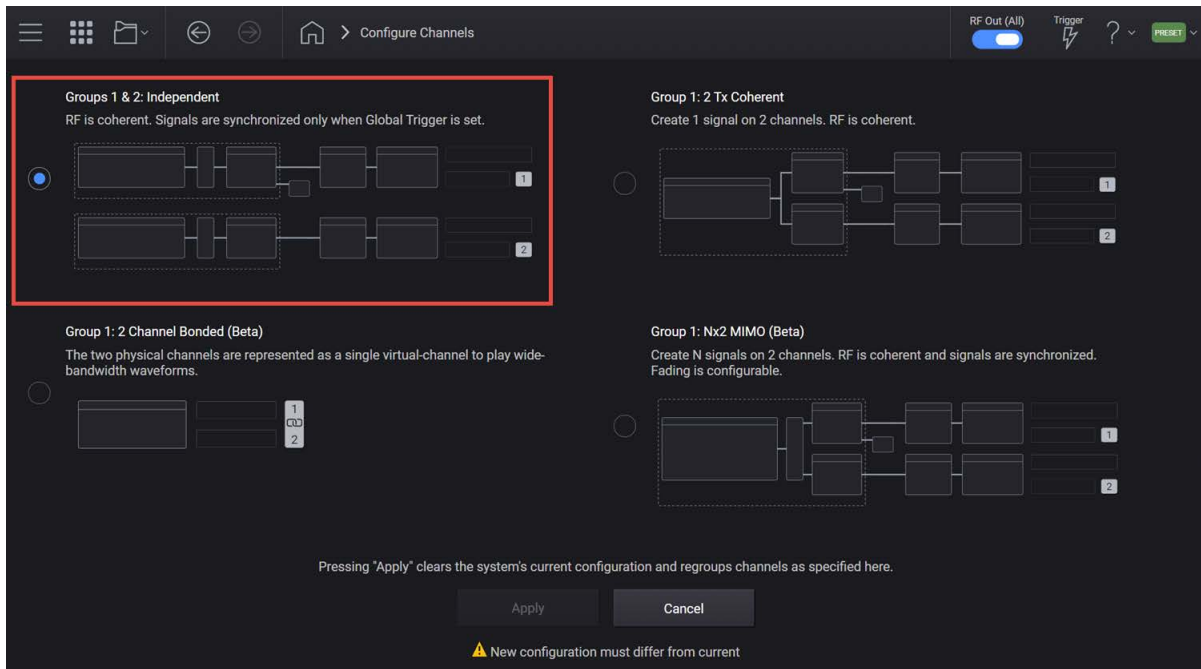
The hardware setup includes a 2-channel VXG and two N9042B UXAs.



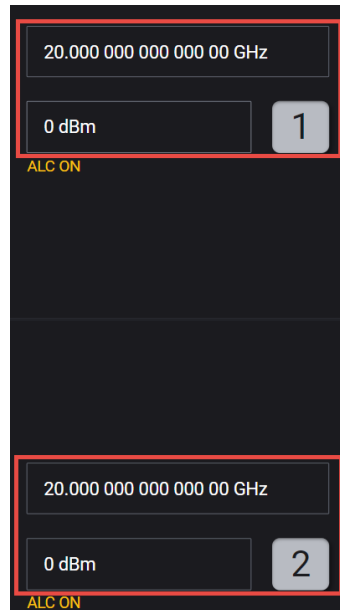
M9484C VXG	N9042B UXA
<p>Required Options</p> <ul style="list-style-type: none">– RF bandwidth of 160 MHz or above– Two-channel configuration	<p>Required Options</p> <ul style="list-style-type: none">– UXA 1 N9042MMOB Multi-box Synchronization for MIMO, Analysis Bandwidth of 160 MHz or above– UXA 2 Analysis Bandwidth of 160 MHz or above
<p>Required Software</p> <ul style="list-style-type: none">– M9484C Firmware version A.11.01 or higher– 7631APPC PathWave Signal Generation for 5G NR	<p>Recommended Software</p> <ul style="list-style-type: none">– N9042B UXA Firmware version 2023 (XA34) or higher– N9085EMOE 5G NR Measurement application– 89600 VSA 89601200C for VSA Base Core 89601BHNC for VSA 5G NR

On the VXG

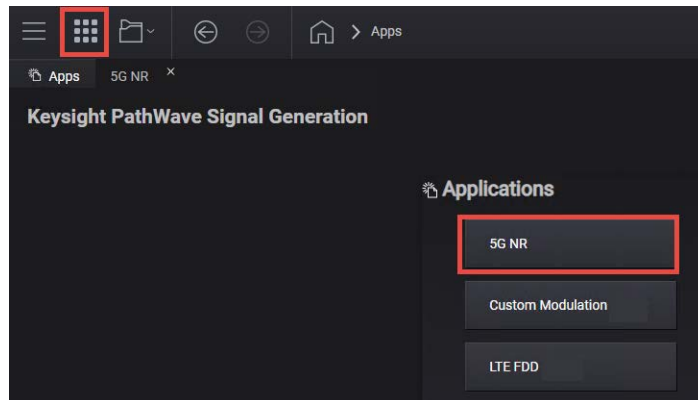
1. Connect the equipment as shown above.
2. Select **Preset > Preset** to set the VXG to a known state.
3. Select the System menu (triple bar tab at the top left of the window), and then select **Configure Channels > Group 1:2 Channel Bonded > Apply Configuration**.



4. Set the Frequency to **20 GHz** and Power to **0 dBm** on both Channel 1 and Channel 2.

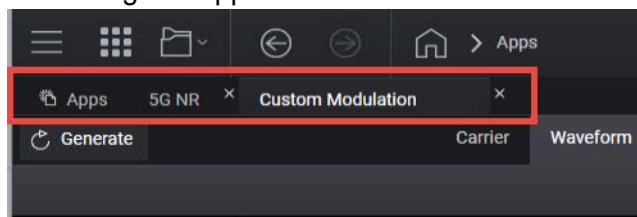


5. Select the **Apps** block to open, then select **5G NR**.

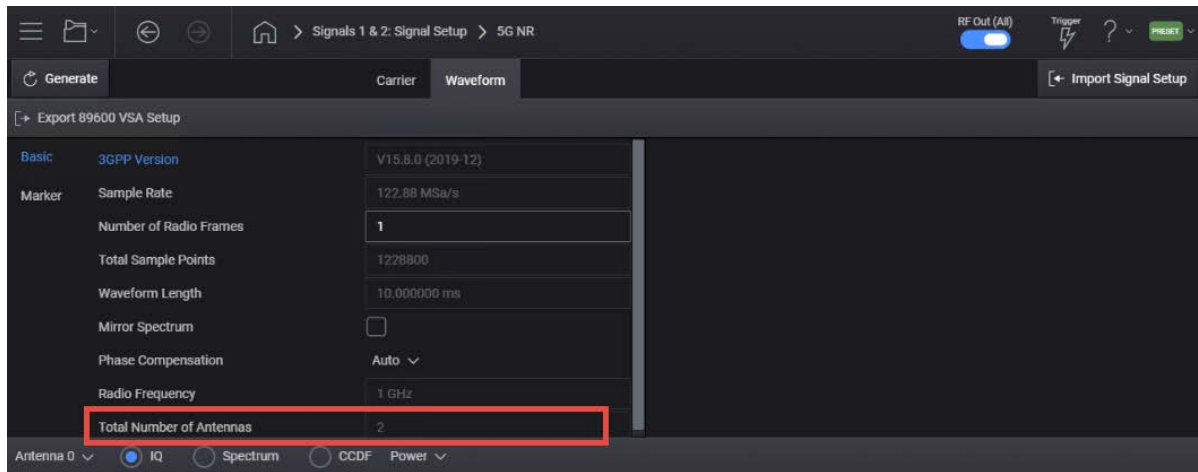


NOTE

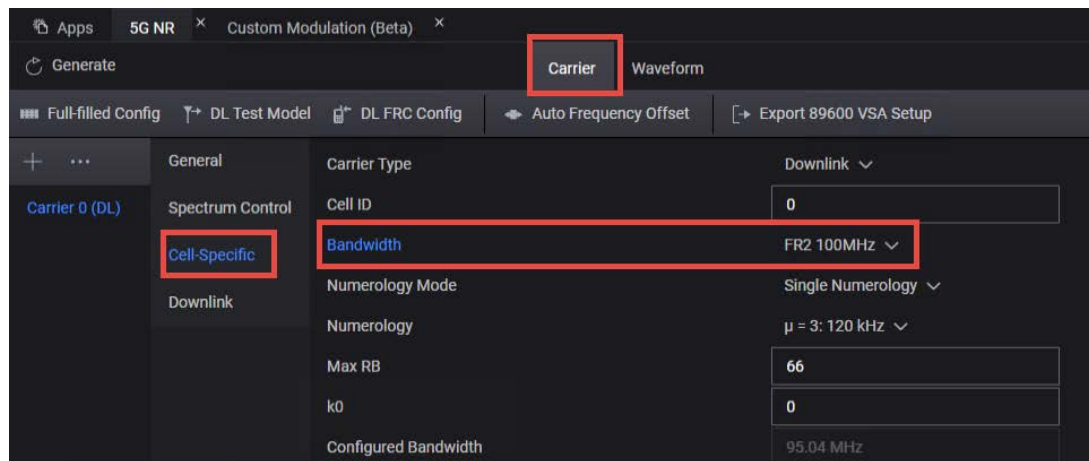
If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



6. Select the **Waveform** tab and set the Total Number of Antennas **2**. This means that two antenna port signals will be generated.

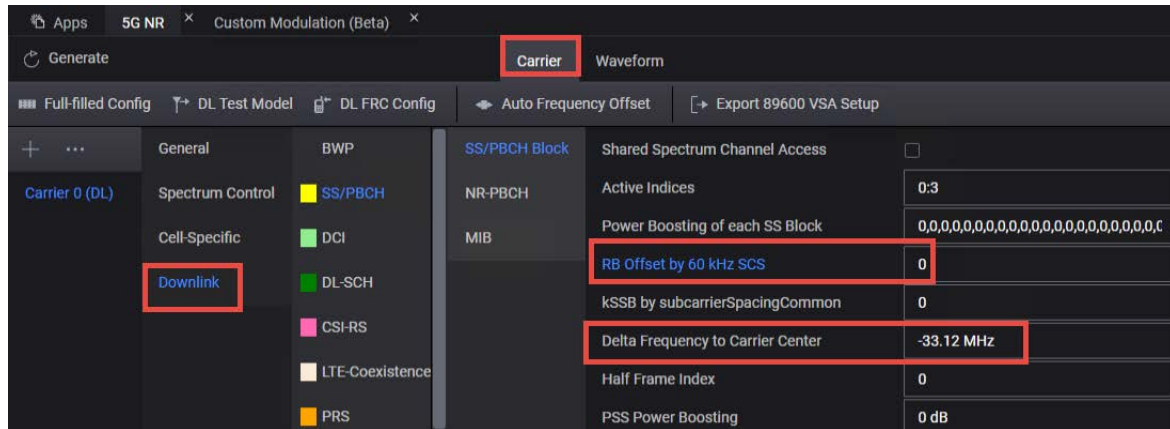


7. Select the **Carriers** tab > **Cell Specific** node, and set Bandwidth to **FR2 100 MHz**. Keep the rest of the default settings.



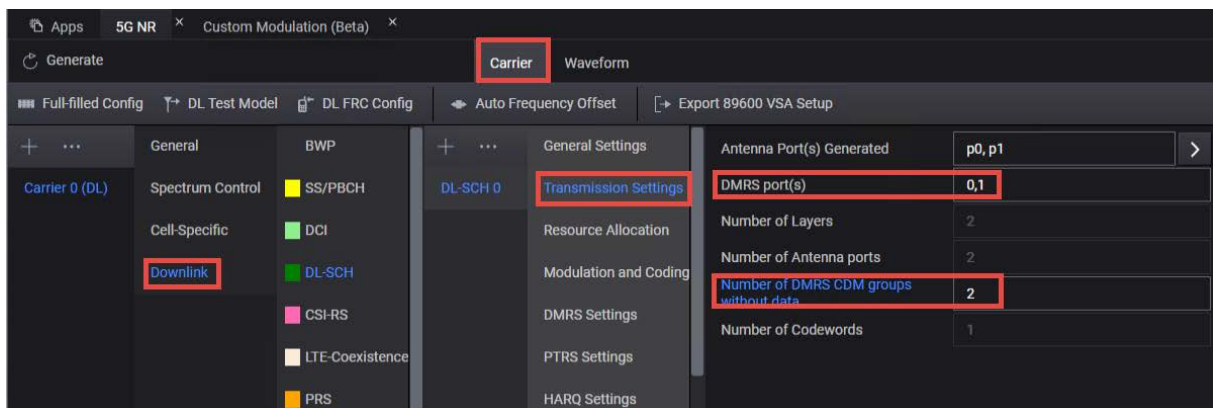
8. Select the **Downlink** node > **SS/PBCH** > **RB Offset by 60 kHz SCS** and set to **0**.

This automatically changes the Delta Frequency to Carrier Center to -33.12 MHz. Using 0 RB Offset puts the SSB at the lower edge of the carrier.



9. Select the **Downlink** node > **DL-SCH** > **Transmission Settings** and confirm DMRS ports is set to 0,1. Set Number of DMRS CDM groups without data to 2.

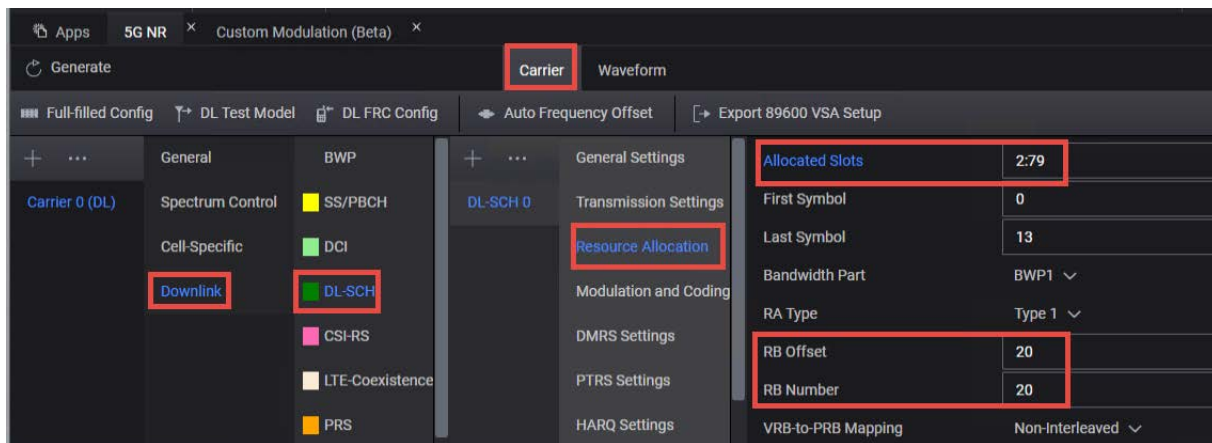
You will see the layer number is updated to 2 and each layer is assigned with a particular DMRS port. You'll also see that Antenna Ports Generated is automatically set to P0,P1, which will map the multiple antenna port signals to different antennas (instruments).



10. Select the **Resource Allocation** node and set:

- Allocated Slots to **2:79**
- RB Offset to **20**
- RB Number to **20**

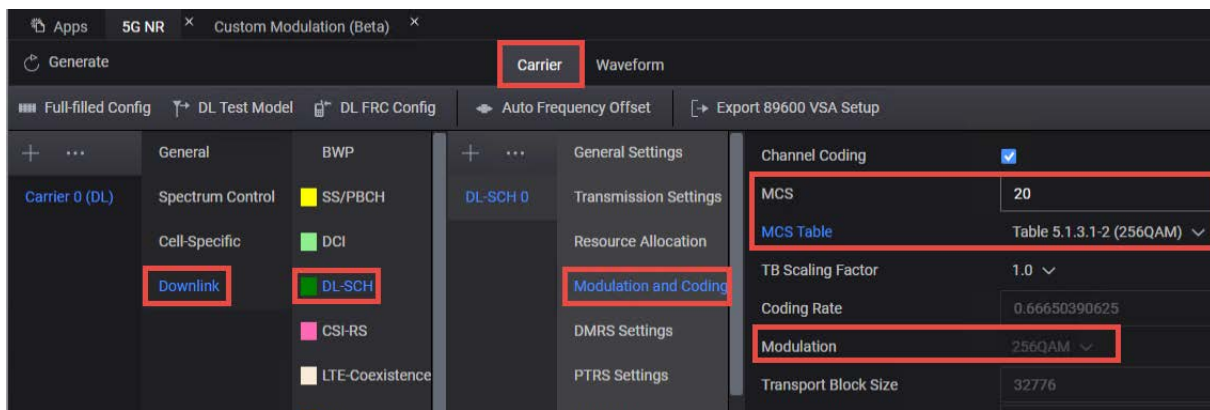
DL-SCH0 will occupy the RBs 20-40 and DL-SCH1 will occupy the rest of the resources.



11. Select the **Modulation and Coding** node and set:

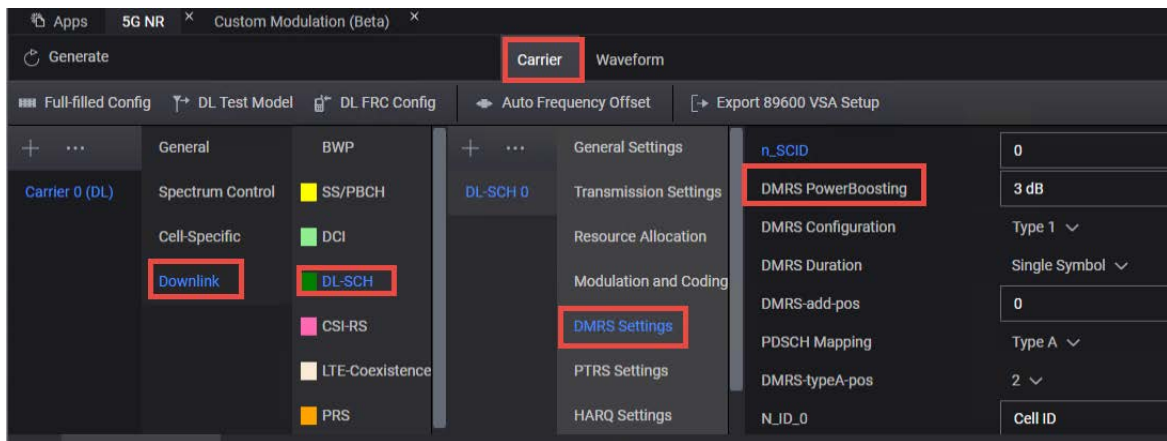
- MCS to 20
- MCS Table to 5.1.3.1-2 (256 QAM)

Notice that modulation is updated to 256 QAM.

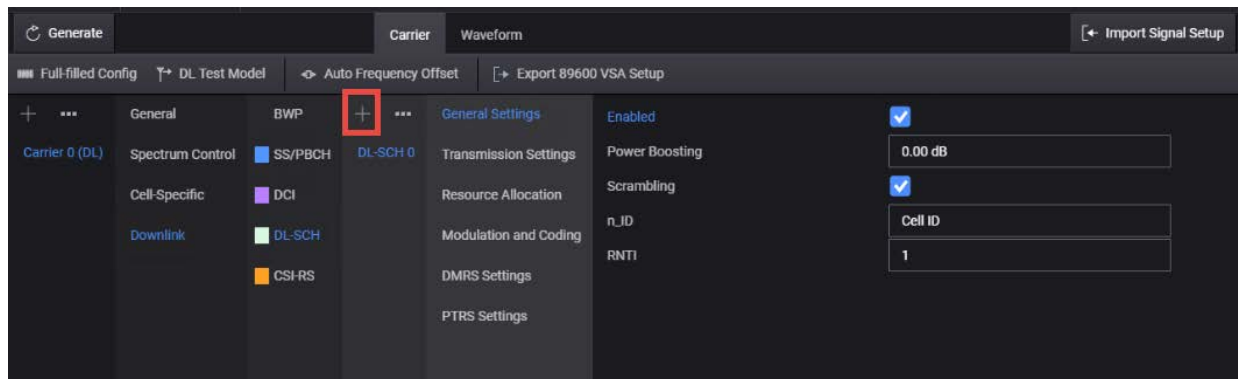


12. Select the **DMRS Settings** node and set DMRS Power Boosting to 3 dB.

When CDM Group Number is 2, DMRS power boosting becomes 3 dB per 3GPP.



13. Under the DL-SCH 0 node, select the + icon to add a new +DL-SCH (DL-SCH1).



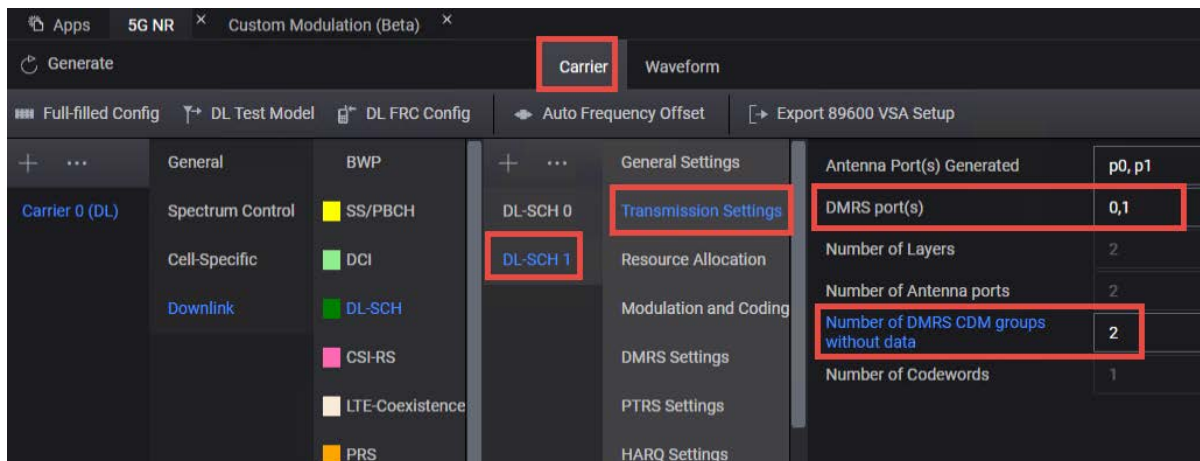
NOTE

This will create a conflict between DL-SCH0 and DL-SCH1. This will be resolved in a later step.




14. From the Channels node, select **DL-SCH > DL-SCH1 > Transmission Settings** and set DMRS port(s) to **0,1**. Change the Number of DMRS CDM groups without data to **2**.

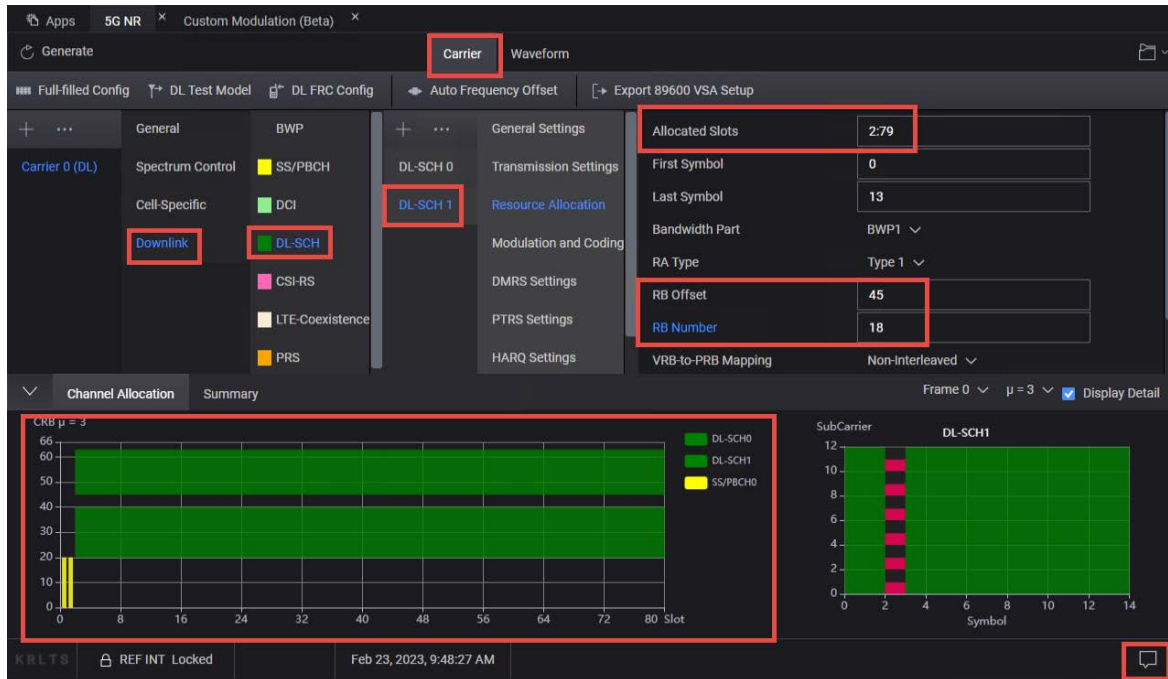
Notice that Number of Layers is updated to 2 and each layer is assigned with a particular DMRS port. Antenna Ports Generated is automatically assigned P0,P1, which will map generated multiple antenna port signals to different antennas (instruments).



15. Select the **Resource Allocation** node and set:

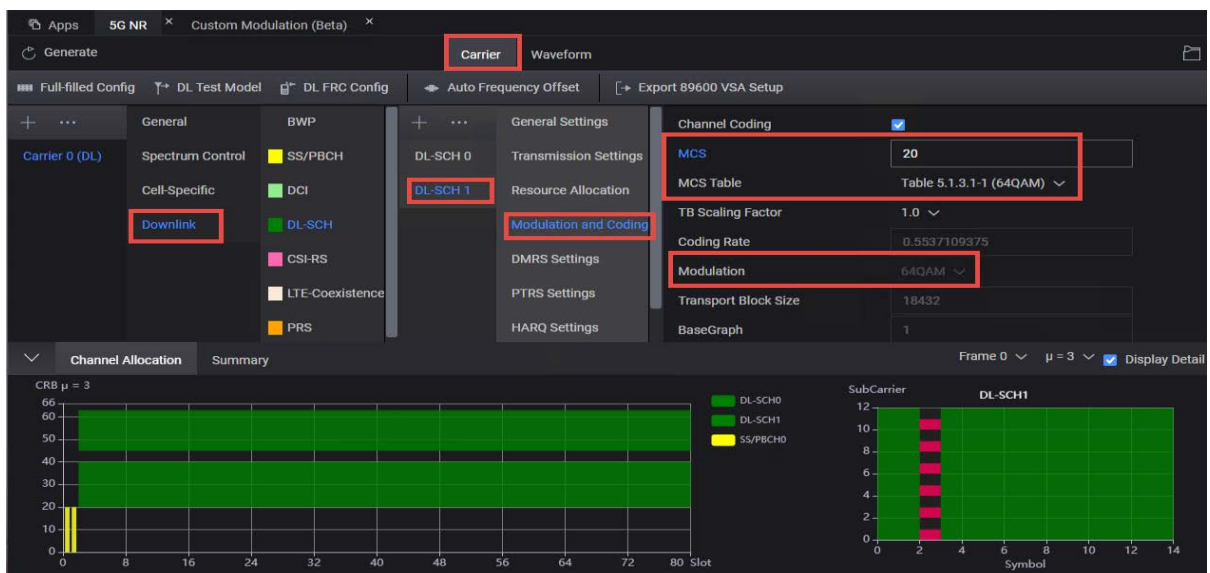
- Allocated Slots to **2:79**
- RB Offset to **45**
- RB Number to **18**

Notice that this resolves the conflict between DL-SCH channels. (The pink shading is removed from the Channel Allocation graph. To clear the conflict error message at the bottom of the display, select the Message icon  (bottom, right corner) and select **Clear**.

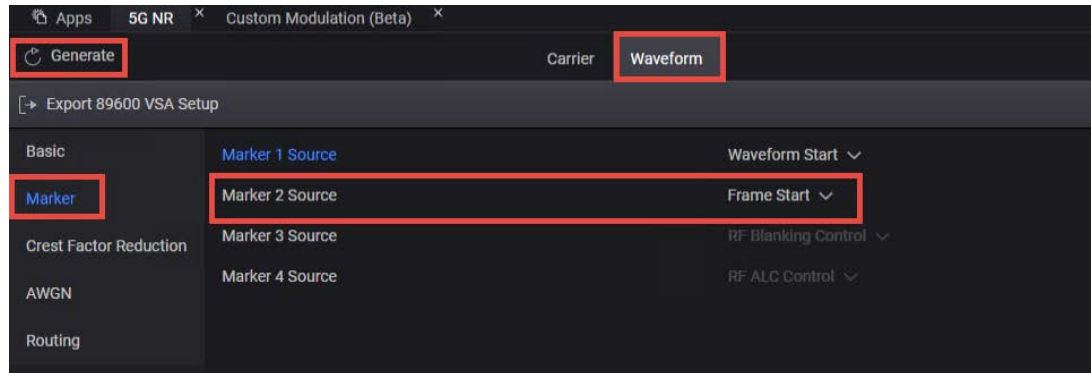


16. Select the **Modulation and Coding** node, and set MCS to 20.

Use the default MCS Table to Table 5.1.3.1-1 (64QAM). You will see the modulation is updated to 64QAM.

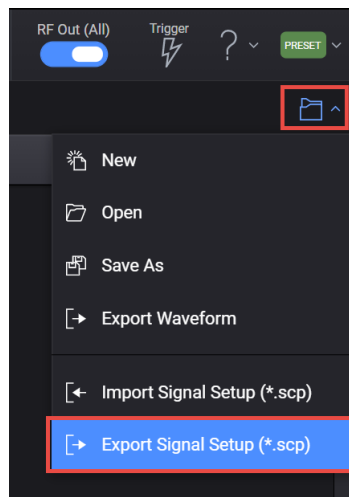


17. Select the **Waveform** tab > Select **Generate**.



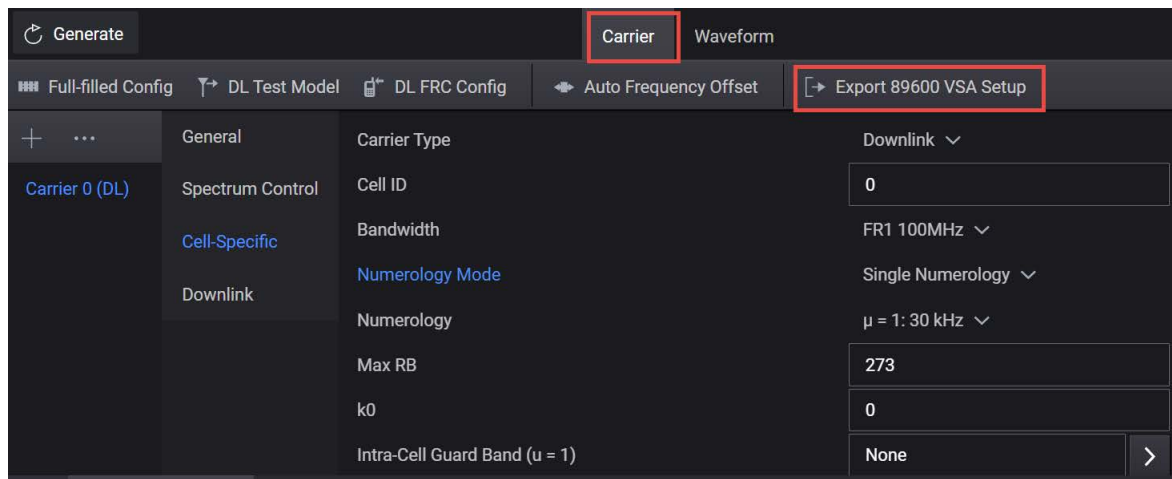
18. Select the **File** icon on the top right and select Export Signal Setup (*.scp), and save the file.

You will need to copy this setup file to the UXA to speed up demodulation on the UXA using X-Apps.

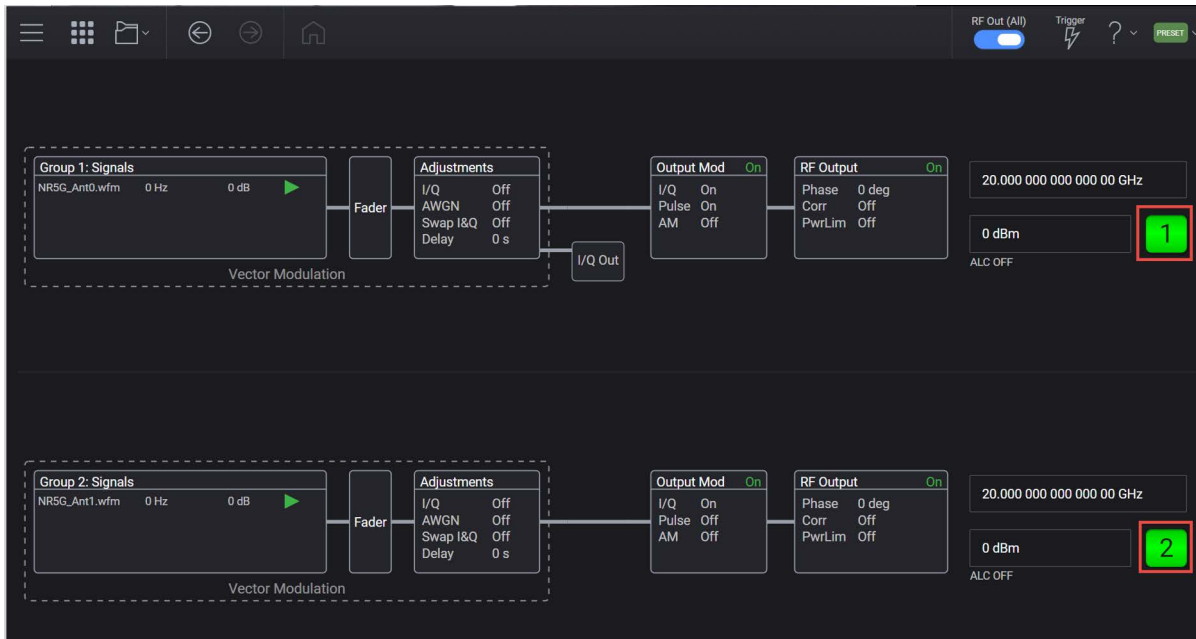


19. Select the **Carrier** tab and select **Export 89600 VSA Setup** and save the file.

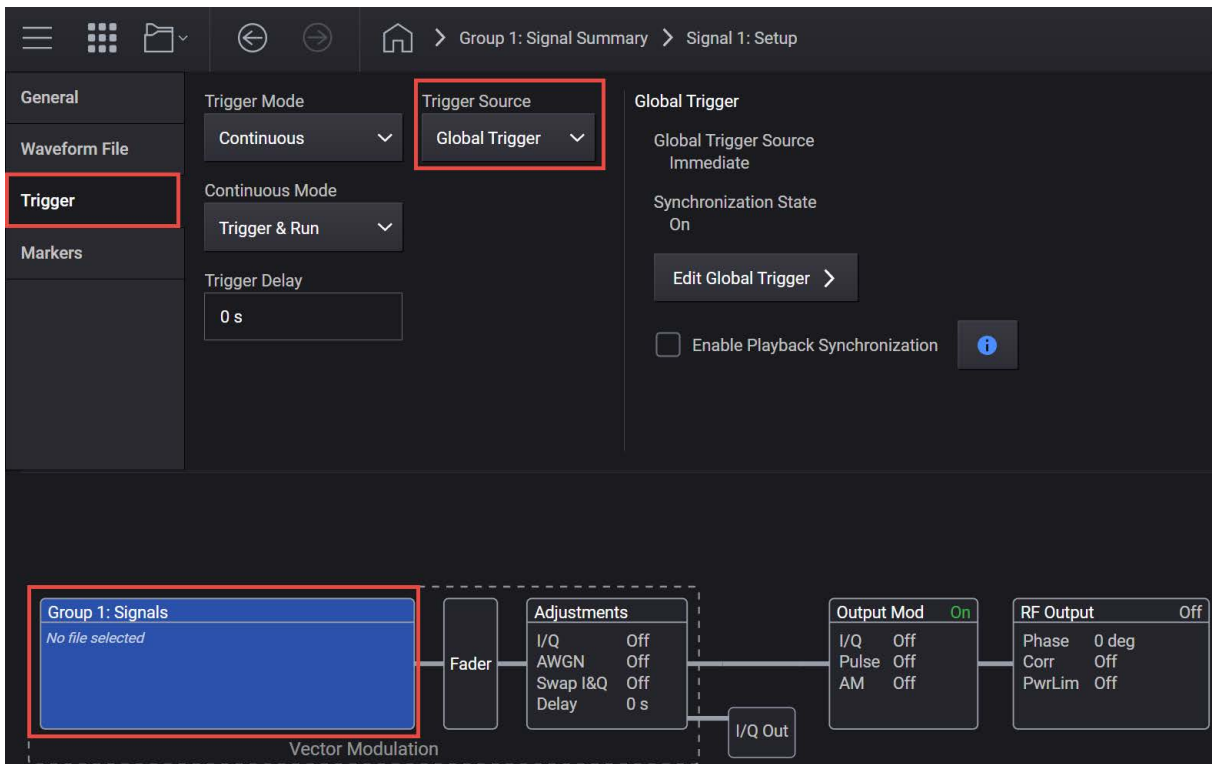
You will need to copy this setup file to the UXA to speed up demodulation on the UXA using the 89600 VSA software.



20. Select the Home icon and set RF Out to **On** by selecting the numbered channel indicator switches, and then select **RF Out (All)** master control switch to turn the RF output On for both channels or off for both channels.



21. Select the **Signal Block > **Trigger** tab and set Trigger Source to **Global Trigger**.**



Demodulate the 5G NR 2x2 MIMO in X-Apps

NOTE

Changing settings on the VSA can take longer to take affect than expected. Wait to change the next setting until the previous setting has been updated.

On the Primary UXa:

1. From the N9042B 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.

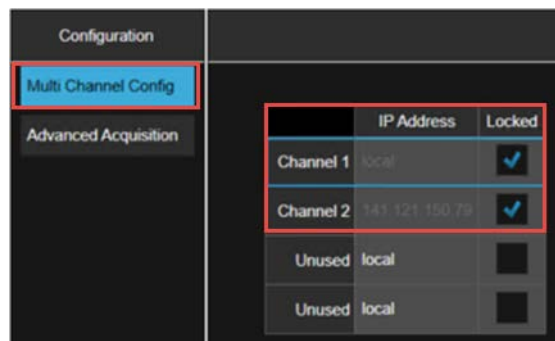
2. Select **Mode Preset** to set Spectrum Analyzer 5G NR mode to a known state.
3. From the N9042B Menu Panel (or the Screen tab), select **Mode/Meas** > **5G NR & V2X Mode** > **Modulation Analysis Measurement** > **OK**.

4. From the Menu Panel, select **Meas Setup** > **Radio** and turn **MIMO On**.

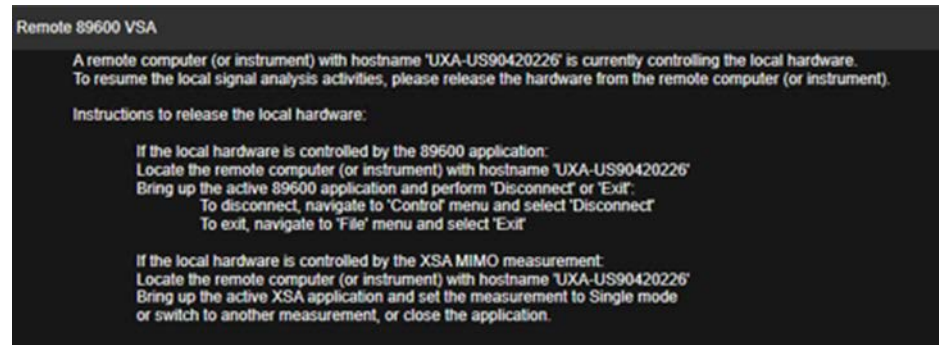


5. Select **Multi Channel Config** to open the Configuration dialog box.

- Set Channel 1 IP Address to **Local**
- Enter the IP address for Channel 2
- Select **Locked** for both Channel 1 and Channel 2

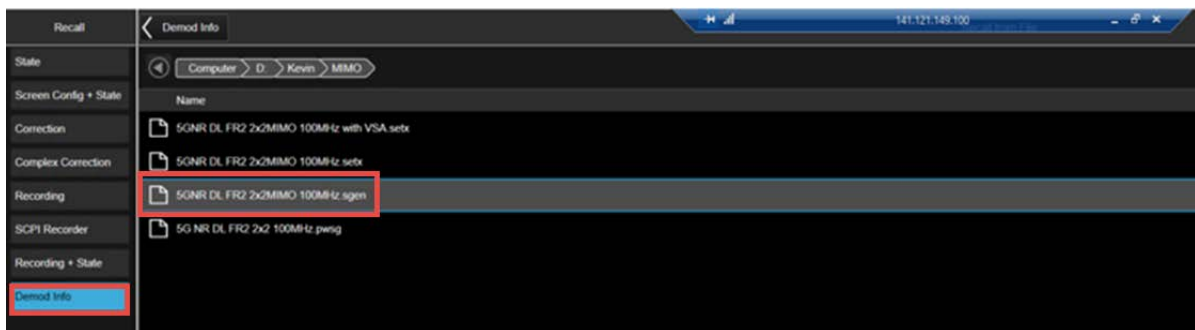


Once MIMO mode is ON and both channels are locked, the secondary N9042B display changes as shown below. THIS LOOKS LIKE THE MESSAGE FOR VSA, NOT X-APPS???

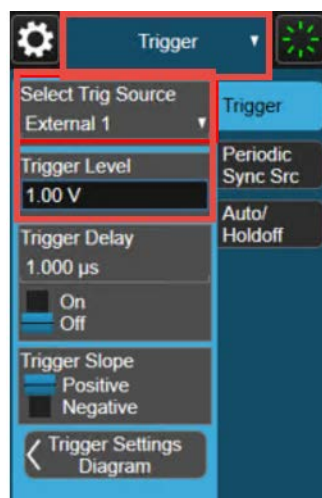


6. Select **Recall** (If accessing the signal analyzer remotely, select the Folder icon at the bottom of the display) > **Demod Info** > set Data Type to **CC Setup** > **Recall From** > and **Recall** the setup file.

You must be in the correct analysis mode to recall the .scp file.



7. Select **Trigger** > **Trigger** tab and set Select Trigger Source to **External 1** and Trigger Level to **1 V**.

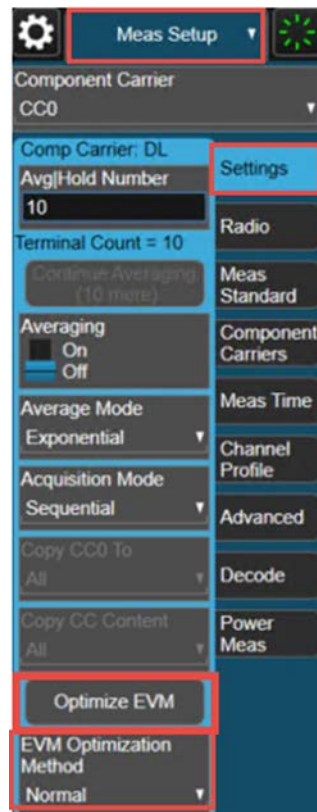


8. Select Meas Setup > Settings tab> Optimize EVM.

Optimize EVM is an immediate action to adjust the hardware settings to minimize EVM.

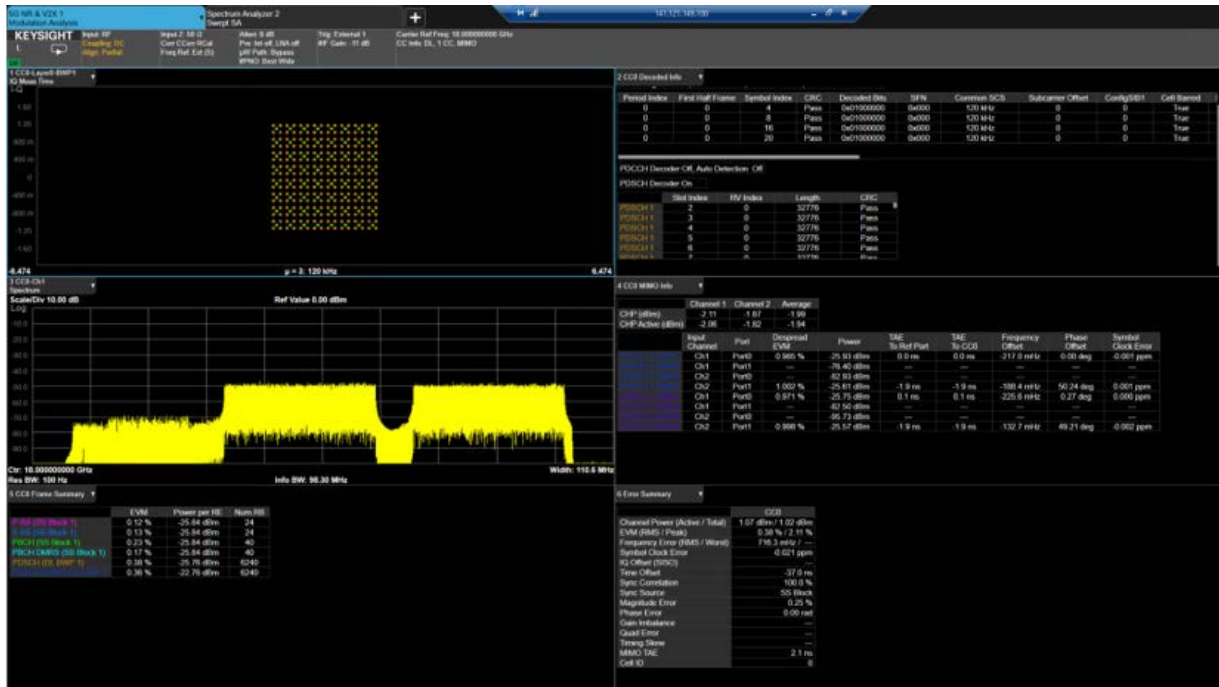
- Normal method will capture input signal, measure its peak power then the algorithm will find proper setting combination for attenuation, preamp and IF Gain.
- Iterative method will capture input signal multiple times in a iteration process, demodulate the signal and calculate EVM for each iteration and find setting combination for attenuation, preamp and IF Gain with minimum EVM.

For 5G NR signals, this method is much slower, than normal, but with achieve better EVM results. You can also manually adjust IF Gain, Frequency Extender Attenuation (use when measurement setup includes a V3050A frequency extender).



Advanced Measurements Creating & Analyzing a 5G NR DL 2x2 MIMO Measurement Using Two UXAs

View the results.



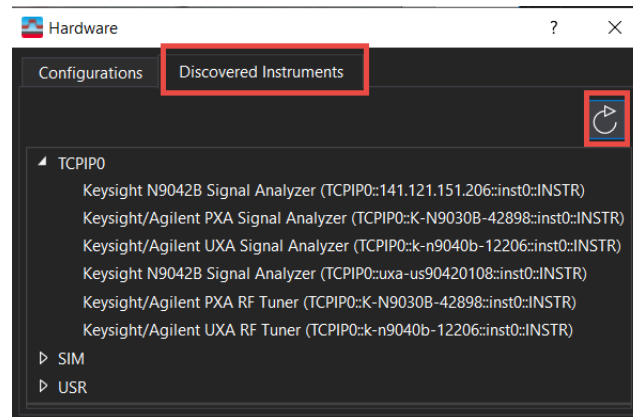
Demodulate the 5G NR 2x2 MIMO Using VSA:

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

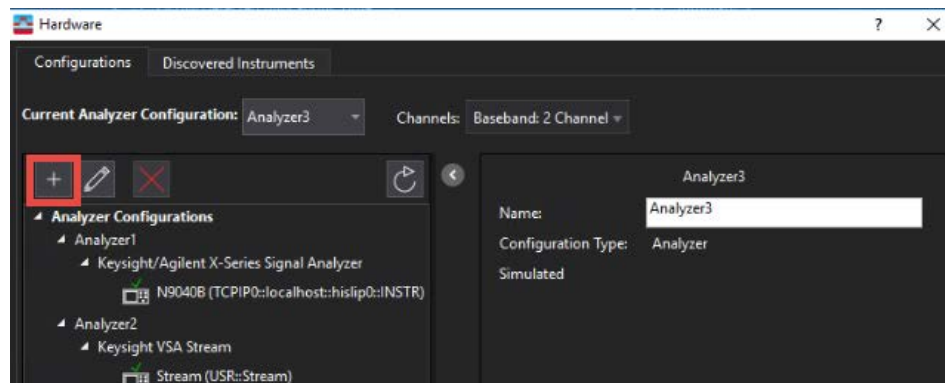
NOTE

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

2. To configure the hardware, go to **Utilities > Hardware > Configurations**.
3. Open the **Discovered Instruments** tab and verify that the two UXAs are listed, if not, select the **Rediscover Instruments** icon.

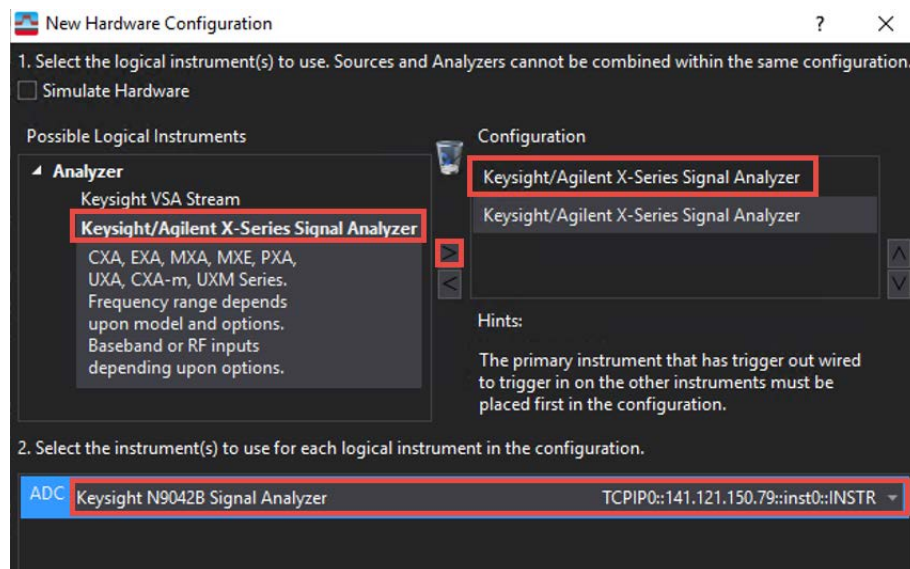


4. In the **Configuration** tab, select the **+** icon.



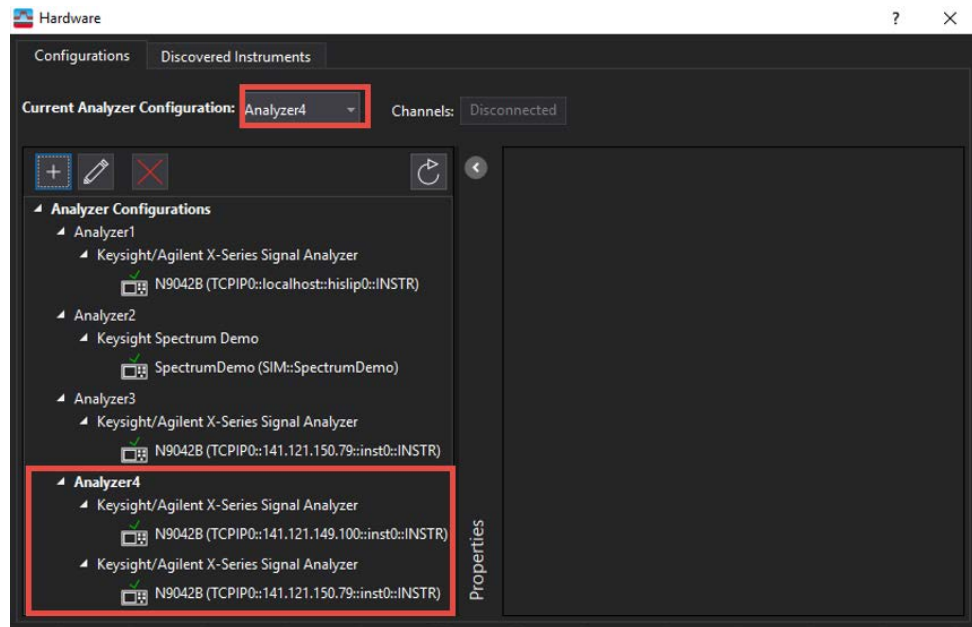
5. Scroll down the Possible Logical Instruments and select **Keysight/Agilent X-Series Signal Analyzer** twice.

- Select the first Keysight/Agilent X-Series Signal Analyzer and then press the right arrow to move it under the Configuration area.
- From the middle of the dialog box, select the down arrow next to the Analyzer and select the IP address of the Primary UXA.
- Repeat the two steps above for the second signal analyzer but select the IP address of the Secondary UXA.

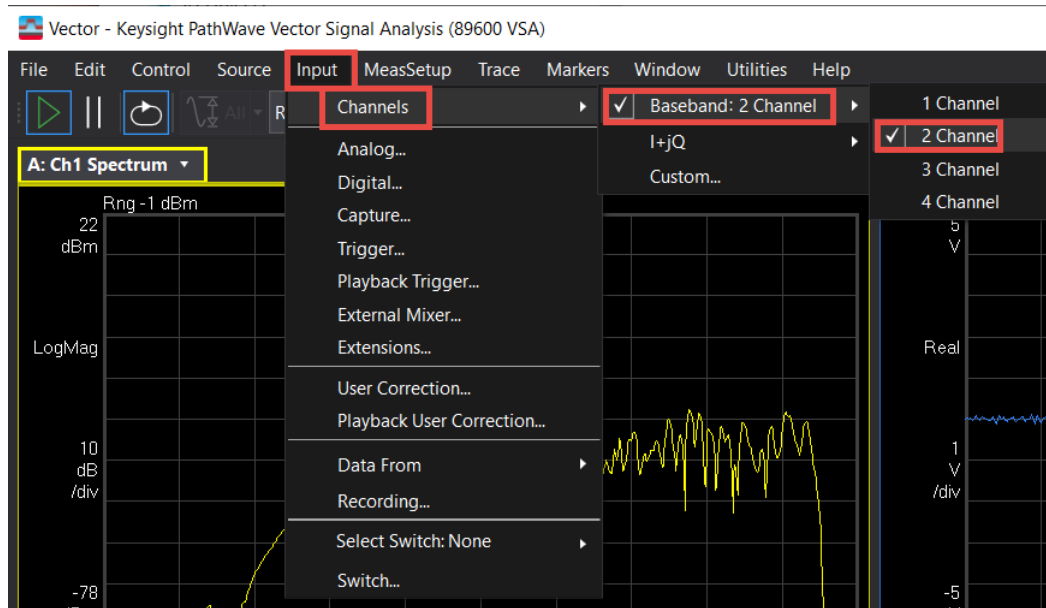


6. Select **OK** to create the new configuration.

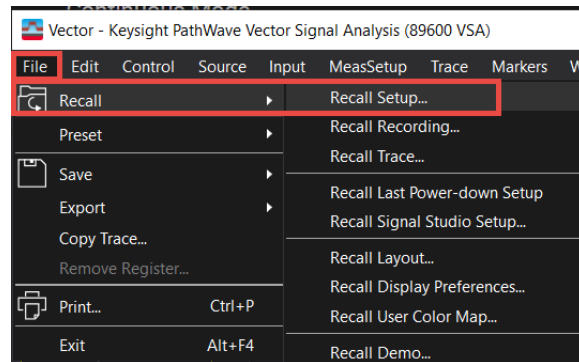
7. In the **Configurations** tab, set the Current Analyzer Configuration, select the Analyzer number for the new configuration. In this example **Analyzer 3**.



8. From the menu bar, select **Input > Channels > RF > 2 Channel**.



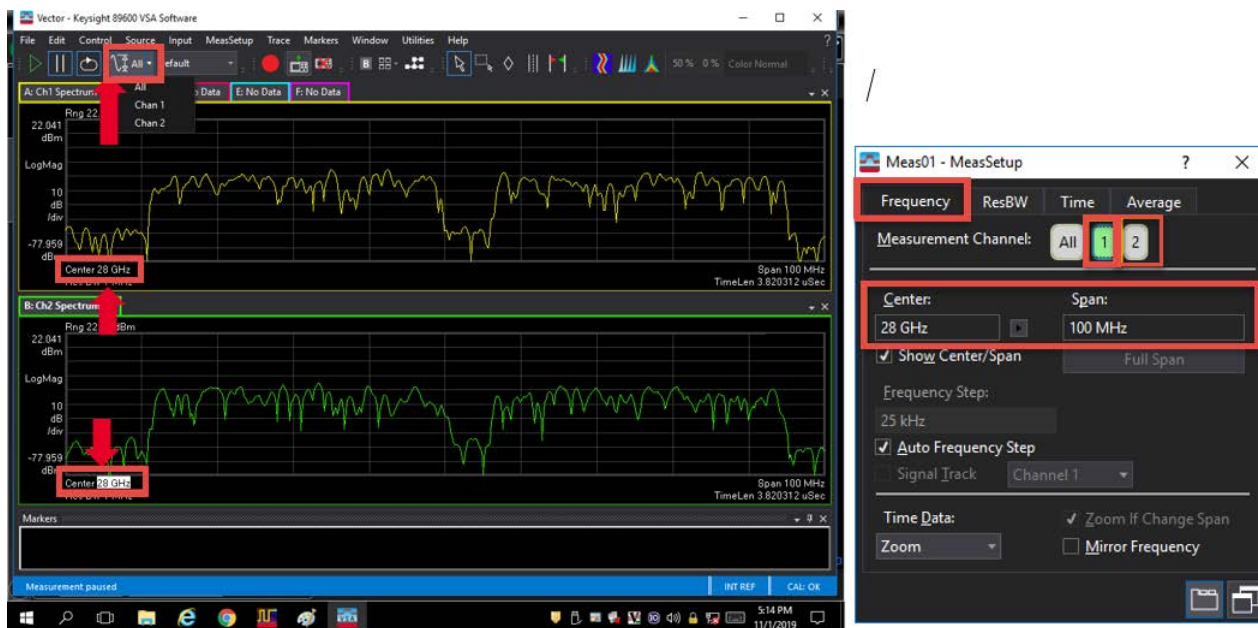
9. From the menu bar, select **File > Recall > Recall Setup** and navigate to the .setx file you save during the VXG waveform generation.



You can also set the frequency and span of both channels under Meas Setup > Frequency.

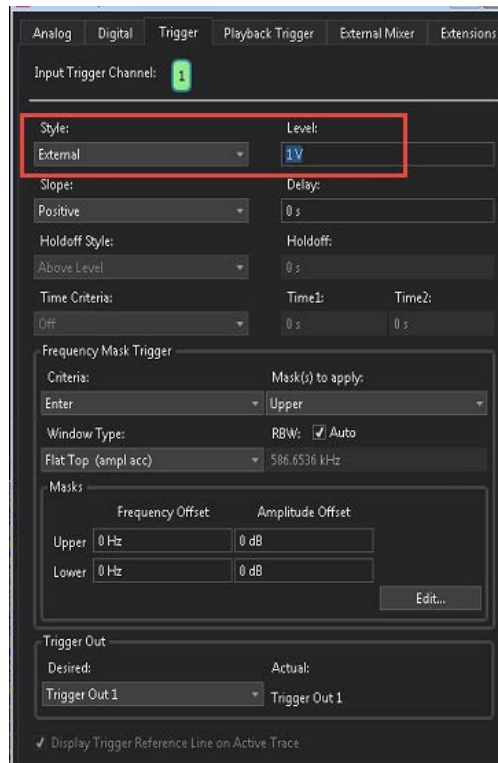
If you are using a UXR, Select Autorange

Auto Range samples the current input signal and then sets the full scale input range to the minimum range that includes the peak voltage sample of the input signal.



10. From the menu bar, select **Input > Trigger** and set:
- Style to **External**

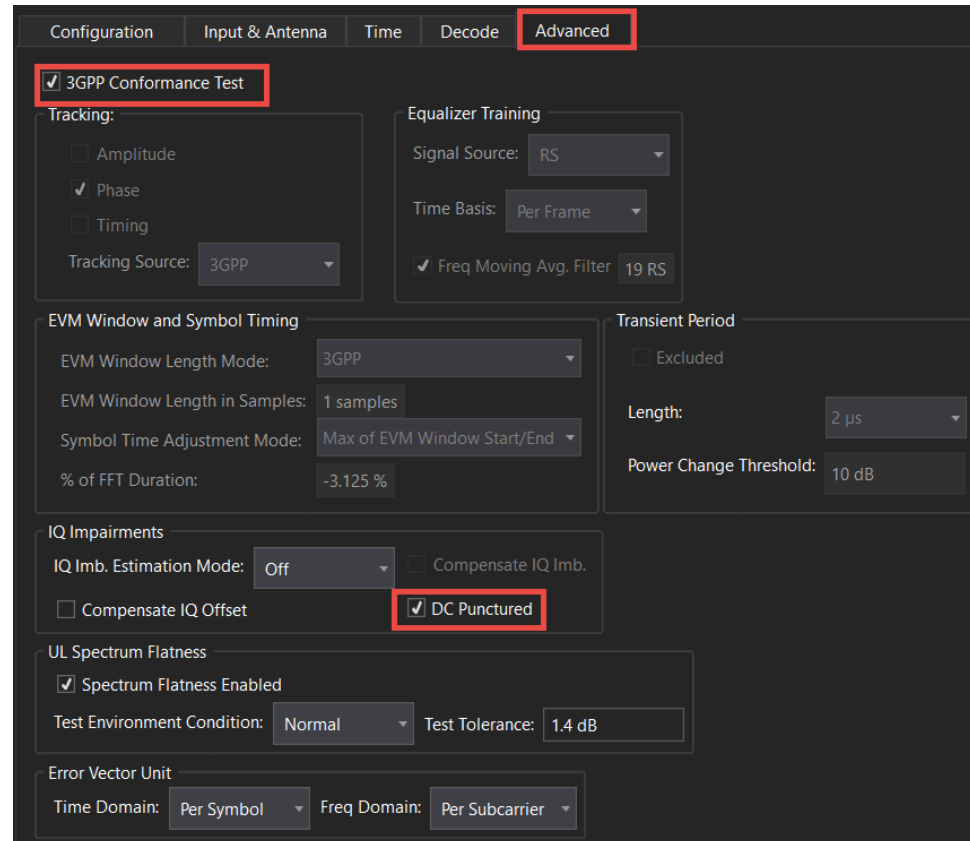
– Level to 1 V



11. From the menu bar, select **MeasSetup > 5G NR Demod Properties> Advanced** tab and select the **DC Punctured** check box.

As part of conformance test, 3GPP has defined different equalizer training and tracking for EVM measurements. 3GPP Conformance Test is enabled by default where Tracking, Equalizer Training and EVM Window, and Symbol Timing is applied per 3GPP conformance test requirement. For FR1, no tracking is applied. For FR2, Phase Tracking using PTRS is applied.

5G NR counts the DC subcarrier as a valid subcarrier for rate-matching purposes. The network decides if the DC subcarrier is modulated or not. High LO feedthrough will impact demodulation and EVM performance of the input signal. This is OFF by default.



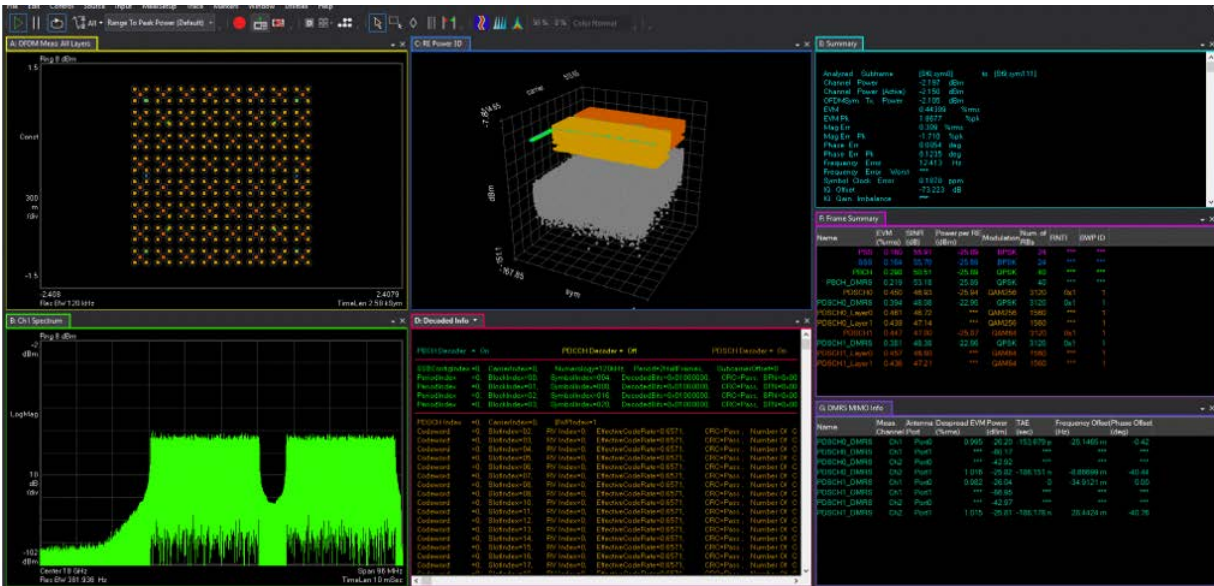
12. Close the 5G NR Properties dialog.

13. From the toolbar, select the **Auto-Range** 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.



Advanced Measurements Creating & Analyzing a 5G NR DL 2x2 MIMO Measurement Using Two UXAs



4 Other X-Series Signal Analyzer Measurements

- “Setting Up a Group Delay Measurement” on page 196
- “Setting Up Millimeter-Wave Measurements” on page 206
 - “Setting up a 5G NR Millimeter-Wave Measurement” on page 206
 - “Setting-up a Millimeter-Wave DVB-S2X 64APSK Measurement” on page 215
 - “Setting-up a Millimeter-Wave 5G NR, 2 GHz BW FR2 Measurement” on page 237
- “Using the X-Series Analyzer’s SCPI Recorder Function” on page 262
- “Using the X-Series Analyzer’s Preload/Unload Function” on page 275

Setting Up a Group Delay Measurement

Group delay is a measure of phase distortion. Group delay is the actual transit time of a signal through a device under test as a function of frequency. When specifying group delay, it is important to specify the aperture used for the measurement.

In a group delay measurement:

- The linear phase shift component is converted to a constant value (representing the average delay).
- The higher order phase shift component is transformed into deviations from constant group delay (or group delay ripple).
- The deviations in group delay cause signal distortion, just as deviations from linear phase cause distortion.
- The measurement trace depicts the amount of time it takes for each frequency to travel through the device under test.

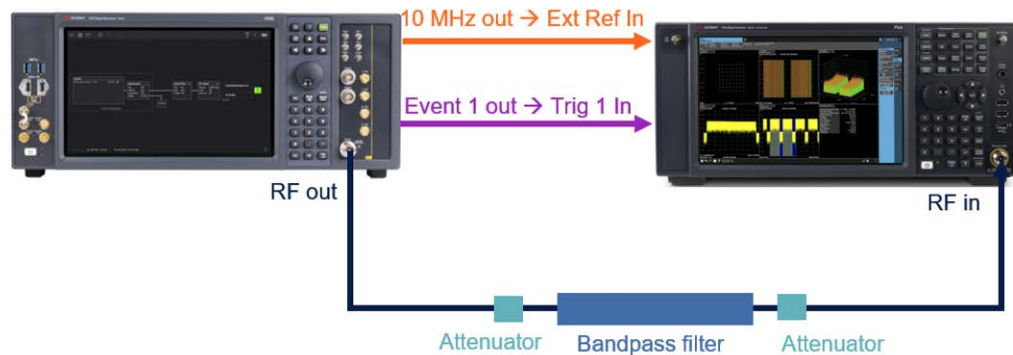
In this measurement example, we will use the M9484C VXG to generate a wideband modulated signal, drive this through a filter and the N9042B UXA will analyze the output signal and display the filter characteristics (gain, phase, and group-delay). Also, all settings to the VXG will be made via the Connection Management setup in the N9042B/N9056EMOE application.

We will start by running a calibration to remove the fixture characteristics (cables, connectors, and other passive components) between the source and the device under test (DUT), in this case the filter. The filter in this example is a 500 MHz bandpass filter, centered at 10.27 GHz. Settings may need to be adjusted for your filter.

For this example we are using the following equipment:

- M9484C
 - Frequency range to 13.5 GHz (M9484C-514, M9484C-520, M9484C-532, or M9484C-544, or M9484C-554)
- N9042B (you can also use a N9040B, N9033B, N9030B, N9020B, or N9021B)
 - N9056EMOE Channel Quality/Group Delay Measurement application
- Accessories
 - Two 3 dB attenuators
 - Baseband filter

1. Connect the two 3 dB attenuators, cables and adapters between the VXG and UXA (omitting the filter).



After running a calibration to remove the effects of the fixturing, we will insert the filter between the two attenuators.

2. From the N9042B, select **Mode/Meas > Channel Quality/Group Delay Mode > Group Delay Measurement > Quad display 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.

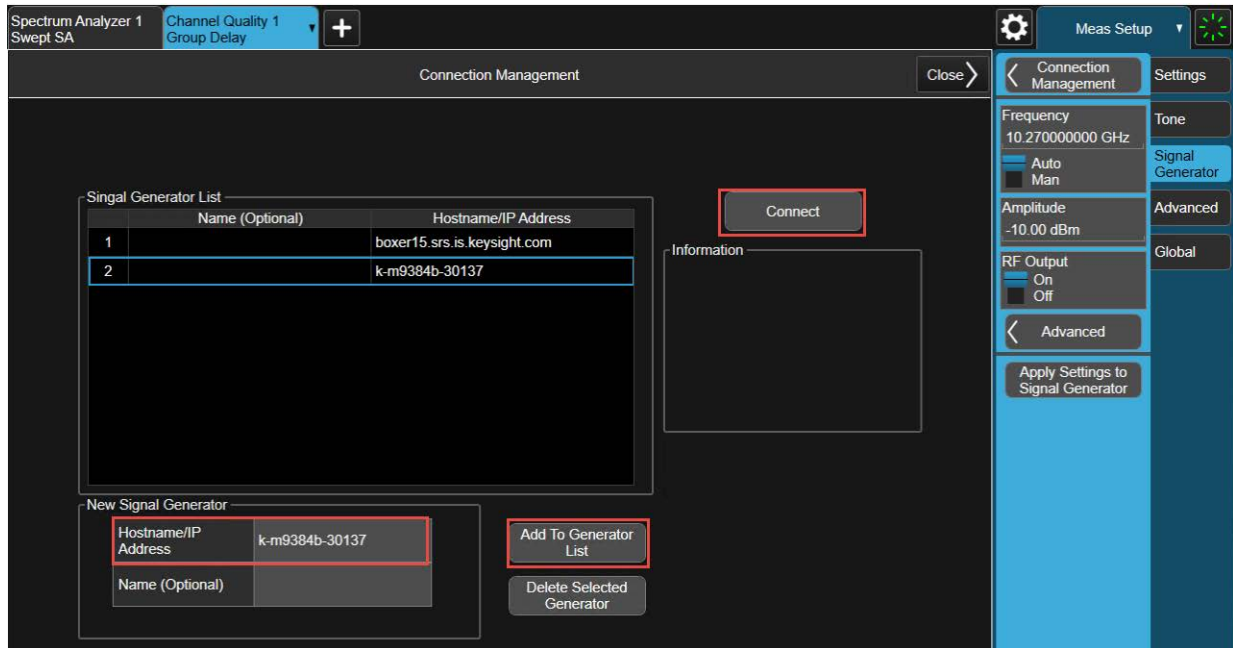
The Quad display shows the Spectrum, Gain Phase, Gain Magnitude, and Group Delay measurements.

3. In the **Frequency** menu panel, set the Center Frequency to **10.27 GHz** and Span to **1 GHz**.
4. In the **Meas Setup** menu panel, select the **Signal Generator** tab and confirm the Center Frequency is set to **10.27 GHz** (the frequency of the filter) and set the Amplitude to **+10 dBm**.

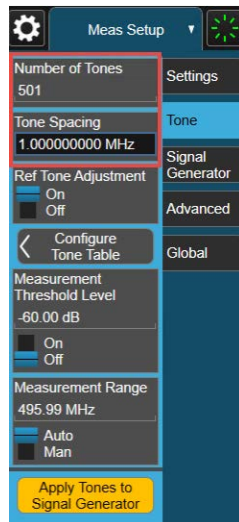
The power is set to +10 dBm to compensate for the affects of the attenuators on the edges of the trace. This is because the SNR has been reduced by the attenuators and without increasing the power you would be essentially measuring the "noise" at the edges.

5. Select **Connection Management**.
6. In the New Signal Generator area, specify the **Hostname or IP address** of the VXG, then select **Add to Generator List > Connect**.

This allows us to setup the VXG directly from the UXA.



7. Select **Apply Settings to Signal Generator** to send these settings directly to the VXG, then **Close** the Connection Management window.
8. In the **Meas Setup** menu panel select the **Tone** tab and set the Number of Tones to **501** with a **Tone Spacing of 1 MHz** to provide a 500 MHz wideband signal.



Notice that the span has automatically changed to 626.3 MHz to accommodate the Tone settings.

9. Select **Configure Tone Table**. There are lots of settings to choose from, but we will use these default settings.

- Fill Type to **Random Phase**
- Random Seed Type to **Fixed**
- Random Seed to **0**

10. Select **Apply Fill** and all of the phase points get filled in for the 501 points. (Originally there were 64.)

11. Select **Apply Tones to Signal Generator** to setup the multitone signal.

You will notice there is some ripple in the traces.

NOTE

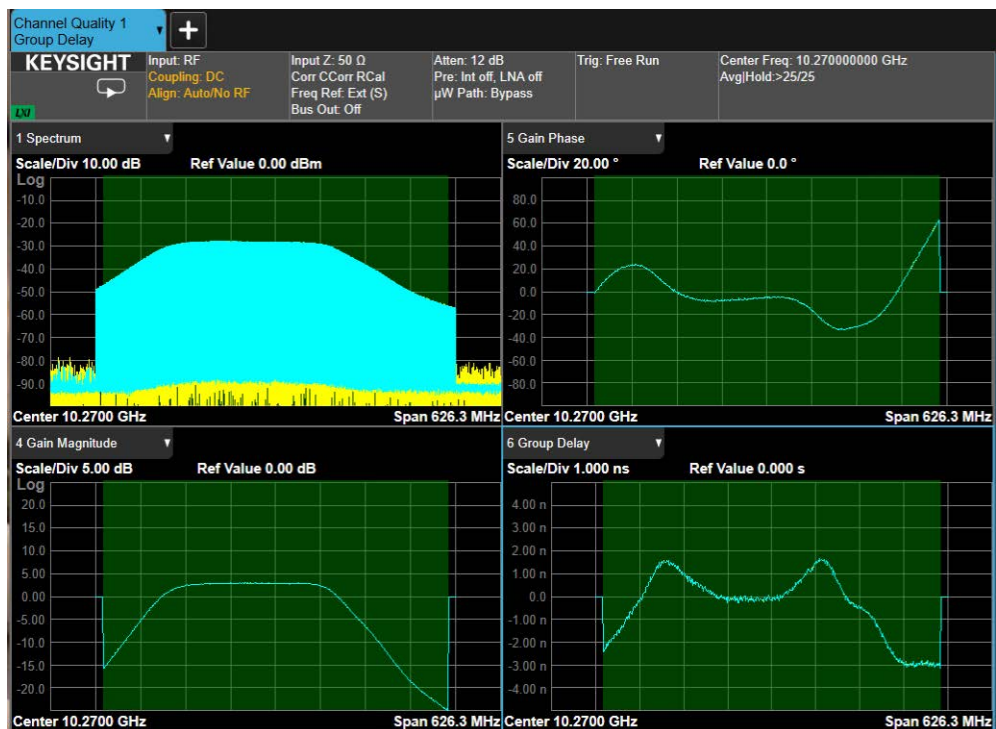
If there is an Input Overload in the UXA, go to **Amplitude > Attenuation** tab > and increase the **Mech Atten 2 dB** at a time until the overload condition is resolved.

12. Select **Do Calibration**.

The calibration will calculate the difference between tone definition and average input trace (magnitude and phase).

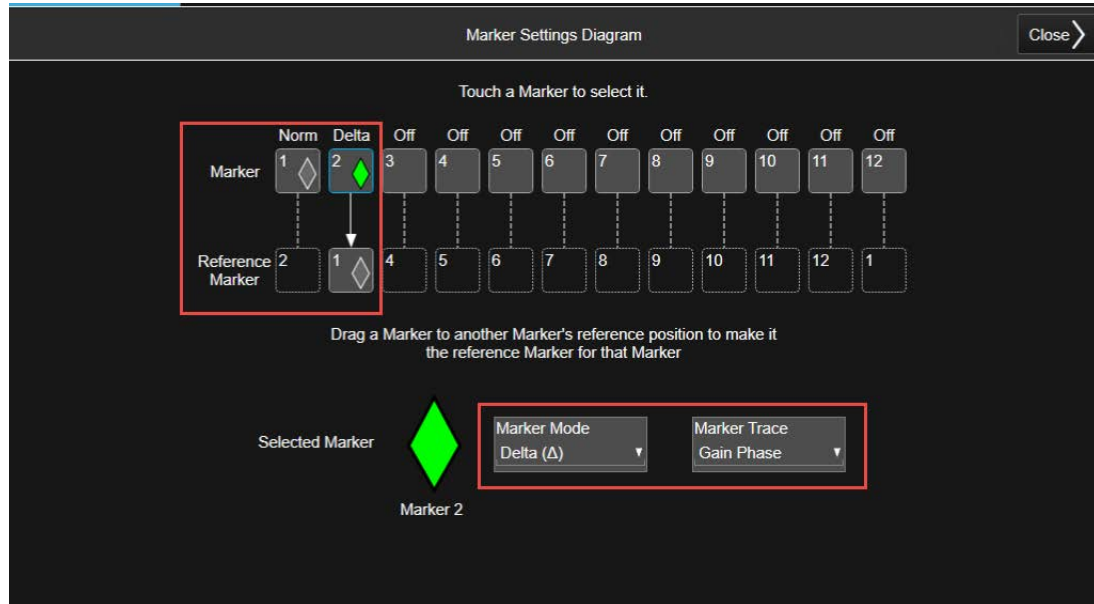
13. Once the calibration is complete, **Close** the Configure Tone table and connect the filter between the two 3 dB attenuators to see the response of the filter.

14. For this example, set the **Gain Magnitude Scale/Div to 5 dB** and the **Group Delay Scale/Div to 1 ns**. For your specific measurement adjust the screen settings to a value that allows you to get the best signal resolution on your measurement displays.



15. From the menu panel, select **Marker** > **Settings** > **Marker Settings Diagram**.
16. Activate Marker 1 by setting Marker Mode to **Normal** and set Marker Trace to **Gain Phase**. Click and drag Marker 1 to the Reference Marker 2 position. Activate Marker 2 by setting Marker Mode to **Delta**, then set Marker Trace to **Gain Phase** to put the marker on the Gain Phase measurement, then **Close** the window.

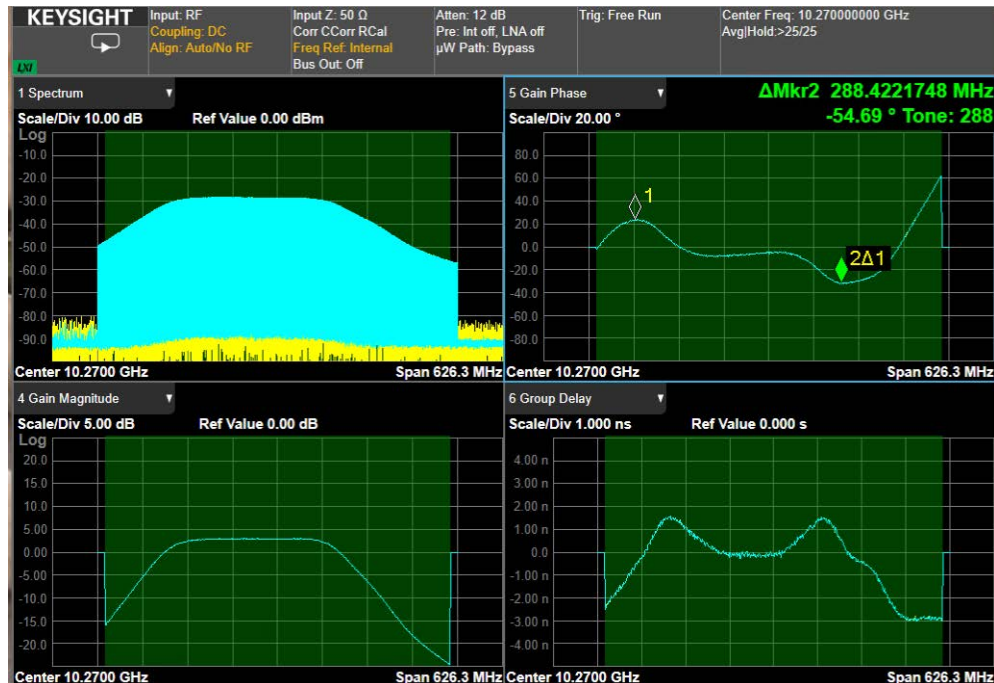
The Gain Phase is really input versus output instead of absolute phase.



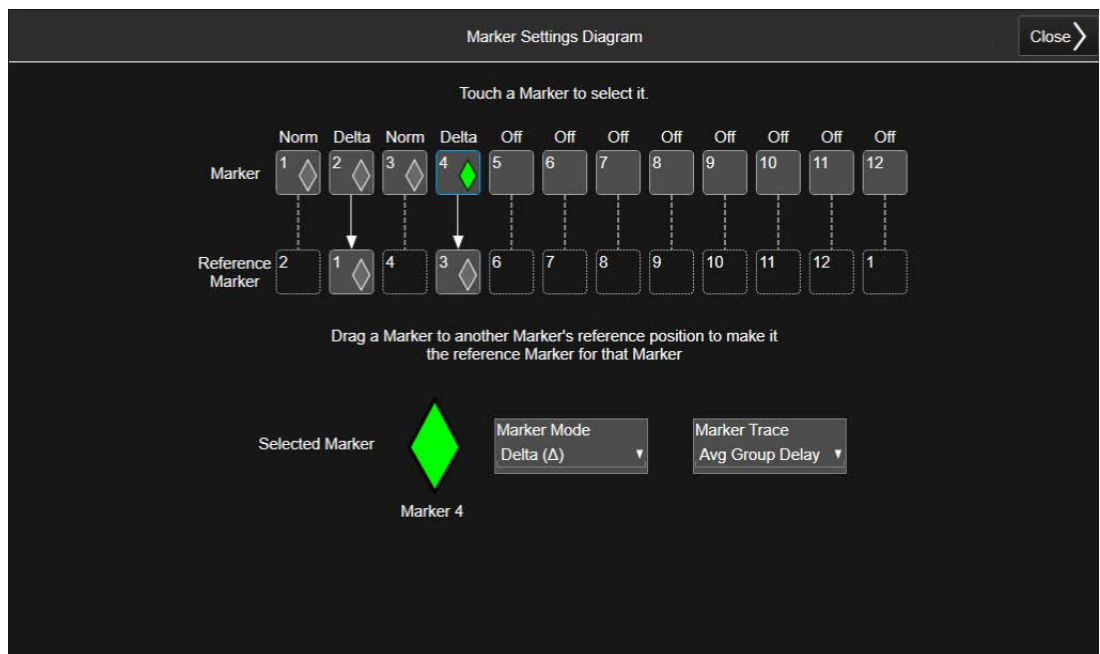
17. Move Marker 1 to the Peak of the Signal within the bandwidth range of the signal and Marker 2 to the minimum.

Other X-Series Signal Analyzer Measurements Setting Up a Group Delay Measurement

This provides the peak-to-peak deviation across this portion of the bandwidth of the filter. For this example, Peak to Peak Deviation is 54.69 °.

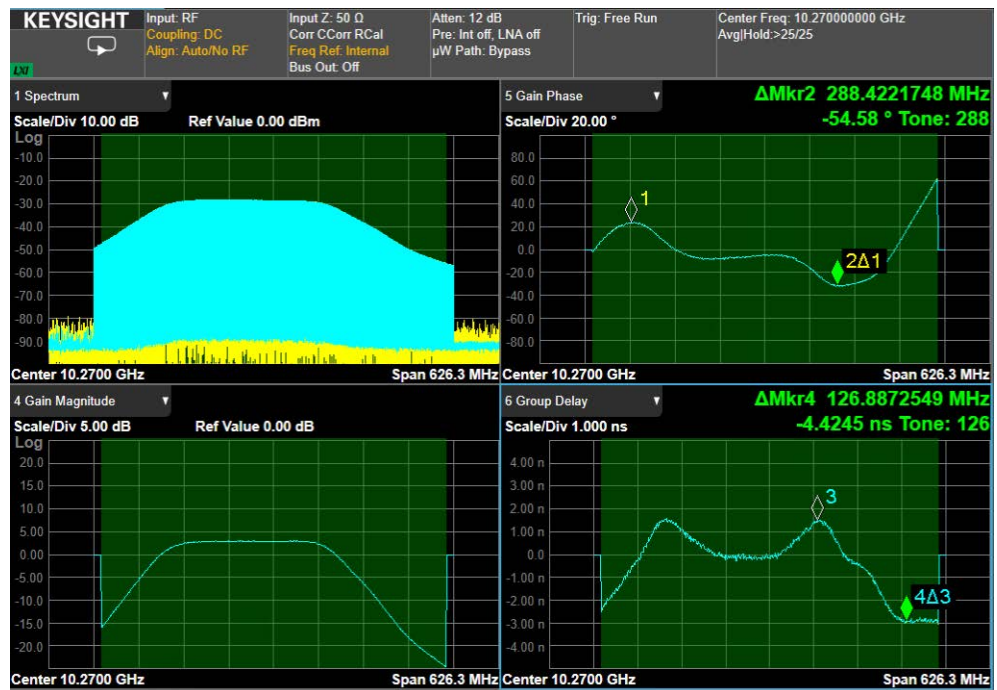


- Go back into the **Marker** Menu and turn on Marker 3 and set Marker Mode to Normal and Marker Trace to **Avg Group Delay**. Drag Marker 3 to Marker 4's Reference Position. Turn on Marker 4 and set Marker Mode to **Delta** and Marker Trace to **Avg Group Delay**. Close the Marker Settings Diagram.

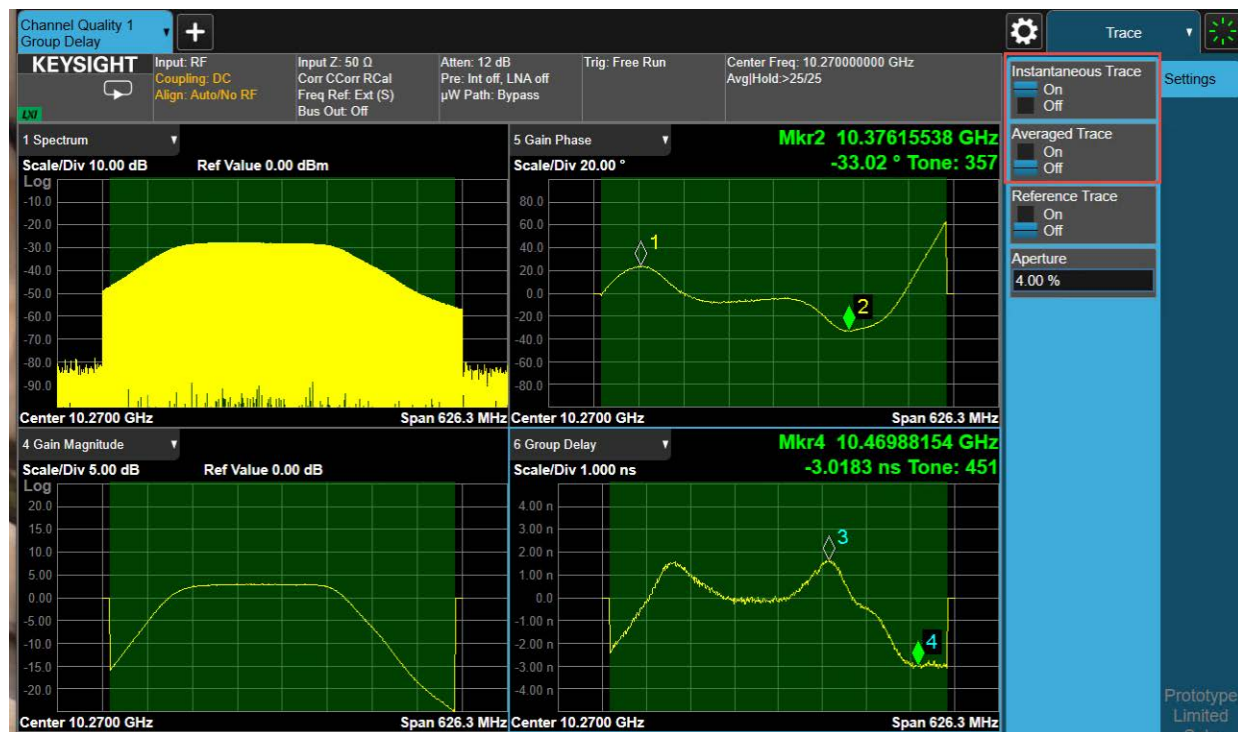


19. Move Marker 3 to the peak of the trace and Marker 4 to the minimum.

For this example, peak to peak Average Group Delay is 4.42 ns.

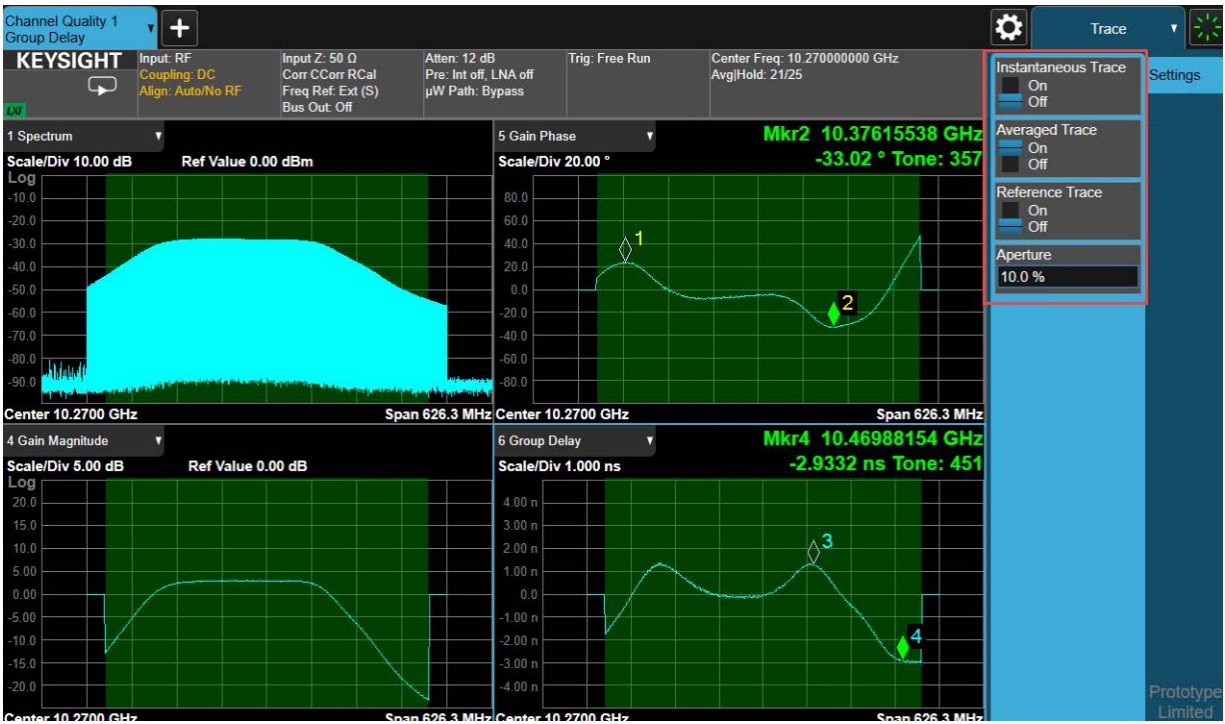


20. From the menu panel, select **Trace > Averaged Trace Off**. With Averaged Trace Off, you can capture small spurs that might occur on the trace.



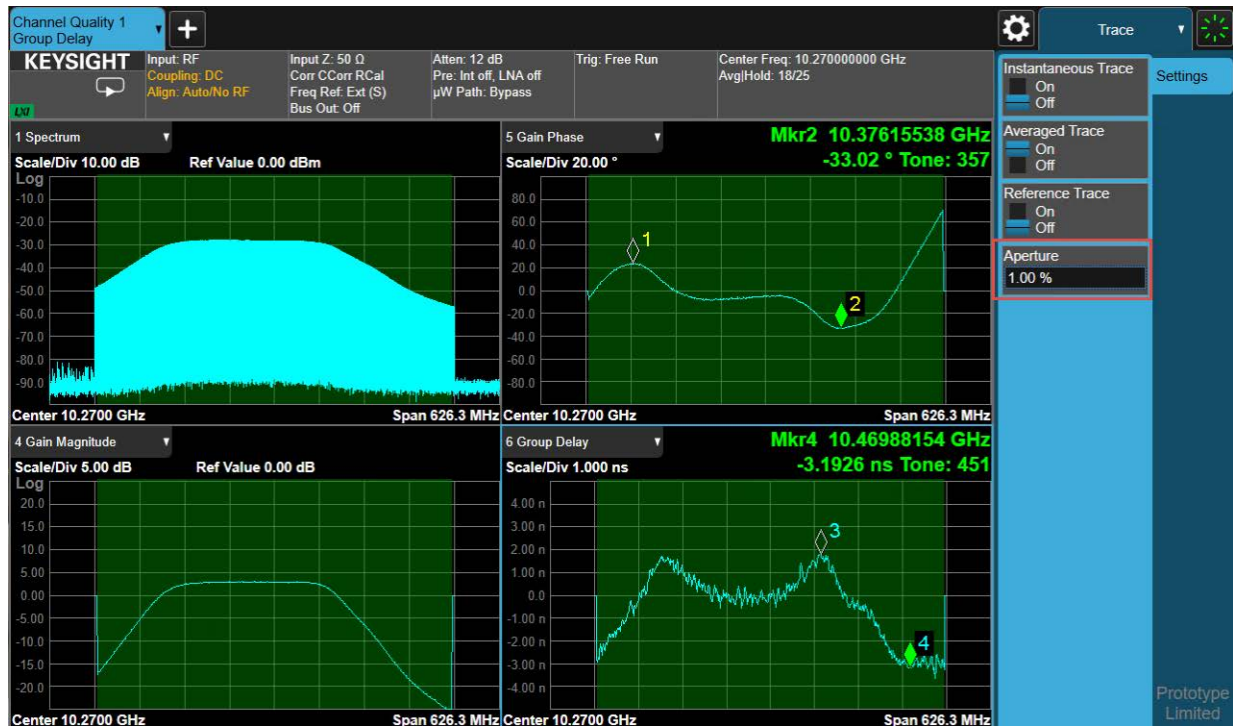
21. Turn Instantaneous Trace **Off** and Averaged Trace **On** then set the Aperture to **10%** to get a smoother result, but lose a little bit more at the beginning and the end of the 500 MHz band.

The Group Delay Aperture is the span over which the math of the delta phase over delta frequency is calculated.



Other X-Series Signal Analyzer Measurements Setting Up a Group Delay Measurement

22. Now set Aperture to a very narrow aperture of 1%. Any deviation or noise in the phase trace will show up a lot more. However as it averages down, the noise will average away.



23. From the N9042B, select **Mode/Meas > Channel Quality/Group Delay Mode > Group Delay Measurement > 3x2 View**.

The 3x2 View will add the RF Envelope (Instantaneous Envelope) and Metrics. Other interesting Views to look are the IQ Waveform that is similar to the RF Envelope, or add the Phase View. Phase only is the absolute phase of the tone.

Other X-Series Signal Analyzer Measurements
Setting Up a Group Delay Measurement

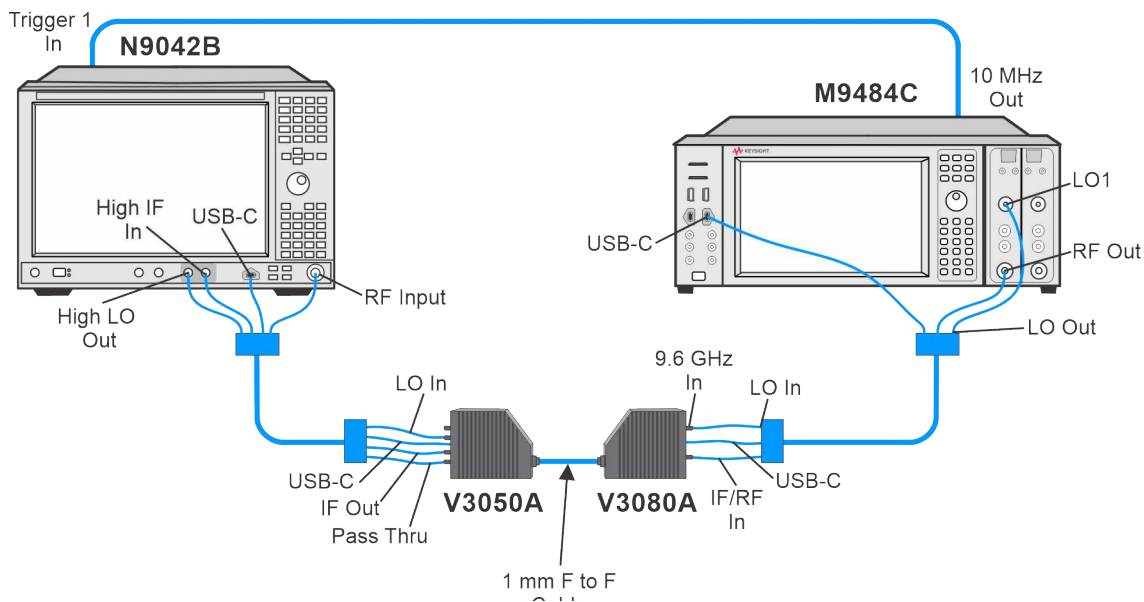


Setting Up Millimeter-Wave Measurements

The V3080A Vector Signal Generator Frequency Extenders are designed to extend the frequency range of Keysight's M9484C for millimeter-wave applications up to 110 GHz.

The V3050A Signal Analyzer Frequency Extenders are unbanded, preselected devices designed to extend the frequency range of Keysight's N9042B UXA for millimeter-wave applications up to 110 GHz.

We will connect the output of the M9484C VXG to the V3080A, then connect the output of the V3080A to the input of the V3050A, and finally connect the V3050A to the UXA to measure frequencies at 60 GHz and above. For complete setup instructions, refer to the V3080A Startup Guide.



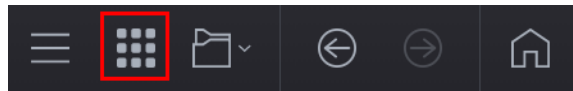
Setting up a 5G NR Millimeter-Wave Measurement

NOTE

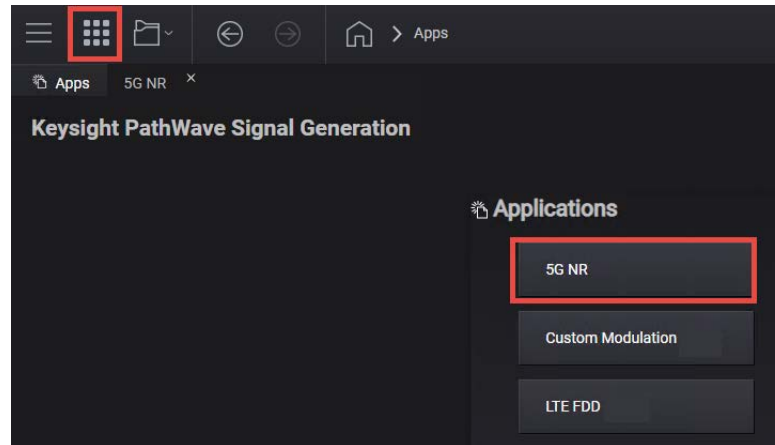
The VXG must have the N7631APPC Signal Generation for 5G NR license installed.

On the VXG:

1. Select **Preset > Preset** to set the VXG to a known state.
2. In the Output area, set Frequency to **60 GHz** and Power to **-10 dBm**.
3. Select the **Radio Apps** block to open the mode selection panel.

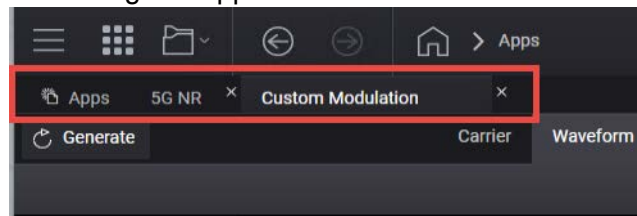


4. Select **5G NR** to enter the 5G NR signal mode.



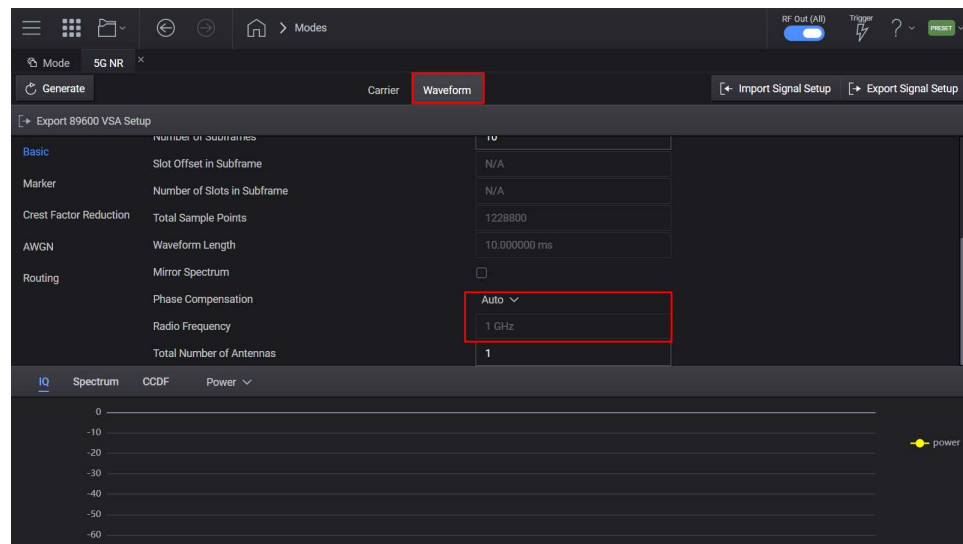
NOTE

If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



5. In the 5G NR setup, select the **Waveform** tab and observe the Phase Compensation and Radio Frequency settings.

Phase Compensation is applied by default at baseband for RF up-conversion. This means it depends on the carrier frequency, and the waveform should only be played at the carrier frequency it was generated for, unlike conventional Signal Studio waveforms, which are independent from carrier frequency. Phase Compensation is set to Auto by default. The frequency is coupled with the VXG frequency setting. You can select Manual to specify a different frequency, or turn it off.



TIP

Some applications, like power amplifier measurements use the same waveform at different frequencies and can be time consuming to generate a separate waveform for each frequency. In this case, you would turn Phase Compensation Off, so the waveform becomes independent from the carrier frequency. You need to do the same on the analysis side, or the demodulation will fail.

6. Select the **Carrier** tab.
7. Select **DL Test Model** and set Bandwidth to **FR2 400 MHz** and **Test Model** to **NR-FR2-TM3.1a**.

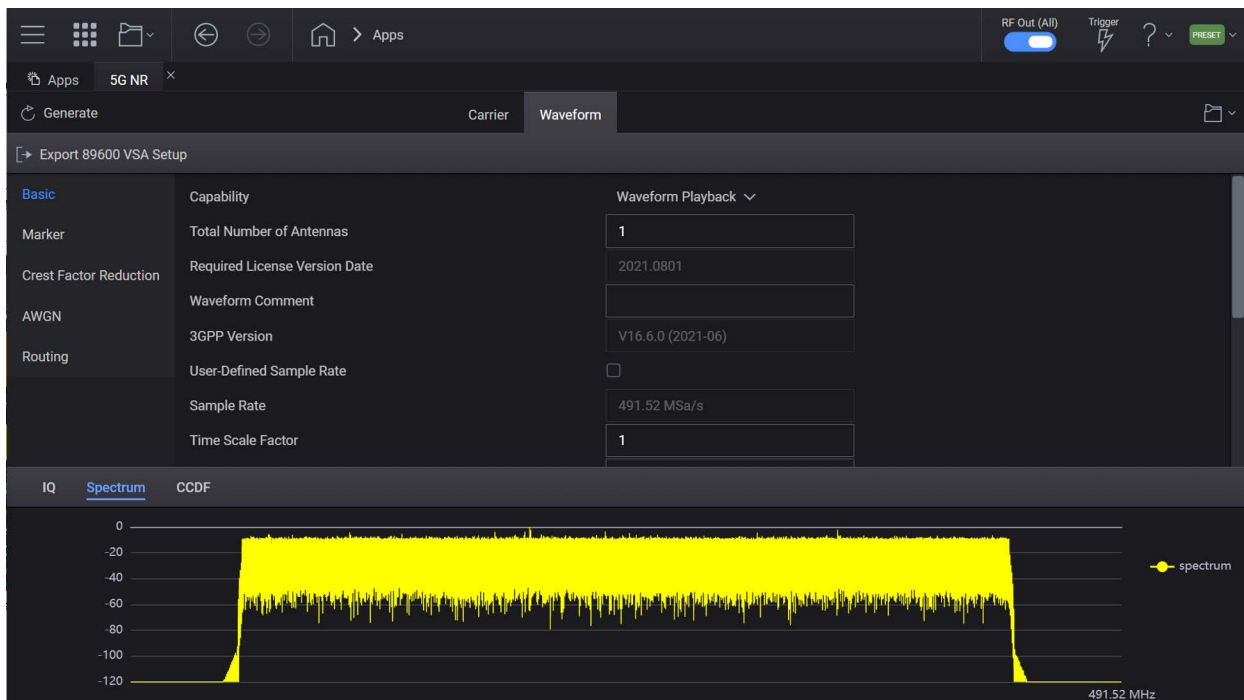
Notice that the description of the currently selected test model appears to the right. These test models are defined in the section 3GPP TS 4.9.2 of 38.141.

Downlink Test Model (Base Station Tx Test based on 38.141 v17.5.0)

Bandwidth	FR2 400MHz	NR-FR2-TM3.1a <ul style="list-style-type: none">• Output power dynamics<ul style="list-style-type: none">◦ Total power dynamic range (upper OFDM symbol power limit at max power with all 256QAM PRBs allocated)• Transmitted signal quality<ul style="list-style-type: none">◦ Frequency error◦ EVM for 256QAM modulation (at max power)
Numerology	$\mu = 3$: 120 kHz	
> Duplex Type	TDD	
Test Model	NR-FR2-TM3.1a	
Phase Compensation	Auto	
DCI/DLSCH Payload Data	PN23	

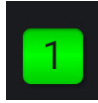
8. Select **OK** to exit the Downlink Test Model setup.

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

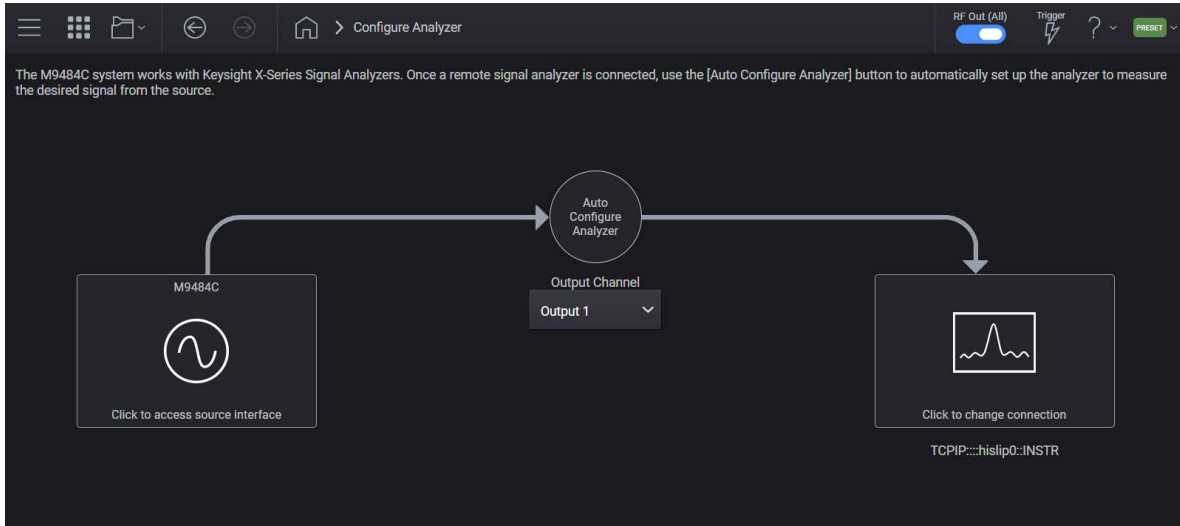


10. Set RF Out to **On** by selecting the numbered channel indicator switch.

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



11. Select the System menu (triple bar tab at the top left of the window) to open the System Menu and then select **Configure Analyzer**.

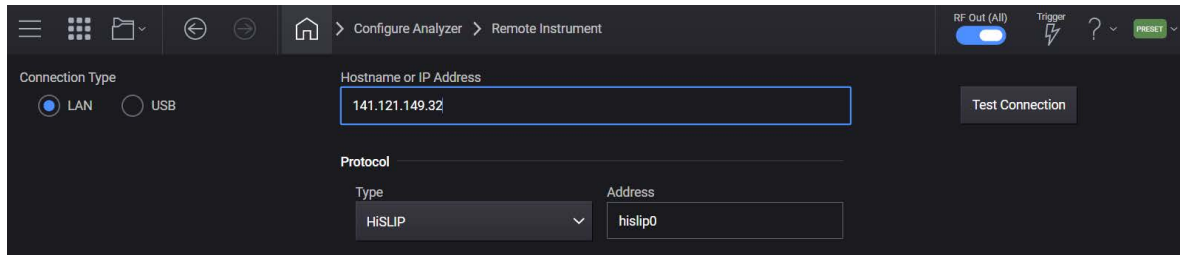


12. In the System Configuration setup, click on the Remote Signal Analyzer block (on far right) to setup the communication channel to the Keysight X-Series Signal Analyzer.



13. Set Connection Type to **LAN**.
14. In the Connect Remote X-Series Signal Analyzer setup, enter the Hostname or IP Address for the signal analyzer.
15. Under Set Protocol, select **HiSLIP** and use the Remote name **hislip0**.

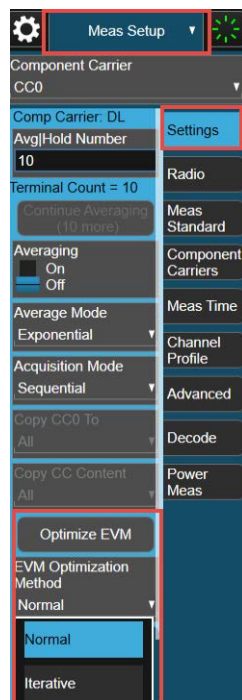
16. Select Test Connection to verify, then Back.



17. Select Auto Configure Analyzer to send the VXG settings to the analyzer.



18. On the N9042B, select Meas Setup > Optimize EVM.



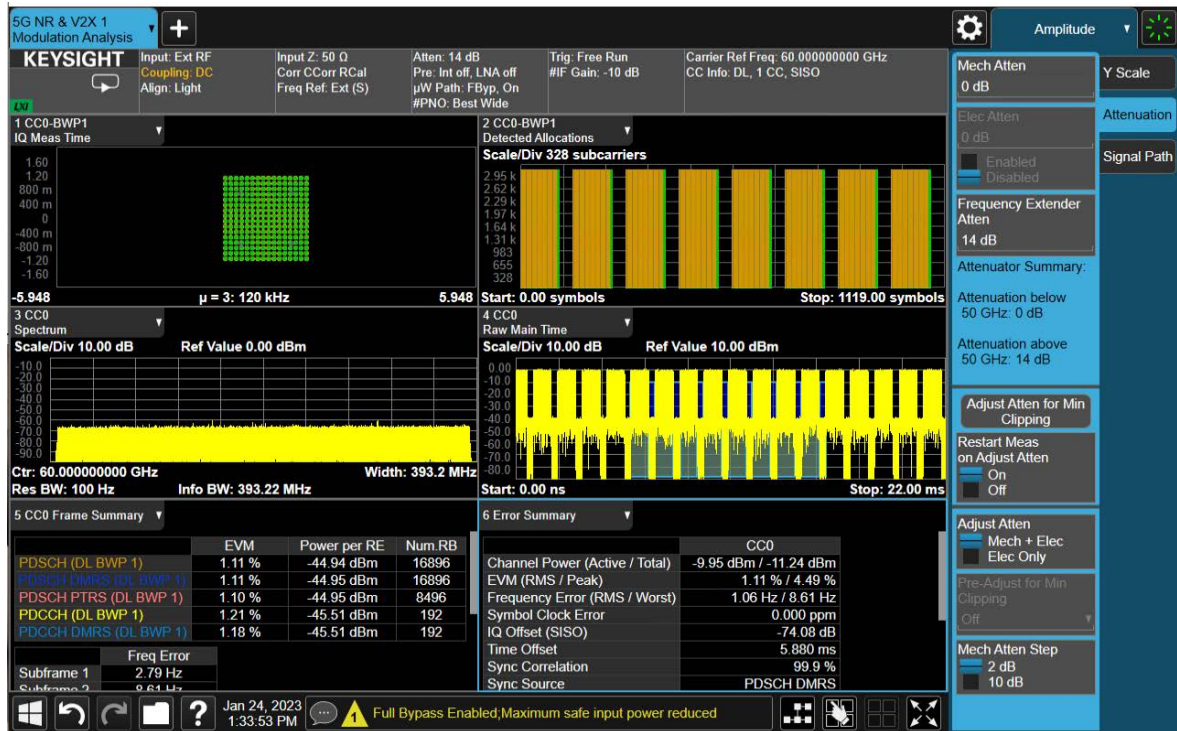
Optimize EVM is an immediate action to adjust the hardware settings to minimize EVM.

- Normal method will capture input signal, measure its peak power then the algorithm will find proper setting combination for attenuation, preamp and IF Gain.

- Iterative method will capture input signal multiple times in a iteration process, demodulate the signal and calculate EVM for each iteration and find setting combination for attenuation, preamp and IF Gain with minimum EVM.

For 5G NR signals, this method is much slower, than normal, but with achieve better EVM results. You can also manually adjust IF Gain, Frequency Extender Attenuation (use when measurement setup includes a V3050A frequency extender).

19. View the results on the signal analyzer.



20. Change the frequency and power level of the M9484C and frequency of the N9042A to view other results. Remember to Optimize EVM after each change.

Other X-Series Signal Analyzer Measurements Setting Up Millimeter-Wave Measurements

This measurement was done at 70 GHz, - 10 dBm.



This measurement was done at 80 GHz, - 10 dBm.



This measurement was done at 85 GHz, - 10 dBm.

Other X-Series Signal Analyzer Measurements
Setting Up Millimeter-Wave Measurements



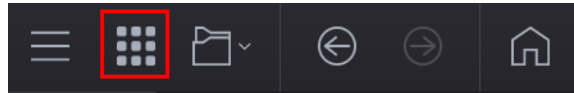
Setting-up a Millimeter-Wave DVB-S2X 64APSK Measurement

NOTE

The VXG must have the N7608C Signal Studio for Custom Modulation license installed.

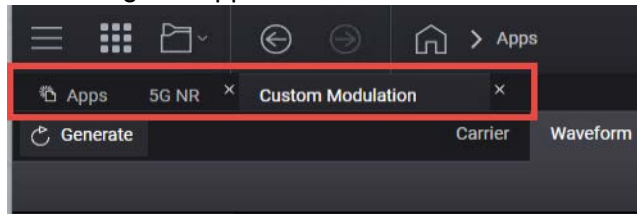
Setting up the VXG

1. Select **Preset > Preset** to set the VXG to a known state.
2. In the Output area, set Frequency to **81 GHz** and Power to **-10 dBm**.
3. Select the **Radio Apps** block to open the mode selection panel.

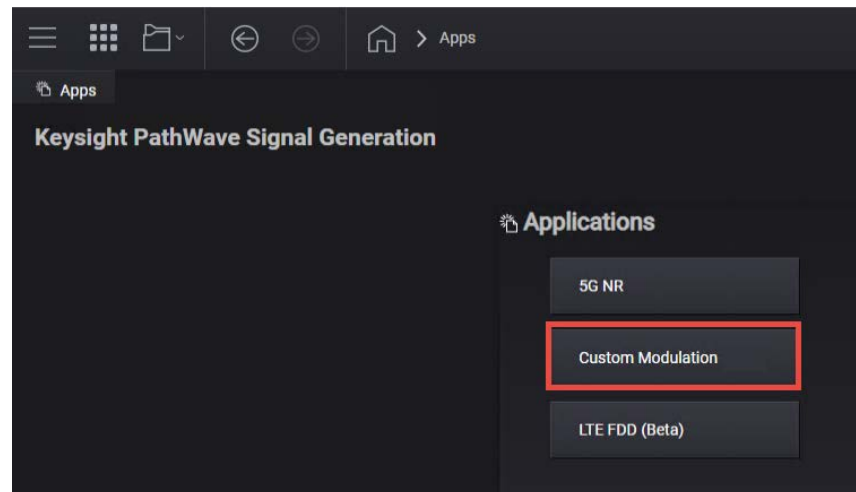


NOTE

If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



4. Select **Custom Modulation** to enter Custom Modulation Signal Mode.

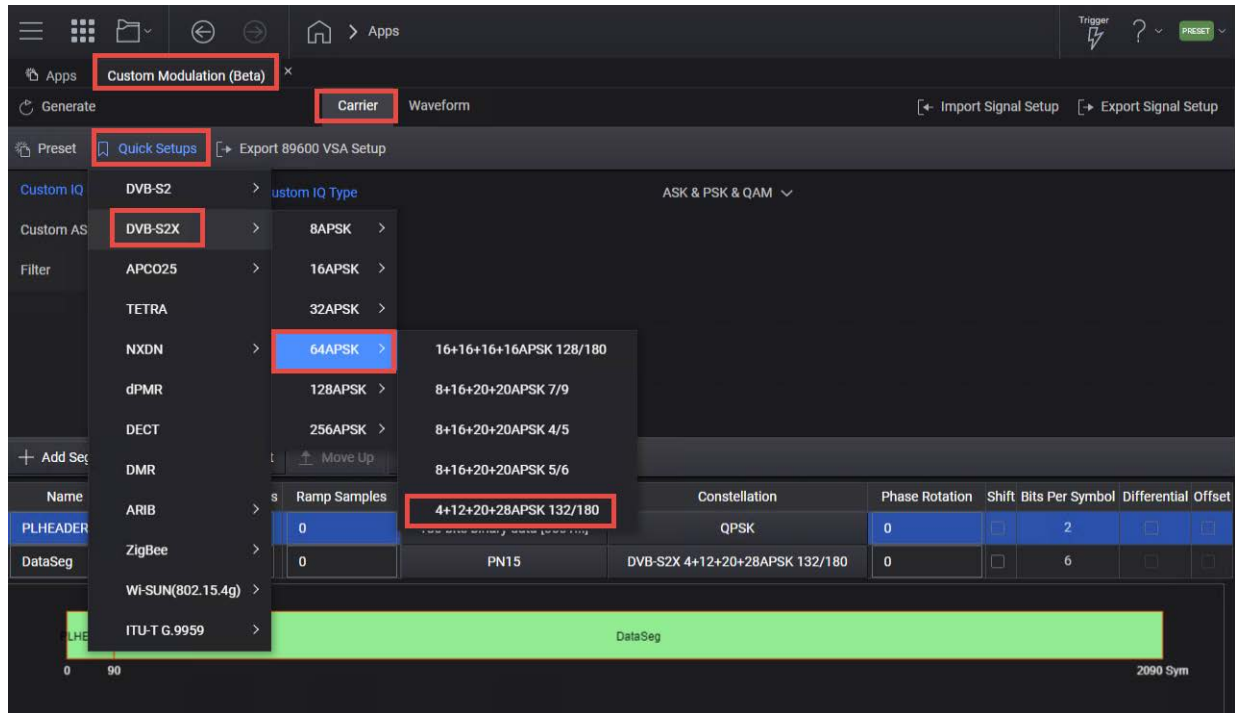


5. Select the **Carrier** tab.

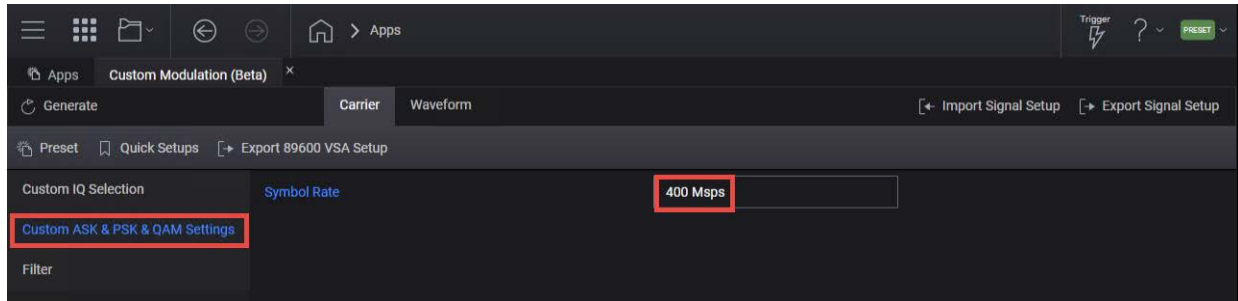
Other X-Series Signal Analyzer Measurements

Setting Up Millimeter-Wave Measurements

- In the Custom Modulation setup, select the **Carrier** tab > **Quick Setups** > **DVB-S2X** > **64APSK** > **4+12+20+28APSK 132/180**.



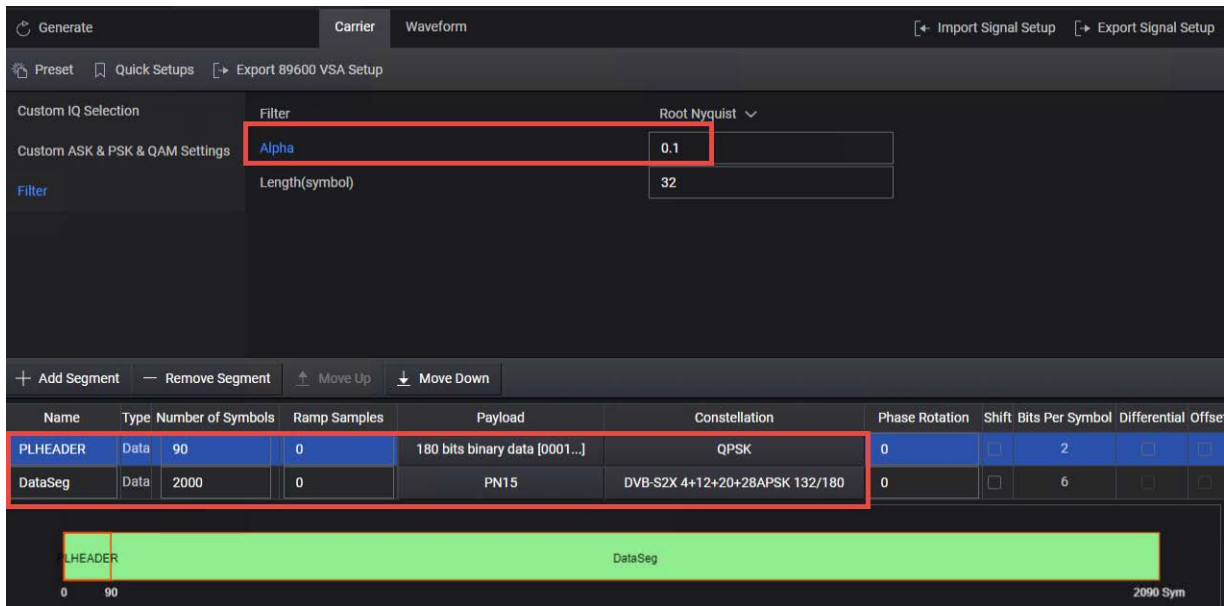
- From the left pane, select **Custom ASK & PSK & QAM Settings** and set the Symbol Rate to **400 Msps** per channel.



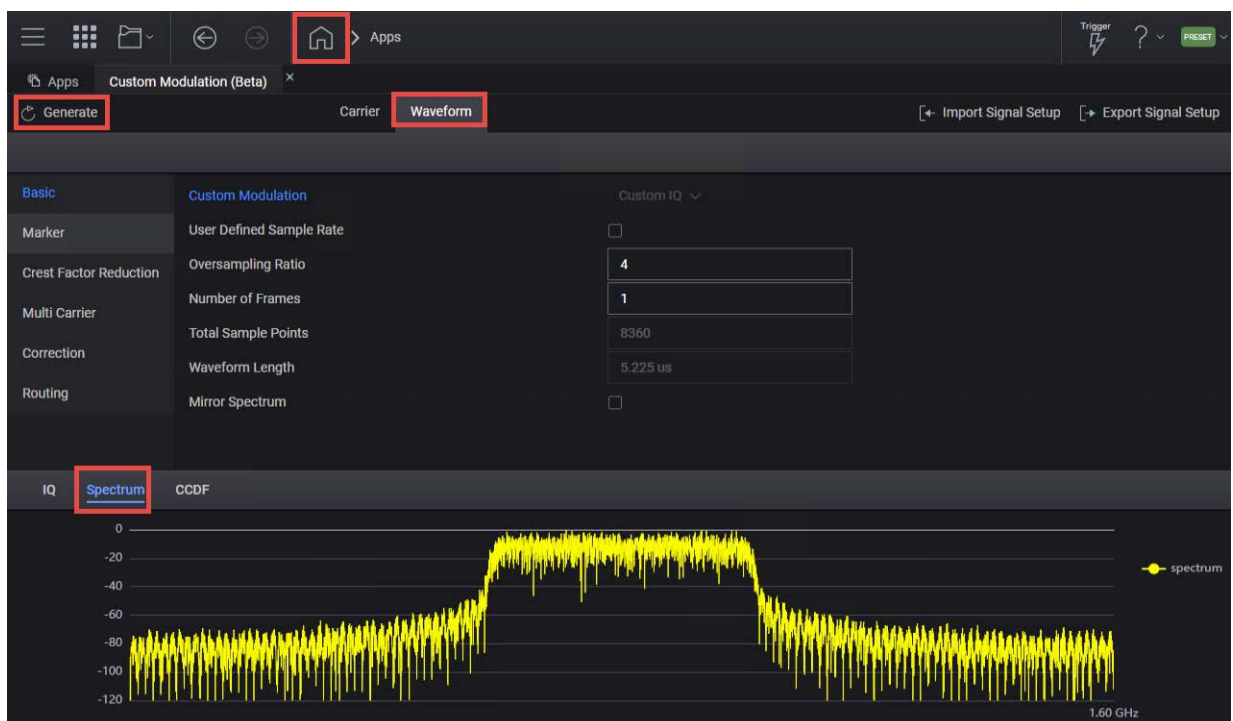
- Select **Filter** > Alpha to **0.1**.

Other X-Series Signal Analyzer Measurements Setting Up Millimeter-Wave Measurements

We will match these settings in the UXA setup.

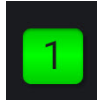


9. Select the Waveform tab, then **Generate** to generate the Waveform, and then select **Home** to exit the setup panel.



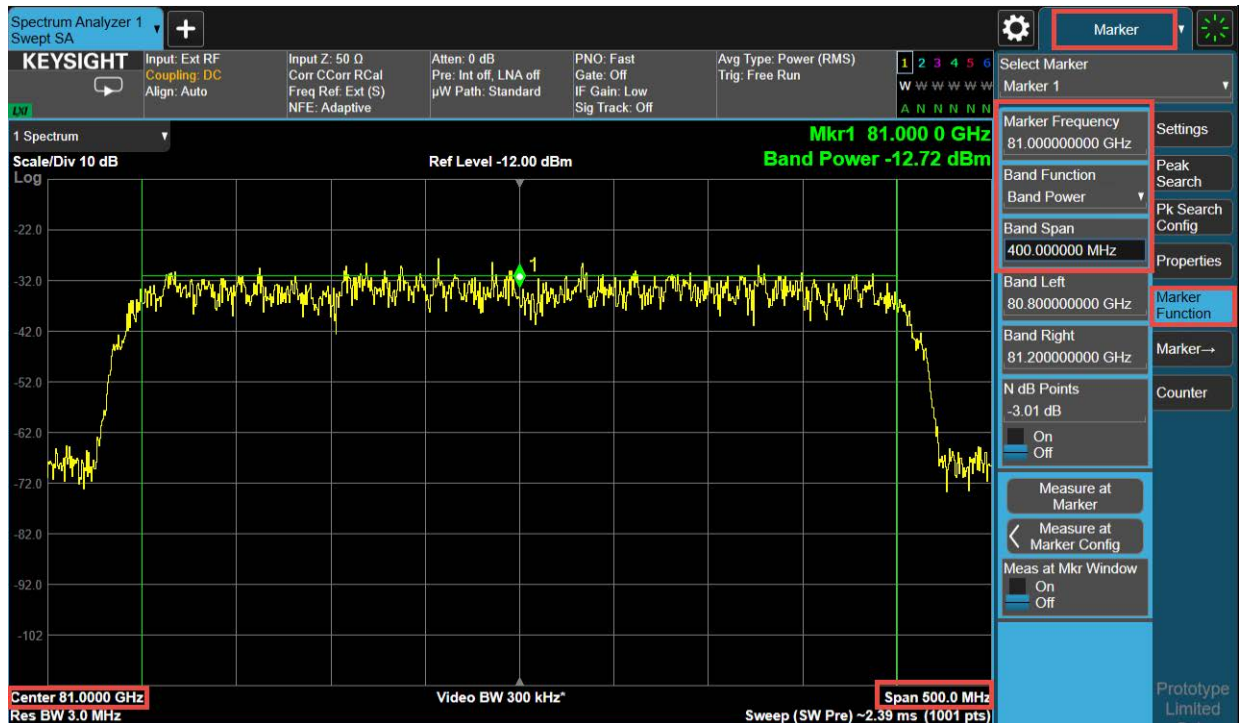
10. Set RF Out to **On** by selecting the numbered channel indicator switch.

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



Setting Up the UXA Using X-Apps

1. Using Spectrum Analyzer Swept SA mode, set Frequency to **81 GHz** and Span to **500 MHz**.
2. Select **Marker** > **Marker Function** tab > Band Function and select to **Band Power**.
3. Set Marker Frequency to **81 GHz**.
4. Set Band Span to **400 MHz**.

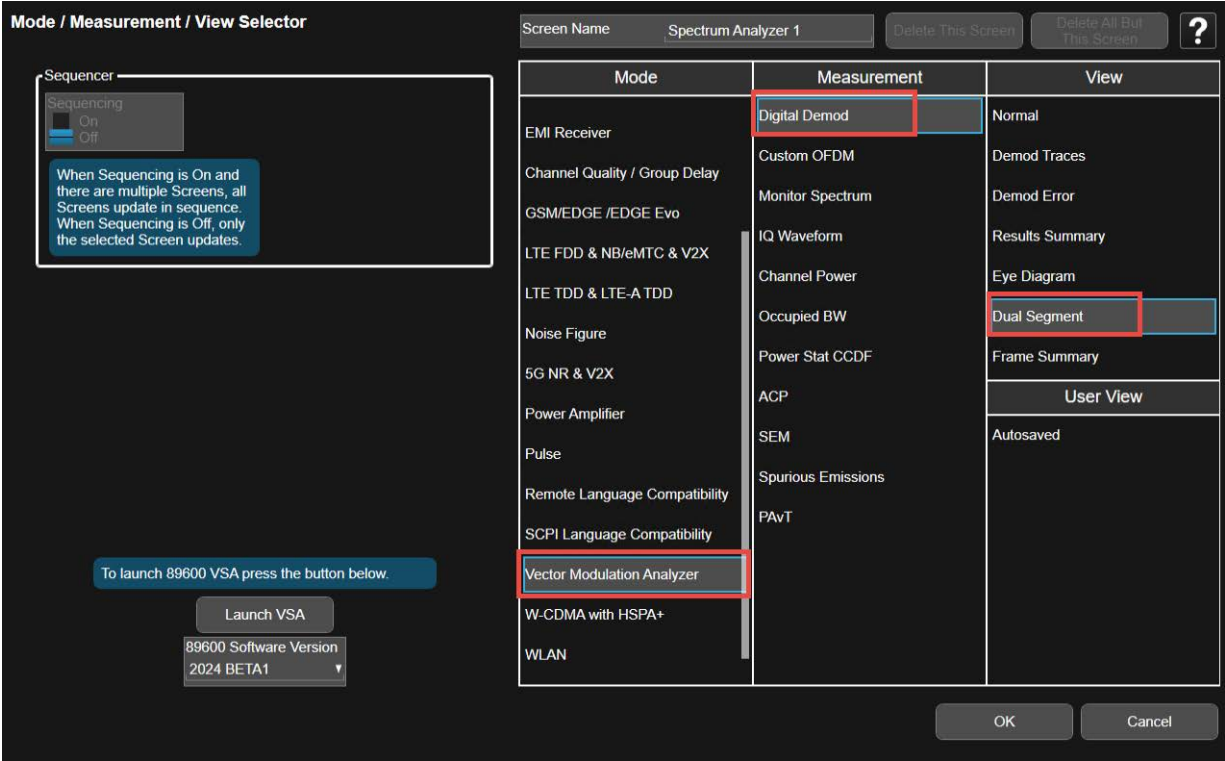


5. Select **Mode/Meas** > **Vector Modulation Analyzer Mode** > **Digital Demod Measurement** > **Dual Segment View**.

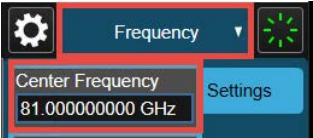
NOTE

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.

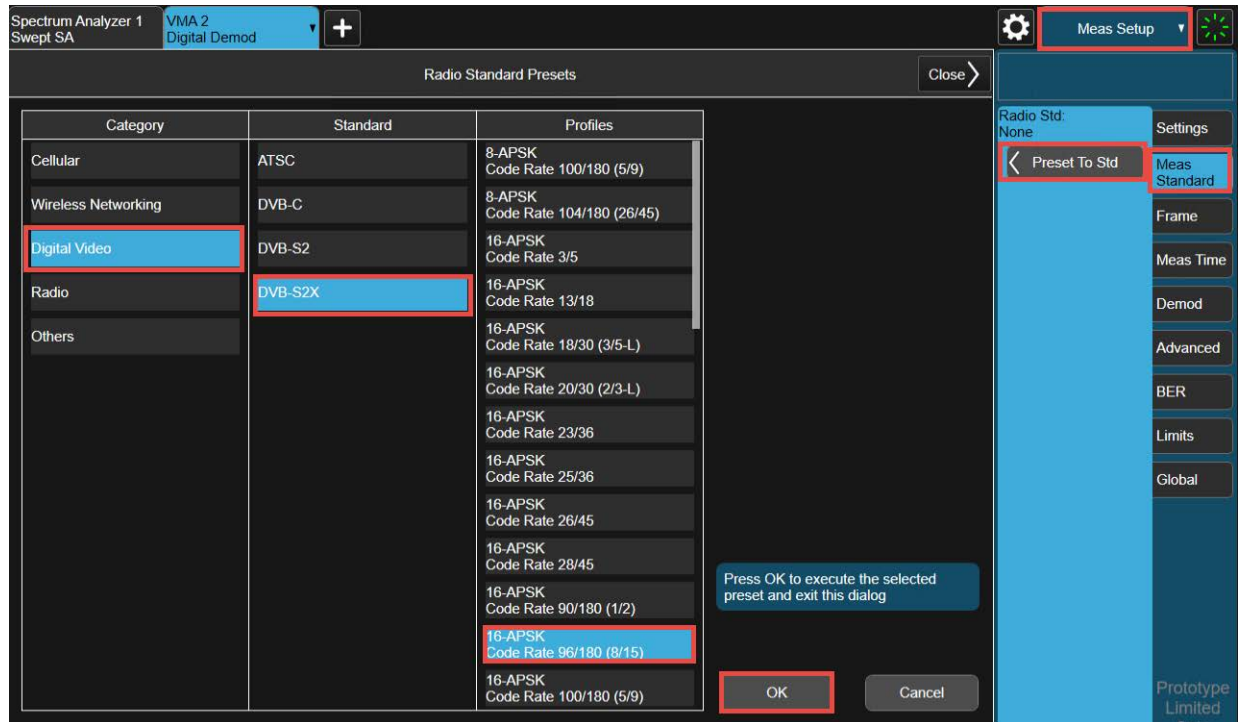
Other X-Series Signal Analyzer Measurements
Setting Up Millimeter-Wave Measurements



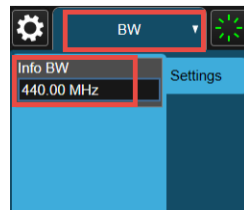
6. Select **Frequency** and set to **81 GHz**.



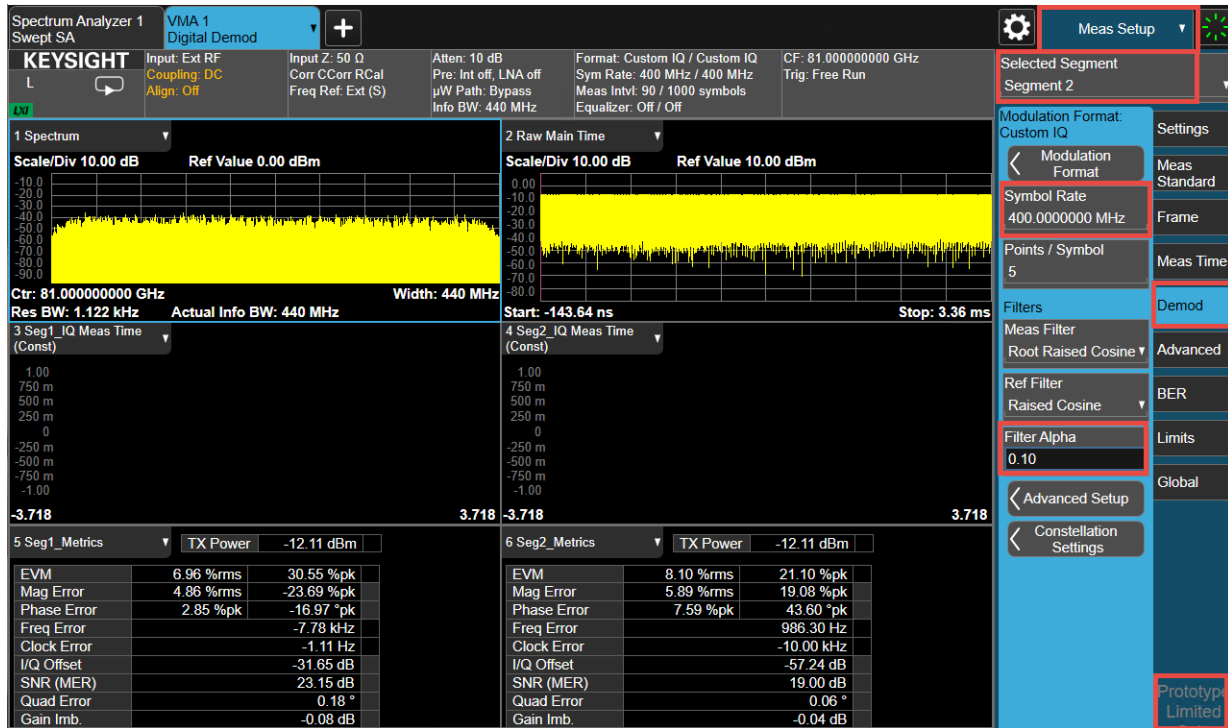
7. Select **Meas Setup** > **Meas Standard** tab > **Presel to Std**, and then select **Digital Video** > **DVB-S2X** > **64-APSK Code Rate 132/180 (11/15)**, then **OK** to close the window.



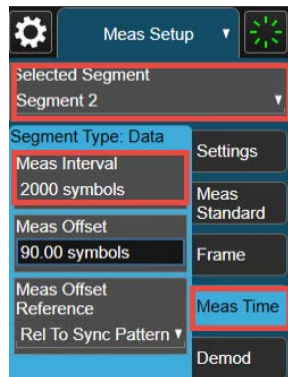
8. Select **BW** and set to Info BW to **440 MHz**.



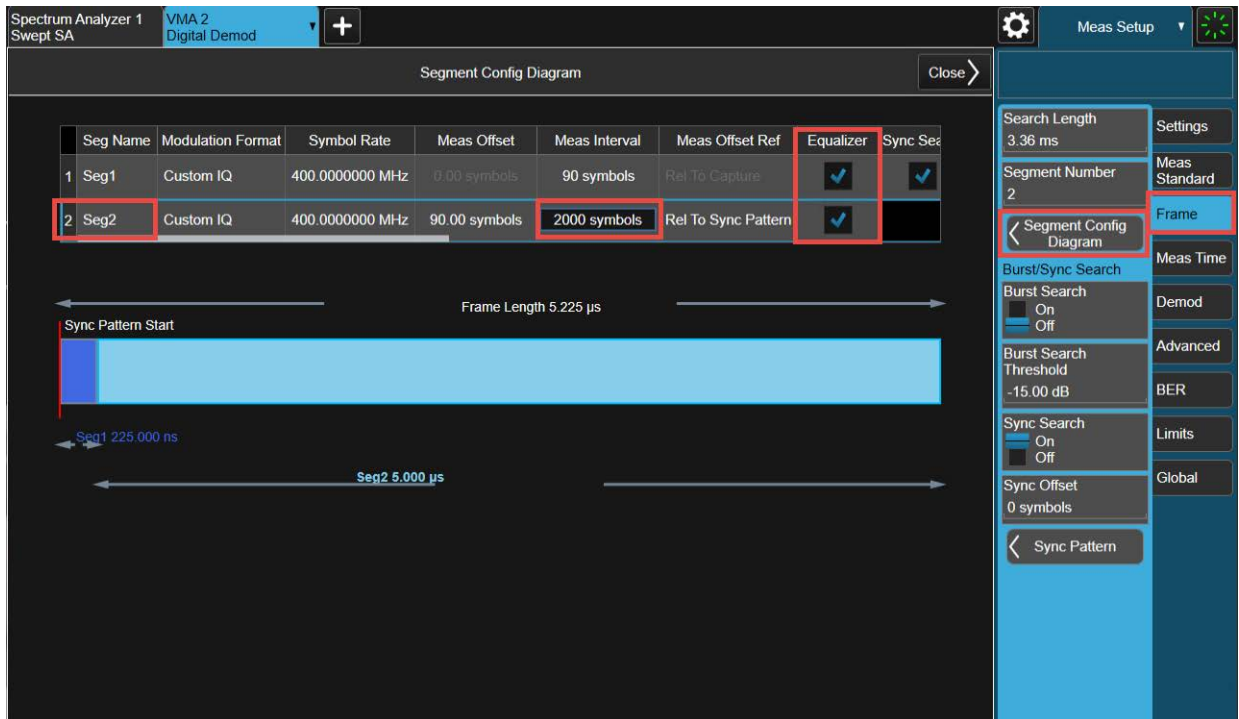
- Select **Meas Setup** > **Demod** tab and set the Symbol Rate to **400 MHz** and Filter Alpha to **0.1** for both **Segment 1** and **Segment 2** to match the settings in the Custom Modulation Setup.



- Select the **Meas Time** tab and note that Meas Interval for Segment 1 is set to 90 symbols, the same as the Header setting in the Custom Modulation setup. Select **Segment 2** and set Meas Interval to **2000** symbols to match the Data Segment in the Custom Modulation setup.

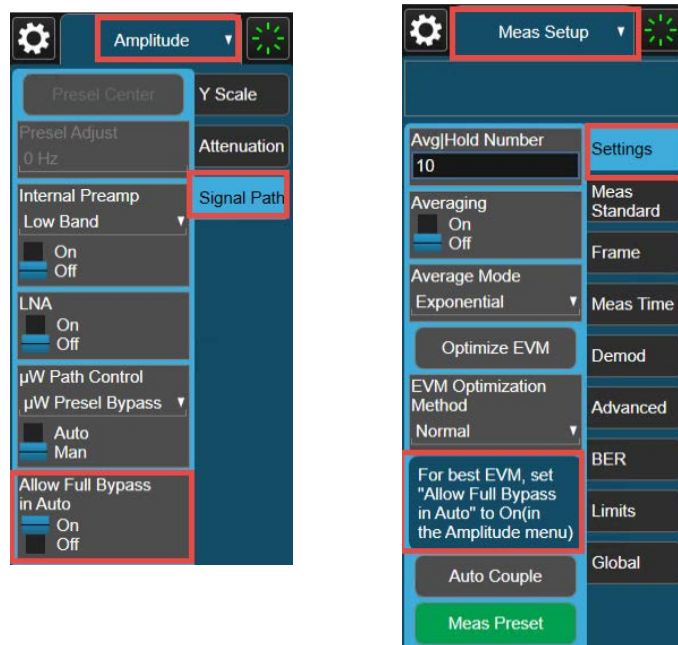


11. Select the **Frame** tab > **Segment Config Diagram** and set **Equalizer** to turn on for both **Segment 1** and **Segment 2**, then **Close** the window.



12. Select **Amplitude** > **Signal Path** tab > select **Allow Full Bypass in Auto** to turn **On**.

Notice that is recommended in the Meas Setup > Settings tab to turn this on for best EVM results.



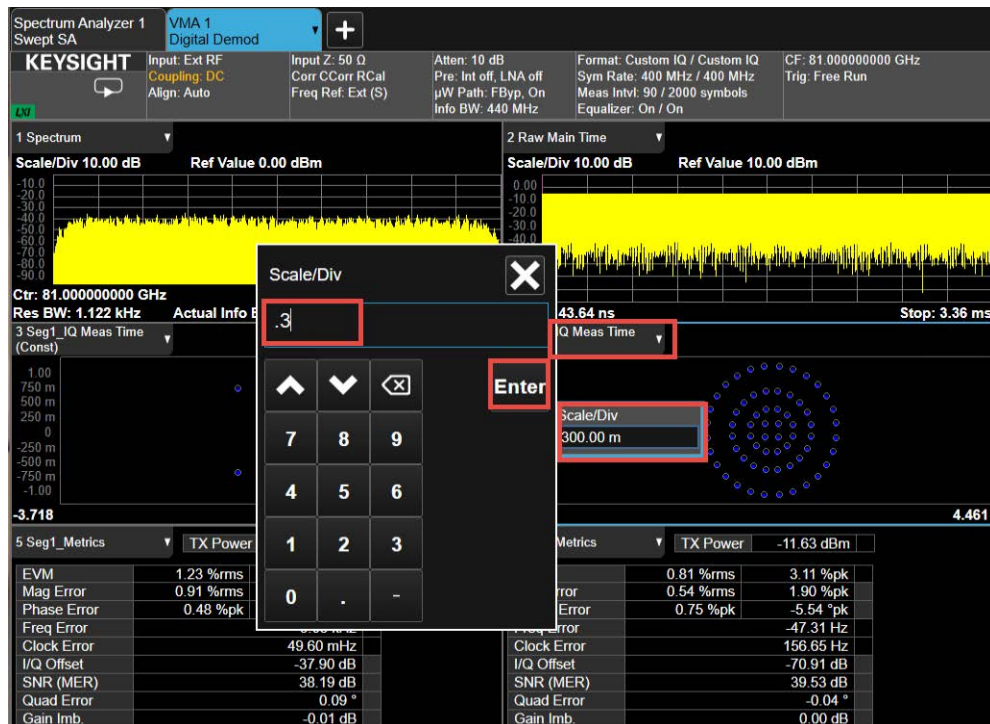
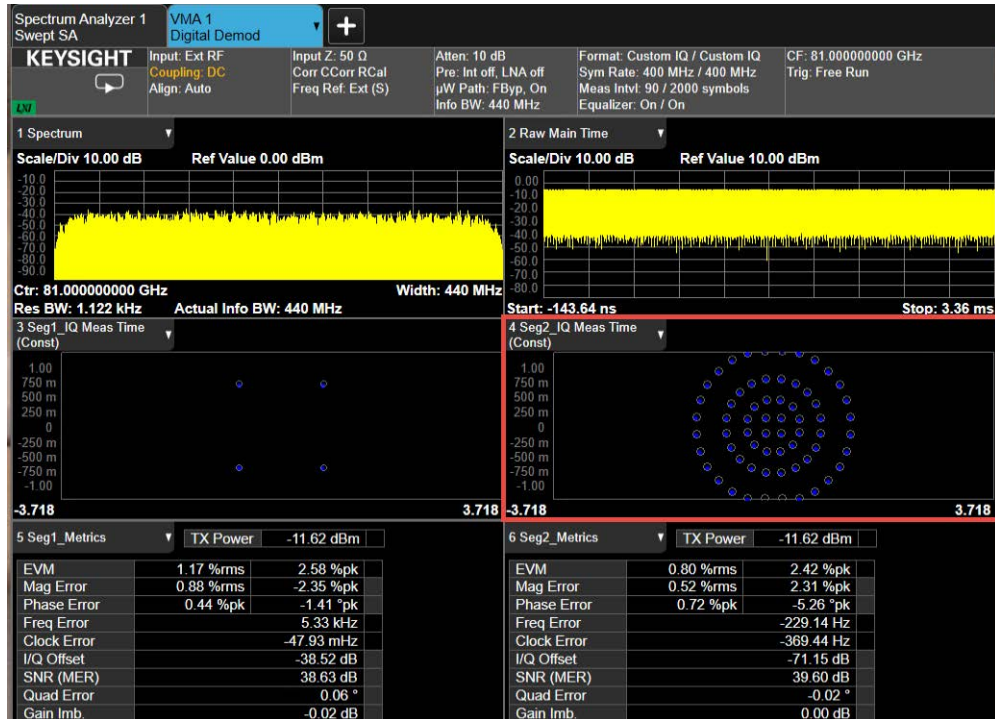
Other X-Series Signal Analyzer Measurements

Setting Up Millimeter-Wave Measurements

13. At the top of the display, select **Equalizer On/Off**. From the dropdown, select **Equalizer Reset**.

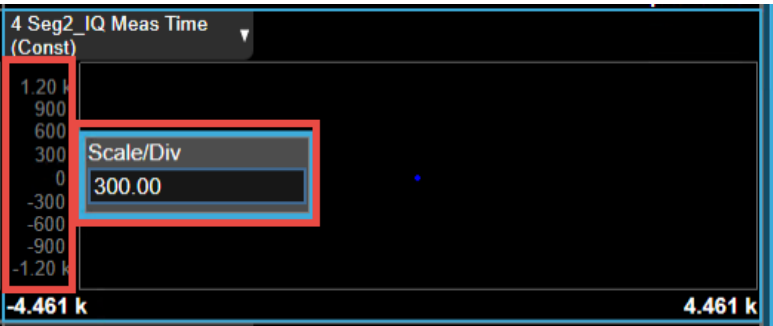


14. In the **Seg2_IQ Meas Time** display, notice that the constellation diagram goes off the display. To adjust the scaling, select the left side of the window and set the **Scale/Div** to **.3 (300.00 m per division) > Enter**.



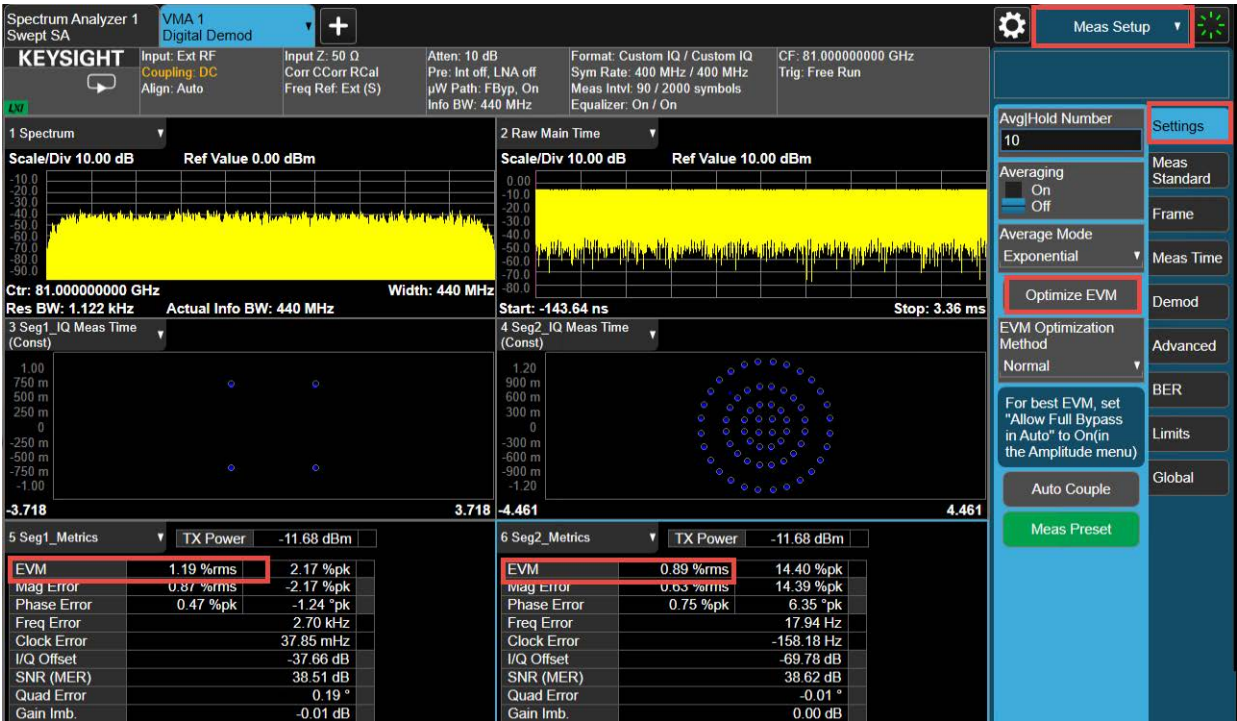
NOTE

You must set this value to 300 instead of .3, the scaling gets changed to 250 k per division instead of 250 m per division.

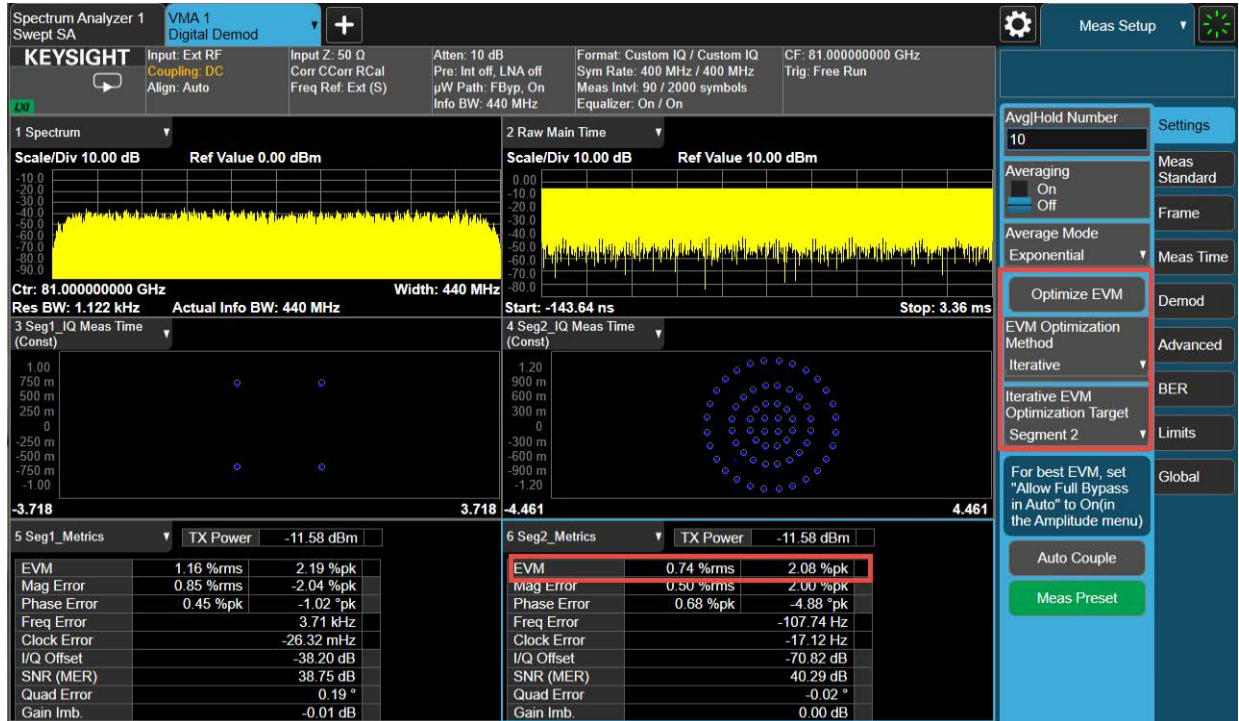


15. Select Meas Setup > Settings tab > Optimize EVM.

The default setting uses the Normal method for Optimize EVM. This is a quick way to improve your measurement results. The EVM will continue to reduce as the UXA continues to sweep. This is because the Equalizer is correcting for linear distortions in the measurement setup.



You can also set EVM Optimization Method Iterative mode, then select either segment for optimization. This method takes a few minutes to complete. For the example below, we set the Optimization Target to Segment 2. Notice how the EVM went from .89% to .74%.



TIP

You can also manually adjust to optimize EVM.

- Select Amplitude menu > Attenuation > Frequency Extender Atten. Use the step keys to increase and decrease the attenuation by 2 dB per step. After each increment, wait for the update to determine where the lowest EVM point is achieved.
- Select Meas Setup > Advanced > IF Gain Other. Use the step keys to increase and decrease the attenuation by 1 dB per step. After each increment, wait for the display to updated to determine where the lowest EVM point is achieved.

In this example, we found the optimum settings were 10 dB of Mechanical Attenuation and -8 dB of IF Gain. We will use these settings in the 89600 VSA setup.

Setting Up the UXA Using 89600 VSA

NOTE

Changing settings on the VSA can take longer to take affect than expected. Pausing the measurement until all settings have been made will help speed up the time. Wait to change the next setting until the previous setting has been updated.

1. Open the VSA software.

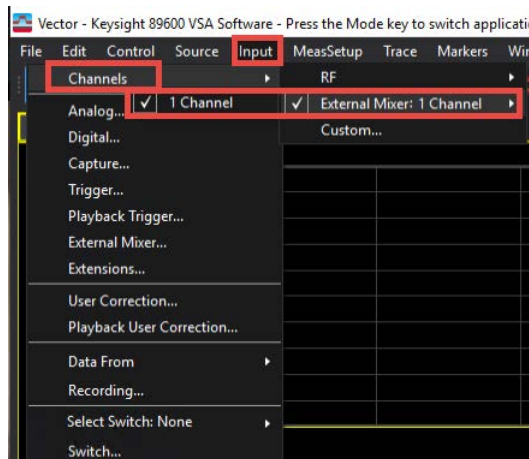
To access the VSA software, go to the Windows Start menu and find Keysight 89600 Software (latest installed version) folder and run the software.

NOTE

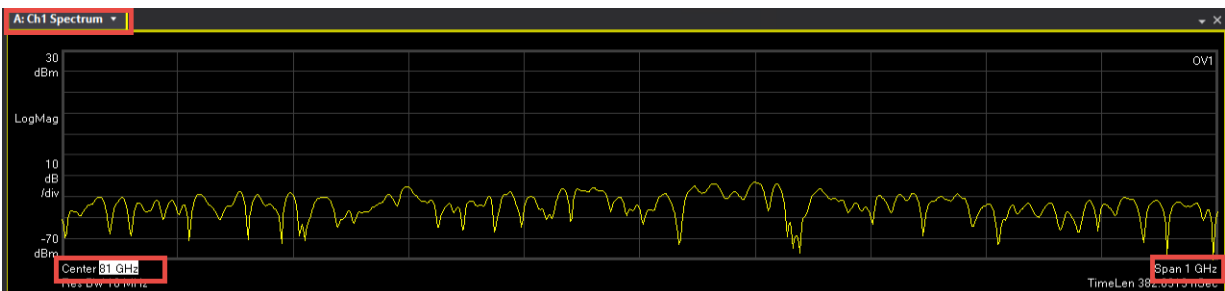
If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

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

3. From the menu bar, select **Input > Channels > External Mixer > 1 Channel**.

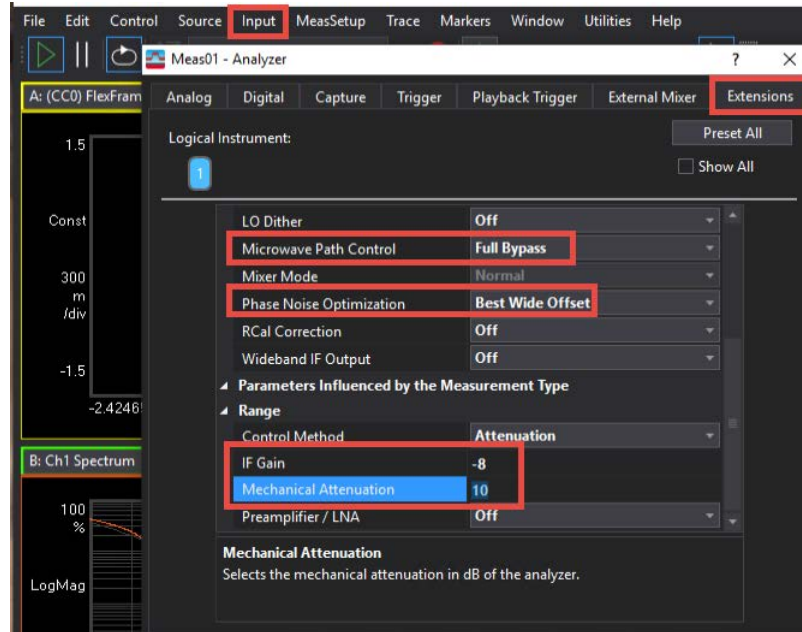


4. In the **Spectrum** window, select **Center** and set the Center Frequency to **81 GHz**. and Span to **1 GHz**.



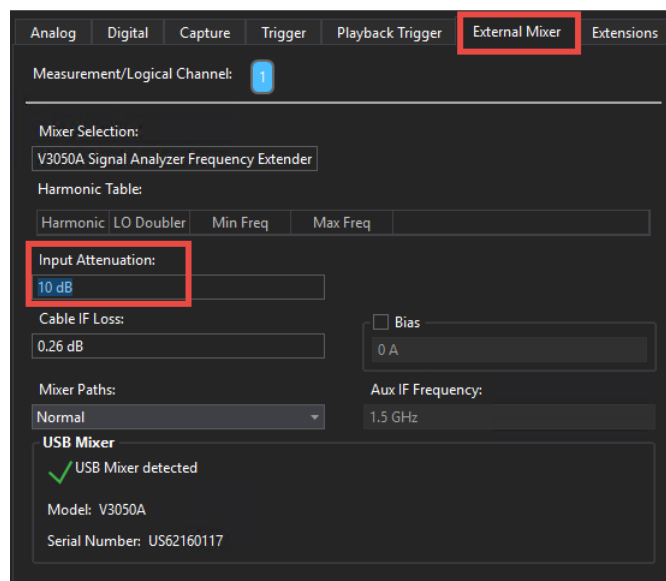
5. From the menu bar, select **Input > Extensions** and set:

- Microwave Path Control to **Full Bypass**
- Phase Noise Optimization to **Best Wide Offset**



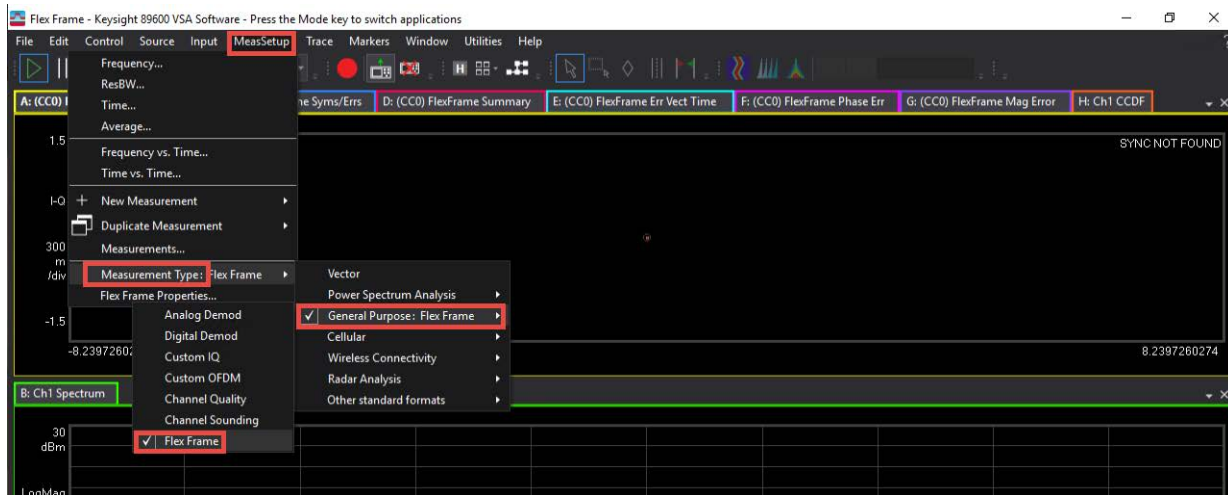
- IF Gain to **-8 dB**
- Select the External Mixer tab and set Input Attenuation to **10 dB**

These are the optimized settings we used in the X-Apps measurement.

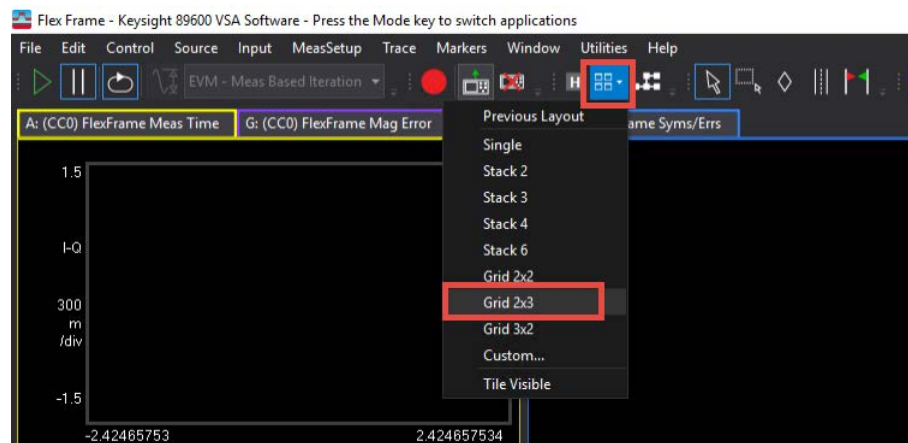


Other X-Series Signal Analyzer Measurements Setting Up Millimeter-Wave Measurements

6. From the menu bar, select **MeasSetup** > **General Purpose** > **Flex Frame**.



7. Change the Trace Layout Grid to 2 x 3.

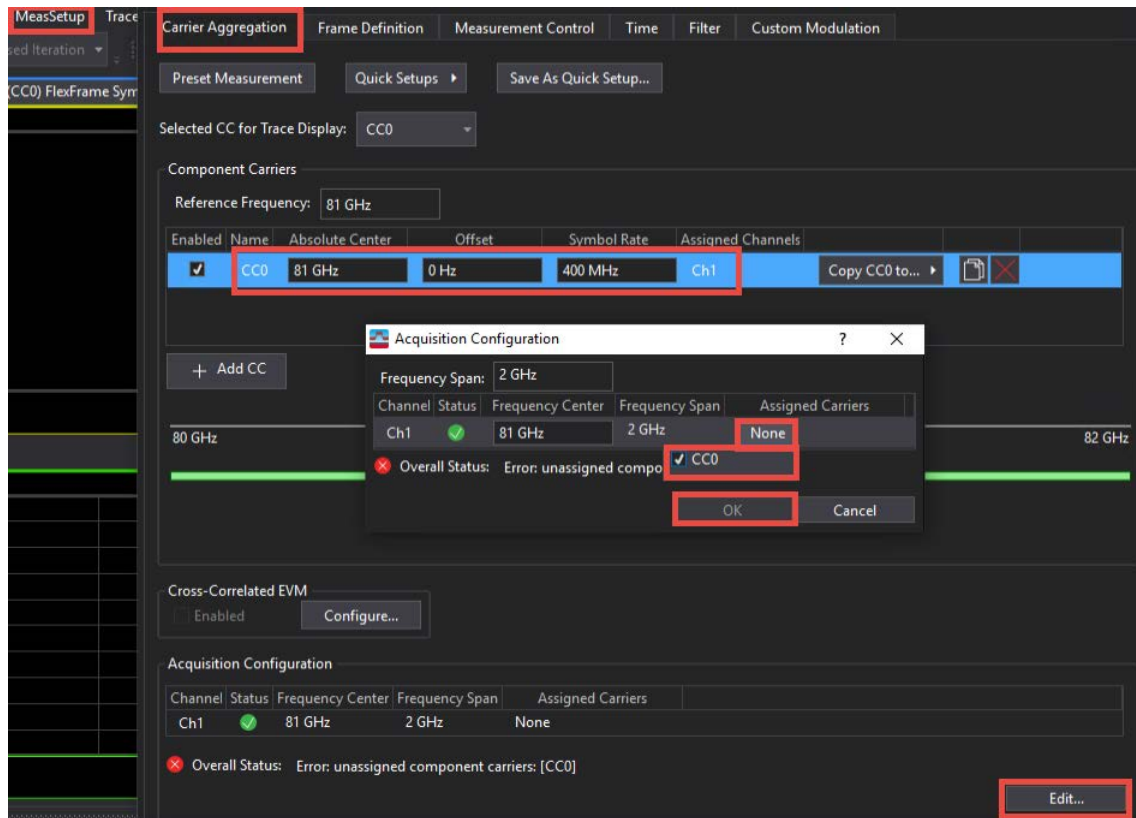


8. Select **MeasSetup** > **Flex Frame Properties** > **Carrier Aggregation** tab, and set:

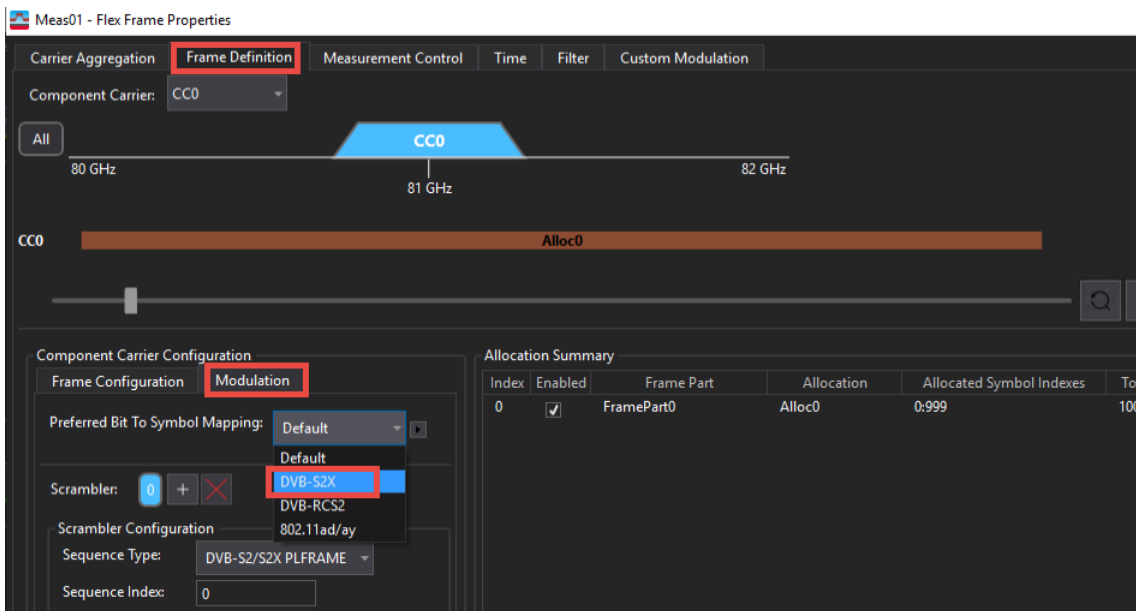
- CCO Absolute Center frequency to **81 GHz**
- Symbol Rate to **400 MHz**.

Other X-Series Signal Analyzer Measurements Setting Up Millimeter-Wave Measurements

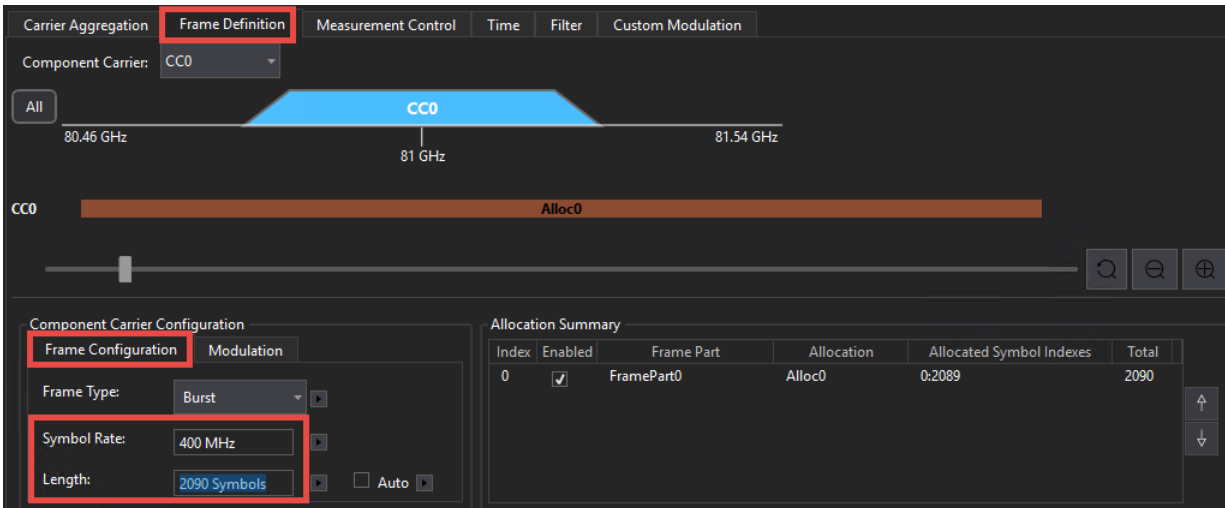
- **Edit** dropdown and set Assigned Carriers to **CC0**.



9. In the Flex Frame Properties window, select the **Frame Definition** tab. Under Component Carrier Configuration, select the **Modulation** tab, and then set Preferred Bit to Symbol Mapping to **DVB-S2X**.



10. In the Frame Definition tab, under Component Carrier Configuration, select the **Frame Configuration** tab and set Symbol Rate to **400 MHz** and Length to **2090 Symbols**.



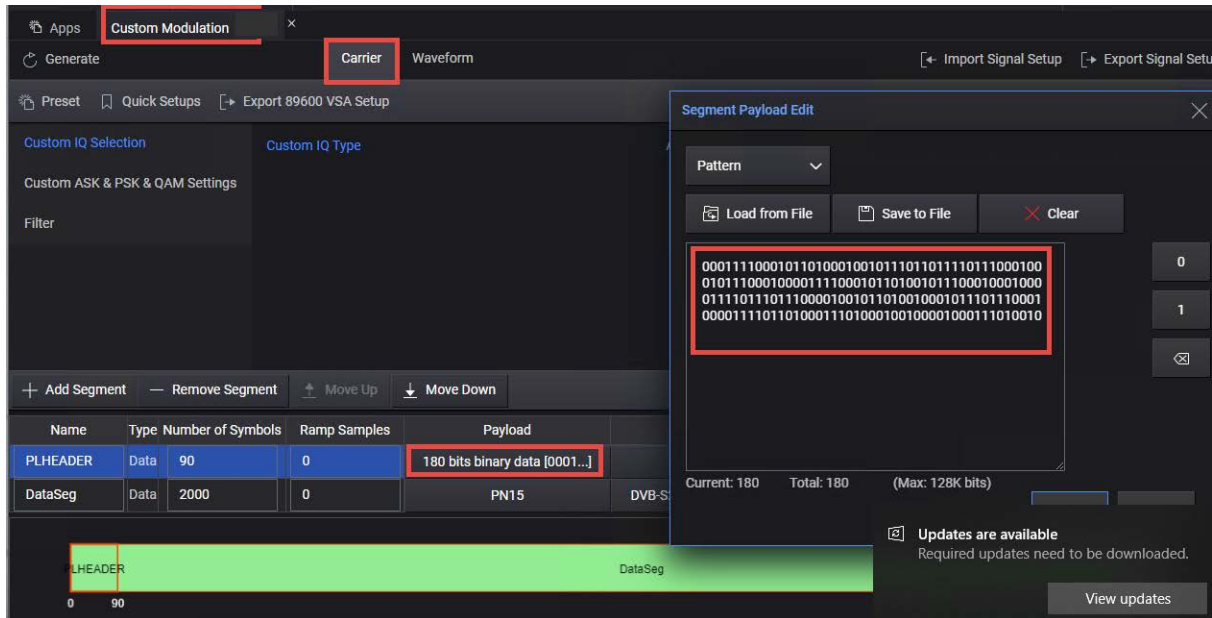
11. To configure the Pilot:

- In the Frame Parts area, select **Alloc0**
- In the Configuration area, set
 - Name to **PLHEADER**
 - Type to **Pilot**
 - Sequence to **Custom**
 - Modulation to **QPSK**
 - Select **Include BER Calculations**

Other X-Series Signal Analyzer Measurements

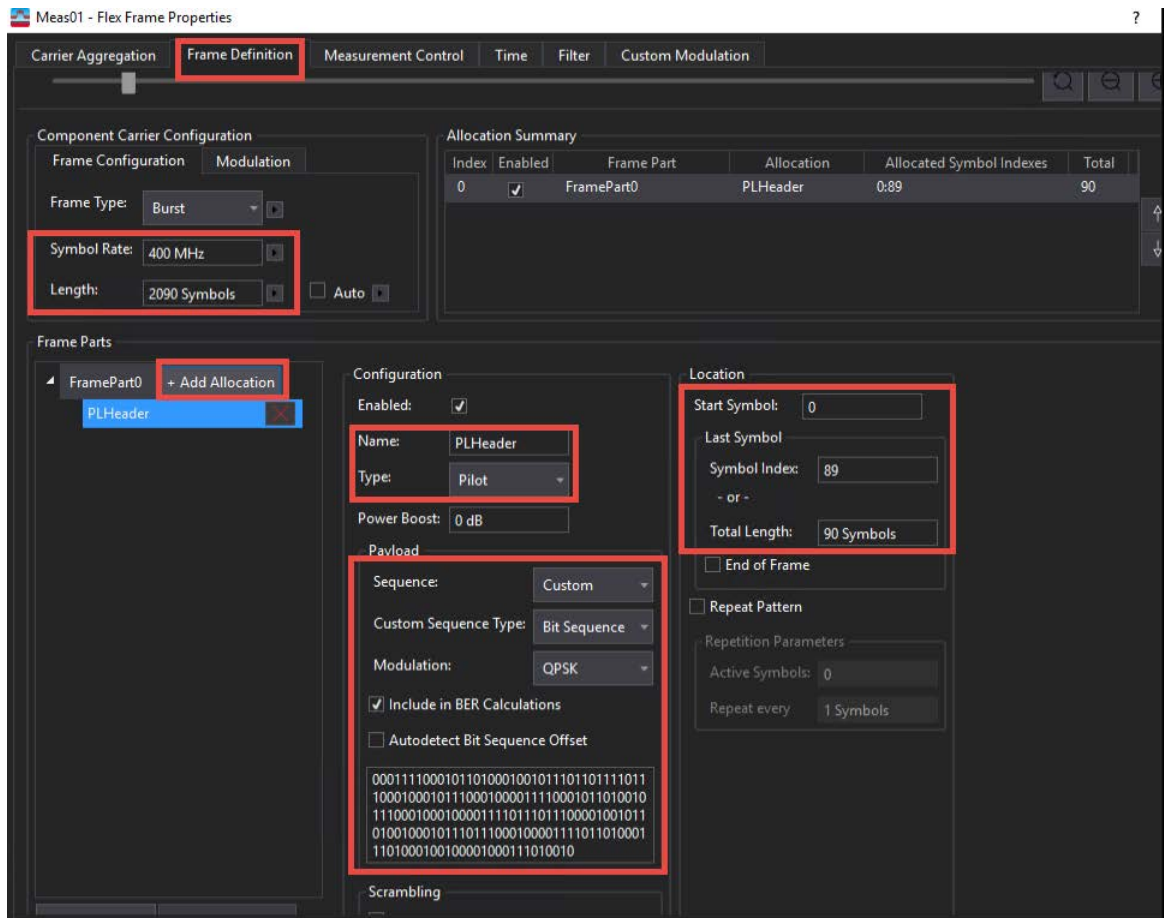
Setting Up Millimeter-Wave Measurements

- Go back into the VXG Custom Modulation setup **Carrier** tab and select **PLHEADER Payload** to open and copy the symbols.



- Paste the symbols you copied over from the Custom Modulation PLHEADER Payload setup.
- In the Location area,
 - Clear the End of Frame checkbox
 - Start Symbol to 0

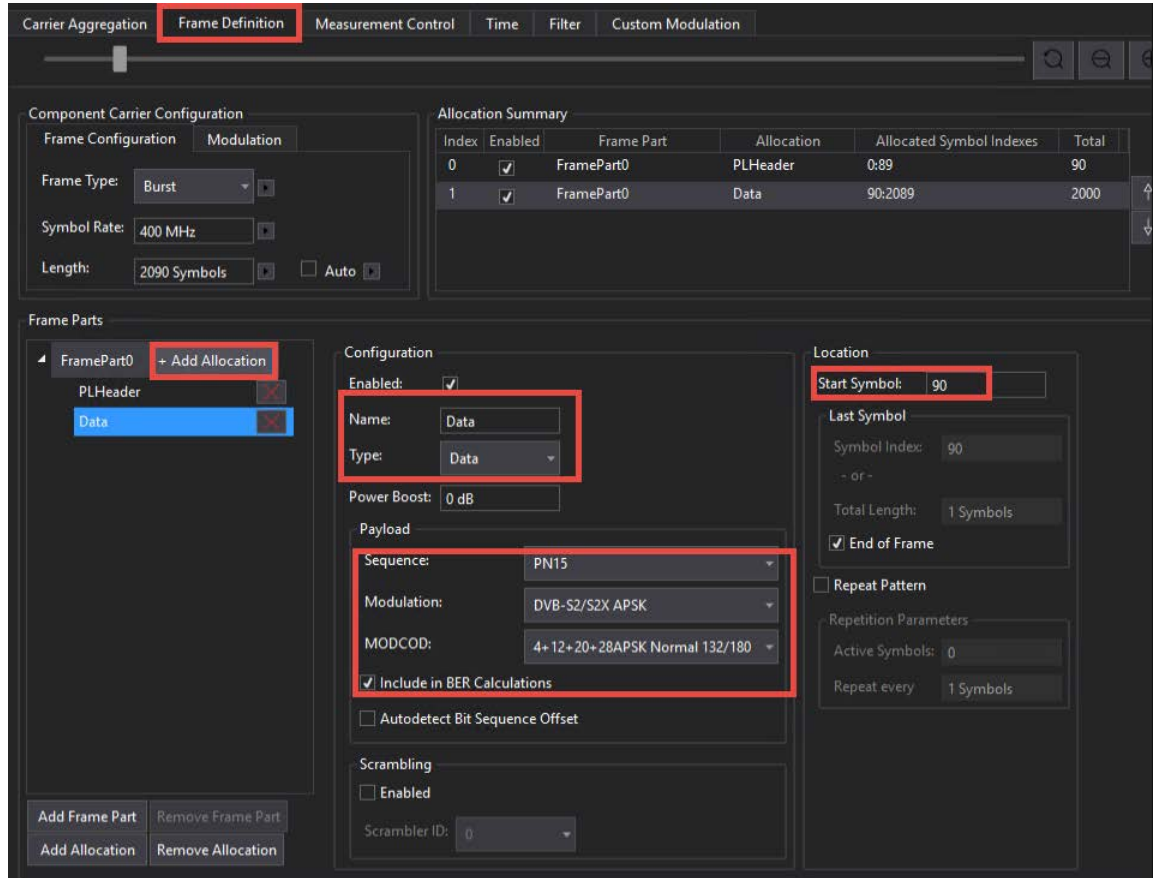
– Total Length to 90



12. In the Frame Parts area, select **Add Allocation** and set:

- Name to **Data**
- Type to **Data**
- Sequence to **PN15**
- Modulation to **DVB S2/S2X APSK**
- MODCOD to **4+12+20+ 28APSK Normal 132/180**
- Select **Include in BER Calculations**

- In the Location area, set Start Symbol to **90**.



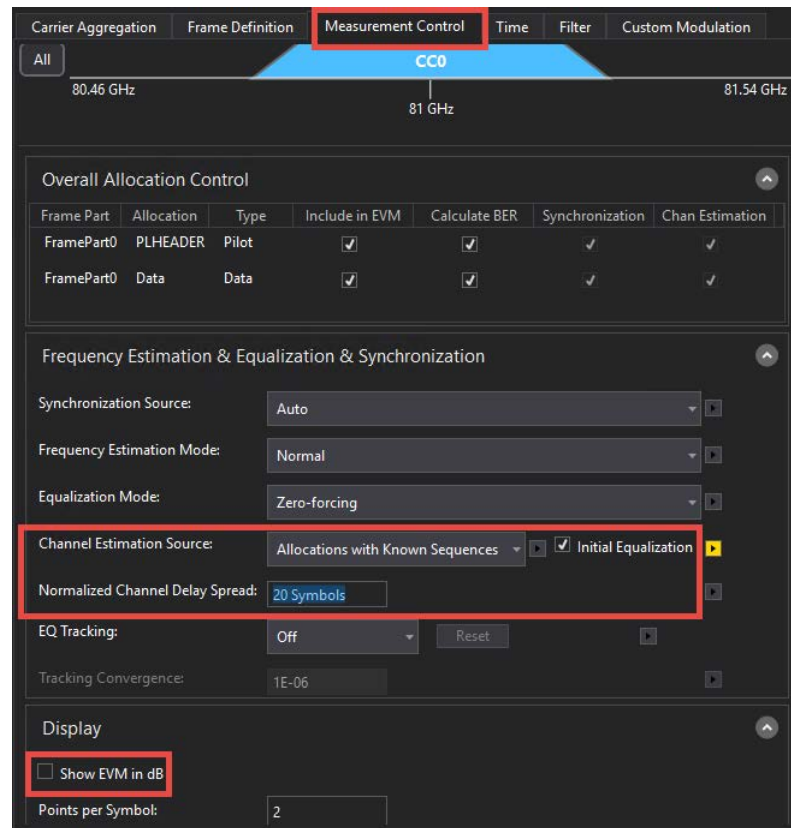
13. In the **Measurement Control** tab, and set:

- Channel Estimation Source to **Allocations with Known Sequences**
- **Select Initial Equalization**
- Normalized Channel Delay Spread to **20 Symbols**

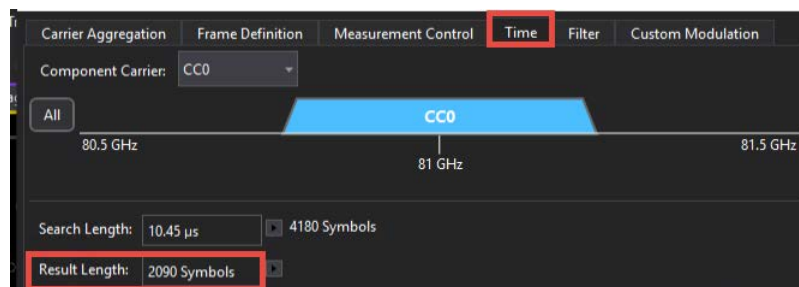
Other X-Series Signal Analyzer Measurements

Setting Up Millimeter-Wave Measurements

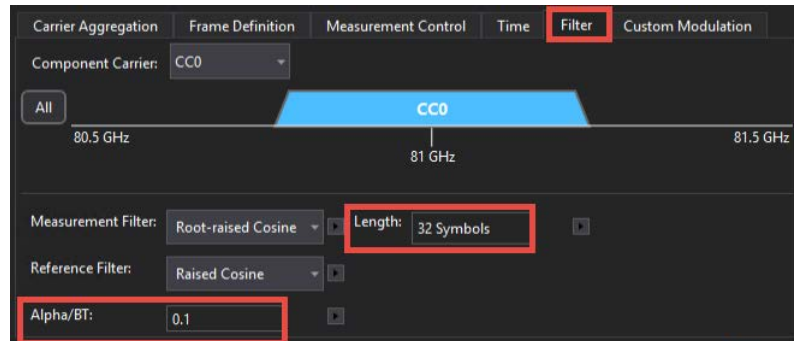
- Clear the **Show EVM in dB** checkbox



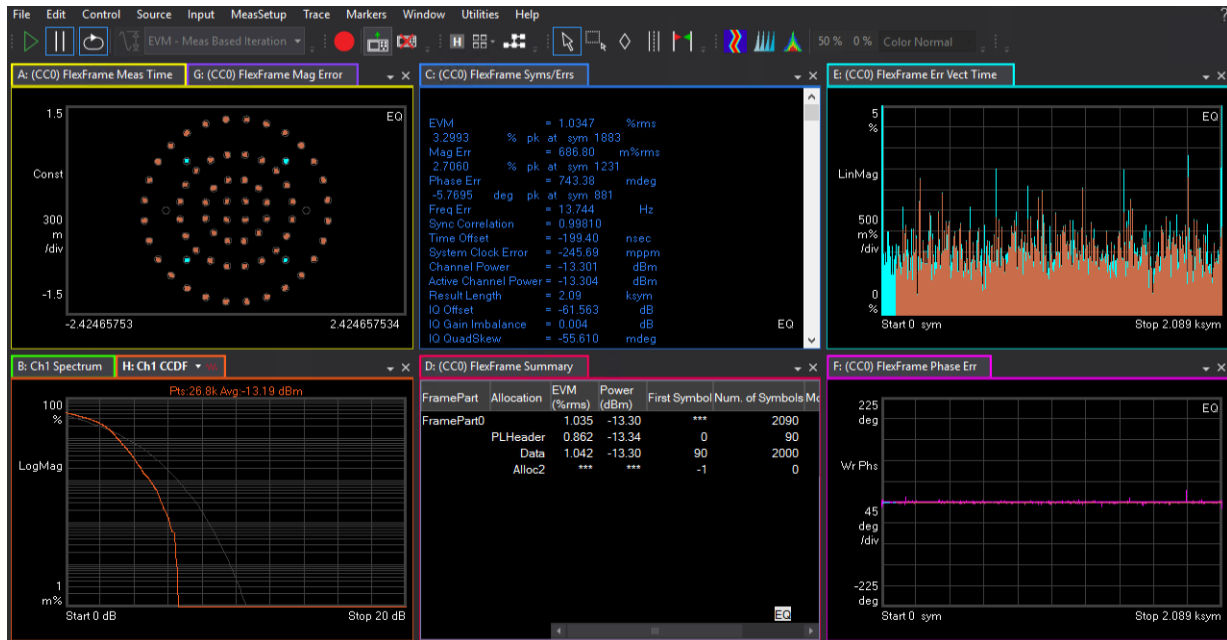
14. In the **Time** tab, set Result Length to 2090 Symbols.



15. In the **Filter** tab, set Alpha BT to **0.1** and Length to **32 Symbols** and then close the Flex Frame Properties window.



16. View the results of the measurement. Try to improve EVM by adjusting the IF Gain and Mechanical Attenuation settings in the **Input > Extensions** and the **Input > External Mixer** windows.



Setting-up a Millimeter-Wave 5G NR, 2 GHz BW FR2 Measurement

This measurement example will show you how to configure and analyze a 2000 MHz 5G NR, FR2, signal. 3GPP Rel-17 introduced a new frequency band 52.6 - 71 GHz, with new numerology (480 kHz, 960 kHz) and new bandwidth (800 MHz, 1600 MHz, 2000 MHz). Support for these new numerologies/bandwidths was added in VSA2023 Update 2.0 release and will be part of PWSG 2023 Update 1.0.

Software Requirements

PathWave Signal Generation for 5G NR	N7631APPC	2023U1 or later
89600 VSA software	89601BHNC	VSA2023U2 or later

Using the graphical user interface

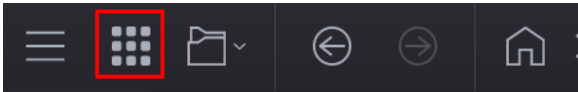
On the VXG:

1. Select **Preset > Preset** to set the VXG to a known state.
2. In the Output area, set Frequency to **70 GHz** and Power to **-10 dBm**.

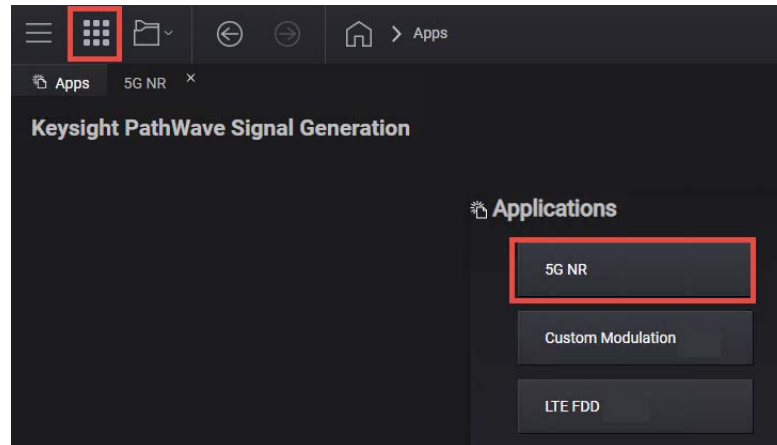
NOTE

Waveform generation and analysis speed will be very slow since we are generating and analyzing a 2 GHz wide NR signal. (That is, 5 times more data compared to a 400 MHz 5G NR signal.) To improve some demodulation speed, use VSA2024, which has some speed improvement and also use an external trigger for demodulation. (N9042B rear panel Trigger 1 In to M9484C rear panel 10 MHz Ref Out.) Furthermore, to improve VSA setup speed Stop the measurement until all parameters are correctly configured, then run the measurement (Control menu > Stop).

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

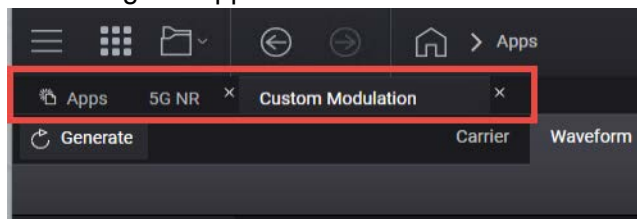


4. Select **5G NR**.



NOTE

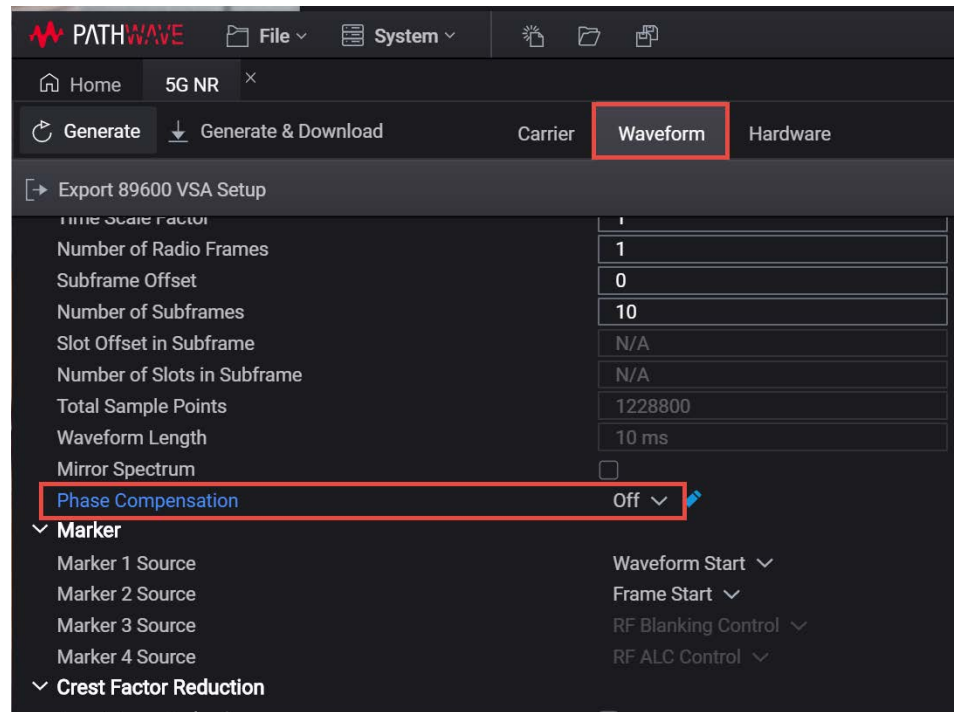
If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



5. Select the **Waveform** tab and turn off **Phase Compensation** so the same waveform can be used at different frequencies.

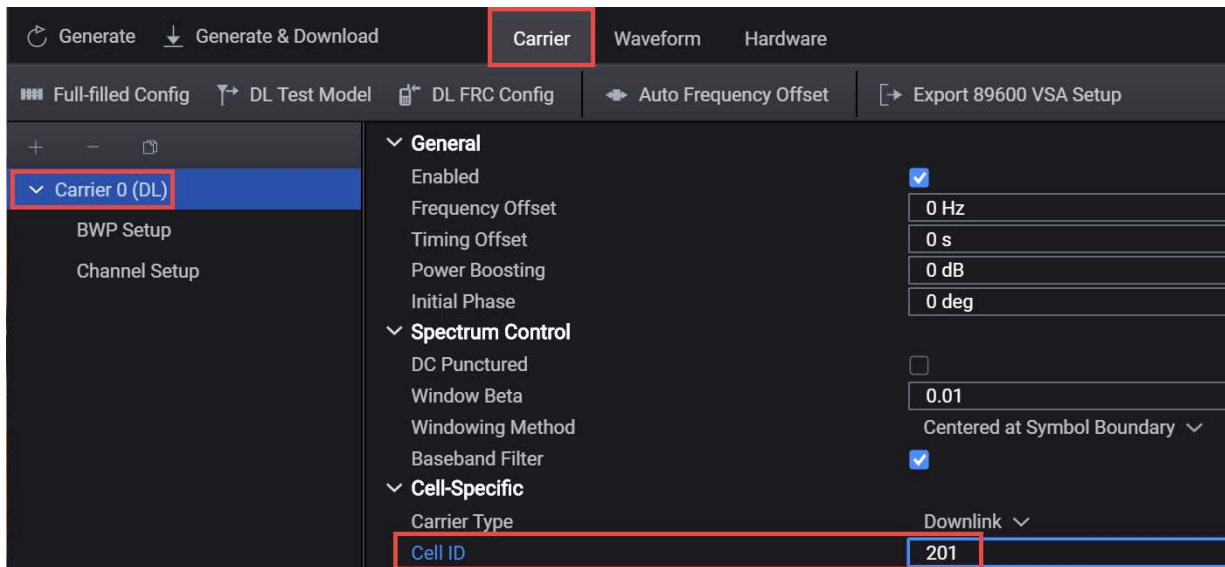
Phase compensation is applied by default at baseband for RF up-conversion. This means, it depends on carrier frequency, so a waveform needs to be generated per carrier frequency unlike conventional waveforms which are independent from carrier frequency. Phase

Compensation default is set to AUTO. The frequency is coupled with VXG frequency setting. You can select Manual to specify different frequency or turn it OFF so it is not frequency dependent.

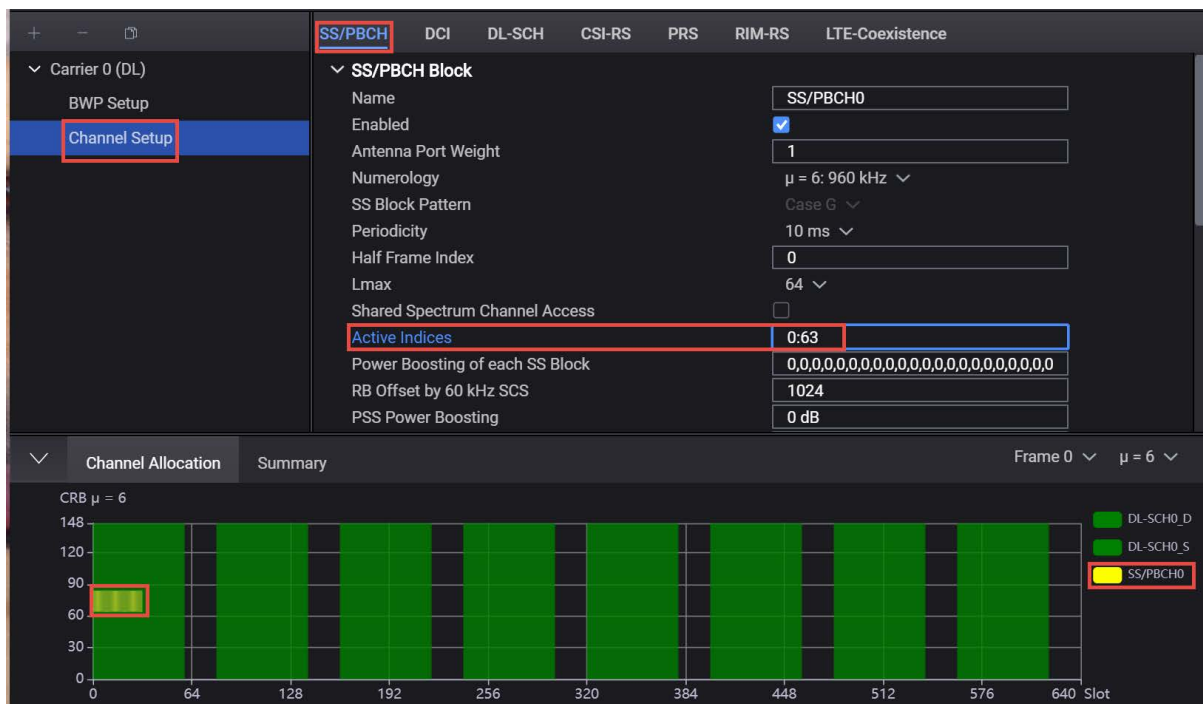


6. To configure the Downlink carrier, select the **Carrier** tab > **Full-filled Config** and set:
- Bandwidth to **FR2 2000 MHz**
 - Duplex Type to **TDD**
 - Number of Downlink slots to **59**
 - Number of Uplink Slots to **18**
 - Modulation to **256 QAM**

7. Under the Carrier (DL) side tab, scroll down and set Cell ID to **201**.



8. Select **Channel Setup** > **SS/PBCH** and set Active Indices to **0:63**.



With RB Offset by 60 kHz SCS set to 1024 and kSSB by subcarrierSpacingCommon set to 0, the SSB is set to the center of the carrier. This is shown in the Channel Allocation graph at the bottom of the window. If you set it to 0, the SSB will be set in the lower band of the carrier.

Unlike LTE, there is no fixed frequency location for SS/PBCH in NR. By default, PWSG transmits SS/PBCH (20 RB or 240 subcarriers wide) centered at the carrier bandwidth (2000 MHz channel BW in this example). This is a very important parameter since it shows where the SS/PBCH is located within the channel bandwidth in the frequency domain and it is relative to common resource block 0 (CRB0).

9. Select DL-SCH > DL-SCH0_D.

You should see DL-SCH0_D and DL-SCH0-S. These are configured from the Full-filled Config settings above. We will make a couple edits to the Reference Signal configurations.

Generate

Generate & Download

Carrier

Waveform

Hardware

Full-filled Config

DL Test Model

DL FRC Config

Auto Frequency Offset

Export 89600 VSA Setup

Carrier 0 (DL)

BWP Setup

Channel Setup

SS/PBCH	DCI	DL-SCH	CSI-RS	PRS	RIM-RS	LTE-Coexistence			
Name	Enabled	Slot	Symbol	BWP	PRB Allocation	RNTI	Coding		
DL-SCH0_D	<input checked="" type="checkbox"/>	0:58,80:138,160:218,240:298,320:378,4...	0:13	BWP1	RAType1, 0:147	1	On		
DL-SCH0_S	<input checked="" type="checkbox"/>	59,139,219,299,379,459,539,619	0:5	BWP1	RAType1, 0:147	1	On		

- Confirm Allocated Slots is set to **0:58,80:138,160:218,240:298,320:378,400:458,480:538,560:618**

These values will be used in the VSA/X-App. You can copy these values for easier setup later.

Resource Allocation	
Allocated Slots	0:58,80:138,160:218,240:298,320:378
First Symbol	0
Last Symbol	13

- Confirm that MCS Table is set to **256QAM** and MCS to **20**. MCS table, MCS value, scaling factor, etc. must match with the VSA (or X-App) for successful decoding (CRC pass/fail).
- Set DMRS-add-pos to **1**. Additional DMRS is transmitted on a symbol before the last symbol.
- Select **PTRS Enabled**. For FR2, PTRS is used for phase tracking.

Other X-Series Signal Analyzer Measurements

Setting Up Millimeter-Wave Measurements

– Set Time Density to 4.

SS/PBCH	DCI	DL-SCH	CSI-RS	PRS	RIM-RS	LTE-Coexistence		
Name	Enabled	Slot	Symbol	BWP	PRB Allocation	RNTI		
DL-SCH0_D	<input checked="" type="checkbox"/>	0:58,80:138,160:218,240:298,320:378,4...	0:13	BWP1	RAType1, 0:147	1		
DL-SCH0_S	<input checked="" type="checkbox"/>	59,139,219,299,379,459,539,619	0:5	BWP1	RAType1, 0:147	1		

Modulation and Coding

☒

Channel Coding

MCS Table

MCS

TB Scaling Factor

xOverhead

Coding Rate

Modulation

Transport Block Size

BaseGraph

Payload Data

Table 5.1.3.1-2 (256QAM)

20

1.0

0

0.66650390625

256QAM

122976

1

PN9

DMRS Settings

☐

DMRS-Downlink-r16

n_SCID

N_ID_0

N_ID_1

DMRS PowerBoosting

DMRS Configuration

DMRS Duration

DMRS-add-pos

PDSCH Mapping

DMRS-typeA-pos

DMRS Mapping Reference

Type 1

Single Symbol

1

Type A

2

CRB0

PTRS Settings

☒

PTRS Enabled

PTRS PowerBoosting

PTRS port(s)

Frequency Density (K_PTRS)

Time Density (L_PTRS)

PTRS RE Offset

0 dB

0

2

4

00

10. Select **DL-SCH0_S**. Set **PTRS Enabled** and Time Density to **4**. Confirm that Allocated Slots is set to **59,139,219,299,379,459,539,619**.

SS/PBCH	DCI	DL-SCH	CSI-RS	PRS	RIM-RS	LTE-Coexistence	+	-	🔍
Name	Enabled	Slot	Symbol	BWP	PRB Allocation	RNTI			
DL-SCH0_D	<input checked="" type="checkbox"/>	0:58,80:138,160:218,240:298,320:378,4...	0:13	BWP1	RAType1, 0:147	1			
DL-SCH0_S	<input checked="" type="checkbox"/>	59,139,219,299,379,459,539,619	0:5	BWP1	RAType1, 0:147	1			

TB Scaling Factor

1.0

xOverhead

0

Coding Rate

0.66650390625

Modulation

256QAM

Transport Block Size

52224

BaseGraph

1

Payload Data

PN9

DMRS Settings

DMRS-Downlink-r16

☐

n_SCID

0

N_ID_0

Cell ID

N_ID_1

Cell ID

DMRS PowerBoosting

0 dB

DMRS Configuration

Type 1

DMRS Duration

Single Symbol

DMRS-add-pos

0

PDSCH Mapping

Type A

DMRS-typeA-pos

2

DMRS Mapping Reference

CRB0

PTRS Settings

PTRS Enabled

☒

PTRS PowerBoosting

0 dB

PTRS port(s)

0

Frequency Density (K_PTRS)

2

Time Density (L_PTRS)

4

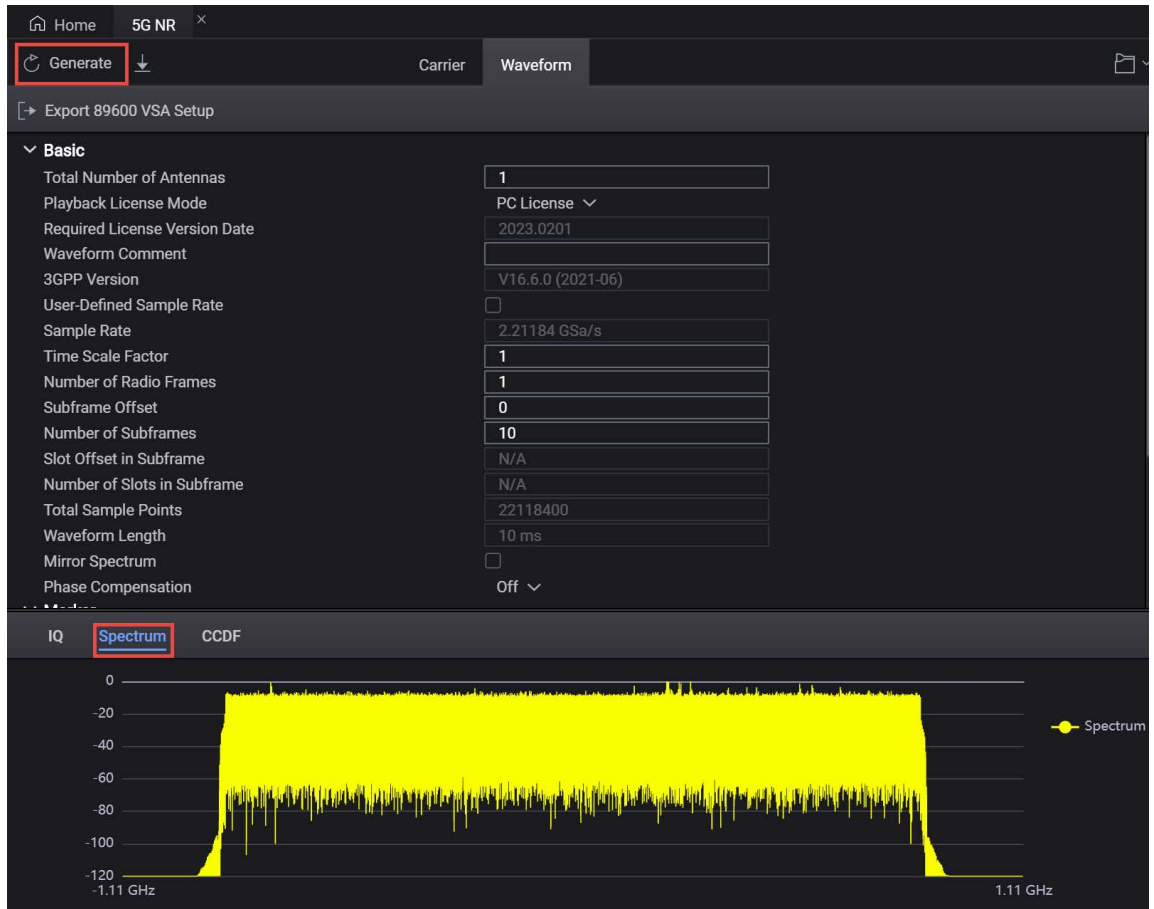
PTRS RE Offset

00

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

TIP

When using 89600 VSA software for demodulation, you can export the VSA setup file from PathWave to demodulate the waveform quickly and easily or export the setup file into X-Apps.



12. 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.



Setting Up the UXA Using 89600 VSA

NOTE

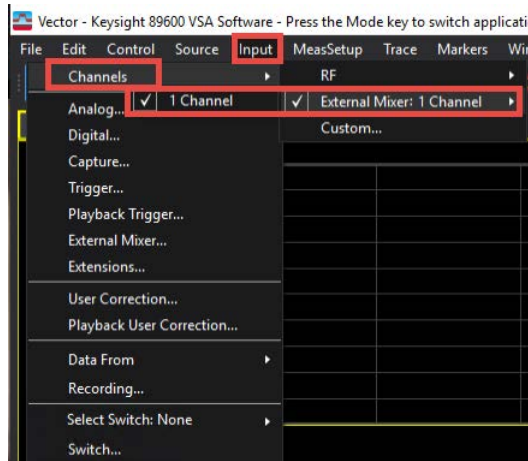
Changing settings on the VSA can take longer to take affect than expected. Stopping the measurement (Control menu > Stop) until all settings have been made will help speed up the setup time.

1. Open the VSA software.

NOTE

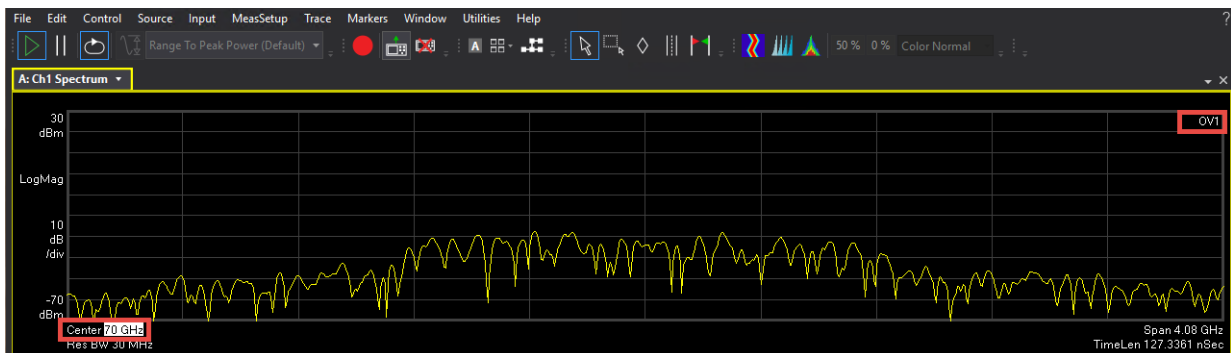
If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window, then select **Launch VSA**.

2. From the VSA menu bar, select **File > Preset > All** to set the VSA to a known state.
3. From the menu bar, select **Input > Channels > External Mixer > 1 Channel**.



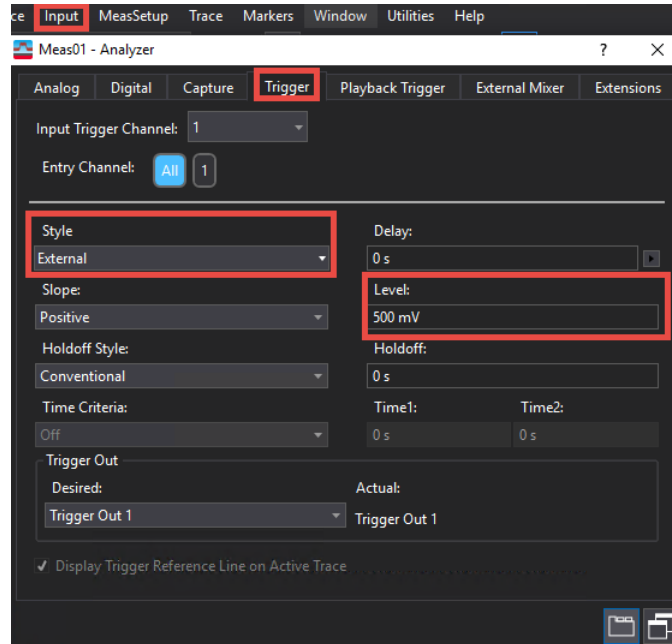
4. In the **Spectrum** window, select **Center** and set the Center Frequency to **70 GHz**.

Notice there is an **OV1** error indicator. The OVx indicator appears when the trace was created from data that contained an ADC overload. We will resolve this in [step 7](#).

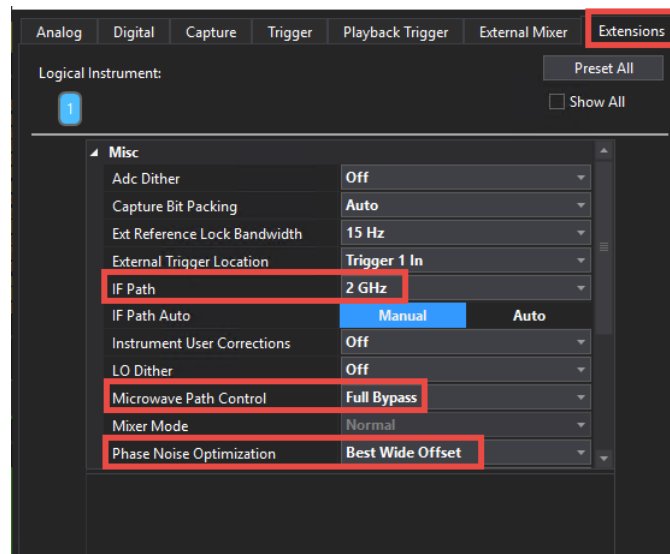


- From the menu bar, select **Input > Trigger** and set Style to **External** and Level to **500 mV**.

Using the External Trigger will help to improve the demod speed.

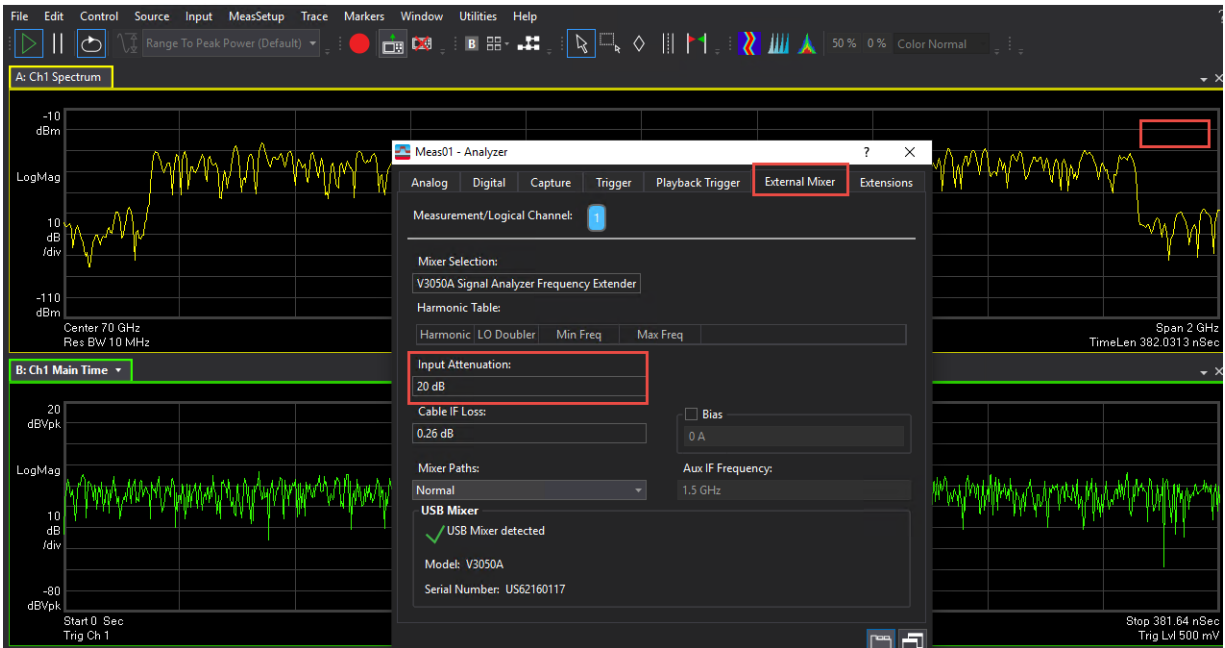


- Select the **Extensions** tab and set:
 - IF Path to **2 GHz**
 - Microwave Path Control to **Full Bypass**
 - Phase Noise Optimization to **Best Wide Offset**

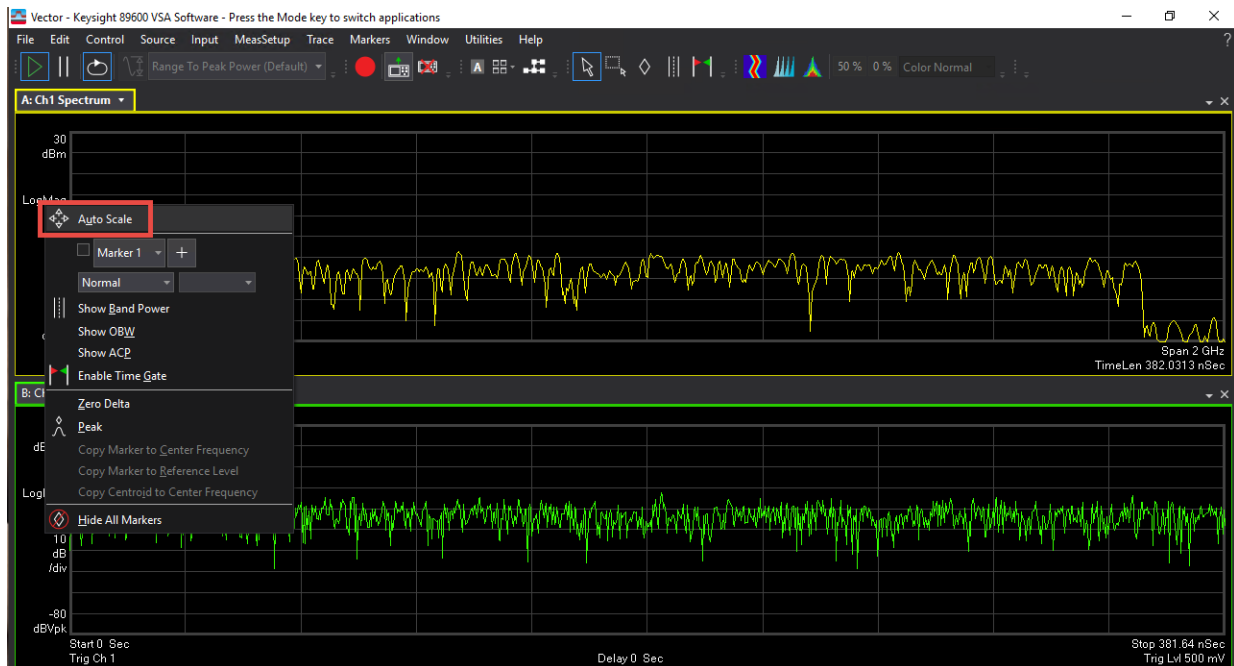


Other X-Series Signal Analyzer Measurements Setting Up Millimeter-Wave Measurements

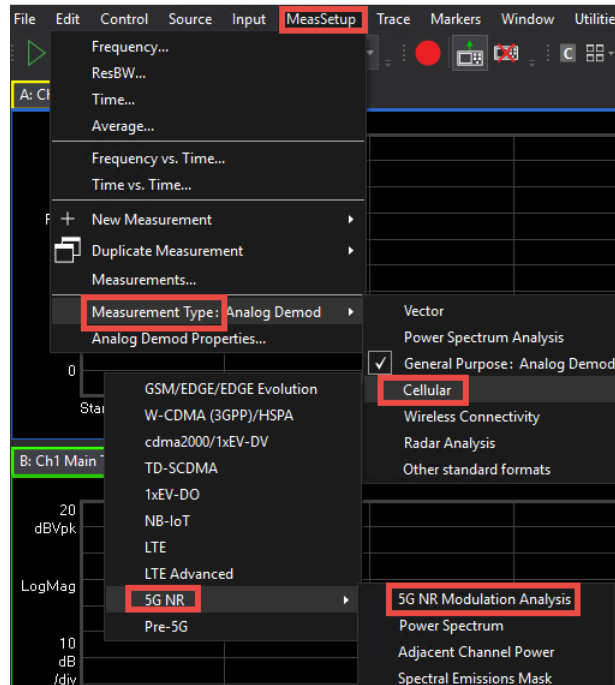
7. Select the **External Mixer** tab and set Input Attenuation to approximately **20 dB**, or a level where the overload flag disappears. This is to bring the waveform up on the spectrum display.



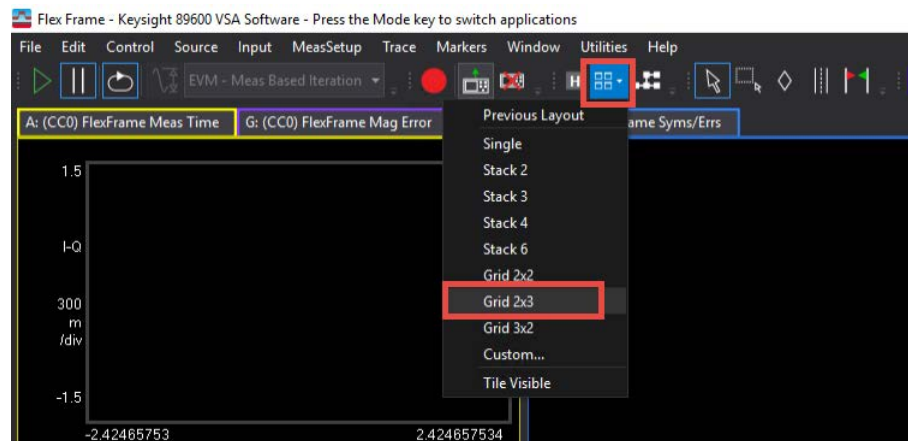
8. In the **Spectrum** window, right click on the Spectrum display and select **Auto Scale**.



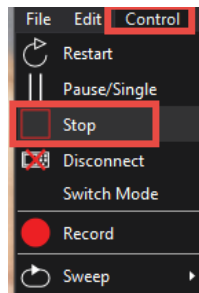
9. From the menu bar, select **MeasSetup** > **Cellular** > **5G NR** > **5G NR Modulation Analysis**.



10. Change the Trace Layout Grid to 2 x 3. Right click on the Spectrum window and select **Auto Scale** to bring the waveform back up on the display.



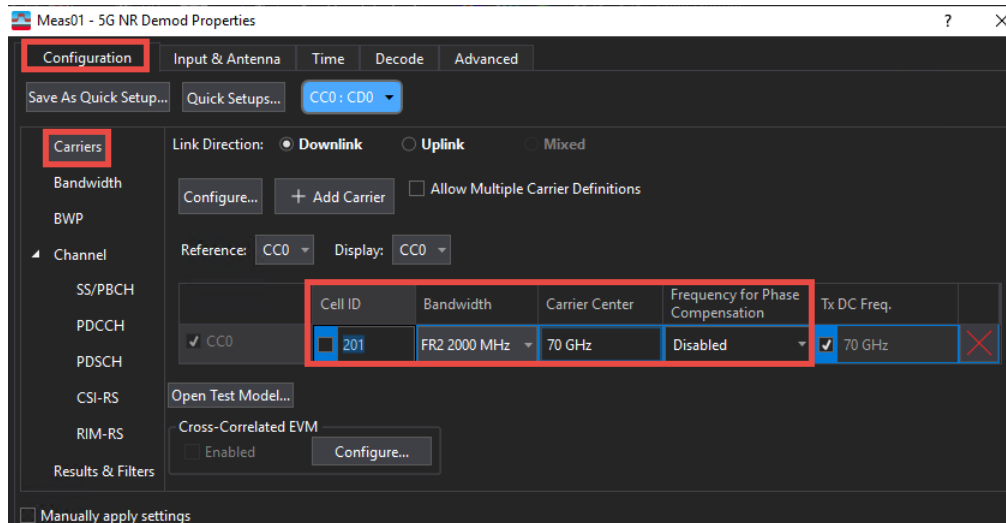
11. Select the **Control** menu > **Stop** to stop the measurement until all parameters have configured. This will greatly improve setup speed.



12. Select **MeasSetup** > **5G NR Demod Properties** > **Configuration** tab > **Carriers** panel and set:

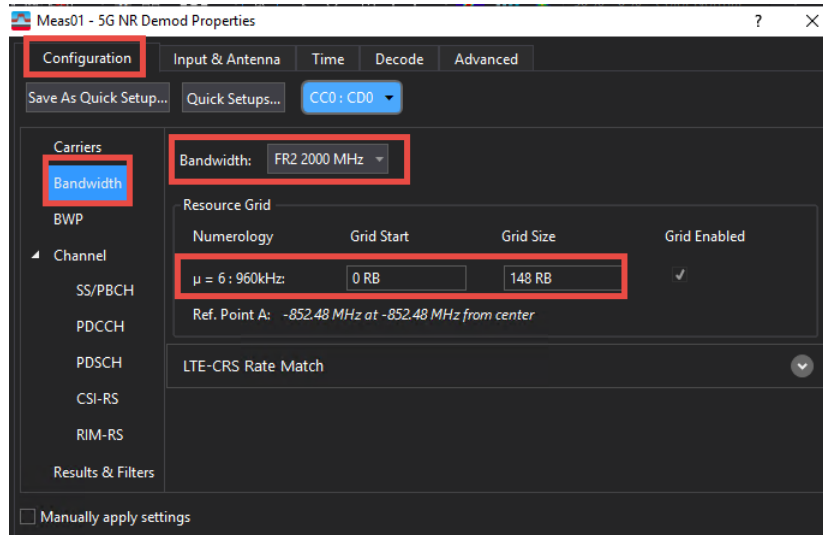
- Cell ID to **201** (or select the box to the right to Auto Detect the cell ID)
- Bandwidth to **FR2 2000 MHz**
- Frequency for Phase Compensation to **Disabled**.

Cell ID is carried on PSS and SSS so the SS/PBCH must be transmitted and enabled for Auto Cell ID to work and must be a Downlink since SS/PBCH is only transmitted in the DL.



13. Select **MeasSetup** > **5G NR Demod Properties** > **Configuration** tab > **Bandwidth** panel. This section of the UI is to configure Resource Grid for each Numerology. Numerology is set to $\mu = 6$:960 kHz.

For FR2 2000 MHz, only the 960 kHz subcarrier spacing is available. This is why the other numerologies are not shown. The Max RB is 148 RB. We will use this value when we configure BWP, SS/PBCH, and PDSCH parameters.

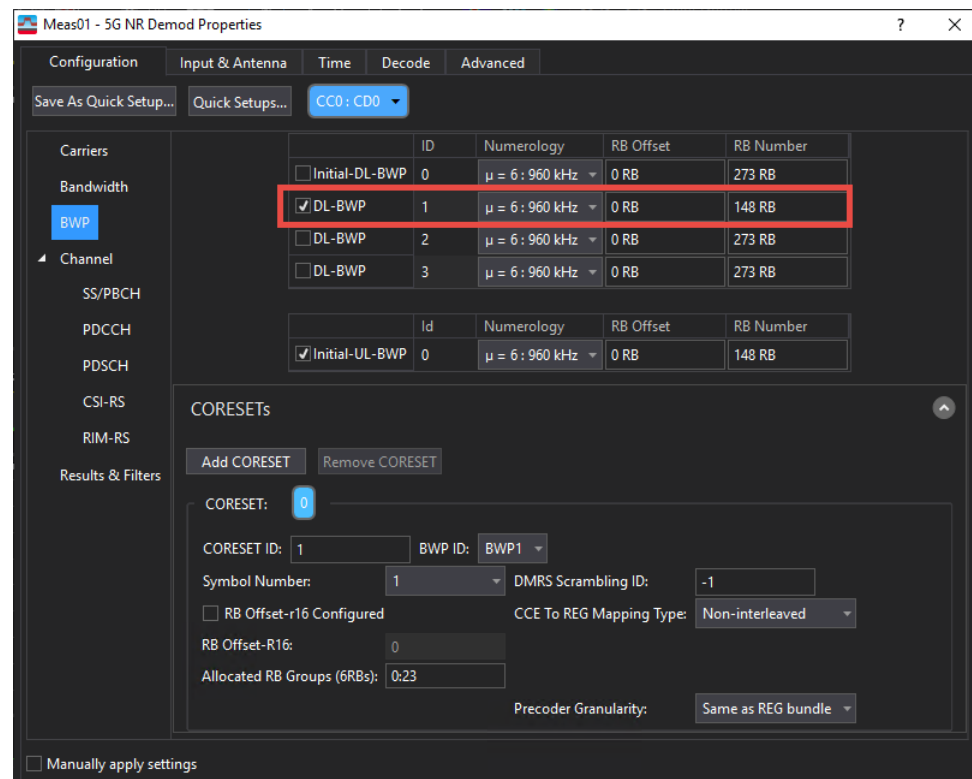


14. Select **MeasSetup** > **5G NR Demod Properties** > **Configuration** tab > **BWP** panel. We will use the default settings for DL-BWP 1.

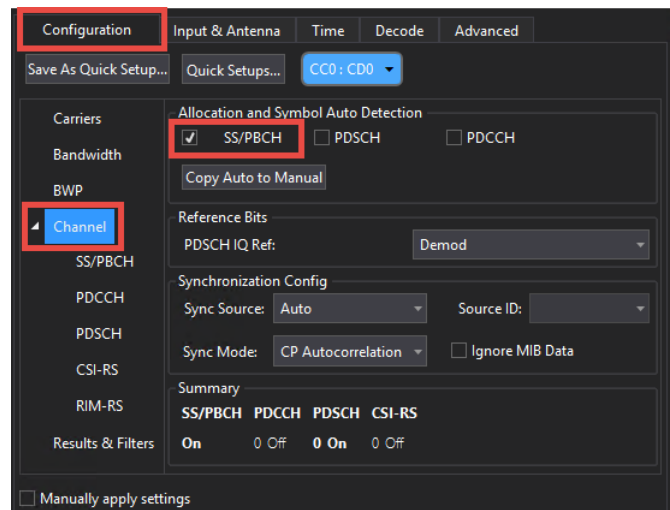
This section of the UI is to configure the DL BWP allocation within the component carrier and the control resource set (CORESET). CORESET is used for PDCCH configuration and there is no PDCCH in this measurement example, so we don't need to make changes.

A CC with 2000 MHz at FR2 has a max RB of 148 for 960 kHz numerology. In this example, the DL-BWP uses the full carrier bandwidth of 148 RBs

When using multiple BWPs within a single component carrier, you will spread the total 148 RBs across the multiple BWPs.



15. Select MeasSetup > 5G NR Demod Properties > Configuration tab > Channel > SS/PBCH.



The auto detected parameters are returned in the Summary table trace. Once you see what has been auto detected and are happy with what you see, you can do "Copy Auto to Manual" to copy the detected parameters into the SS/PBCH settings. See image below.

The auto detected SSB parameters are returned in the Summary table. "Copy Auto to Manual" will copy these detected parameters into the SS/PBCH settings.

A: Summary	
Analyzed Subframe	[Sf0,sym0] to [Sf0,sym96]
Channel Power	-13.40 dBm
Channel Power (Active)	-13.07 dBm
OFDM Sym Tx Power	-13.04 dBm
EVM	2.7805 %rms
EVM Pk	11.243 %pk
Mag Err	1.944 %rms
Mag Err Pk	-9.808 %pk
Phase Err	0.0343 deg
Phase Err Pk	-0.777 deg
Frequency Error	3.8148 Hz
Frequency Error Worst	6.4285 Hz
Symbol Clock Error	0.0044 ppm
IQ Offset	-56.124 dB
IQ Gain Imbalance	***
IQ Quad Error	***
IQ Timing Skew	***
Time Offset	-36.859 ns
Sync Correlation	99.527 %
Sync Source	PSS, SSS
Cell ID	201
SSB 0 Num SCS Common = 120kHz, Case B, L=64, Period can't be detected, RB Offset=1024, SC Offset=0, Active Indices=0:63	

16. Select MeasSetup > 5G NR Demod Properties > Configuration tab > Channel > SS/PBCH.

PSS and PBCH Power boosting cannot be auto detected, you must enter power boosting values under SS/PBCH. We will use the default values. Notice that the remaining values are grayed out as we are in Auto Detection mode.

Note that the frequency location of a SSB block is not fixed. In our software, the default value of 1024RB and kSSB of 0 subcarriers places it in the center of the carrier bandwidth. If you set RB Offset to 0 dB, it places the SSB on the lower edge of the carrier bandwidth

Configuration
Input & Antenna
Time
Decode
Advanced

Save As Quick Setup...
Quick Setups...
CC0: CD0

Carriers
Bandwidth
BWP
Channel
SS/PBCH
PDCCH
PDSCH
CSI-RS
RIM-RS
Results & Filters

SS/PBCH

Lmax: L64
SSB Transmitted: 0:63

Auto Detect Active Block
Det Power Threshold: -30

RB Offset(60kHz): 1024 RB
Numerology: $\mu = 6: 960 \text{ kHz}$

kSSB(60kHz): 0
SCS Common: 60kHz

Periodicity: 10 ms
Half Frame Index: 0

230.4 MHz bandwidth 0 MHz from center

Power Boosting
PSS power boosting 0 dB
PBCH power boosting 0 dB

3GPP Version: R17 Latest (2022-09)

☐ Manually apply settings

17. Select MeasSetup > 5G NR Demod Properties > Configuration tab > Channel > PDSCH and set:

- MCS Table to **Table 256QAM**
- MCS to **20**

Transport Block Size value must match the PathWave 5G NR settings for successful decoding (CRC result).

- Allocated Slots to
0:58,80:138,160:218,240:298,320:378,400:458,480:538,560:618

TIP

You can copy/paste these values from **PathWave 5G NR Signal Generation**.

Configuration | Input & Antenna | Time | Decode | Advanced

Save As Quick Setup... | Quick Setups... | CC0 : CD0

Carriers | Bandwidth | BWP | Channel | SS/PBCH | PDCCH | **PDSCH** | CSI-RS | RIM-RS | Results & Filters

Add PDSCH | Remove PDSCH | Clear All | Enable Channels...

PDSCH: 0

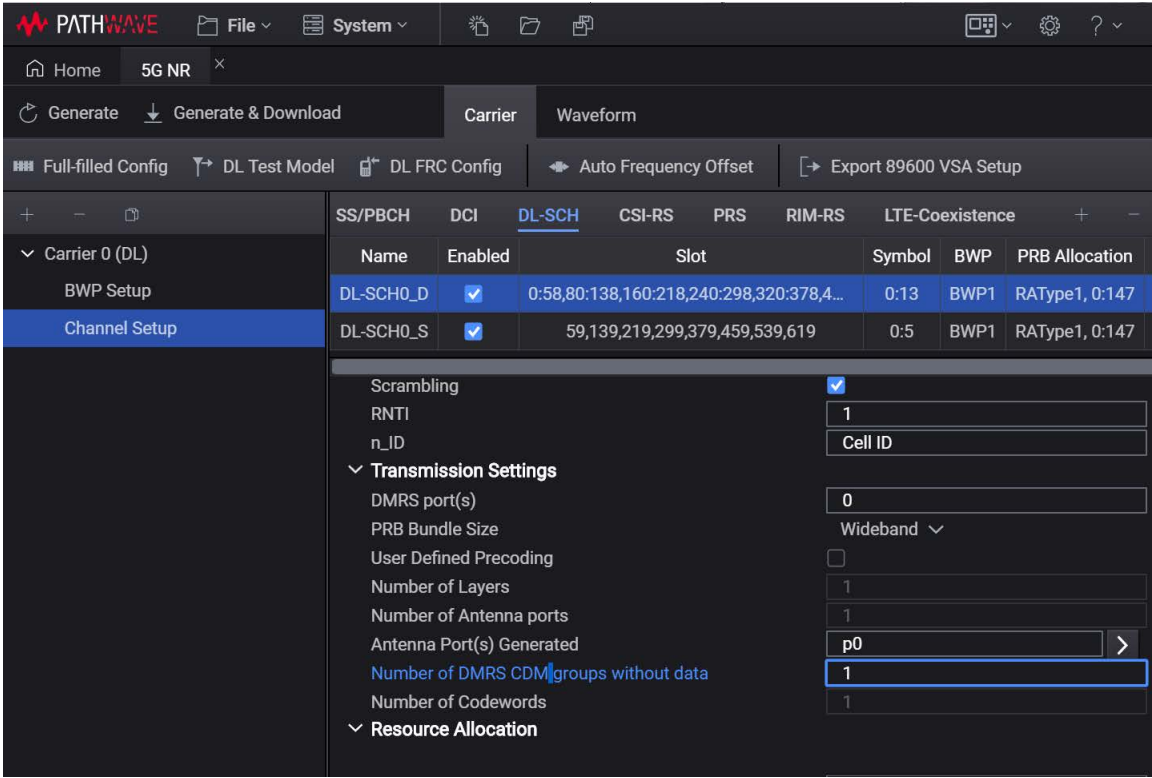
☒ Enabled | BWP ID: BWP1 | RNTI: 1 | 3GPP Version: R17 Latest (2022-09)

Modulation and Coding | Time/Freq Allocation

Modulation and Coding		Time/Freq Allocation	
RV Index:	0	Frame Period:	1 Frames
MCS Table:	Table 256QAM	Allocated Slots:	0:58,80:138,160:218,240:298,320:378,400:458,480:538,560:618
MCS:	20	Slot Format:	0: D,D,D,D,D,D,D,D,D,D,D,D
TB Scaling Factor S:	1	DL X Symbols:	
xOverhead:	0	Mapping Type:	TypeA TypeA Pos: Pos2:
Target Code Rate:	0.66650390625	First Symbol:	0 Last Symbol: 13
Modulation:	QAM256	Resulting Format:	D D D D D D D D D D D D
Transport Block Size:	122976	RB Ref CORESET ID:	-1 RA Type: Type1
Transport Block 2		RB Offset:	0 RB RB Number: 148 RB
ng Source:	Cell ID	RA Configuration:	Config1 RBG Size [P]: 16
ng:	201	Allocated RBGs:	
CORESET ID:	-1	VRB-To-PRB Mapping:	Non-Interleaved VRB-To-PRB Interleaver: n2
Custom ModFormat:	Off	Rate Match Patterns:	None Edit...

BWP Max RB: 148
Unused RBs: 37 | Allocated RBs: 111

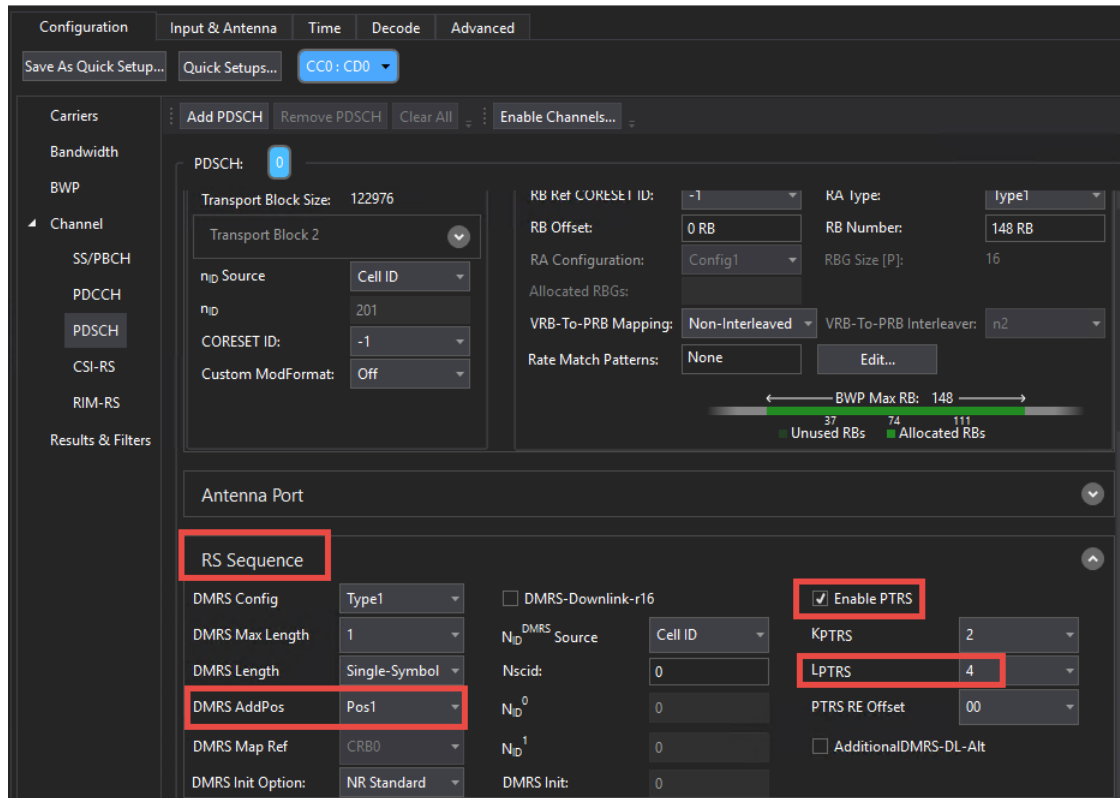
Other X-Series Signal Analyzer Measurements
Setting Up Millimeter-Wave Measurements



18. Scroll Down to **RS Sequence** and set:

- DMRS AddPos to **Pos1**
- Select **Enable PTRS**

– LPTRS to 4



19. Select **Add PDSCH** and then select **PDSCH 1**. Set:

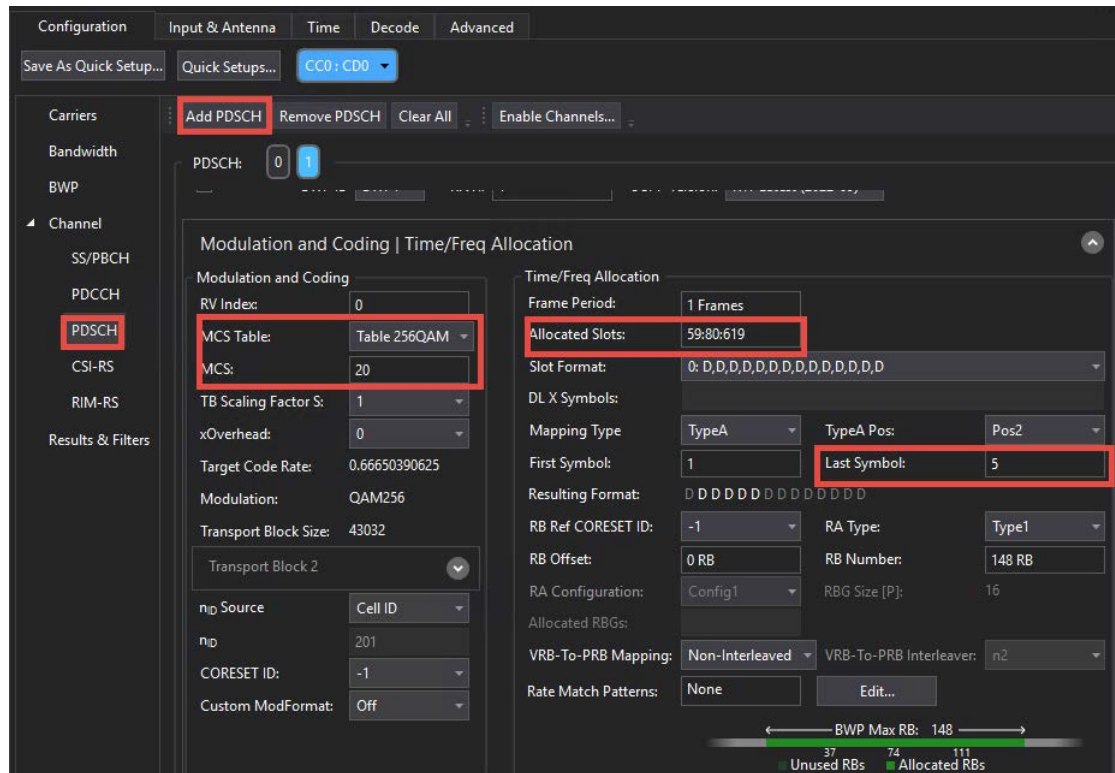
- MCS Table to **Table 256 QAM**
- MCS to **20**

Transport Block Size value must match the PathWave 5G NR settings for successful decoding (CRC result). The Value depends on parameters in this section and the RNTI value of the PDSCH much also match. This will not affect EVM.

- Allocated Slots to **59:80:619**

Other X-Series Signal Analyzer Measurements Setting Up Millimeter-Wave Measurements

– Last Symbol to 5

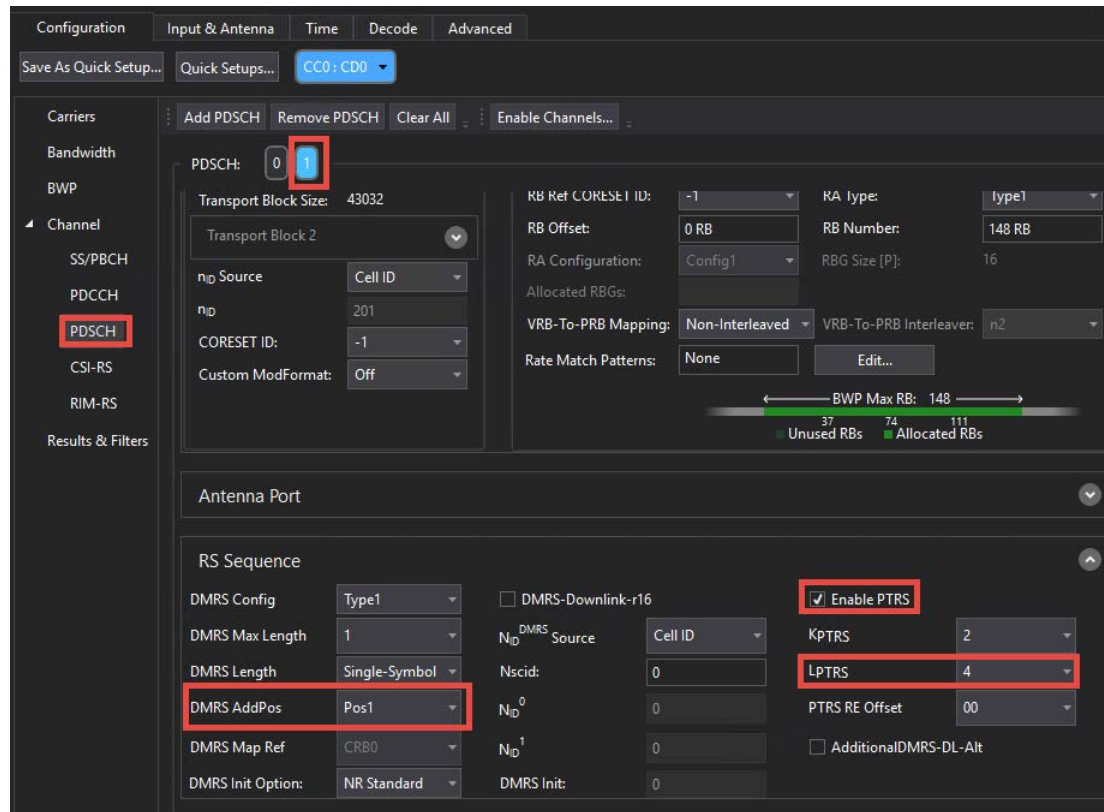


20. Scroll Down to **RS Sequence** and set:

- DMRS AddPos to **Pos1**
- Select **Enable PTRS**

Other X-Series Signal Analyzer Measurements Setting Up Millimeter-Wave Measurements

– LPTRS to 4



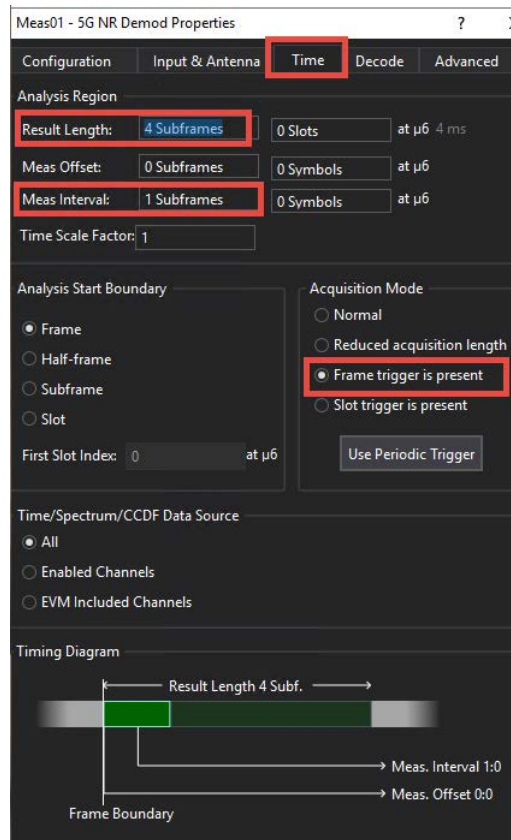
21. In the Time tab set:

- Result Length to **4 Subframes**
- Meas Interval to **1 Subframes**

We are reducing the analysis region since a 2000 MHz carrier has a large amount of data resulting in very slow demod speed. (That is, 5x more data than 400 MHz carrier.)

- Acquisition Mode to **Frame Trigger is Present**

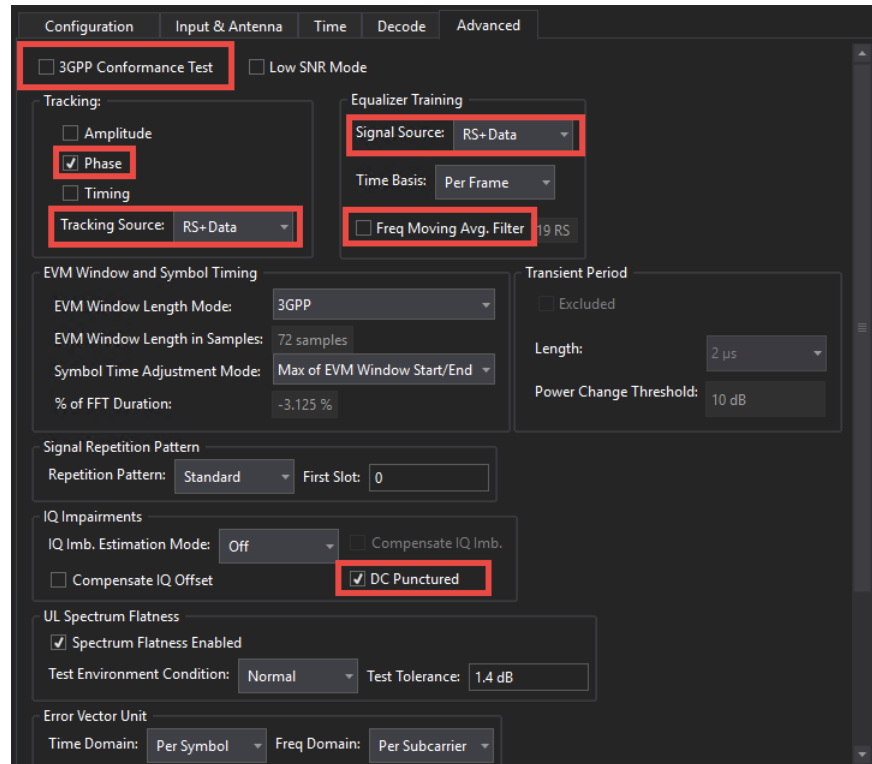
We are using an external trigger for this example, so selecting "Frame Trigger is Present" will use the external trigger and will speed up the measurement significantly.



22. Select the **Advanced** tab:

- Clear the **3GPP Conformance** checkbox
- In the Tracking area, set Tracking Source to **RS + Data** and select **Phase**
- In the Equalizer Training area, set Signal Source to **RS + Data** and clear the **Freq Moving Avg. Filter** checkbox.
- Turn on **DC Punctured**.

5G NR counts the DC subcarrier as a valid subcarrier for rate-matching purposes. High LO feedthrough will impact demodulation and EVM performance of the input.

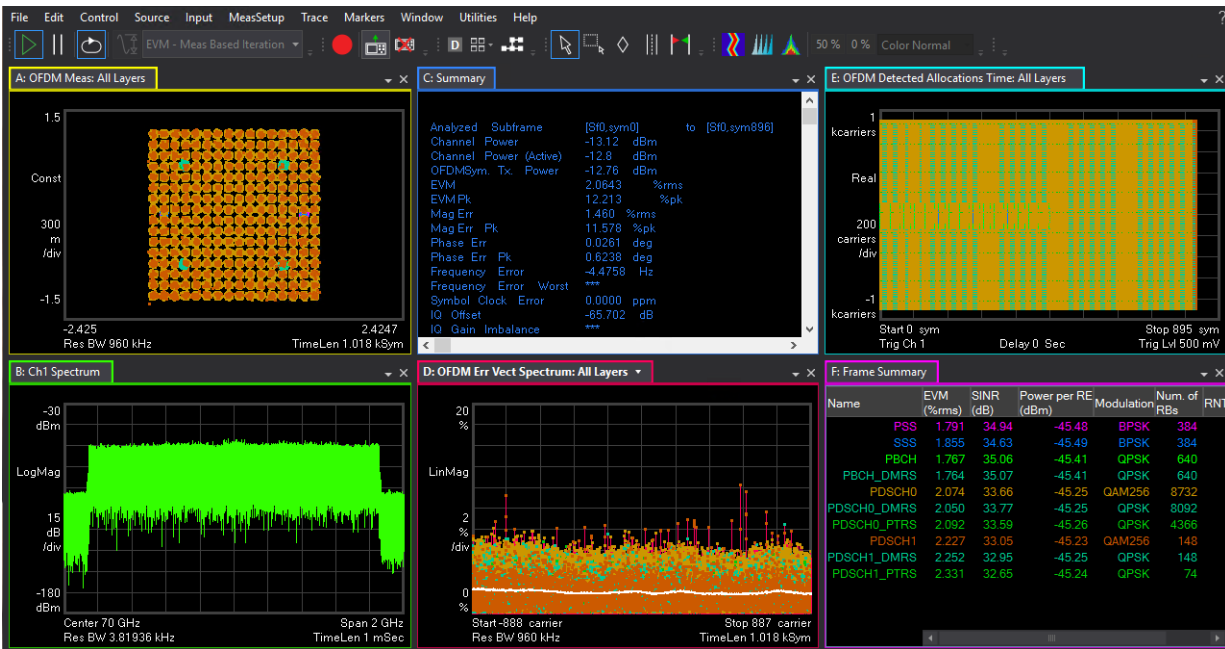


23. Close the 5G NR Demod Properties window and select Control > Restart to restart the measurement.

24. View the results of the measurement. Try to improve EVM by adjusting the Mechanical Attenuation setting until the OV1 indicator goes away in the IF Gain and Mechanical Attenuation settings in the **Input > Extensions** and the **Input > External Mixer** windows.

For this example, the optimum settings were Input Attenuation set to 8 dB and IF gain set to -12 dB.

Other X-Series Signal Analyzer Measurements Setting Up Millimeter-Wave Measurements



Using the X-Series Analyzer's SCPI Recorder Function

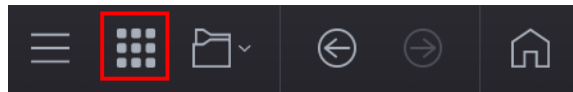
The SCPI Recorder feature allows you to view active recording content, and edit the content. Right-click or touch and hold on any UI control to display a menu allowing you to record the SCPI associated with the control. You can also record a series of commands. These commands can be viewed and edited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

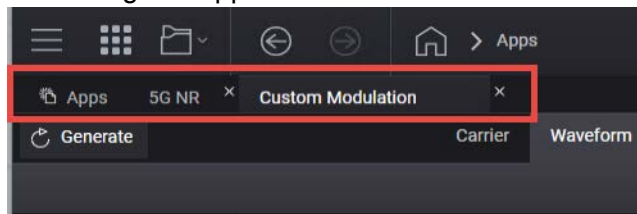
On the VXG:

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.

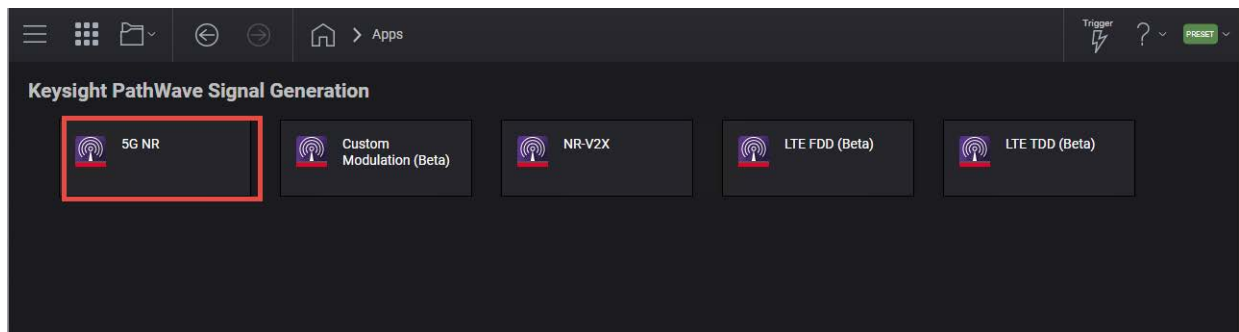


NOTE

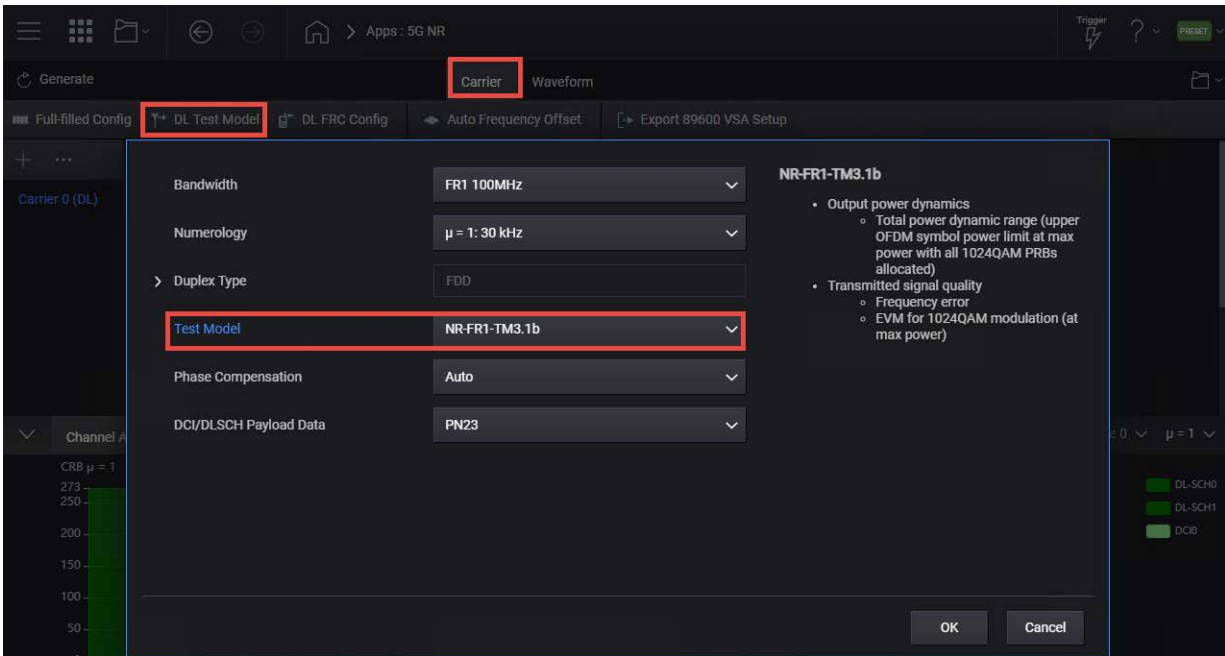
If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



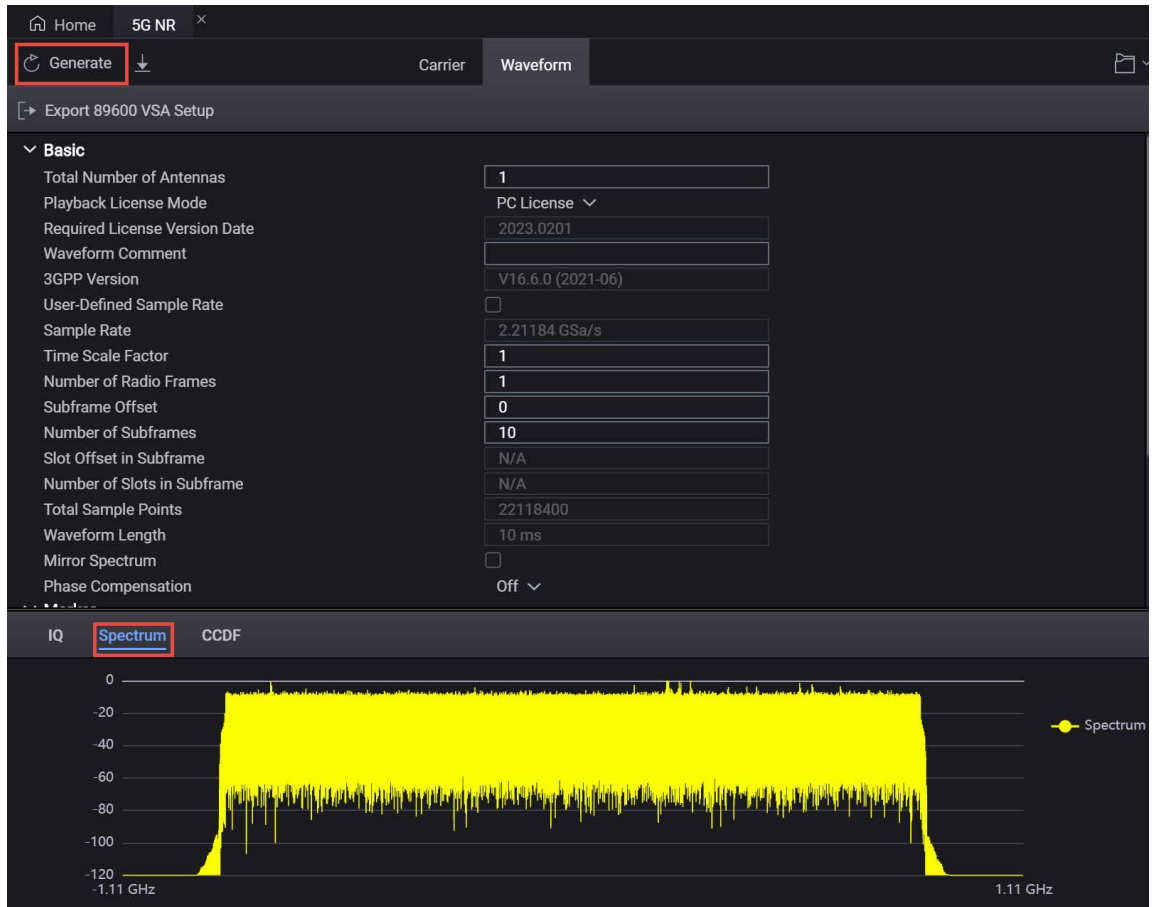
4. Select **5G NR**.



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:

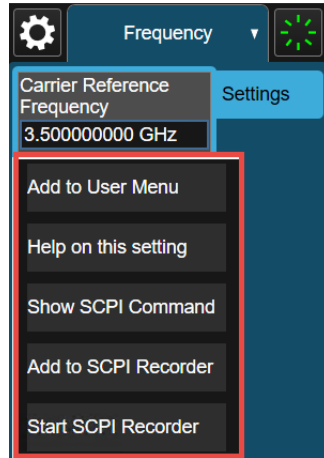
1. Select **Mode/Meas > 5G NR &V2X Mode > OK**.

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.

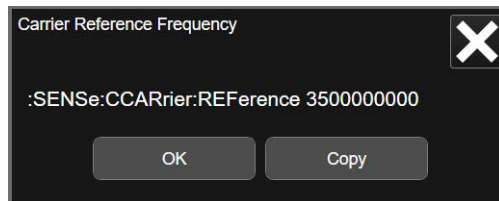
2. Select **Mode Preset** to set Spectrum Analyzer 5G NR mode to a known state.

3. From the N9042B 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.

?

A

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	<code>[:SENSe]:CCARrier:REFerence <freq></code> <code>[:SENSe]:CCARrier:REFerence?</code>
Example	<code>:CCAR:REF 2GHz</code> <code>:CCAR:REF?</code>
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

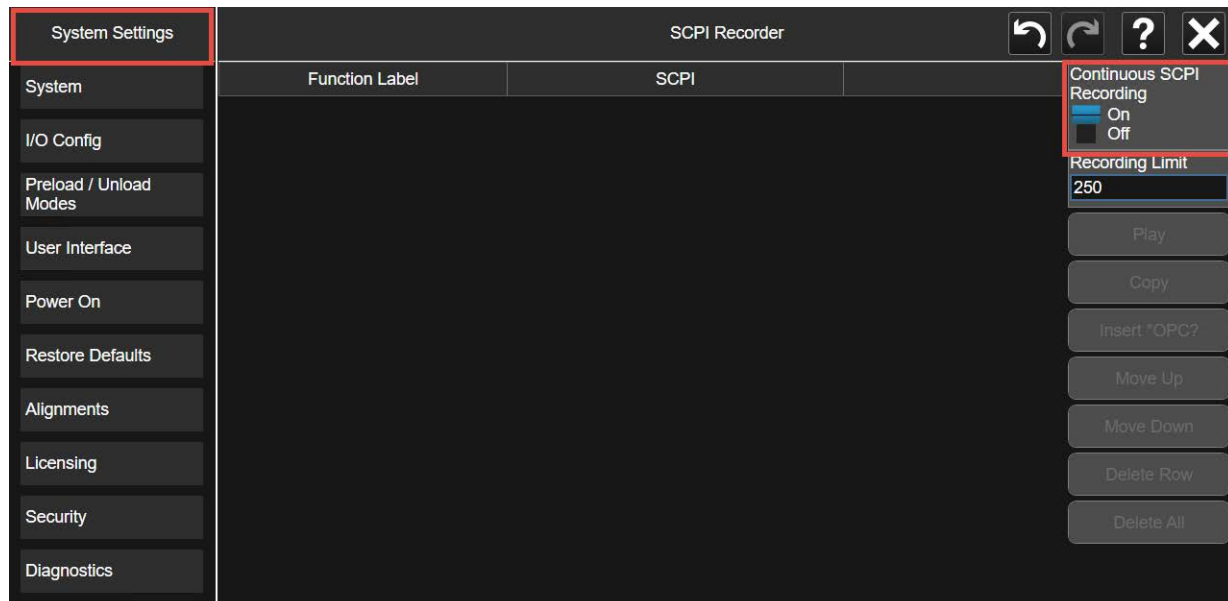
To Start Continuous SCPI Recording:

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.

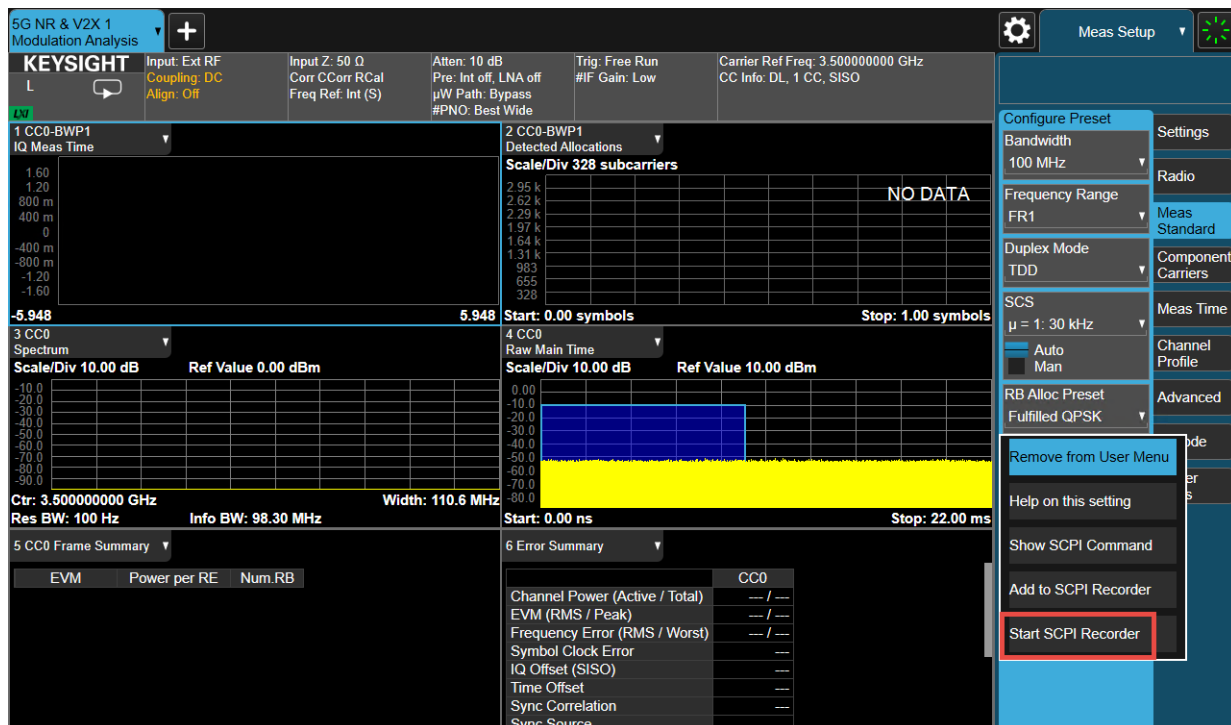
There are two ways to start continuous SCPI recording:

Other X-Series Signal Analyzer Measurements Using the X-Series Analyzer's SCPI Recorder Function

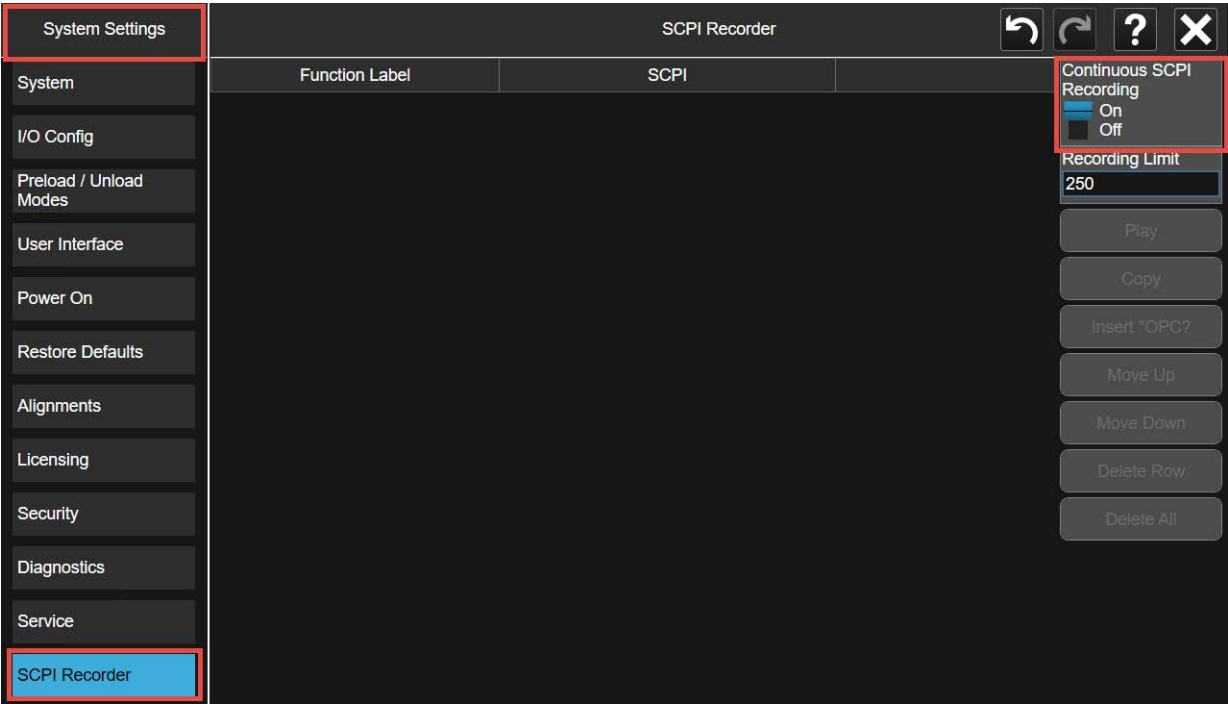
- From the System Settings > SCPI Recorder.



- 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.



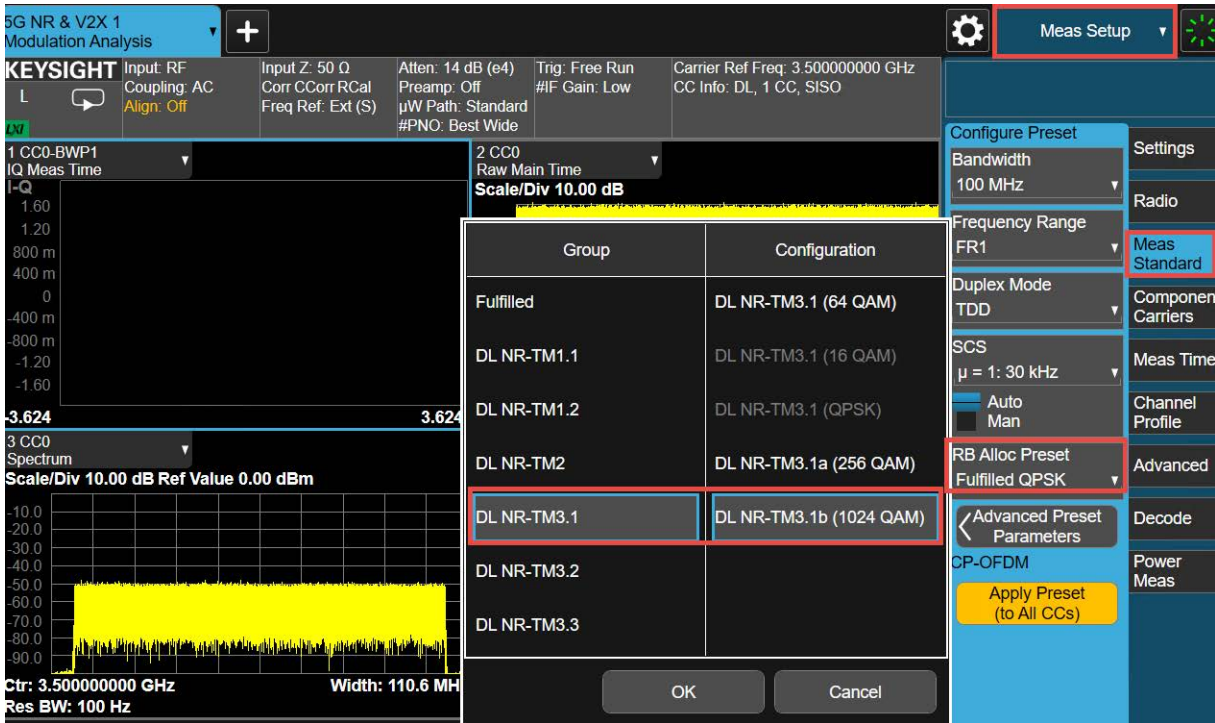
3. Select **Mode/Meas > 5G NR &V2X Mode > Modulation Analysis Measurement > Normal View > OK.**

NOTE

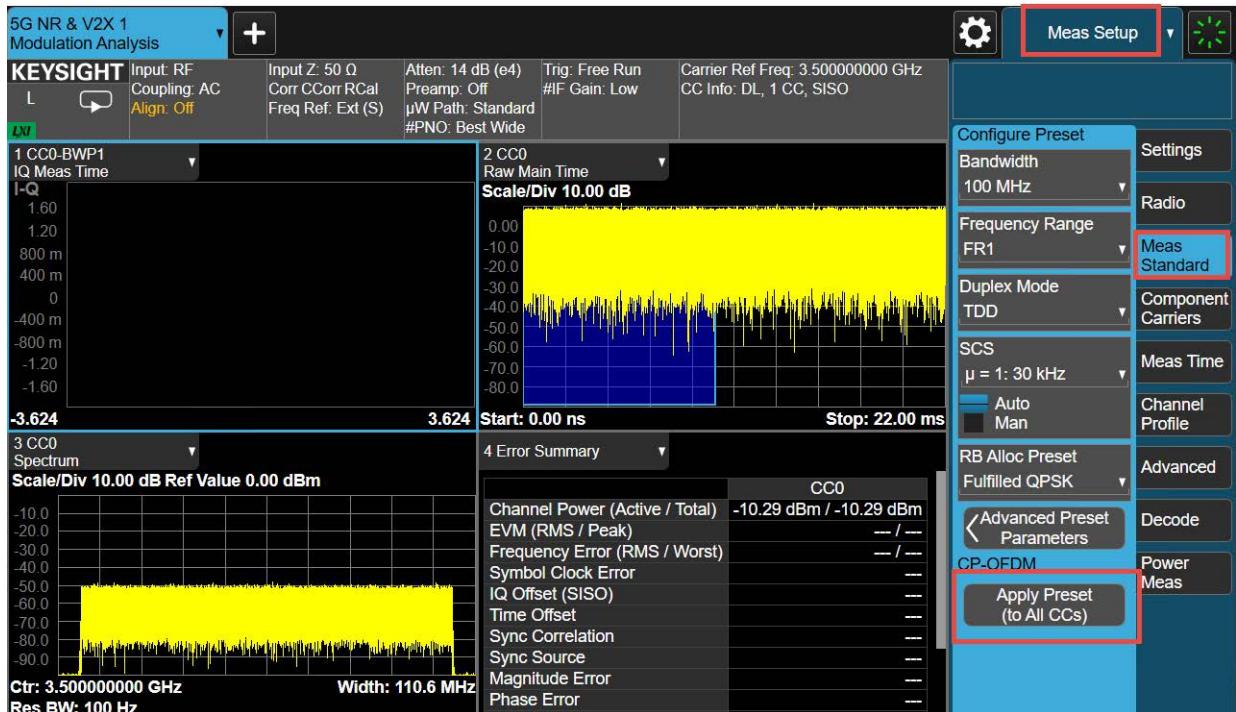
If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top left of the display) to open the Mode/Measurement/View Selector window.

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**.



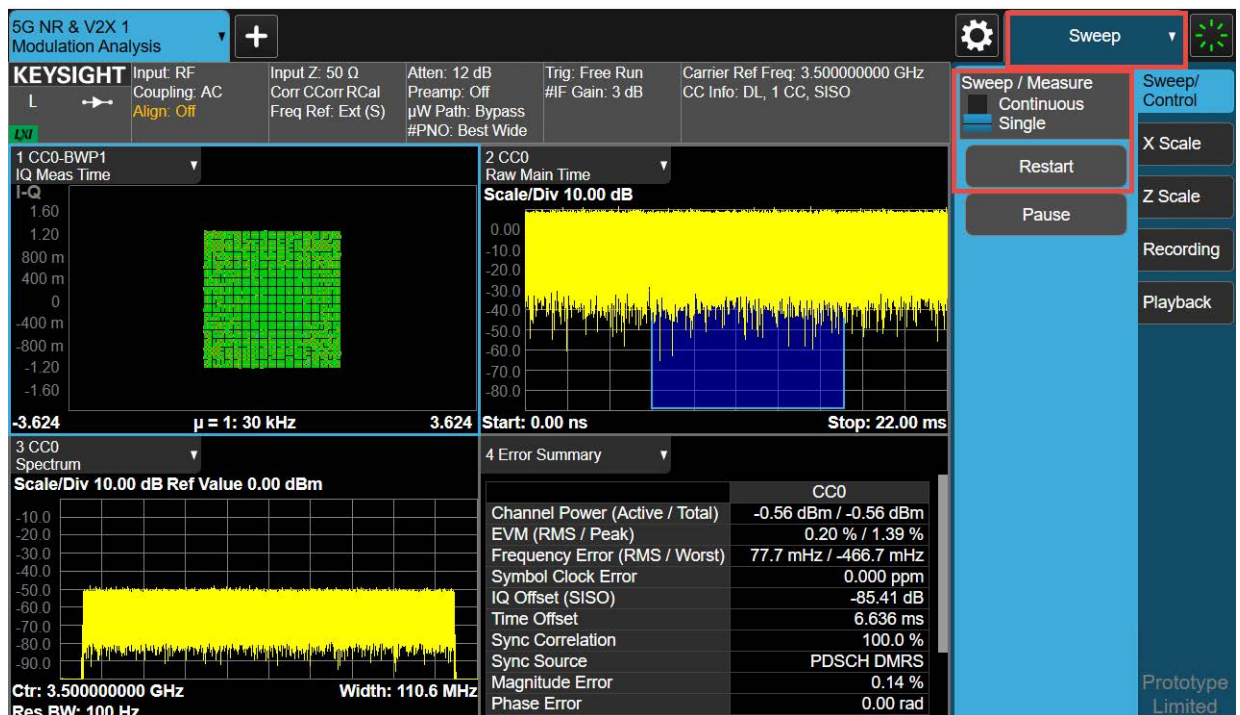
6. Select **Apply Preset (to All CCs)**.



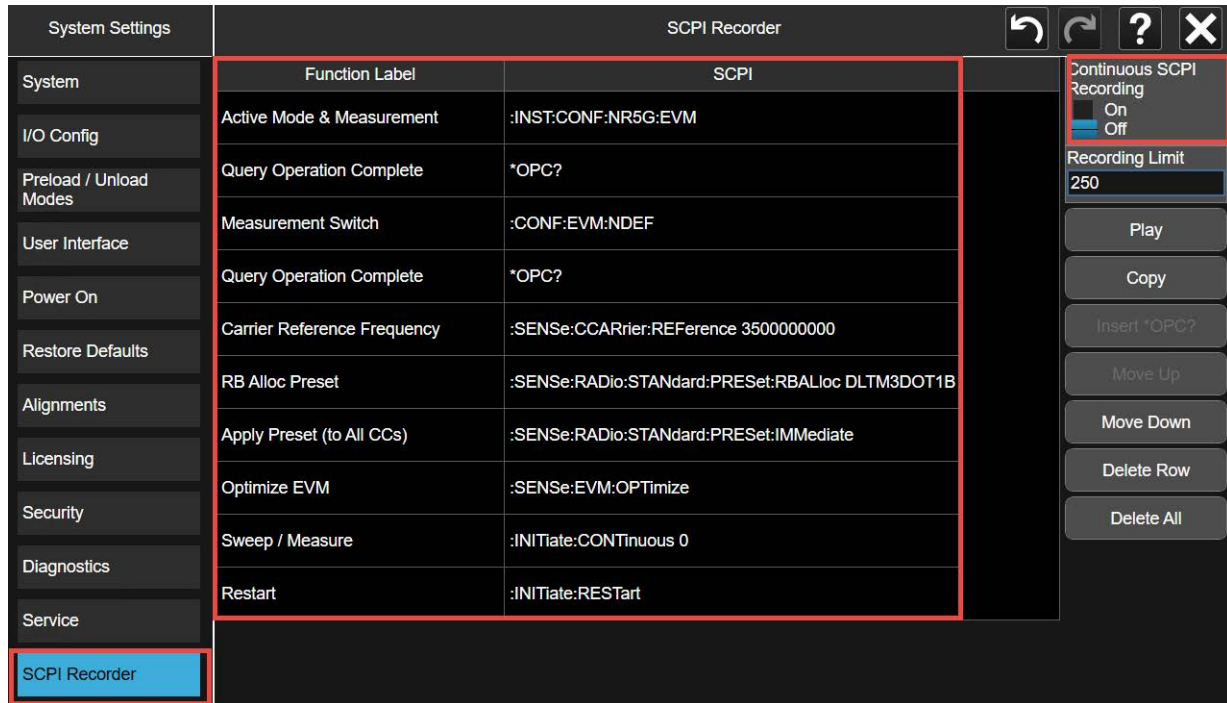
7. Select the **Settings** side tab and select **Optimize EVM**.



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.

Other X-Series Signal Analyzer Measurements

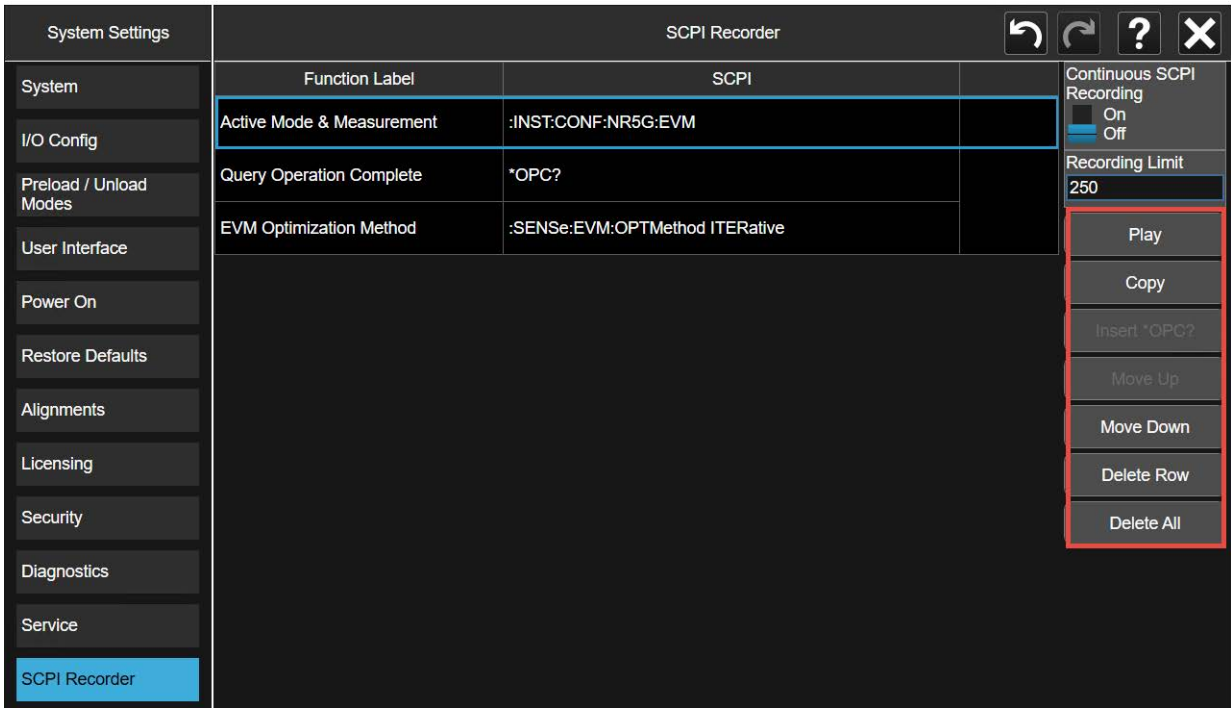
Using the X-Series Analyzer's SCPI Recorder Function

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.

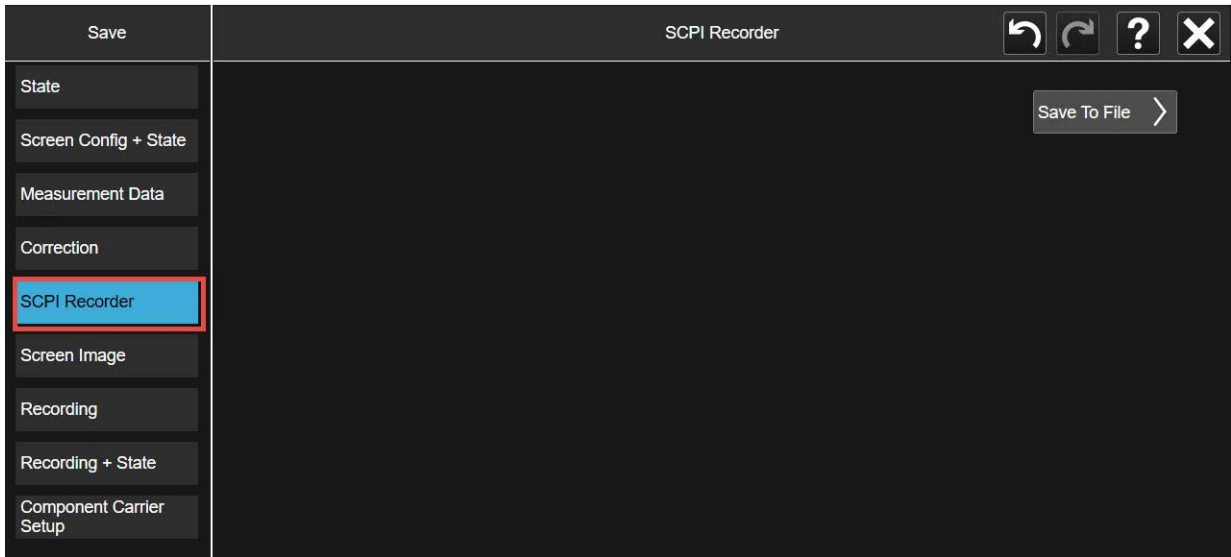


2. To view the newly added command, go to **System Settings** icon (Gear wheel on top right of the display) > **SCPI Recorder**.

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.



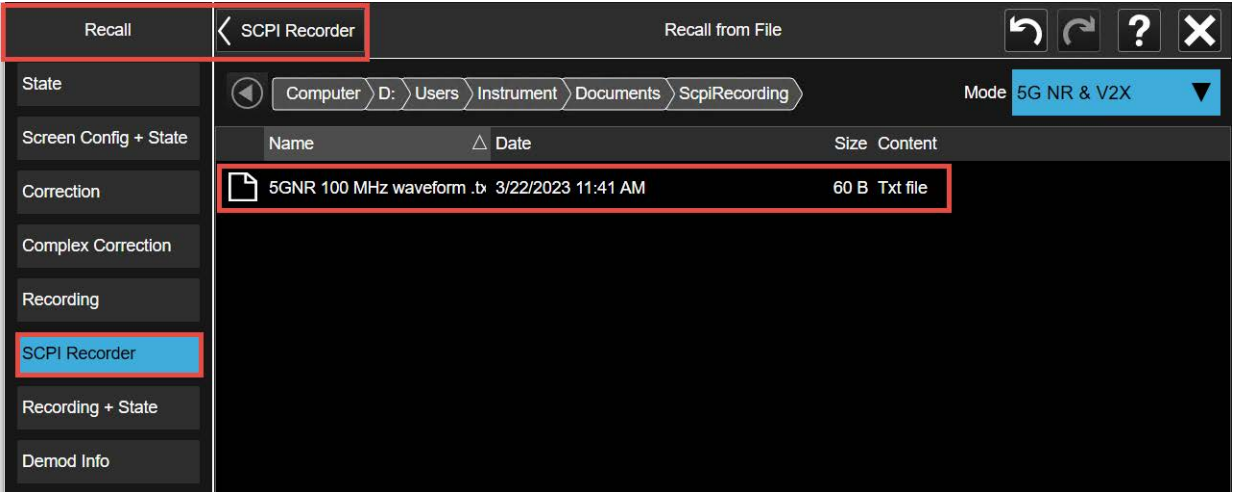
The recorded SCPI list can be exported as a script file in .TXT format via the Save/Recall function at the bottom of the main window.



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.

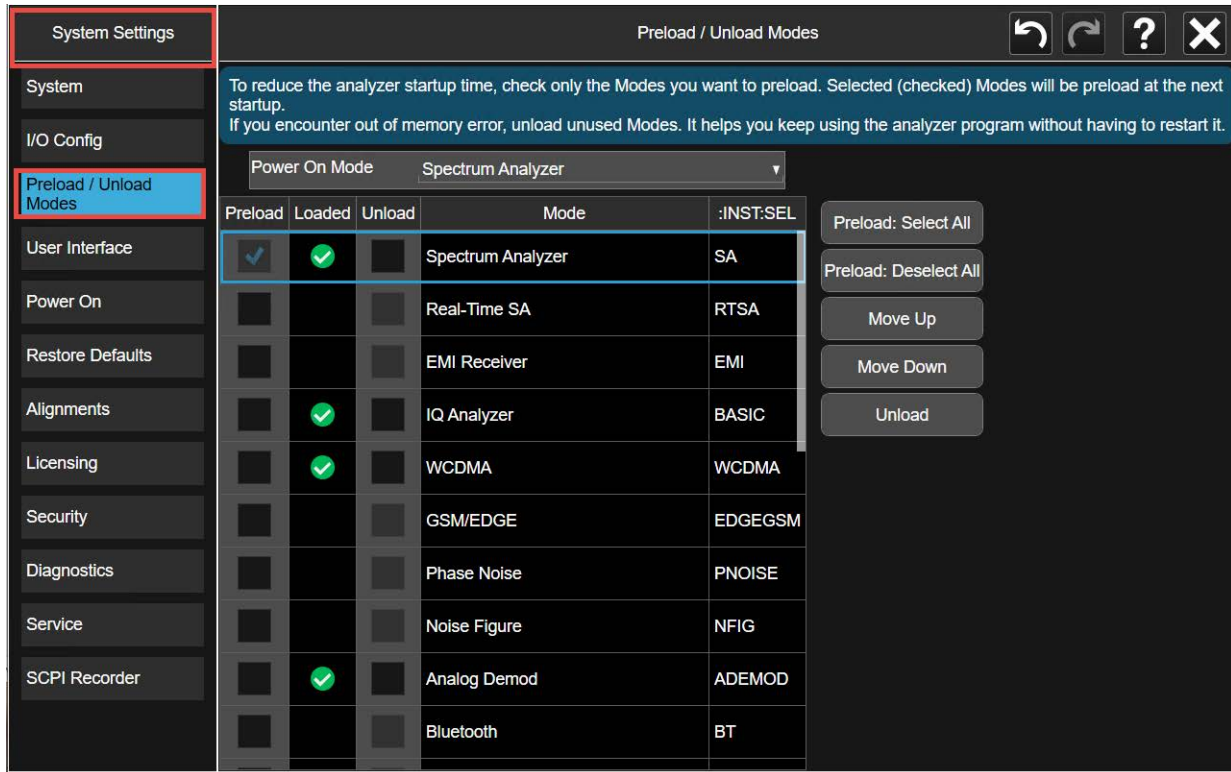
To recall the SCPI recording, go to Save/Recall and navigate to the saved file.



Using the X-Series Analyzer's Preload/Unload Function

The Preload/Unload function allows you to flexibly configure which applications should be preloaded when the software starts up, or also unload any previously loaded applications. This can help to save startup time or system memory as needed.

1. Select the **System Settings** icon (Gear wheel on top right of the display) > **Preload/Unload**.



- **Power On Mode** displays a list of licensed Applications. Use this control to change the factory default Power-On Mode. The instrument will execute the selected Application after power up. Selecting the Power-On Mode here automatically enables that Mode for preloading
- **Select All, Deselect All** toggles the Preload checkbox state for all applications listed, except for the Power-On application.
- **Move Up, Move Down** allows you to reorder the listed applications in the table. This is the order in which they are displayed in the Mode/Measurement/View Selector dialog.
- **Unload Mode** unloads the specified mode.
- **Loaded Modes** returns a list of loaded modes.

Other X-Series Signal Analyzer Measurements
Using the X-Series Analyzer's Preload/Unload Function

5 5G New Radio (NR) Measurements using X-Apps

This section includes the following topics:

- “5G Waveform, EVM, and ACP Analysis Using X-Applications” on page 278
 - “Setting Up Triggers on the Signal Analyzer using 5G NR Mode” on page 278
 - “Setting Up a 1 CC 28 GHz EVM Measurement” on page 280
 - “Setting up an 8 CC 28 GHz EVM Measurement” on page 287
 - “Setting Up a 1 CC 3.5 GHz ACP Measurement” on page 297
 - “Using PathWave N7631APPC to Create a Waveform File then Automatically Configure the Analyzer to View the Results” on page 301

5G Waveform, EVM, and ACP Analysis Using X-Applications

The VXG enables 5G testing with a low error vector magnitude (EVM) at high frequencies. The VXG 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 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 11** for connecting the instruments and accessing the VXG SFP.

Setting Up Triggers on the X-Series Signal Analyzer

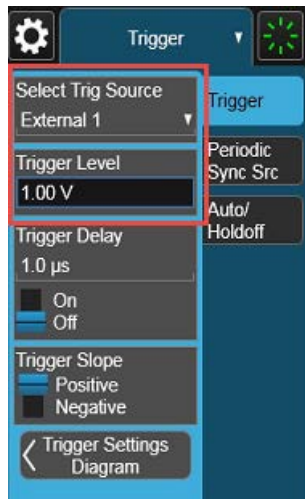
Using the graphical user interface

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:NR
```

```
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
```

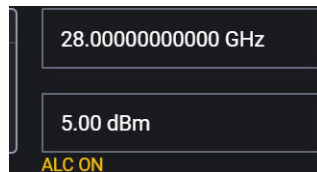
Setting Up a 1 CC 28 GHz EVM Measurement

NOTE

Ensure the equipment and triggers are properly configured. Refer to [“Equipment Setup” on page 11](#) and [“Setting Up Triggers on the Signal Analyzer using 5G NR Mode” on page 278](#).

On the VXG:

1. Select **Preset > Preset** to set the instrument to a known state.
2. In the Output 1 area, set Frequency to **28 GHz** and Power to **5 dBm**.



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



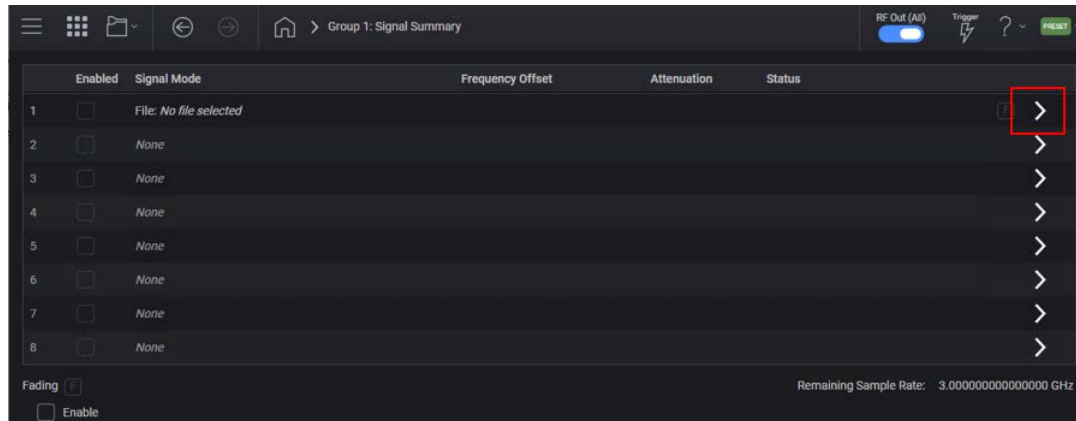
4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.

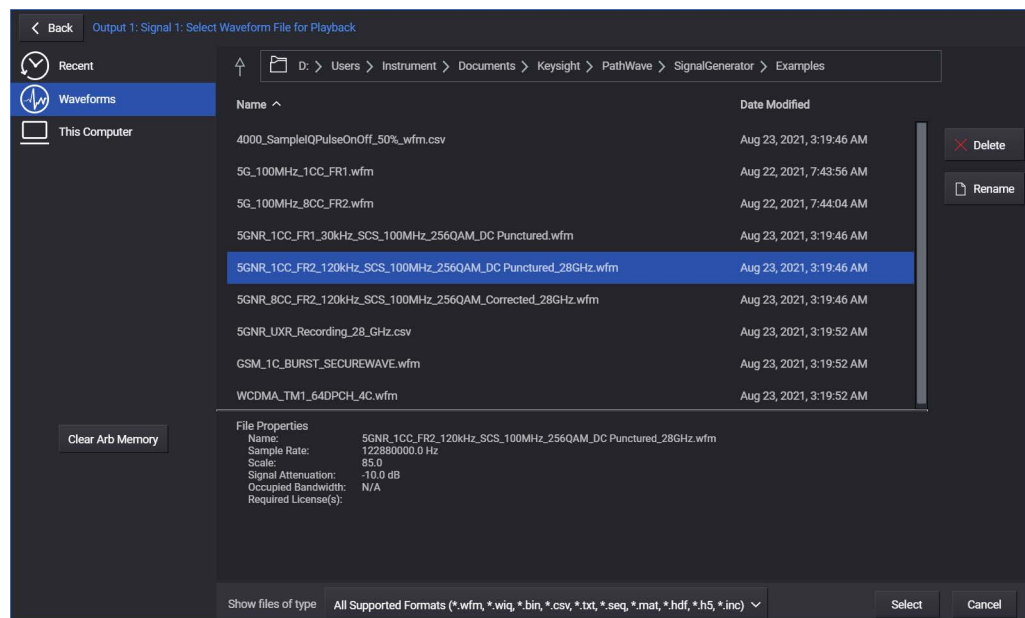
5G New Radio (NR) Measurements using X-Apps

5G Waveform, EVM, and ACP Analysis Using X-Applications

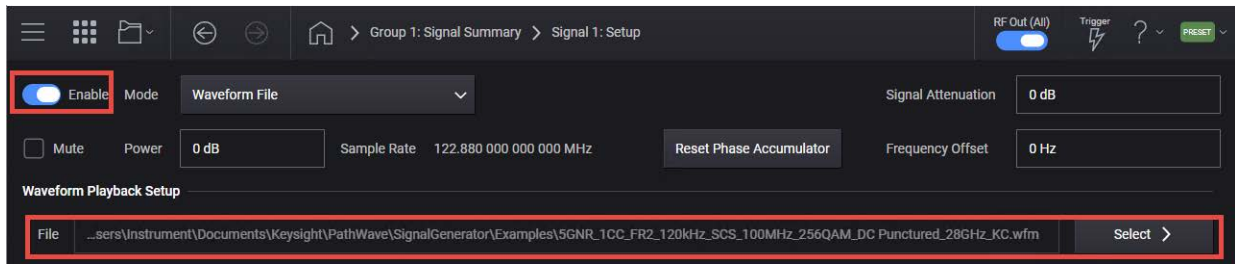


5. In the Waveform Playback Setup area, use **File Select** to navigate to:

D:\Users\Instrument\Documents\Keysight\PathWave
 \SignalGenerator\Examples
 and choose
 5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DCPunctured_28GHz.wfm
 then **Select**.



6. Select **Enable** Vector Modulation Signal.



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

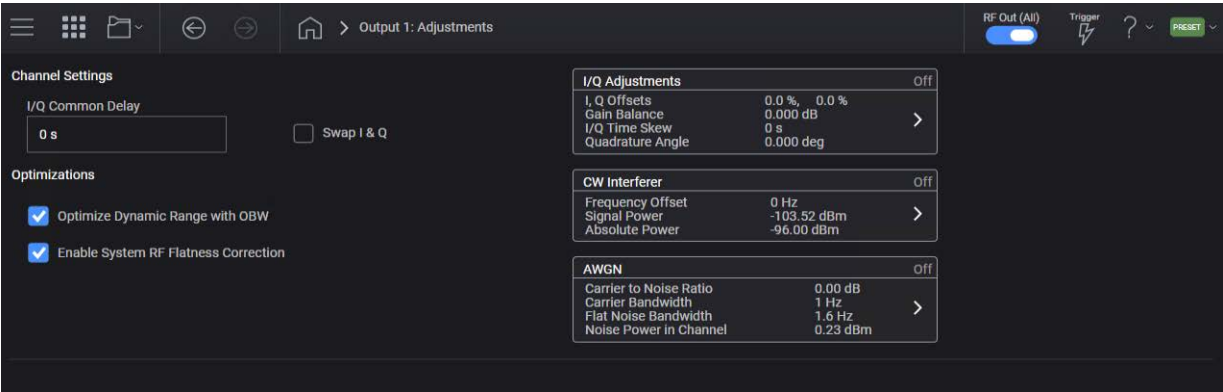


8. Select the **Adjustments** block and select **Optimize Dynamic Range with OBW** and **Enable System RF Flatness Correction**.

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 2 GHz, 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.



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

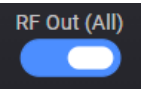


10. Set RF Out to **On** by selecting the numbered channel indicator switch.

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



11. **For two 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:

NOTE

All example waveforms and setup files are located on the VXG at:

D:\Users\Instrument\Documents\Keysight\PathWave
 \SignalGenerator\Examples

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

1. 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_FR2_120kHz_SCS_100MHz_256QAM_DC_punctured_28GHz_34.scp

Recall

Recall	Demod Info		Recall from File		<div><div><div></div><div></div><div></div><div></div></div></div>	
State	<div><div><div>Computer</div><div>D:</div><div>Users</div><div>Instrument</div><div>Documents</div><div>NR5G</div><div>data</div><div>Example setup demo files</div></div></div>				Mode	5G NR
Screen Config + State	Name		Date	Size	Content	
Correction	<div><div></div></div> 4-carrier_APSK.scp	1/30/2020 10:56 AM		402 KB	Scp file	
Complex Correction	<div><div></div></div> 4-carrier_APSK.setx	1/30/2020 10:56 AM		594 KB	Setx file	
Recording	<div><div></div></div> 5G_100MHz_8CC_FR2.scp	3/3/2021 10:51 PM		431 KB	Scp file	
Recording + State	<div><div></div></div> 5G_MIMO.setx	1/30/2020 10:56 AM		133 KB	Setx file	
Demod Info	<div><div></div></div> 5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC Punctured.scp	9/21/2018 3:53 PM		274 KB	Scp file	
	<div><div></div></div> 5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC Punctured.setx	8/30/2018 4:57 PM		90 KB	Setx file	
	<div><div></div></div> 5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DC Punctured_28GHz.scp	2/21/2019 1:58 PM		455 KB	Scp file	
	<div><div></div></div> 5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DC Punctured_28GHz.setx	2/21/2019 2:01 PM		131 KB	Setx file	
	<div><div></div></div> 5GNR_2x2_MIMO_VXG_Scope_Updated.scp	5/15/2019 12:14 PM		74 KB	Scp file	
	<div><div></div></div> 5GNR_2x2_MIMO_VXG_Scope_Updated.setx	5/15/2019 12:14 PM		135 KB	Setx file	
	<div><div></div></div> 5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_28GHz.scp	2/21/2019 1:48 PM		455 KB	Scp file	
	<div><div></div></div> 5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_DC Punctured_28GHz.setx	2/21/2019 1:05 PM		131 KB	Setx file	
	<div><div></div></div> Jacque.setx	8/23/2021 10:24 AM		131 KB	Setx file	
File name: Jacquie.setx		File type:	All Supported Files (*.scp;*.sgen;*.nrcc;*.pws;*.setx)		Recall	

2. Select **Meas Setup** > **Meas Time** and set:

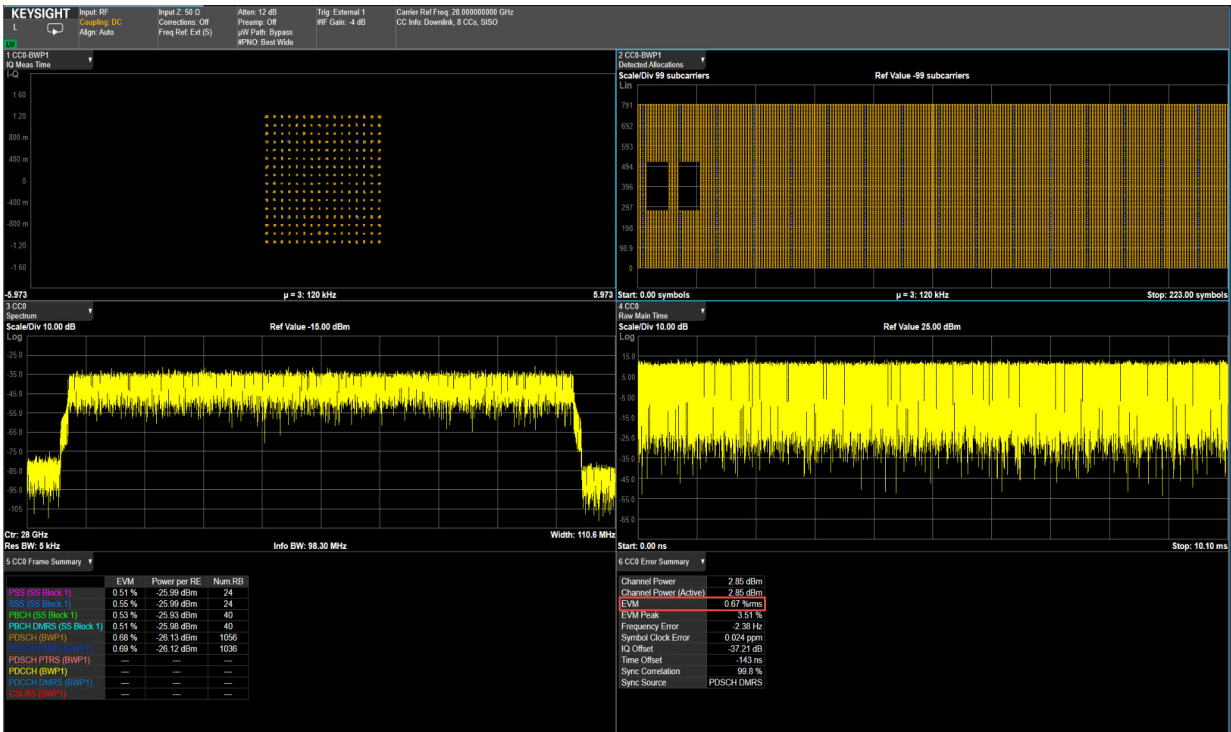
- Search Length to **10 ms**
- Result Length to **2 Sub Frame**
- Frame Trigger to **On**

3. Ensure that RF for Phase Compensation Auto is *not* selected and the value is **0 Hz**. **Close** the Advanced Settings table.

4. 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%.



Using the equivalent SCPI commands

On the VXG:

SYSTem:PRESet

RF1:FREQuency:CW 28GHZ

RF1:POWer:AMPLitude 5dBm

SIGNal1:MODE WAVeform

Navigate to the desired waveform file.

```
SIGNal1:WAVeform "D:\Users\Instrument\Documents\demo
waveforms
5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DC_punctured_
28GHz_34.scf"
```

SIGNal1 ON

IQO:CORR:OPT:DYN:RANG:OBW ON

RF1:OUTPut ON

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

RFAL1:OUTPut ON

On the X-Series Signal Analyzer:

NOTE

All example waveforms and setup files are located on the VXG at:

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

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

```
MMEMory:LOAD:EVM:SETup CC0,
"D:\Users\Instrument\Documents\NR5G\data\NR5GEvm\CarrierSetu
p\5GNR_1CC_FR2_120kHz
SCS_100MHz_256QAM_DCpunctured_28GHz.scf"
```

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

Setting up an 8 CC 28 GHz EVM Measurement

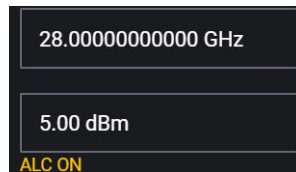
This procedure shows you how to use the X-Series signal analyzer with the 5G NR & V2X X-Series application to observe EVM on an eight-carrier waveform.

NOTE

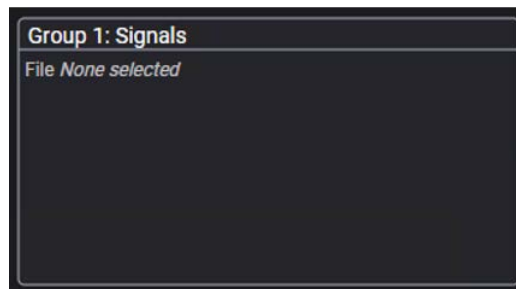
Ensure the equipment and triggers are properly configured. Refer to [“Equipment Setup” on page 11](#) and [“Setting Up Triggers on the Signal Analyzer using 5G NR Mode” on page 278](#).

On the VXG:

1. Select **Preset** > **Preset** to set the VXG to a known state.
2. Set Frequency to **28 GHz** and Amplitude to **5 dBm**.



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



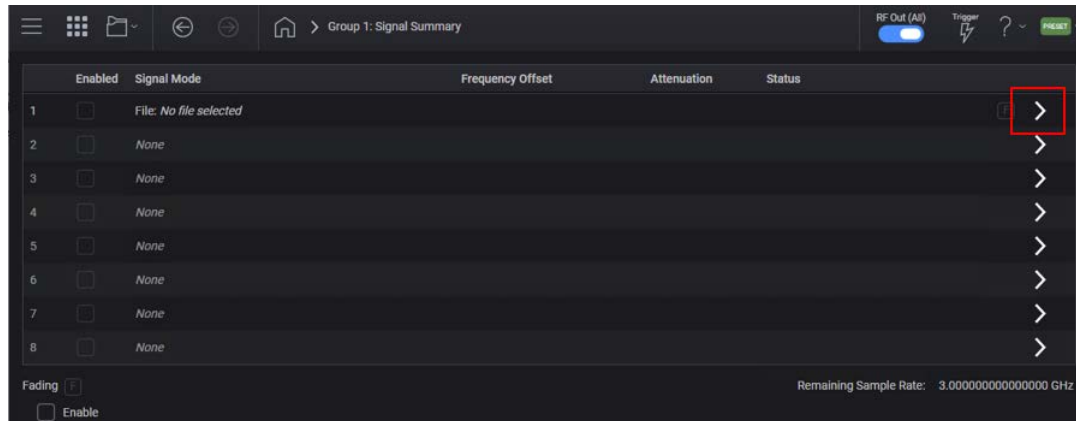
4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.

5G New Radio (NR) Measurements using X-Apps

5G Waveform, EVM, and ACP Analysis Using X-Applications



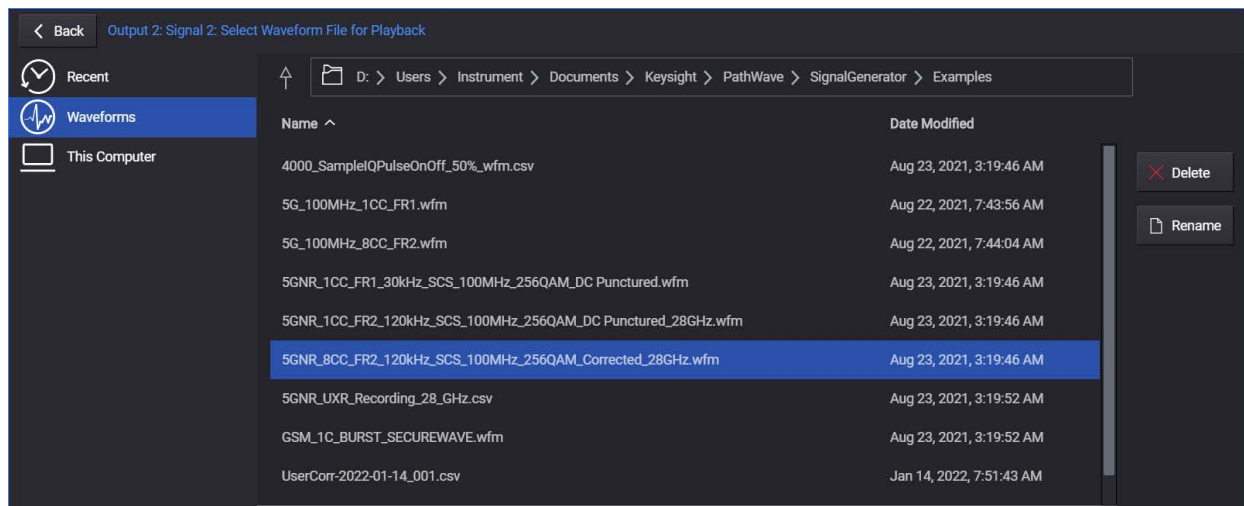
5. Use **File Select** to navigate to:

D:\Users\Instrument\Documents\Keysight\PathWave
 \SignalGenerator\Examples

and choose

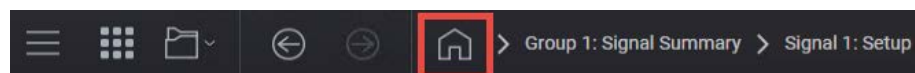
5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_28GHz.
 wfm

then **Select**.



6. Select **Enable** Vector Modulation Signal.

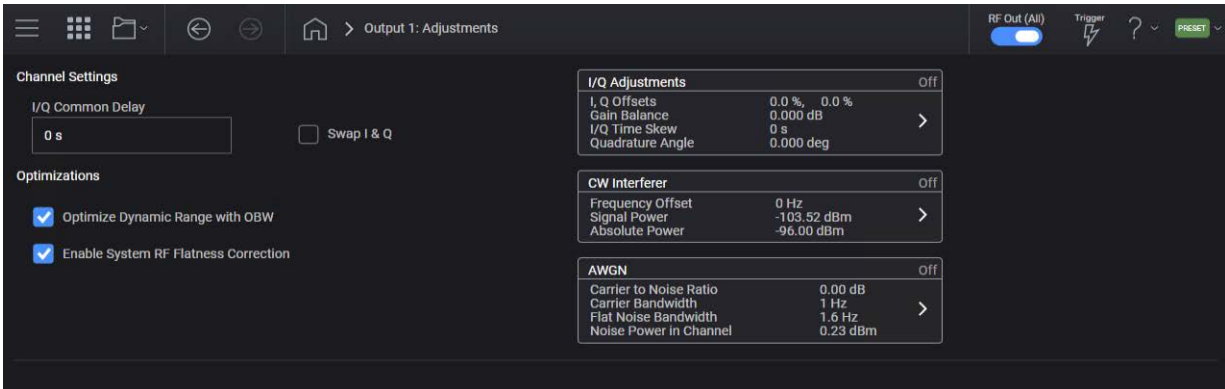
7. Close the Signal Setup by selecting the Home icon at the top of the display.



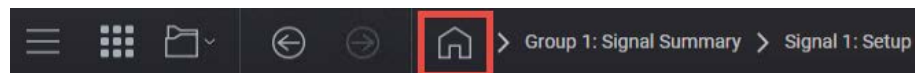
8. Select the **Adjustments** block and select **Optimize Dynamic Range with OBW** and **Enable System RF Flatness Correction**.

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 2 GHz, 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.

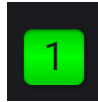


9. Close the Vector Modulation Signal Setup by selecting the **Home** icon at the top of the display.

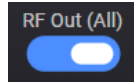


10. Set RF Out to **On** by selecting the numbered channel indicator switch.

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



- 11. 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:

NOTE

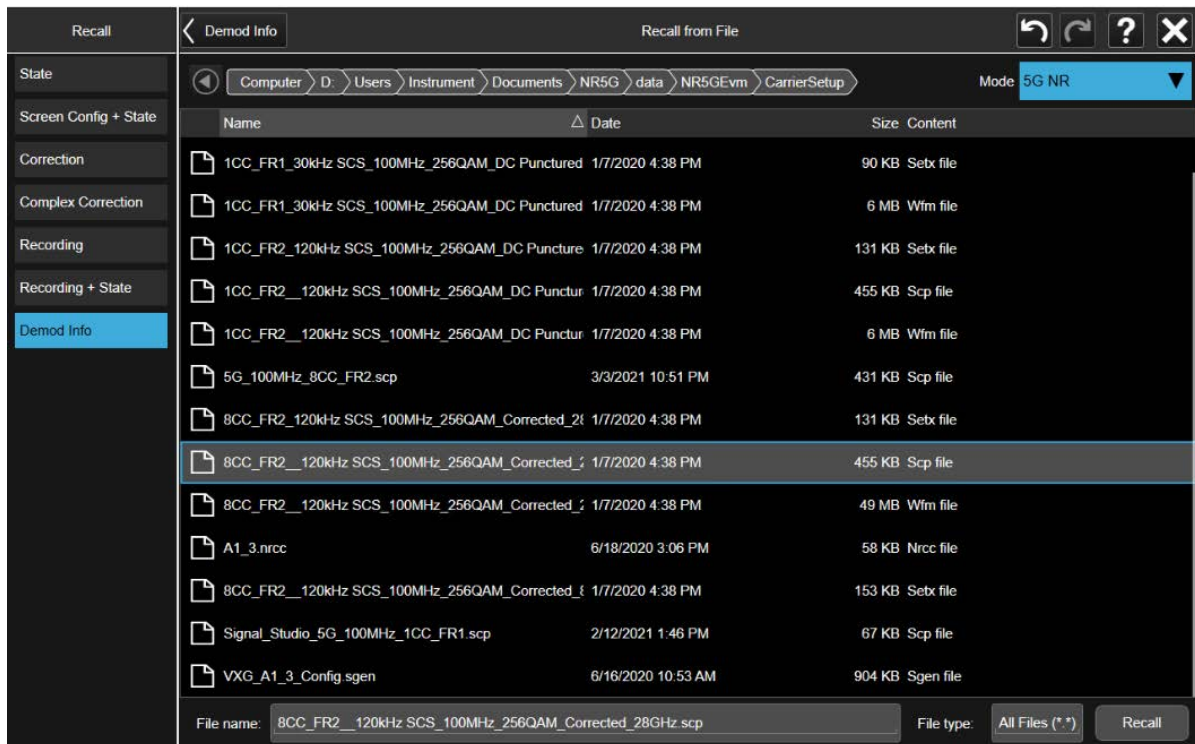
All example waveforms and setup files are located on the VXG at:

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

You will need to copy over the setup files to the signal analyzer or the PC running the VSA application.

1. 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** > 8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_28GHz_34.scf > **Recall**.

You must be in the correct analysis mode to recall the .scp file.




2. Select **Meas Setup** > **Meas Time** tab and set:

- Search Length to **10 ms**
- Result Length to **2 Sub Frame**
- Frame Trigger to **On**

3. Select **Meas Setup** > **Advanced** tab > **Advanced Demod Setup** and select both **Multi-Carrier Filter** and **DC Punctured** to turn on.

The multi-carrier filter is used to filter out the unwanted carriers and minimize leakage into the component carrier of interest.

4. Ensure that RF for Phase Compensation is *not* selected and the value is **0 Hz**, then **Close** the Advanced Settings table.

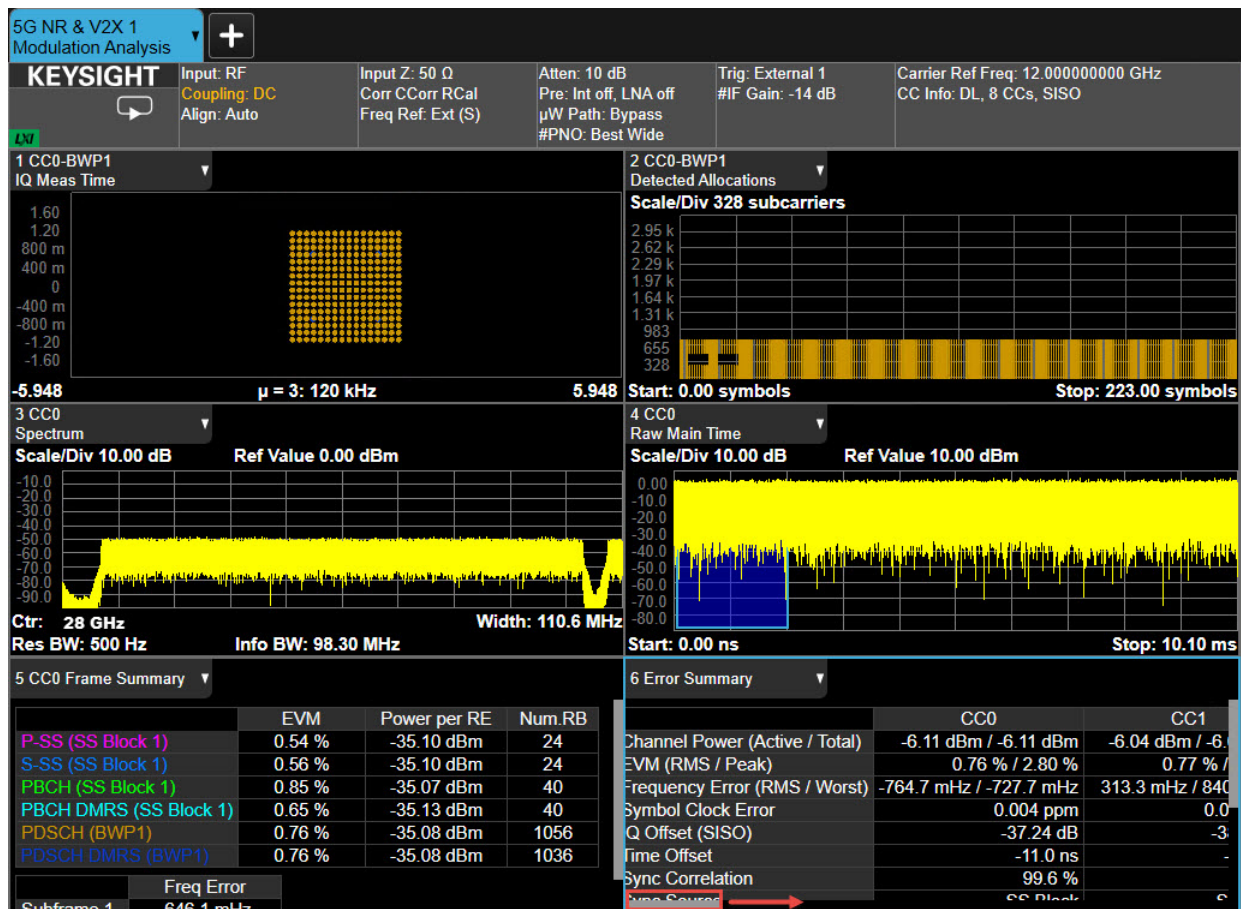
Component Carrier	CC0
Sync Mode	CP Auto Correlation
Multi-Carrier Filter	On  AUTO
Extended Frequency Lock Range	On Off
DC Punctured	On Off
DC Offset from CC Center	0 Hz AUTO
RF for Phase Compensation	0 Hz AUTO
Channel Power Threshold	-30.00 dB
Report EVM in DB	On Off
Time Scale Factor	1.0000

5. Select the **Sweep > Single Sweep**.
6. Select **Meas Setup > Settings tab > Optimize EVM**.

It will take a couple of minutes for the UXA to measure all 8 carriers.

Notice that the Error Summary measurement has a scroll bar allowing you to view the results of all 8 component carriers.

5G New Radio (NR) Measurements using X-Apps 5G Waveform, EVM, and ACP Analysis Using X-Applications



Using the equivalent SCPI commands

On the VXG:

SYSTem:PRESet

RF1:FREQuency:CW 28GHZ

RF1:POWer:AMPLitude 5dBm

SIGNal1:MODE WAVeform

Navigate to the desired waveform file.

```
SIGNal1:WAVeform "D:\Users\Instrument\Documents\demo  
waveforms\5GNR_8CC_FR2_120kHz_SCS_100MHz_Corrected_28GHz.wfm  
"
```

SIGNal1 ON

IQO:CORR:OPT:DYN:RANG:OBW ON

IQO:CORR:CHANnel:FLATness ON

RF1:OUTPut ON

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

RFAl1:OUTPut ON

On the X-Series Signal Analyzer:

NOTE

All example waveforms and setup files are located on the VXG at:

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

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

Navigate to the desired waveform file.

```
MMEMory:LOAD:EVM:SETup CC0,  
"D:\Users\Instrument\Documents\NR5G\data\NR5GEvm\CarrierSetu  
p\8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_28GHz_34.scp"
```

EVM:CCARrier0:TIME:LENGth:SEARch 10ms

EVM:CCARrier0:TIME:LENGth:RESult 2

EVM:CCARrier0:FRAME:TRIGger ON

EVM:CCARrier0:MCFilter ON

EVM:CCARrier0:DC:PUNcture ON

EVM:CCARrier0:PHASe:COMPensation:AUTO OFF

EVM:CCARrier0:PHASe:COMPensation:FREQuency 0 Hz

5G New Radio (NR) Measurements using X-Apps
5G Waveform, EVM, and ACP Analysis Using X-Applications

To Optimize EVM for Multi-Carrier Waveforms

POWer:ATTenuation 0dB

[POWer:ATTenuation 2dB], ...

EVM:IF:GAIN:LEVel 0dB

5G New Radio (NR) Measurements using X-Apps
5G Waveform, EVM, and ACP Analysis Using X-Applications

To View the Results of Two Carriers

Set the top right window (Window 2) to display IQ Meas Time

DISPlay:EVM:WINDow2:DATA MTIM

Set the top right window to display Component Carrier 1

DISPlay:EVM:WINDow2:CCARrier CC1

Set the middle right window to display the FFT of the Raw Main Time waveform

DISPlay:EVM:WINDow4:DATA SPEC

DISPlay:EVM:WINDow4:CCARrier CC1

Set the bottom right window to display a table of general measurement numeric results

DISPlay:EVM:WINDow6:DATA DRES

DISPlay:EVM:WINDow6:CCARrier CC1

Set the bottom left window to display the error summary for CC0

DISPlay:EVM:WINDow5:DATA DRES

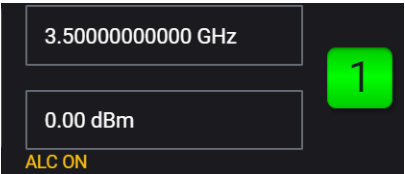
Setting Up a 1 CC 3.5 GHz ACP Measurement

NOTE

Ensure the equipment and triggers are properly configured. Refer to [“Equipment Setup” on page 11](#) and [“Setting Up Triggers on the Signal Analyzer using 5G NR Mode” on page 278](#).

On the VXG:

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



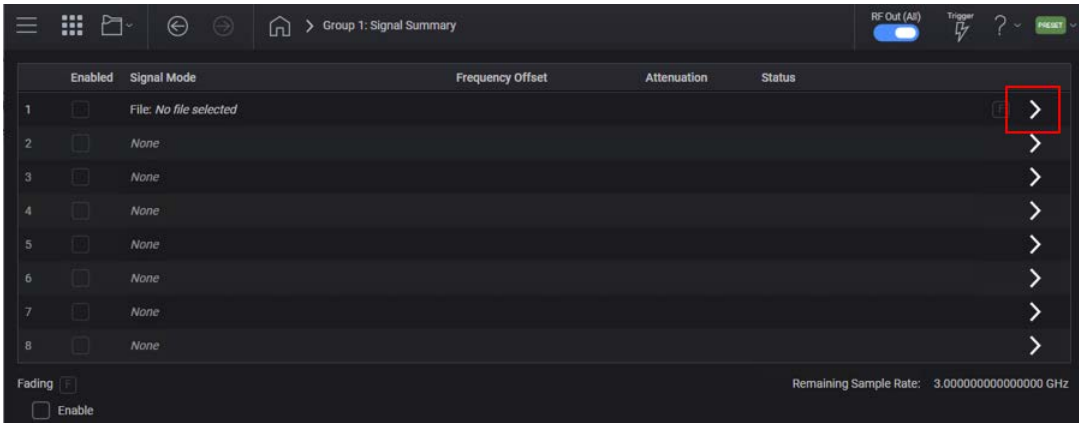
- 3. Select **Group 1: Signals** block to open.



- 4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.



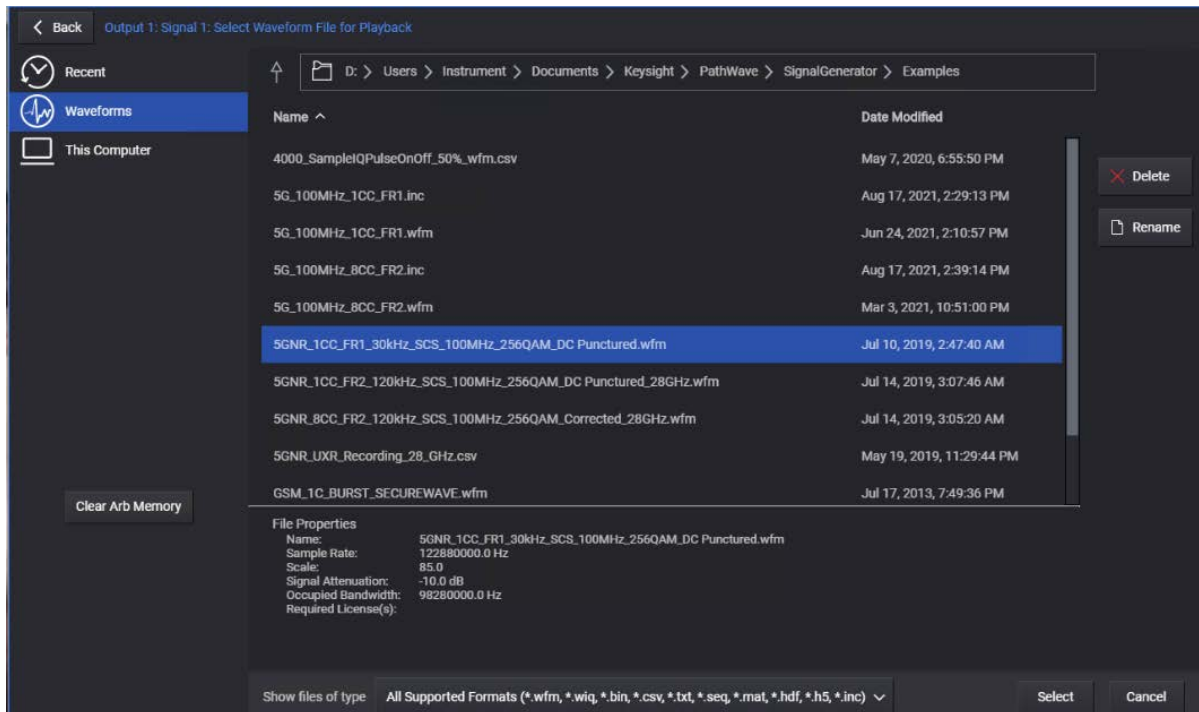
5. Use File **Select** to navigate to:

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

and choose

5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DCPunctured.wfm

then **Select**.



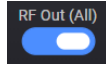
6. In the Vector Modulation Signal Setup, ensure that **Enable** Vector Modulation Signal is selected, then close the Signal block.

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.



- 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.

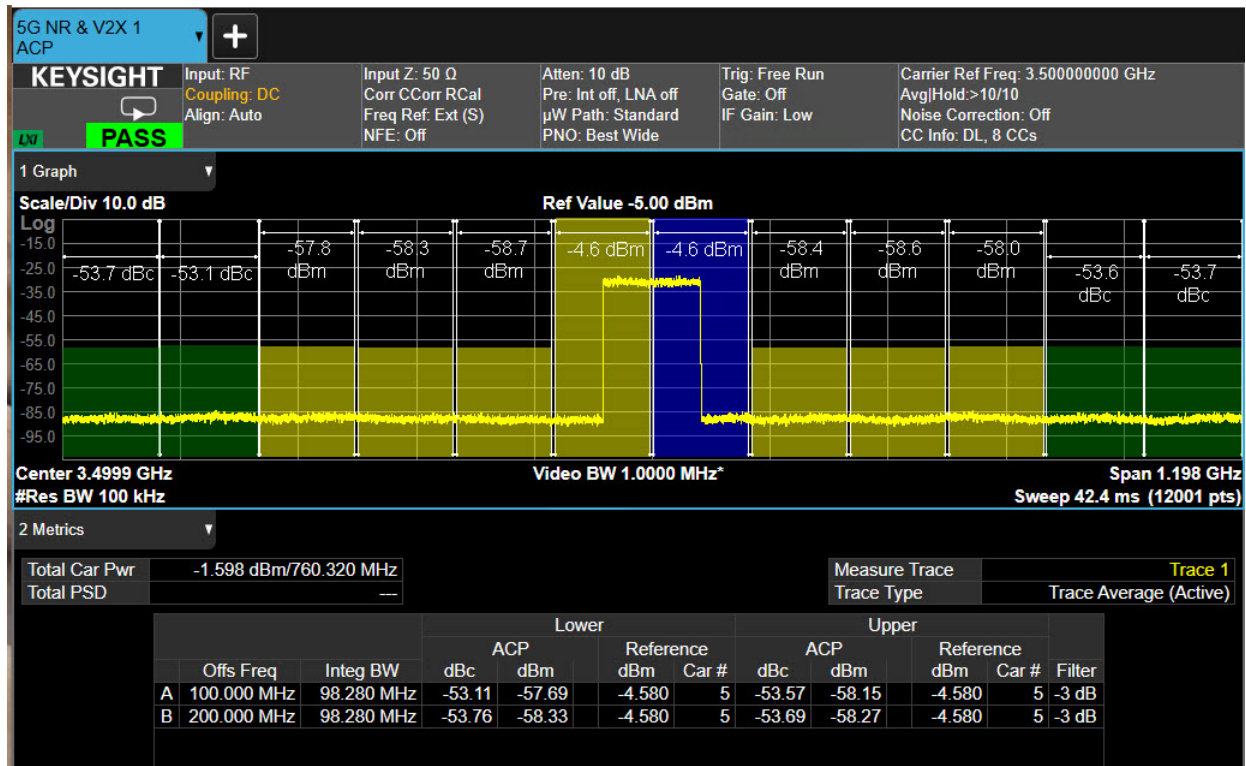
On the X-Series Signal Analyzer:

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

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



Using the equivalent SCPI commands

On the VXG:

```
SYSTem:PRESet
```

```
RF1:FREQuency:CW 3.5GHZ
```

```
RF1:POWer:AMPLitude 0dBm
```

```
SIGNal1:MODE WAVeform
```

```
SIGNal1:WAVeform "D:\Users\Instrument\Documents\MCS demo  
waveforms\5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DCPunctured.w  
fm"
```

```
SIGNal1 ON
```

```
DM:OPTimization:CHANnel ACP
```

```
RF1:OUTPut ON
```

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

```
RFAL1:OUTPut ON
```

On the X-Series Signal Analyzer:

```
SYSTem:PRESet
```

```
INSTrument:CONFigure: NR5G:ACP
```

```
CCARrier:REFerence 3.5GHZ
```

```
ACPower:CORRection:NOISe ON
```


Using PathWave N7631APPC 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 VXG.

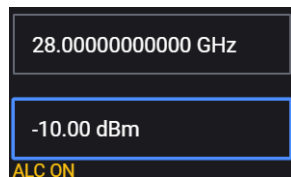
This example shows you how to create and analyze a 5G NR signal using the embedded PathWave software and then automatically configure the analyzer to make the measurement.

NOTE

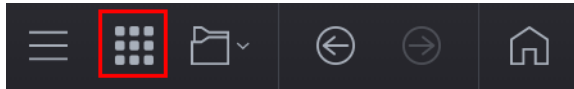
The VXG must have the N7631APPC Signal Generation for 5G NR license installed.

On the VXG:

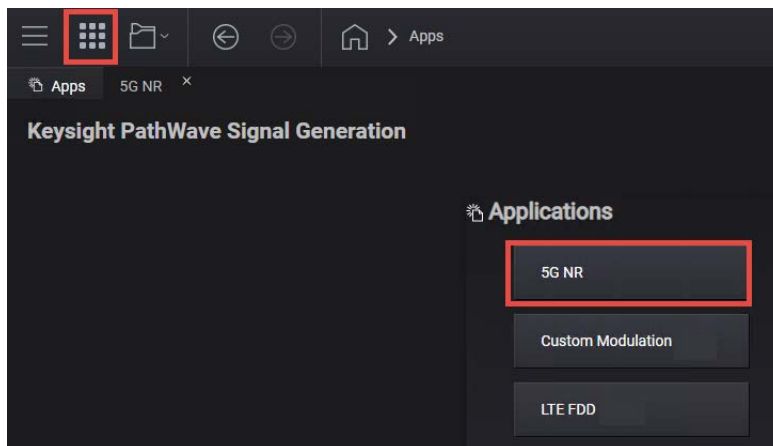
1. Select **Preset > Preset** to set the VXG to a known state.
2. In the Output area, set Frequency to **28 GHz** and Power to **-10 dBm**.



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

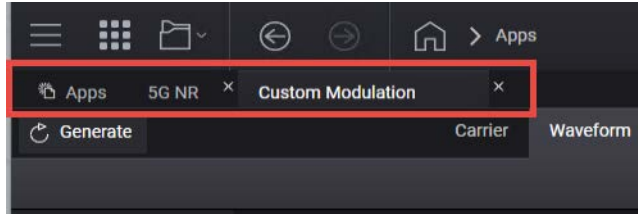


4. Select **5G NR** to enter the 5G NR signal mode.



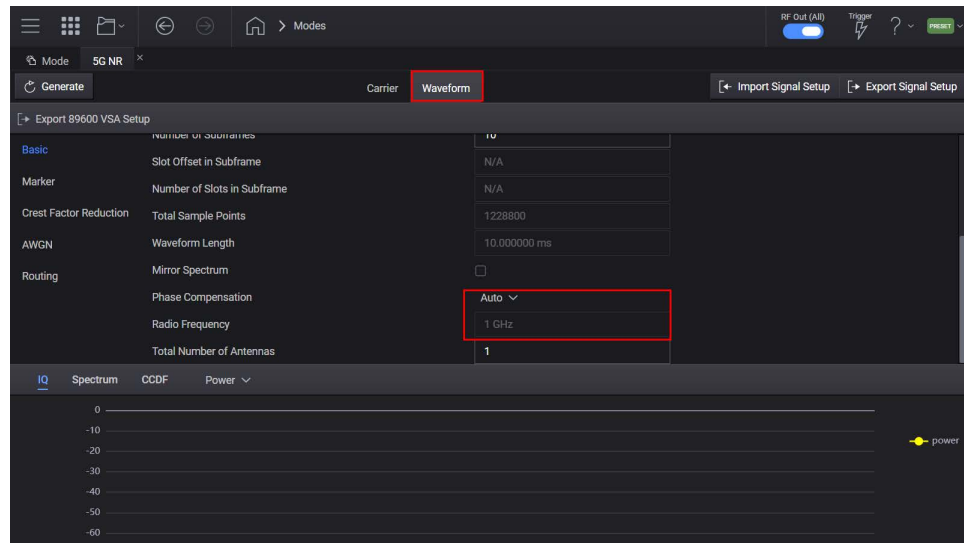
NOTE

If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



5. In the 5G NR setup, select the **Waveform** tab and observe the Phase Compensation and Radio Frequency settings.

Phase Compensation is applied by default at baseband for RF up-conversion. This means it depends on the carrier frequency, and the waveform should only be played at the carrier frequency it was generated for, unlike conventional Signal Studio waveforms, which are independent from carrier frequency. Phase Compensation is set to Auto by default. The frequency is coupled with the VXG frequency setting. You can select Manual to specify a different frequency, or turn it off.



TIP

Some applications, like power amplifier measurements use the same waveform at different frequencies and can be time consuming to generate a separate waveform for each frequency. In this case, you would turn Phase Compensation Off, so the waveform becomes independent from the carrier frequency. You need to do the same on the analysis side, or the demodulation will fail.

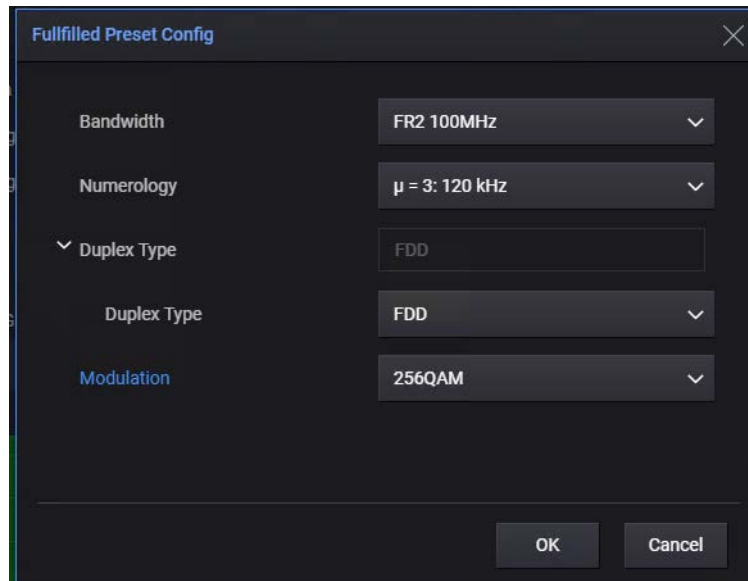
6. Select the **Carrier** tab.

7. Select **Full-Filled Config** and set Bandwidth to **FR2 100 MHz**, Numerology to $\mu=3:120$ kHz, Duplex Type to **FDD**. Modulation to **256 QAM**.

NOTE

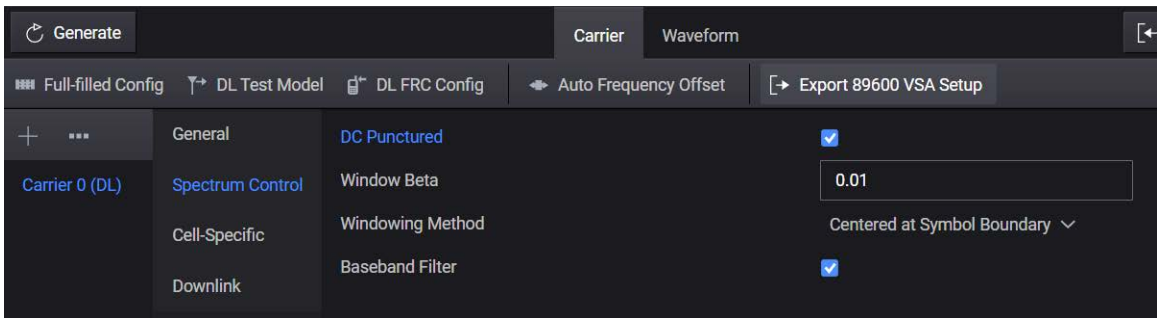
If you have a signal analyzer with demodulation bandwidth that is wide enough to cover the other FR2 bandwidths, 200 MHz or 400 MHz, you can choose to use a wider bandwidth.

Full Filled Configurations is a great place to start creating your waveform. You can select FR, bandwidth, and modulation format with a fully allocated PDSCH data channel. This would represent a spectrally correct signal that is typically used in power amplifier measurements. You can modify the RB allocations and Slot allocations if fully allocated data channels are not desired.



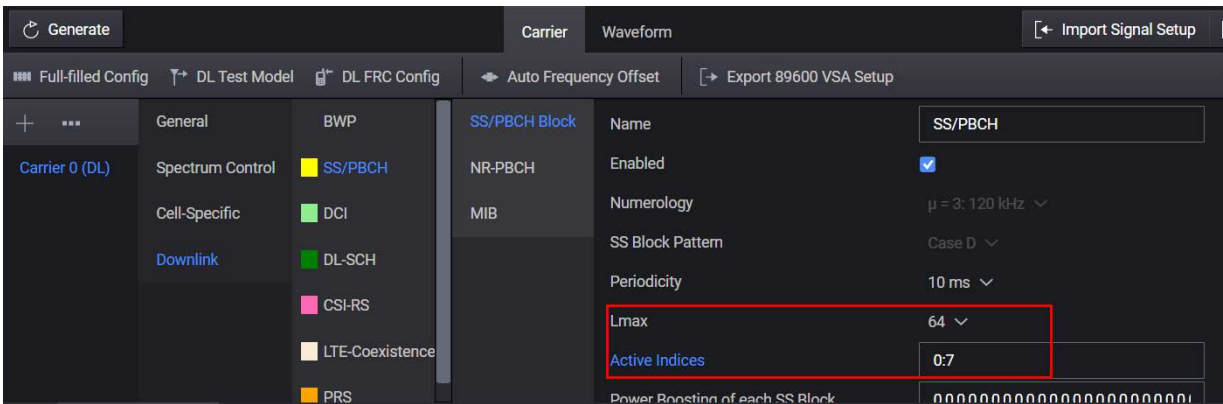
8. Select **OK** to exit the Full Filled Config setup.
9. From the Carrier panel (in the left pane), select **Spectrum Control > DC Punctured On**.

When DC Punctured is enabled, the DC subcarrier is excluded from the measurement results. This is often helpful to avoid obscuring measurement results with artifacts of LO feedthrough.



10. From the Carrier panel (in the left pane), select **Downlink** > **SS PBCH** > **SS PBCH Block** and set Lmax to **64** and Active Indices to **0:7**.

Instead of transmitting all 64 beams, we enable only 8 of them by setting Active Indices to 0:7.

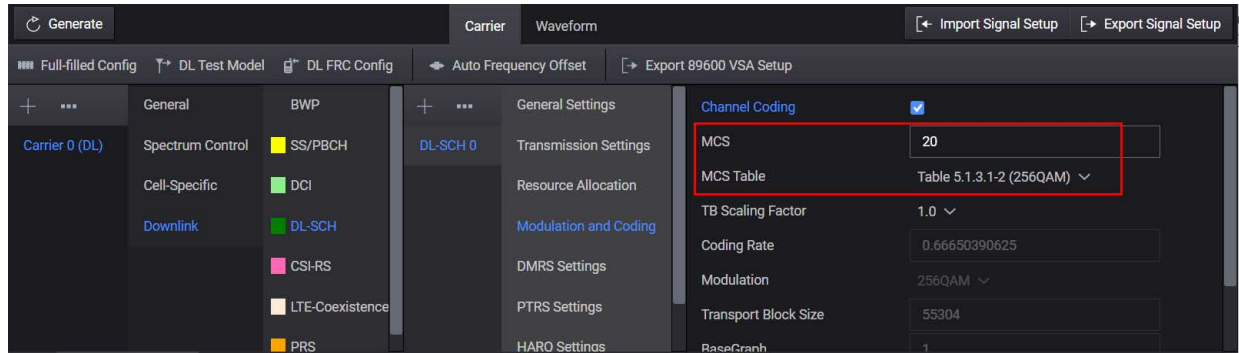


NOTE

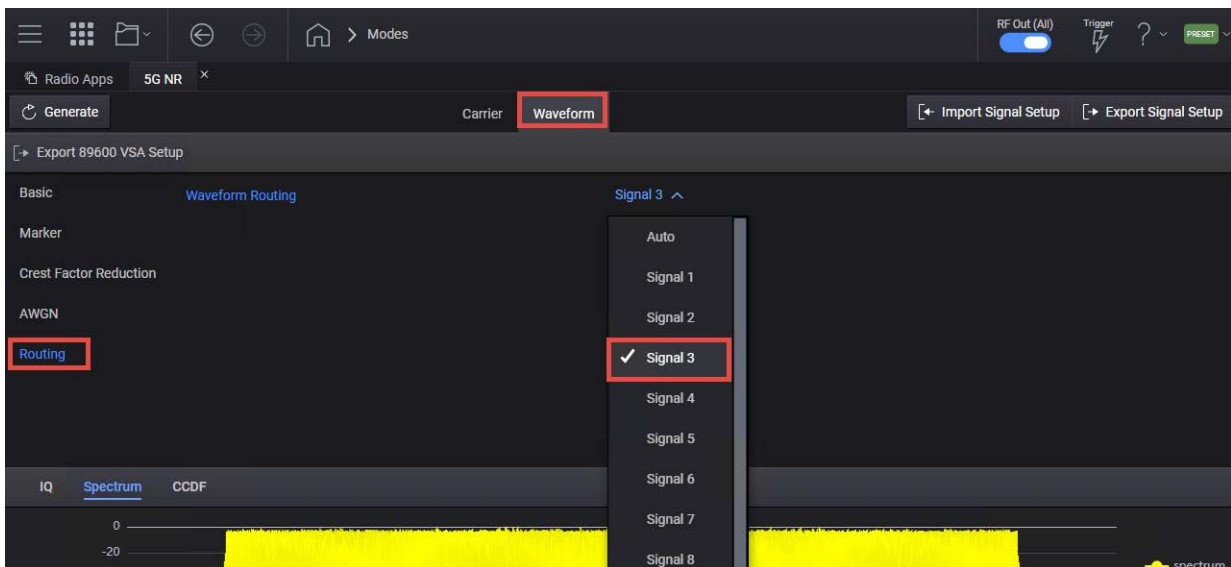
Lmax sets the maximum number of possible SS/PBCH blocks in a transmission opportunity. This value is fixed for a given carrier bandwidth. Typically, higher frequency and bandwidth carriers use a larger set of SS/PBCH opportunities to support a larger set of antenna beams. Lmax is either 4 or 8 for FR1 and 64 for FR2.

11. From the **Carrier** panel (in the left pane), select **Downlink** > **DL-SCH** > **DL-SCH0** > **Modulation and Coding** and set MCS Table to **Table 5.1.3.1-2 (256QAM)** and MCS to **20**.

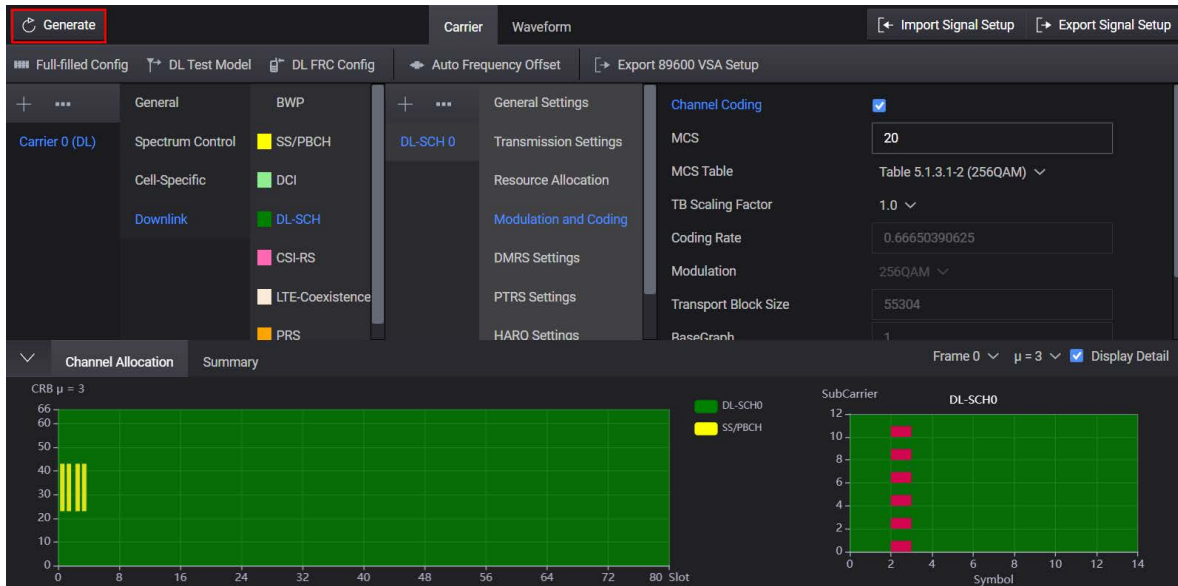
The Modulation Coding Scheme (MCS) specifies the modulation, coding and overall spectral efficiency of the PDSCH as specified in 3GPP Table 5.1.3.1.



12. Optional: For use with Option 8SG (eight virtual signal generators) and multi-channel instruments, select the **Waveform** tab > **Routing** and select the signal number to route to.



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



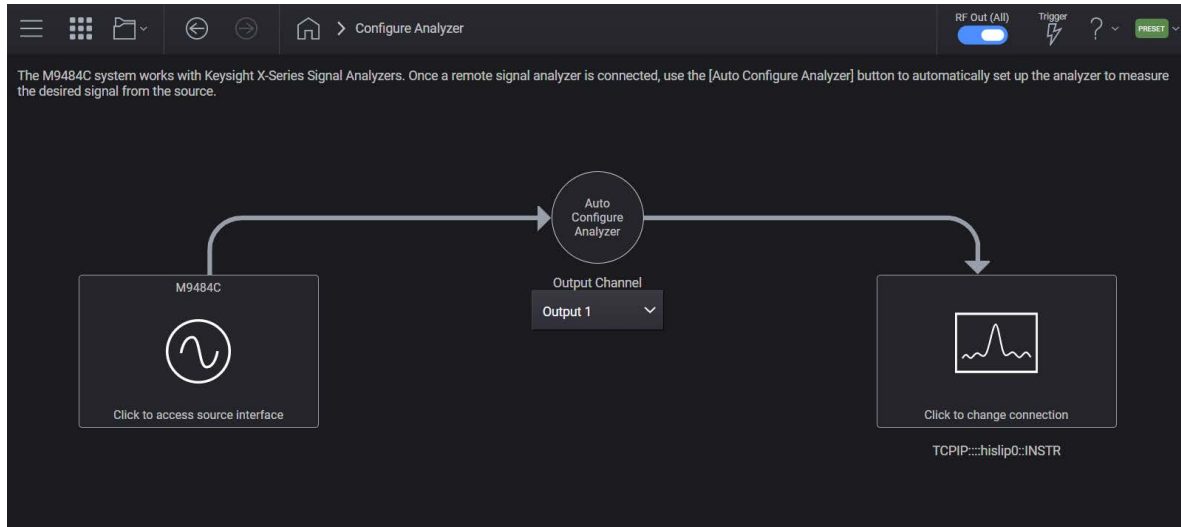
14. Set RF Out to **On by selecting the numbered channel indicator switch.**

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



Setup Auto Configure Analyzer

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

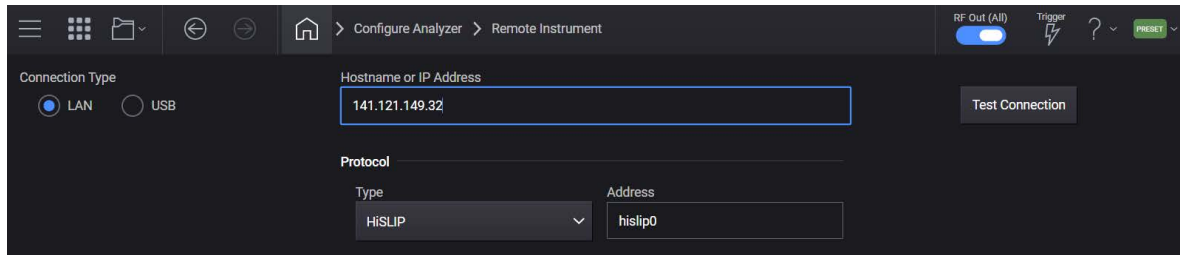


2. In the System Configuration setup, click on the Remote Signal Analyzer block (on far right) to setup the communication channel to the Keysight X-Series Signal Analyzer.

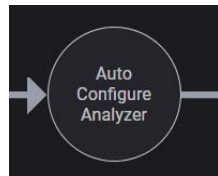


3. Set Connection Type to **LAN**.
4. In the Connect Remote X-Series Signal Analyzer setup, enter the Hostname or IP Address for the signal analyzer.
5. Under Set Protocol, select **HiSLIP** and use the Remote name **hislip0**.

6. Select **Test Connection** to verify, then **Back**.



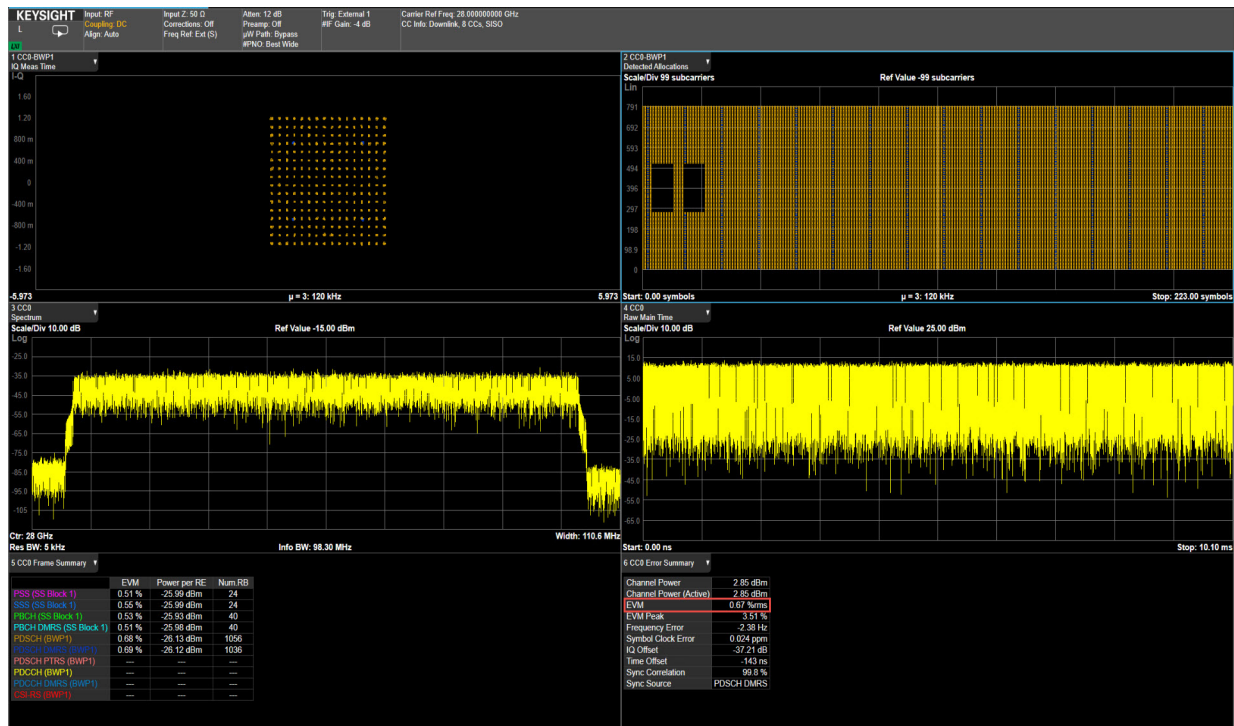
7. Select **Auto Configure Analyzer** to send the VXG settings to the analyzer.



8. Set up triggers, refer to **“Setting Up Triggers on the Signal Analyzer using 5G NR Mode”** on page 278.

9. From the menu panel, select **Meas Setup > Advanced > Advanced Demod Setup > DC Punctured On**.

10. View the results on the signal analyzer.



The System Configuration selection brings up a screen that lets you perform a Generation-to-Analysis work flow. The “Auto Configure Analyzer” button will

automatically transfer the setup from the source to a Keysight X-Series signal analyzer, in order to measure the desired signal from the source. If you are generating a 3GPP 5G New Radio signal, and the 5G New Radio application is licensed on the analyzer, the analyzer will perform demodulation of the signal. Otherwise, the analyzer will auto-tune on the signal being generated. The Keysight X-Series Signal Analyzer requires firmware version x.24.00 or greater.

More About the 5G NR Traces

- Trace 1: shows the composite constellation diagram showing different modulation formats for the different channels/signals present in the transmitted signal. See Trace 6 (Frame Summary) for the list of channels. Again, when enabling BWP, SS Block is grayed out. When enabling SS Block, channels withing BWP are grayed out.
- Trace 2: shows the envelope of the captured raw data. This data is unprocessed and includes additional points acquired for settling of the filters involved in subsequent processing, such as the demodulation filtering.
- Trace 3: shows the FTT of the Raw Main Time waveform.
- Trace 4: shows the general measurement numeric results.
- Trace 5: shows the detected allocations of all channels/signals within the measurement interval (2 Subframes in this example).
- Trace 6: shows EVM, Power, and Number of RB of the individual channels/signals.

TIP

The Frame Summary table shows Num. RB for PDSCH of 1056 and 1016 for PDSCH-DMRS. The signal configuration has only 66 RBs. The RB result in the Frame Summary Table is per Slot. In this example procedure, we changed the measurement interval to 2 Subframes, which is 16 slots for 120 kHz numerology (8 slots/subframe). $66 * 16 = 1056$. For PDSCH-DMRS, the value is 1016 because two of the 16 slots overlap with the SS Block which occupies 20 RBs resulting in 20 RBs being punctured from DMRS in these two slots. Therefore, the total RB Number for DMRS is $1056 - 20 * 2 = 1016$.

Using the equivalent SCPI commands

On the VXG:

SYSTem:PRESet

RF1:FREQuency:CW 28GHZ

RF1:POWer:AMPLitude -10dBm

RADio:SElect NR5G

RADio:NR5G:WAVEform:CCARrier:BWIDth FR2BW100M

Select $\mu = 3$: 120kHz:

RADio:NR5G:WAVEform:CCARrier:SNUMerology MU3

RADio:NR5G:WAVEform:CCARrier:DLINK:SSBLock:LMAX 64

RADio:NR5G:WAVEform:CCARrier:DLINK:SSBLock:ACTive:INDices
"0:7"

RADio:NR5G:WAVEform:CCARrier:DLINK:SCH0:MCS 20

RADio:NR5G:WAVEform:CCARrier:DLINK:SCH0:MCS:TABLE TABLE52

RADio:NR5G:WAVEform:GENerate

GROup:SIGNall ON

RF1:OUTPut ON

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

RFALl:OUTPut ON

6 5G NR Measurements Using the VSA Software

This section includes the following topics:

- “5G Waveform and EVM Analysis Using VSA Software” on page 312
 - “Setting Up a 1 CC 28 GHz EVM Measurement” on page 312
 - “Setting Up an 8 CC 28 GHz EVM Measurement” on page 322
 - “Creating a Basic 5G NR Signal Using PathWave N7631APPC Embedded Software” on page 332
 - “Creating a DL MIMO Signal Using PathWave N7631APPC Signal Generation” on page 353

5G Waveform and EVM Analysis Using VSA Software

The VXG enables 5G testing with a low error vector magnitude (EVM) at high frequencies. The VXG 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 Vector Signal Analysis (VSA) software to observe EVM.

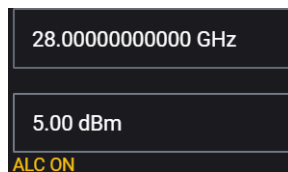
Setting Up a 1 CC 28 GHz EVM Measurement

NOTE

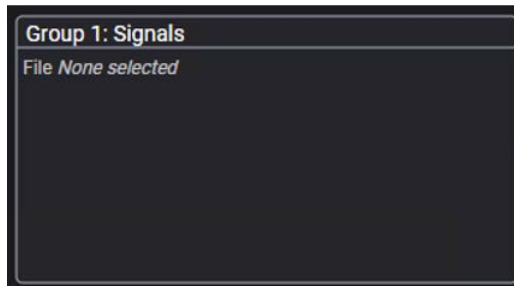
Ensure the equipment and triggers are properly configured. Refer to **“Equipment Setup”** on page 11.

On the VXG:

1. Select **Preset > Preset** to set the VXG to a known state.
2. In the Output 1 area, set Frequency to **28 GHz** and Power to **5 dBm**.



3. Select the **Signal** block to open the Vector Modulation Signal Setup panel.



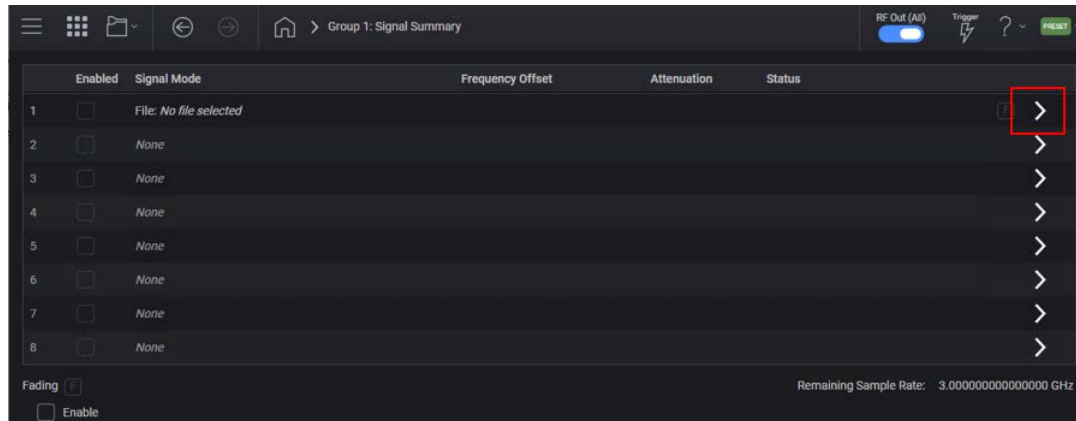
4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.

5G NR Measurements Using the VSA Software

5G Waveform and EVM Analysis Using VSA Software



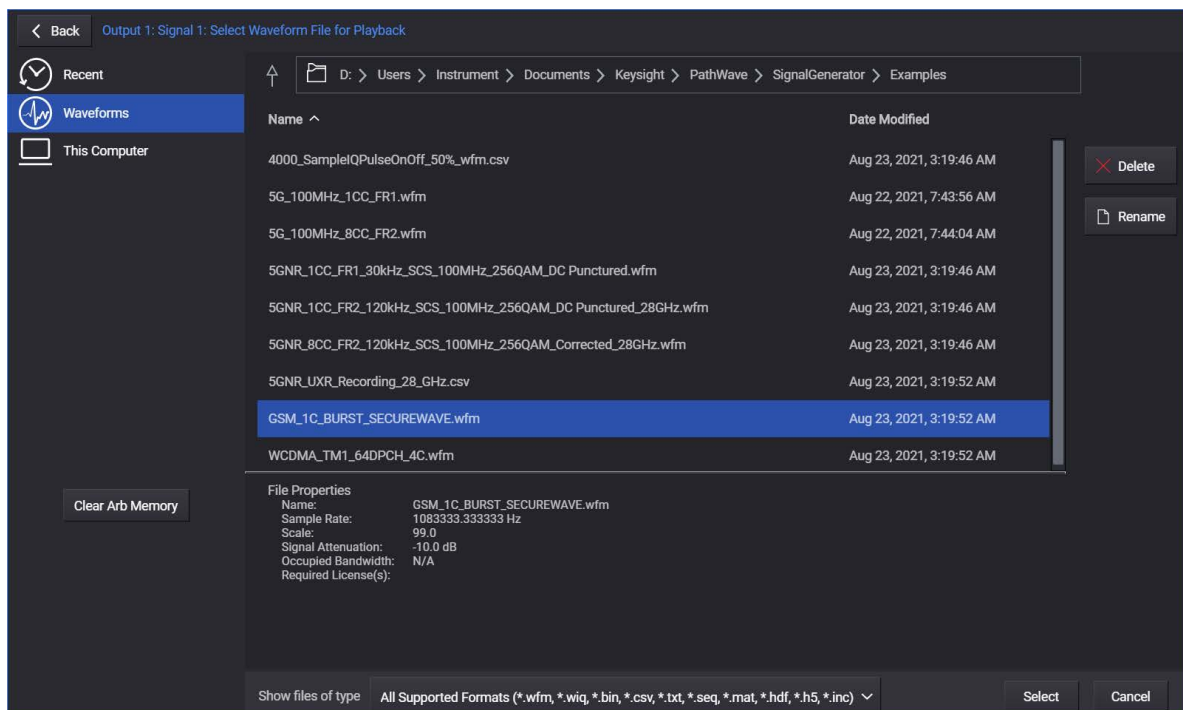
5. Use **File Select** to navigate to:

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

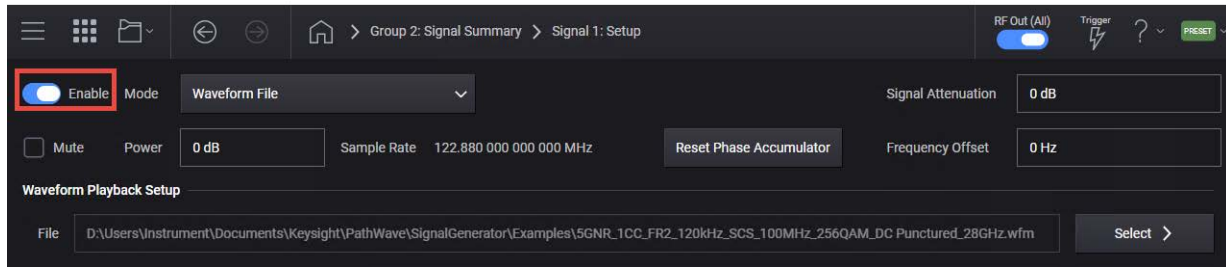
and choose

5G NR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DCPunctured_28GHz.wfm

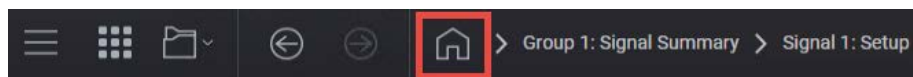
then **Select**.



6. Select **Enable** Vector Modulation Signal.



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

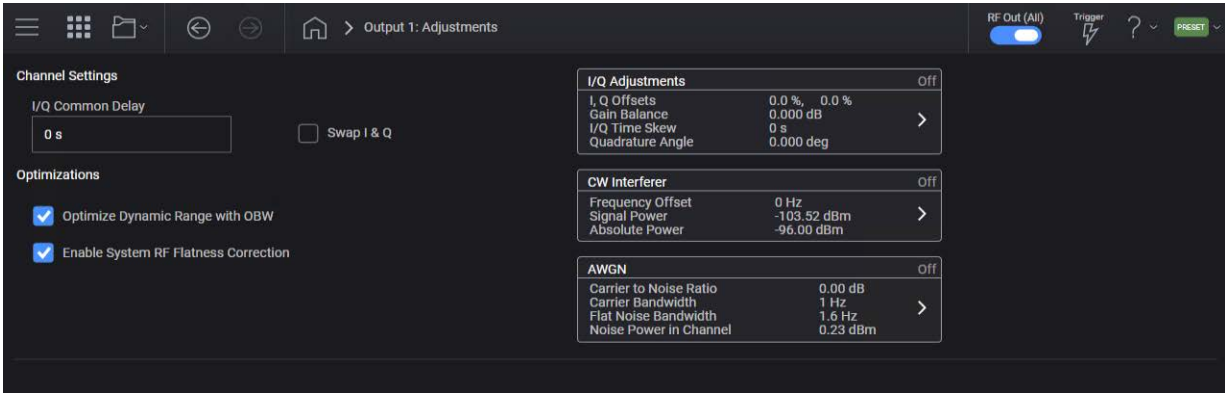


8. Select the **Adjustments** block and select **Optimize Dynamic Range with OBW** and **Enable System RF Flatness Correction**. Close the Adjustments block by selecting the Back icon (<-).

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 2 GHz, 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.

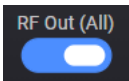


9. Set RF Out to **On** by selecting the numbered channel indicator switch.

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



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:

- 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.

In the VSA software:

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

NOTE

All example waveforms and setup files are located on the VXG at:

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

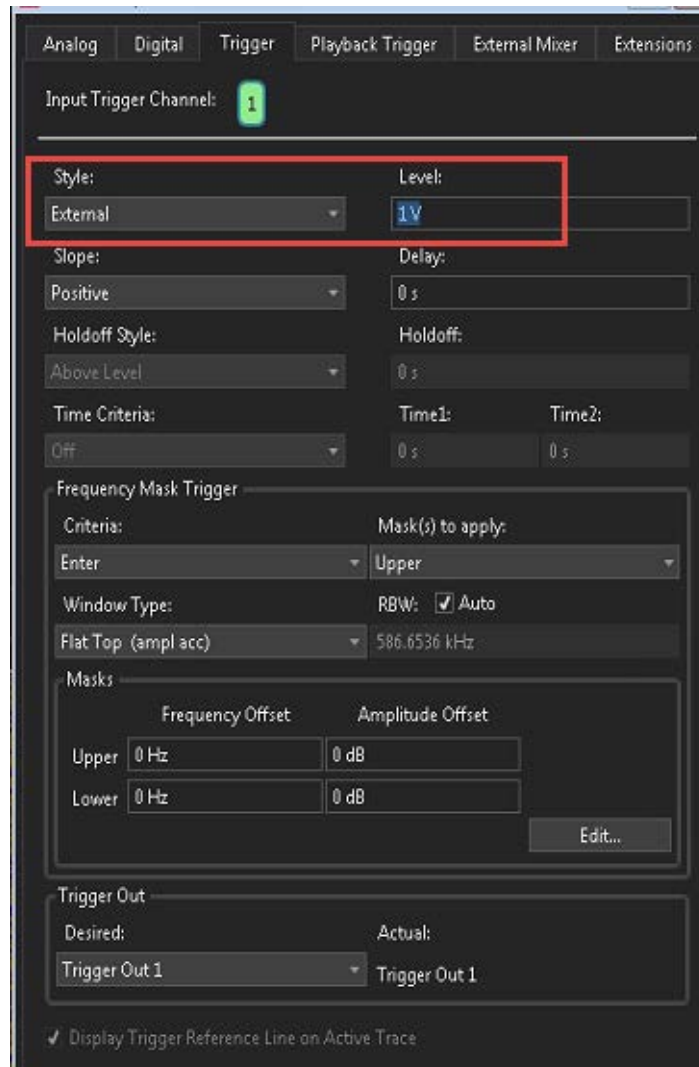
You will need to copy over the setup files to the X-Series Signal Analyzer or the PC running the VSA application.

2. Select **File** > **Recall** > **Recall Setup** and navigate to
5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DC
Punctured_28GHz.setx

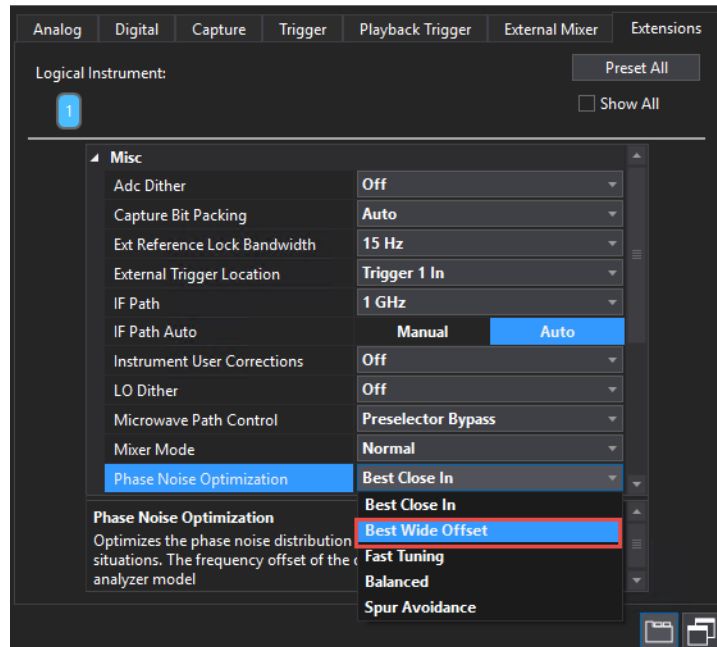
3. From the toolbar, select the **Pause** icon. 

Pausing the measurement will help to speed up the setup time.

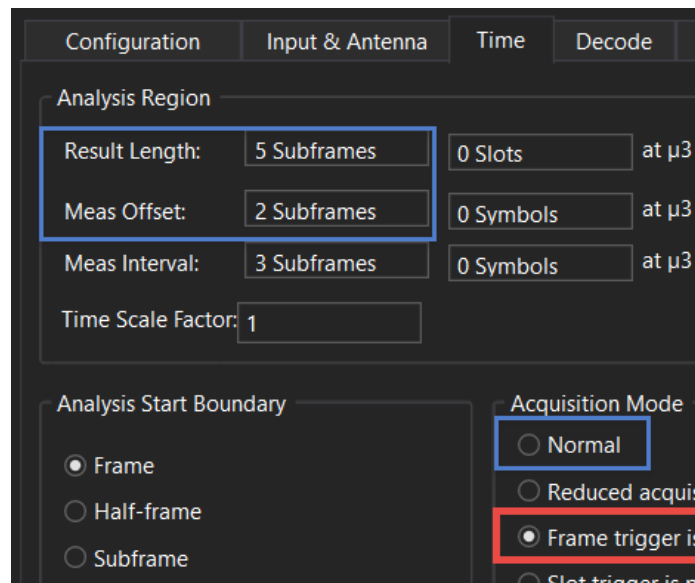
4. From the menu bar, select **Input > Trigger** and set Style to **External** and Level to **1.0 V**.



5. 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**.



6. From the menu bar, select **MeasSetup > 5G NR Demod Properties > Time** tab.
 - Set Result Length to **10 Subframes**.
 - Set Meas Interval to **2 Subframes**.
 - Select **Frame Trigger is Present**.

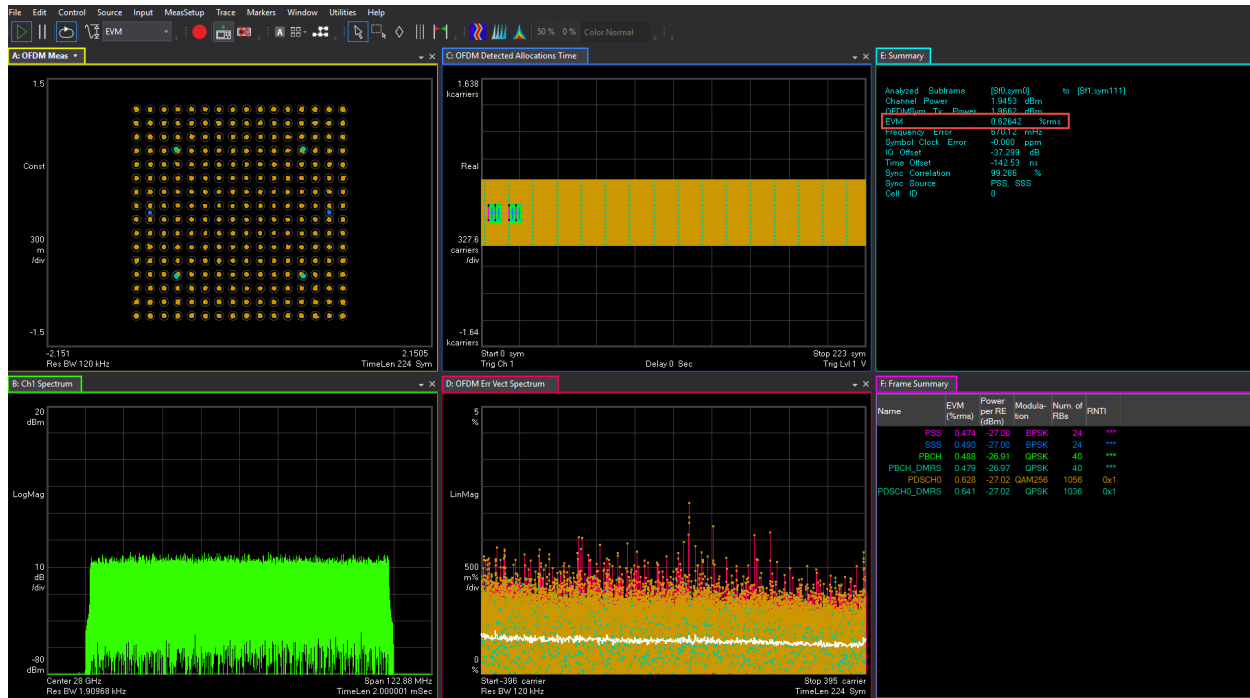


7. From the toolbar, select the **Auto-Range** dropdown and select **EVM-Table or Algorithm Based**.

- 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.



Using the equivalent SCPI commands

On the VXG:

```
SYSTem:PRESet
RF1:FREQuency:CW 28GHZ
RF1:POWer:AMPLitude 5dBm
SIGNal1:MODE WAVeform
SIGNal1:WAVeform "D:\Users\Instrument\Documents\MCS demo
waveforms
5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DCPunctured_28GHz.wfm"
SIGNal1 ON
IQO:CORR:OPT:DYN:RANG:OBW ON
IQO:CORR:CHAN:FLAT ON
RF1:OUTPut ON
For multi-channel instruments, set RF Out (all) to On.
RFAL1:OUTPut ON
```

On the X-Series Signal Analyzer:

```
INSTRument:SELEct VSA89601
```

NOTE

All example waveforms and setup files are located on the VXG at:

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

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

```
SYSTem:PRESet
MMEMory:LOAD
"D:\Users\Instrument\Documentts\NR5G\data\NR5GEvm\Carrier
Setup\5GNR_1CC_FR2_120kHz
SCS_100MHz_256QAM_DCPunctured_28GHz.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:
```

5G NR Measurements Using the VSA Software
5G Waveform and EVM Analysis Using VSA Software

NR5G:RLENgth 10

NR5G:SUBFrame:INTerval 2

Set the Acquisition Mode to “Frame Trigger is Present”

nr5g:FRAMe:TRIGger:ENABled 1

Setting Up an 8 CC 28 GHz EVM Measurement

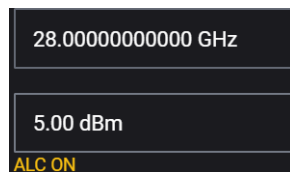
NOTE

Ensure the equipment and triggers are properly configured. Refer to [“Equipment Setup” on page 11](#).

Using the graphical user interface

On the VXG:

1. Select **Preset > Preset** to set the VXG to a known state.
2. In the Output 1 area, set Frequency to **28 GHz** and Power to **5 dBm**.



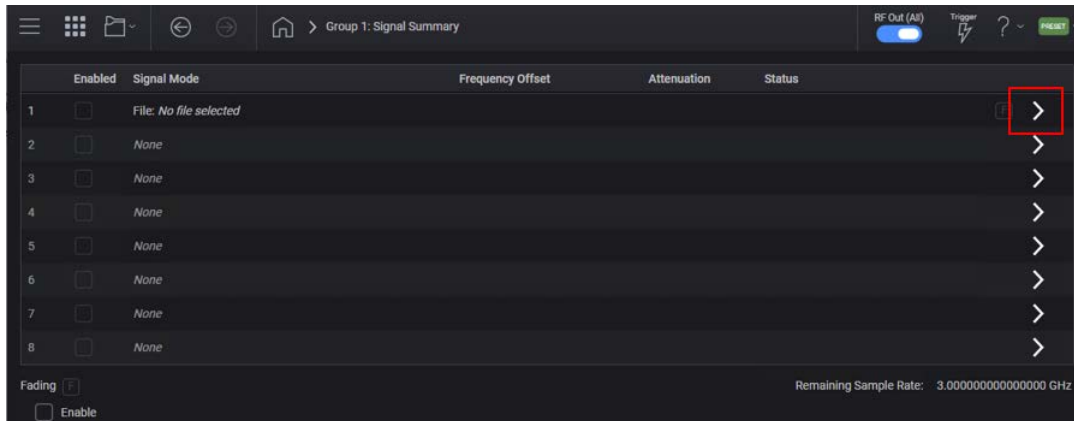
3. Select the **Signal** block to open the Vector Modulation Signal Setup panel.



4. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.



5. Use **File Select** to navigate to:

D:\Users\Instrument\Documents\Keysight\PathWave
 \SignalGenerator\Examples

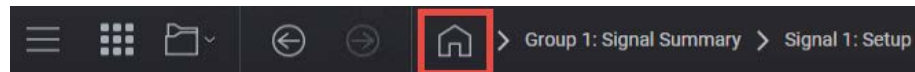
and choose

5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_1.wfm

then **Select**.

6. Select **Enable** Vector Modulation Signal.

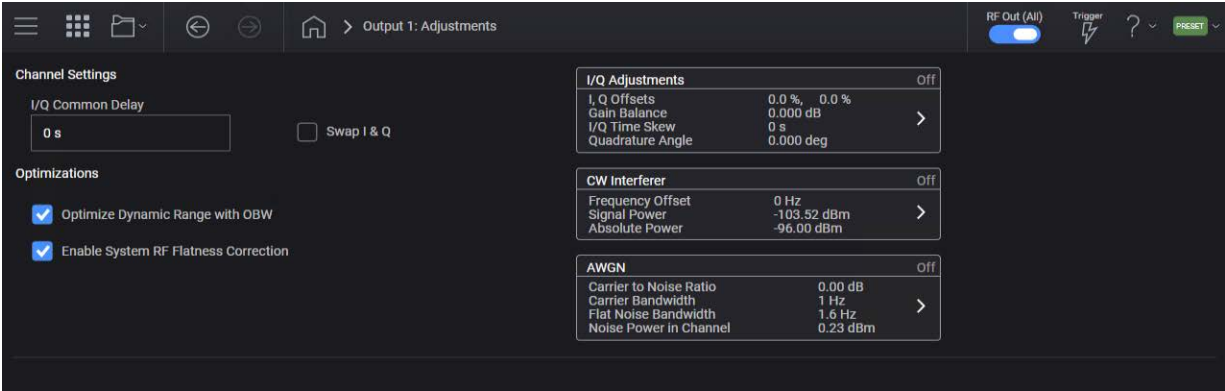
7. Close the Vector Modulation Signal Setup by selecting the **Home** icon at the top of the display.



8. Select the **Adjustments** block and select **Optimize Dynamic Range with OBW** and **Enable System RF Flatness Correction**. Close the Adjustments window by selecting the Back (<-) button.

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 2 GHz, 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.

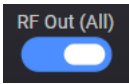


9. Set RF Out to **On** by selecting the numbered channel indicator switch.

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



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:

- 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.

In the VSA software:

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

NOTE

All example waveforms and setup files are located on the VXG at:

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

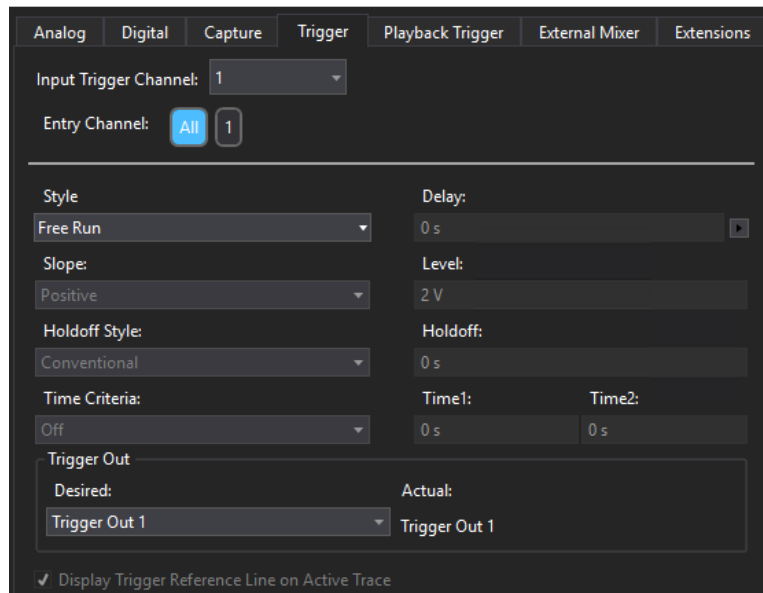
You will need to copy over the setup files to the X-Series Signal Analyzer or the PC running the VSA application.

2. Select **File** > **Recall** > **Recall Setup** and navigate to
D:\Users\Instrument\Documents\NR5G\data\NR5GEvm\Carrier Setup,
then open
5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_1.setx

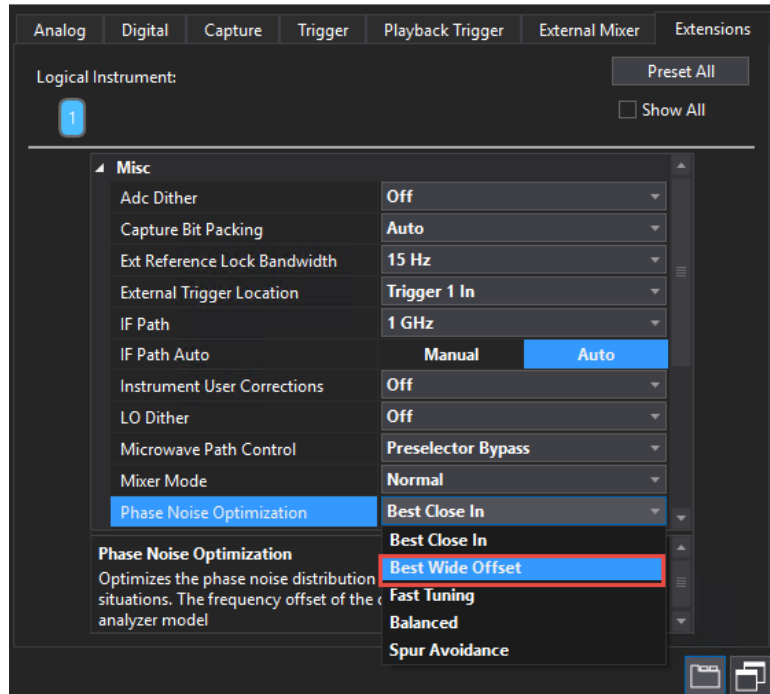
3. From the toolbar, select the **Pause** Icon. 

Pausing the measurement will help to speed up the setup time.

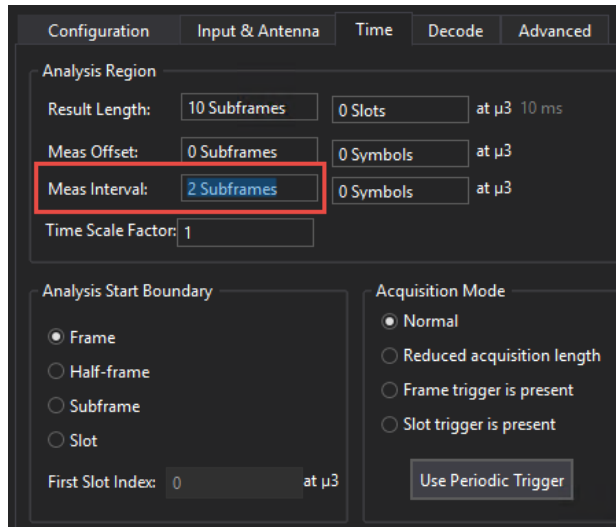
4. From the menu bar, select **Input** > **Trigger** and set Style to **FreeRun**.



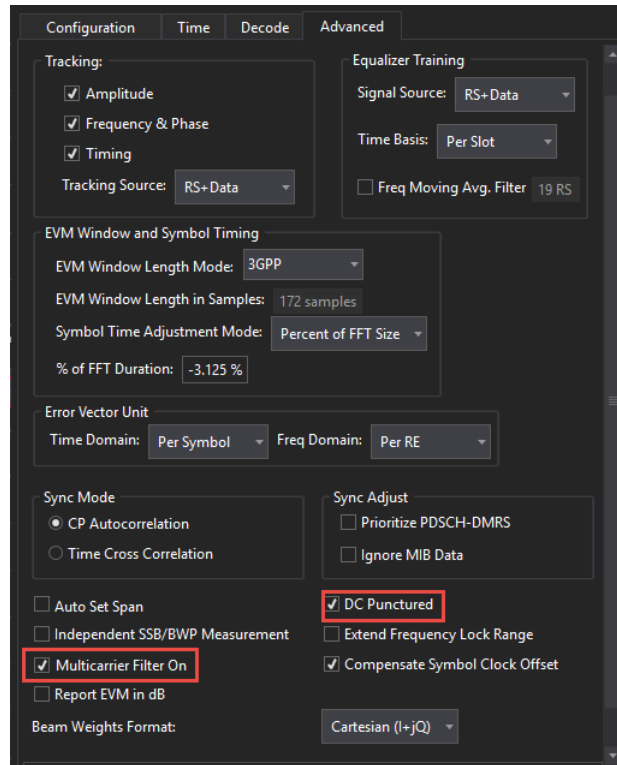
5. Select the **Extensions** tab and change Phase Noise Optimization to **Best Wide Offset**. (For an N9040B only, set External Trigger Location to Trigger 3 In.)



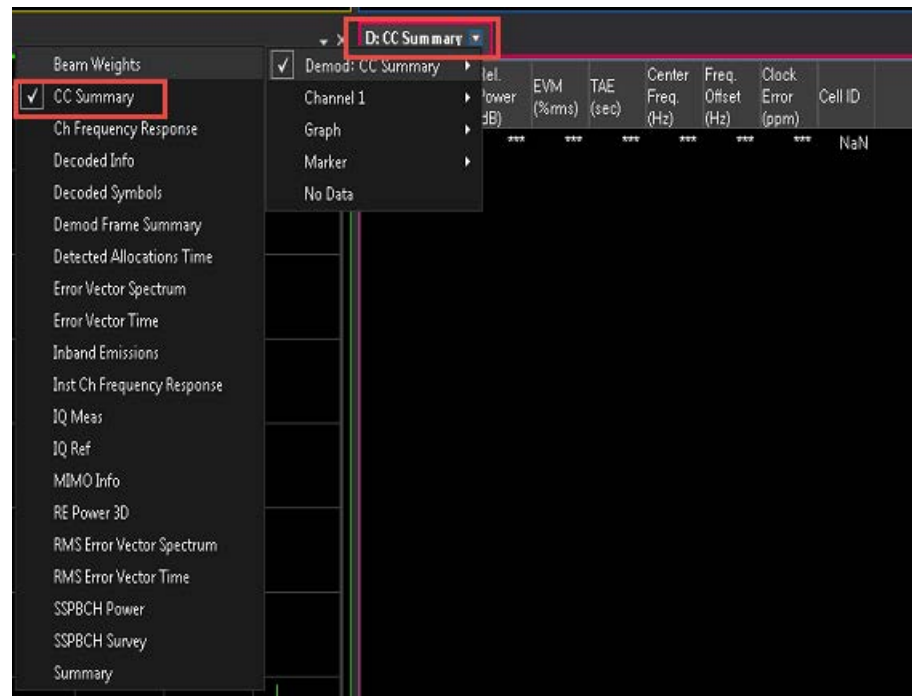
6. From the menu bar, select **MeasSetup > 5G NR Demod Properties > Time** tab.
 - Set Result Length to **10 Subframes**.
 - Set Meas Interval to **2 Subframes**.



7. Select the **Advanced** tab select **DC Punctured** to On.



8. In the bottom center trace window, select the Trace Data menu and select **Demod: > CC Summary**.



9. In the Spectrum trace window (bottom left window), select **Center** and change the frequency to **28 GHz**.
10. From the toolbar, select the **Auto-Range** 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.



11. Select the **Auto-Range** icon to run the measurement for EVM optimization on all eight channels. This may take a few minutes to complete.



5G NR Measurements Using the VSA Software
5G Waveform and EVM Analysis Using VSA Software

D: CC Summary								
TAE Min -58.208 ps between CC4 and CC0								
TAE Max 291.04 ps between CC1 and CC0								
CC	Channel Power (dBm)	Rel. Power (dB)	EVM (%rms)	TAE (sec)	Center Freq. (Hz)	Freq. Error (Hz)	Clk Error (ppb)	
CC0(Ref.)	-5.86	0.00	0.739	0	11.65 G	-115.575 m	-0.0	
CC1	-5.72	0.14	0.732	291.038 p	11.75 G	19.3616 m	0.0	
CC2	-5.79	0.07	0.743	58.2077 p	11.85 G	45.8891 m	0.0	
CC3	-5.87	-0.01	0.773	116.415 p	11.95 G	43.2913 m	0.0	
CC4	-5.81	0.05	0.792	-58.2077 p	12.05 G	-891.232 μ	-0.0	
CC5	-5.89	-0.03	0.806	-58.2077 p	12.15 G	44.2917 m	0.0	
CC6	-5.90	-0.04	0.807	0	12.25 G	74.1079 m	-0.0	
CC7	-5.87	-0.01	0.798	116.415 p	12.35 G	109.725 m	-0.0	

Using the equivalent SCPI commands

On the VXG:

SYSTem:PRESet

RF1:FREQuency:CW 28GHZ

RF1:POWer:AMPLitude 5dBm

SIGNal1:MODE WAVeform

SIGNal1:WAVeform "D:\Users\Instrument\Documents\MCS demo
waveforms\5GNR_8CC_FR2_120kHz_SCS_100MHz_Corrected_28GHz.wfm
"

SIGNal1 ON

IQO:CORR:OPT:DYN:RANG:OBW ON

IQO:CORR:CHAN:FLAT ON

RF1:OUTPut ON

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

RFAL1:OUTPut ON

On the X-Series Signal Analyzer

INSTrument:SElect VSA89601

MMEMory:LOAD:DEMO

"D:\Users\Instrument\Documents\NR5G\data\NR5GEvm\CarrierSetu
p\1CC_FR2_120kHz_SCS_100MHz_256QAM_DC_Punctured_28GHz.setx"

INITiate:PAUSe

INPut:TRIGger:STYLe "External"

INPut:TRIGger:LEVel:EXTernal 1V

INPut:EXTension:PARAmeters:SET "ExtTriggerLoc", 2

INPut:EXTension:PARAmeters:SET "PhaseNoiseOptDualLoop", 1

NR5G:RLENgth 10

NR5G:SUBFrame:INTerval 2

NR5G:FRAME:TRIGger:ENABled 1

NR5G:CAGGregation:CONFigure "Contiguous8CC"

NR5G:DC:PUNCTured 1

NR5G:MCFilter:ENABled 1

`FREQuency:CENTer 28 GHz`

`INPut:ANALog:CRITeria:RANGe:AUTO "EVM", -1`

NOTE

All example waveforms and setup files are located on the VXG at:

`D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples`

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

Creating a Basic 5G NR Signal Using PathWave N7631APPC Embedded Software

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

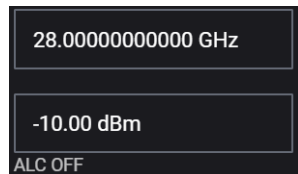
This example shows you how to create and analyze a 5G NR signal using the embedded PathWave software. Your VXG must include the N7631APPC license.

NOTE

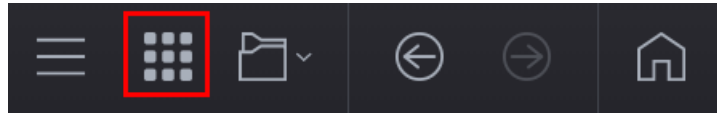
The VXG must have the N7631APPC Signal Generation for 5G NR license installed.

On the VXG:

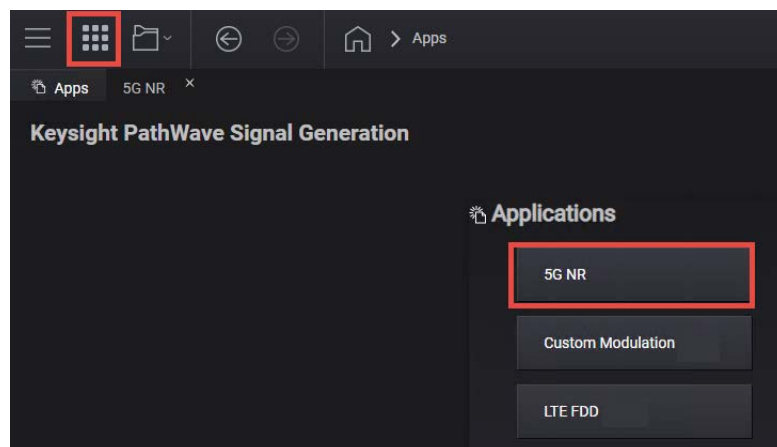
1. Select **Preset** > **Preset** to set the VXG to a known state.
2. In the Output area, set Frequency to **28 GHz** and Power to **-10 dBm**.



3. Select the **Radio Apps** block to open the Vector Modulation Signal Setup panel.

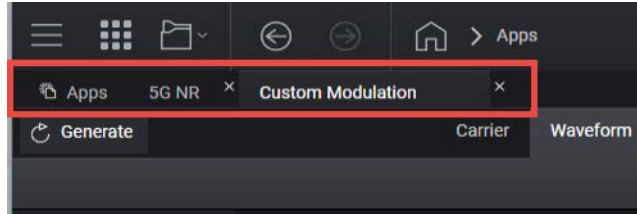


4. Select **5G NR** to enter 5GNR Signal Mode.

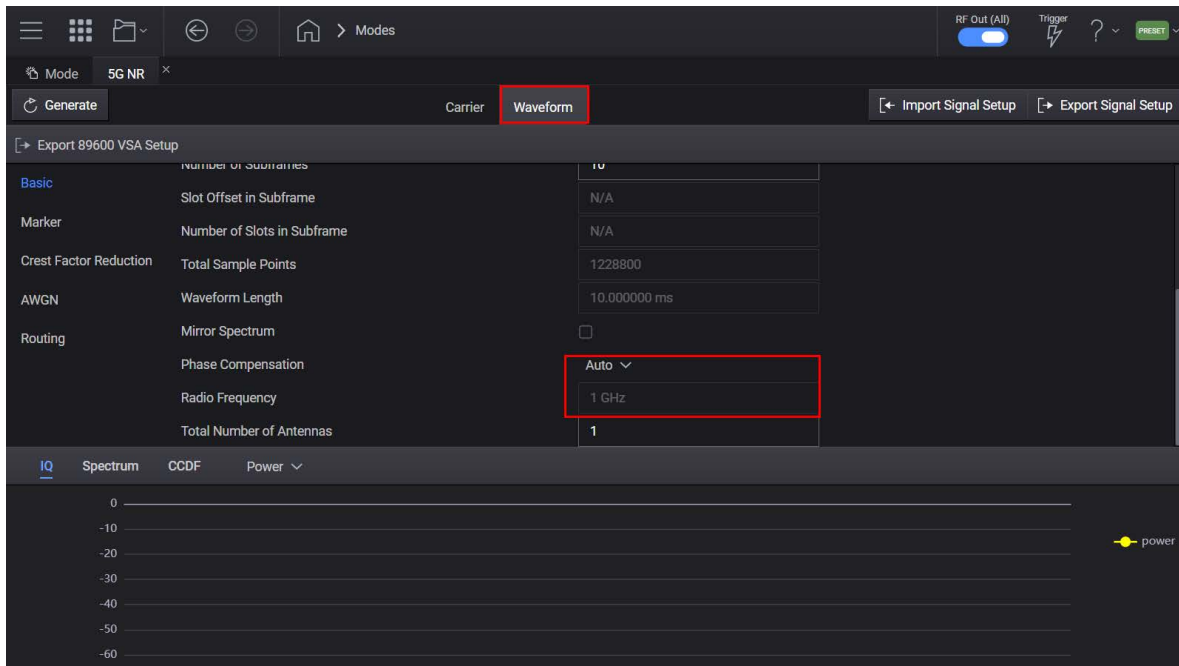


NOTE

If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



5. In the 5G NR setup, select the **Waveform** tab and observe the Phase Compensation and Radio Frequency settings.



TIP

Phase Compensation is applied by default at baseband for RF up-conversion. This means the waveform generation is per the carrier frequency, unlike conventional Signal Studio waveforms, which are independent from carrier frequency. Phase Compensation is set to Auto by default. The frequency is coupled with the VXG frequency setting under the Instrument node. You can select Manual to specify a different frequency, or turn it off.

Some applications, like power amplifier measurements use the same waveform at different frequencies and can be time consuming to generate a separate waveform for each frequency. In this case, you would turn Phase

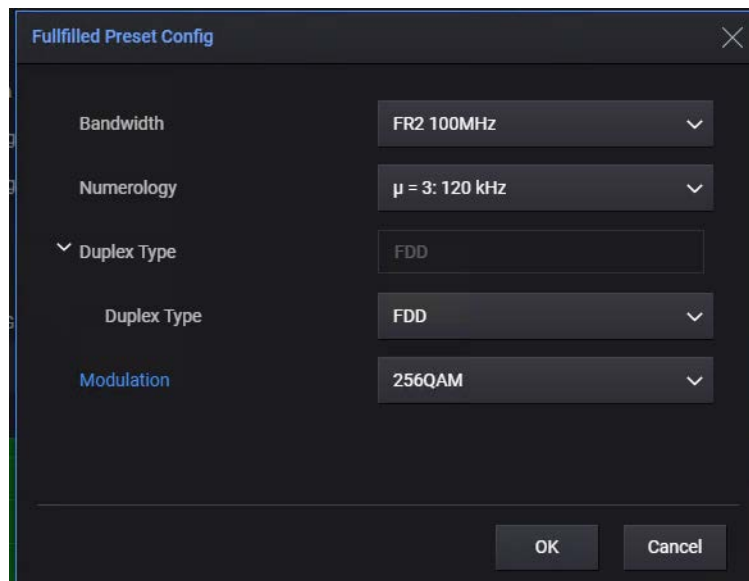
Compensation Off, so the waveform becomes independent from the carrier frequency. You need to do the same on the analysis side, or the demodulation will fail.

6. Select the **Carriers** tab.
7. Select the **Full-Filled Config** tab and set Bandwidth to **FR2 100 MHz**, Numerology to **$\mu = 3$: 120 kHz**, Duplex Type to **FDD**, Modulation to **256QAM** and then select **OK**.

NOTE

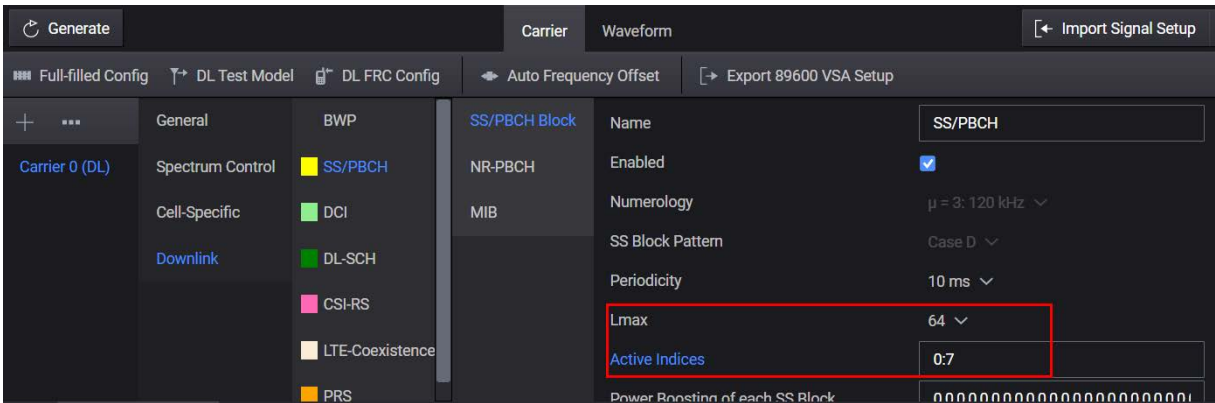
If you have a signal analyzer with demodulation bandwidth that is wide enough to cover the other FR2 bandwidths, 200 MHz or 400 MHz, you can choose to use a wider bandwidth.

Full Filled Configurations is a great place to start creating your waveform. You can select FR, bandwidth, and modulation format with a fully allocated PDSCH data channel. This would represent a spectrally correct signal that is typically used in power amplifier measurements. You can modify the RB allocations and Slot allocations if fully allocated data channels are not desired.



8. Select **OK** to exit the Full Filled Config setup.
9. From the Carrier panel (in the left pane), select **Downlink** > **SS PBCH** > **SS PBCH Block** and change Lmax to **64** and Active Indices to = **0:7**.

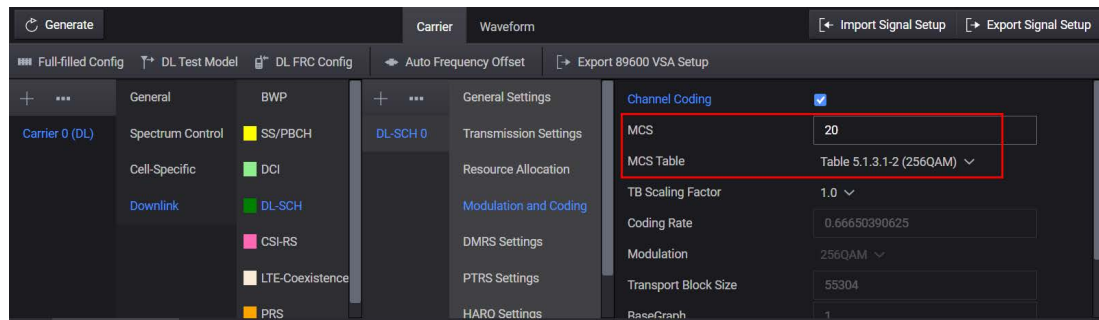
Instead of transmitting all 64 beams, we enable only 8 of them by setting Active Indices to 0:7.



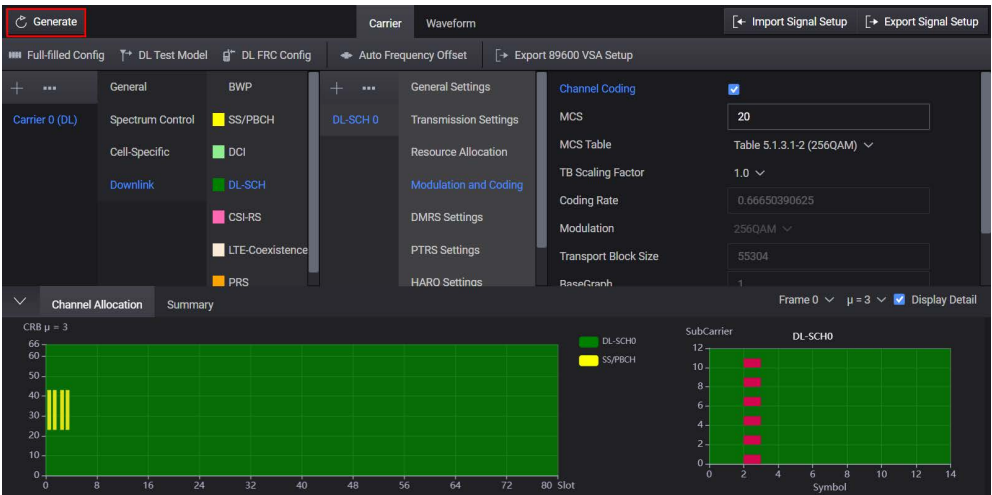
NOTE

Lmax sets the maximum number of possible SS/PBCH blocks in a transmission opportunity. This value is fixed for a given carrier bandwidth. Typically, higher frequency and bandwidth carriers use a larger set of SS/PBCH opportunities to support a larger set of antenna beams. Lmax is either 4 or 8 for FR1 and 64 for FR2.

10. From the Carrier panel (in the left pane), select **Downlink** > **DL-SCHs** > **DL-SCH0** > **Modulation and Coding** and verify that MCS Table is set to **Table 5.1.3.1-2 (256QAM)** and MCS to **20**.



11. Select **Generate** to generate the Waveform.



12. Select the Home icon to return to the main window 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 VXG.



On the X-Series Signal Analyzer:

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

NOTE

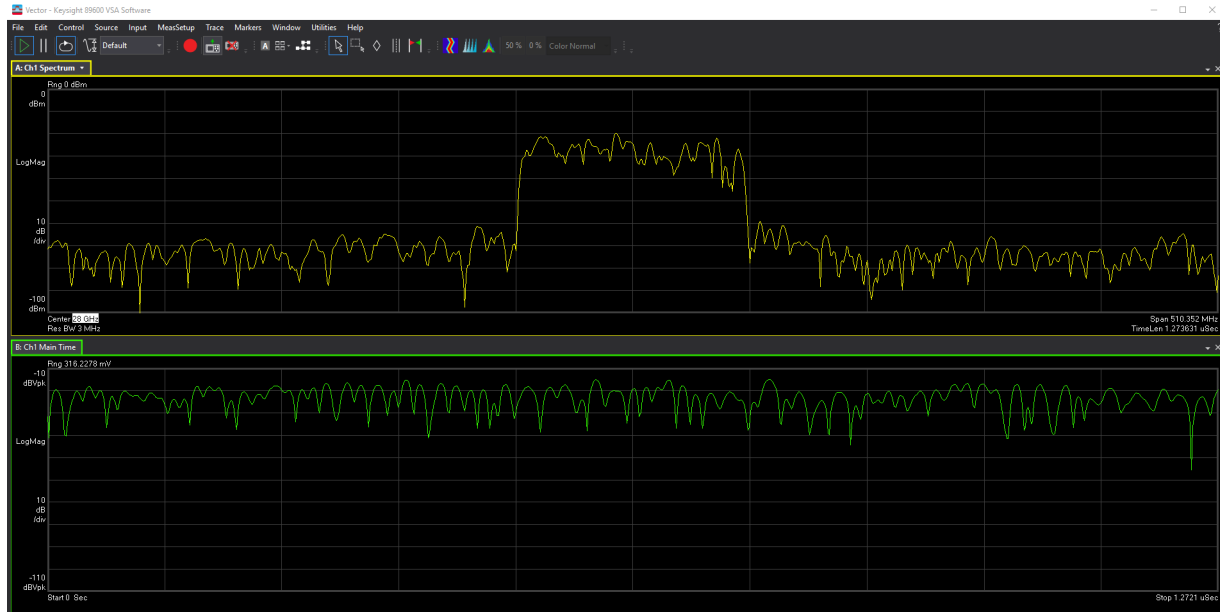
If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.


In the VSA software:

1. From the menu bar, select **File > Preset > All** to set the VSA to a known state.
2. Set the Center Frequency to **28 GHz**, then select **Auto Range**.



Auto Range samples the current input signal and then sets the full scale input range to the minimum range that includes the peak voltage sample of the input signal.

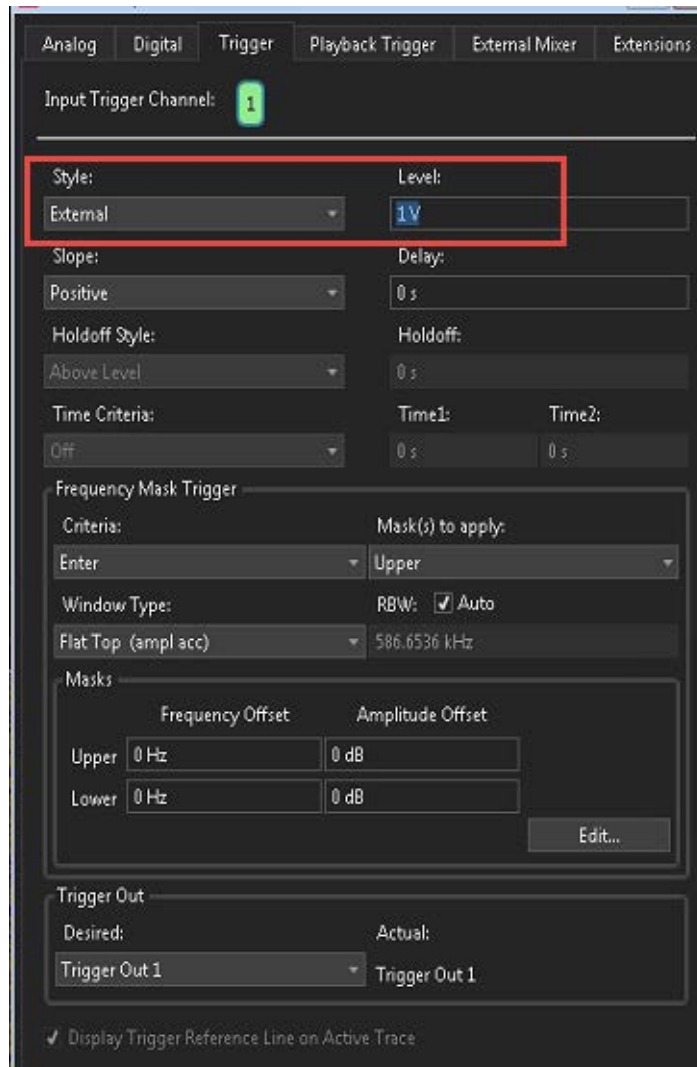


3. From the toolbar, select the **Pause** Icon. 

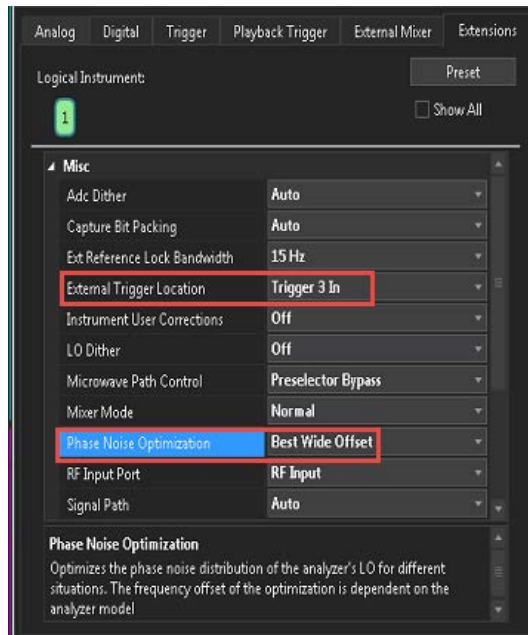
TIP

Pausing the measurement will help to speed up the setup time.

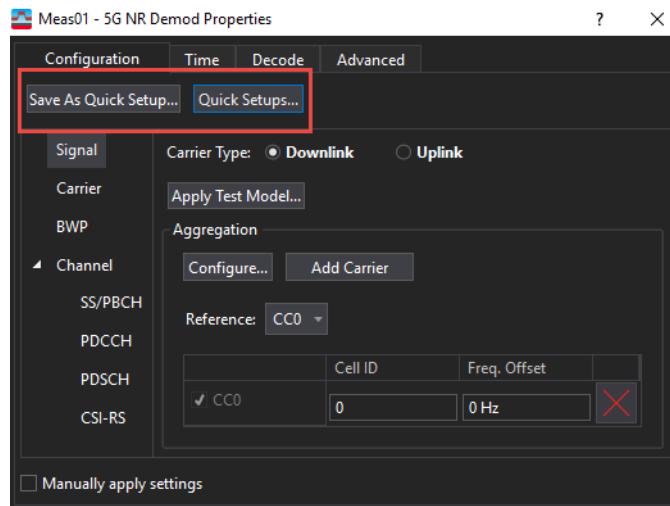
4. From the menu bar, select **Input > Trigger** and set Style to **External** and Level to **1.0 V**.



5. Select the **Extensions** tab and change the External Trigger location to **Trigger 1 In** or **Trigger 3 In** (Use Trigger 3 if your N9040B has Option H1G, 1 GHz BW) and set Phase Noise Optimization to **Best Wide Offset**.



6. From the menu bar, select **MeasSetup > Measure Type Cellular > 5G NR**.
7. From the menu bar, select **MeasSetup > 5G NR Demod Properties > Configuration** tab.



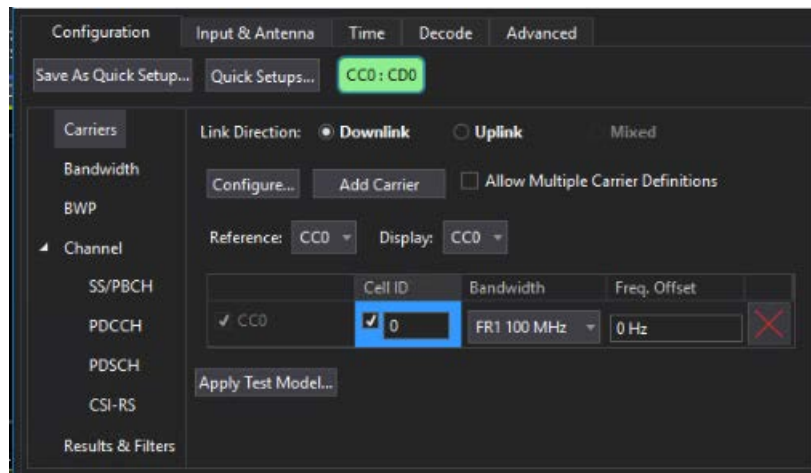
TIP

Use Quick Setups for convenient saving and loading of common configurations. Quick Setups are factory supplied configurations and cannot be deleted by users. (This includes Signal Studio Downlink and Uplink defaults.)

Save As Quick Setup (saved by the user) can be specific to the current user or can be made available to others users. These setups can also be deleted.

8. Select the Carrier panel.

The Carrier dialog is used to configure component carrier level parameters: Cell ID, Bandwidth, and Resource Grid for each Numerology.



– Set Cell ID to 0

When the checkbox is selected, Cell ID auto-detection is enabled for the carrier.

NOTE

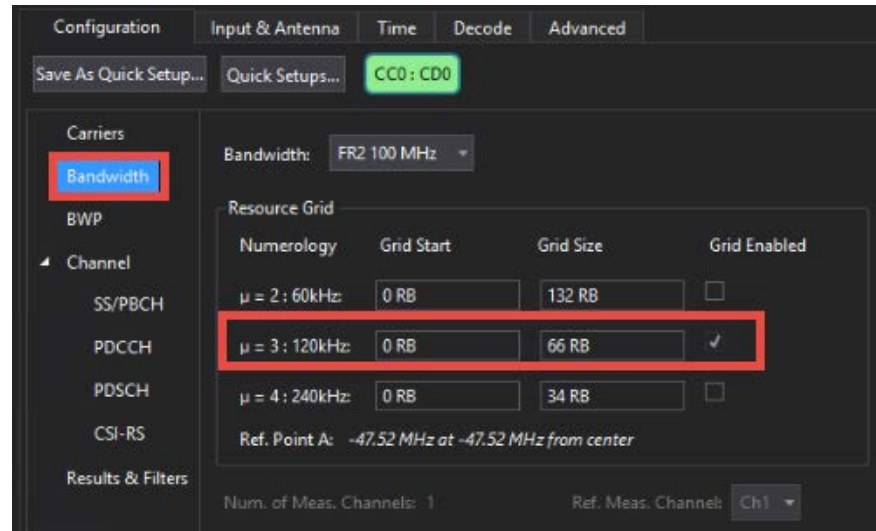
Cell ID is carried on PSS and SSS so the SS/PBCH must be transmitted and enabled for Auto Cell ID to work. It must also be a downlink since SS/PBCH is only transmitted on a downlink.

– Set Bandwidth to **FR2 100 MHz**

9. Select the Bandwidth panel and set Numerology to $\mu = 3$: 120 kHz

For FR2 100 MHz, the Max RB for 120 kHz numerology is 66 RB. This value will be used when we configure BWP, SS/PBCH, and PDSCH.

FR2 only uses 60, 120, or 240 kHz numerologies. This is why 15 and 30 kHz numerologies do not show under the Resource Grid.

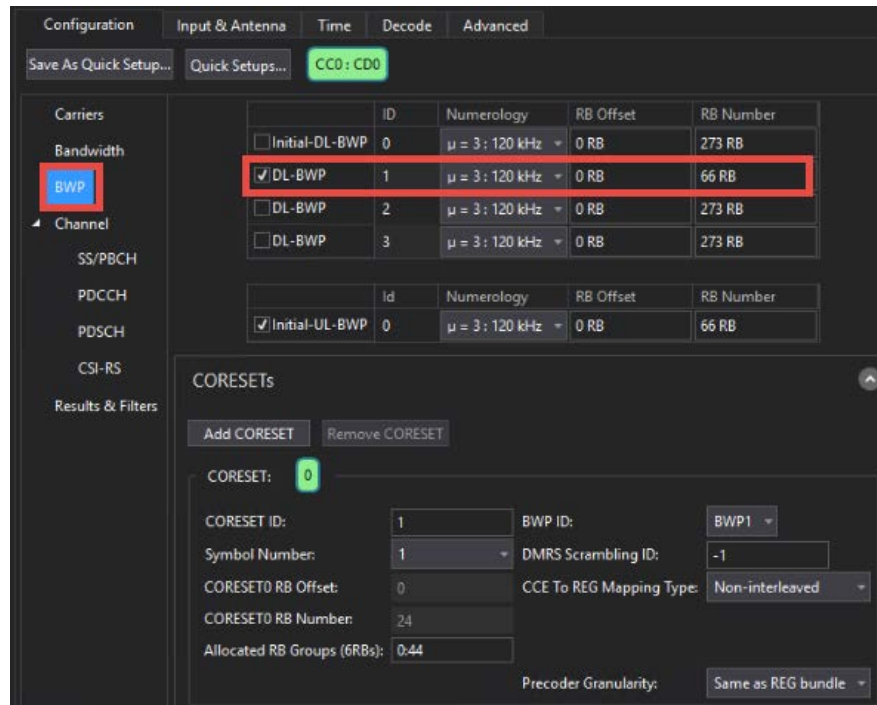


10. Select the **BWP** pane, then enable **DL-BWP**.

This section is used to configure the Downlink BWP allocation within the component carrier and the control resource set (CORESET). CORESET is used for PDCCH configuration and will not be used in this example. We will use the default values of:

- Numerology $\mu = 3$: **120 kHz**
- RB offset **0 RB**
- RB Number **66 RB**

A component carrier with 100 MHz at FR2 has a maximum RB of 66 for 120 kHz numerology. In this example, DL-BWP uses the full carrier bandwidth of 66 RBs as shown below.



TIP

VSA supports a single BWP within a component carrier (CC). Signal Studio and X-Apps support multiple BWPs within a CC. You can use VSA multi-measurement to analyze multiple BWPs simultaneously.

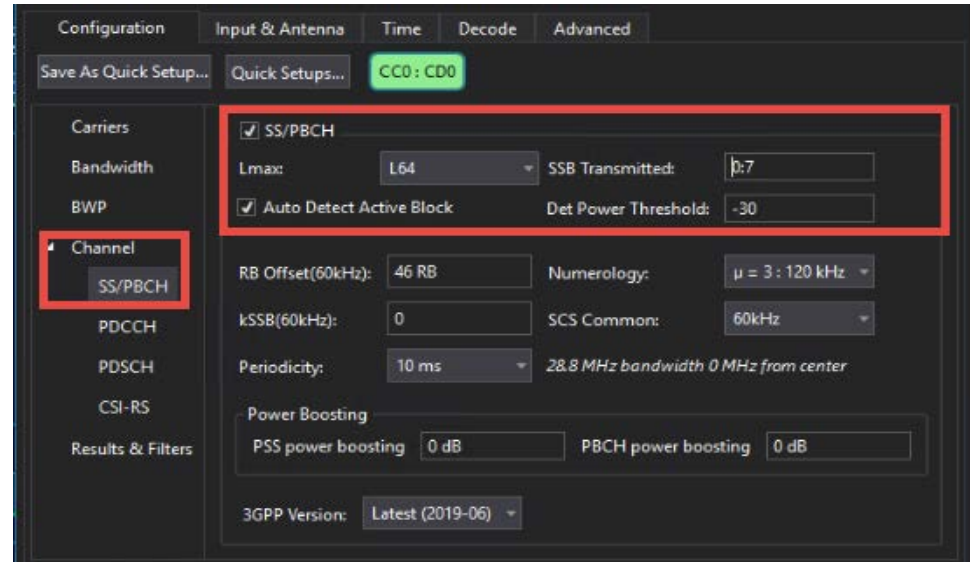
11. Select the **Channel** pane > **SS/PBCH**, enable **SS/PBCH** and set the following parameters:

- Lmax to **L64**

Lmax specifies the maximum number of SS/PBCH Blocks (that is, beams) in an SS Block period.

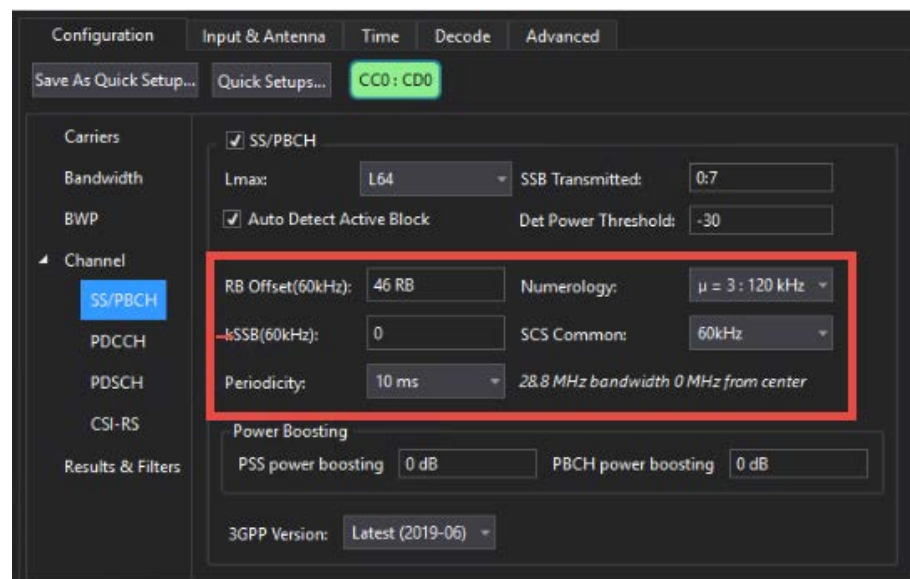
- FR1 up to 3 GHz, Lmax = 4
- FR1 3 to 6 GHz, Lmax = 8
- FR2 6 to 52.6 GHz, Lmax = 64
- SSB Transmitted to **0:7**

For this example, we will not use all 64 SS Blocks; we will activate only 8 of them. You can also select the **Auto Detect Active Block** and set the **Det Power Threshold** to auto detect the active SS Blocks.



These following settings use the default values.

- RB Offset(60kHz) = **46 RB**
- kSSB(60kHz) = **0**
- Periodicity = **10 ms**
- Numerology = $\mu = 3 = 120 \text{ kHz}$



The frequency location of an SS Block is not fixed. The default value of 46 RB and kSSB of 0 subcarriers places it in the center of the carrier bandwidth. This value is calculated based on the 60 kHz numerology as defined by 3GPP (15 and 30 kHz sub-carrier spacing uses 15 kHz numerology, 120 and 240 kHz spacing uses 60 kHz numerology.)

For example, to calculate the 120 kHz sub-carrier spacing, the value would be

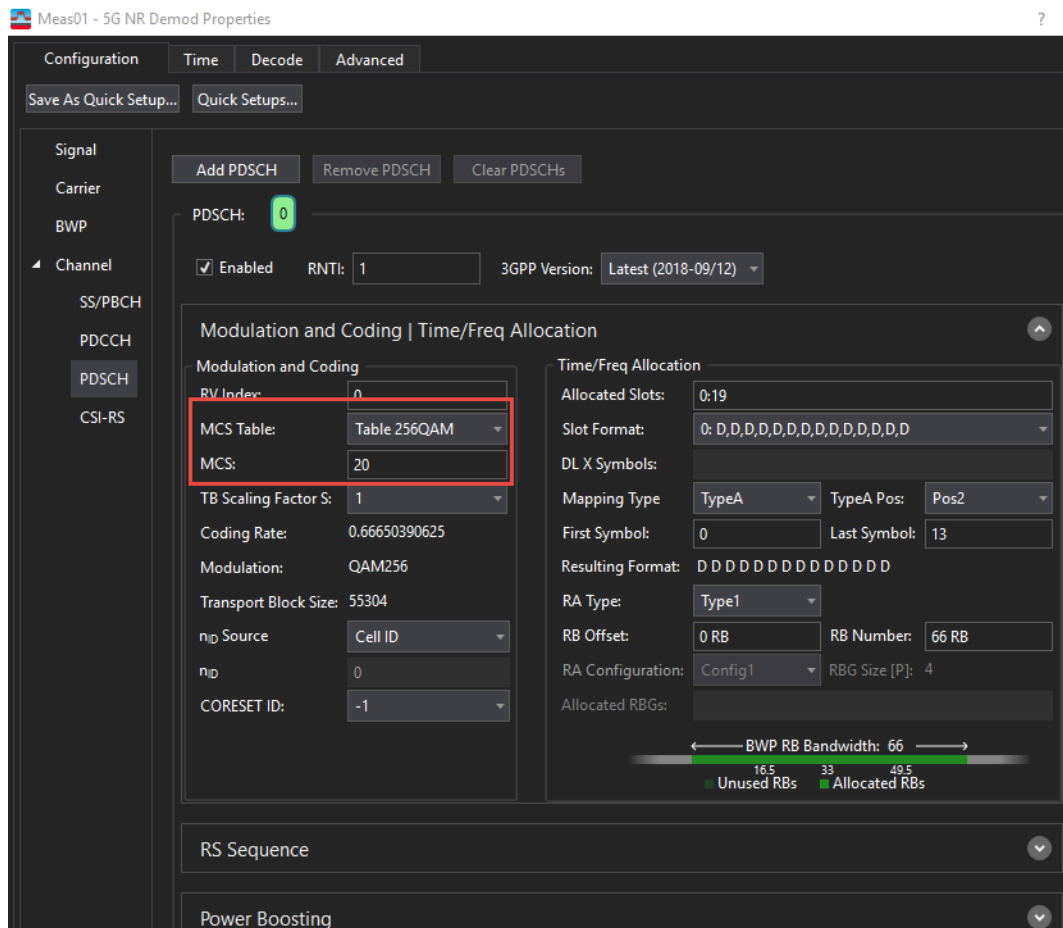
$$66\text{RB}/2 = 33 \text{ RB}$$

This is the center of the carrier bandwidth. However, the SS Block is 20 RB wide, so the start of the SS Block is 23 RB.

$$23 \text{ RB in } 120 \text{ kHz is } 23 * 2 = 46 \text{ RB in } 60 \text{ kHz}$$

This is the default value used in the VSA software for 120 kHz numerology.

12. From the Channel pane, select **PDSCH** and then set the following parameters:
 - Under Modulation and Config section, set MCS Table to **Table 256QAM** and MCS to **20**.



TIP

3GPP has different Tables for PDSCH MCS.

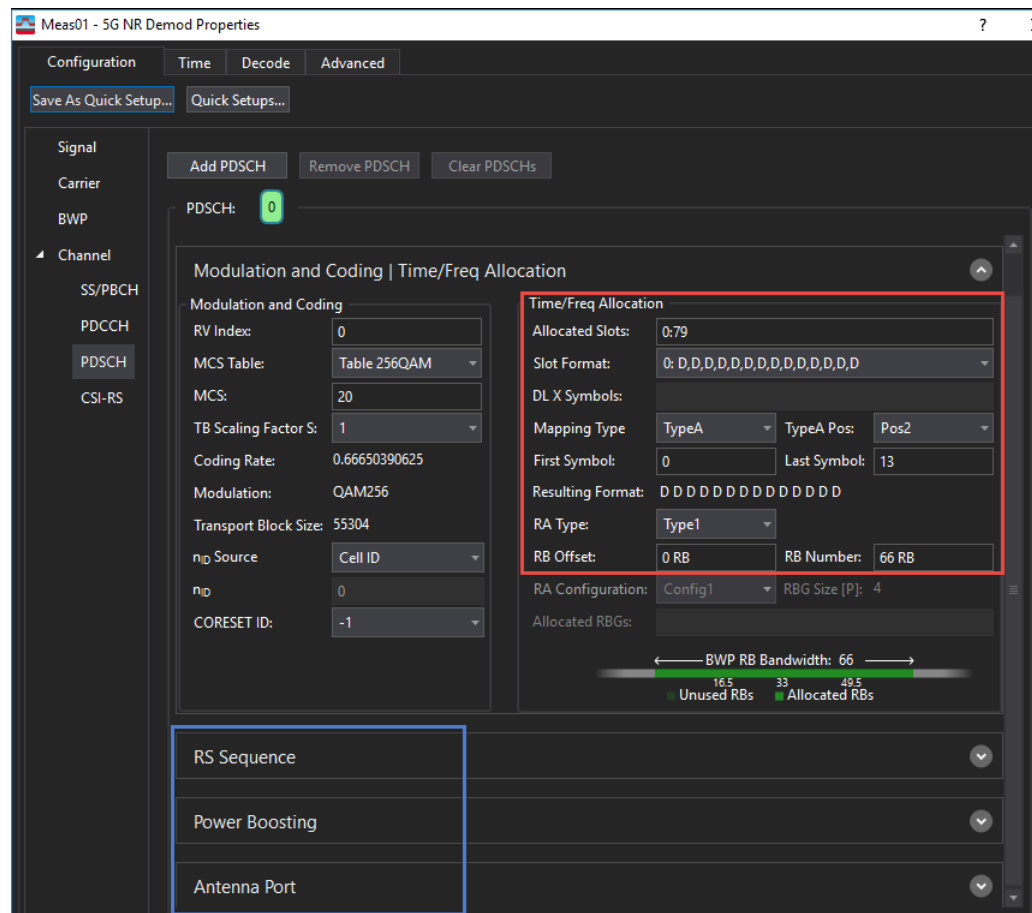
Table 5.1.3.1-2 has 256 QAM as maximum modulation

Table 5.1.3.1-3 has 64 QAM as maximum modulation

Table 5.1.3.1-1 has 64 QAM as maximum modulation, and is for low spectrum efficiency (LowSE).

See 3GPP TS38.214 for more information.

- Under the Time/Freq Allocation section, set
 - Allocated Slots to **0:79**
 - Slot Format to **0**
 - First Symbol to **0**
 - Last Symbol to **13**
 - RB Offset to **0 RB**
 - RB Number to **66 RB**



We will use the default values for RS Sequence, Power Boosting, and Antenna Port. Power s would not change the DMRS sequences, but they might be interested in modifying Power Boosting.

13. Select the **Time** tab and set:

- Result Length to **10 Subframes**.
- Meas Interval to **2 Subframes**.
- Select **Frame Trigger is Present**.

The screenshot shows the 'Time' tab in the VSA Software configuration window. The 'Analysis Region' section has 'Result Length' set to 5 Subframes, 'Meas Offset' to 2 Subframes, and 'Meas Interval' to 3 Subframes. The 'Analysis Start Boundary' section has 'Frame' selected. The 'Acquisition Mode' section has 'Frame trigger is present' selected. The 'Timing Diagram' at the bottom shows a frame boundary, a result length of 5 subframes, and measurement intervals and offsets.

Configuration Input & Antenna Time Decode Advanced

Analysis Region

Result Length: 5 Subframes 0 Slots at $\mu 3$ 5 ms

Meas Offset: 2 Subframes 0 Symbols at $\mu 3$

Meas Interval: 3 Subframes 0 Symbols at $\mu 3$

Time Scale Factor: 1

Analysis Start Boundary

☒ Frame

☐ Half-frame

☐ Subframe

☐ Slot

First Slot Index: 0 at $\mu 3$

Acquisition Mode

☐ Normal

☐ Reduced acquisition length

☒ Frame trigger is present

☐ Slot trigger is present

Use Periodic Trigger

Timing Diagram

Result Length 5 Subf.

Meas. Interval 3:0

Meas. Offset 2:0

Frame Boundary

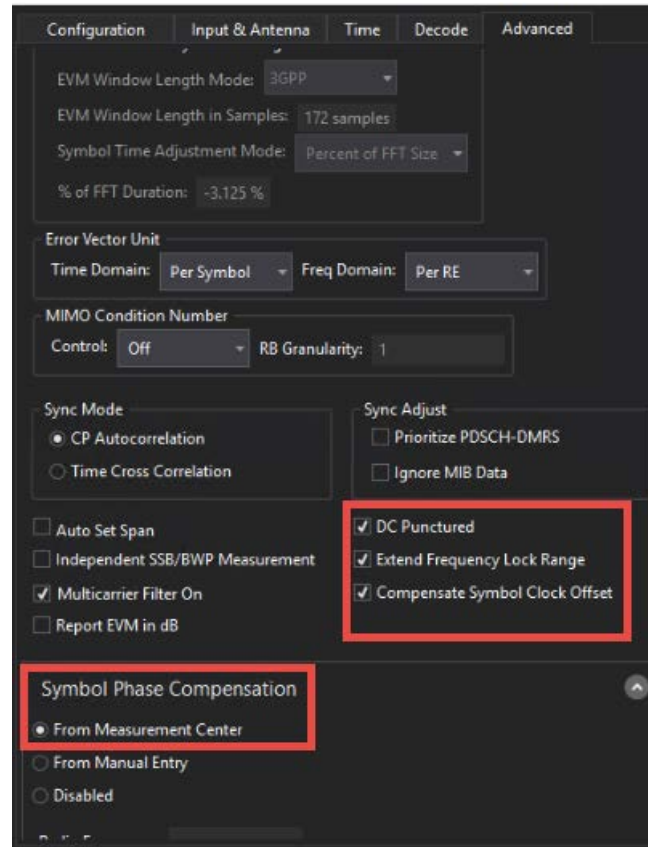
14. Select the **Advanced Settings** tab and select **DC Punctured**.

5G NR counts the DC subcarrier as a valid subcarrier for rate-matching purposes. The network decides if the DC subcarrier is modulated or not. High LO feedthrough will impact demodulation and EVM performance of the input signal. This setting is off by default.

Use **Extend Frequency Lock Range** if you cannot lock to the input signal.

Compensate Symbol Clock Offset is used along with timing track to compensate for clock error in the input signal. The Symbol Clock Error result is reported in the Summary trace.

Symbol Phase Compensation > From Measurement Center is enabled by default. It is specified in the 3GPP requirement and is used to compensate for phase differences between symbols caused by up conversion or down conversion. Getting this setting wrong will cause demod issues.



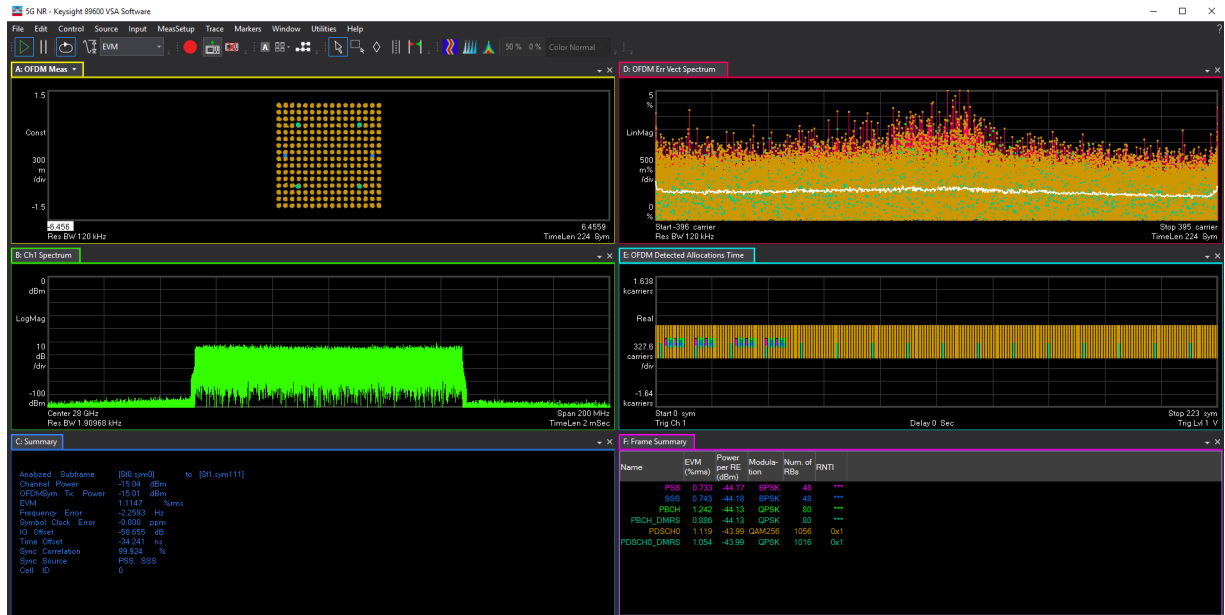
15. From the menu bar, select **Window > Trace Layout > Tile Visible**.

This will display all six 5G NR traces on the display.

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

TIP

The VSA has color coding based on channel type, marker coupling to pinpoint error, symbol level analysis (by changing the measurement interval, and measurement offset into a single symbol).



More About the 5G NR Traces

- Trace A: shows the composite constellation diagram showing different modulation formats for the different channels/signals present in the transmitted signal.
- Trace B: shows the frequency spectrum.
- Trace C: shows the composite error metrics. You can also see the automatically detected Cell ID value and the Channel Power.
- Trace D: shows the EVM versus subcarrier and symbol.
- Trace E: shows the detected allocations of all channels/signals within the measurement interval. (For this example, 2 Subframes) You can see the 8 active SS Blocks in the first four slots.
- Trace F: shows the frame summary: EVM Power per RE, Modulation format, Number of RB and RTNI of the individual channels/signals.

For more information on these traces, see the Online help.

Trace Filtering

The VSA has per-trace filtering to filter by subsegments and channels. Subsegment refers to Layers, (in case of MIMO), BWP, and SS Block. In the downlink, Layers in DL-BWP and SS Block are presented as subsegments. In the uplink, Layers in UL-BWP are presented as subsegments.

The following traces can be filtered by subsegments and channel types.

- OFDM Meas
- OFDM Ref
- Error Vector Spectrum
- Error Vector Time
- Detected Allocations Time trace can be filtered per channel only

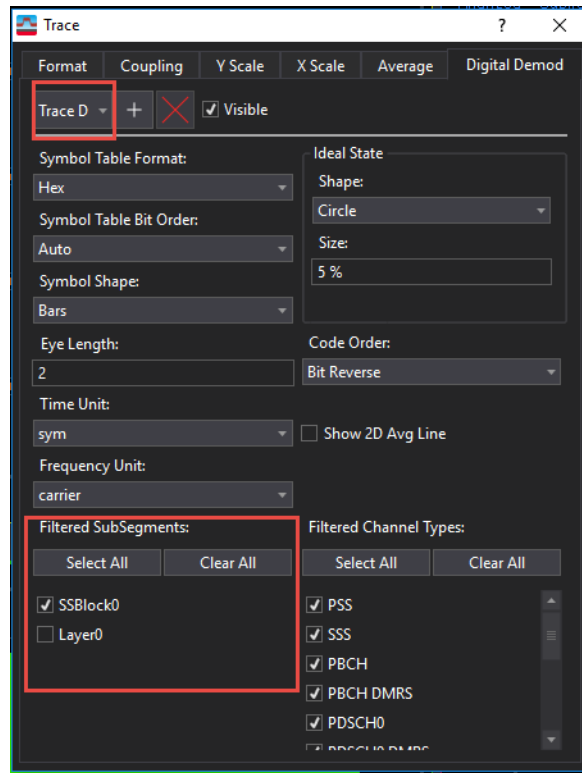
The rest of the traces do not support per-trace filtering.

A Simple Example

We will apply per-trace filtering to Error Vector Spectrum (Trace D) and Detected Allocations Time (Trace E) traces.

1. From the menu bar, select **Trace > Digital Demod.**
2. In the Trace Dialog, select **Trace D** (OFDM Error Vector Spectrum) from the dropdown.
3. In the Filtered SubSegments area, clear the **Layer0** check box.

This allows you to take a look at SS Block. You can also filter with SS Block Channels/Signals you want to see by using the Filtered Channel Type.



4. Select Trace E (OFDM Detected Allocations Time) from the Trace dialog.
5. In the Filtered SubSegments area, clear the **SS Block0** check box.

This allows you to look at Layer 0 information, which is the DL-BWP information.

6. In the Filter Channel Types area, **Clear All** selections, then select just **PDSCH-DMRS**.

You now see a gap in two of the DMRS symbols. Why is this?

Notice that the Frame Summary table shows Num. of RBs for PDSCH of 1056 and 1016 for PDSCH-DMRS. The signal configuration only had 66 RBs. Why the change in the measurement result?

The RB result in the Frame Summary table is per Slot. In this example, we changed the measurement interval to 2 Subframes, which is 16 slots for 120 kHz numerology (8 slots/subframe). $66 \times 16 = 1056$. For PDSCH-DMRS, the value is 1016 because of the 16 slots overlap with the SS Block, which occupies 20 RBs. This results in 20 RBs being punctured from DMRS in these two slots, so the total RB Number for DMRS is $1056 - 20 \times 2 = 1016$.

Using the equivalent SCPI commands

On the VXG:

```
SYSTem:PRESet
RF1:FREQuency:CW 28GHZ
RF1:POWer:AMPLitude -10dBm
RADio:SElect NR5G
RADio:NR5G:WAVEform:CCARrier:BWIDth FR2BW100M
RADio:NR5G:WAVEform:CCARrier:SNUMerology MU3
RADio:NR5G:WAVEform:CCARrier:DLINK:SSBLoK:LMAX 64
RADio:NR5G:WAVEform:CCARrier:DLINK:SSBLoK:ACTive:INDices
"0:7"
RADio:NR5G:WAVEform:CCARrier:DLINK:SCH0:MCS 20
RADio:NR5G:WAVEform:CCARrier:DLINK:SCH0:MCS:TABLE TABLE52
RADio:NR5G:WAVEform:GENerate
GROup:SIGNal ON
RF1:OUTPut ON
For multi-channel instruments, set RF Out (all) to On.
RFALl:OUTPut ON
```

On the X-Series Signal Analyzer:

```
INSTrument:SElect VSA89601
SYSTem:PRESet
FREQuency:CENTer 28 GHz
INPut:ANALog:RANGe:AUTO
INITiate:PAUSE
INPut:TRIGger:STYLe "External"
INPut:TRIGger:LEVel:EXternal 1V
INPut:EXTension:PARAMeters:SET "ExtTriggerLoc", 2 (This will
set it to Trigger 3)
NR5G:FRAMe:TRIGger:ENABLEd 1
INPut:EXTension:PARAMeters:SET "PhaseNoiseOptDualLoop", 1
MEASure:CONFigure NR5G
```

5G NR Measurements Using the VSA Software
5G Waveform and EVM Analysis Using VSA Software

```
NR5G:CCARrier:CIDentity:AUTO 1 |OR| NR5G:CCARrier:CIDentity
0
NR5G:CCARrier:TBANdwidth "FRTwo100MHz"
NR5G:DBWP:ENABled 1
NR5G:DBWP:NUMerology "Mu3"
NR5G:DBWP:ROFFset 0
NR5G:DBWP:RNUMber 66
NR5G:SSBLock:ENABled 1
NR5G:SSBLock:LMAX "L64"
NR5G:SSBLock:AINDexes "0:7"
NR5G:DBWP:PDSCh1:MCS:TABLE "Table2"
NR5G:DBWP:PDSCh1:MCS 20
NR5G:DBWP:PDSCh1:SLOT:ALLocated "0:79"
NR5G:CCAR:PDSCH1:SFI 0
NR5G:CCAR:PDSCH1:SINDex:FIRST 0
NR5G:CCAR:PDSCH1:SINDex:LAST 13
NR5G:CCAR:PDSCH1:ROFFset 0
NR5G:CCAR:PDSCH1:RNUMber 66
NR5G:RLENgth 10
NR5G:SUBFrame:INTerval 2
NR5G:FRAME:TRIGger:ENABled 1
NR5G:DC:PUNCTured 1
NR5G:MCFilter:ENABled 1
NR5G:FREQuency:LOCK:EXTended 1
NR5G:COMPensate:SYMBOL:CLOCK:OFFset 1
DISPlay:LAYout 3,2
INPut:ANALog:CRITeria:RANGE:AUTO "EVM", -1
```

Creating a DL MIMO Signal Using PathWave N7631APPC Signal Generation

NOTE

The VXG must have the N7631APPC Signal Generation for 5G NR license installed.

This procedure will show you how to configure and analyze a downlink (DL) multiple input, multiple output (MIMO) signal using PathWave Signal Generation and the 89600 VSA software. The hardware setup below includes a 2-channel VXG signal generator and a 2+ channel, 33 GHz or higher Infiniium UXR-Series Oscilloscope.

TIP

If you do not have access to a Keysight Infiniium UXR Real-Time Oscilloscope, a UXR recording waveform file has been included in the Example waveform file folder:

D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

You will need to copy the **5GNR_UXR_Recording_28GHz.sdf** file to the X-Series Signal Analyzer or the PC running the VSA application. Steps have been included below to successfully run the recording.

Hardware Requirement

- 2 channel M9484C VXG
- UXR with DDC option:
 - UXR000-601: 160 MHz BW or
 - UXR000-602: 2 GHz BW

Hardware accelerated DDC decimates oscilloscope captures in real-time enabling deep captures and fast measurement speed.

Software Requirements

PathWave Signal Generation for 5G NR	N7631APPC	Use latest release from Keysight.com
89600 VSA software	89601BHNC	VSA2023U2 or later

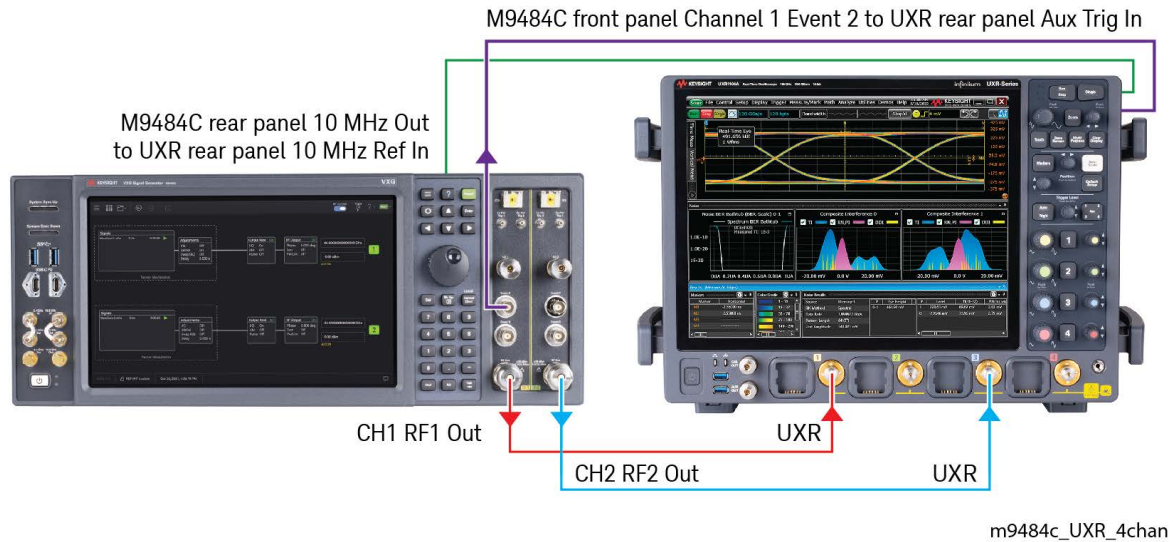
Equipment Setup for the M9484C

- M9484B CH1 front panel RF Out to UXR front panel CH1
- M9344B CH2 front panel RF Out to UXR front panel CH3
- M9484C front panel Channel 1 Event 2 to UXR rear panel Aux Trig In

5G NR Measurements Using the VSA Software

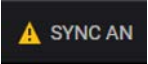
5G Waveform and EVM Analysis Using VSA Software

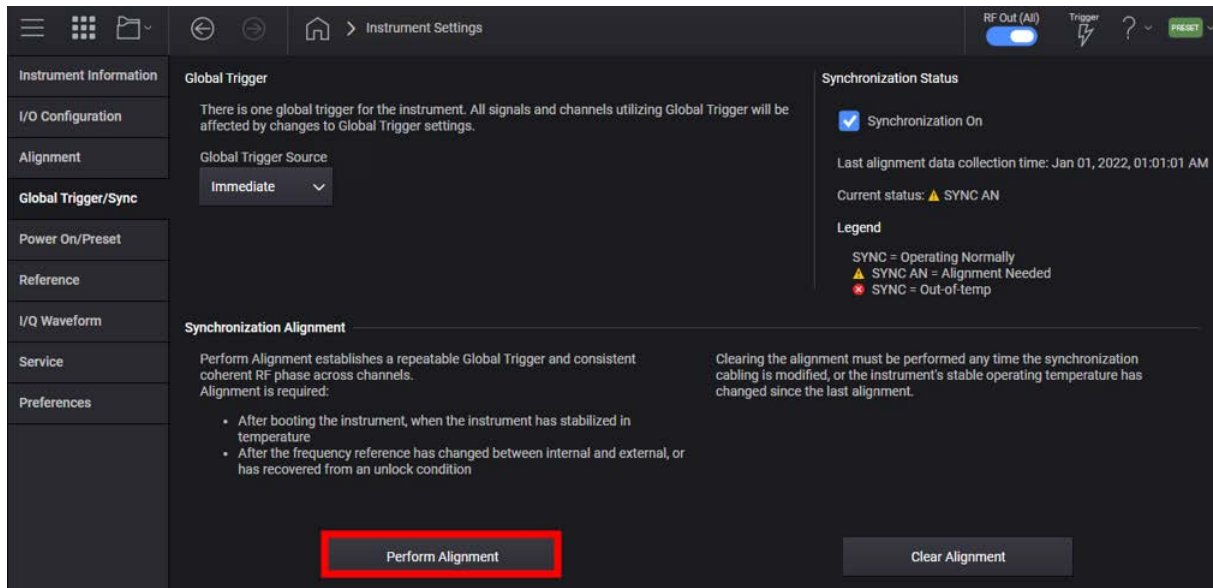
- M9484C rear panel 10 MHz Out to UXR rear panel 10 MHz Ref In.



On the VXG:

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

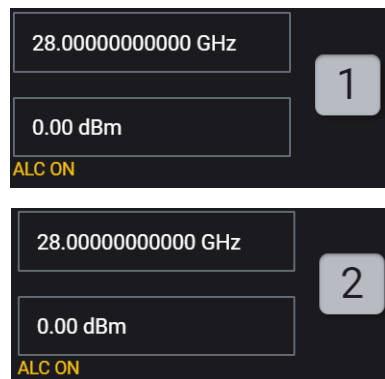
If a Synchronization Alignment is required, indicated by  in the bottom left corner, tap or click the warning message and choose **Perform Alignment** before proceeding.



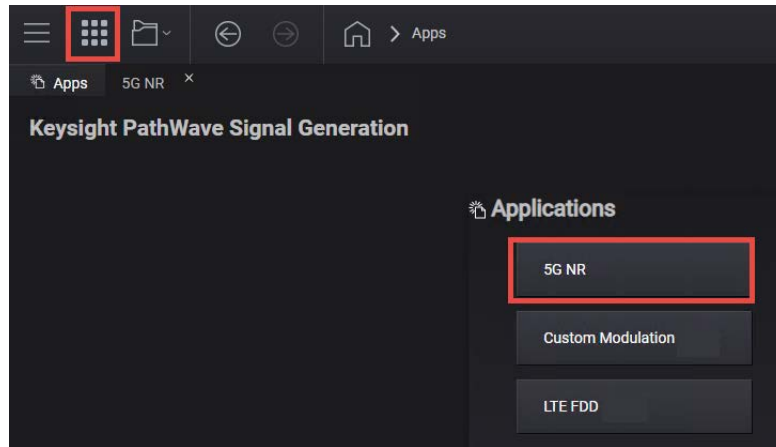
2. In the Menu/Tool Bar, select the Triple Bar icon (top left corner of the display, and then select **Configure Channels**. Change the signal configuration from Independent to **Group 1: 2 Tx Coherent** > **Apply**.



3. In the Output area for both Channel 1 and Channel 2, set Frequency to **28 GHz**, or the frequency you are using, and Power to **0 dBm**.

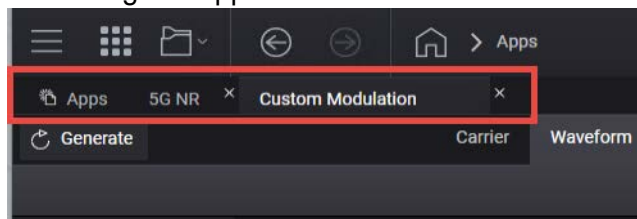


4. Select the **Apps** block to open, then select **5G NR**.

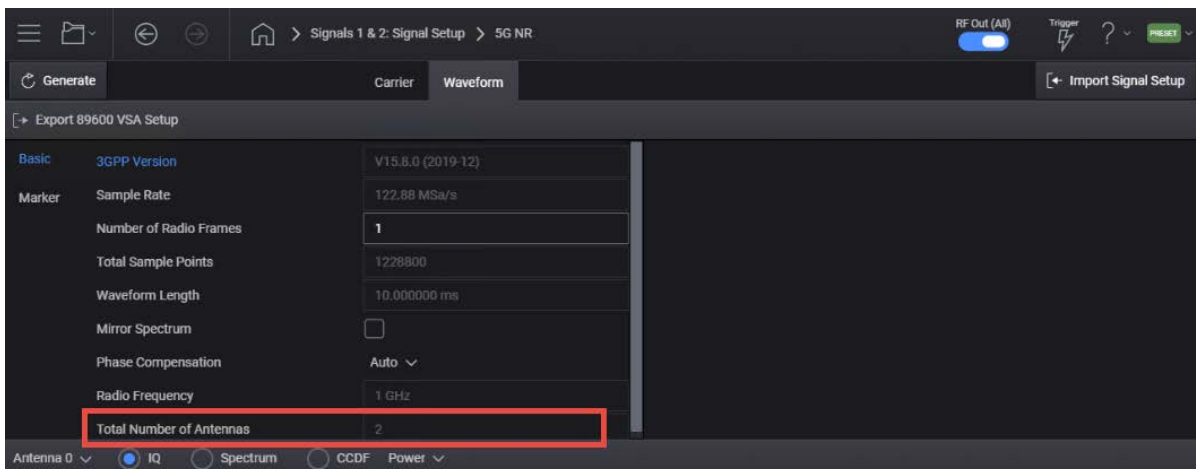


NOTE

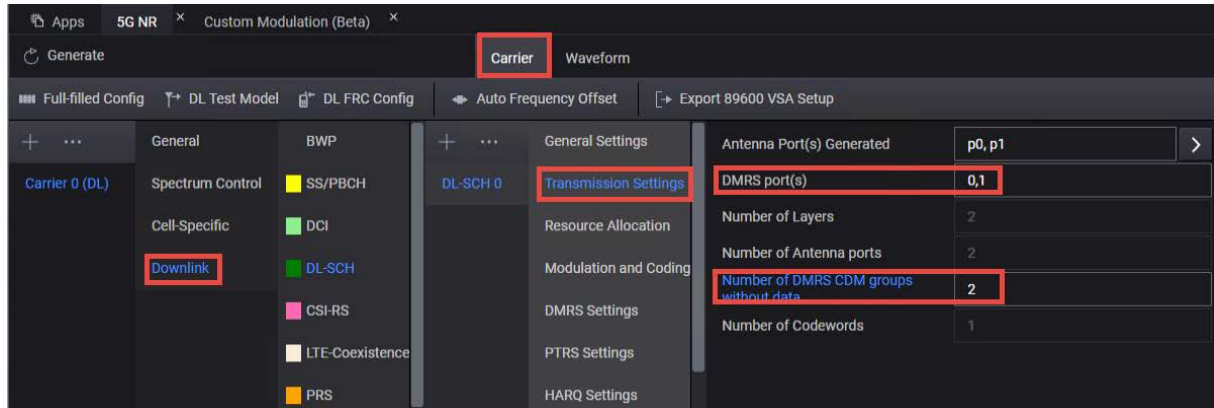
If you have previously opened any of your available applications, the dialog box will not be displayed. Instead, you will see tabs of the applications that have already been used. You can view all of your available applications by selecting the Apps tab.



5. Select the **Waveform** tab and set the Total Number of Antennas **2**. This means that two antenna port signals will be generated.



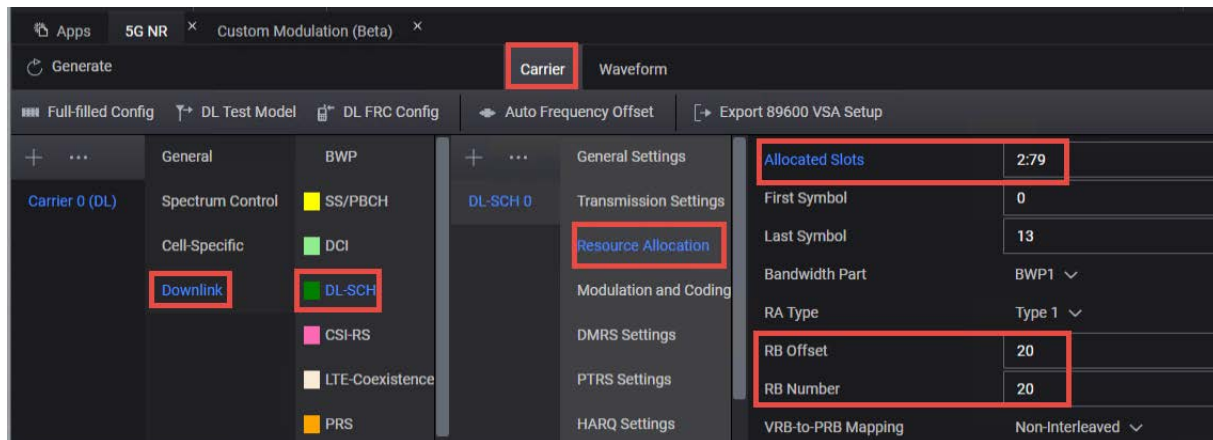
You will see the layer number is updated to 2 and each layer is assigned with a particular DMRS port. You'll also see that Antenna Ports Generated is automatically set to P0,P1, which will map the multiple antenna port signals to different antennas (instruments).



9. Select the **Resource Allocation** node and set:

- Allocated Slots to **2:79**
- RB Offset to **20**
- RB Number to **20**

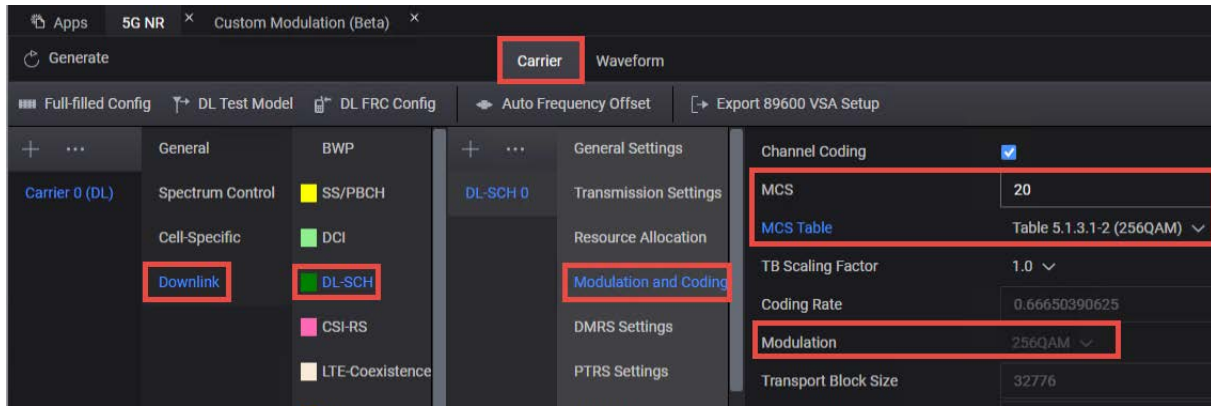
DL-SCH0 will occupy the RBs 20-40 and DL-SCH1 will occupy the rest of the resources.



10. Select the **Modulation and Coding** node and set:

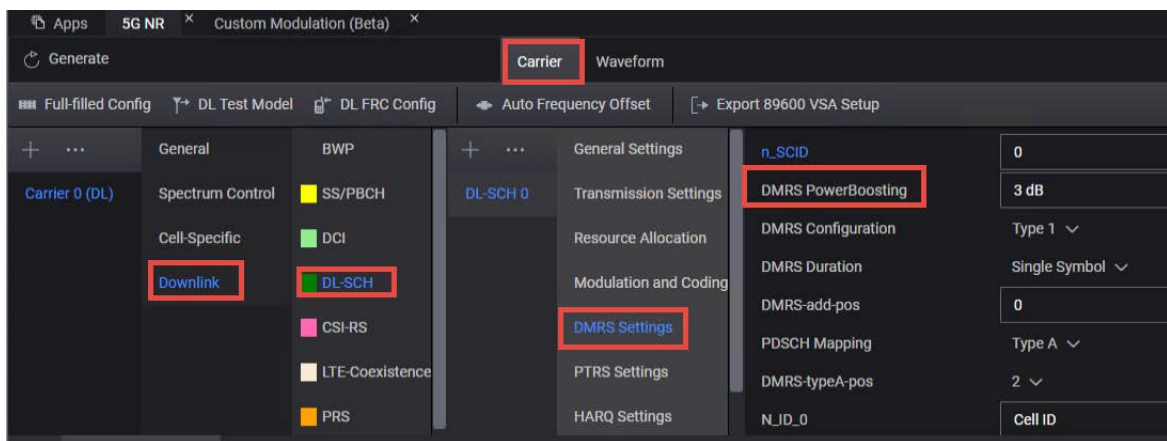
- MCS to **20**
- MCS Table to **5.1.3.1-2 (256 QAM)**

Notice that modulation is updated to 256 QAM.

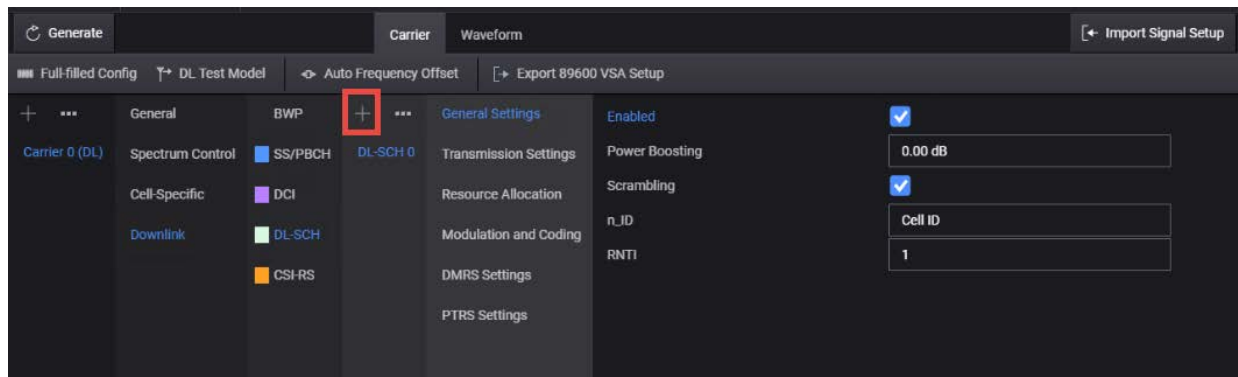


11. Select the **DMRS Settings** node and set DMRS Power Boosting to **3 dB**.

When CDM Group Number is 2, DMRS power boosting becomes 3 dB per 3GPP.

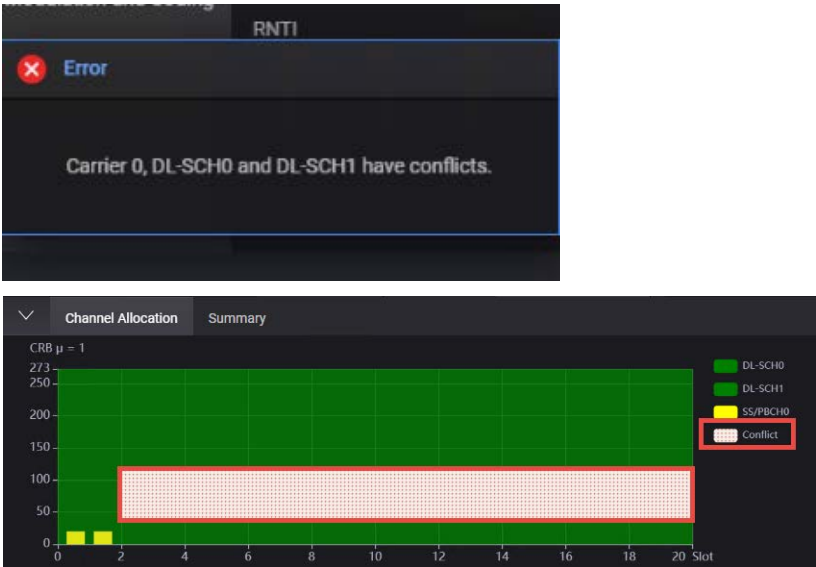


12. Under the DL-SCH 0 node, select the + icon to add a new +DL-SCH (DL-SCH1).



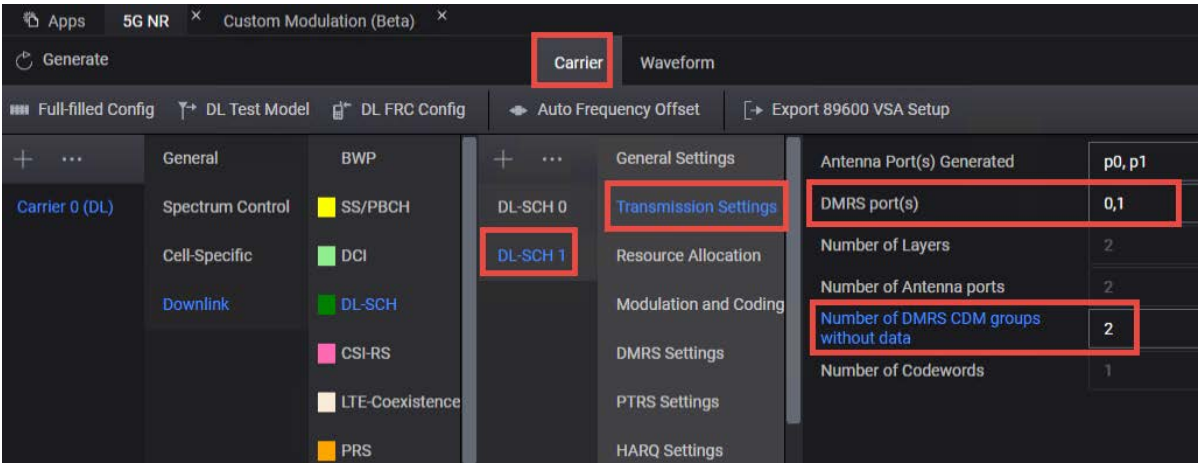
NOTE

This will create a conflict between DL-SCH0 and DL-SCH1. This will be resolved in a later step.




13. From the Channels node, select **DL-SCH > DL-SCH1 > Transmission Settings** and set DMRS port(s) to **0,1**. Change the Number of DMRS CDM groups without data to **2**.

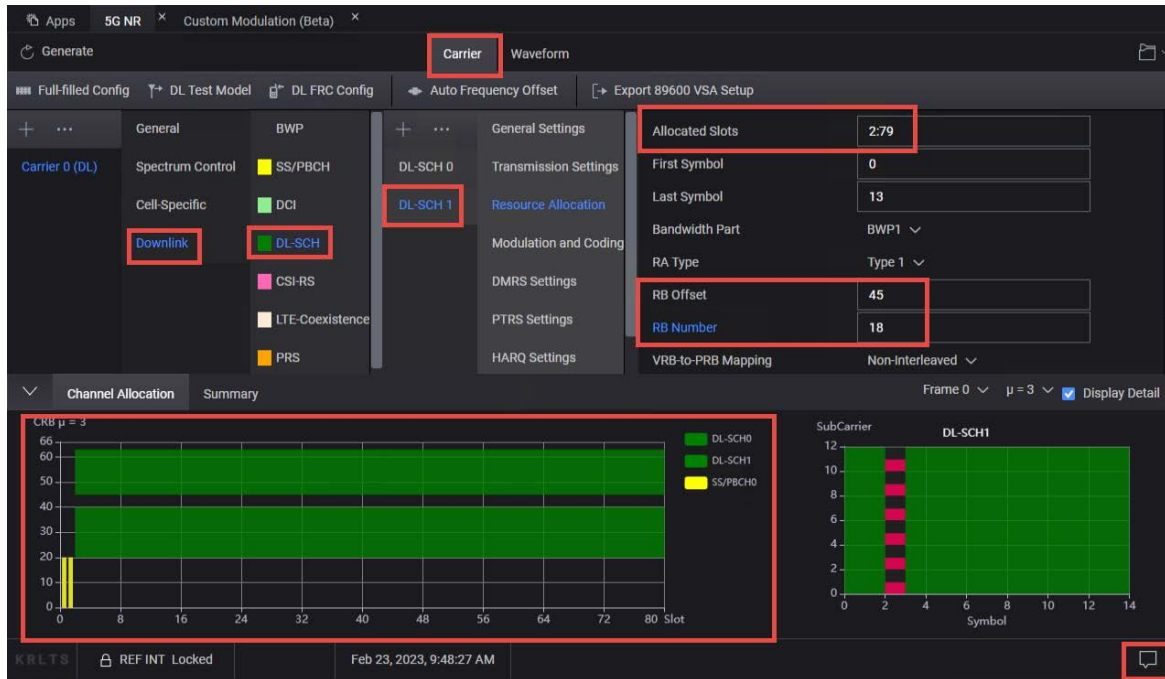
Notice that Number of Layers is updated to 2 and each layer is assigned with a particular DMRS port. Antenna Ports Generated is automatically assigned P0,P1, which will map generated multiple antenna port signals to different antennas (instruments).



14. Select the **Resource Allocation** node and set:

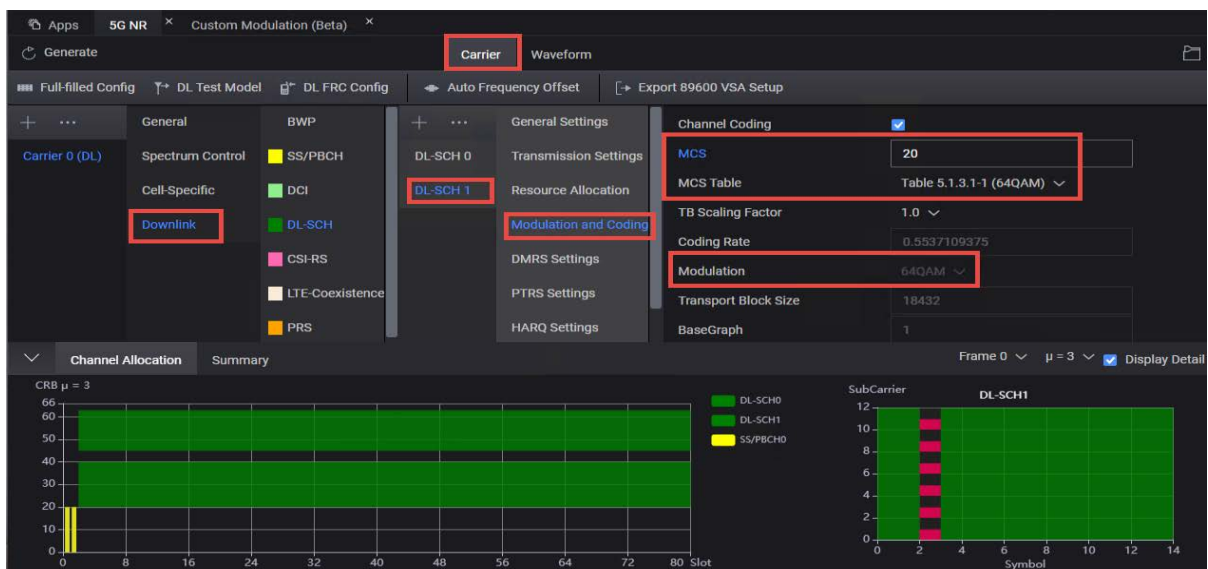
- Allocated Slots to **2:79**
- RB Offset to **45**
- RB Number to **18**

Notice that this resolves the conflict between DL-SCH channels. (The pink shading is removed from the Channel Allocation graph. To clear the conflict error message at the bottom of the display, select the Message icon  (bottom, right corner) and select **Clear**.

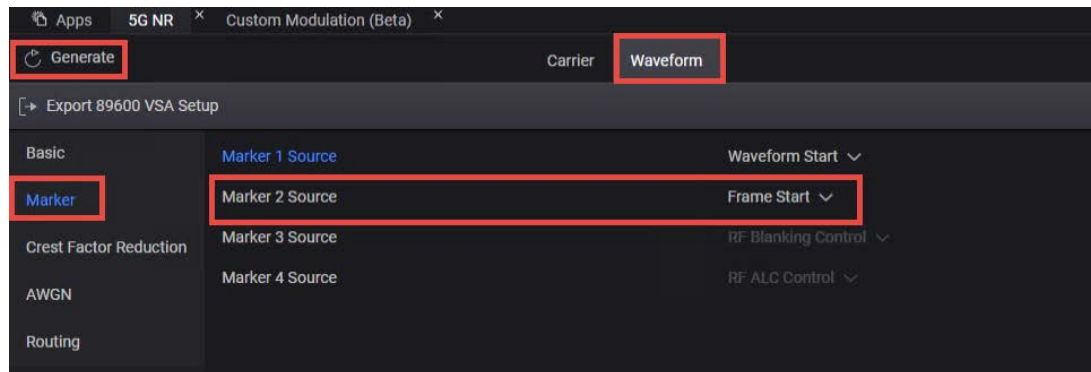


15. Select the **Modulation and Coding** node, and set MCS to 20.

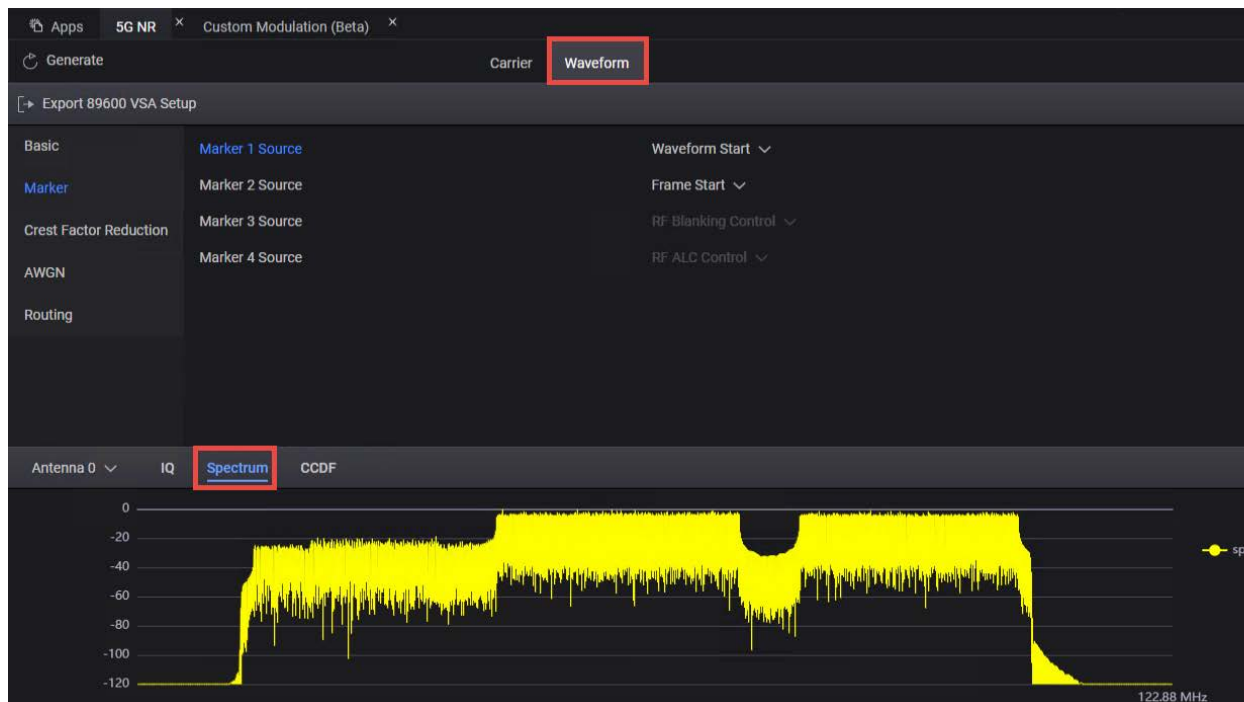
Use the default MCS Table to Table 5.1.3.1-1 (64QAM). You will see the modulation is updated to 64QAM.



16. Select the **Waveform** tab > **Marker** and notice that Marker 2 Source is set to **Frame Start**. Select **Generate**.

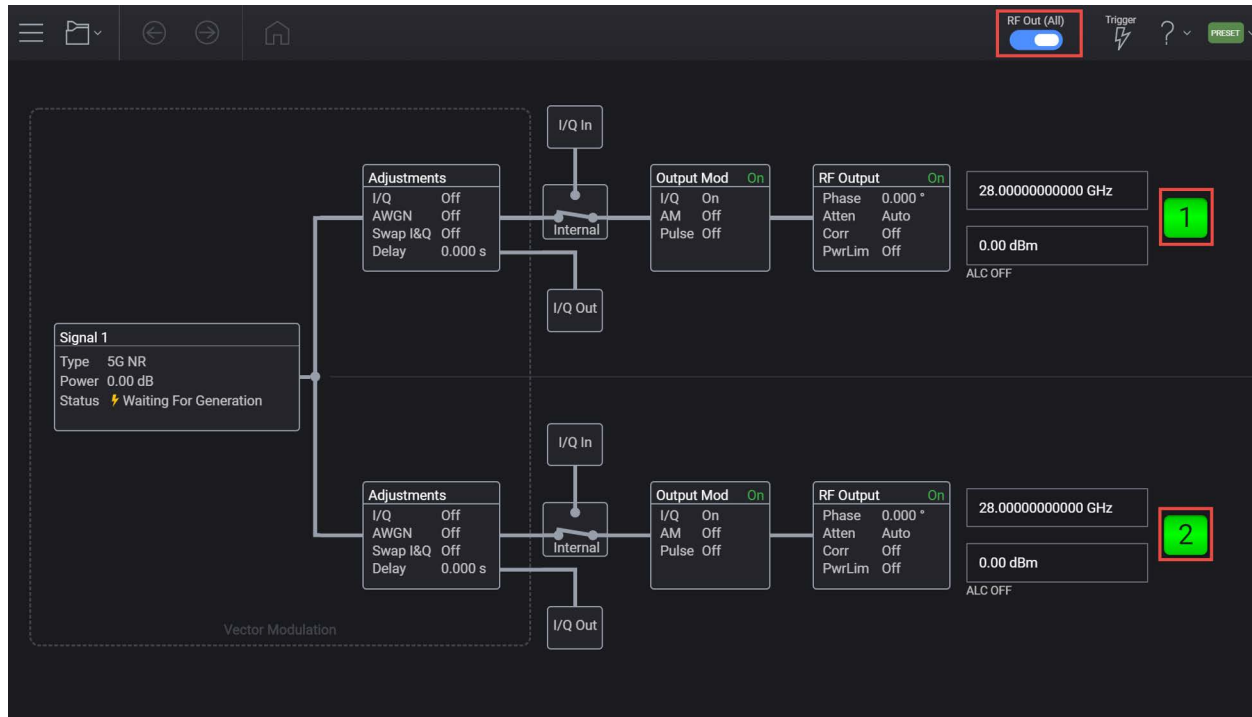


17. In the bottom panel, select **Spectrum**.
You should see a spectrum like the one below.



18. Return to the **Carriers** tab and select **Export 89600 VSA Setup**. Save the .setx file to a USB drive to transfer to the VSA. We will also set up the 89600 VSA manually in the next section.

19. Select the Home icon and set RF Out to **On** by selecting the numbered channel indicator switches, and then select **RF Out (All)** master control switch to turn the RF output On for both channels or off for both channels.



To Setup the VSA Using the Infiniium UXR Real Time Scope

NOTE

There are two different VSA setup process.

- If you have access to a Keysight Infiniium UXR Real Time Scope continue to the first step below.
- If you do not have access to a Keysight Infiniium UXR Real-Time Oscilloscope, a UXR recorded waveform file has been included in the Example waveform file folder of the VXG. Go to **“To setup the VSA Using a UXR Recorded Waveform File” on page 385**

To analyze the signal using the VSA on the UXR307944

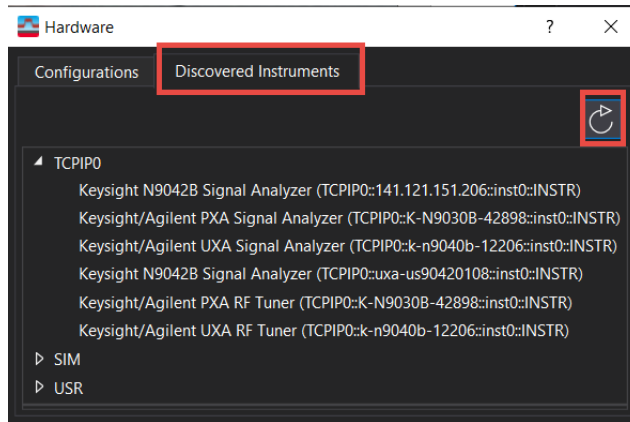
1. Open the VSA software.

To access the VSA software, go to the Windows Start menu and find Keysight 89600 Software (latest installed version) folder and run the software.

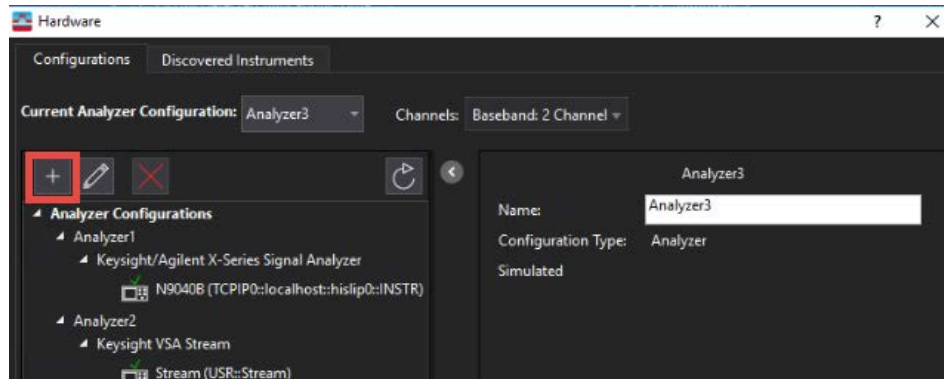
NOTE

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.

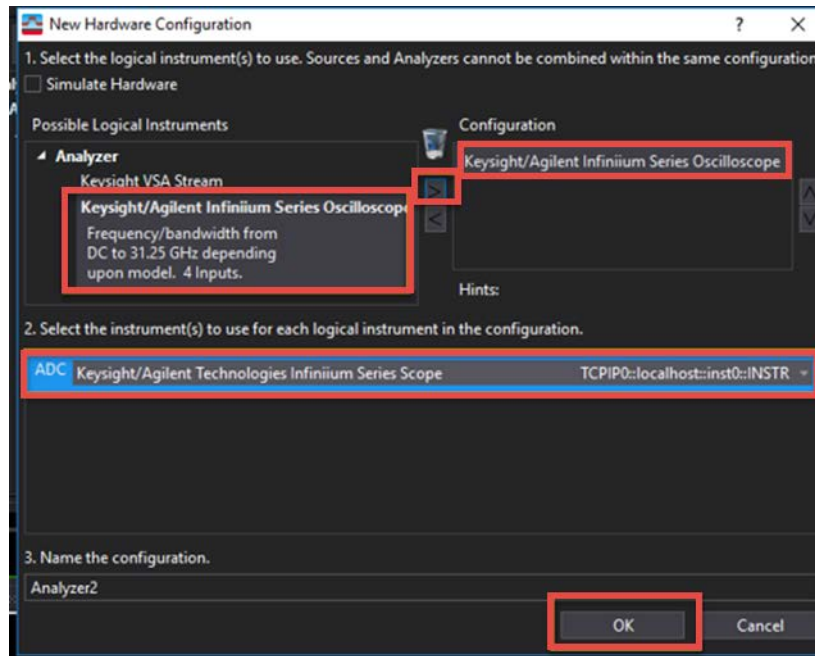
2. From the VSA menu bar, select **File > Preset > All** to set the VSA to a known state.
3. To configure the hardware, go to **Utilities > Hardware > Configurations**.
If it is already configured, go to **step 10**.
4. Open the **Discovered Instruments** tab and verify that the UXR is listed, if not, select the **Rediscover Instruments** icon.



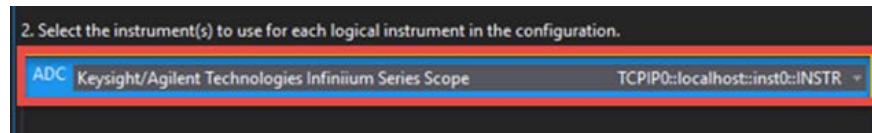
5. In the **Configuration** tab, select the **+** icon.



6. Scroll down the Possible Logical Instruments and select **Keysight/Agilent Infiniium Series Oscilloscope**, and then select the right arrow to move it under Configuration.

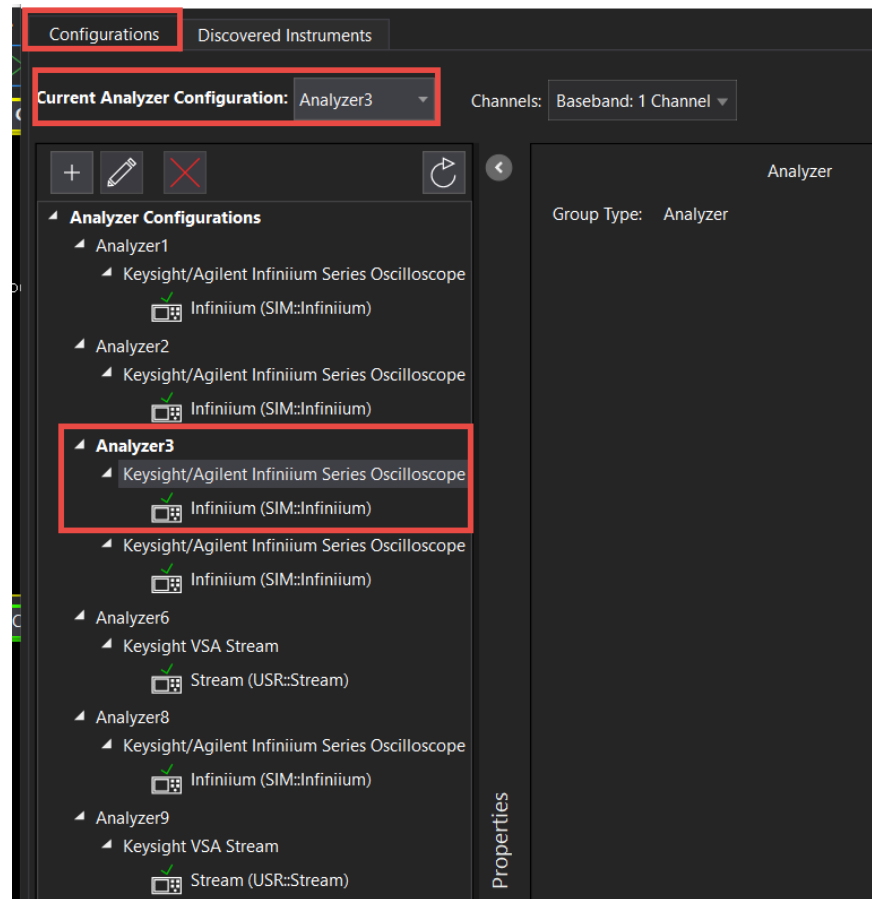


7. From the middle of the dialog box, select the UXR to be used.

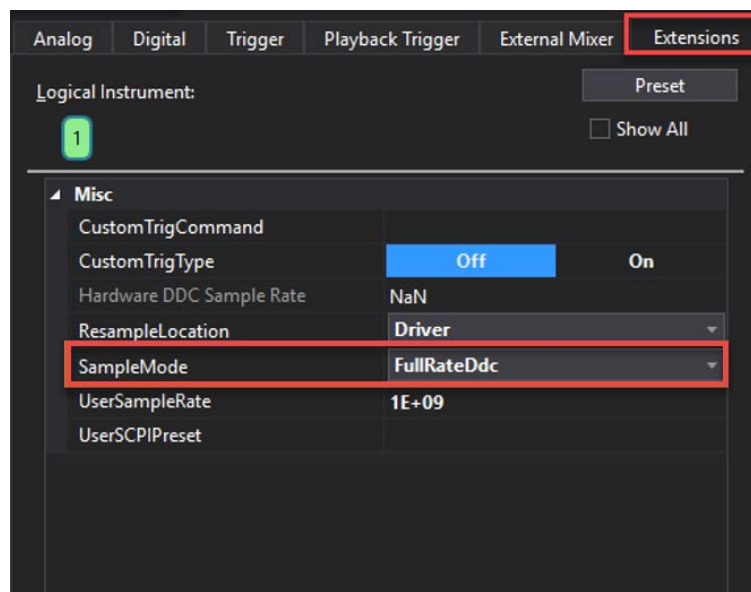


8. Select **OK** to create the UXR configuration.

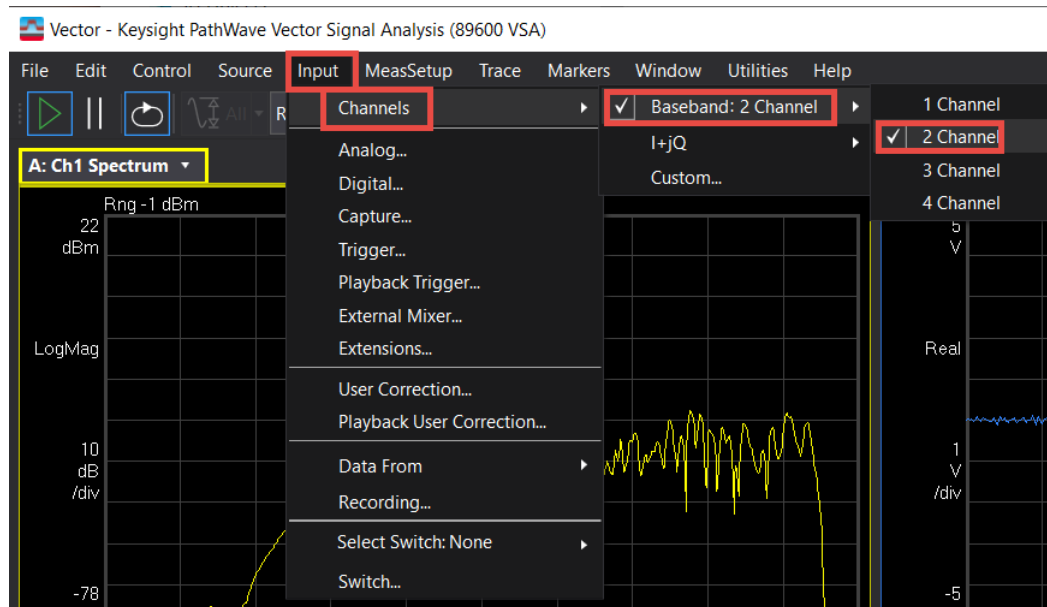
9. In the **Configurations** tab, set the Current Analyzer Configuration, select the Analyzer number for the new configuration. In this example **Analyzer 3**.



10. From the menu bar, select **Input > Extensions > Sample Mode > FullRate DDC**.




11. From the menu bar, select **Input > Channels > RF > 2 Channels.**

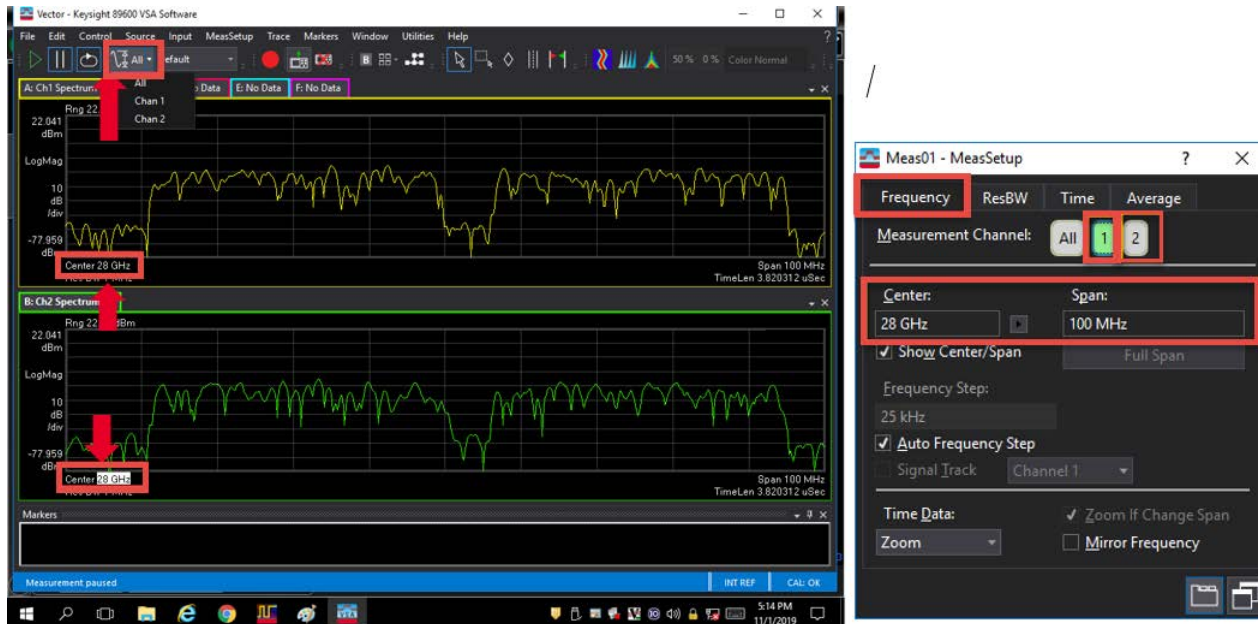


12. Set the center frequency of both channels to **28 GHz, or the frequency you are using, and span to **100 MHz**.**

You can also set the frequency and span of both channels under Meas Setup > Frequency.

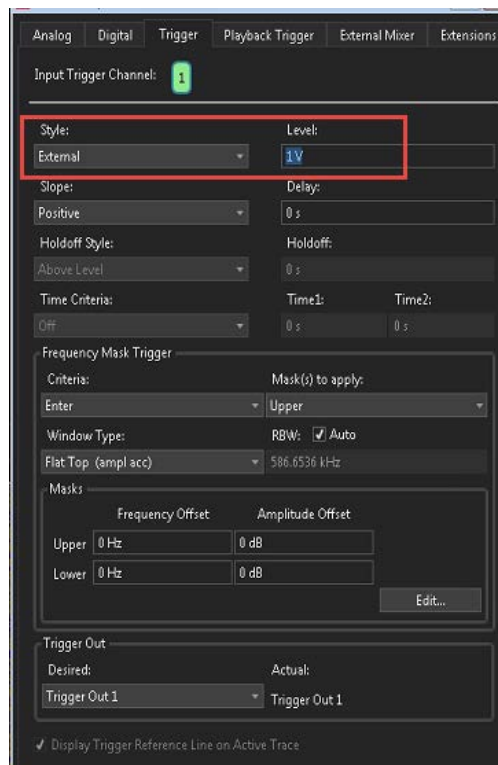
If you are using a UXR, Select Autorange .

Auto Range samples the current input signal and then sets the full scale input range to the minimum range that includes the peak voltage sample of the input signal.



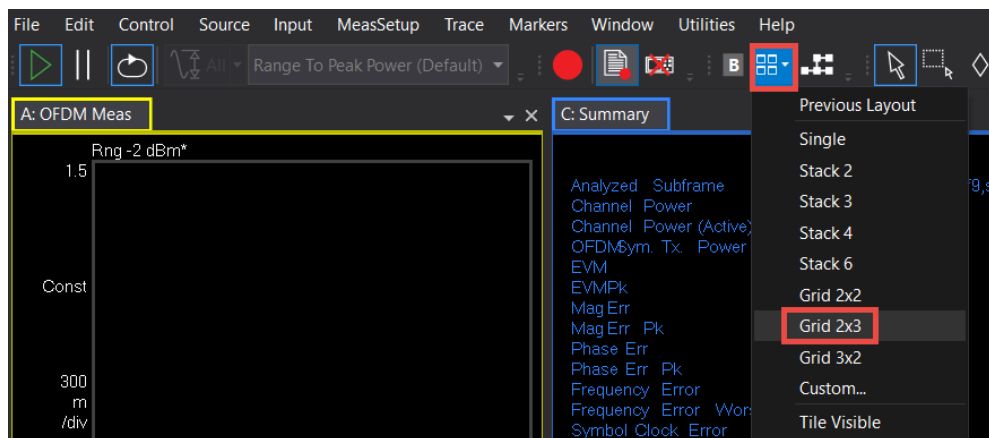
13. From the menu bar, select **Input > Trigger** and set:
- Style to **External**

– Level to 1 V



14. From the menu bar, select **MeasSetup** > **Measurement Type** > **Cellular** > **5G NR** > **5G NR Modulation Analysis**.

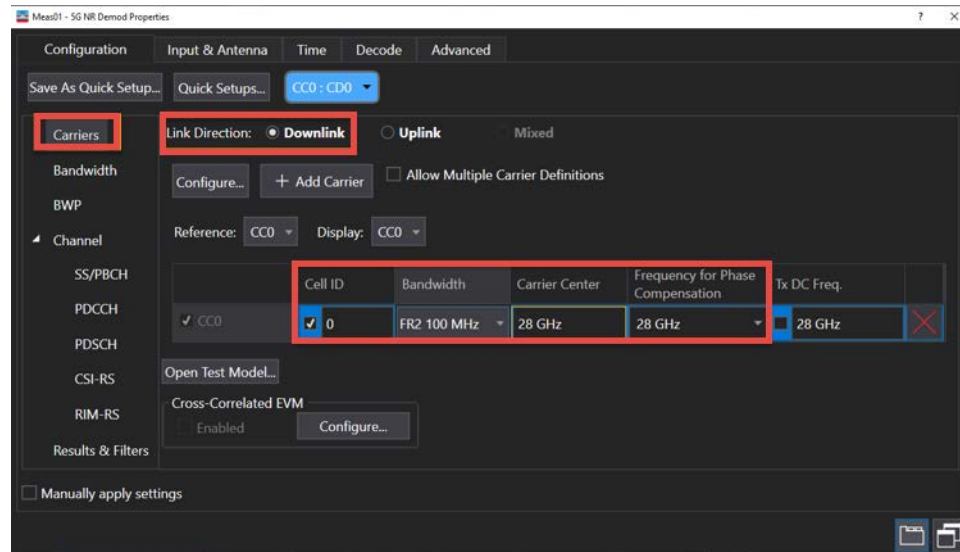
15. Change the trace layout to **Grid 2x3**.



TIP

To improve setup speed, Pause the measurement until all parameters are correctly configured, then run the measurement.

16. Select **MeasSetup > 5G NR Demod Properties > Configuration** tab and set that Bandwidth **FR2 100 MHz**, Carrier Center and Frequency for Phase compensation are set to **28 GHz**. Select the **Cell ID** checkbox.

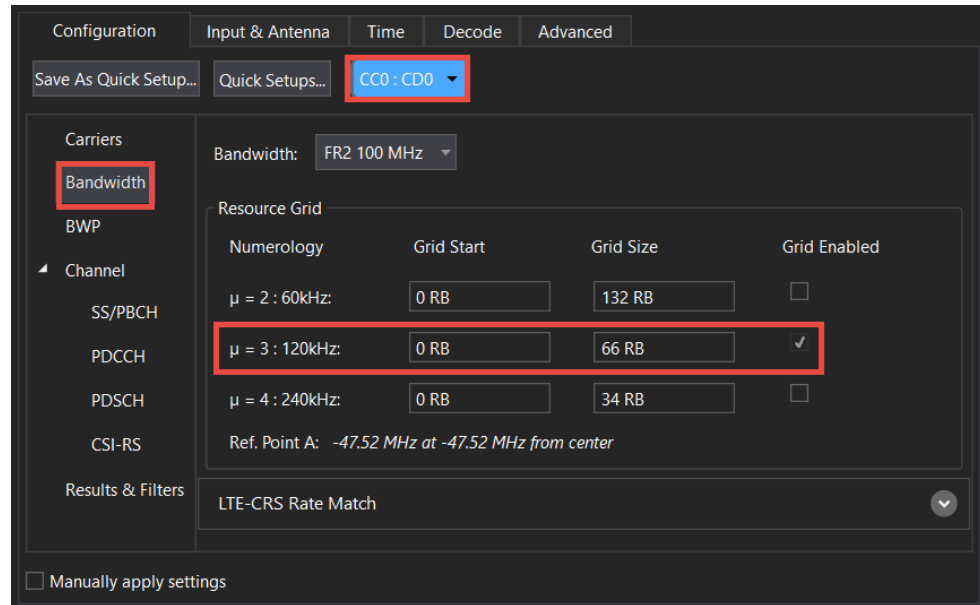


Cell ID is carried on PSS and SSS so that SS/PBCH must be transmitted and enabled for Auto Cell ID to work and must be a Downlink since SS/PBCH is only transmitted in the DL.

Phase compensation is per the 3GPP requirement, and is enabled by default. It is used to compensate for phase differences between symbols caused by upconversion or downconversion. Getting this setting wrong will cause a demod issue. For this example, it is ON and it is applied at the center frequency.

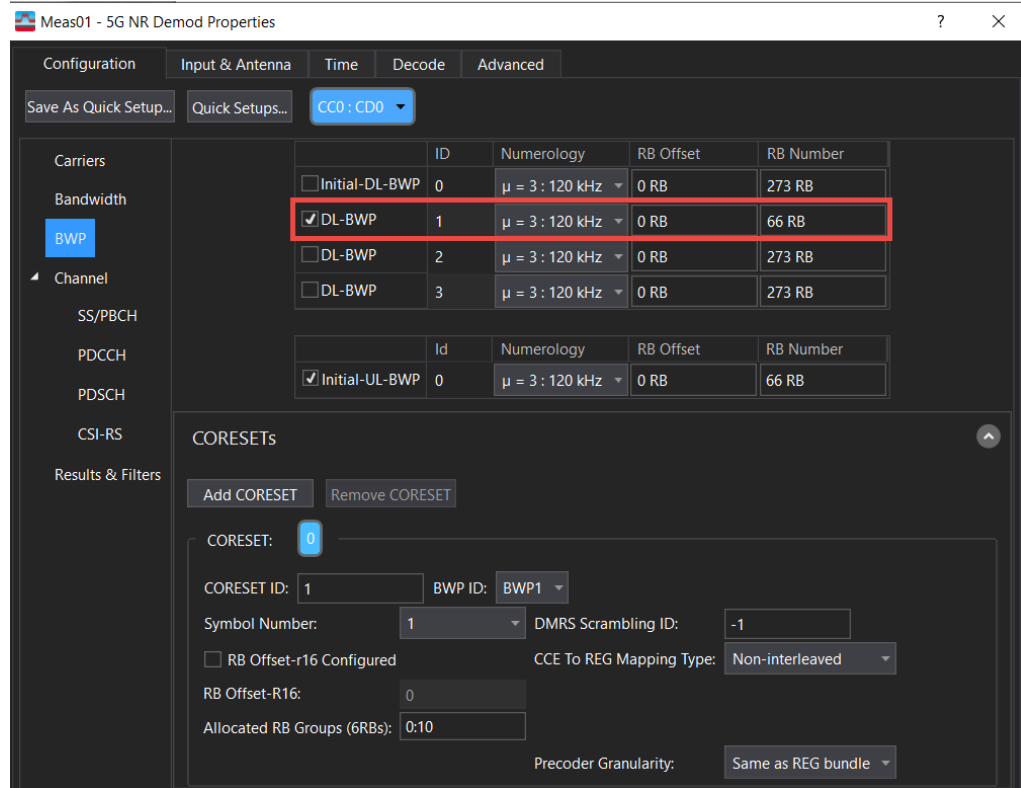
17. Select the **Bandwidth** pane and confirm that numerology is set to $\mu=3:120$ kHz.

The Bandwidth panel is used to configure the Resource Grid for each Numerology. Note that for FR2 100 MHz, the Max RB for 120 kHz Numerology is 66 RB. We will use this value when we configure the PDSCH parameters.



18. Select the **BWP** pane and confirm that **DL-BWP ID 1** is enabled.

For each BWP allocation, configure the numerology (μ) as well as RB allocation information. In this example, we will use the default 120 kHz numerology, RB Offset = 0 and RB number = 66 RB for a 100 MHz bandwidth signal.



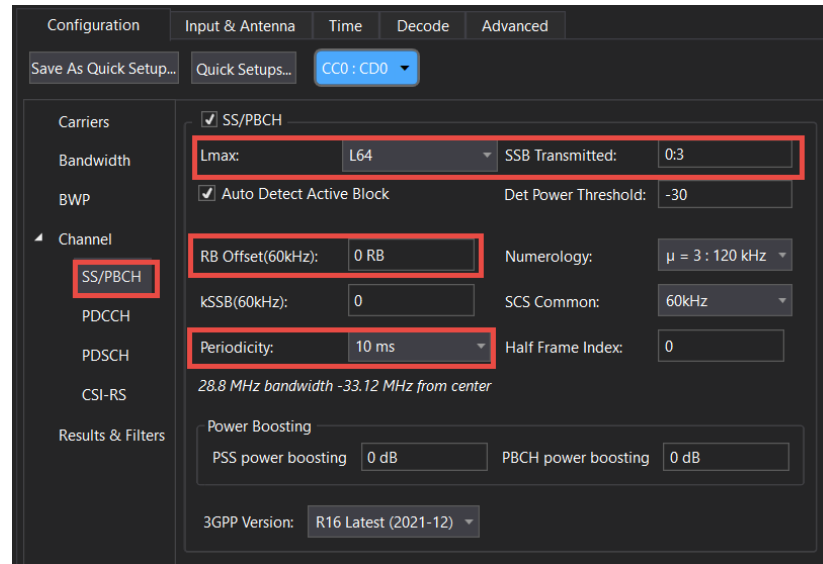
19. Select the **Channel** pane > **SS/PBCH** and set:

- a. RB Offset (60 kHz) to **0 RB**
- b. Periodicity to **10 ms**
- c. Lmax to **L64**
- d. SSB Transmitted to **0:3**

For this example we will use 4 of the 64 SS/PBCH Blocks (beams). In an SSBlock, the period is different for the different numerologies.

- FR1 up to 3 GHz, L=4
- FR1 3 GHz to 7.125 GHz, L8
- FR2-1, FR2-2, L = 64

The frequency location of an SSBlock is not fixed. In the VSA software, a default value of 46 RB and kSSB of 0 subcarriers places it in the center of the carrier bandwidth. Using 0 RB Offset puts the SSB at the lower edge of the carrier.



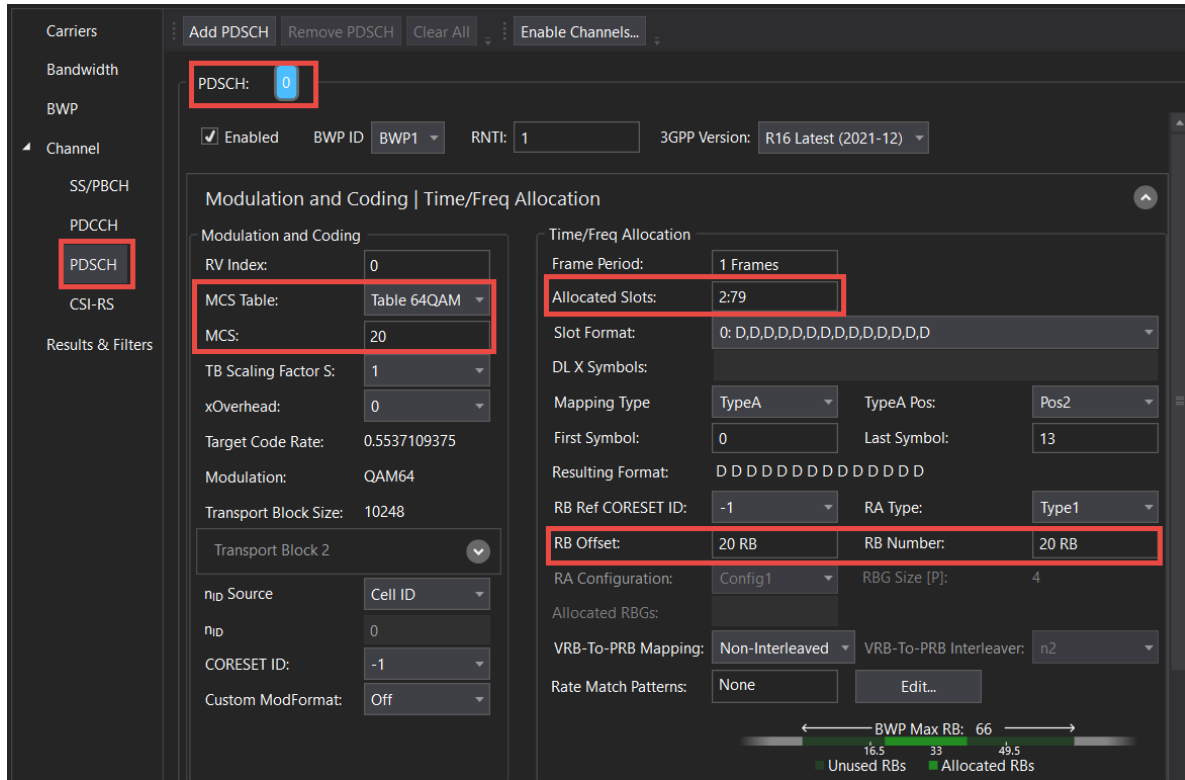
20. To configure the PDSCH0, select the **PDSCH** pane and for PDSCH 0, set:

- MCS Table to **Table 256 QAM**
- MCS to **20**

3GPP has different Tables for PDSCH MCS.

- Table 5.1.3.1-1 has 64QAM as max modulation
- Table 5.1.3.1-2 has 256QAM as max modulation
- Table 5.1.3.1-4 has 1024QAM as max modulation
- Table 5.1.3.1-3 has 64QAM as max modulation and is for low spectrum efficiency (LowSE). See 3GPP TS38.214 for more information.
- Allocated Slots to **2:79**
- RB Offset to **20 RB**

– RB Number to **20 RB**



21. Scroll down and select the Antenna Port dropdown and set:

- Antenna Ports Used, 1 to 0:1
- DMRS CDM Group(s) without data to 2 (to match the PathWave setup)

22. Under the RS Sequence dropdown, we will use the default settings for DMRS and PTRS. However, this is where you would change the RS settings.

23. Select the **Power Boosting** dropdown and verify that DMRS Power Boosting has automatically been set to **3 dB**.

When "DMRS CDM group without data" is set to 2, the DMRS power boosting becomes 3 dB per 3GPP definition.

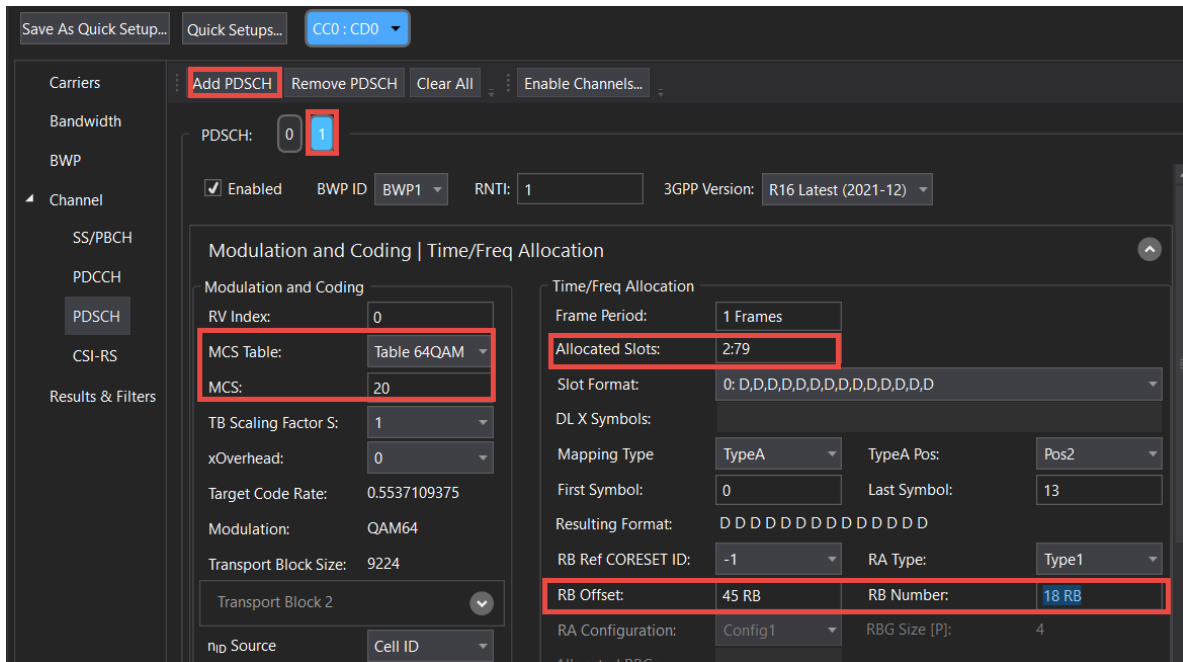
The screenshot displays the VSA Software configuration interface for the PDSCH channel. The left sidebar lists various configuration categories: Carriers, Bandwidth, BWP, Channel, SS/PBCH, PDCCH, PDSCH, CSI-RS, and Results & Filters. The PDSCH category is selected. The main configuration area is divided into several sections. The 'Antenna Port' section is highlighted with a red box and contains the following settings: 'Ref. Antenna Port' (1000), 'Ant. Det. Threshold' (-36 dB), 'Use Antenna Ports Index' (unchecked), 'Antenna Ports Used' (0:1), 'Codeword Number' (1), and 'DMRS CDM group(s) without data' (2). The 'RS Sequence' section is also highlighted with a red box and contains the following settings: 'DMRS Config' (Type1), 'DMRS Max Length' (1), 'DMRS Length' (Single-Symbol), 'DMRS AddPos' (Pos0), 'DMRS Map Ref' (CRB0), 'DMRS Init Option' (NR Standard), 'DMRS-Downlink-r16' (unchecked), 'DMRS Source' (Cell ID), 'N_{ID}^{DMRS}' (0), 'N_{ID}⁰' (0), 'N_{ID}¹' (0), 'DMRS Init' (0), 'Enable PTRS' (unchecked), 'KPTRS' (2), 'LPTRs' (1), 'PTRS RE Offset' (00), and 'AdditionalDMRS-DL-Alt' (unchecked). The 'Power Boosting' section at the bottom is highlighted with a red box and contains the following settings: 'Power Boosting' (0 dB), 'DMRS Power Boosting' (3 dB), and 'PTRS Power Boosting' (0 dB). A red box also highlights the 'DMRS CDM group(s) without data' dropdown menu, which is set to 2.

24. To add and configure PDSCH1, select **Add PDSCH**.

25. Select **PDSCH1** and set:

- MCS Table to **Table 64 QAM**
- MCS to **20**
- Allocated Slots to **2:79**
- RB Offset to **45 RB**

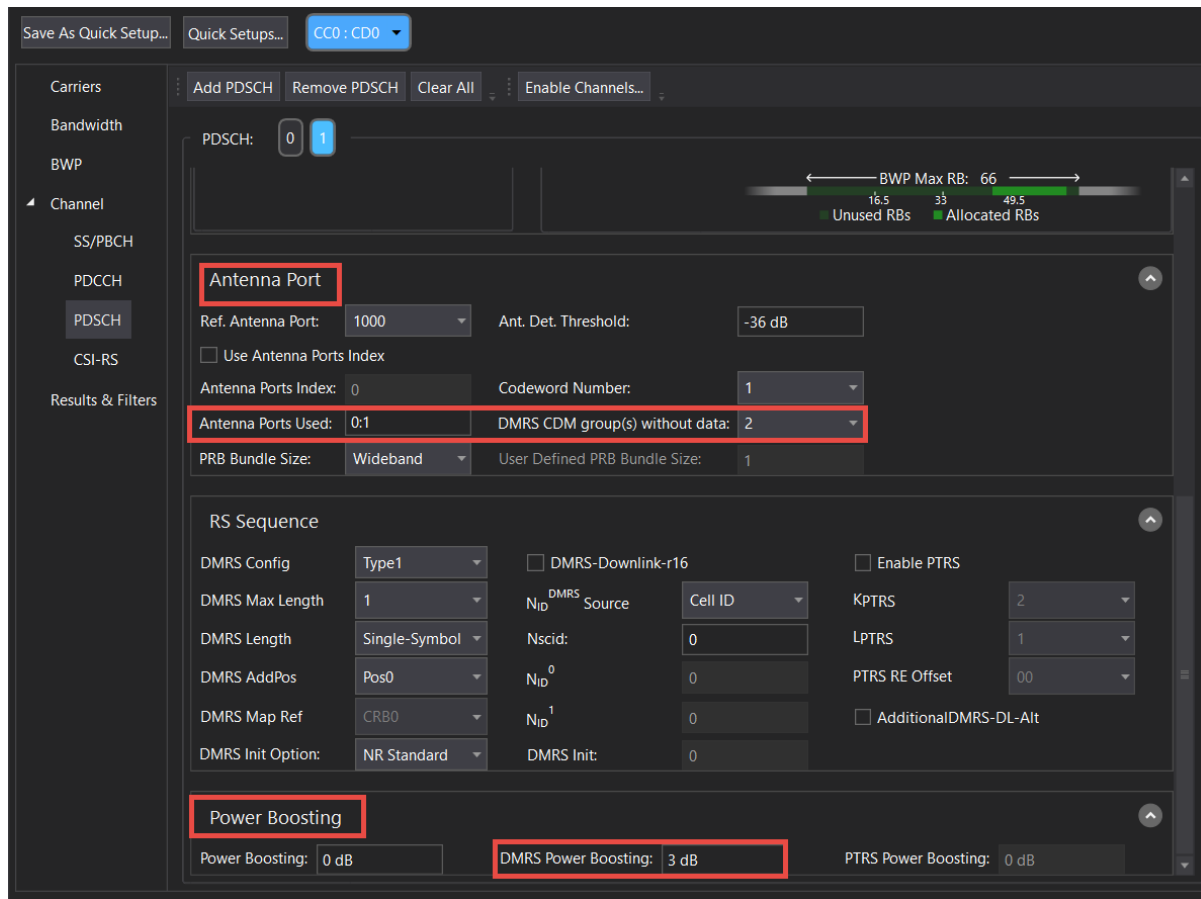
– RB Number to **18 RB**



26. Scroll down and open the Antenna Port dropdown and set:

- Antenna Ports Used to **0:1**
- DMRS CDM group(s) without data to **2**.

27. Select the **Power Boosting dropdown and verify that DMRS Power Boosting is set to **3 dB**.**

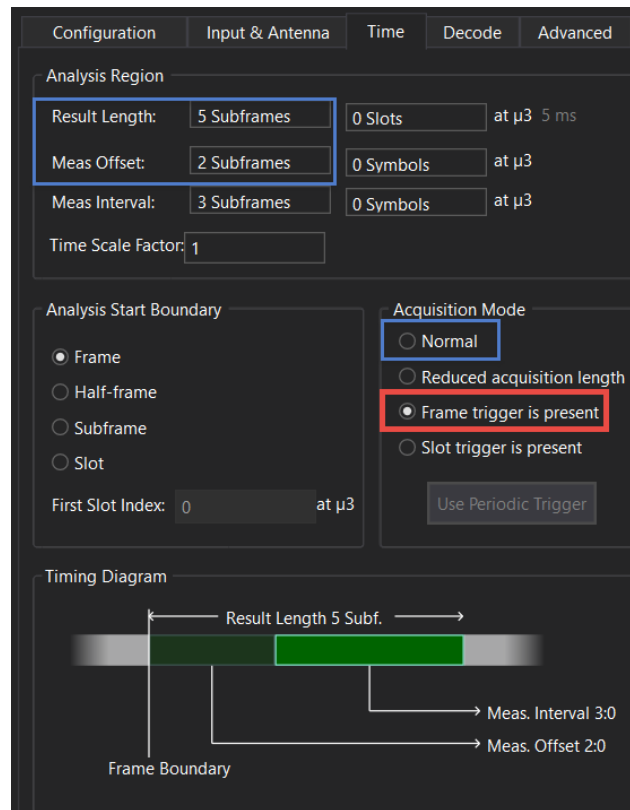


Now you should see the demodulated signal and EVM results per layer in the Frame Summary for PDSCH0 and PDSCH1.

28. To configure the Analysis region, select the **Time tab and set:**

- Result Length to **5 Subframes**
- Meas Interval to **2 Subframes**
- Enable **Frame Trigger** is present.

We are using an external trigger for this example so selecting Frame Trigger is Present will use the external trigger and will speed up the measurement significantly. If not using an external trigger, set to Normal.



TIP

To improve setup speed

Live measurement:

- Use external frame trigger and enable Frame trigger is present. The real frame boundary must be within $\pm 50 \mu\text{s}$ of the external trigger.
- If external frame trigger is not available, use Reduced acquisition length. The reduced acquisition length may fail to synchronize in scenarios where > 1 frame SSB periodicity are defined, unless hardware triggering is used.
- Change Analysis Start Boundary to Subframe.
- Reduce Result Length and Measurement Interval.

Playback mode

- Reduce the Result Length and Measurement Interval.
- Set Analysis Start Boundary to Subframe.
- Reduce the number of active traces.

29. To configure the PBCH and PDSCH decoding, select the **Decode** tab and set.

- PBCH Decode to **Decoded TB**
- PDSCH Decode to **Decoded TB**
- PDSCH Decoder Algorithm to **Offset Min Sum** (default)

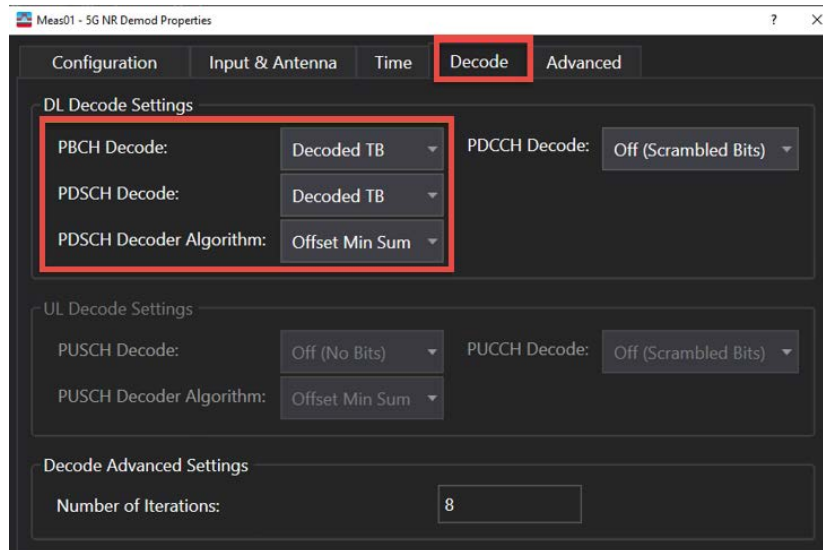
NOTE

VSA2023U2 or later releases support a user selectable Decoder Algorithm.

Offset Min-Sum (Default) - Specifies the layered belief propagation algorithm with offset min-sum approximation. This is faster but less accurate than Belief Propagation.

Belief Propagation - Specifies the belief-passing or message-passing algorithm. This is better for accuracy but slow. Use for receiver sensitivity test where the SNR is very small.

For successful PDSCH decoding (i.e. CRC pass), make sure the RNTI values (used for scrambling) and Transport Block Size matches between the transmitted signal and VSA. (Transport block size depends on MCS table, MCS value, TB Scaling Factor S, and xOverhead under PDSCH channel setting).



30. Select the **Advanced** tab and select the **DC Punctured** check box.

As part of conformance test, 3GPP has defined different equalizer training and tracking for EVM measurements. 3GPP Conformance Test is enabled by default where Tracking, Equalizer Training and EVM Window, and Symbol Timing is applied per 3GPP conformance test requirement. For FR1, no tracking is applied. For FR2, Phase Tracking using PTRS is applied.

5G NR counts the DC subcarrier as a valid subcarrier for rate-matching purposes. The network decides if the DC subcarrier is modulated or not. High LO feedthrough will impact demodulation and EVM performance of the input signal. This is OFF by default.

The screenshot displays the 'Advanced' configuration tab in the VSA Software. The '3GPP Conformance Test' checkbox is checked and highlighted with a red box. Below it, the 'Tracking' section has 'Phase' checked and 'Timing' unchecked, with 'Tracking Source' set to '3GPP'. The 'Equalizer Training' section has 'Signal Source' set to 'RS', 'Time Basis' set to 'Per Frame', and 'Freq Moving Avg. Filter' checked and set to '19 RS'. The 'EVM Window and Symbol Timing' section has 'EVM Window Length Mode' set to '3GPP', 'EVM Window Length in Samples' set to '1 samples', 'Symbol Time Adjustment Mode' set to 'Max of EVM Window Start/End', and '% of FFT Duration' set to '-3.125 %'. The 'Transient Period' section has 'Excluded' unchecked, 'Length' set to '2 μs', and 'Power Change Threshold' set to '10 dB'. The 'IQ Impairments' section has 'IQ Imb. Estimation Mode' set to 'Off', 'Compensate IQ Imb.' unchecked, 'Compensate IQ Offset' unchecked, and 'DC Punctured' checked and highlighted with a red box. The 'UL Spectrum Flatness' section has 'Spectrum Flatness Enabled' checked, 'Test Environment Condition' set to 'Normal', and 'Test Tolerance' set to '1.4 dB'. The 'Error Vector Unit' section has 'Time Domain' set to 'Per Symbol' and 'Freq Domain' set to 'Per Subcarrier'.

Configuration | Input & Antenna | Time | Decode | **Advanced**

☒ 3GPP Conformance Test

Tracking:

☐ Amplitude
☒ Phase
☐ Timing
Tracking Source: 3GPP

Equalizer Training

Signal Source: RS
Time Basis: Per Frame
☒ Freq Moving Avg. Filter: 19 RS

EVM Window and Symbol Timing

EVM Window Length Mode: 3GPP
EVM Window Length in Samples: 1 samples
Symbol Time Adjustment Mode: Max of EVM Window Start/End
% of FFT Duration: -3.125 %

Transient Period

☐ Excluded
Length: 2 μs
Power Change Threshold: 10 dB

IQ Impairments

IQ Imb. Estimation Mode: Off
☐ Compensate IQ Imb.
☐ Compensate IQ Offset
☒ **DC Punctured**

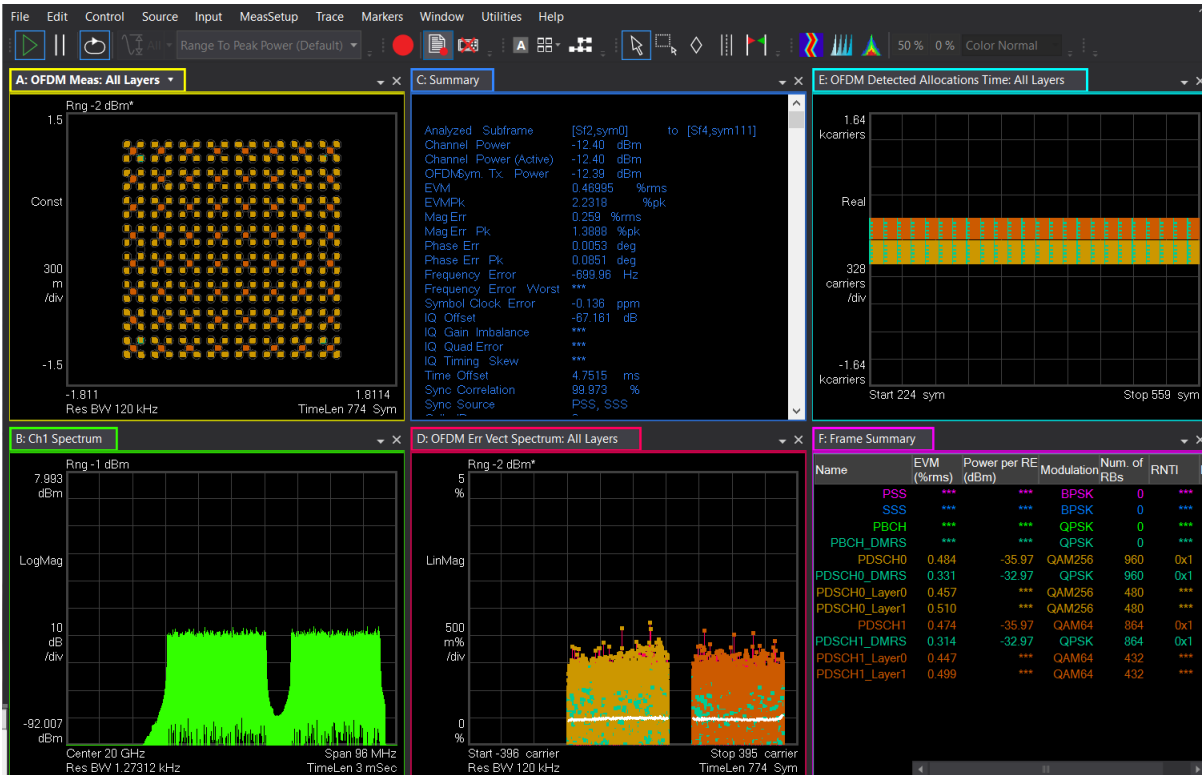
UL Spectrum Flatness

☒ Spectrum Flatness Enabled
Test Environment Condition: Normal
Test Tolerance: 1.4 dB

Error Vector Unit

Time Domain: Per Symbol
Freq Domain: Per Subcarrier

31. Close the 5G NR Properties dialog, start a new sweep to update the display, then view the results.



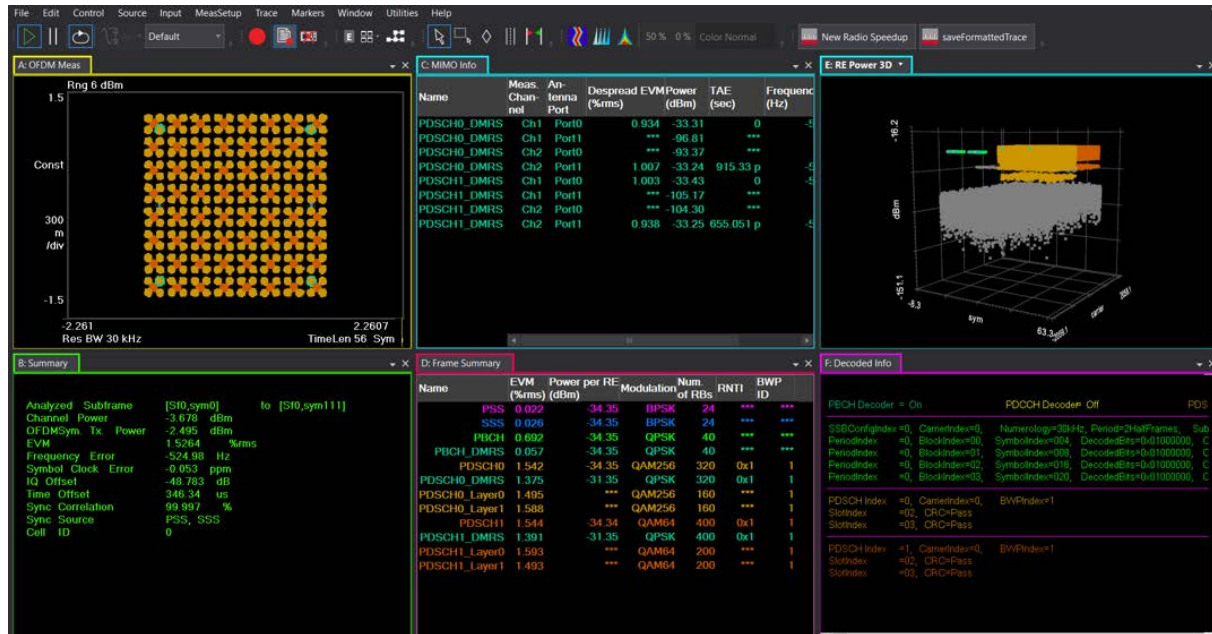
- Trace A: Composite constellation diagram showing different modulation formats for the different channels/signals present in the transmitted signal. See Trace F (Frame Summary) for the list of channels and modulation formats.
- Trace C: Summary trace showing composite error metrics.
- Trace D: Error Vector Spectrum showing EVM versus subcarrier and symbol.
- Trace E: Detected Allocations Time showing the detected allocations of all channels/signals within the measurement interval.
- Trace F: Frame Summary. EVM, per Layer EVM, Power per RE, Mod Format, Number of RB, RNTI, and BWP ID of the individual channels/signals.

One of the most powerful tools in the 89600 VSA is the coupling of markers across different measurements, traces, and domains. Coupled markers allow you to understand the identity and characteristics of a symbol simultaneously in time, frequency, and error.

Place a marker on Traces A, D, and E and couple the markers (Markers > Couple Markers), and then show the results in a markers window (Window > Markers).

Right click on Trace D and select **Peak**. The exact symbol associated with this peak EVM can now be understood in terms of time domain symbol index, frequency domain subcarrier number, channel type, modulation format, IQ magnitude, and phase values. Other parameters are shown in the Marker window.

Change the traces so you can see the Constellation diagram, MIMO Info table, Frame Summary Table (or Slot Summary Table), Summary table, 3D Power, Decoded Info plus any additional traces.



- Trace C: MIMO Info table shows EVM, power, and time, frequency and phase offset for each antenna port.

MIMO Info is a type of Matrix Table that provides sortable rows by column, selectable column visibility, and copy/paste and export functionality to share rows of content or complete tables to applications like email, text editing or spreadsheet programs.

- Trace E: 3D trace showing resource element (RE) power per symbol and per subcarrier. This is very useful when verifying base station systems, for example, to make sure the power per each RE is balanced. You can use a marker to read the power and channel information. A marker on this trace cannot be coupled with other traces.
 - Press the mouse wheel and rotate the wheel forward to zoom in, backward to zoom out.
 - Hold left-click of the mouse for panning. Note: If marker is enabled (i.e. not a normal pointer), you will need to hold Alt in order to pan.

- Use right click to auto scale, enable the marker, and change the display to different axes.
- Trace F: The Decoded Info table provides CRC pass/fail for PDSCH and PBCH plus the high layer information that is carried on PBCH.

If CRC of PDSCH fails, make sure the Transport Block Size matches between the transmitted signal and VSA (this depends on MCS table, MCS value, TB Scaling Factor S, and xOverhead under PDSCH channel setting). Also, make sure the RNTI values match since RNTI is used for scrambling.

Result and Display Filtering

Meas Setup > NR Demod Properties > Configuration tab > Results & Filters panel.

BWP ID	Channel	Color	Is Displayed	EVM Include
***	Inactive		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
***	DC		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
***	PSS		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
***	SSS		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
***	PBCH		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
***	PBCH_DMRS		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
1	PDSCH0		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
1	PDSCH0_DMRS		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
1	PDSCH1		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
1	PDSCH1_DMRS		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Results & Filters

Results & Filters table has three configurable columns

Color – sets the color for each channel (affects all traces that display channel-specific information)

- By default colors are kept as they were in previous release.

Is Displayed - Enables or disables the display of the channel in all traces (supplements the per-Trace filtering under Trace -> Digital Demod)

- Uncheck a box to filter the channel out of the trace results. This setting does not affect any EVM calculations.

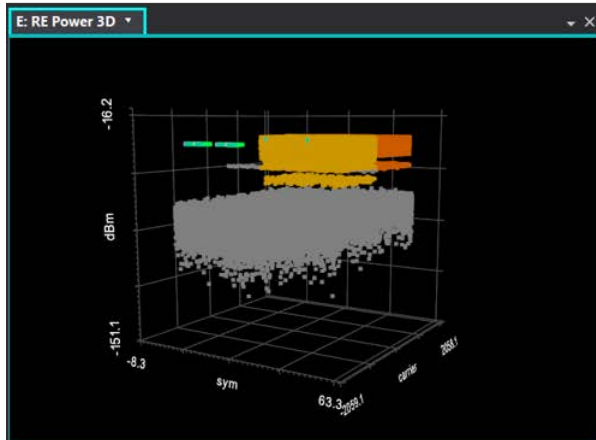
EVM Include - Includes or excludes the channel in the EVM calculations. This also affects trace filtering.

Note 1: Frame Summary table doesn't get affected by Results & Filters settings except for the color setting.

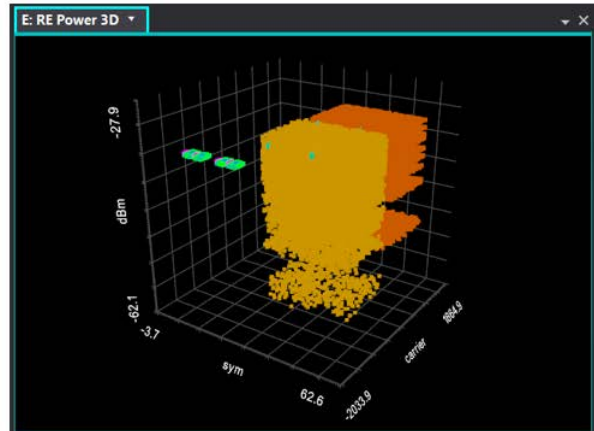
You can try to change colors of some of the channels, and/or filtering out all channels/signals except for SSBlock (PSS, SSS & PBCH) etc.

Clear (Uncheck) "Inactive" and "DC" to remove the inactive resources (subcarriers, symbols) and the DC subcarrier from the display and see the change in the 3D plot:

Before:



After:



You can now auto-scale the 3D plot and only see the active channels/signals being displayed.

Per-Trace Filtering

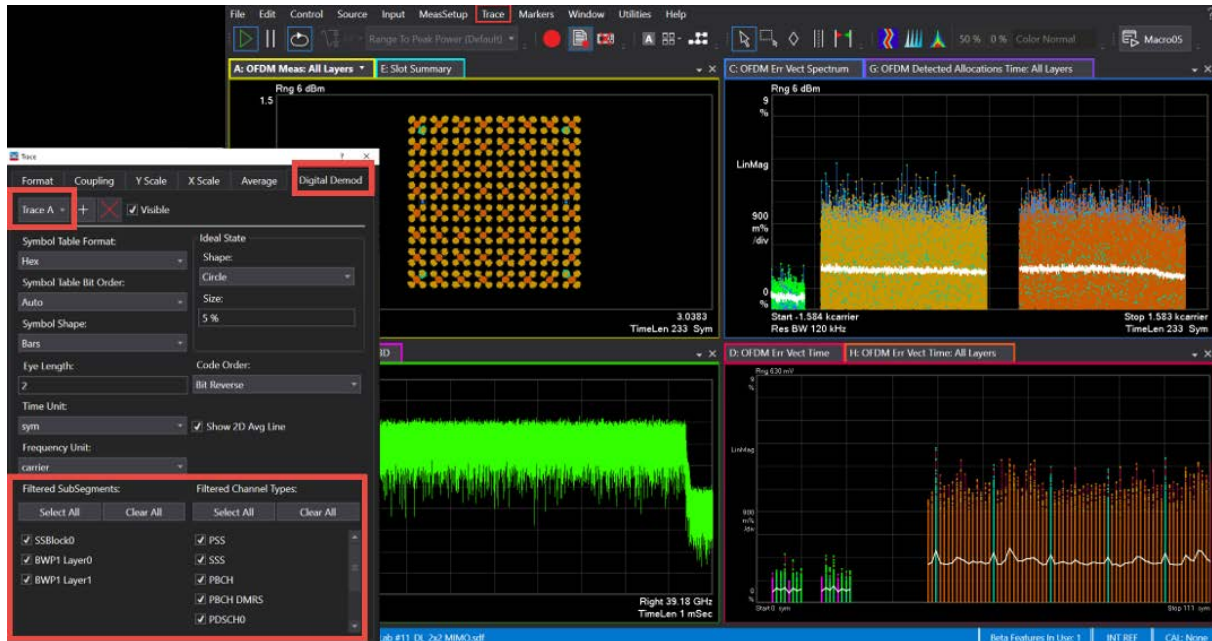
Trace > Digital Demod

In addition to the Results & Filters, VSA also has per-trace filtering to filter by subsegments and/or channels. Subsegment means MIMO Layers, BWP and SSBlock.

The following traces can be filtered by subsegments:

- OFDM Meas
- OFDM Ref
- Error Vector Spectrum
- Error Vector Time

– Detected Allocations Time trace



To setup the VSA Using a UXR Recorded Waveform File

1. Open the VSA software.

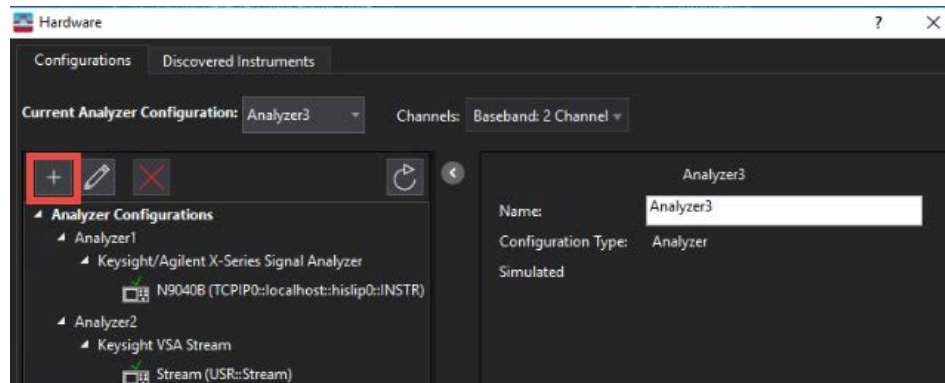
To access the VSA software, go to the Windows Start menu and find Keysight 89600 Software (latest installed version) folder and run the software.

NOTE

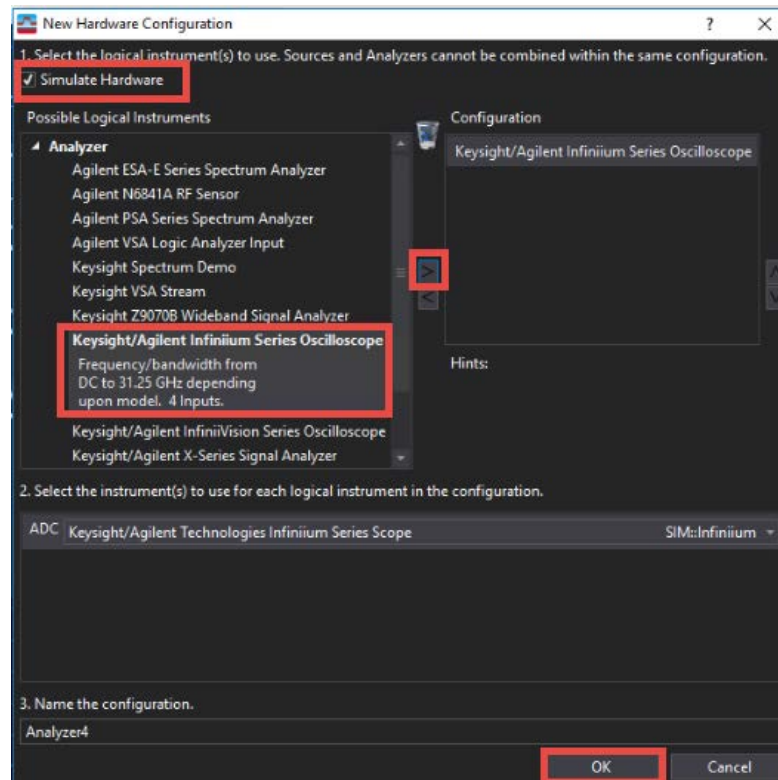
If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

2. From the VSA menu bar, select **File > Preset > All** to set the VSA to a known state.
3. To configure the hardware, go to **Utilities > Hardware > Configurations**.
If it is already configured, continue with **step 9**.

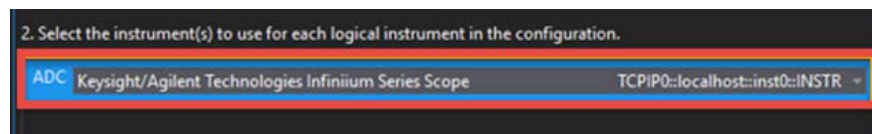
4. In the **Configuration** tab, select the **+** icon.



5. In the New Hardware Configuration dialog, select **Simulate Hardware** and scroll down the Possible Logical Instruments and select **Keysight/Agilent Infiniium Series Oscilloscope**, and then select the right arrow to move it under Configuration.

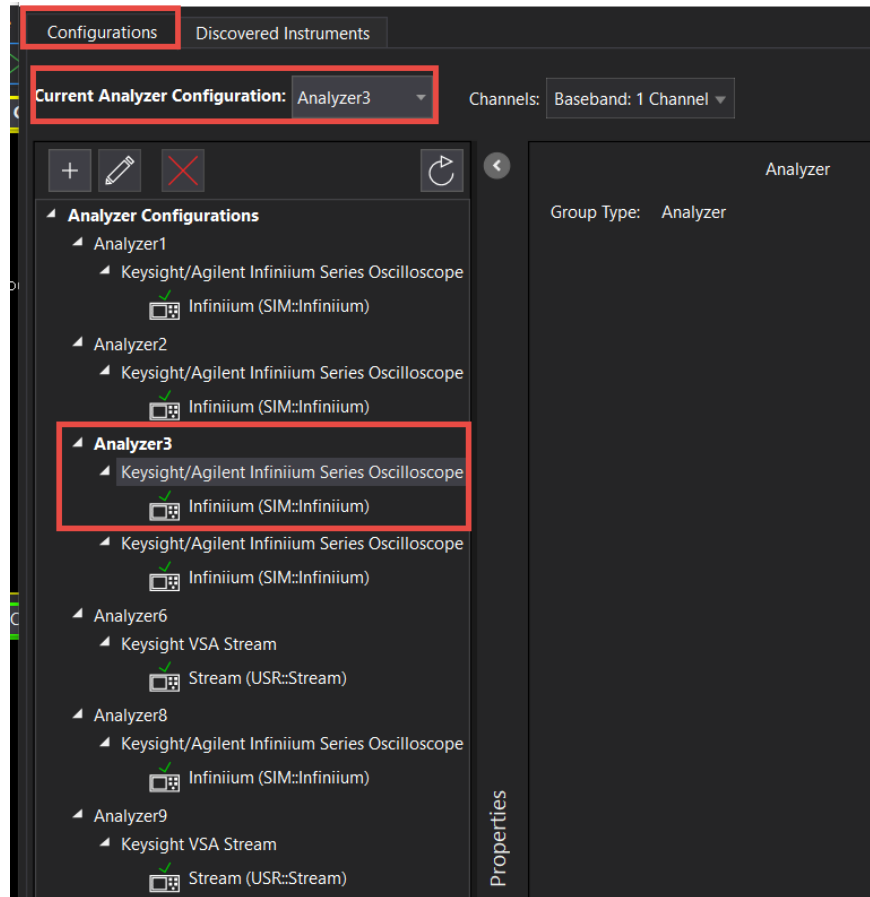


6. From the middle of the dialog box, select the UXR to be used.



7. Select **OK** to create the UXR configuration.

8. In the **Configurations** tab, set the Current Analyzer Configuration, select the Analyzer number for the new configuration. In this example **Analyzer 3**.



9. If you do not have access to a Keysight Infiniium UXR Real-Time Oscilloscope, a UXR recorded waveform file has been included in the Examples waveform file folder on the VXG.

Go to: D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

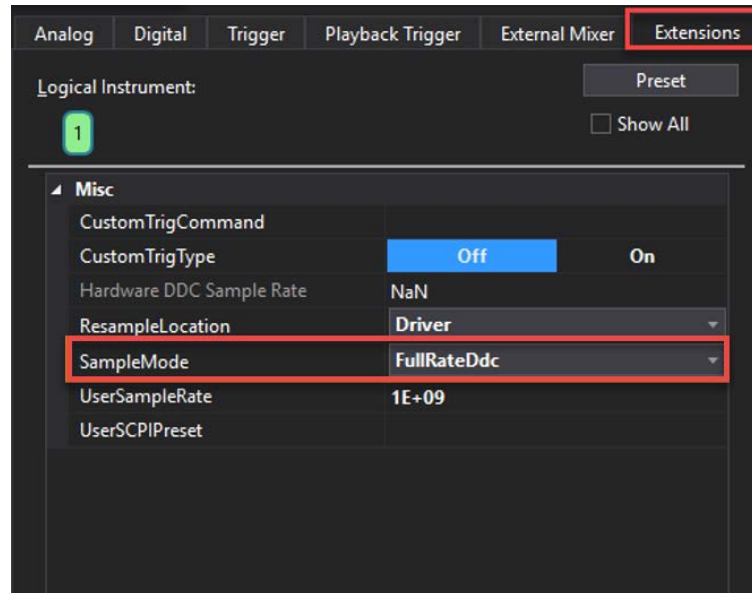
Copy the **MIMO_UXR_Recording.sdf** file to the signal analyzer or the PC running the VSA application.

10. From the Menu Bar, select **File > Recall > Recall Recording** and select **MIMO_UXR_Recording.sdf**.

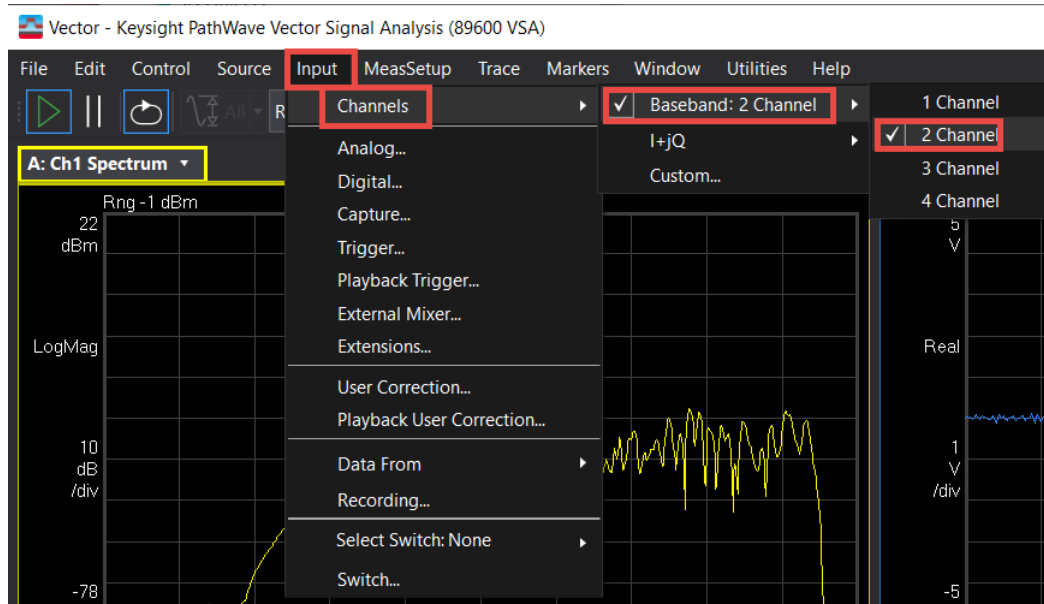
NOTE

Recalling the recording will setup all of the parameters described below. If you want to become familiar with the VSA setup, continue on with the remaining steps.

11. From the menu bar, select **Input > Extensions > Sample Mode > FullRate DDC**.




12. From the menu bar, select **Input > Channels > RF > 2 Channels**.



13. Set the center frequency of both channels to **28 GHz** and span to **100 MHz**.

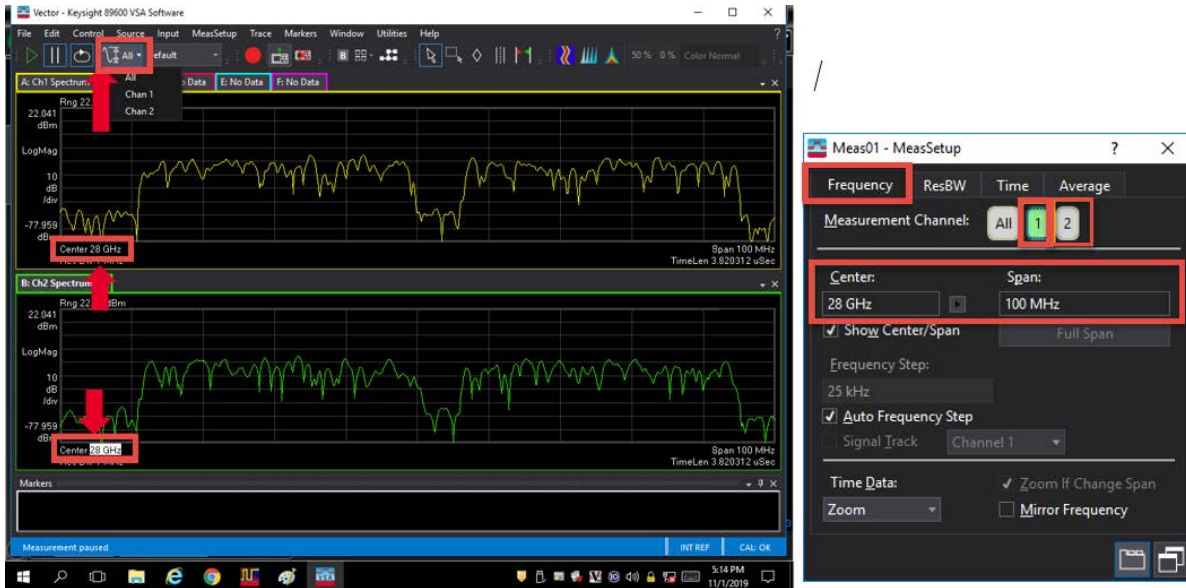
You can also set the frequency and span of both channels under Meas Setup > Frequency.

If you are using a UXR, Select Autorange .

NOTE

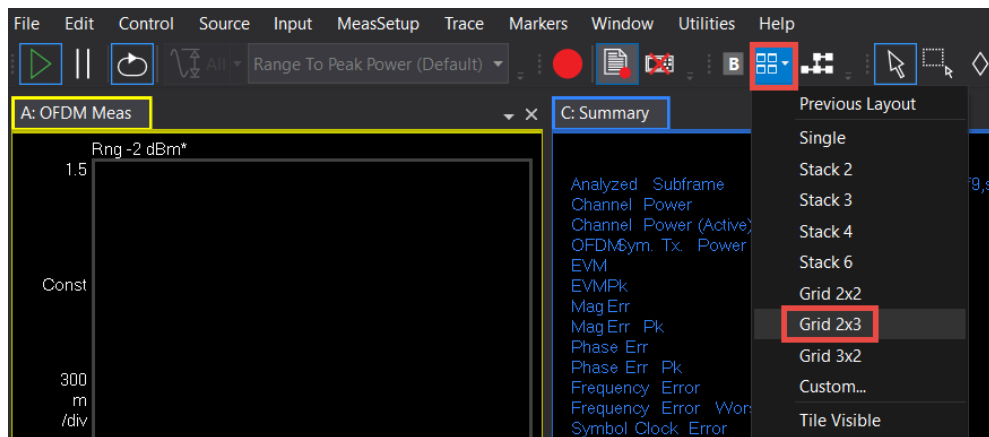
Autorange does not work if you are simulating the waveform with the UXR recording. Continue with the next step.

Auto Range samples the current input signal and then sets the full scale input range to the minimum range that includes the peak voltage sample of the input signal.

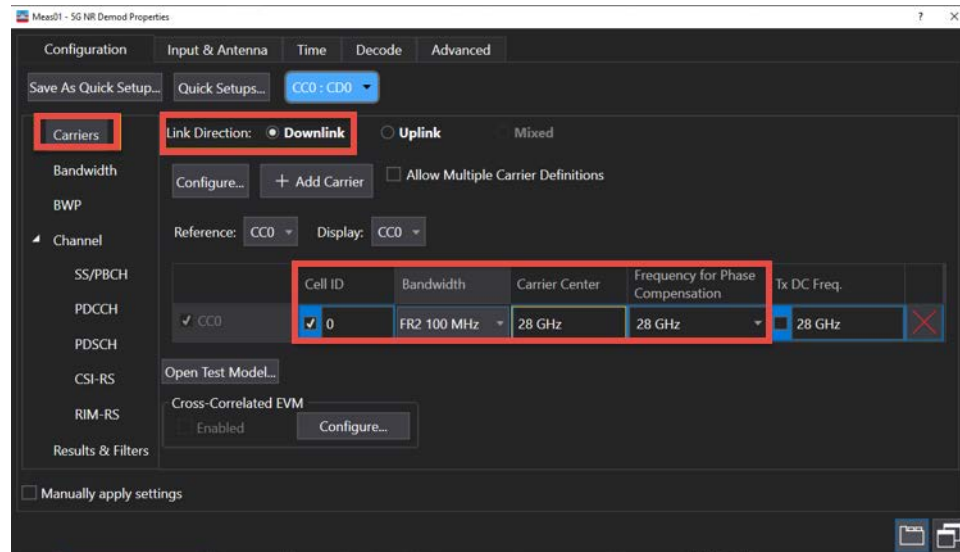


14. From the menu bar, select **MeasSetup** > **Measurement Type** > **Cellular** > **5G NR** > **5G NR Modulation Analysis**.

15. Change the trace layout to **Grid 2x3**.



16. Select **MeasSetup > 5G NR Demod Properties > Configuration** tab and set Bandwidth to **FR2 100 MHz**, Carrier Center and Frequency for Phase compensation are set to **28 GHz**. Select the **Cell ID** checkbox.

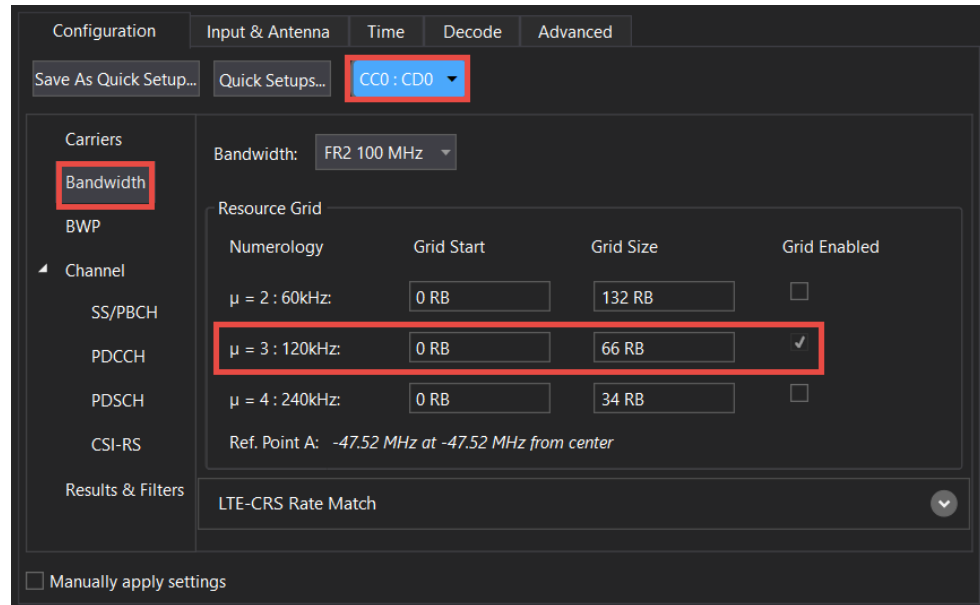


Cell ID is carried on PSS and SSS so that SS/PBCH must be transmitted and enabled for Auto Cell ID to work and must be a Downlink since SS/PBCH is only transmitted in the DL.

Phase compensation is per the 3GPP requirement, and is enabled by default. It is used to compensate for phase differences between symbols caused by upconversion or downconversion. Getting this setting wrong will cause a demod issue. For this example, it is ON and it is applied at the center frequency.

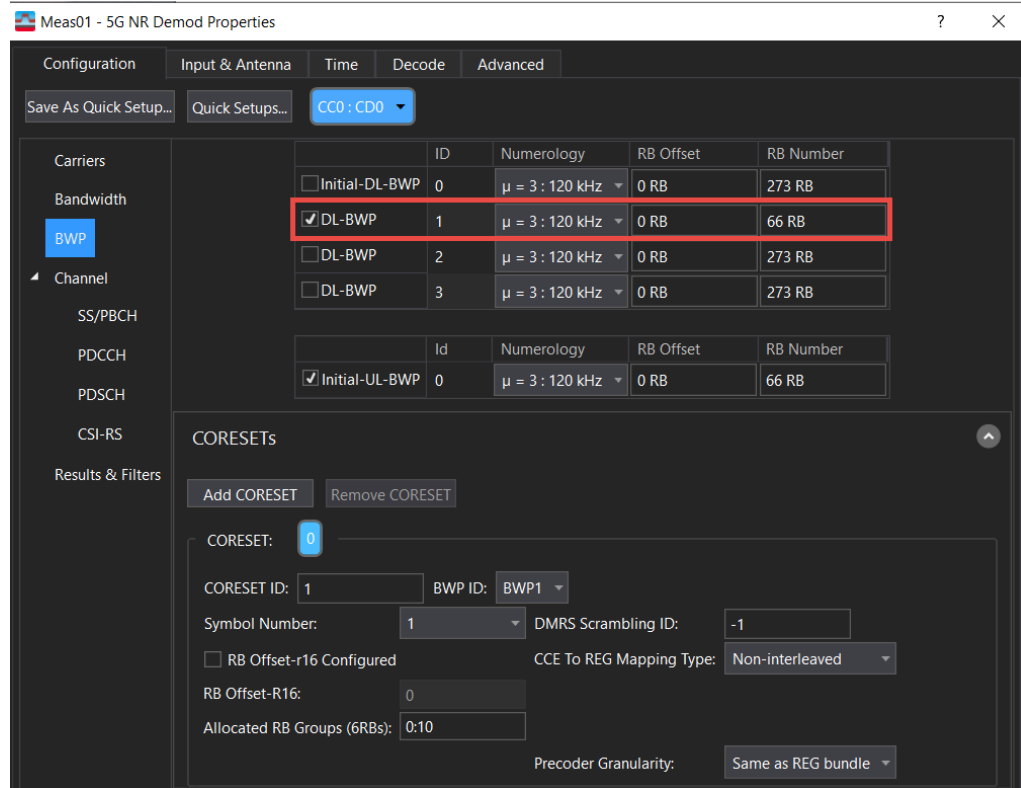
17. Select the **Bandwidth** pane and confirm that numerology is set to $\mu=3:120$ kHz.

The Bandwidth panel is used to configure the Resource Grid for each Numerology. Note that for FR2 100 MHz, the Max RB for 120 kHz Numerology is 66 RB. We will use this value when we configure the PDSCH parameters.



18. Select the **BWP** pane and confirm that **DL-BWP ID 1** is enabled.

For each BWP allocation, configure the numerology (μ) as well as RB allocation information. In this lab, we will use the default 120 kHz numerology, RB Offset = 0 and RB number = 66 RB for a 100 MHz bandwidth signal.



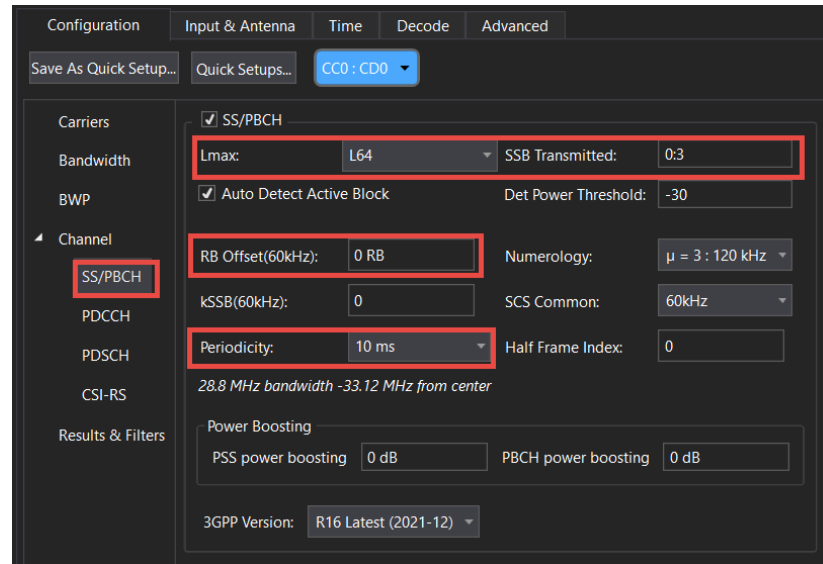
19. Select the **Channel** pane > **SS/PBCH** and set:

- a. RB Offset (60 kHz) to **0 RB**
- b. Periodicity to **10 ms**
- c. Lmax to **L64**
- d. SSB Transmitted to **0:3**

For this example we will use 4 of the 64 SS/PBCH Blocks (beams). In an SSBlock, the period is different fr the different numerologies.

- FR1 up to 3 GHz, L=4
- FR1 3 GHz to 7.125 GHz, L8
- FR2-1, FR2-2, L = 64

The frequency location of an SSBlock is not fixed. In the VSA software, a default value of 46RB and kSSB of 0 subcarriers places it in the center of the carrier bandwidth. Using 0 RB Offset puts the SSB at the lower edge of the carrier.



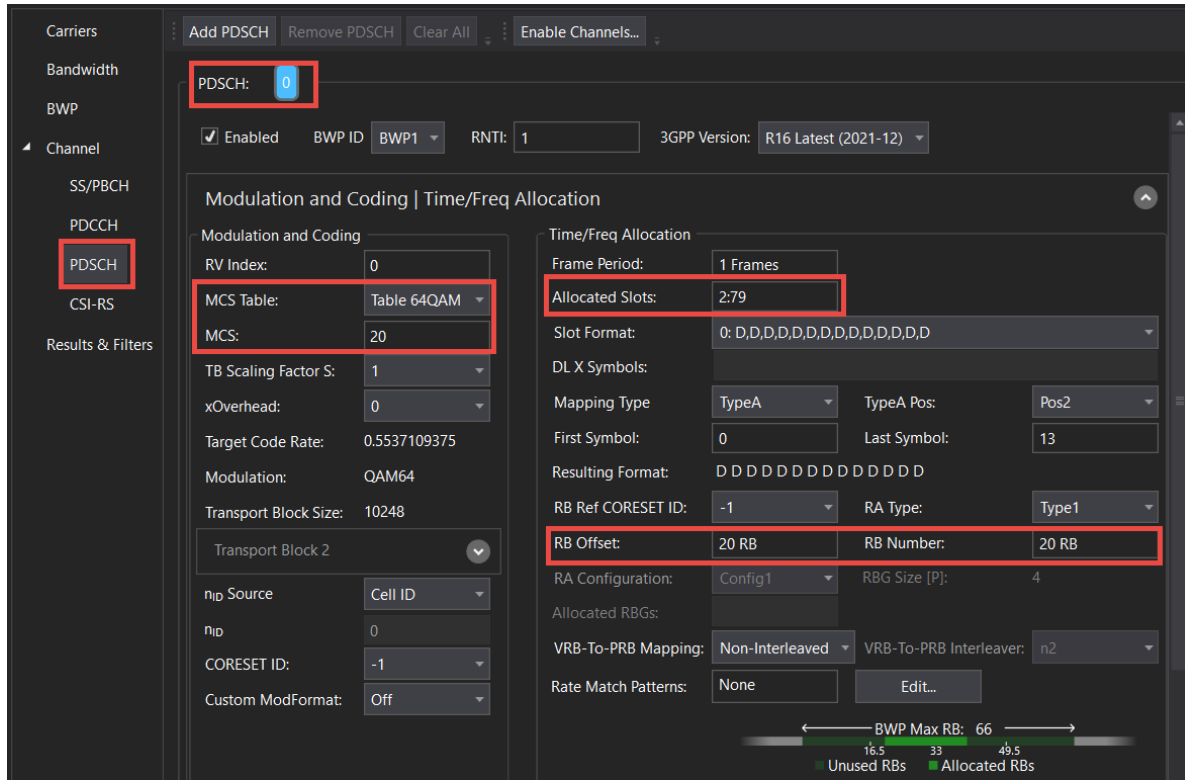
20. To configure the PDSCH0, select the **PDSCH** pane and for PDSCH 0, set:

- MCS Table to **Table 256 QAM**
- MCS to **20**

3GPP has different Tables for PDSCH MCS

- Table 5.1.3.1-1 has 64QAM as max modulation
- Table 5.1.3.1-2 has 256QAM as max modulation
- Table 5.1.3.1-4 has 1024QAM as max modulation
- Table 5.1.3.1-3 has 64QAM as max modulation and is for low spectrum efficiency (LowSE). See 3GPP TS38.214 for more information.
- Allocated Slots to **2:79**
- RB Offset to **20 RB**

– RB Number to **20 RB**



21. Scroll down and select the Antenna Port dropdown and set:

- Antenna Ports Used, 1 to **0:1**
- DMRS CDM Group(s) without data to **2** (to match the PathWave setup)

22. Under the RS Sequence dropdown, DMRS and PTRS are default settings, but this is where you would change the RS settings.

23. Select the **Power Boosting** dropdown and verify that DMRS Power Boosting has automatically been set to **3 dB**.

When "DMRS CDM group without data" is set to 2, the DMRS power boosting becomes 3 dB per 3GPP definition.

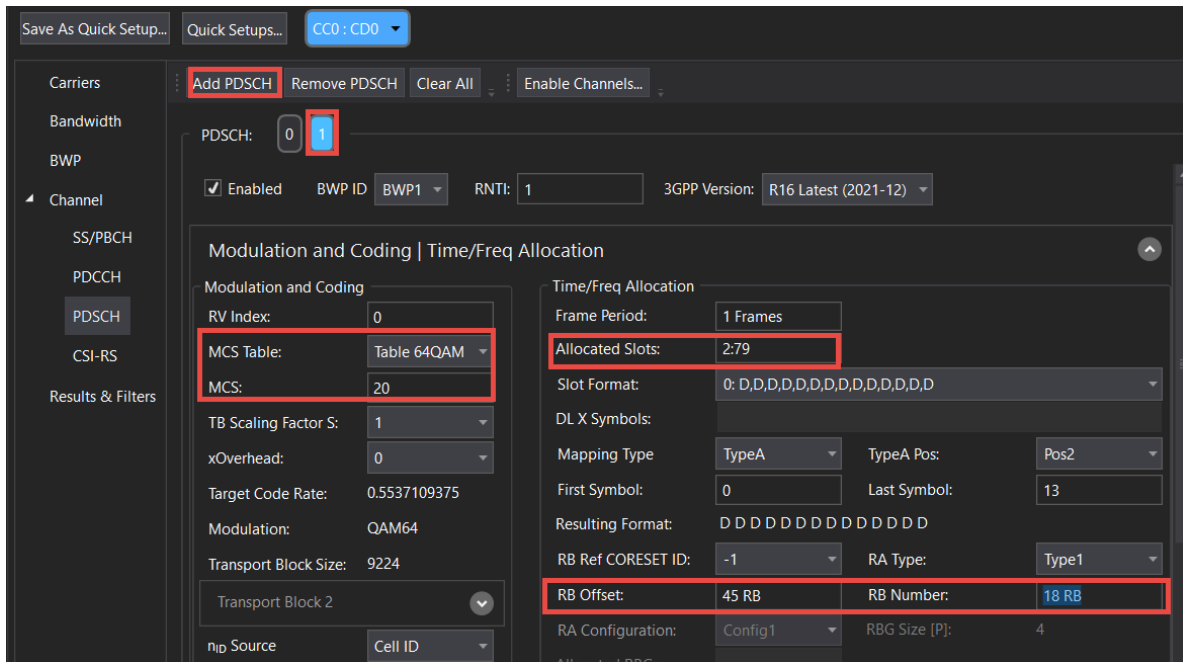
The screenshot displays the VSA Software configuration interface for PDSCH1. The left sidebar lists various configuration categories: Carriers, Bandwidth, BWP, Channel, SS/PBCH, PDCCH, PDSCH, and CSI-RS. The 'PDSCH' category is selected. The main configuration area is divided into several sections. The 'Antenna Port' section is highlighted with a red box and contains the following settings: 'Ref. Antenna Port' (1000), 'Ant. Det. Threshold' (-36 dB), 'Use Antenna Ports Index' (unchecked), 'Antenna Ports Used' (0:1), 'Codeword Number' (1), and 'DMRS CDM group(s) without data' (2). The 'RS Sequence' section is also highlighted with a red box and contains the following settings: 'DMRS Config' (Type1), 'DMRS Max Length' (1), 'DMRS Length' (Single-Symbol), 'DMRS AddPos' (Pos0), 'DMRS Map Ref' (CRB0), 'DMRS Init Option' (NR Standard), 'DMRS-Downlink-r16' (unchecked), 'DMRS Source' (Cell ID), 'N_{ID}^{DMRS}' (0), 'N_{ID}⁰' (0), 'N_{ID}¹' (0), 'DMRS Init' (0), 'Enable PTRS' (unchecked), 'KPTRS' (2), 'LPTRS' (1), 'PTRS RE Offset' (00), and 'AdditionalDMRS-DL-Alt' (unchecked). The 'Power Boosting' section at the bottom is highlighted with a red box and contains the following settings: 'Power Boosting' (0 dB), 'DMRS Power Boosting' (3 dB), and 'PTRS Power Boosting' (0 dB). A red box also highlights the 'DMRS CDM group(s) without data' dropdown menu, which is set to 2.

24. To add and configure PDSCH1, select **Add PDSCH**.

25. Select **PDSCH1** and set:

- MCS Table to **Table 64 QAM**
- MCS to **20**
- Allocated Slots to **2:79**
- RB Offset to **45 RB**

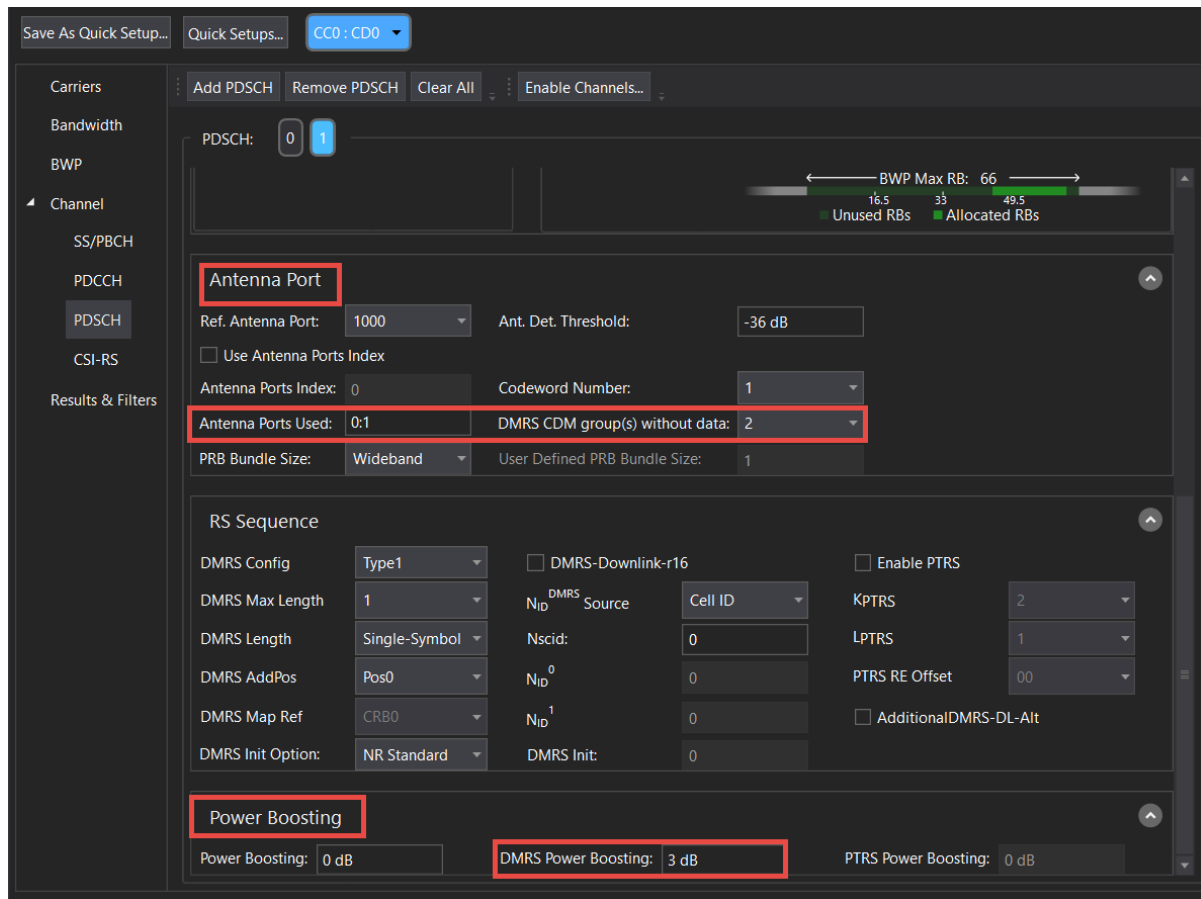
– RB Number to **18 RB**



26. Scroll down and open the Antenna Port dropdown and set:

- Antenna Ports Used to **0:1**
- DMRS CDM group(s) without data to **2**.

27. Select the **Power Boosting dropdown and verify that DMRS Power Boosting is set to 3 dB.**



28. To configure the Analysis region, select the **Time tab and set:**

- Result Length to **5 Subframes**
- Meas Interval to **2 Subframes**
- Enable **Frame Trigger** is present. **NOTE:** if using the UXR recording, leave Frame Trigger set to **Normal**.

The example measurement above uses an external trigger thus we would use Frame Trigger is Present to speed up the measurement significantly. If not using an external trigger or are using the UXR recording, set to Normal.

The screenshot shows the 'Configuration' tab of the VSA Software interface. The 'Analysis Region' section has 'Result Length' set to 5 Subframes, 'Meas Offset' to 2 Subframes, and 'Meas Interval' to 3 Subframes. The 'Analysis Start Boundary' is set to 'Frame'. The 'Acquisition Mode' section has 'Frame trigger is present' selected. A 'Timing Diagram' at the bottom illustrates the measurement window relative to the frame boundary, showing a result length of 5 subframes, a measurement interval of 3 subframes, and a measurement offset of 2 subframes.

TIP

To improve setup speed

Live measurement:

- Use external frame trigger and enable Frame trigger is present. The real frame boundary must be within $\pm 50 \mu\text{s}$ of the external trigger.
- If external frame trigger is not available, use Reduced acquisition length. The reduced acquisition length may fail to synchronize in scenarios where > 1 frame SSB periodicity are defined, unless hardware triggering is used.
- Change Analysis Start Boundary to Subframe.
- Reduce Result Length and Measurement Interval.

Playback mode

- Reduce the Result Length and Measurement Interval.
- Set Analysis Start Boundary to Subframe.

- Reduce the number of active traces.

29. To configure the PBCH and PDSCH decoding, select the **Decode** tab and set.

- PBCH Decode to **Decoded TB**
- PDSCH Decode to **Decoded TB**
- PDSCH Decoder Algorithm to **Offset Min Sum** (default)

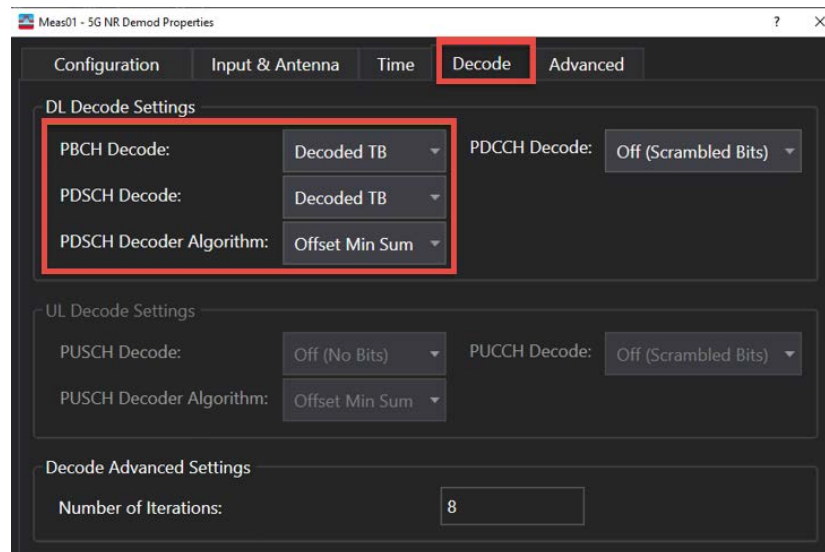
NOTE

VSA2023U2 or later releases support user selectable Decoder Algorithm.

Offset Min-Sum (Default) - Specifies the layered belief propagation algorithm with offset min-sum approximation. This is faster but less accurate than Belief Propagation.

Belief Propagation - Specifies the belief-passing or message-passing algorithm. This is better for accuracy but slow. Use for receiver sensitivity test where the SNR is very small.

For successful PDSCH decoding (i.e. CRC pass), make sure the RNTI values (used for scrambling) and Transport Block Size matches between the transmitted signal and VSA. (Transport block size depends on MCS table, MCS value, TB Scaling Factor S, and xOverhead under PDSCH channel setting).



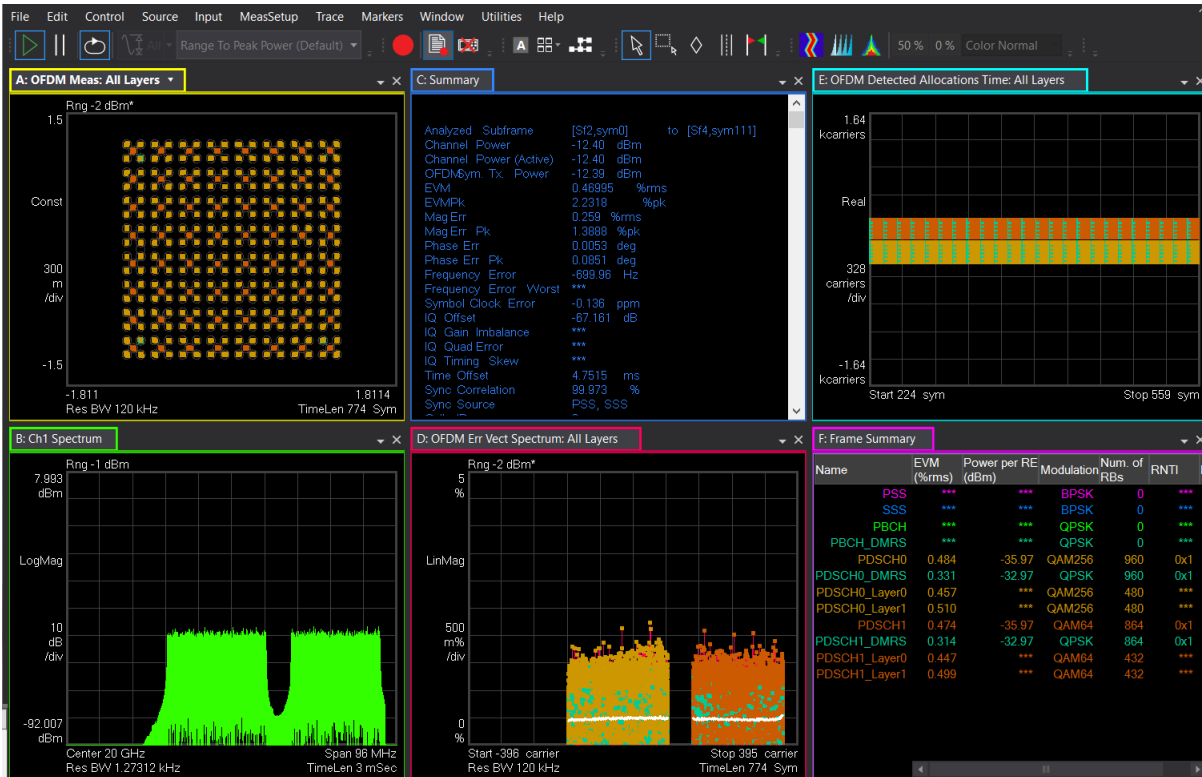
30. Select the **Advanced** tab and select the **DC Punctured** check box.

As part of conformance test, 3GPP has defined different equalizer training and tracking for EVM measurements. 3GPP Conformance Test is enabled by default where Tracking, Equalizer Training and EVM Window, and Symbol Timing is applied per 3GPP conformance test requirement. For FR1, no tracking is applied. For FR2, Phase Tracking using PTRS is applied.

5G NR counts the DC subcarrier as a valid subcarrier for rate-matching purposes. The network decides if the DC subcarrier is modulated or not. High LO feedthrough will impact demodulation and EVM performance of the input signal. This is OFF by default.

The screenshot displays the 'Advanced' configuration tab in the VSA Software. The '3GPP Conformance Test' checkbox is checked. The 'Tracking' section shows 'Amplitude' and 'Timing' are unchecked, while 'Phase' is checked. The 'Tracking Source' is set to '3GPP'. The 'Equalizer Training' section shows 'Signal Source' as 'RS' and 'Time Basis' as 'Per Frame'. The 'Freq Moving Avg. Filter' is set to '19 RS'. The 'EVM Window and Symbol Timing' section shows 'EVM Window Length Mode' as '3GPP', 'EVM Window Length in Samples' as '1 samples', 'Symbol Time Adjustment Mode' as 'Max of EVM Window Start/End', and '% of FFT Duration' as '-3.125 %'. The 'Transient Period' section shows 'Excluded' is unchecked, 'Length' is '2 μ s', and 'Power Change Threshold' is '10 dB'. The 'IQ Impairments' section shows 'IQ Imb. Estimation Mode' as 'Off', 'Compensate IQ Imb.' is unchecked, 'Compensate IQ Offset' is unchecked, and 'DC Punctured' is checked. The 'UL Spectrum Flatness' section shows 'Spectrum Flatness Enabled' is checked, 'Test Environment Condition' as 'Normal', and 'Test Tolerance' as '1.4 dB'. The 'Error Vector Unit' section shows 'Time Domain' as 'Per Symbol' and 'Freq Domain' as 'Per Subcarrier'.

31. Close the 5G NR Properties dialog to view the results.



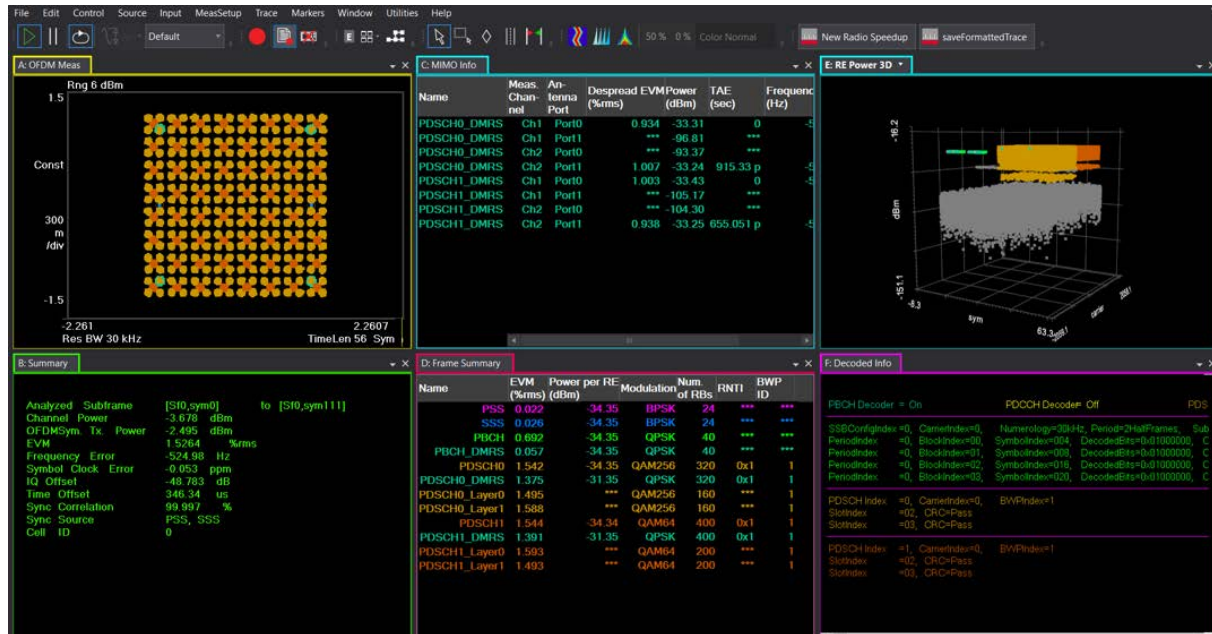
- Trace A: Composite constellation diagram showing different modulation formats for the different channels/signals present in the transmitted signal. See Trace F (Frame Summary) for the list of channels and modulation formats.
- Trace C: Summary trace showing composite error metrics.
- Trace D: Error Vector Spectrum showing EVM versus subcarrier and symbol.
- Trace E: Detected Allocations Time showing the detected allocations of all channels/signals within the measurement interval.
- Trace F: Frame Summary. EVM, per Layer EVM, Power per RE, Mod Format, Number of RB, RNTI, and BWP ID of the individual channels/signals.

One of the most powerful tools in the 89600 VSA is the coupling of markers across different measurements, traces, and domains. Coupled markers allow you to understand the identity and characteristics of a symbol simultaneously in time, frequency, and error.

Place a marker on Traces A, D, and E and couple the markers (Markers > Couple Markers), and then show the results in a markers window (Window > Markers).

Right click on Trace D and select **Peak**. The exact symbol associated with this peak EVM can now be understood in terms of time domain symbol index, frequency domain subcarrier number, channel type, modulation format, IQ magnitude, and phase values. Other parameters are shown in the Marker window.

Change the traces so you can see the Constellation diagram, MIMO Info table, Frame Summary Table (or Slot Summary Table), Summary table, 3D Power, Decoded Info plus any additional traces.



- Trace C: MIMO Info table shows EVM, power, and time, frequency and phase offset for each antenna port.

MIMO Info is a type of Matrix Table that provides sortable rows by column, selectable column visibility, and copy/paste and export functionality to share rows of content or complete tables to applications like email, text editing or spreadsheet programs.

- Trace E: 3D trace showing resource element (RE) power per symbol and per subcarrier. This is very useful when verifying base station systems, for example, to make sure the power per each RE is balanced. You can use a marker to read the power and channel information. A marker on this trace cannot be coupled with other traces.
 - Press the mouse wheel and rotate the wheel forward to zoom in, backward to zoom out.
 - Hold left-click of the mouse for panning. Note: If marker is enabled (i.e. not a normal pointer), you will need to hold Alt in order to pan.

- Use right click to auto scale, enable the marker, and change the display to different axes.
- Trace F: The Decoded Info table provides CRC pass/fail for PDSCH and PBCH plus the high layer information that is carried on PBCH.

If CRC of PDSCH fails, make sure the Transport Block Size matches between the transmitted signal and VSA (this depends on MCS table, MCS value, TB Scaling Factor S, and xOverhead under PDSCH channel setting). Also, make sure the RNTI values match since RNTI is used for scrambling.

Working with Traces

- Trace A: Composite constellation diagram showing different modulation formats for the different channels/signals present in the transmitted signal. See Trace F (Frame Summary) for the list of channels and modulation formats.
- Trace C: Summary trace showing composite error metrics.
- Trace D: Error Vector Spectrum showing EVM versus subcarrier and symbol.
- Trace E: Detected Allocations Time showing the detected allocations of all channels/signals within the measurement interval.
- Trace F: Frame Summary. EVM, per Layer EVM, Power per RE, Mod Format, Number of RB, RNTI, and BWP ID of the individual channels/signals.

One of the most powerful tools in the 89600 VSA is the coupling of markers across different measurements, traces, and domains. Coupled markers allow you to understand the identity and characteristics of a symbol simultaneously in time, frequency, and error.

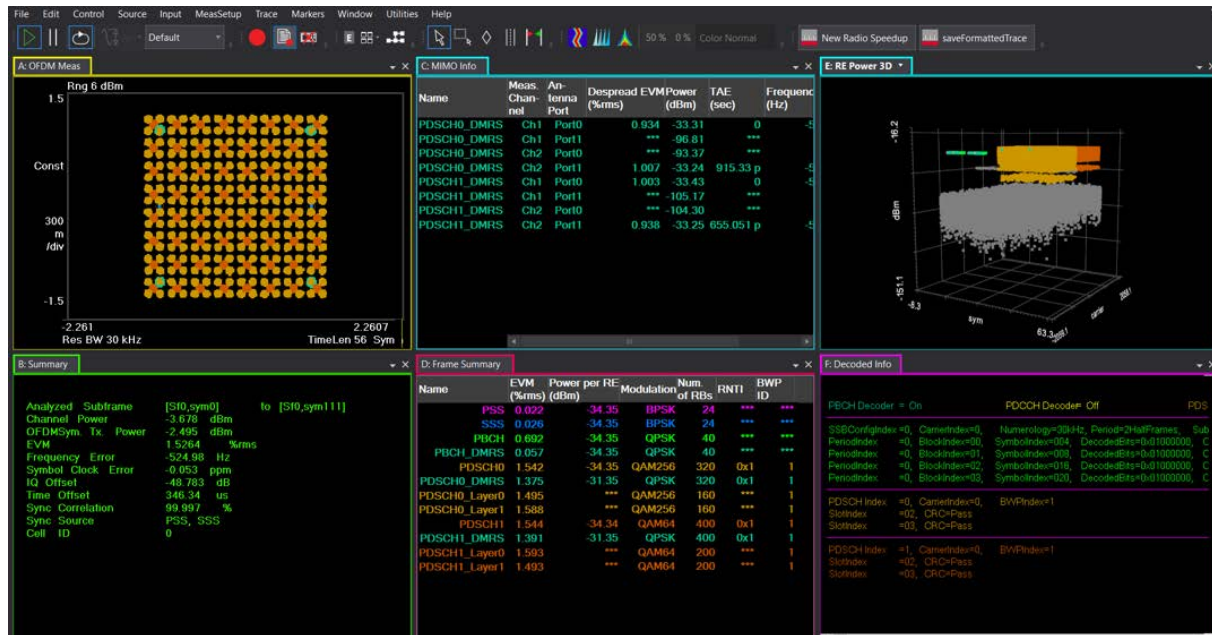
Place a marker on Traces A, D, and E and couple the markers (Markers > Couple Markers), and then show the results in a markers window (Window > Markers).

Right click on Trace D and select **Peak**. The exact symbol associated with this peak EVM can now be understood in terms of time domain symbol index, frequency domain subcarrier number, channel type, modulation format, IQ magnitude, and phase values. Other parameters are shown in the Marker window.

5G NR Measurements Using the VSA Software

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Change the traces so you can see the Constellation diagram, MIMO Info table, Frame Summary Table (or Slot Summary Table), Summary table, 3D Power, Decoded Info plus any additional traces.



- Trace C: MIMO Info table shows EVM, power, and time, frequency and phase offset for each antenna port.

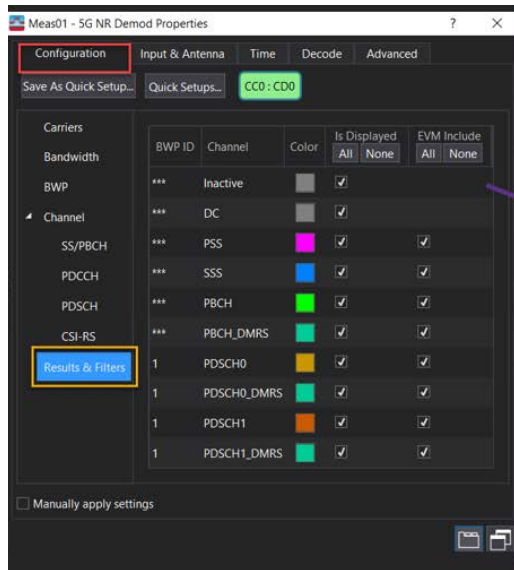
MIMO Info is a type of Matrix Table that provides sortable rows by column, selectable column visibility, and copy/paste and export functionality to share rows of content or complete tables to applications like email, text editing or spreadsheet programs.

- Trace E: 3D trace showing resource element (RE) power per symbol and per subcarrier. This is very useful when verifying base station systems, for example, to make sure the power per each RE is balanced. You can use a marker to read the power and channel information. A marker on this trace cannot be coupled with other traces.
 - Press the mouse wheel and rotate the wheel forward to zoom in, backward to zoom out.
 - Hold left-click of the mouse for panning. Note: If marker is enabled (i.e. not a normal pointer), you will need to hold Alt in order to pan.
 - Use right click to auto scale, enable the marker, and change the display to different axes.
- Trace F: The Decoded Info table provides CRC pass/fail for PDSCH and PBCH plus the high layer information that is carried on PBCH.

If CRC of PDSCH fails, make sure the Transport Block Size matches between the transmitted signal and VSA (this depends on MCS table, MCS value, TB Scaling Factor S, and xOverhead under PDSCH channel setting). Also, make sure the RNTI values match since RNTI is used for scrambling.

Result and Display Filtering

Meas Setup > NR Demod Properties > Configuration tab > Results & Filters panel.



Results & Filters

Results & Filters table has three configurable columns

Color – sets the color for each channel (affects all traces that display channel-specific information)

- By default colors are kept as they were in previous release.

Is Displayed - Enables or disables the display of the channel in all traces (supplements the per-Trace filtering under Trace -> Digital Demod)

- Uncheck a box to filter the channel out of the trace results. This setting does not affect any EVM calculations.

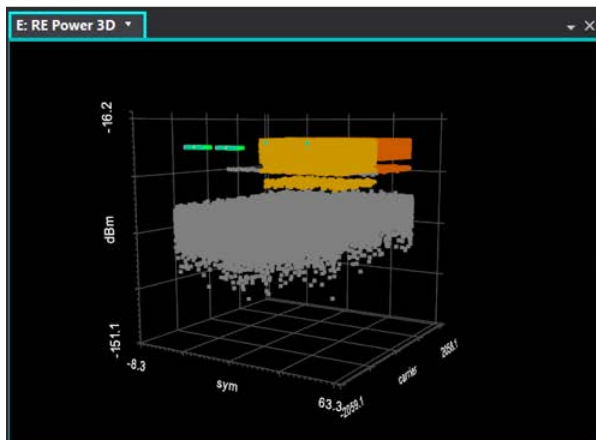
EVM Include - Includes or excludes the channel in the EVM calculations. This also affects trace filtering.

Note 1: Frame Summary table doesn't get affected by Results & Filters settings except for the color setting.

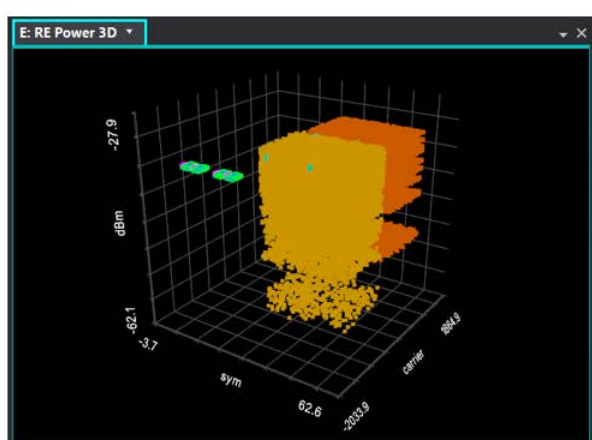
You can try to change colors of some of the channels, and/or filtering out all channels/signals except for SSBLOCK (PSS, SSS & PBCH) etc.

Clear (Uncheck) "Inactive" and "DC" to remove the inactive resources (subcarriers, symbols) and the DC subcarrier from the display and see the change in the 3D plot:

Before:



After:



You can now auto-scale the 3D plot and only see the active channels/signals being displayed.

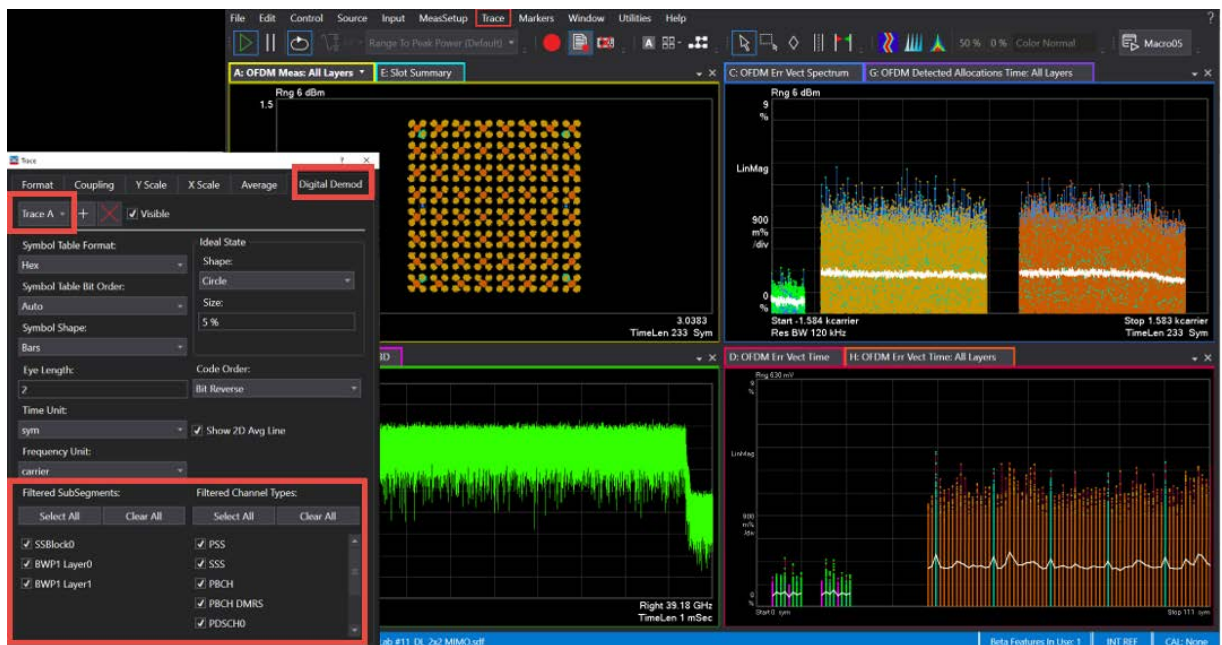
Per-Trace Filtering

Trace > Digital Demod

In addition to the Results & Filters, VSA also has per-trace filtering to filter by subsegments and/or channels. Subsegment means MIMO Layers, BWP and SSBlock.

The following traces can be filtered by subsegments:

- OFDM Meas
- OFDM Ref
- Error Vector Spectrum
- Error Vector Time
- Detected Allocations Time trace



Using the equivalent SCPI commands

On the VXG:

```
SYSTem:PRESet
RF1:FREQuency:CW 28GHz
RF1:POWer:AMPLitude 0dBm
RF2:FREQuency:CW 28GHz
RF2:POWer:AMPLitude 0dBm
CONFigure TX2
SIGNal:MODE NR
SIGNal:NR5G:CCARrier0:TYPE DL
SIGNal:NR5G:CCARrier0:CIDentity 0MIMO
SIGNal:NR5G:CCARrier0:NUM:MODE SINGLE
SIGNal:NR5G:CCARrier0:BWID FR1BW100M
SIGNal:NR5G:CCARrier0:SNUM MU1
SIGNal:NR5G:CCARrier0:SNUM:RB:NUMB 273
SIGNal:NR5G:CCARrier0:DLINK:SSBL:PERiodicity P10MS
SIGNal:NR5G:CCARrier0:DLINK:SSBL:RB:OFFSet 0
SIGNal:NR5G:CCARrier0:DLINK:SCH0:DMRS:PORT '0,1'
SIGNal:NR5G:CCARrier0:DLINK:SCH0:SLOT "2:19"
SIGNal:NR5G:CCARrier0:DLINK:SCH0:RB:OFFSet 2
SIGNal:NR5G:CCARrier0:DLINK:SCH0:RB:NUMBer 80
SIGNal:NR5G:CCARrier0:DLINK:SCH0:MCS:TABL TABL52
SIGNal:NR5G:CCARrier0:DLINK:SCH0:MCS 20
SIGNal:NR5G:CCARrier0:DLINK:SCH0:DMRS:POWer 3
SIGNal:NR5G:CCARrier0:DLINK:SCH0:ADD
SIGNal:NR5G:CCARrier0:DLINK:SCH1:DMRS:PORT '0,1'
SIGNal:NR5G:CCARrier0:DLINK:SCH1:DMRS:CGWD:COUN 2
SIGNal:NR5G:CCARrier0:DLINK:SCH1:SLOT "2:19"
SIGNal:NR5G:CCARrier0:DLINK:SCH1:RB:OFFSet 150
SIGNal:NR5G:CCARrier0:DLINK:SCH1:RB:NUMBer 100
SIGNal:NR5G:CCARrier0:DLINK:SCH1:MCS:TABL TABL51
SIGNal:NR5G:CCARrier0:DLINK:SCH1:MCS 20
```

```
SIGNa1:NR5G:WAVEform:GENerate  
SIGNa1 ON  
SIGNa1:NR5G:TRIGger:SYNC:MARKer M2  
RF1:OUTPut ON  
RF2:OUTPut ON  
RFAL1:OUTPut ON
```

On the Analyzer:

```
INSTRument:SElect VSA89601  
SYSTem:PRESet  
FREQuency:CENTer 28 GHz  
FREQuency:SPAN 122.88 MHz  
INPut:ANALog:RANGe:AUTO  
INITiate:PAUSe  
INP:CHAN:CONF RF,RF  
MEASure:CONFigure NR5G  
NR5G:DBWP:ENABled 1  
NR5G:SSBLoK:ENABled 1  
NR5G:SSBLoK:ROFFset 0  
NR5G:SSBLoK:PERiodicity "Period10Milliseconds"  
NR5G:DBWP:PDSCh1:MCS:TABLE "Table2"  
NR5G:DBWP:PDSCh1:MCS 20  
NR5G:DBWP:PDSCh1:SLOT:ALlocated "2:19"  
NR5G:CCARrier:PDSCh1:ROFFset 40  
NR5G:CCARrier:PDSCh1:RNUMber 80  
NR5G:CCARrier:PDSCh1:ANTenna:PORT:USED 3  
NR5G:CCARrier:PDSCh1:RCGNumber "Two"  
NR5G:DBWP:PDSCh1:BPOWer:DMRS 3  
NR5G:DBWP:PDSCh2:MCS:TABLE "Table1"  
NR5G:DBWP:PDSCh2:MCS 20  
NR5G:DBWP:PDSCh2:SLOT:ALlocated "2:19"  
NR5G:CCARrier:PDSCh2:ROFFset 150
```

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```
NR5G:CCARrier:PDSch2:RNUMber 100
NR5G:CCARrier:PDSch2:ANTenna:PORT:USED 3
NR5G:CCARrier:PDSch2:RCGNumber "Two"
NR5G:DBWP:PDSch2:BPOWer:DMRS 2
NR5G:RLENgth 10
NR5G:SUBFrame:INTerval 2
NR5G:FRAMe:TRIGger:ENABled 1
NR5G:DC:PUNCTured 1
NR5G:MCFilter:ENABled 1
NR5G:COMPensate:SYMBol:CLOCK:OFFset 1
INPut:TRIGger:STYLe "External"
INPut:TRIGger:LEVel:EXTernal 1V
INPut:EXTension:PARameters:SET "ExtTriggerLoc", 2
INPut:EXTension:PARameters:SET "PhaseNoiseOptDualLoop", 1
NR5G:FRAMe:TRIGger:ENABled 1
NR5G:DECode:MODE "DecodedTB"
DISPlay:LAYout 3,2
```

