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.

KEYSIGHT

MEASUREMENT GUIDE

Notices

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CAUTION

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

WARNING

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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

1 M9484C VXG Basic Measurements

KEYSIGHT TECHNOLOGIES

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

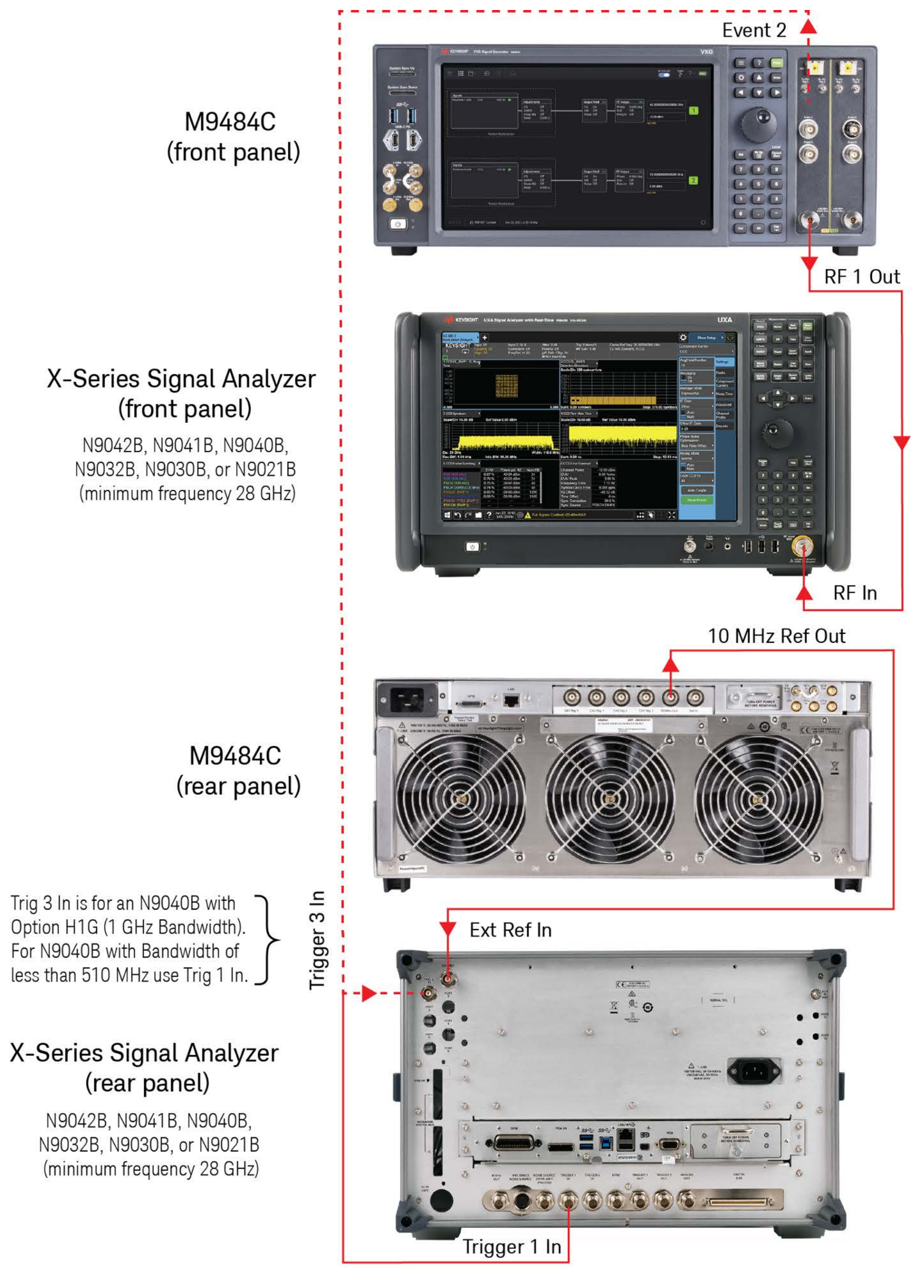
The software versions used in this measurement guide are:

– VXG: A.12.02
– 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 dropdown on the top right, select **Trigger** and set Trigger Source to **Free Run.**

Basic Measurements

Generating a Continuous Waveform (CW)

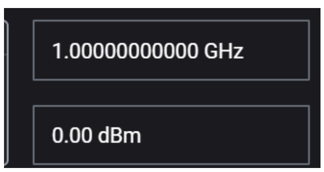
This procedure will demonstrate the amplitude and frequency accuracy of the VXG at RF and µW frequencies.

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:

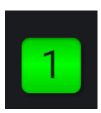
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. In the Output area, set Frequency to **1 GHz** and Power to **0 dBm**.

   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.

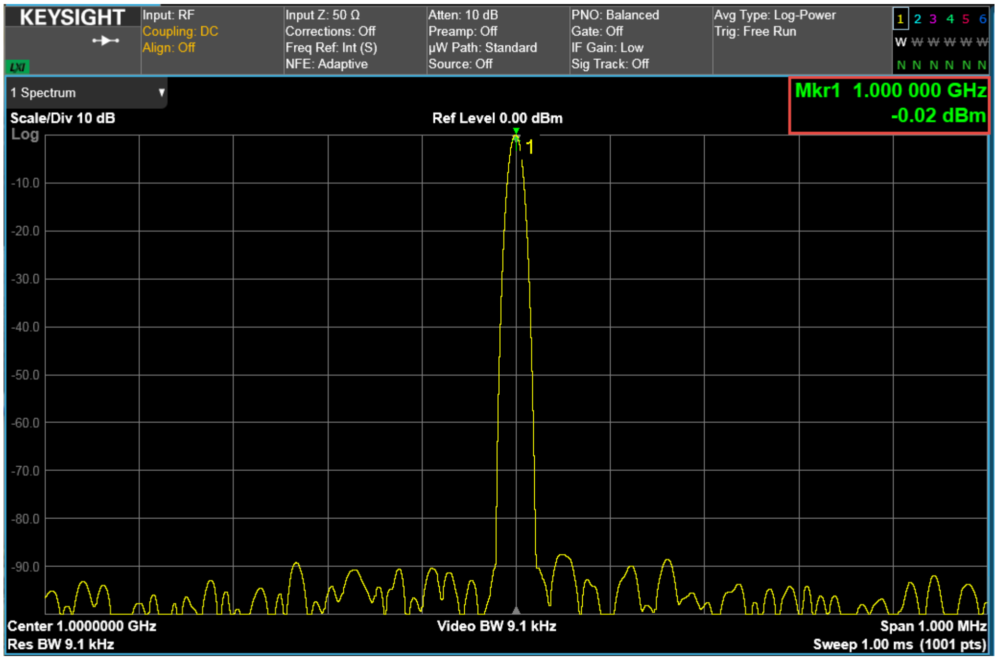
NOTE In order to turn on RF for any channel, both the RF Out for the specific channel (for example, Channel 1 or Channel 2), and RF Out All must be turned on.

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.



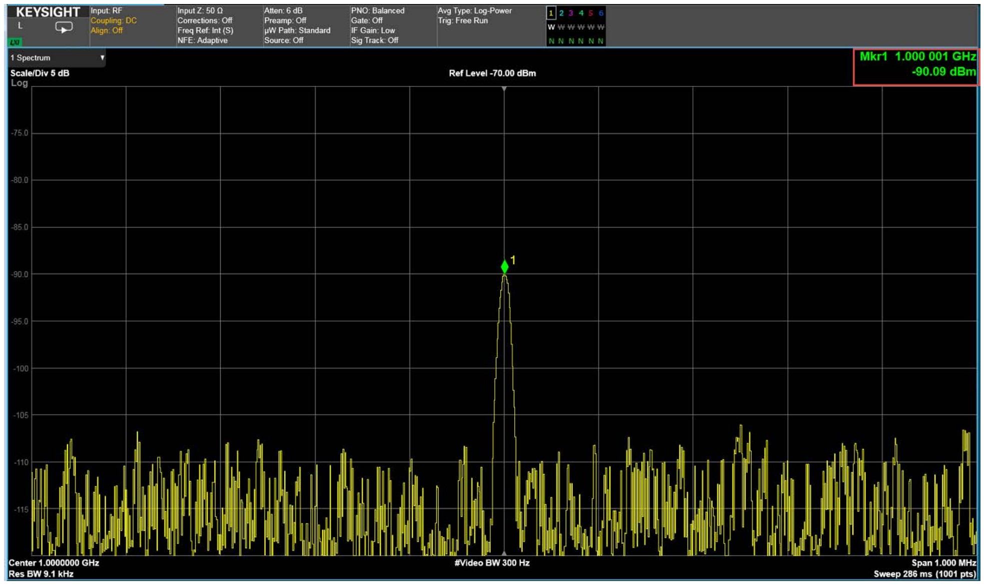
On the VXG:

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.

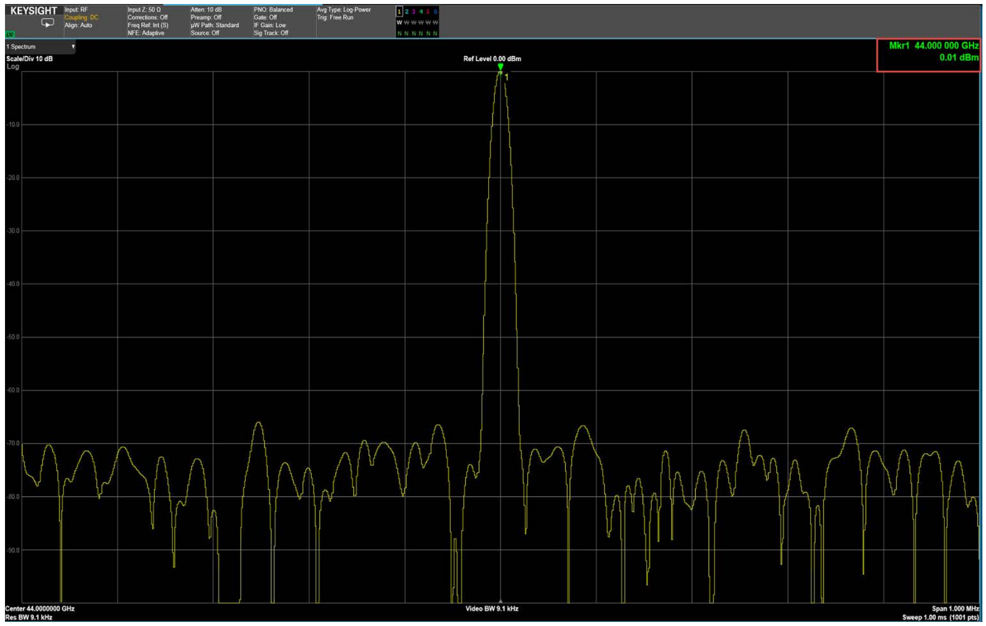


On the VXG:

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**.



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.

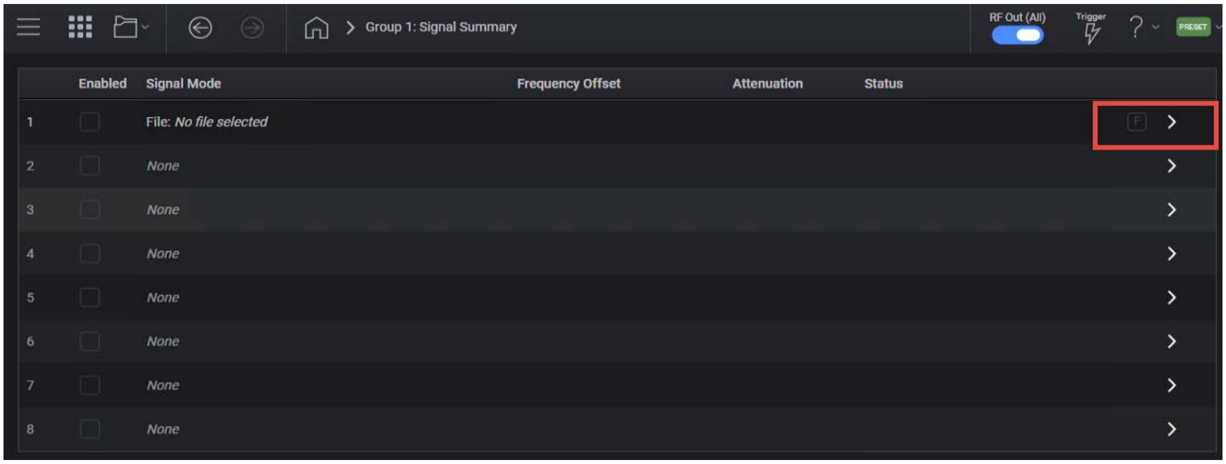
Follow the steps below for AM analog modulation using the internal or an external I/Q modulation source.

On the VXG:

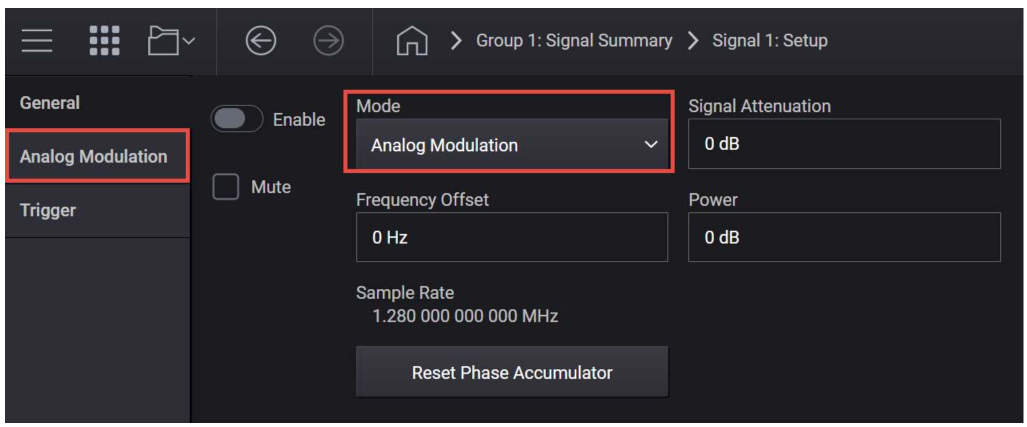
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Set Frequency to **20 GHz** and Amplitude to **0 dBm**.
3. Select the **Signal** block.

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.



5. In the **Mode** dropdown, select **Analog Modulation** and then select the **Analog Modulation** tab in the left pane.



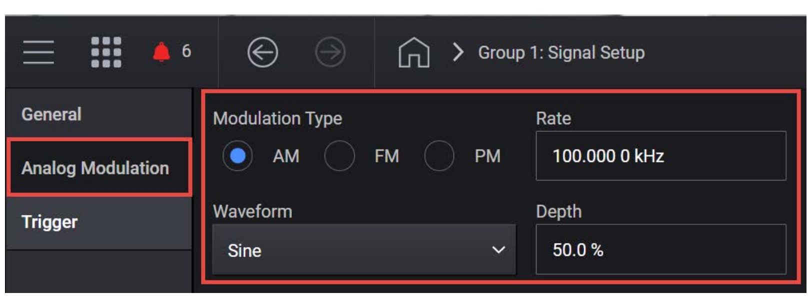
6. In the Analog Modulation Signal Setup:

   a. Set Modulation Type to **AM**.

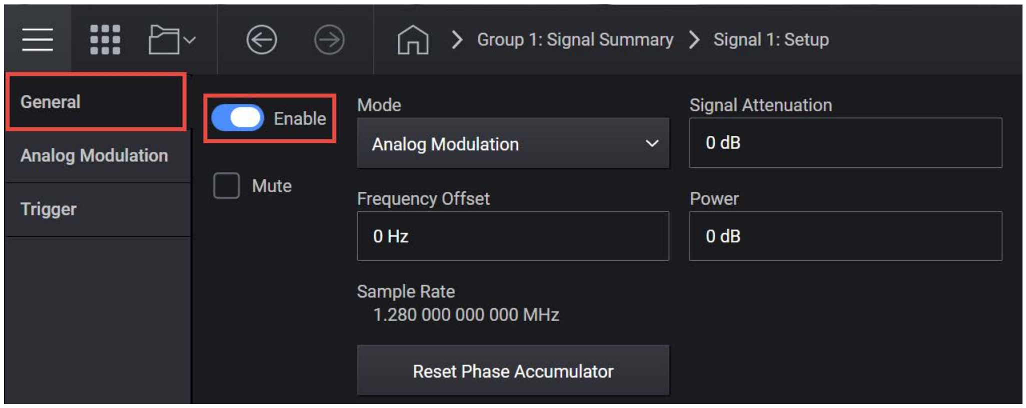
   b. Set Waveform to **Sine**.

   c. Set Rate to **100 kHz**.

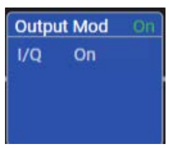
   d. Set Depth to **50%**.



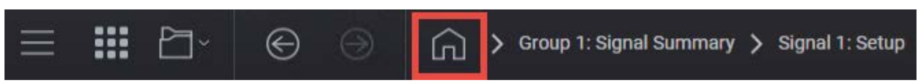
7. Select the **General** tab > **Enable.**



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

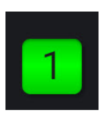


8. Close the Vector Modulation Signal Setup by selecting the **Home** icon at the top of the display.



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

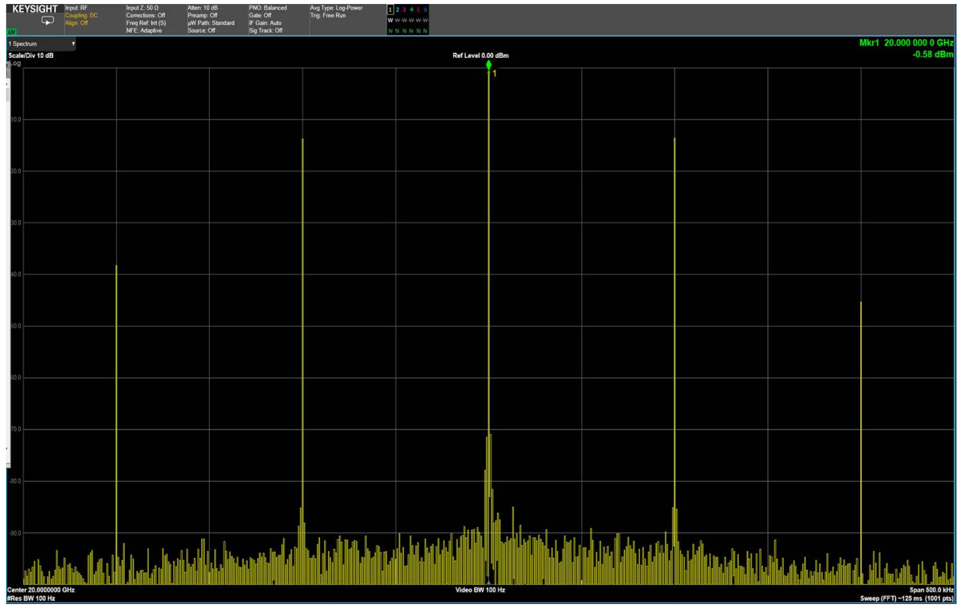
   This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel VXG.



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**.

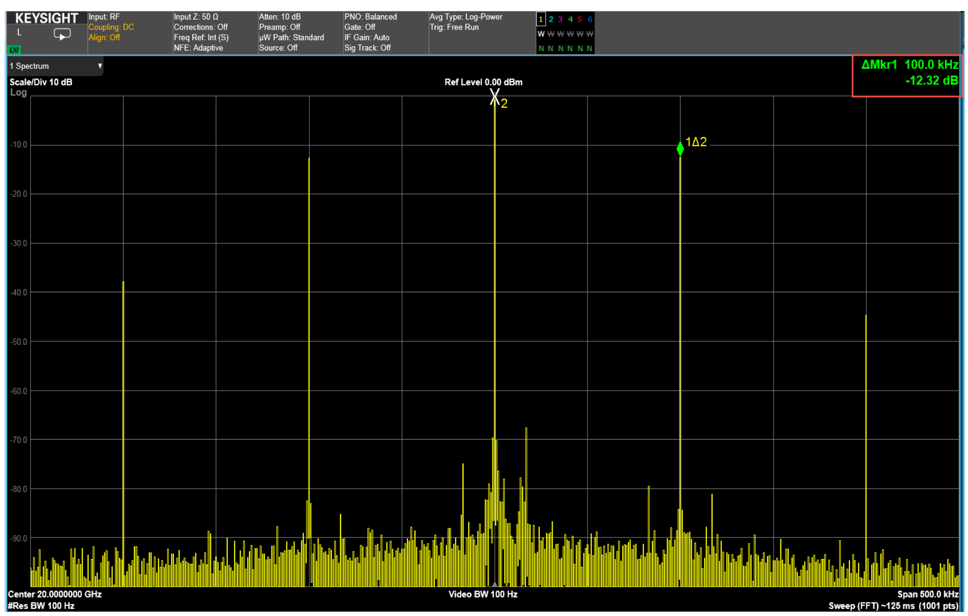
3. Select **BW** and set Res BW to **100 Hz**.



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.

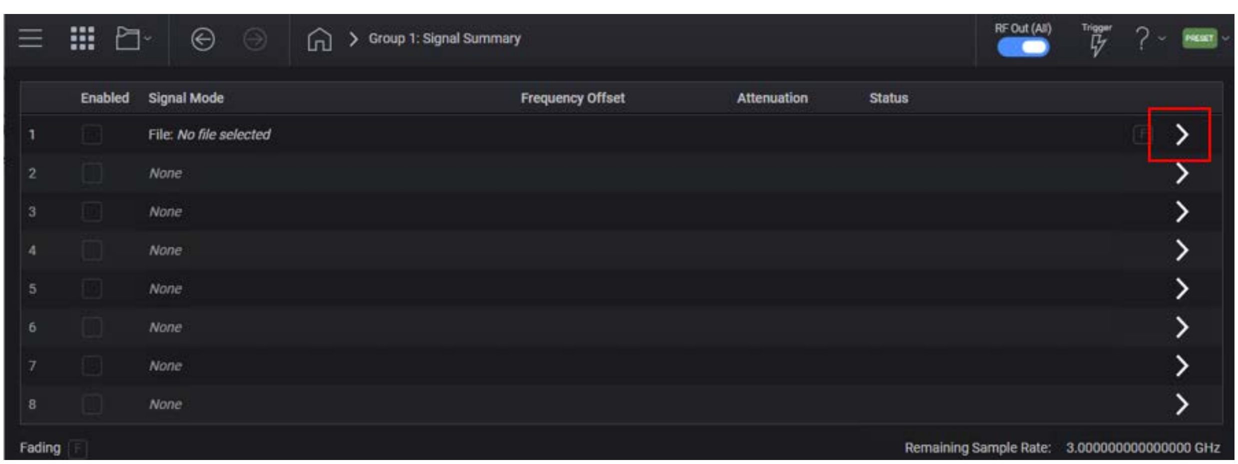
Follow the steps below for FM analog modulation using the internal or an external I/Q modulation source.

On the VXG:

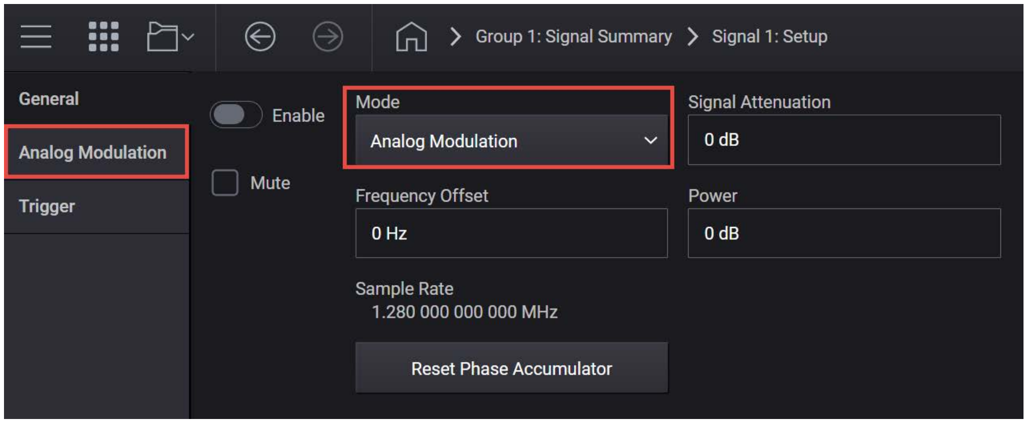
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Set Frequency to **20 GHz** and Amplitude to **0 dBm**.
3. Select the **Signal** block.

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

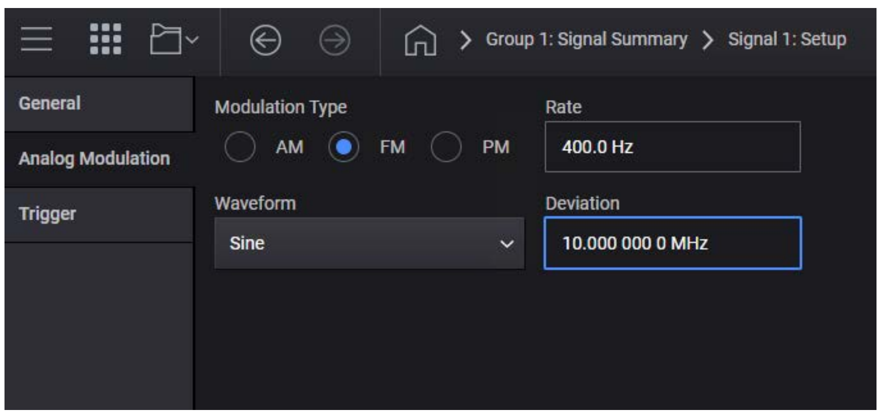
NOTE This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.



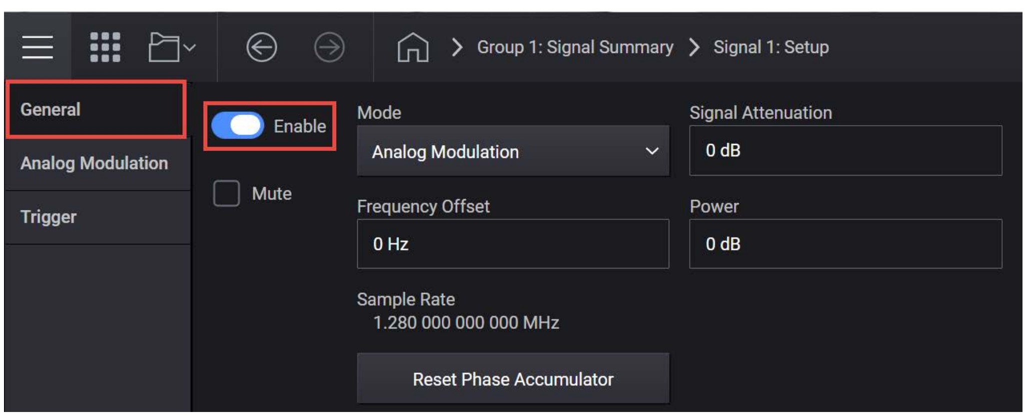
5. In the Mode dropdown, select **Analog Modulation** and then the **Analog Modulation** tab.



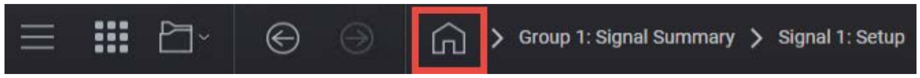
   a. Set Modulation Type to **FM**.
   b. Set Waveform to **Sine**.
   c. Set Rate to **400 Hz**.
   d. Set Deviation to **10 MHz**.



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



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

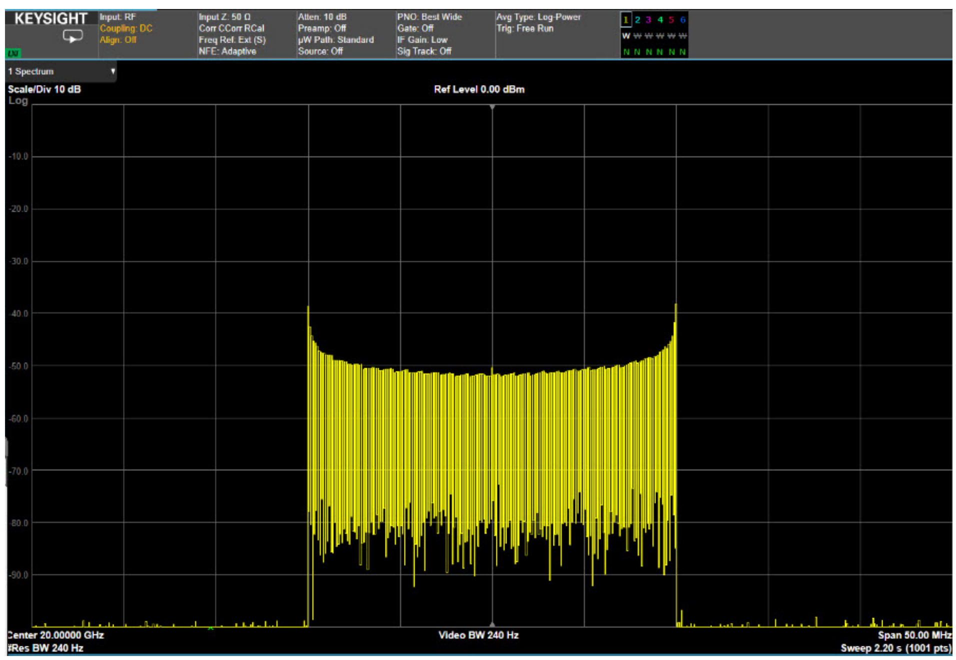


8. Set RF Out to **On** by selecting the numbered channel indicator switch.

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

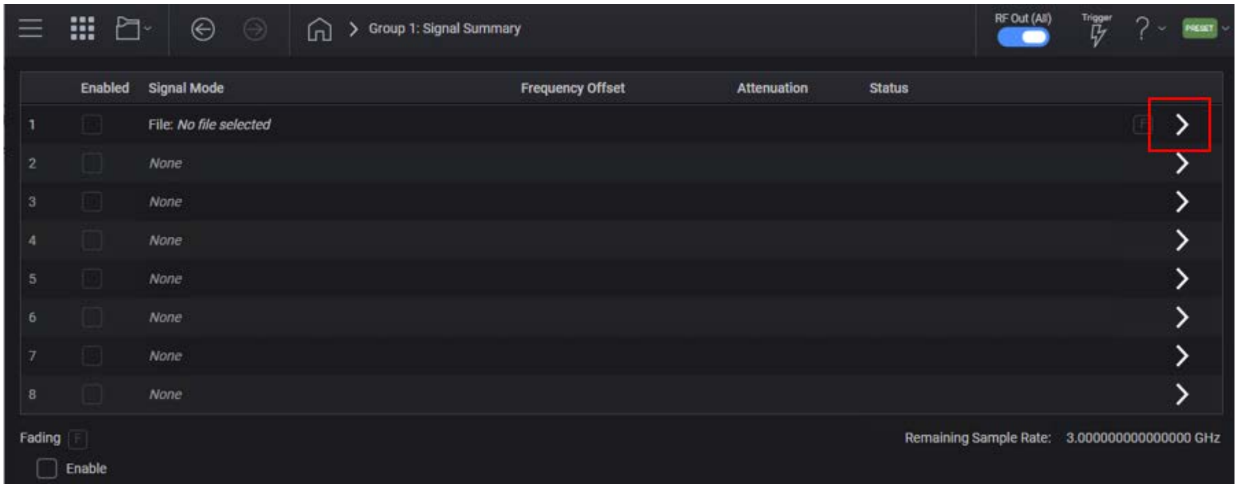
On the VXG:

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.

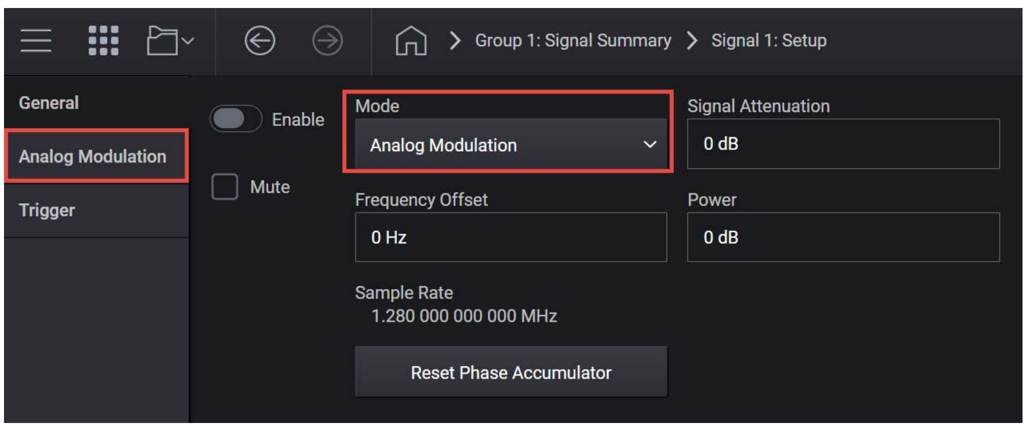
4. Select the arrow for Signal 1 to open the Signal Setup window.

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.

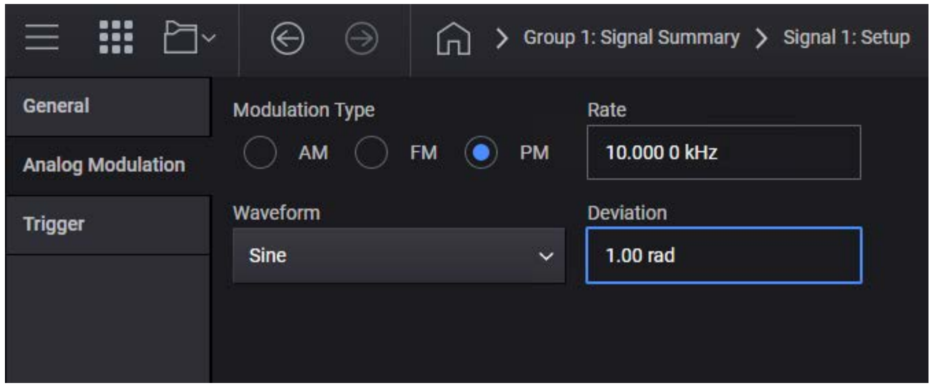


5. In the Mode dropdown, select **Analog Modulation** and then the **Analog Modulation** tab.

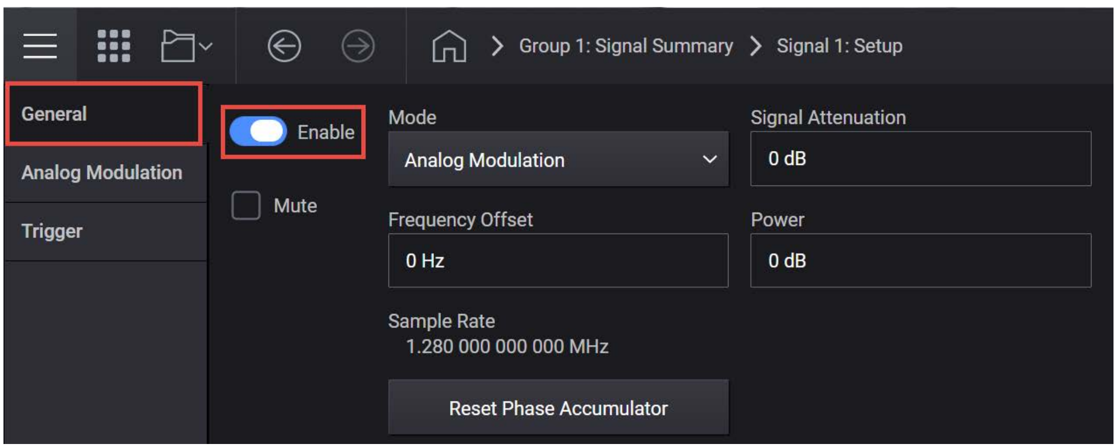


6. In the Analog Modulation Signal Setup:
   a. Set Modulation Type to **PM**.
   b. Set Waveform to **Sine**.
   c. Set Rate to **10 kHz**.

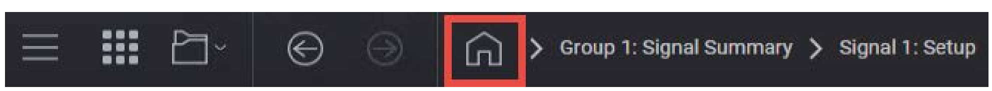
d. Set Deviation to **1 rad**.



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

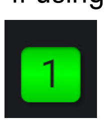


8. Close the Vector Modulation Signal Setup by selecting the **Home** icon at the top of the display.



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

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

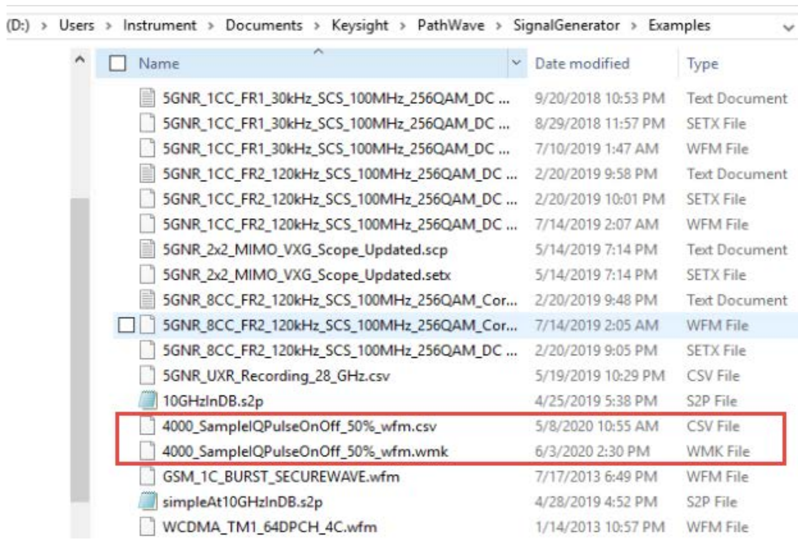
On the X-Series Signal Analyzer:

```
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.

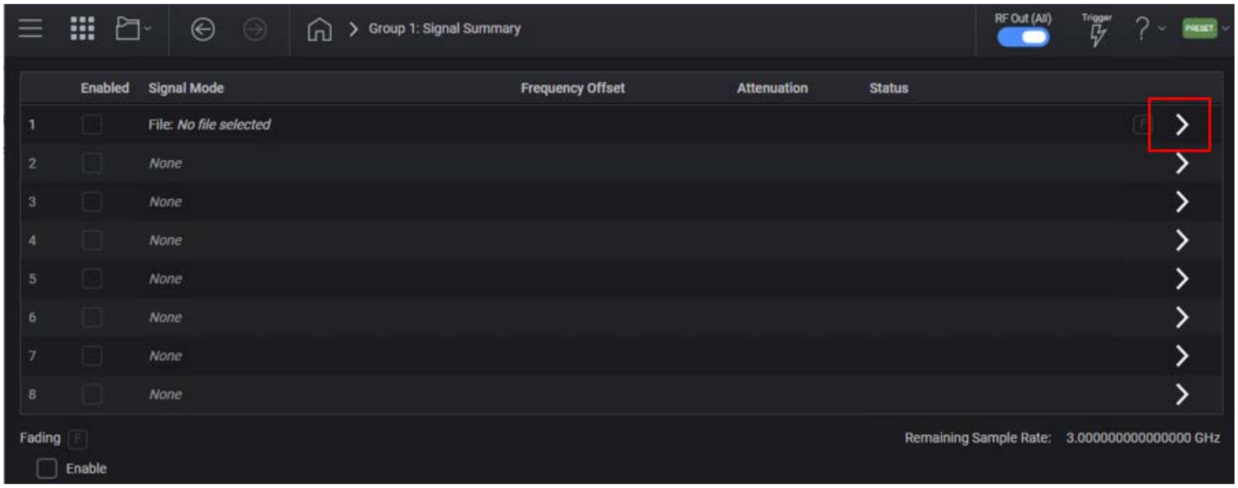


On the VXG:

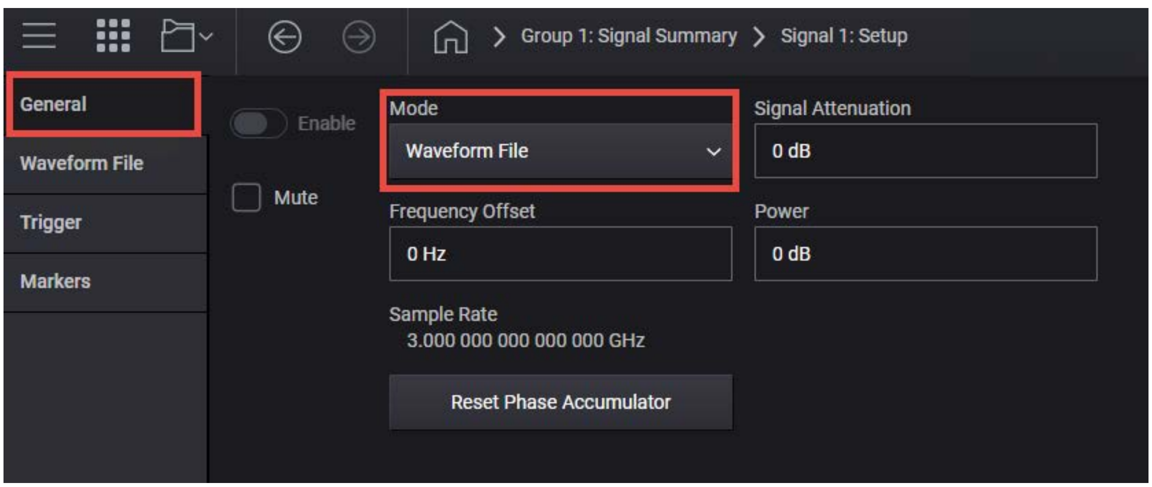
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Set the Frequency to **1 GHz** and Power to **0.0 dBm**.
3. Select the **Signal** block to open.

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.



5. Select the **Mode** dropdown and select **Waveform File**.



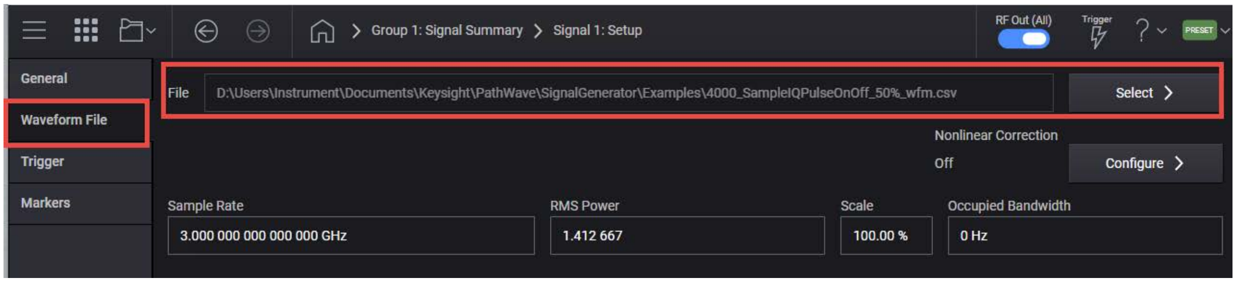
6. Select the **Waveform File** tab (left pane), and then in the Waveform Setup area, use File **Select** to navigate to:

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

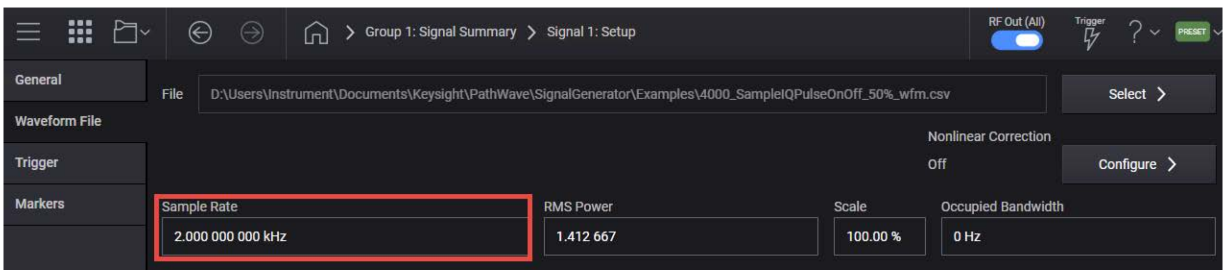
and choose

`4000_SampleQPulseOnOff_50%_wfm.csv`

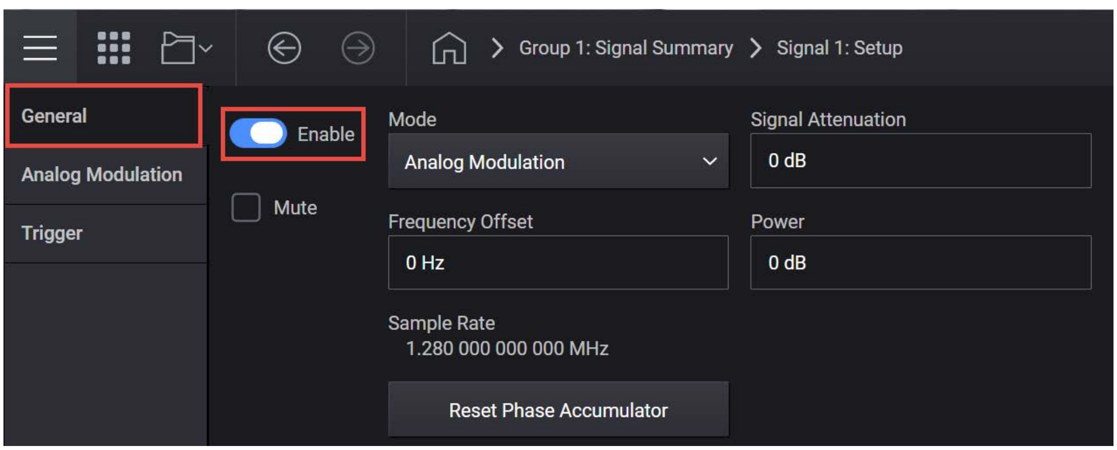
then **Select**.



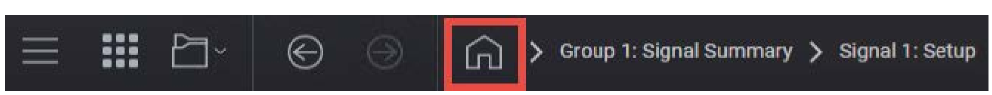
7. Set the Sample Rate to **2 kHz**.



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



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.

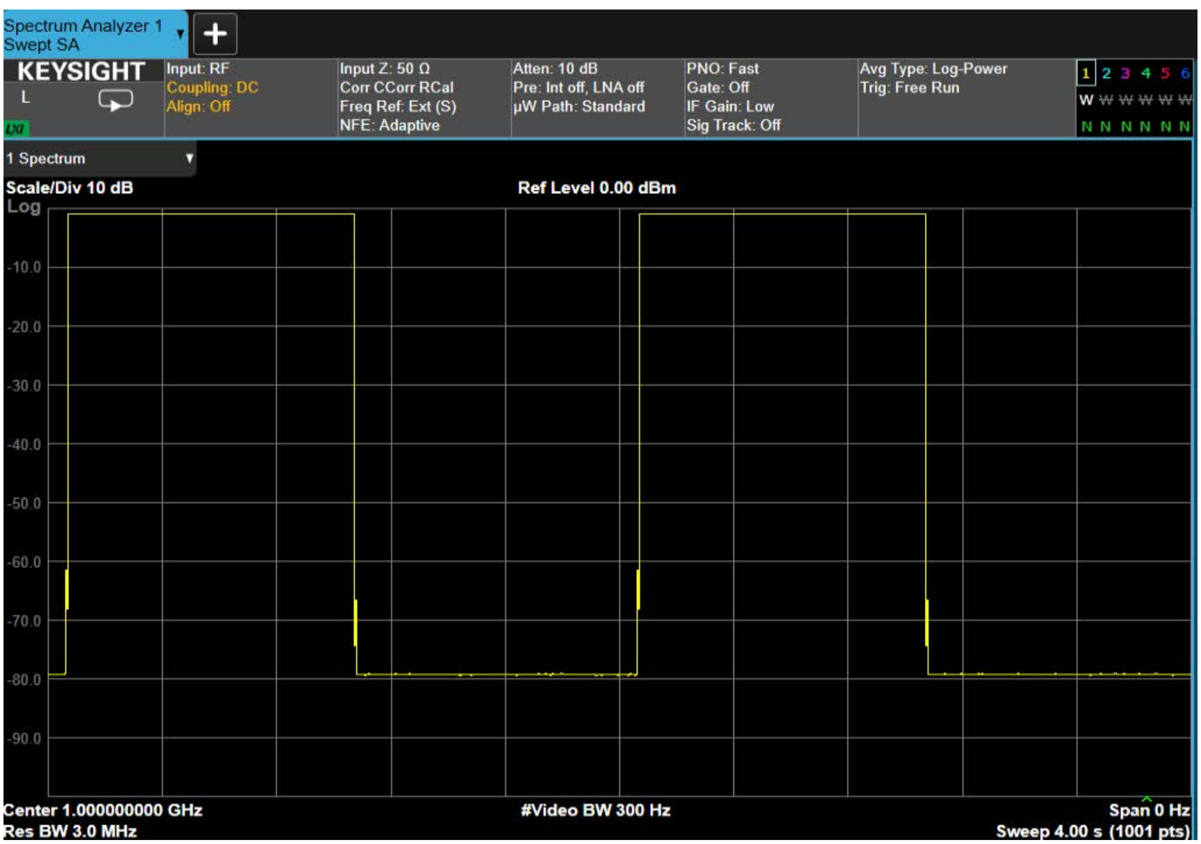
This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel VXG.

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.

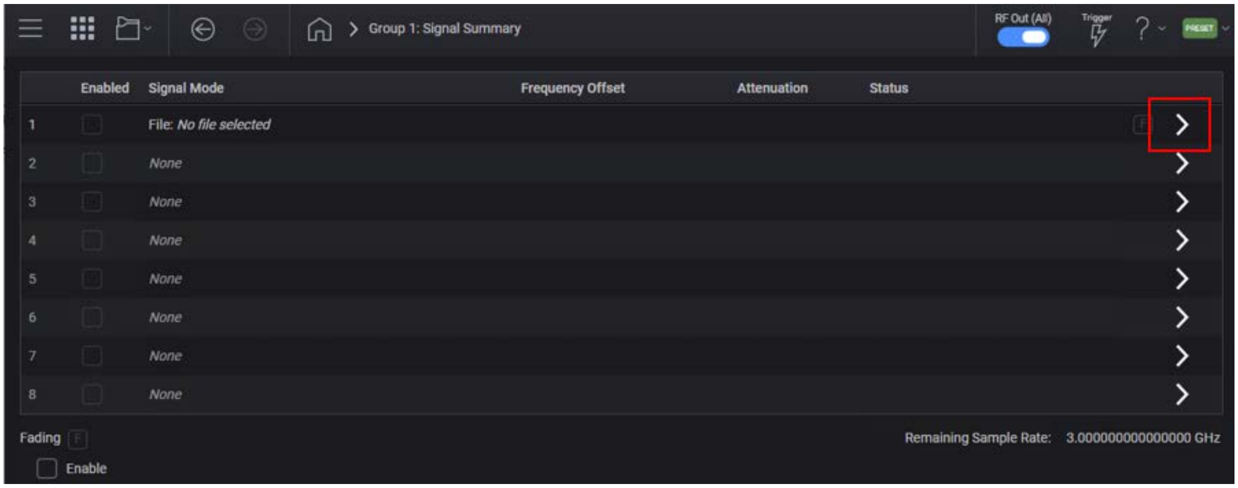
NOTE Ensure the equipment and triggers are properly configured. Refer to "Equipment Setup" on page 11 and "Setting Up Triggers on the X-Series Signal Analyzer" on page 13.

On the VXG:

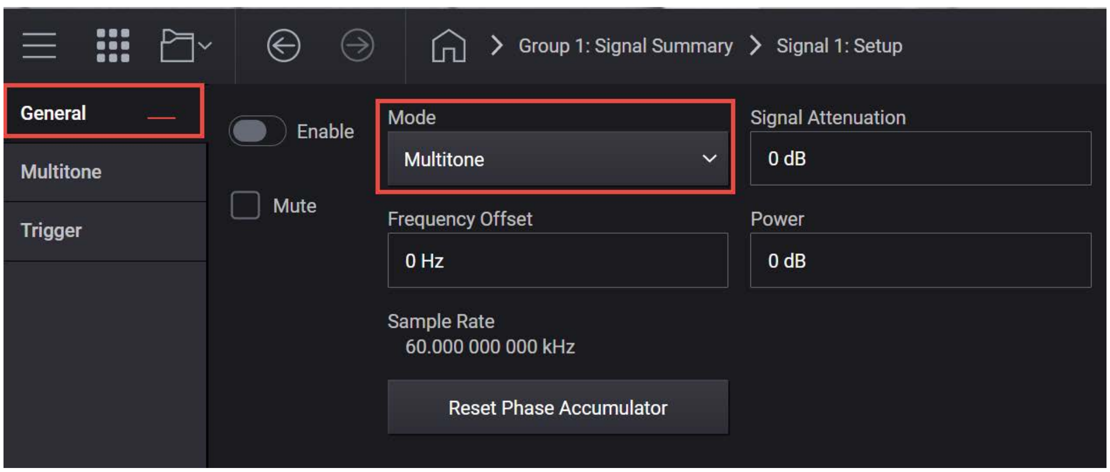
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. Set Frequency to **20 GHz** and Amplitude to **-10 dBm**.
3. Select the **Signal** block to open.

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. Select the **Mode** dropdown and select **Mutitone**.

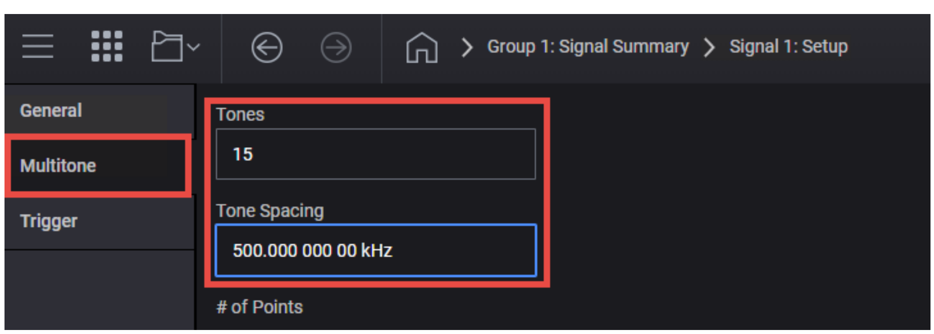


6. Select the **Multitone** tab and set:

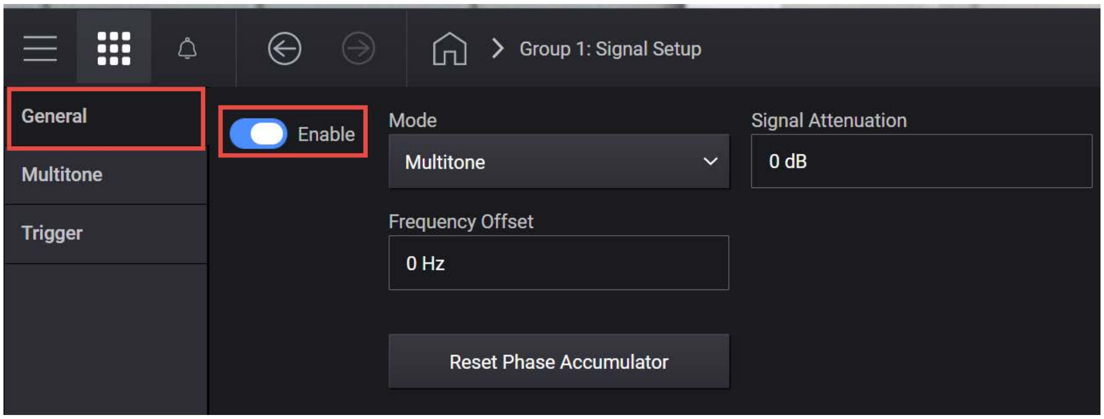
   a. Set Vector Modulation Signal Mode to **Multitone**.

   b. Set Tones to **15**.

   c. Set Tone Spacing to **500 kHz**.



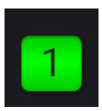
7. Select the **General** tab > **Enable**.



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

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

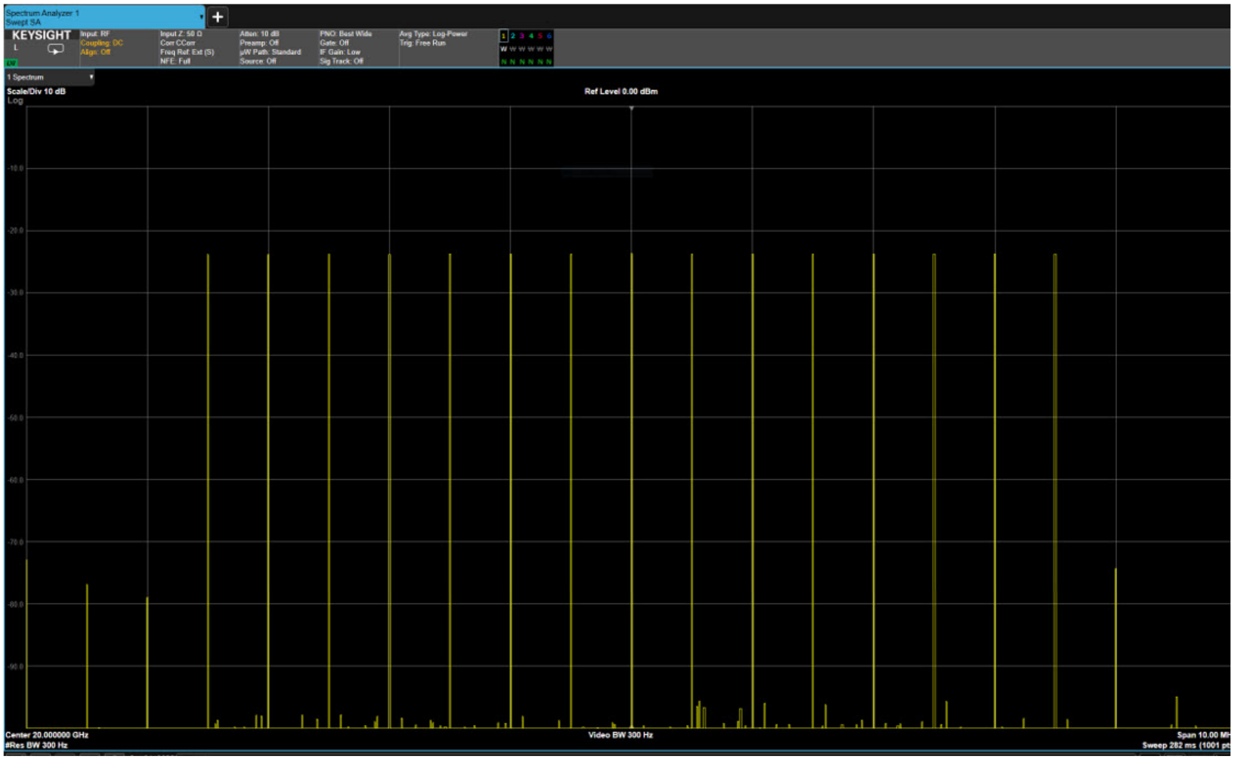
   This enables the RF Out for the indicated channels, in this case Channel 1 if using a multi-channel VXG.



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**.

   Observe the 15 tones.


Spectrum Analyzer 1
Swept SA
KEYSIGHT
Input: RF
Coupling: DC
Align: Off
Input Z: 50 Ω
Corr CCorr
Freq Ref: Ext (S)
NFE: Full
Atten: 10 dB
Preamp: Off
µW Path: Standard
Source: Off
PNO: Best Wide
Gate: Off
IF Gain: Low
Sig Track: Off
Avg Type: Log-Power
Trig: Free Run
1 Spectrum
Scale/Div 10 dB
Log
Ref Level 0.00 dBm
Center 20.000000 GHz
#Res BW 300 Hz
Video BW 300 Hz
Sweep 282 ms (1001 pts

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.

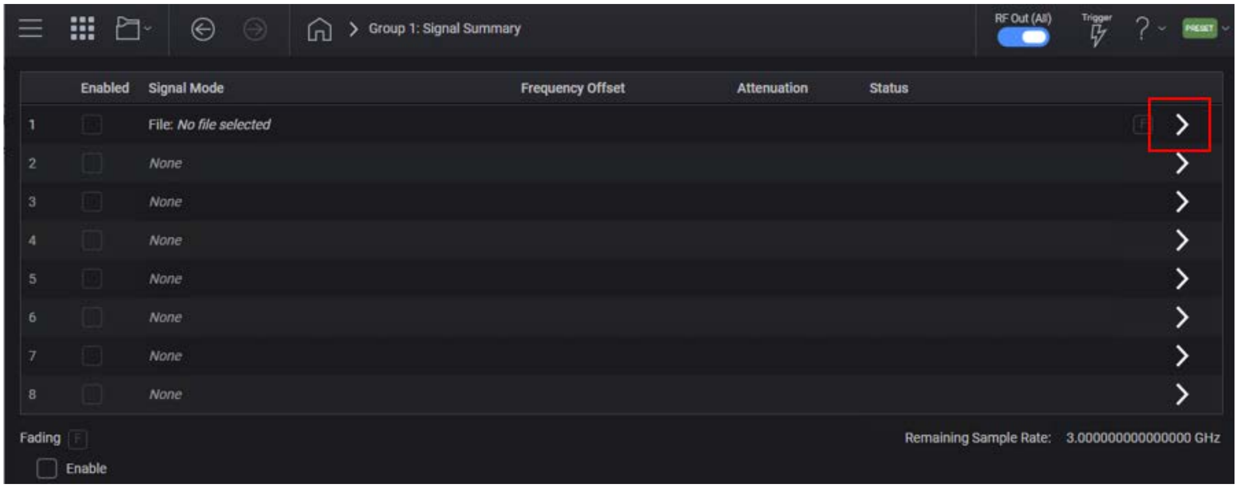
NOTE Ensure the equipment and triggers are properly configured. Refer to "Equipment Setup" on page 11 and "Setting Up Triggers on the X-Series Signal Analyzer" on page 13.

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.

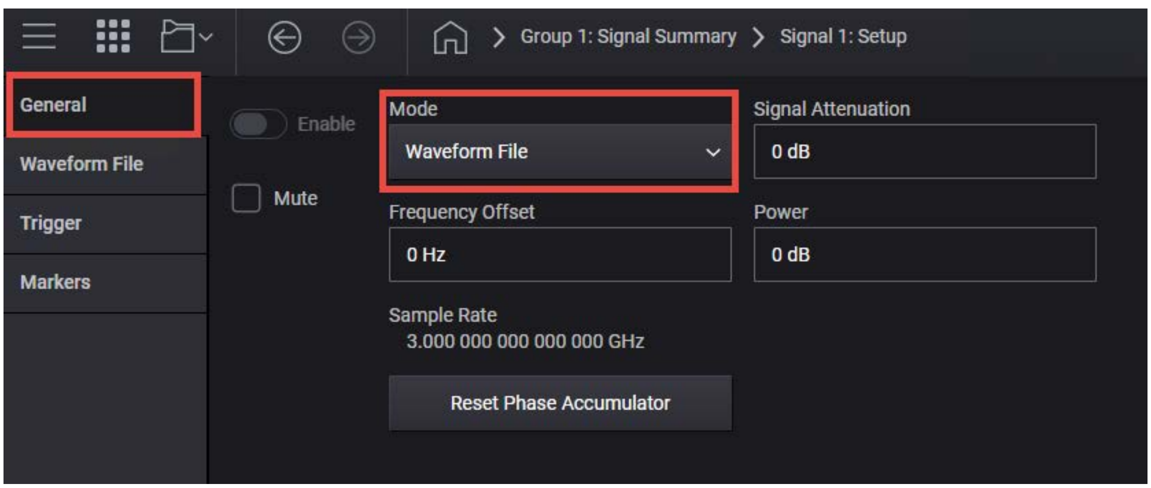
4. Select the arrow for Signal 1 to open the Signal Setup window.

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.



5. In the Vector Modulation Signal Setup:

   a. Select the **Mode** dropdown and set to **Waveform File**.

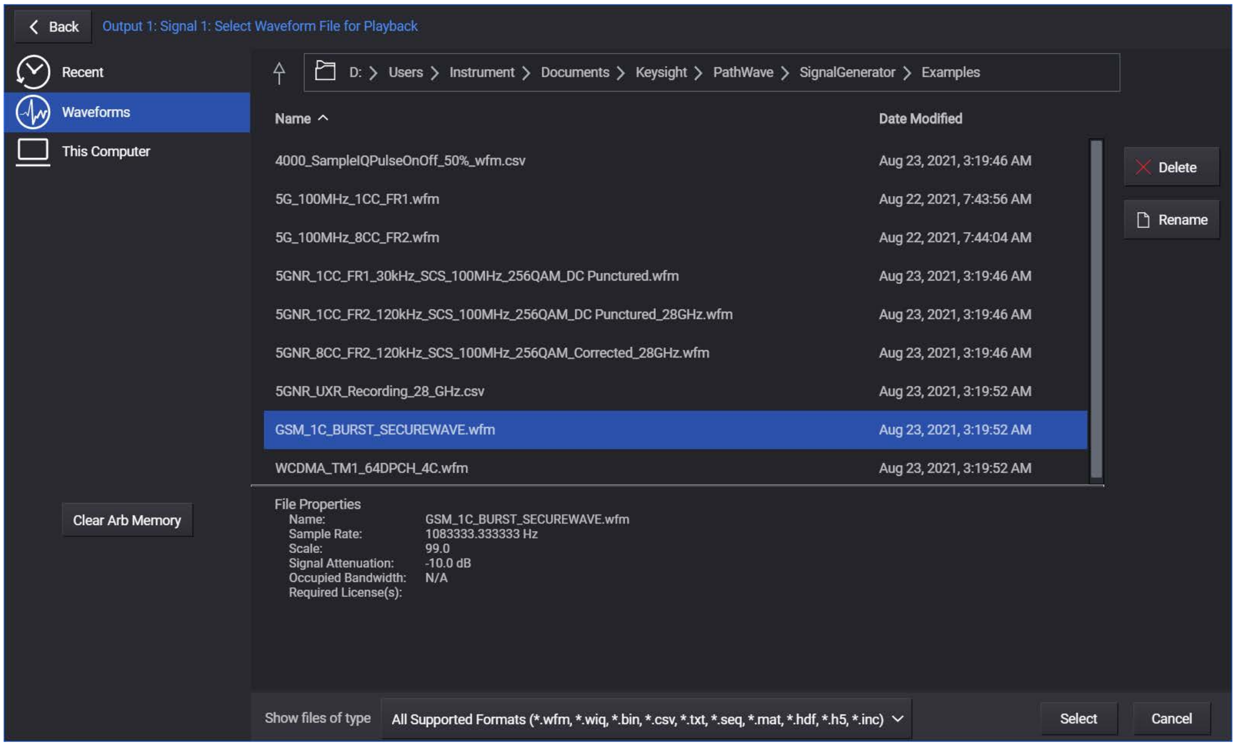


   b. In the left pane, select the **Waveform File** tab.

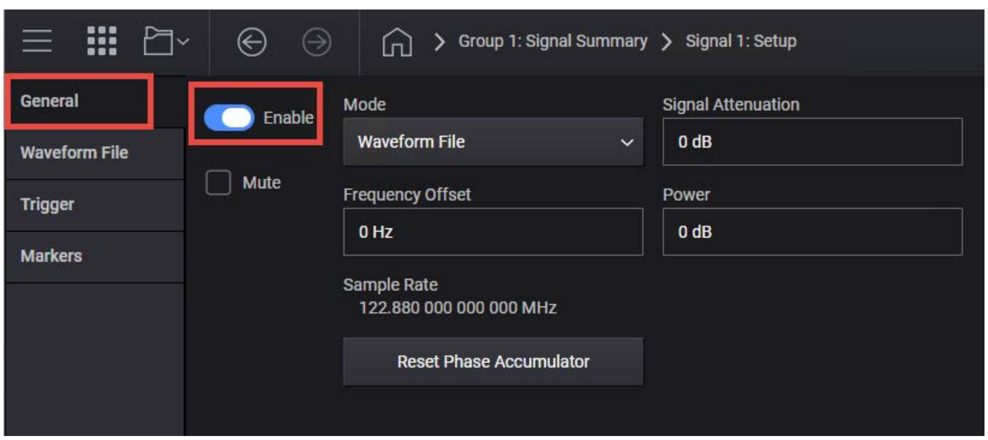
   c. Use File **Select** to navigate to:

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

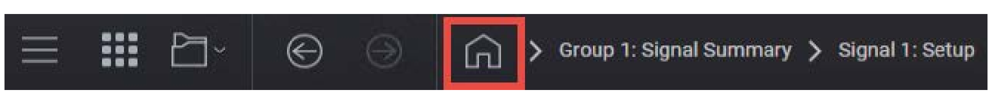
d. Highlight `GSM_1C_BURST_SECUREWAVE.wfm`, then **Select**.



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



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

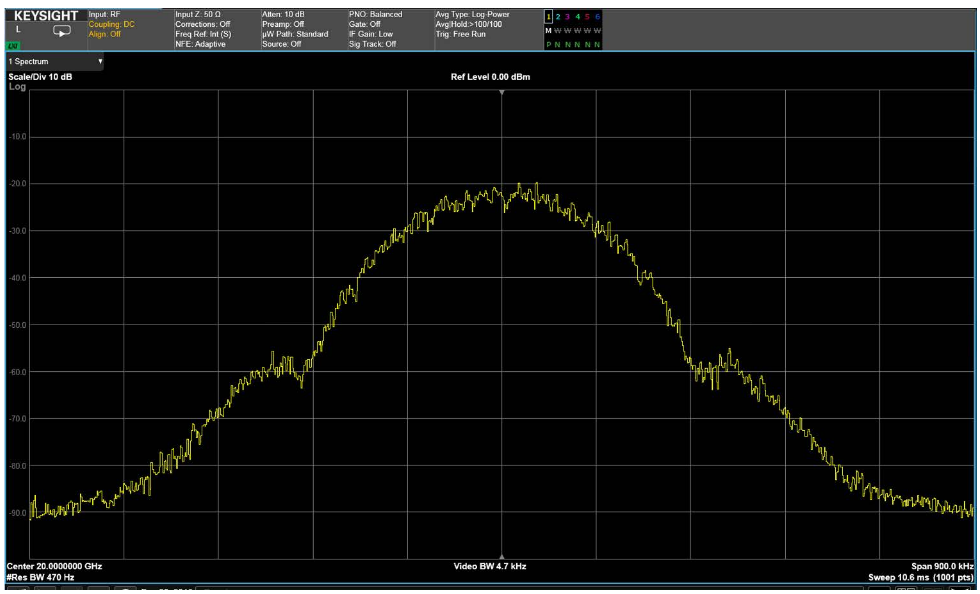


7. Set RF Out to **On** by selecting the numbered channel indicator switch.

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

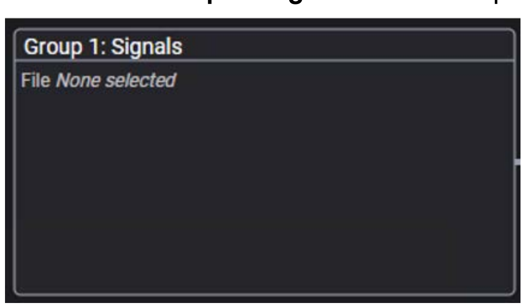
On the X-Series Signal Analyzer:

1. 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 **900 kHz**.
3. Select **BW** and set Res BW to **470 Hz**.
4. Select **Trace** and set Trace Type to **Max Hold**.
5. Observe the GSM signal.



On the VXG:

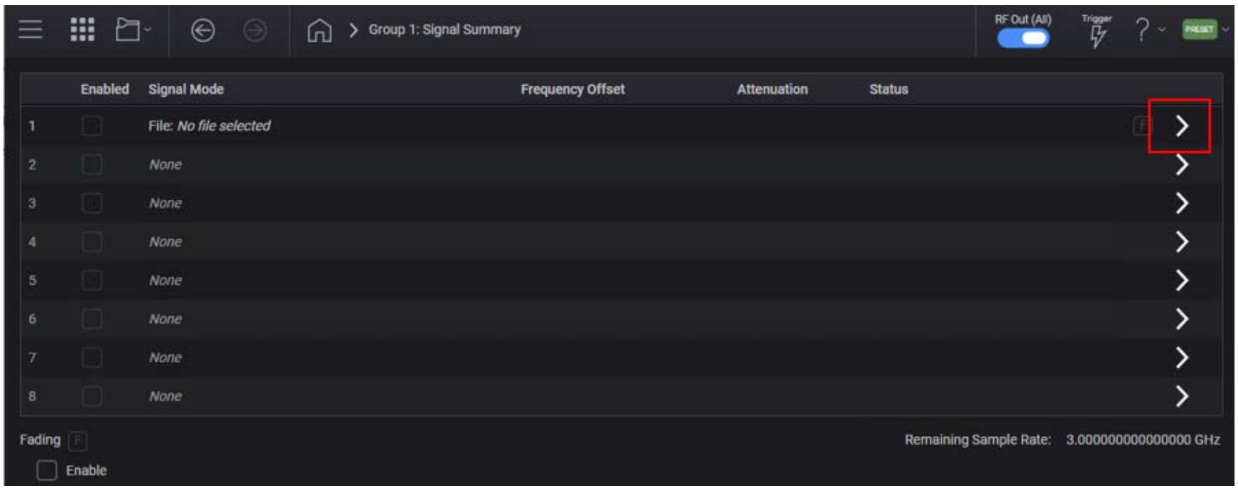
1. Select the **Group 1: Signals** block to open.



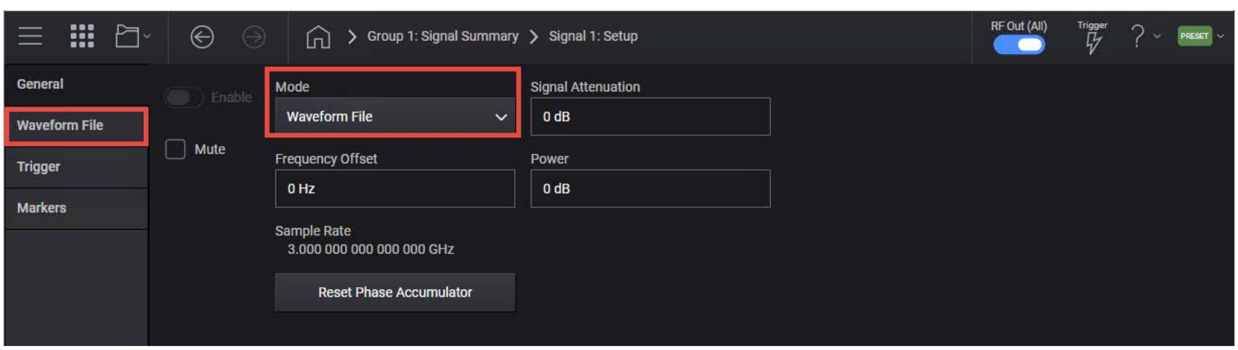
2. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

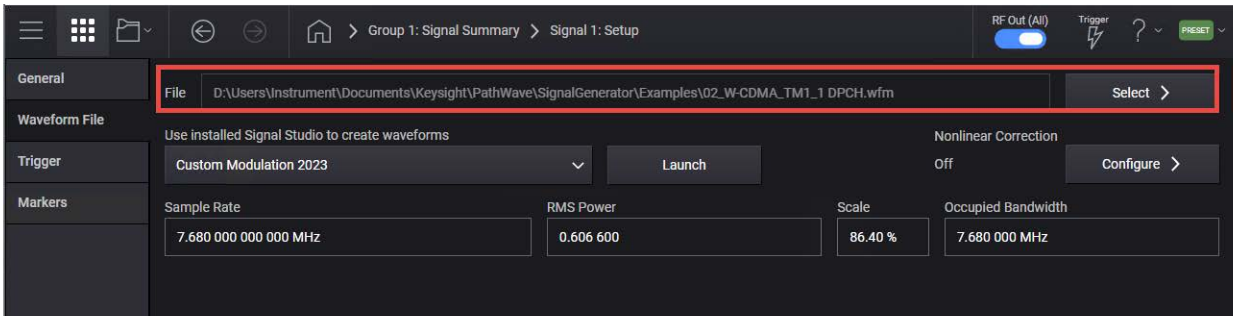
This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.



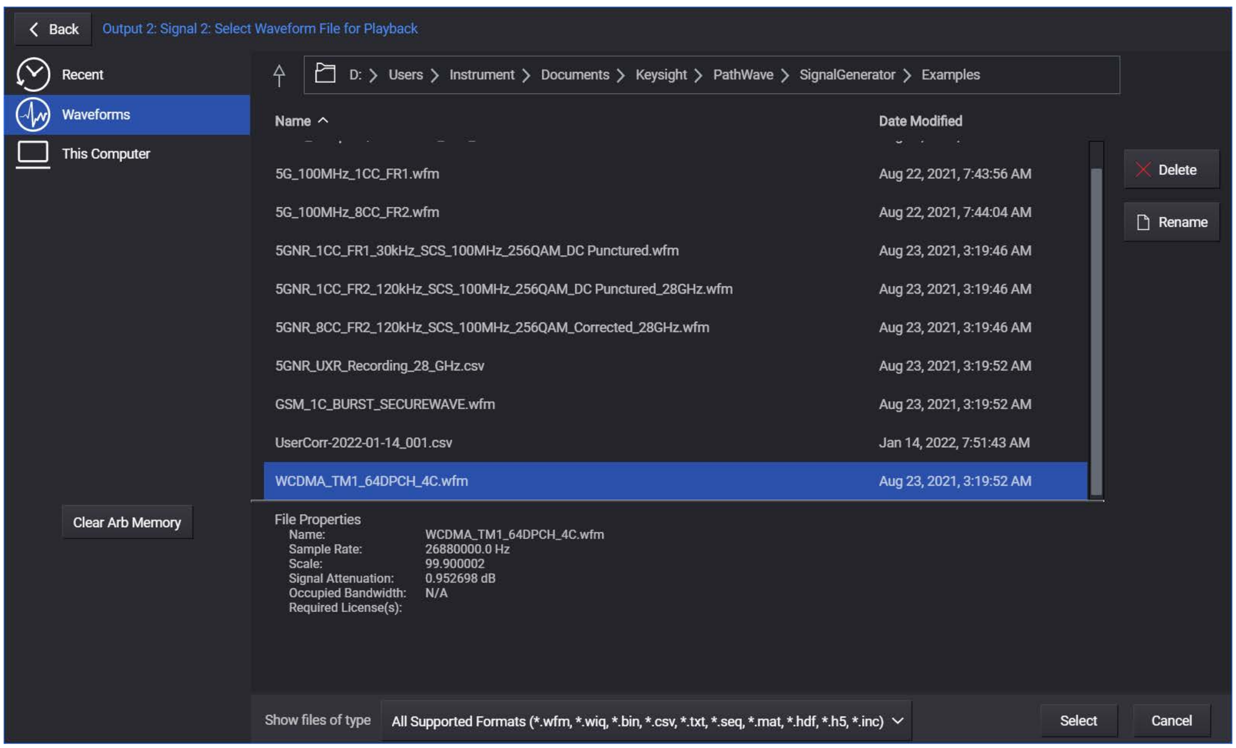
3. Select the **Mode** drop down menu and select **Waveform File** and then select the **Waveform File** tab on the left side.



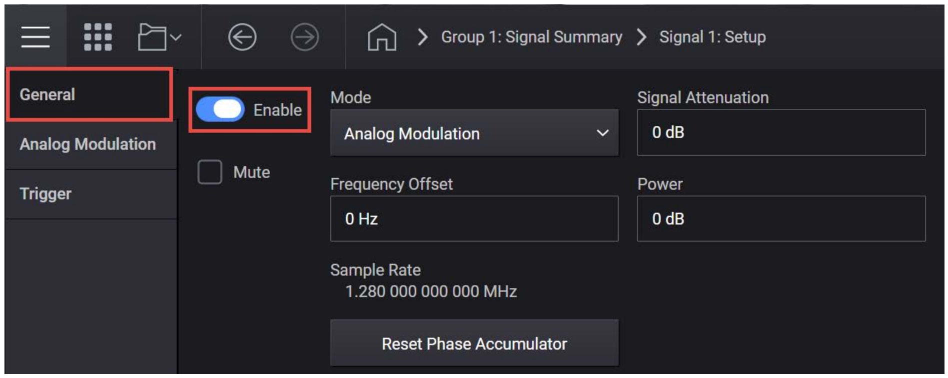
4. Use File **Select** to navigate to:
`D:\Users\Instrument\Documents\Keysight\PathWave\SignalGenerator\Examples`



5. Set the file extension to All Files (*.*), highlight `WDCMA_TM1_64DPCH_4C.wfm`, then **Select**.



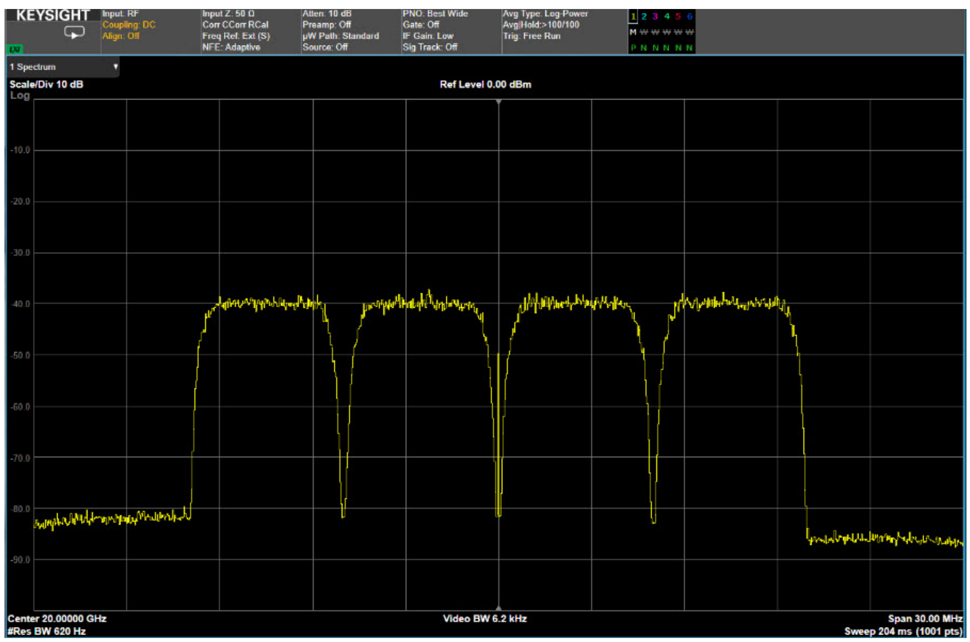
6. Select the **General** tab > **Enable**.



7. 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 WCDMA 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

KEYSIGHT TECHNOLOGIES

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.**

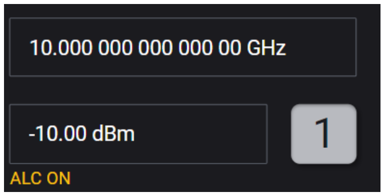
1. Create s2p files in Notepad in the format shown above.

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.

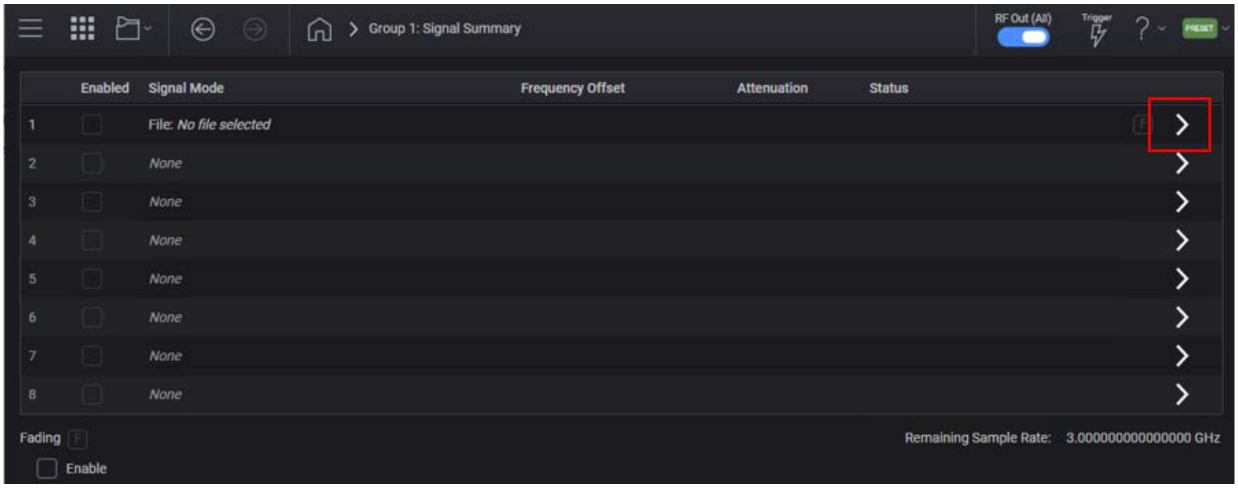


4. Select the **Group 1: Signals** block to open.

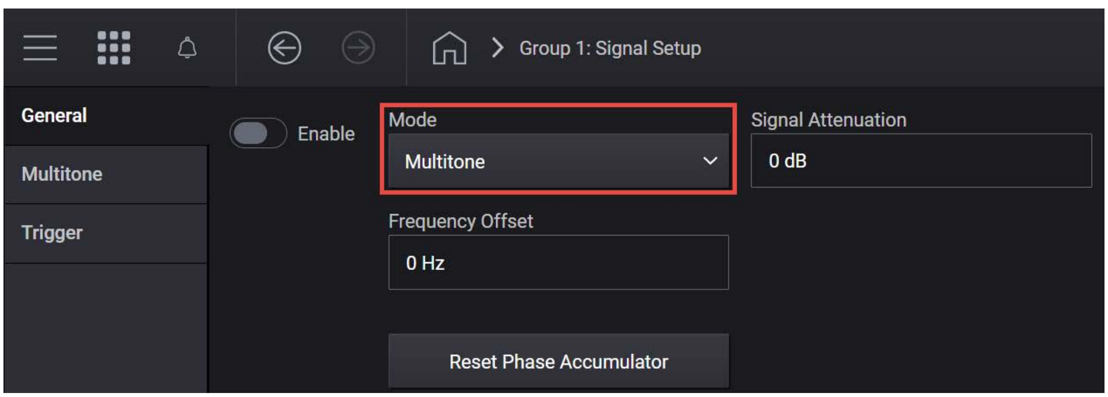
5. Select the arrow for Signal 1 to open the Signal Setup window.

NOTE

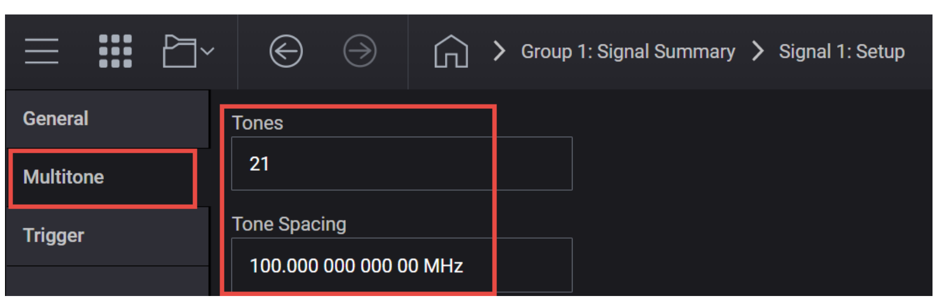
This screen is only accessible if Option M9484C-8SG (8 virtual signal generators) is installed. For all other option configurations, continue to the next step.



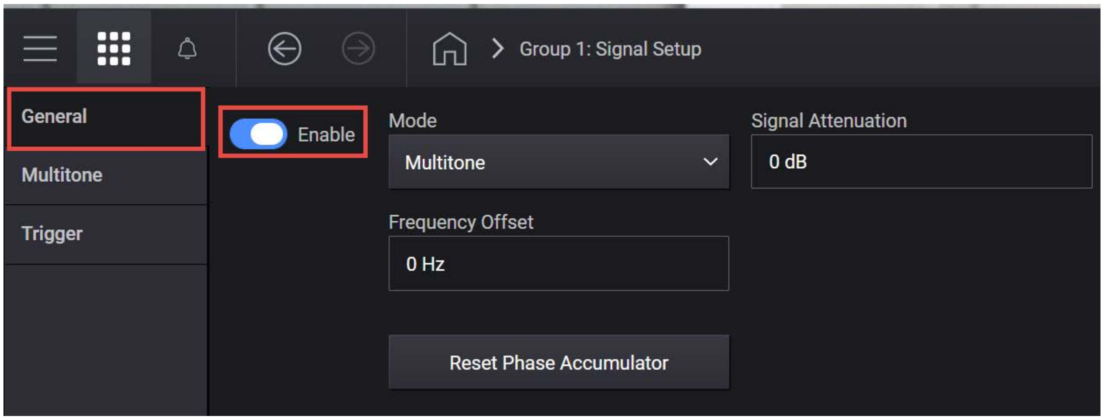
6. Select the **Mode** dropdown and select **Multitone.**



7. From the left pane, select **Multitone** and set:
   - Vector Modulation Signal Mode to **Multitone**
   - Tones to **21**
   - Tone Spacing to **100 MHz**



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



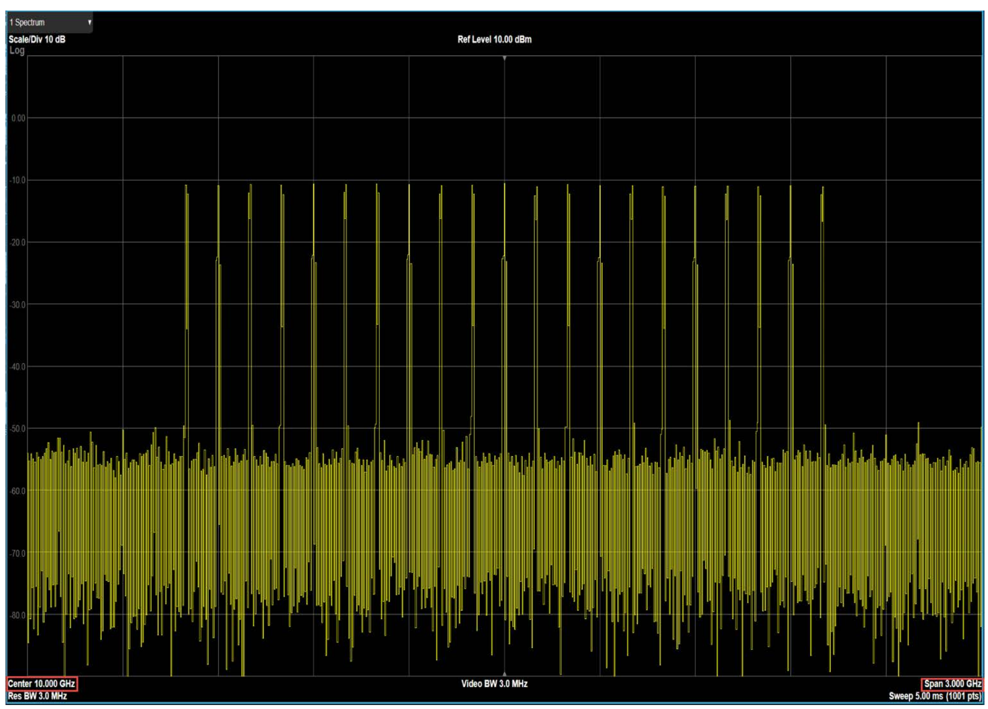
9. Close the Signal block by selecting the **Home** icon, and then select **RF Out** to turn on.

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

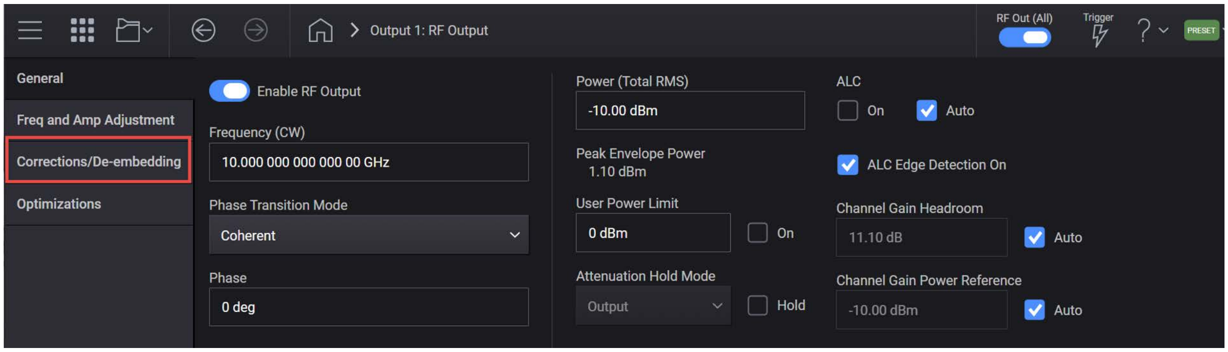
   – Select **Mode Preset** to set Spectrum Analyzer mode to a known state.

   – Set the Center to **10 GHz**

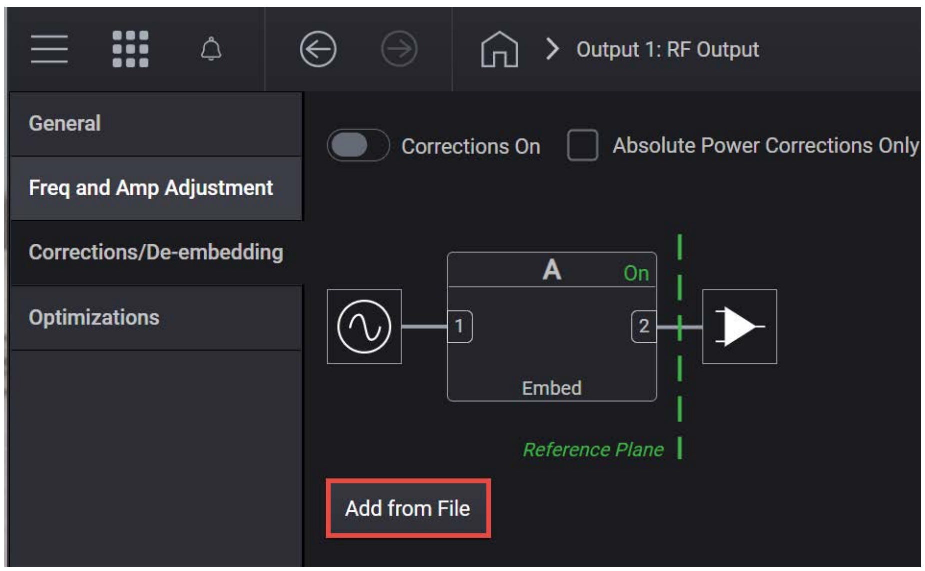
   – Set Span to **3 GHz**



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

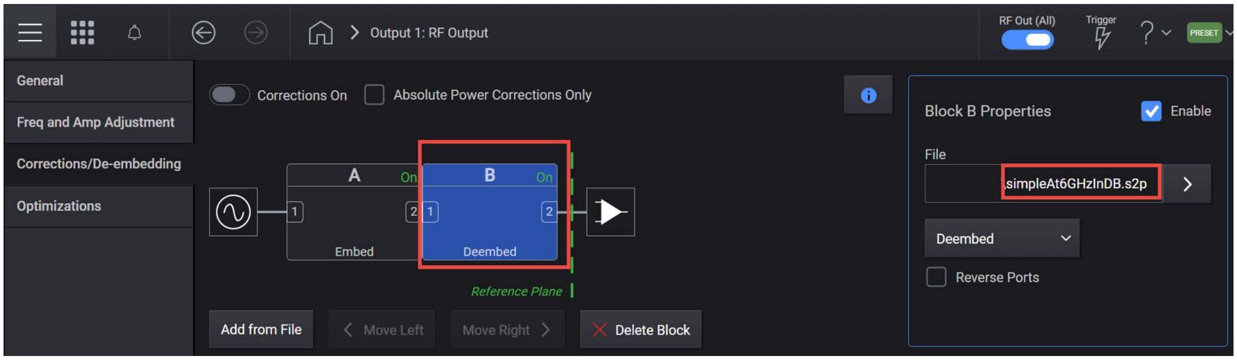


12. In the Corrections Setup dialog, select **Add from File**.



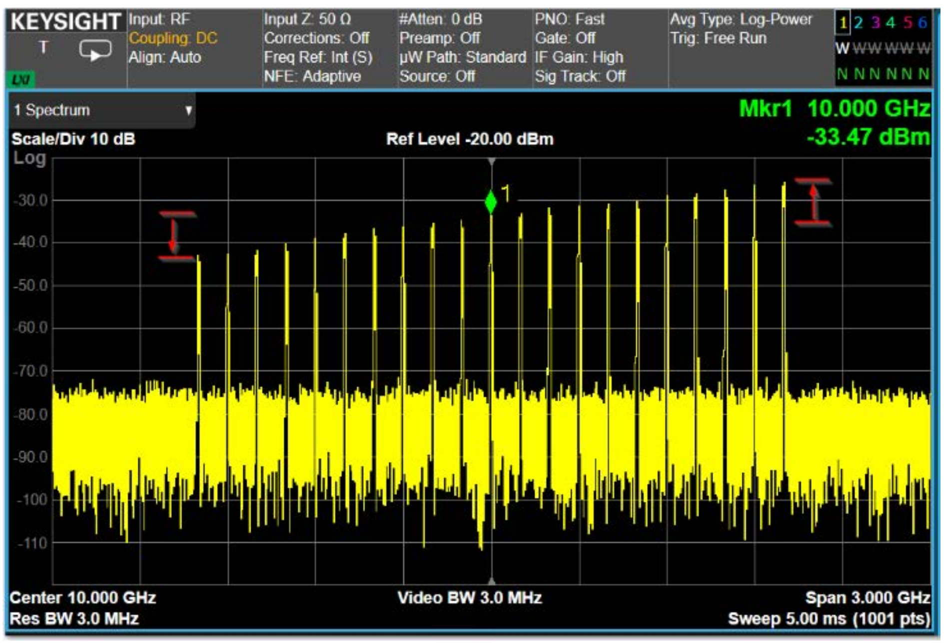
13. Navigate and select the s2p file and then **Select**.
`D:\Users\Instrument\Documents\Keysight\PathWave`
`\SignalGenerator\Examples\simpleAt10GHzInDB.s2p`

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

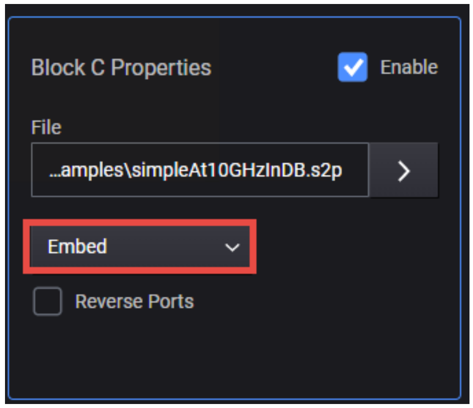


14. Turn **Corrections On**.

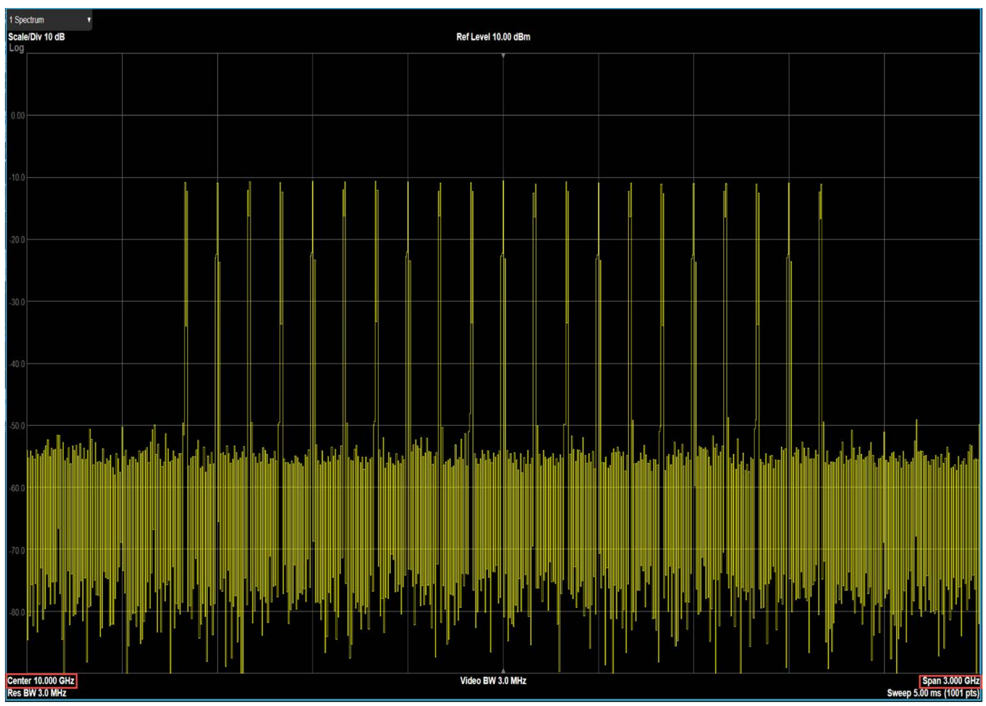
View the results on the signal analyzer. Observe how the .s2p file has impacted the signal.



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



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



Using a Spectrum Analyzer to Make the Corrections Measurement

When using a spectrum analyzer, it must be locked to the 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:

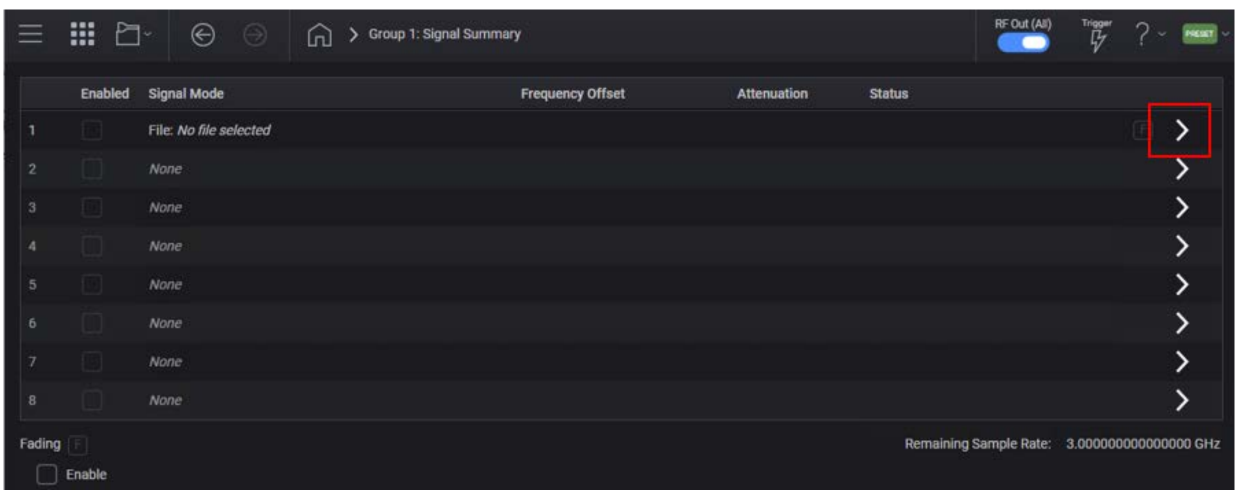
– N9000A/B CXA

- N9010A/B EXA
- N9020A/B MXA
- N9030A/B PXA
- N9040B and N9041B UXA

On the VXG:

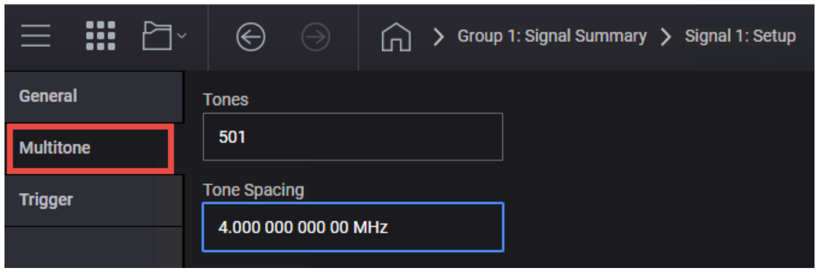
1. Connect the VXG 10 MHz Out to the N90x0A/B Ext Reference In.
2. Connect cable or DUT between the VXG RF Out and the signal analyzer RF in.
3. Select **Preset** > **Preset** to set the instrument to a known state.
4. Set the Frequency to **12 GHz** and Amplitude to **–10 dBm**.
5. Select the **Signal** 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.



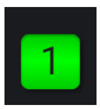
7. Select the **Mode** dropdown and select **Multitone**.

8. Select the **Multitone** tab from the left pane and then, configure the signal to have **501 Tones** with **4 MHz Tone Spacing**, then select the **General** tab > **Enable**.



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

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

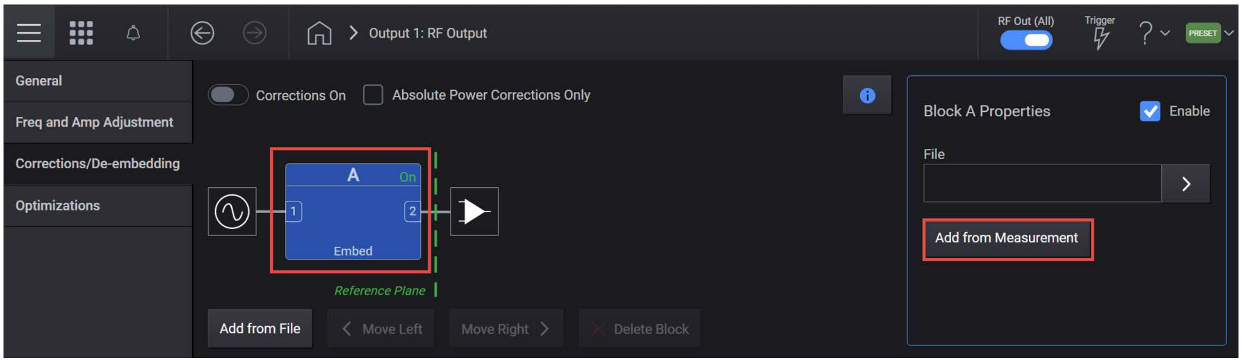
NOTE If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

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

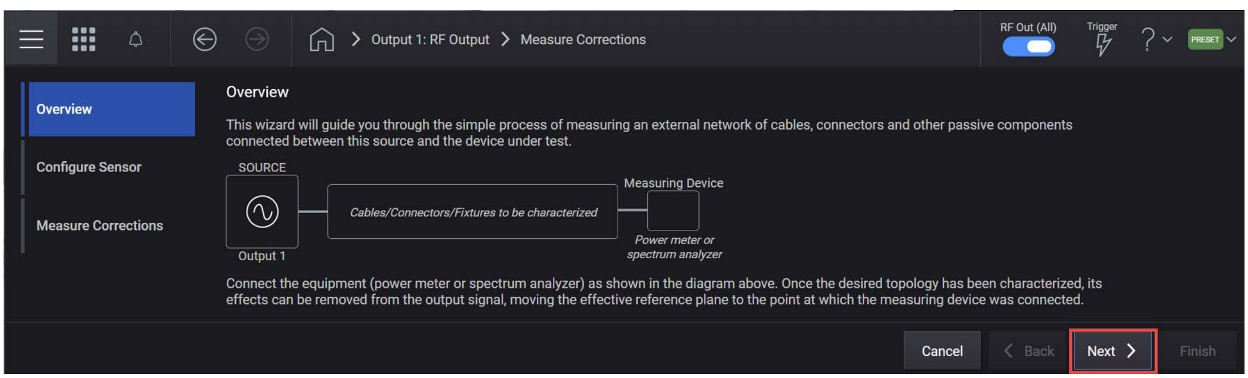
   Observe how the fixturing is impacting this signal, including the flatness and the total power.

On the VXG:

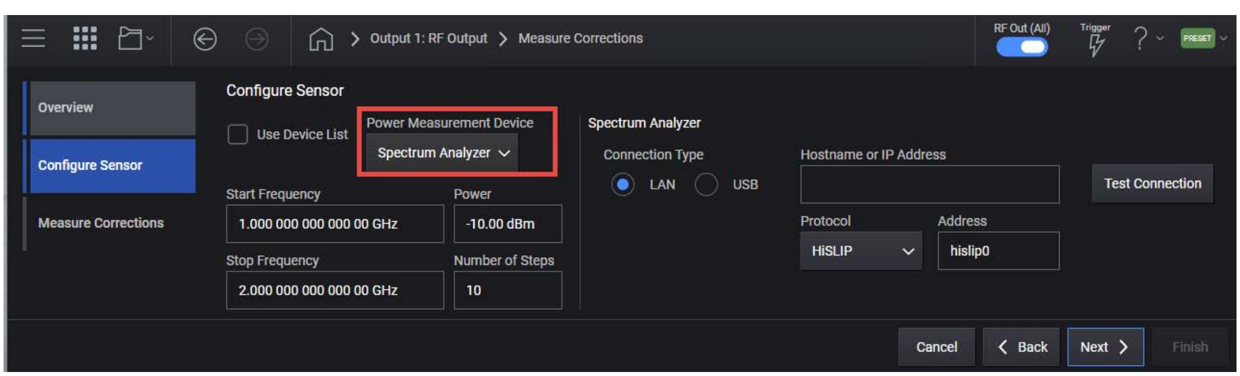
1. Select the **RF Output** block > **Corrections/De-embedding** tab to open the Correction Setup.
2. Select **Block A** to highlight > **Add from Measurement** to open the Measure Corrections Block Wizard.



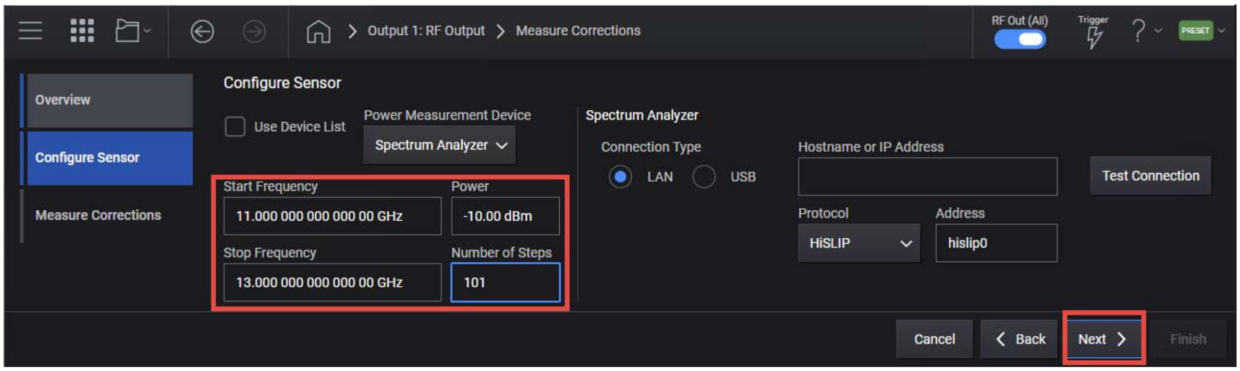
3. Connect the power sensor (in this case, the X-Series signal analyzer) as shown in the diagram below. After reading the overview, select **Next** to move to the Configure Sensor setup.



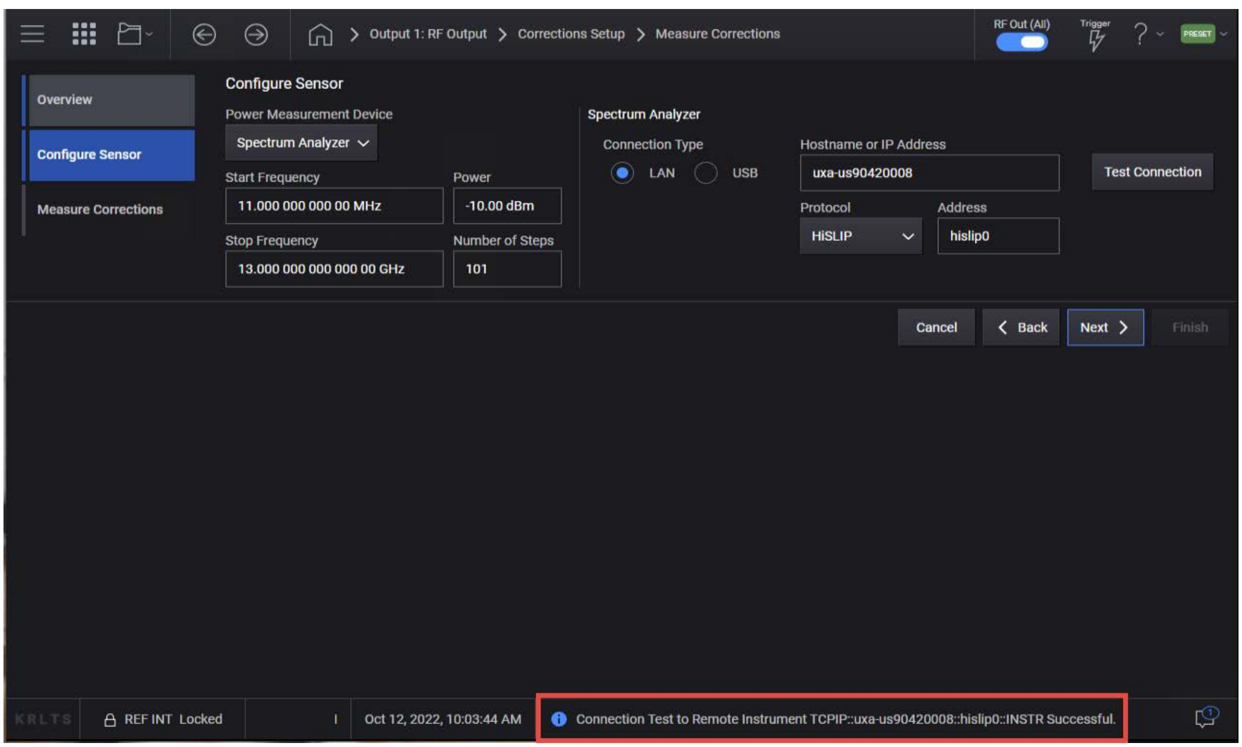
4. In the Configure Sensor setup, select the **Power Measurement Device** dropdown and select **Spectrum Analyzer**.



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**.



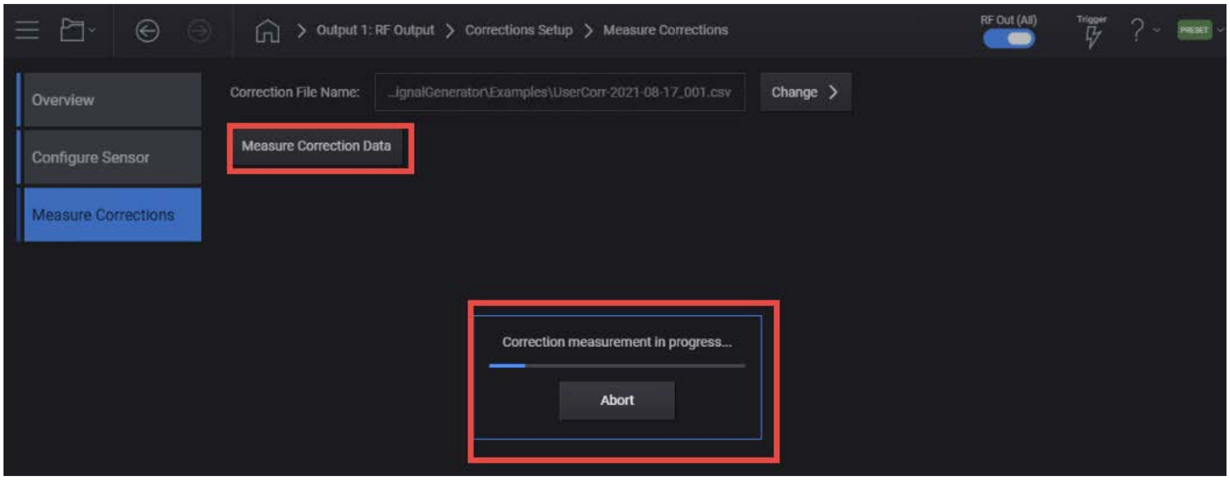
6. Set Connection Type to **LAN**, enter the LAN Address and set the Protocol parameters to **HiSLIP,** and then select **Test Connection**.



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

8. Select **Measure Correction Data**.

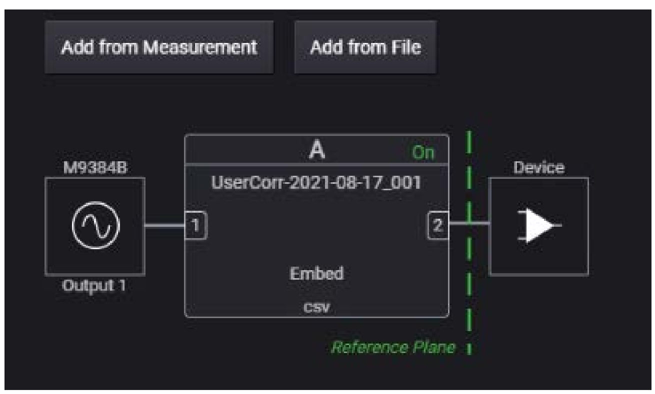
During the measurement, the VXG outputs a CW between the Start and Stop Frequencies for the specified number of steps and output power. It will take some time to measure all 101 points, and the progress is indicated by the blue bar. You can watch the signal analyzer as it steps through this process.



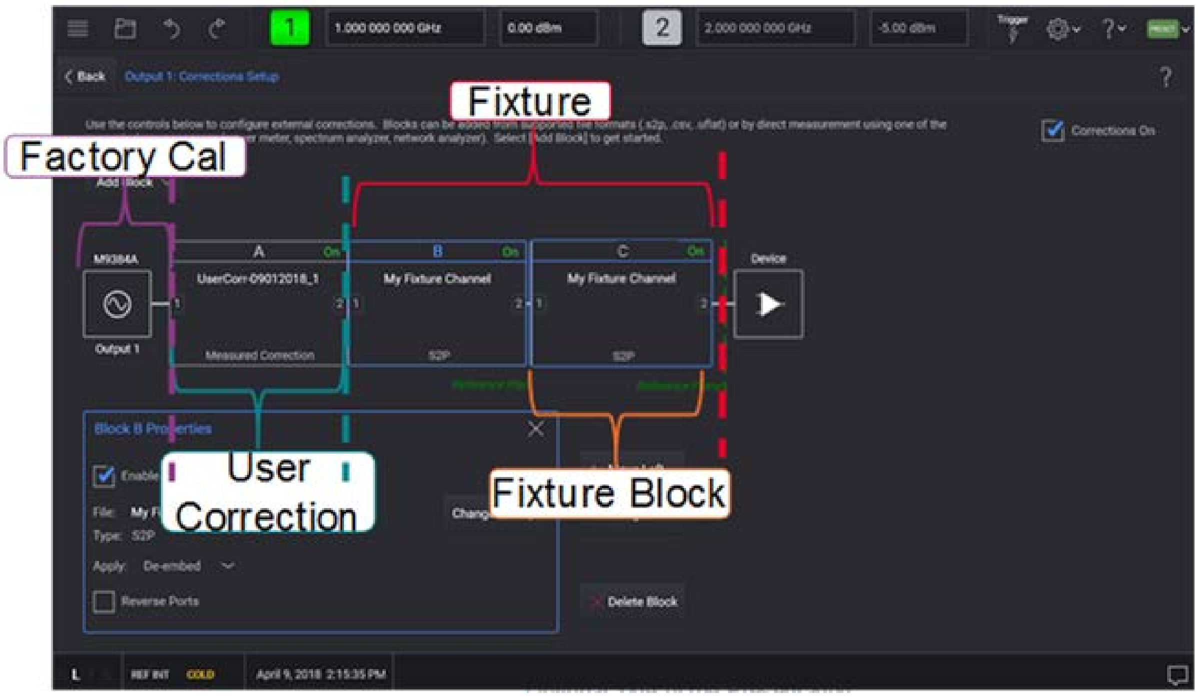
The measurement results are saved to a csv file using an automatically generated file name.

9. 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.



10. On the signal analyzer, **Restart** (on the left corner of the user interface) the 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.

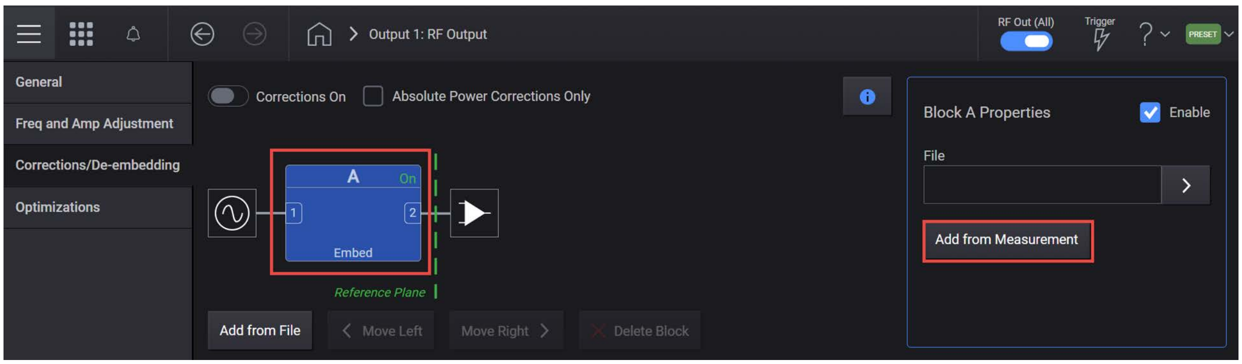
Using a Power Meter to Make the Corrections Measurement

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

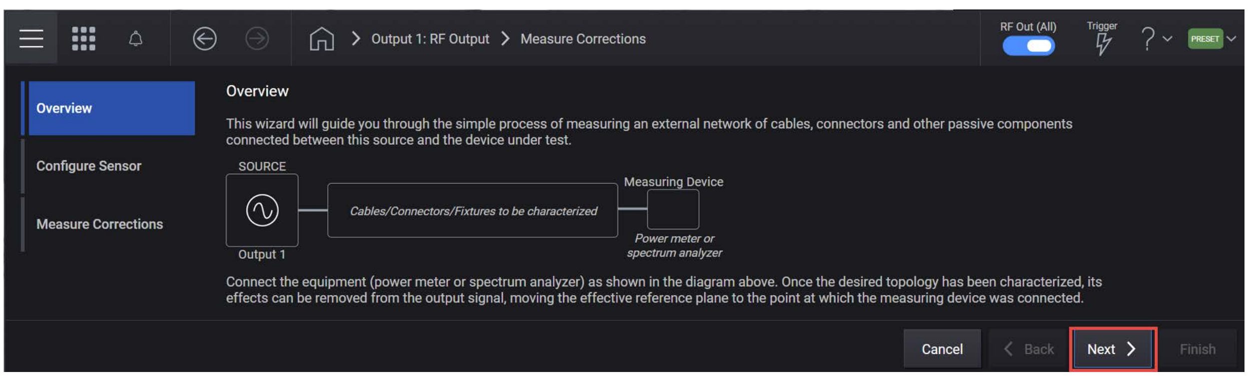
- U8487A-CFG007
- U8485A-CFG006
- U2000A
- U2001A
- U2002A
- U2004A
- U2000B
- U2001B
- U2000H
- U2001H
- U2002H

On the VXG:

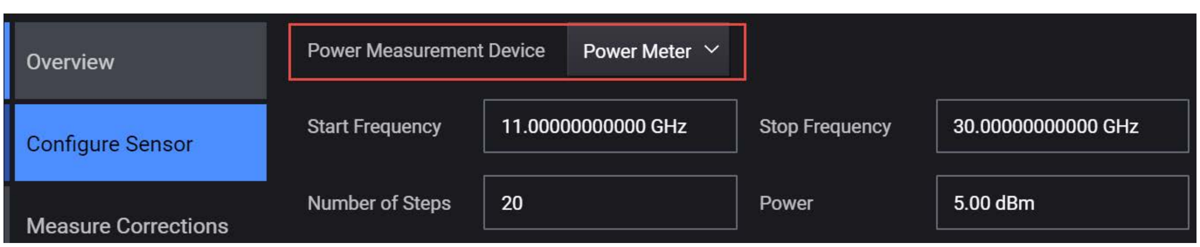
1. Connect the VXG 10 MHz Out to the N90x0A/B Ext Reference In.
2. Select the **RF Output** block > **Corrections/De-embedding** block to open the Correction Setup.
3. Select the **A Block** (to highlight) then **Add from Measurement** to open the Measure Corrections Block Wizard.



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



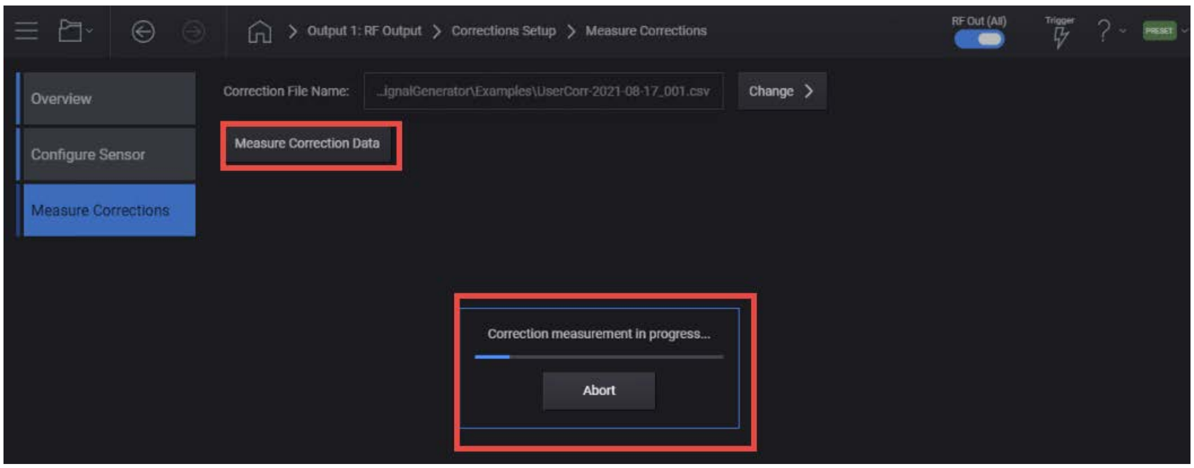
5. Select **Next** to go to Configure Sensor dialog and select the **Power Measurement Device** dropdown > **Power Meter.**



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

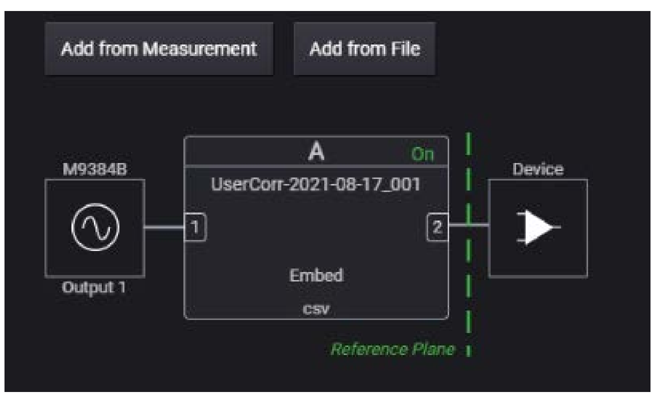
7. Select the Connection Type to **USB**, and then specify the Device and VISA Address.
8. Select **Test Connection** to verify connectivity, and then select **OK** then **Next** to continue.

   You can also calibrate and zero out the power sensor before measuring corrections.
9. Select **Next** to go to the Measure Corrections dialog and select **Measure Correction Data**.

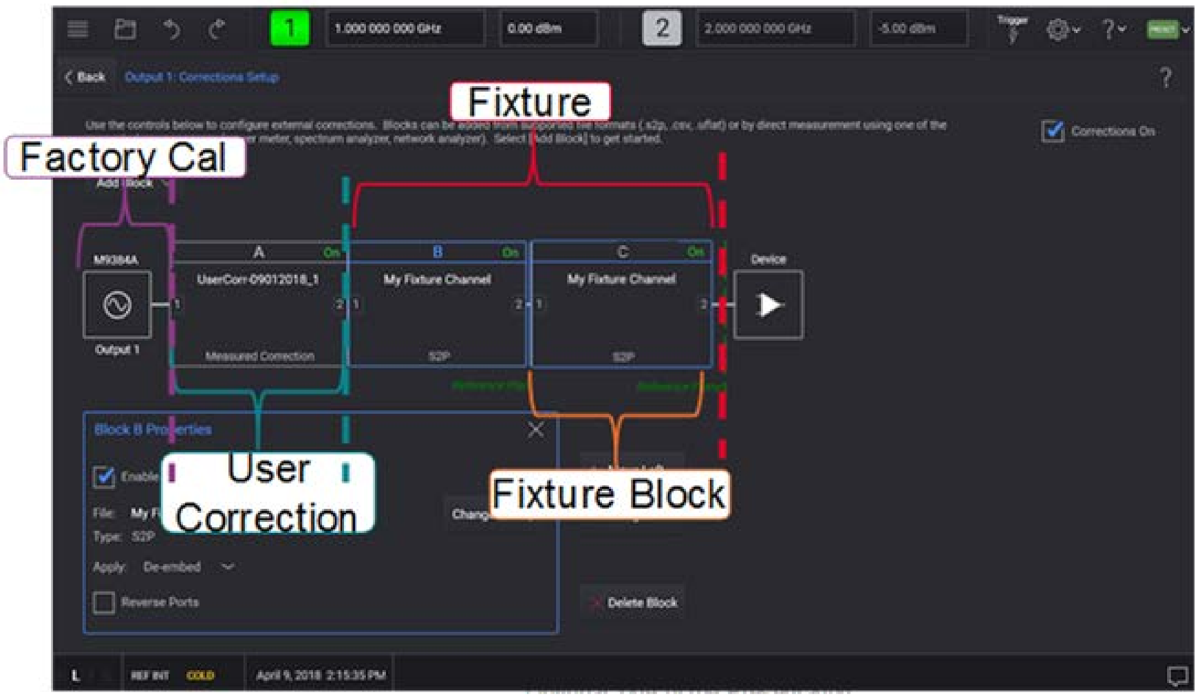


During the measurement, the VXG outputs a CW between the Start and Stop Frequencies for the specified number of steps and output power. The measurement results are saved to a csv file using an automatically generated file name.

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



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.

`RFALl: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"`

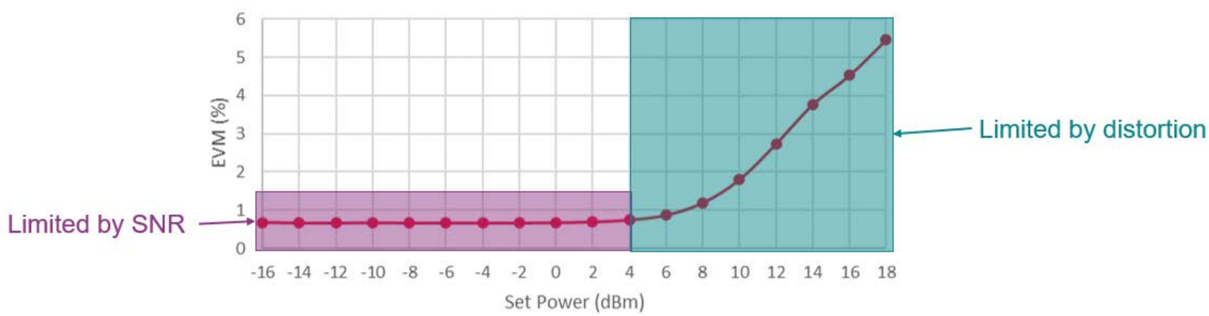
Change Block C to Embed.

```
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.

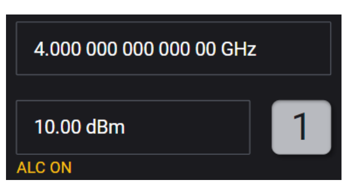


Setting Up an INC 1CC 4 GHz, 10 dBm EVM Measurement

On the VXG:

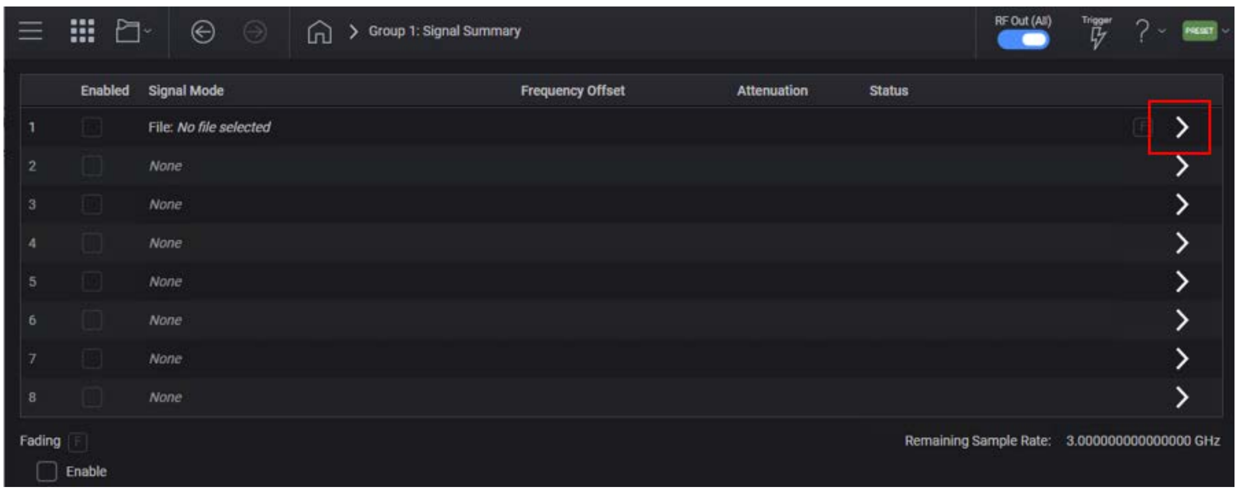
In order to compare before and after correction results, we will start by making an EVM measurement without applying corrections.

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



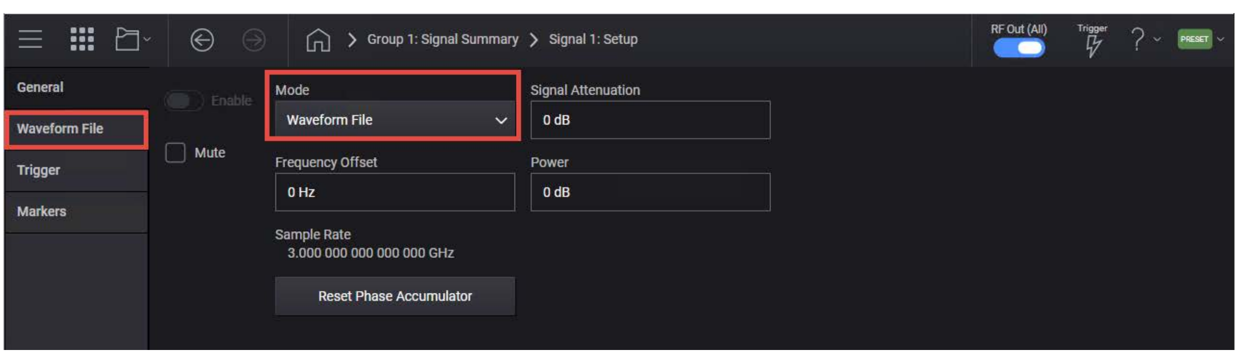
3. Select the **Signal** block to open the Vector Modulation Signal Setup panel.

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. Set Mode to **Waveform File**, then select the **Waveform File** tab in the left pane.

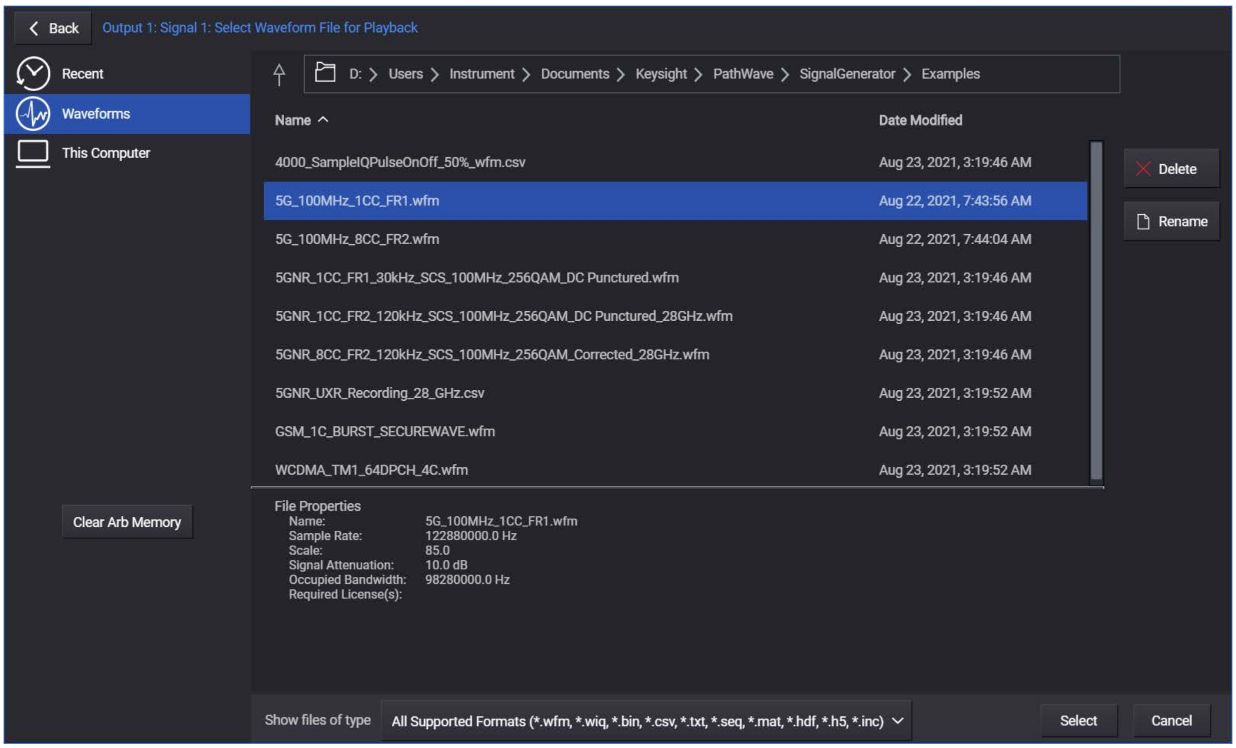


6. In the Waveform Playback Setup area, use File **Select** to navigate to:

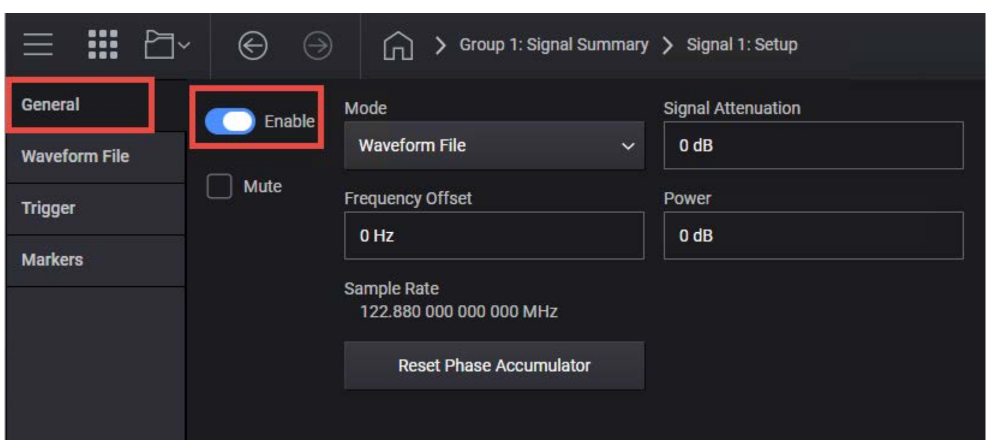
   `D:\Users\Instrument\Documents\Keysight\PathWave\SignalGenerator\Examples`

   and choose
   `5G_100MHz_1CC_FR1.wfm`

   then **Select**.



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



8. 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 & V2X** Mode > **Modulation Analysis** Measurement > **OK**.

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

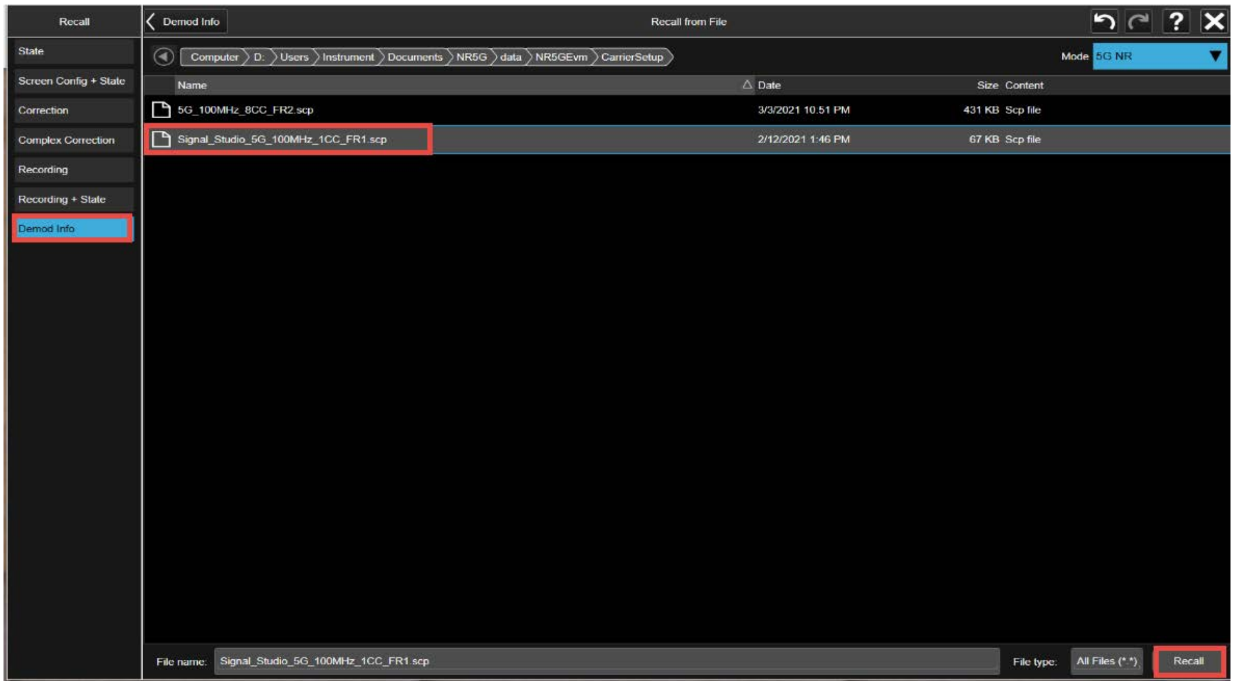
D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples

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** > Data Type set to **CC Setup** > **Recall From** >

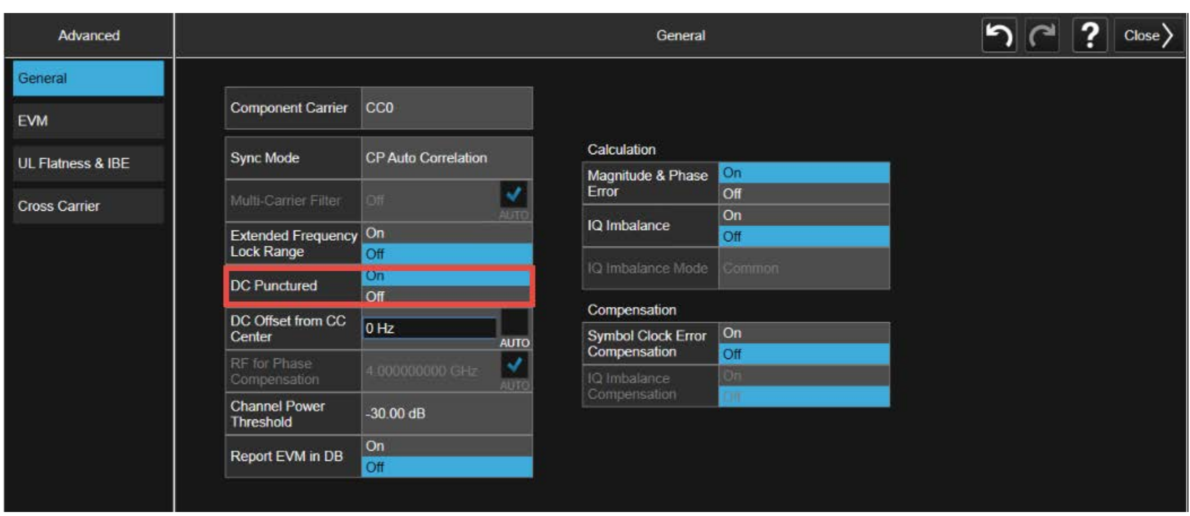
`Signal Studio_5G_100 MHz_1CC_FR1.scp`

Recall



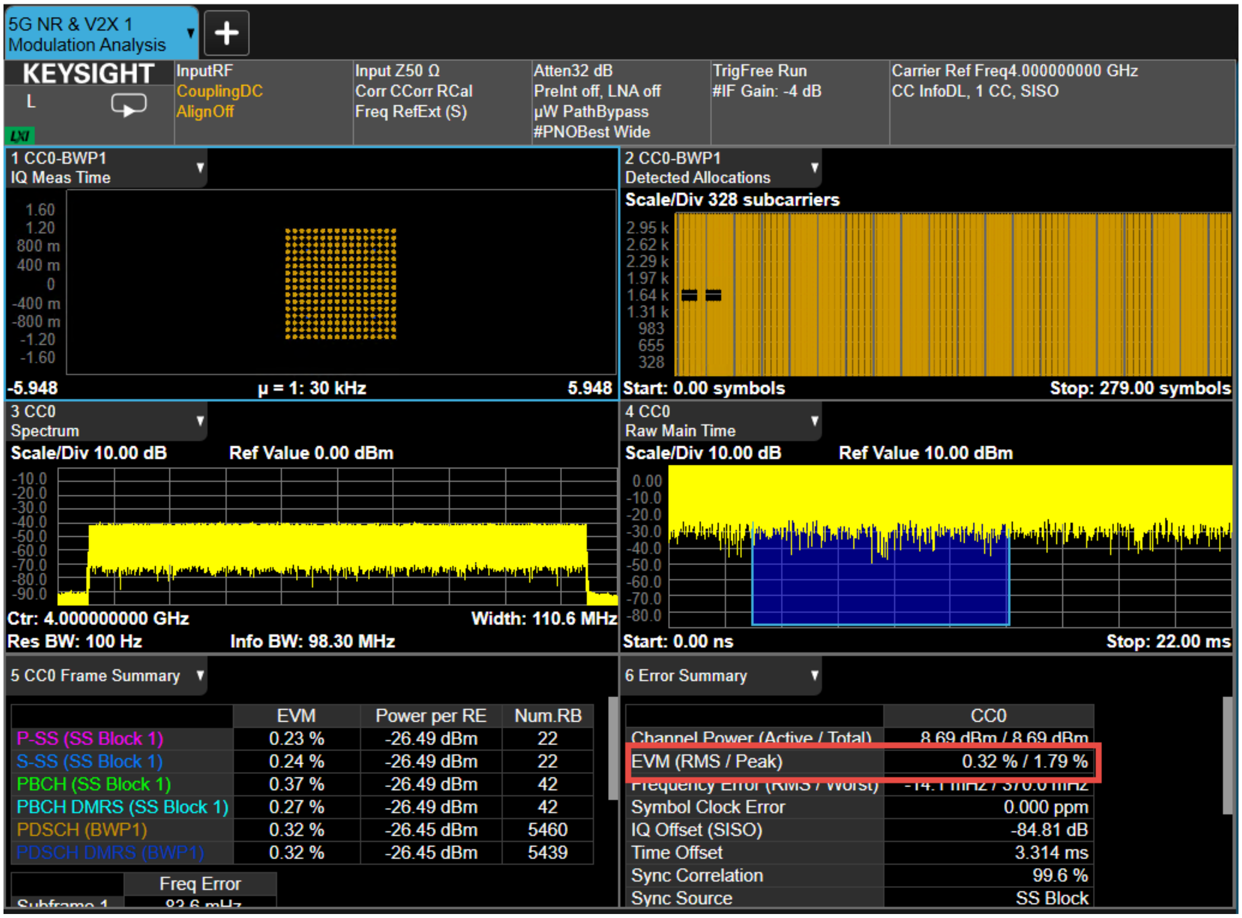
5. The Signal Stuidio_5G_100 MHz_1CC_FR1.scp file automatically sets the Carrier Frequency to 4 GHz.

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%

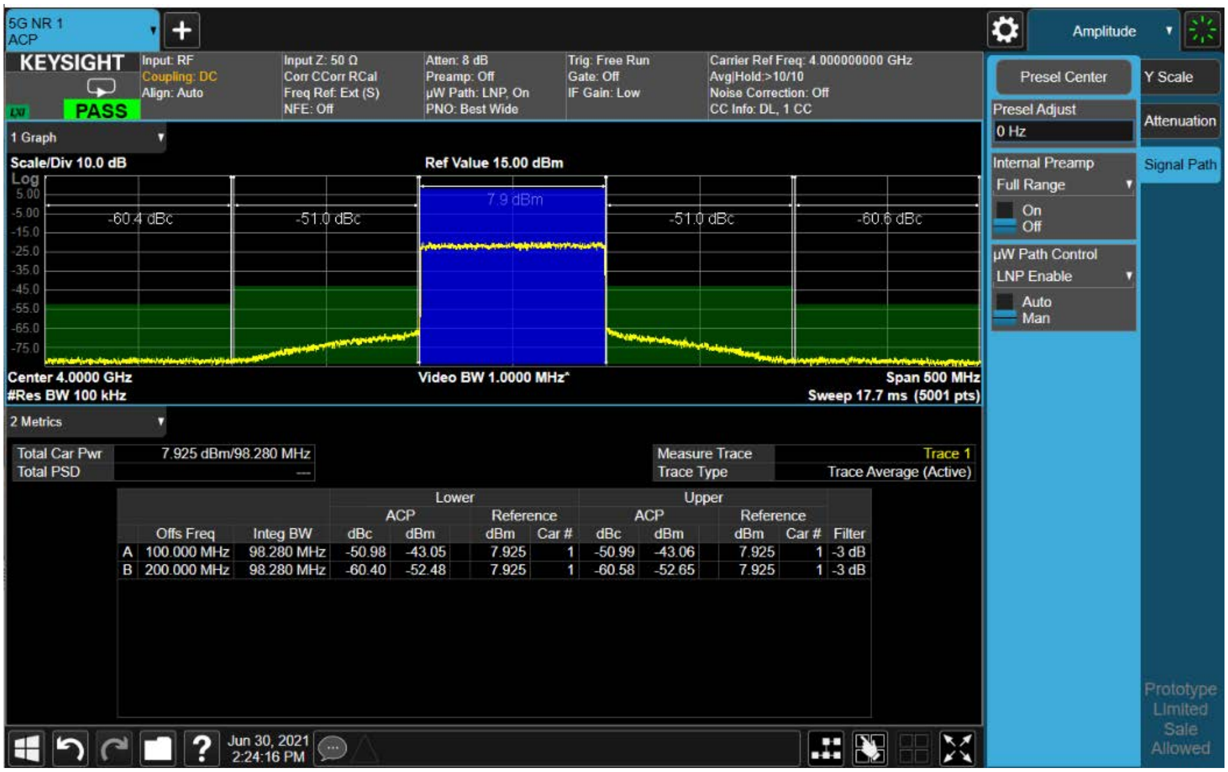

5G NR & V2X 1
Modulation Analysis
KEYSIGHT
Input RF
Coupling DC
Align Off
Input Z 50 Ω
Corr CCorr RCal
Freq Ref Ext (S)
Atten 32 dB
PreInt off, LNA off
µW Path Bypass
#PNO Best Wide
Trig Free Run
#IF Gain: -4 dB
Carrier Ref Freq 4.000000000 GHz
CC Info DL, 1 CC, SISO
1 CC0-BWP1
IQ Meas Time
2 CC0-BWP1
Detected Allocations
Scale/Div 328 subcarriers
Start: 0.00 symbols
Stop: 279.00 symbols
µ = 1: 30 kHz
3 CC0
Spectrum
Scale/Div 10.00 dB
Ref Value 0.00 dBm
Ctr: 4.000000000 GHz
Width: 110.6 MHz
Res BW: 100 Hz
Info BW: 98.30 MHz
4 CC0
Raw Main Time
Scale/Div 10.00 dB
Ref Value 10.00 dBm
Start: 0.00 ns
Stop: 22.00 ms
5 CC0 Frame Summary
EVM
Power per RE
Num.RB
P-SS (SS Block 1) 0.23 % -26.49 dBm 22
S-SS (SS Block 1) 0.24 % -26.49 dBm 22
PBCH (SS Block 1) 0.37 % -26.49 dBm 42
PBCH DMRS (SS Block 1) 0.27 % -26.49 dBm 42
PDSCH (BWP1) 0.32 % -26.45 dBm 5460
PDSCH DMRS (BWP1) 0.32 % -26.45 dBm 5439
Freq Error
6 Error Summary
CC0
EVM (RMS / Peak) 0.32 % / 1.79 %
Symbol Clock Error 0.000 ppm
IQ Offset (SISO) -84.81 dB
Time Offset 3.314 ms
Sync Correlation 99.6 %
Sync Source SS Block

To Measure ACP:

a. Select **Mode/Meas** > **5GNR & V2X** Mode > **ACP** > **OK.**

b. Select **Amplitude** > **Signal Path** tab > and set µW Path Control to **Low Noise Path Enable** (if Option LNP is available on your analyzer).

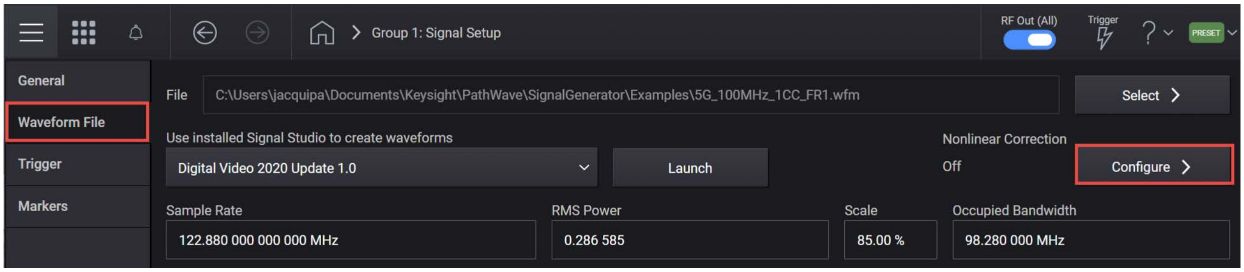
Record the results for the Lower and Upper ACP results. For this example -50.9 dBc (lower) and -50.9(upper).



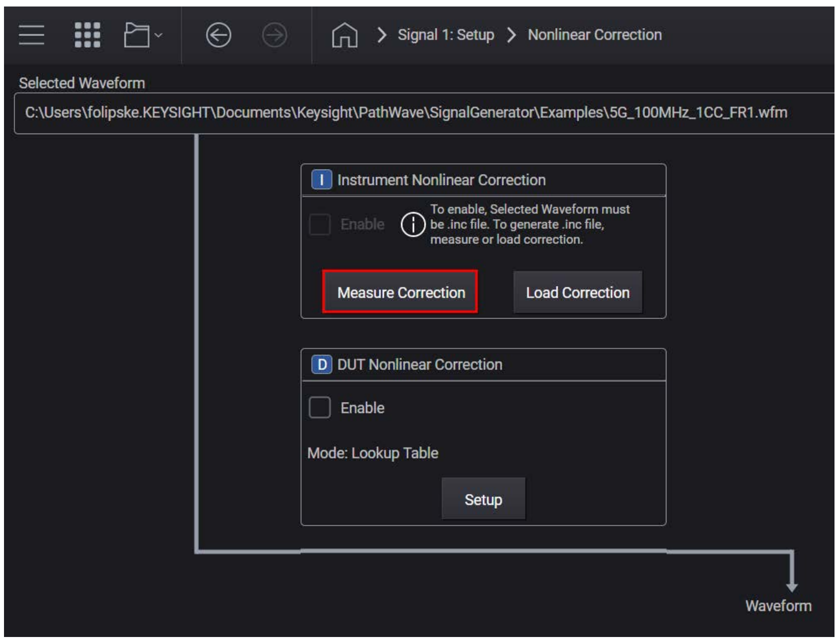
c. Select **Mode/Meas** > **5GNR & V2X** > **Modulation Analysis** > **OK.**

On the VXG:

1. Open the Signal block and select the **Waveform File** tab > **Configure** to open the Nonlinear Correction Setup.

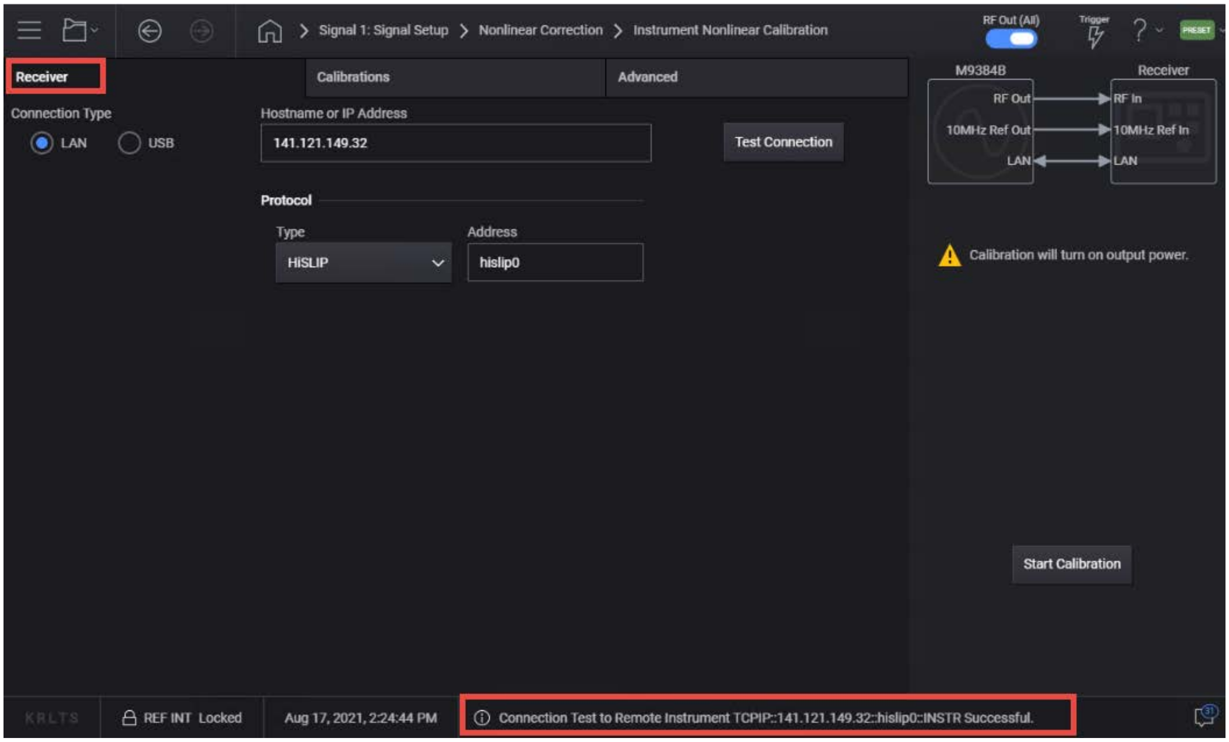


2. In the Instrument Nonlinear Correction area, select **Measure Correction** to open the Instrument Nonlinear Calibration screen.

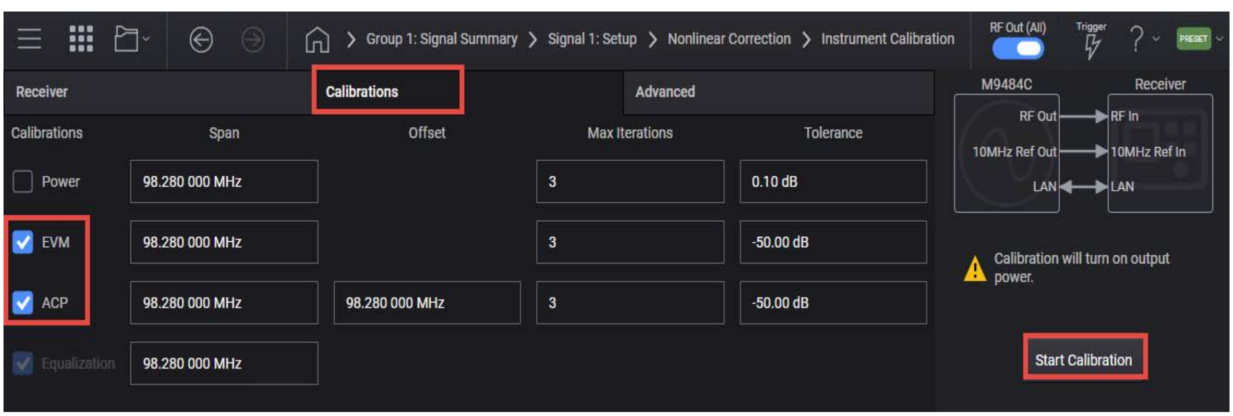


3. Under the Receiver tab (opened by default), enter your connection information and test the connection. For this example, select **LAN** as the Connection Type > Enter the IP address for you signal analyzer (for this example, 141.121.149.32) as the Hostname > **Test Connection**.

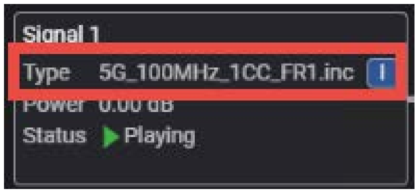
The Connection status will be displayed in the Notifications area at the bottom of the main window.



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



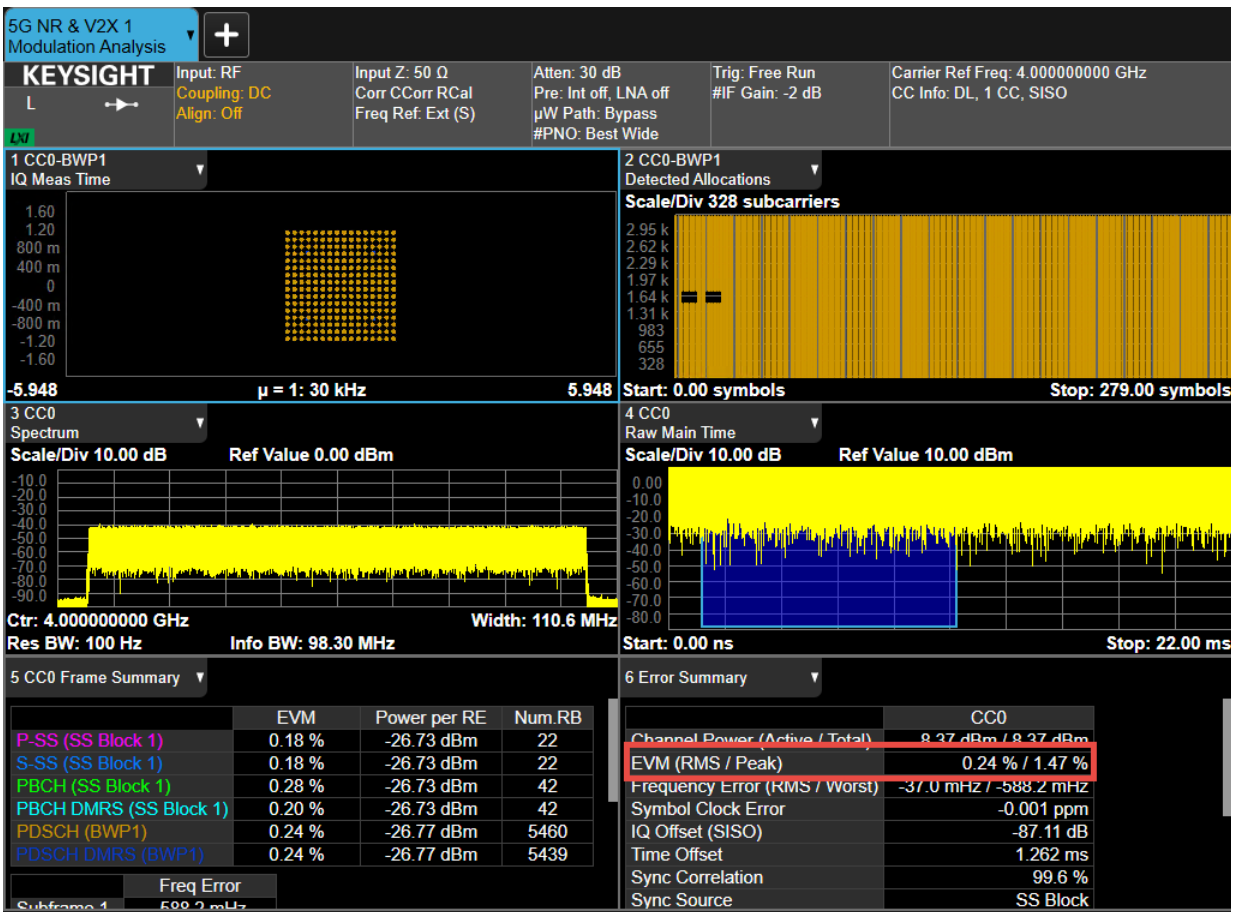
The calibration will take a few minutes to complete. Once done, the INC file will be created and it will automatically be used in place of the .wfm file originally loaded. An "I" will be displayed in the Signal block indicating this status.



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%).

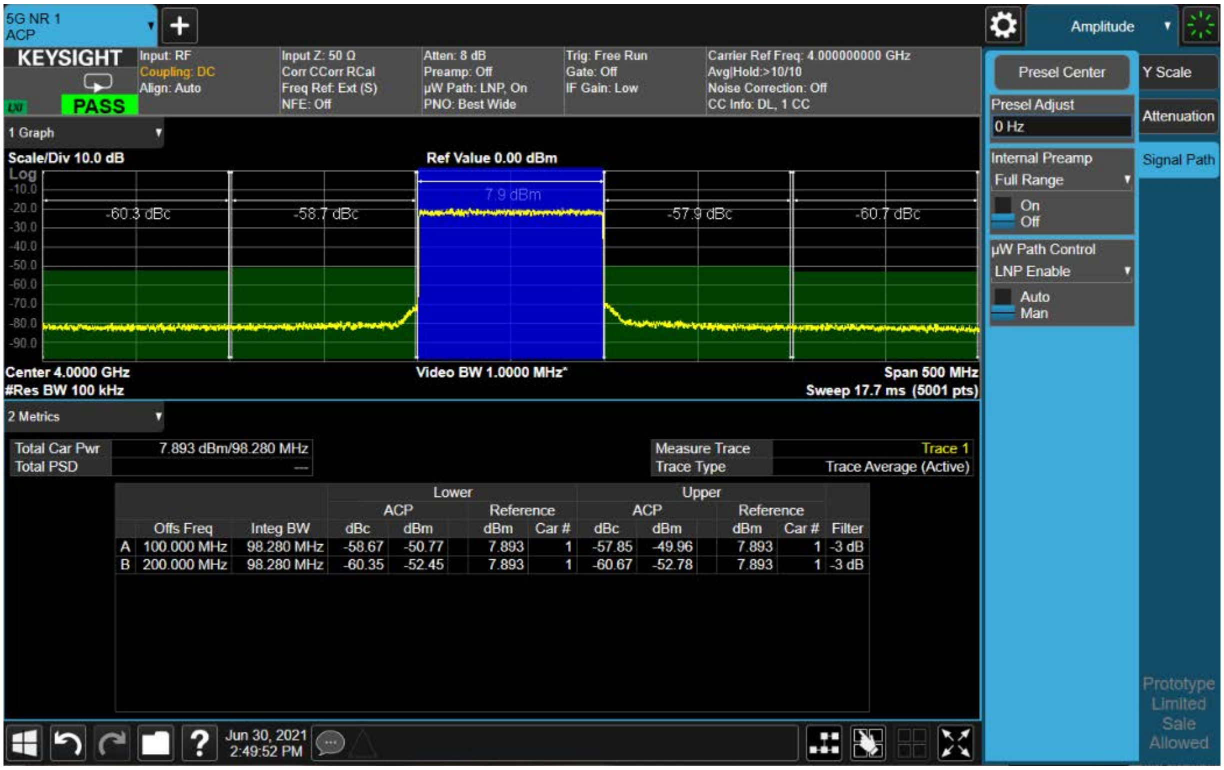


To Measure ACP:

a. Select **Mode/Meas** > **5GNR & V2X** Mode > **ACP** > **OK**.

b. Select **Amplitude** > **Signal Path** tab > and set µW Path Control to **Low Noise Path Enable**.

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).

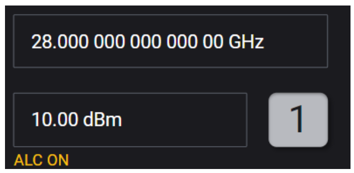


Setting Up an INC 8CC 28 GHz, 10 dBm EVM Measurement

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**.

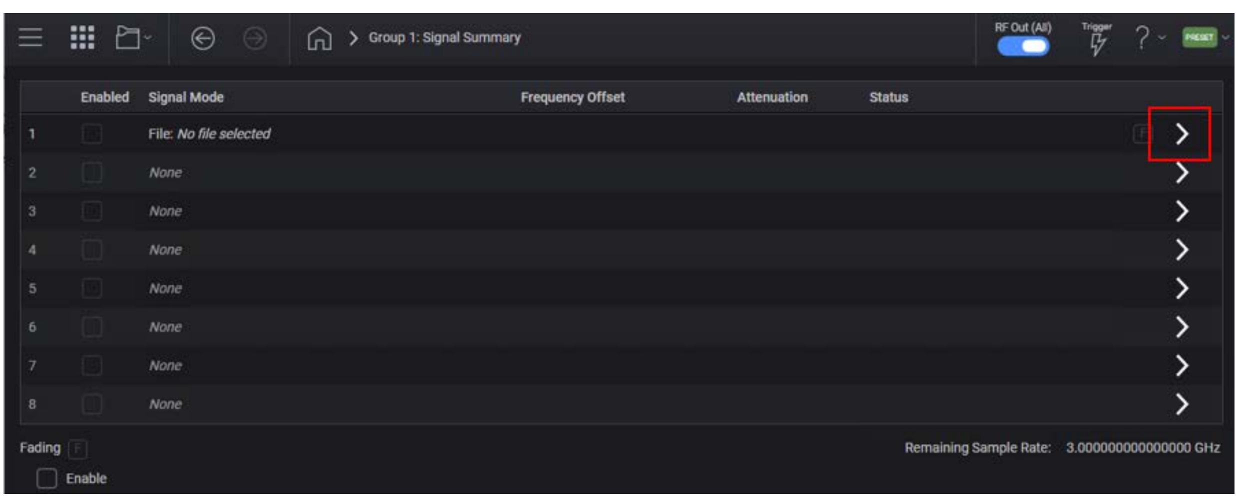


3. Select the **Group 1: Signals** block to open.

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.

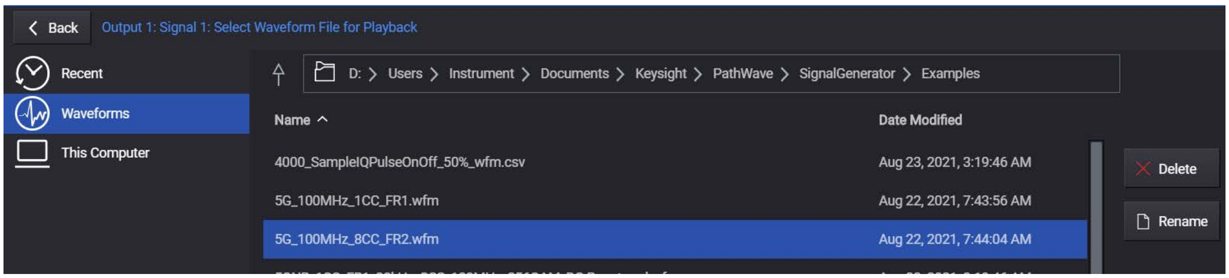


5. Set Mode to **Waveform File** and then select the **Waveform File** tab in the left pane.
6. In the Waveform Playback Setup area, use File **Select** to navigate to:

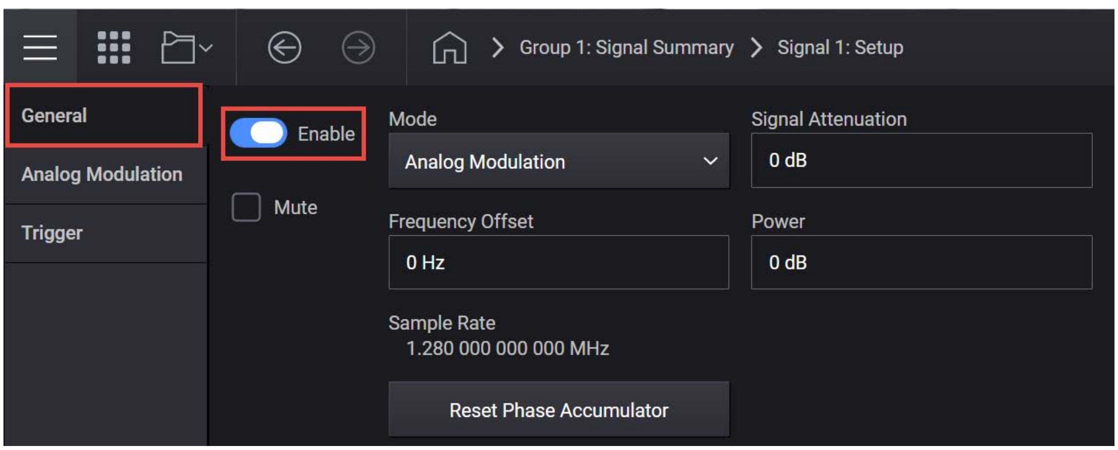
   `D:\Users\Instrument\Documents\Keysight\PathWave\SignalGenerator\Examples`

   `5G_100MHz_8cc_FR2.wfm`

   then **Select**.



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



8. 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** > **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:

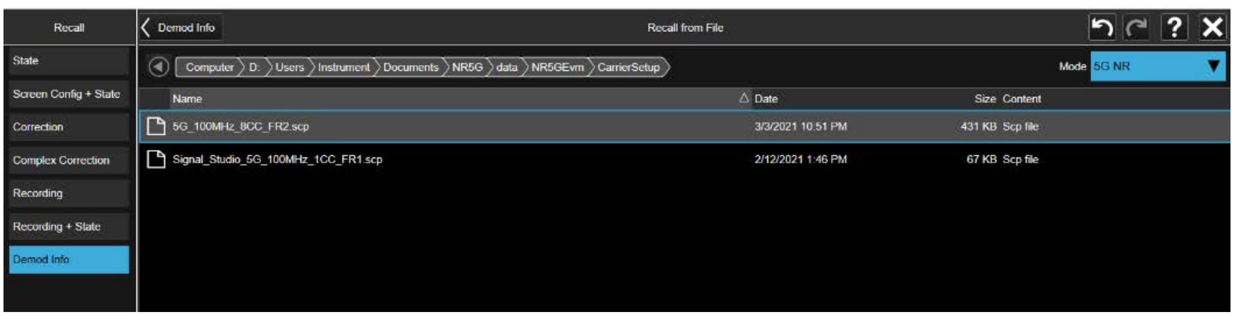
D:\Users\Instrument\Documents\Keysight\PathWave \SignalGenerator\Examples

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 few minutes for the UXA to measure all 8 carriers.

   Record the results.

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:

a. Select **Mode/Meas** > **5GNR & V2X** Mode > **ACP** > **OK.**

b. Select **Amplitude** > **Signal Path** tab > and set µW Path Control to **LNP (Low Noise Path) Enable** (if your analyzer has Option LNP).

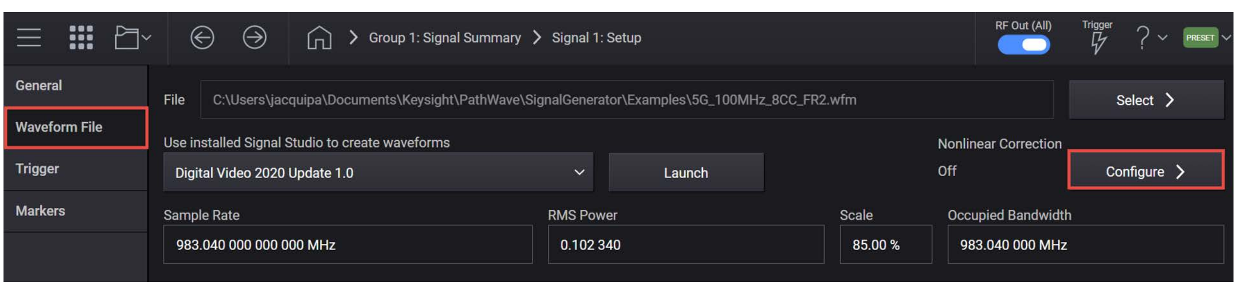
c. Select **Sweep** > **Restart** to take a new sweep.

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.**

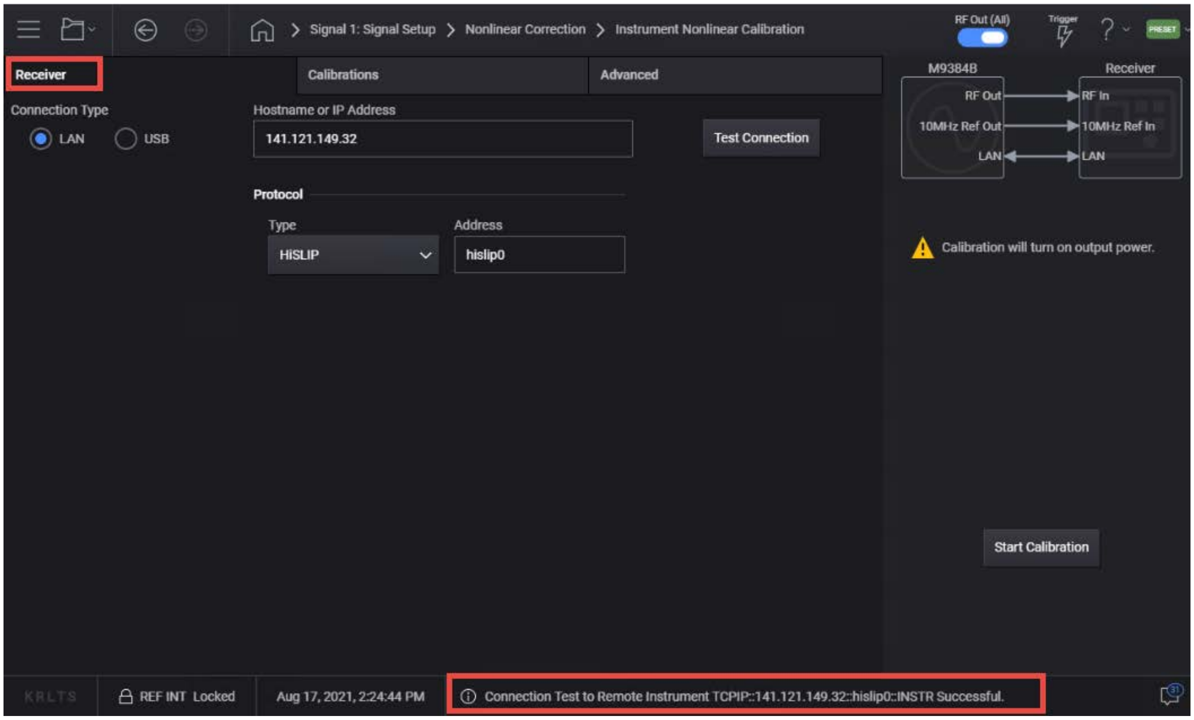
On the VXG:

1. In the Signal block, select **Waveform File** Mode > **Waveform File** tab > **Configure** to open the Nonlinear Correction Setup.

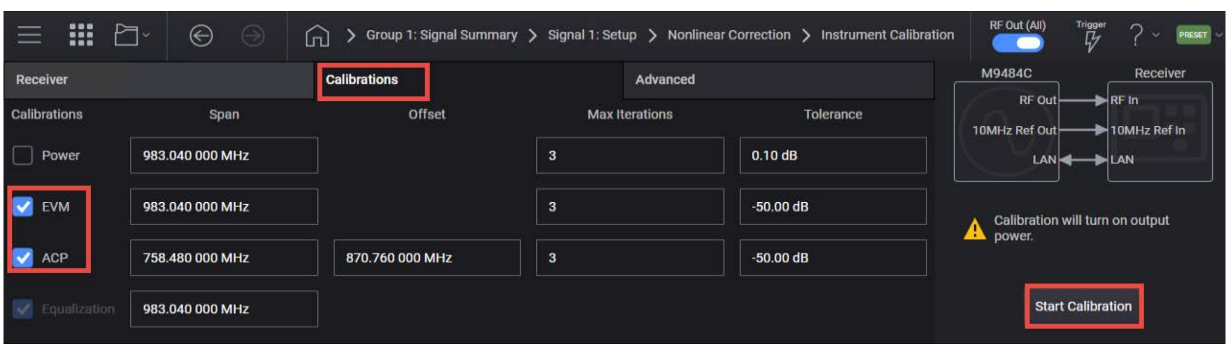


2. In the Instrument Nonlinear Correction area, select **Measure Correction** to open the Instrument Nonlinear Calibration screen.
3. Under the Receiver tab (opened by default), enter your connection information and test the connection. For this example, select **LAN** as the Connection Type > Enter the IP address for you signal analyzer (for this example, 141.121.149.32) as the Hostname > **Test Connection**.

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.

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:

a. Select **Mode/Meas** > **5GNR & V2X** Mode > **ACP** > **OK**.

b. Select **Amplitude** > **Signal Path** tab > and set µW Path Control to **LNP (Low Noise Path) Enable**.

c. Select **Sweep** > **Restart** to take a new sweep.

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).

			Lower				Upper				
			ACP		Reference		ACP		Reference		
	Offs Freq	Integ BW	dBc	dBm	dBm	Car #	dBc	dBm	dBm	Car #	Filter
A	100.000 MHz	98.280 MHz	-32.27	-37.04	-4.775	1	-33.15	-37.92	-4.775	1	-3 dB
B	200.000 MHz	98.280 MHz	-31.85	-36.63	-4.775	1	-33.32	-38.10	-4.775	1	-3 dB

3 Advanced Measurements

KEYSIGHT TECHNOLOGIES

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

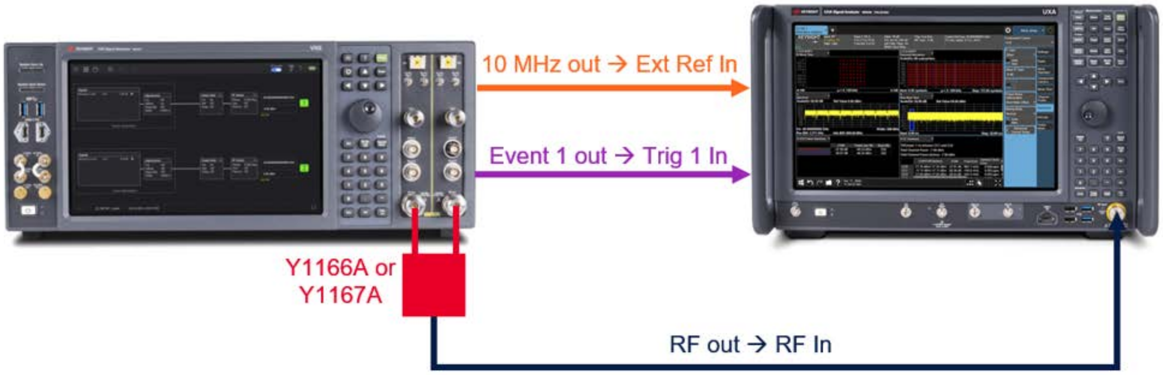
The following three examples are showing

- "Generating a Multi-Carrier DVB-S2X Signal for Satellite TV" on page 93
- "Generating a Wide Band QPSK" on page 107
- "Generating a 5G NR Waveform" on page 116

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**

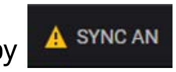


Generating a Multi-Carrier DVB-S2X Signal for Satellite TV

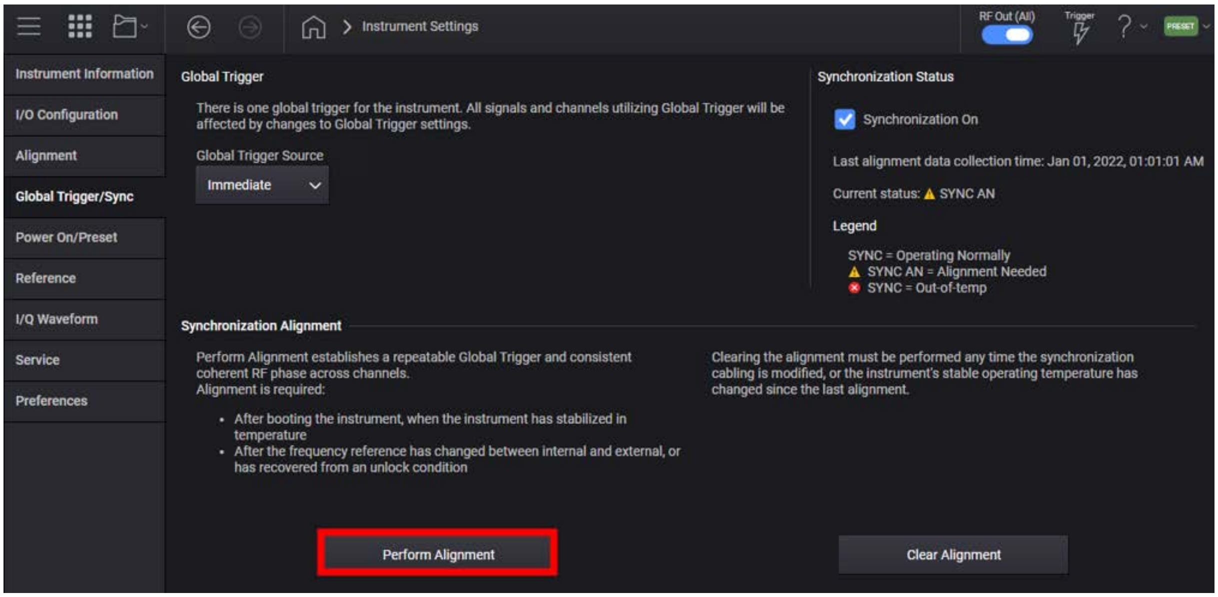
DVB-S2X is a digital satellite television broadcast standard. Channel bonding can be used for UHDTV services where statistical multiplexing is used to allow many television channels can use the same bandwidth. Other applications include Direct to Home (DTH), Digital Satellite News Gathering (DSNG) and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

On the VXG:

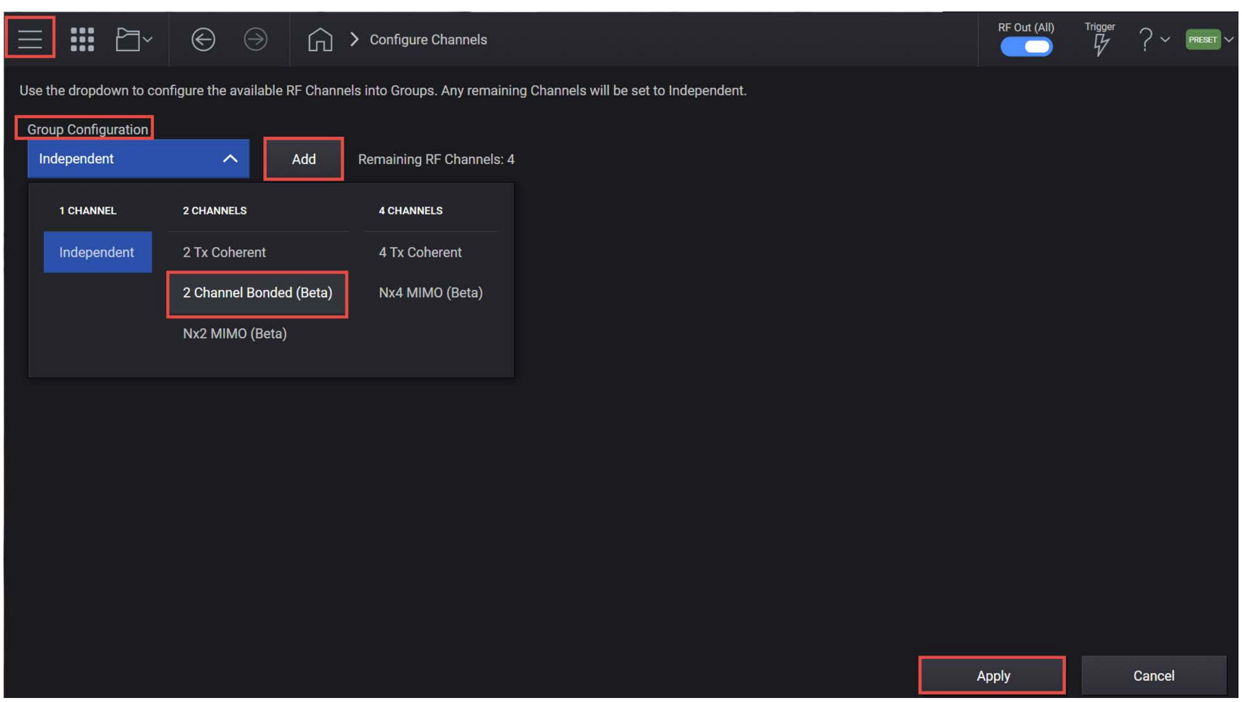
1. Connect the equipment as shown above.
2. Select **Preset** > **Preset** to set the VXG to a known state.

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.

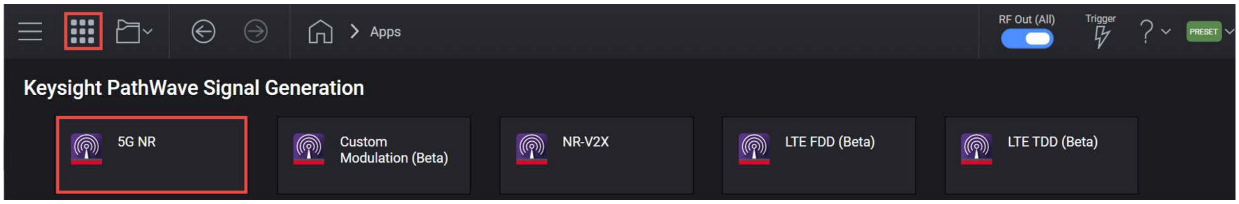


3. Select the System menu (triple bar icon at the top left of the window), and then select **Configure Channels** > **2 Channel Bonded** > **Add** (for 4 channel instruments only) > **Apply** > **Apply**.

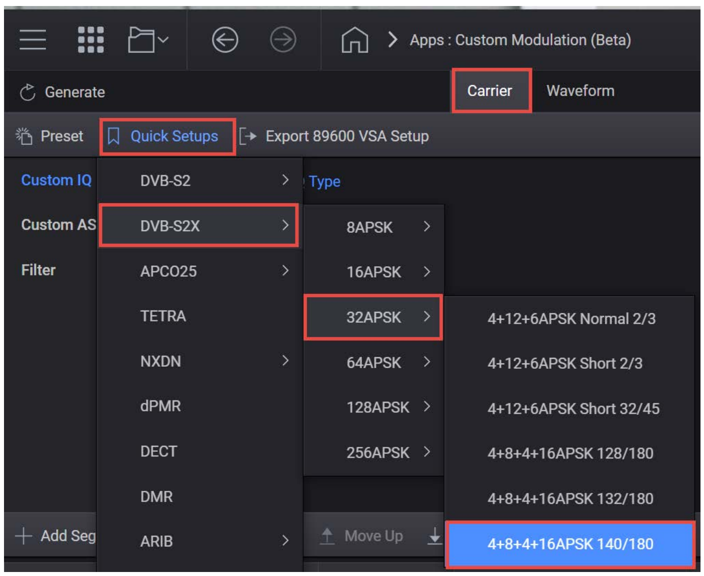


4. Set the Center Frequency to **12 GHz** and Power to **0 dBm**.

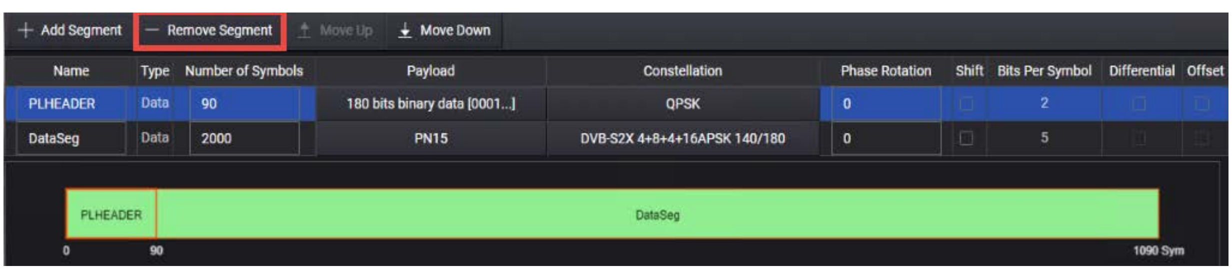
5. Select the **Apps** block to open, then select **Custom Modulation**.



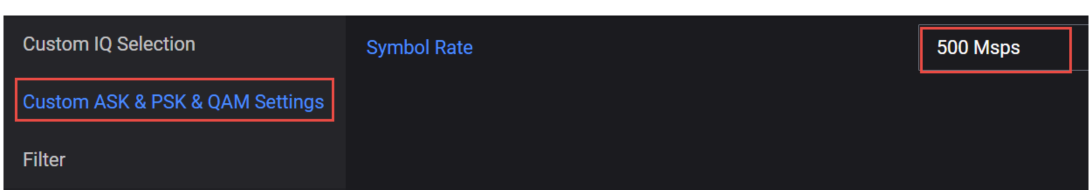
6. In the Custom Modulation setup, select the **Carrier** tab > **Quick Setups** > **DVB-S2X** > **32APSK** > **4+8+4+16APSK 140/180**.



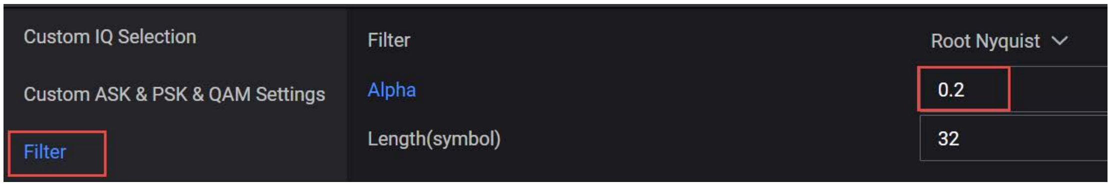
7. From the bottom pane, select **Remove Segment** to remove the Header. This will simplify the demonstration.



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

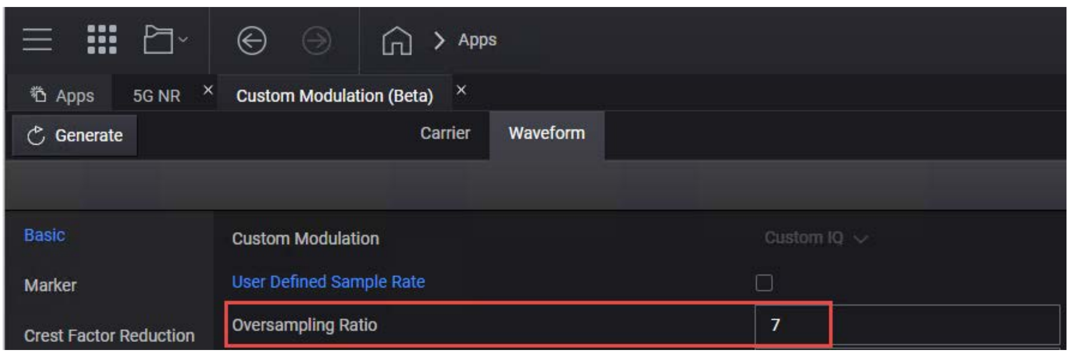


9. Select **Filter** > Alpha to **0.2**.



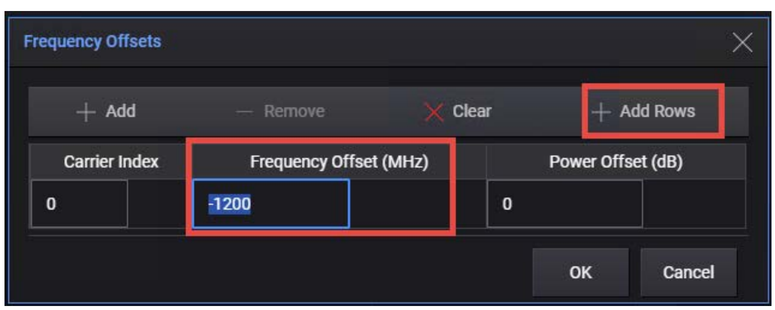
10. Select the **Waveform** tab > **Basic** > Oversampling Ratio to **7** x multiplier which provides a span of 3.5 GHz.

    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.

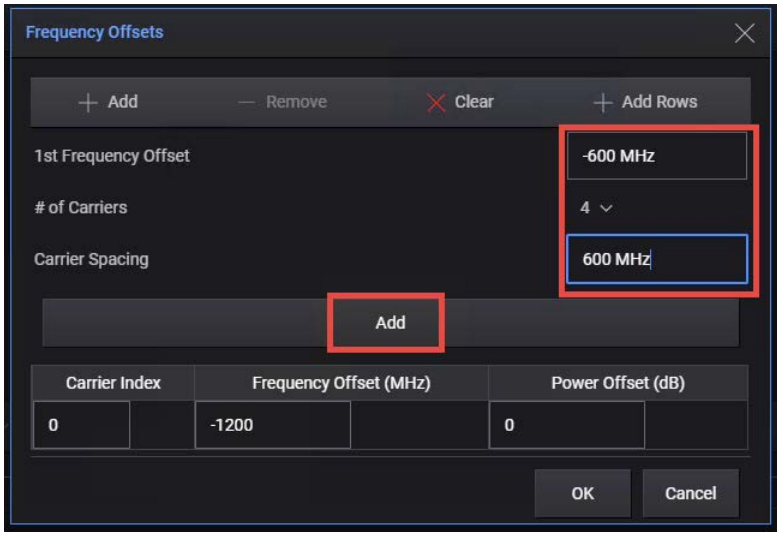


11. From the left pane, select **Multi Carrier** and select **Multicarrier Enabled**.

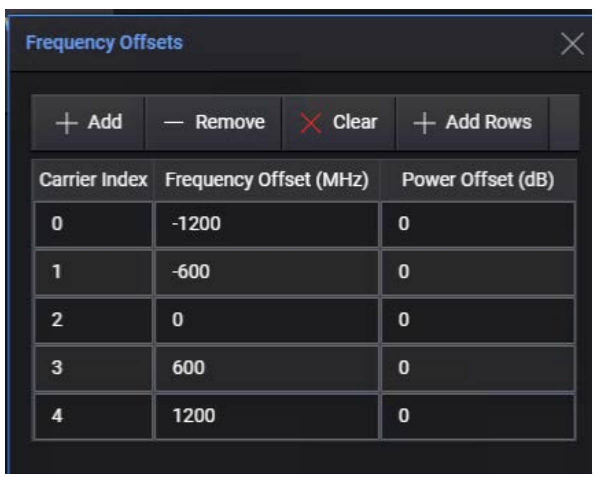
12. Open the **Frequency Offsets** setup screen. For Carrier Index 0, set the Frequency Offset to **-1200 MHz**, then select **Add Rows**.



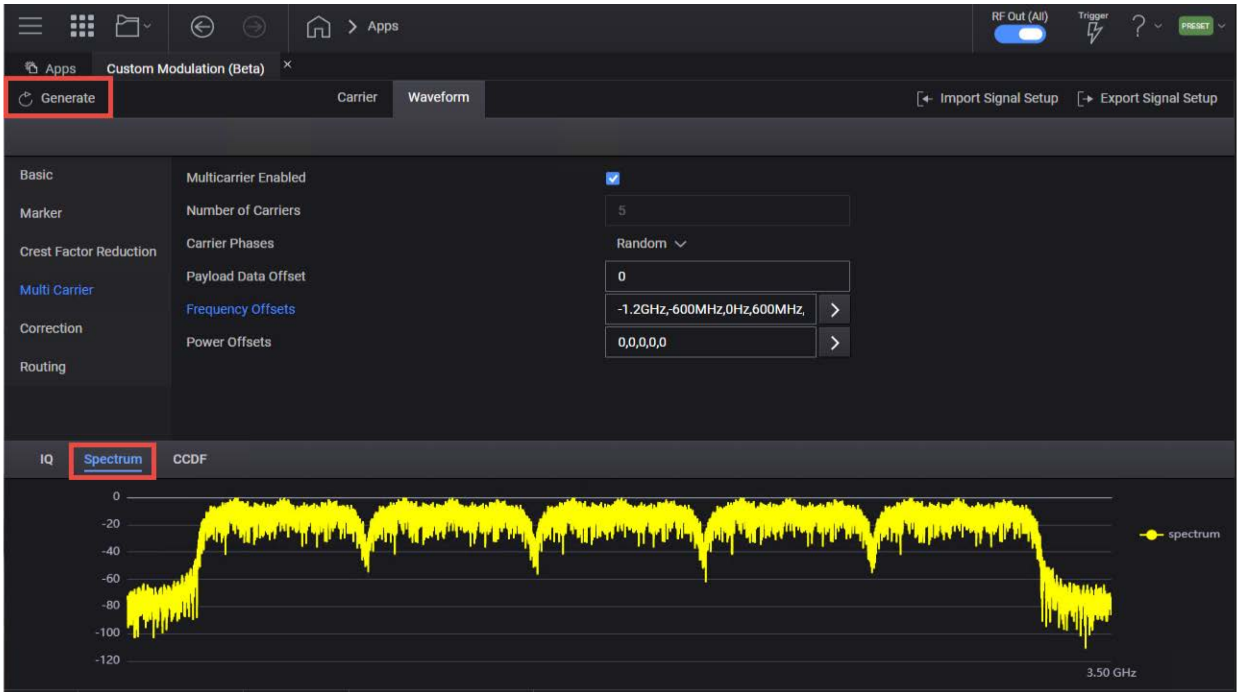
13. Enter the 1st Frequency Offset of **-600 MHz**, # of Carriers **4**, and Carrier Spacing **600 MHz**. Select **Add**.



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

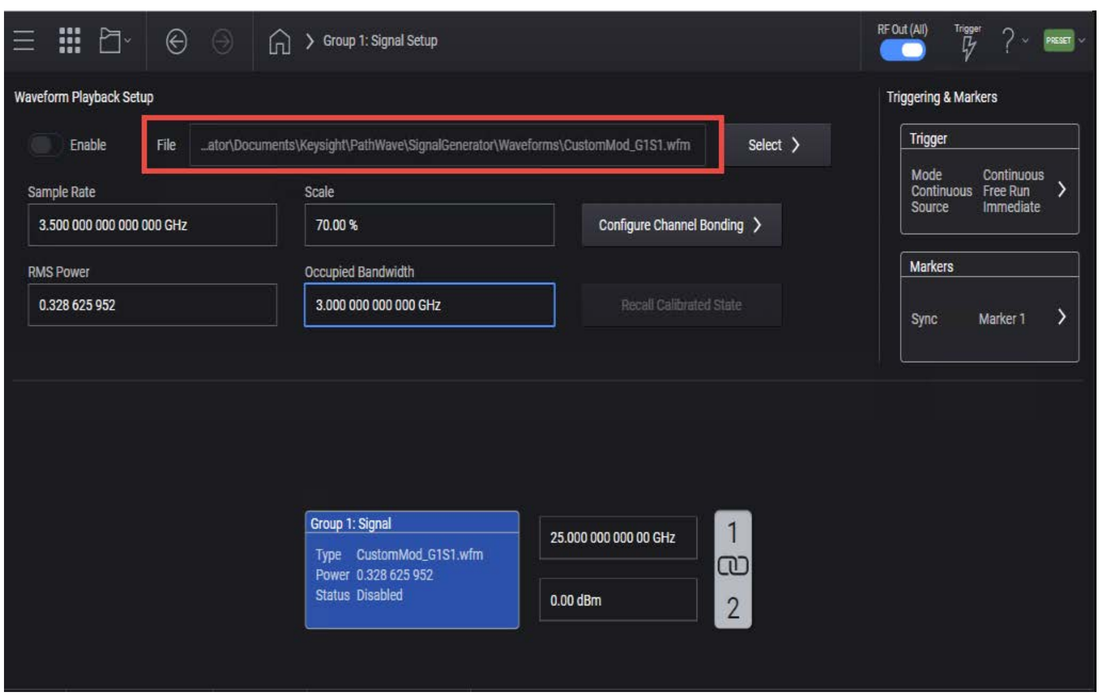


14. **Generate** the waveform and select the **Spectrum** tab from the bottom pane to ensure the resulting waveform is correct.

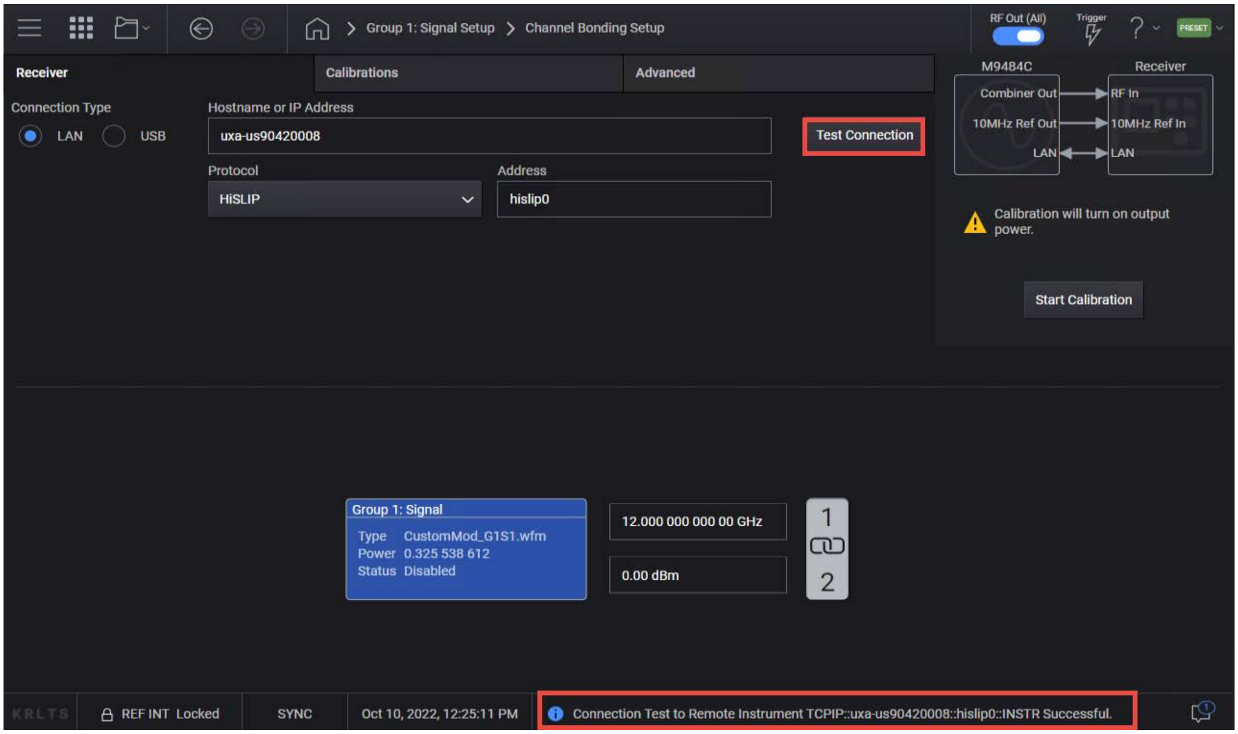


15. Select the **Home** icon to return to the main window and then select the **Signal Block** to open.

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.

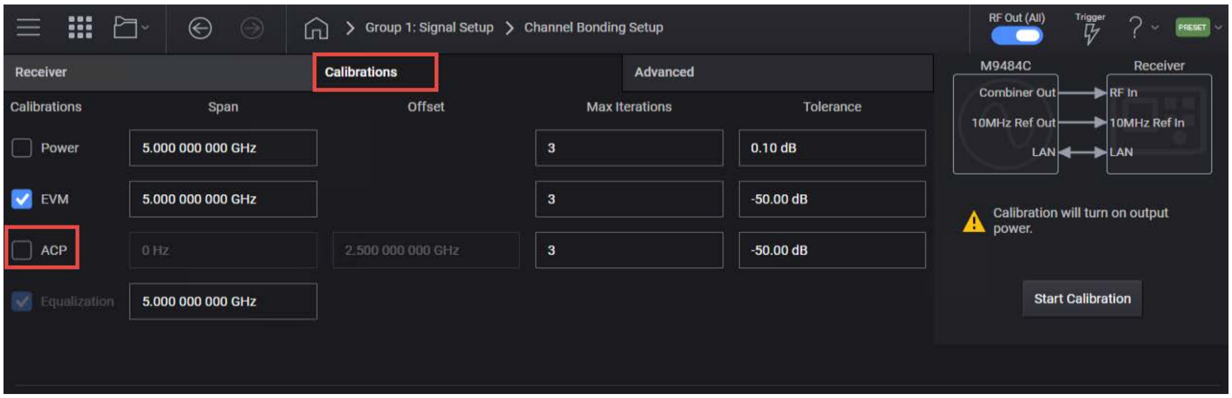
In some cases it is not possible (or necessary) to improve the ACP of the bonded waveform. In these cases, it is best to disable it.

– 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.

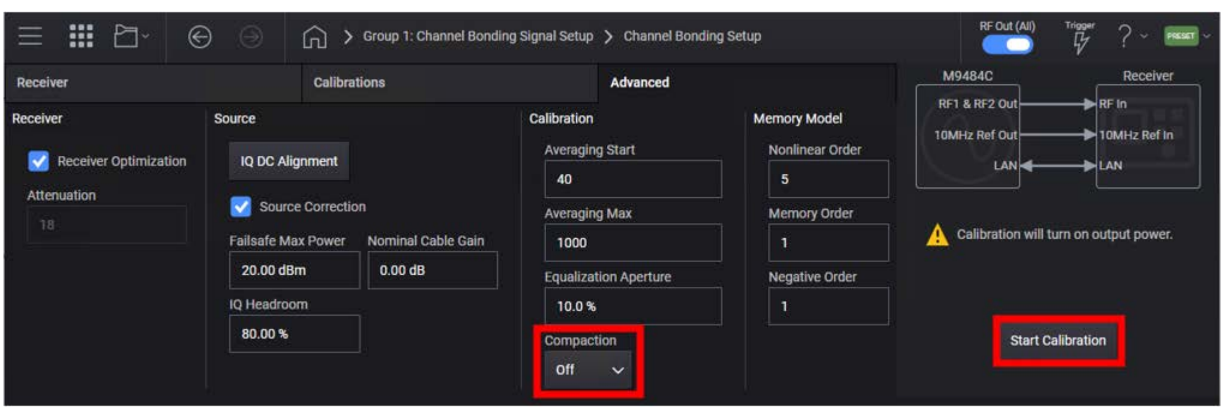
– With ACP enabled, the resulting signal will typically have significantly increased bandwidth, sample rate, and number of samples (as compared to a Bonded signal with ACP disabled).

– 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.



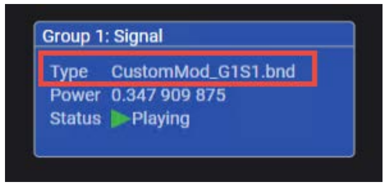
19. Select the **Advanced** tab and set **Compaction Off**, then **Start Calibration**.

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.

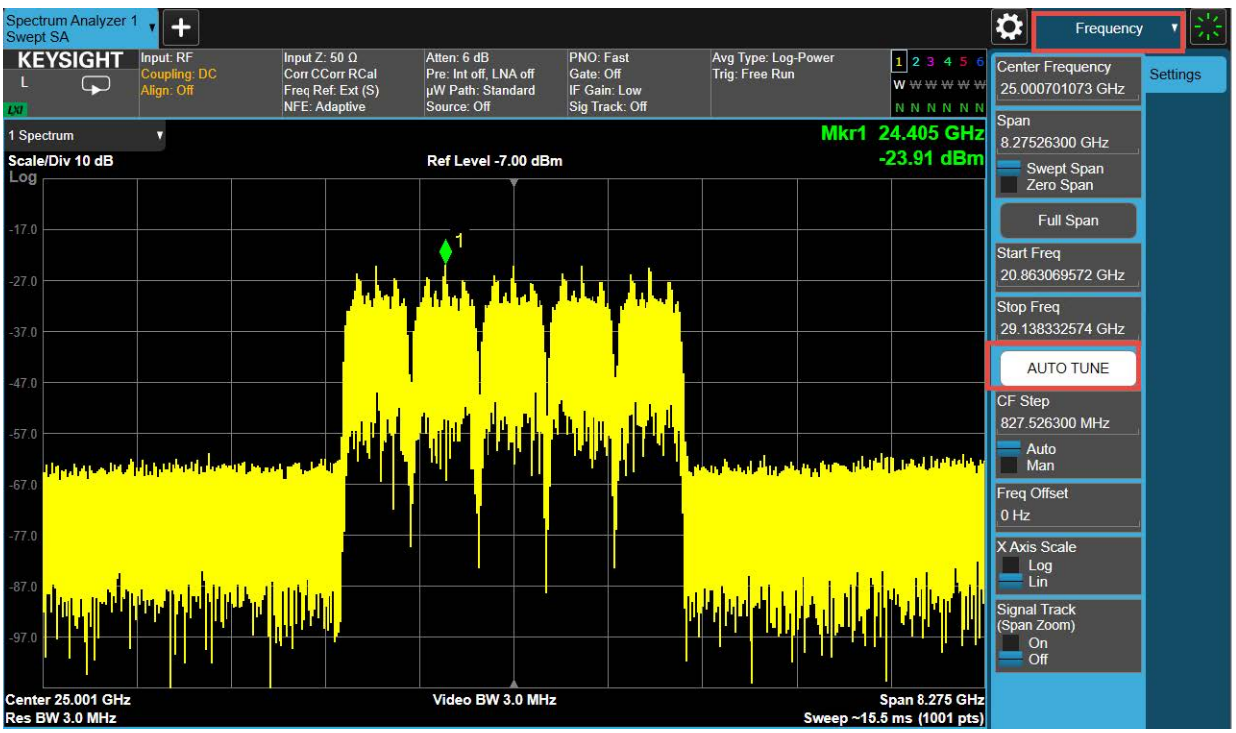


On the Signal Analyzer:

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

NOTE

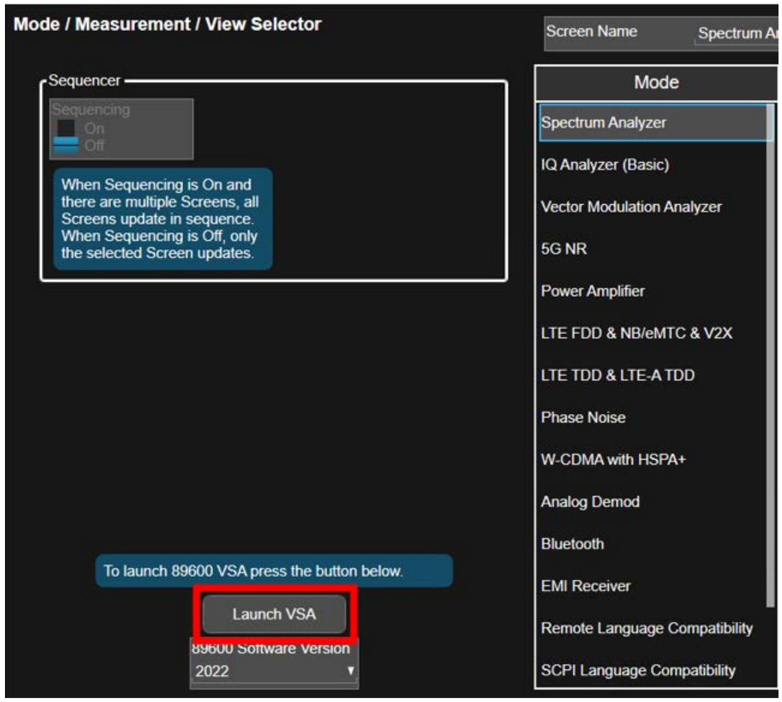
Ensure that signal analyzer is set to Spectrum Analyzer mode > Swept SA Measurement > View Normal.



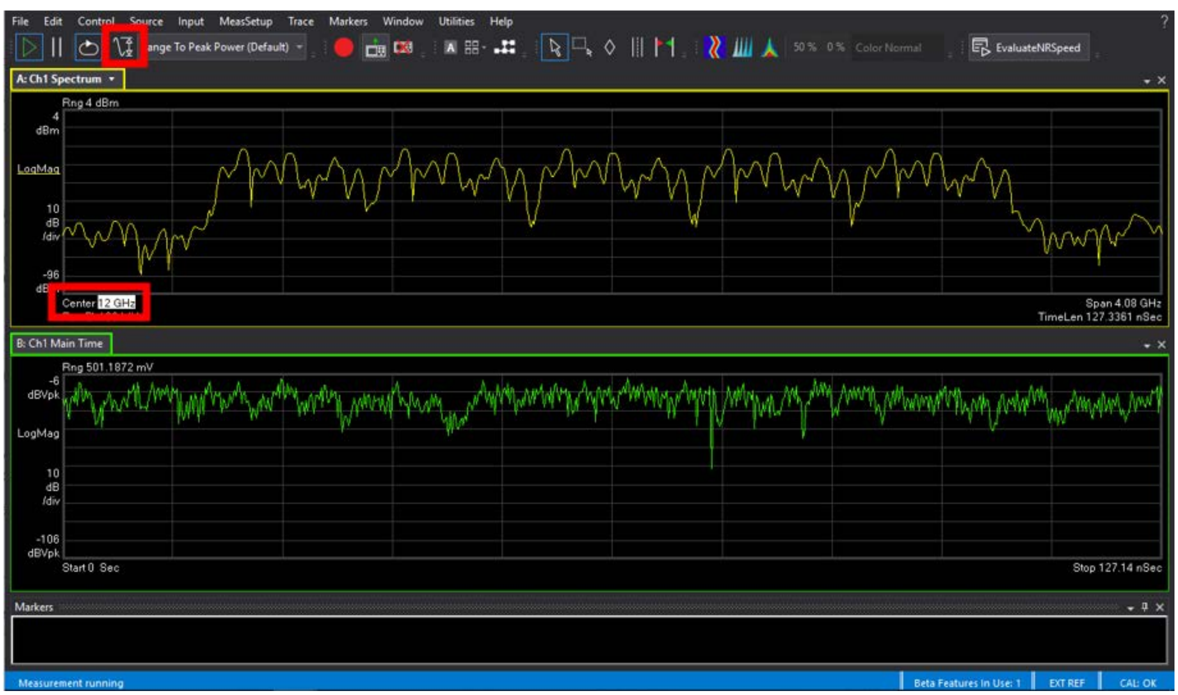
2. Open the VSA software by selecting **Mode Meas** > **Launch VSA**.

NOTE

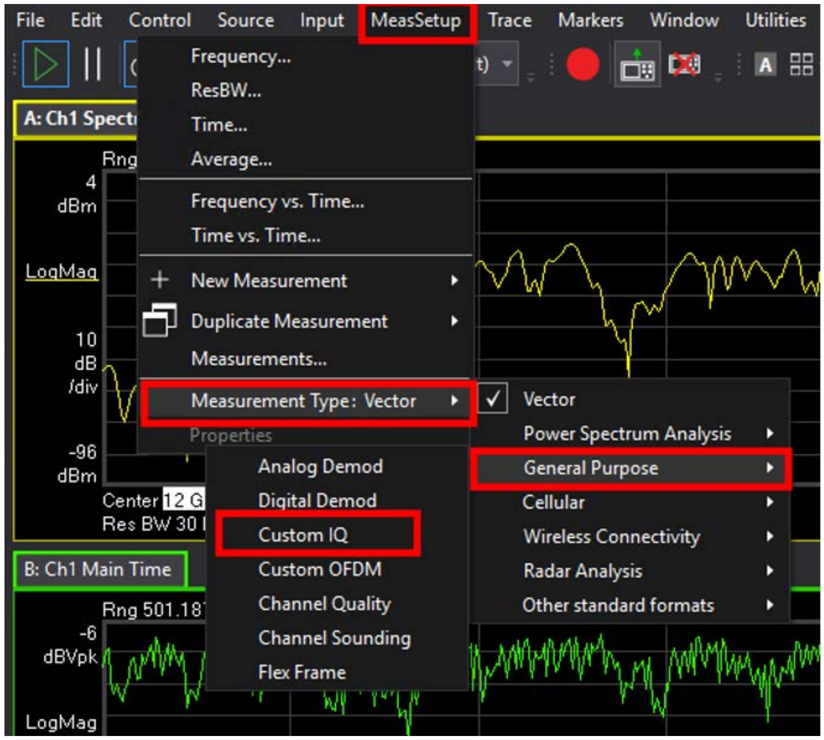
If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top left of the display) to open the Mode/Measurement/View Selector window.



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

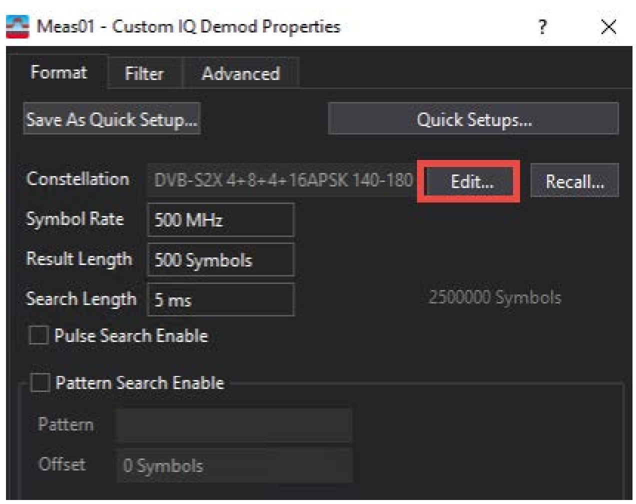


4. From the menu bars, select **MeasSetup** > **Measurement Type: Vector** > **General Purpose** > **Custom IQ**.



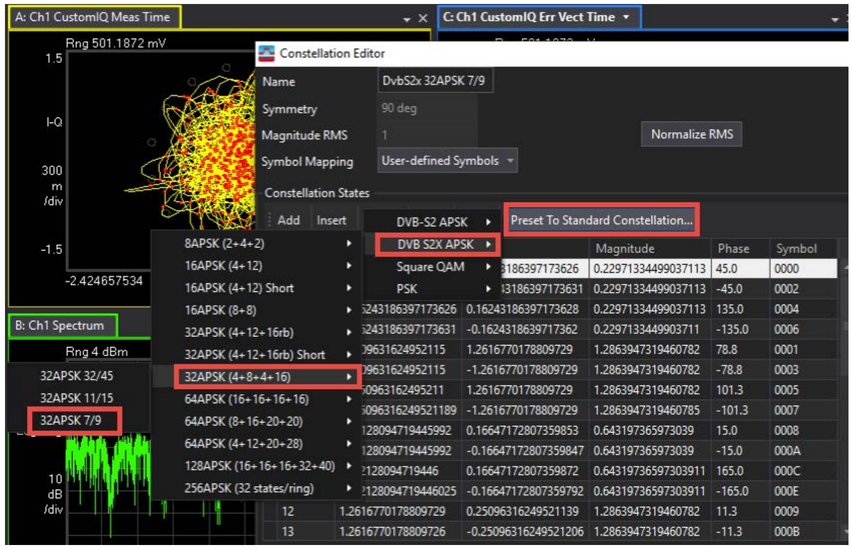
5. Select **MeasSetup** > **Custom IQ Demod Properties.**

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.

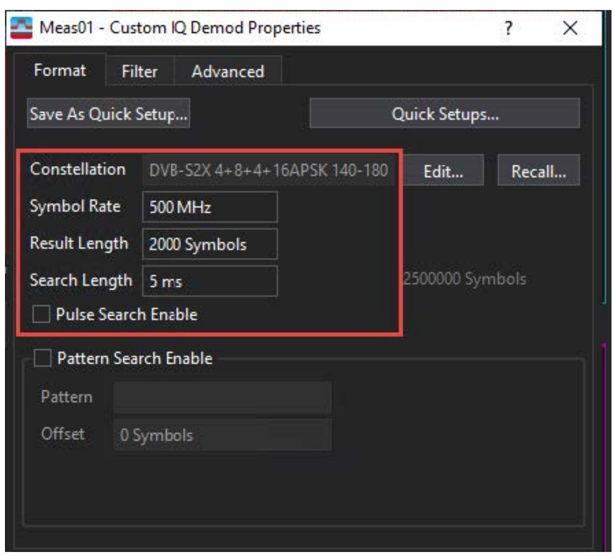
c. Select **OK** to close the Constellation Edit dialog.



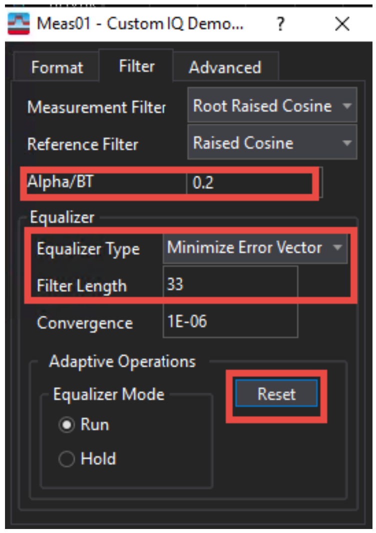
d. Turn off **Pulse Search Enable** (checkbox cleared).

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

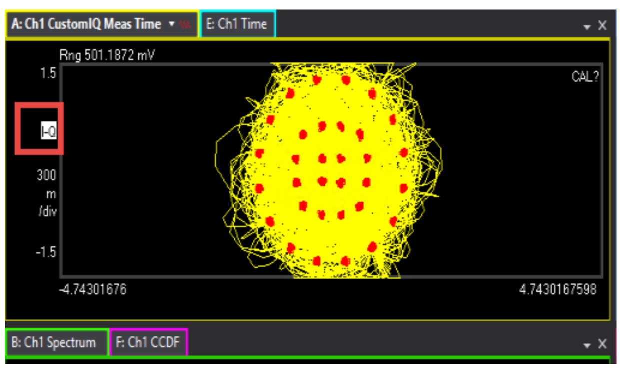
f. Set the Symbol Rate to **500 MHz**. The Result Length and Symbol Rate will adjust the resolution bandwidth to better define the waveform.



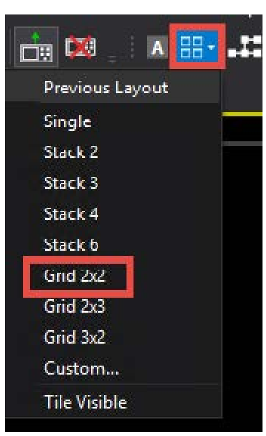
g. Select the **Filter** tab and set Alpha/BT to **0.2**, Filter Length to **33**, and Equalizer Type to **Minimize EVM**. Close the Custom IQ Demod Properties window and notice the center carrier is now being demodulated.



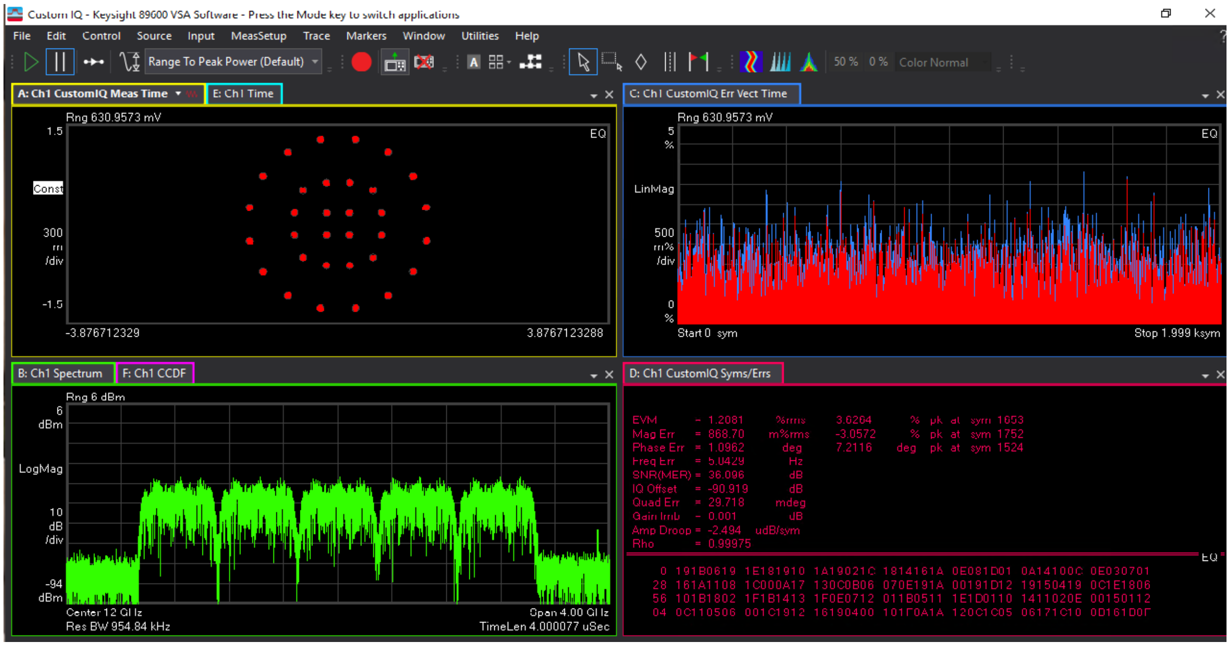
6. In the CustomIQMeas Time window, click on **I-Q** and change to **Constellation**, if desired.



7. Change the window layout to Grid 2x2.



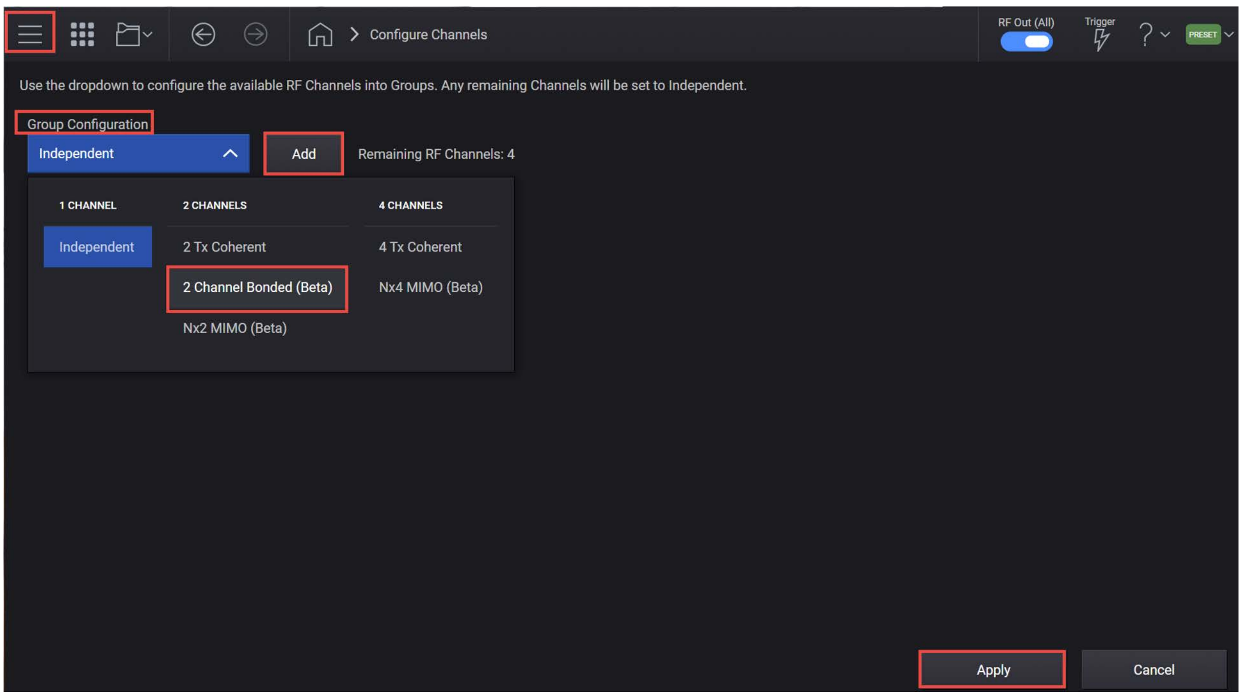
8. Note the measured EVM value in the CustomIQSyms/Errs window. For this example, 1.2%rms.



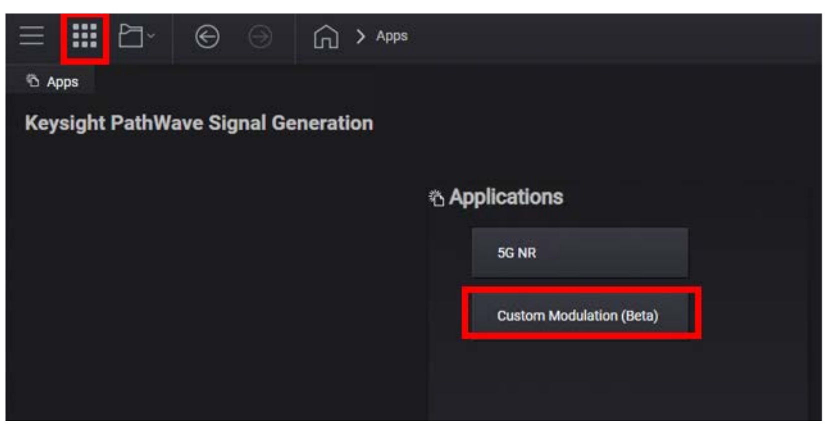
Generating a Wide Band QPSK

On the VXG:

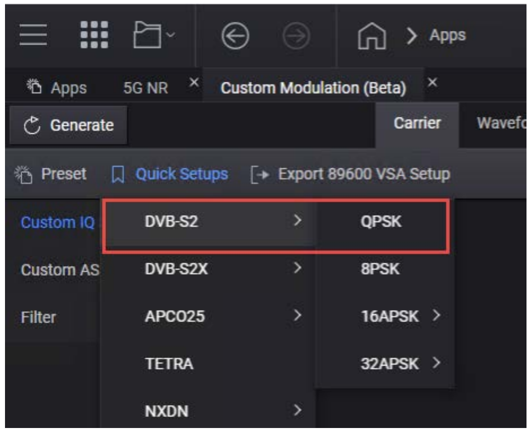
1. Connect the equipment as shown in Figure 3-1 on page 93.
2. Select **Preset** > **Preset** to set the VXG to a known state.
3. Select the System menu (triple bar tab at the top left of the window), and then select **Configure Channels** > **Group 1:2 Channel Bonded** > **Add** (for 4 channel instruments only) > **Apply**.



4. Set the Center Frequency to **12 GHz** and Power to **0 dBm**.
5. Select the **Apps** block to open, then select **Custom Modulation**.

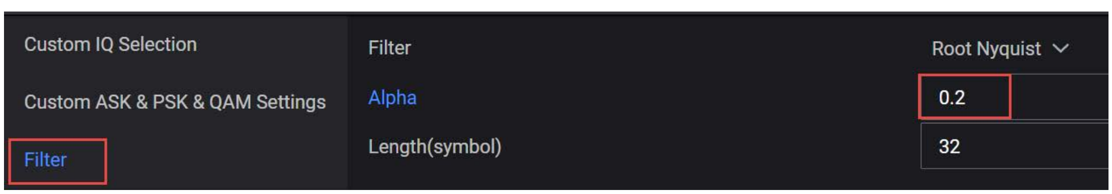


6. In the Custom Modulation setup, select the **Carrier** tab > **Quick Setups** > **DVB-S2** > **QPSK**.



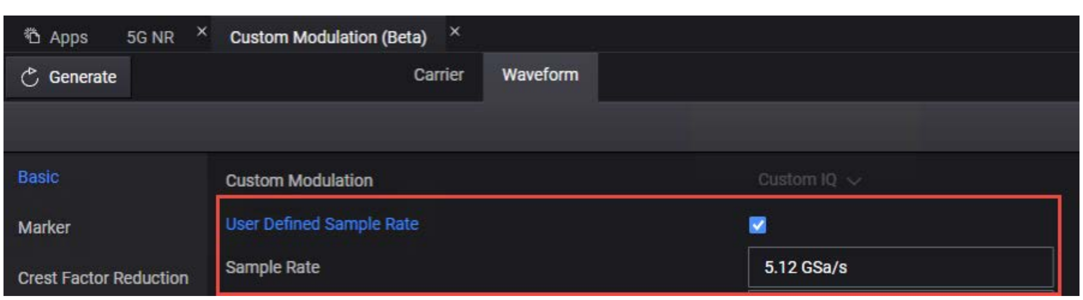
7. From the bottom pane, select **Remove Segment** to remove the Header. This will simplify the demonstration.
8. From the left pane, select **Custom ASK & PSK & QAM Settings** and set the Symbol Rate to **3 Gsps** per channel.

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

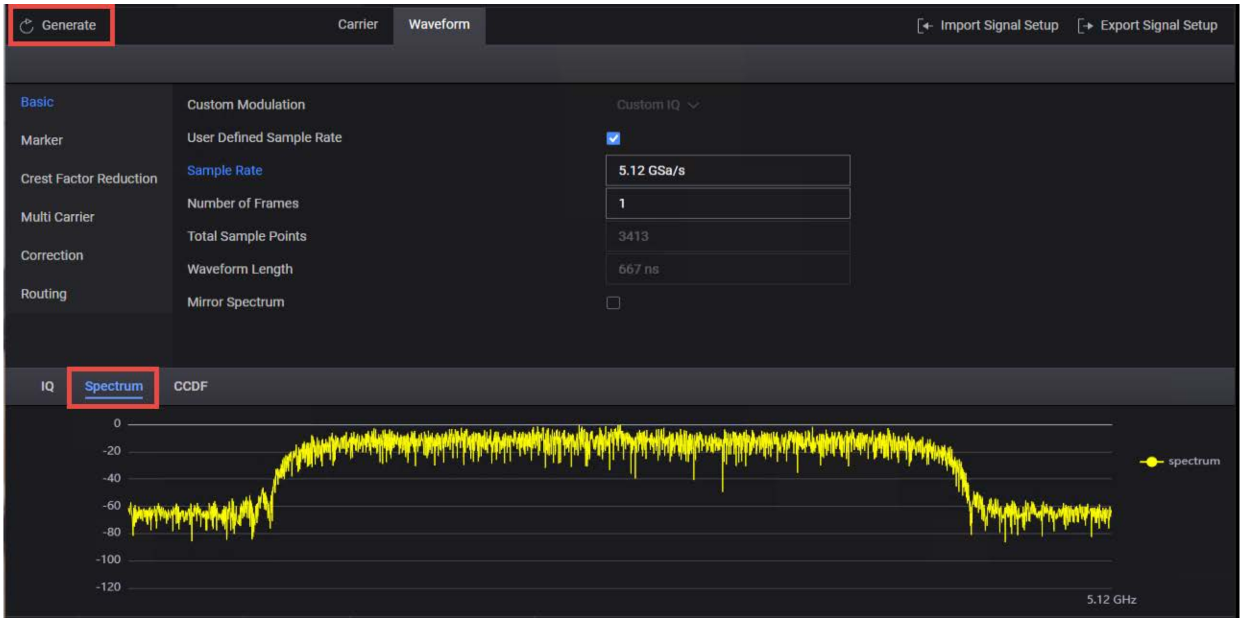


10. Select the **Waveform** tab > **Basic** > Select **User Defined Sample Rate** and set Sample Rate to **5.12 GSa/s**.

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



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



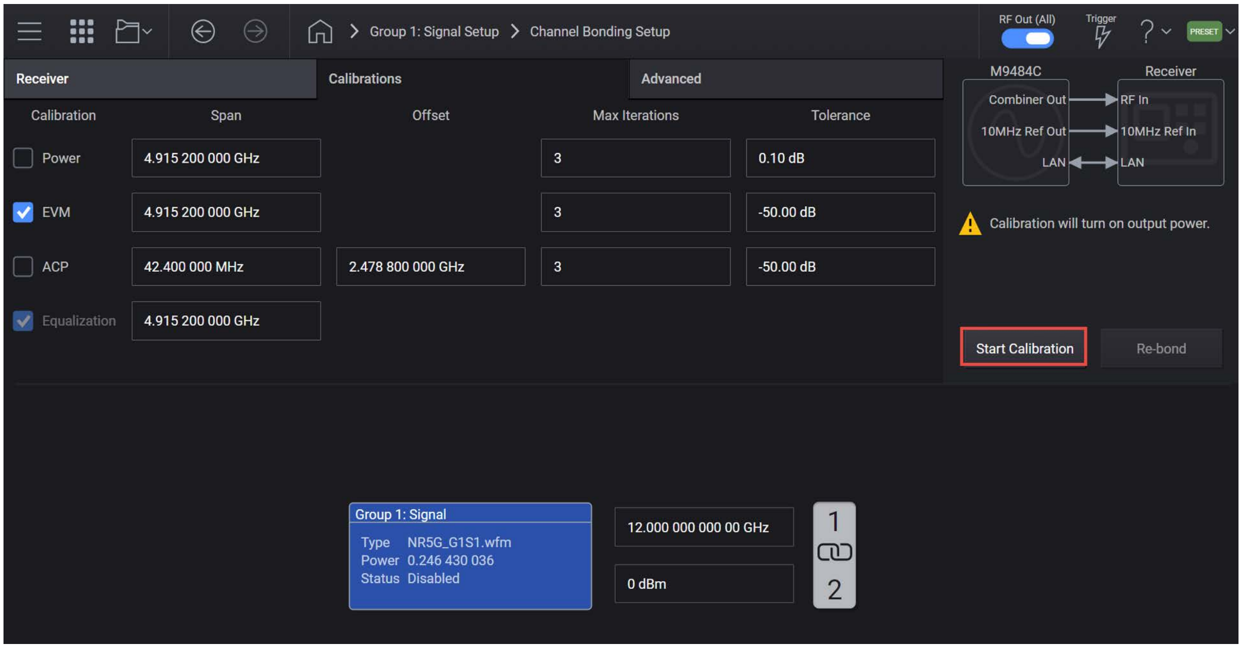
12. Select the **Home** icon to return to the main window and then select the **Signal Block** to open.

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 x 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.

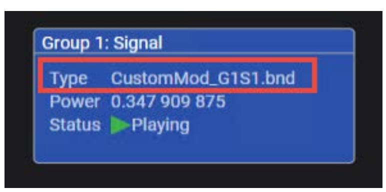
16. Select the **Calibrations** tab and clear the **ACP** calibration.



17. Select **Start Calibration.**

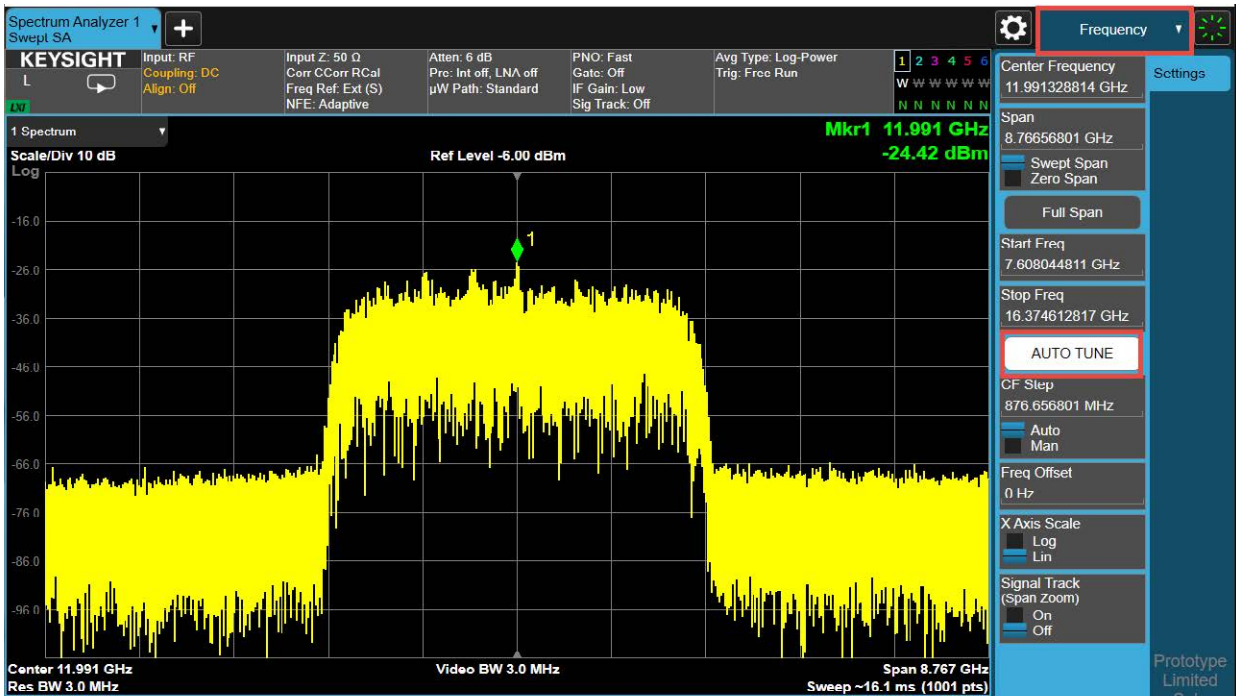
The calibration takes a few minutes to complete. Note that the VXG displays an `Invalid file selection` message. This is because the VXG no longer sees the .wfm waveform instead the newly calibrated waveform has a .bnd file extension.

Notice that the CustomMod_G1S1.bnd waveform is now playing.



On the Signal Analyzer:

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

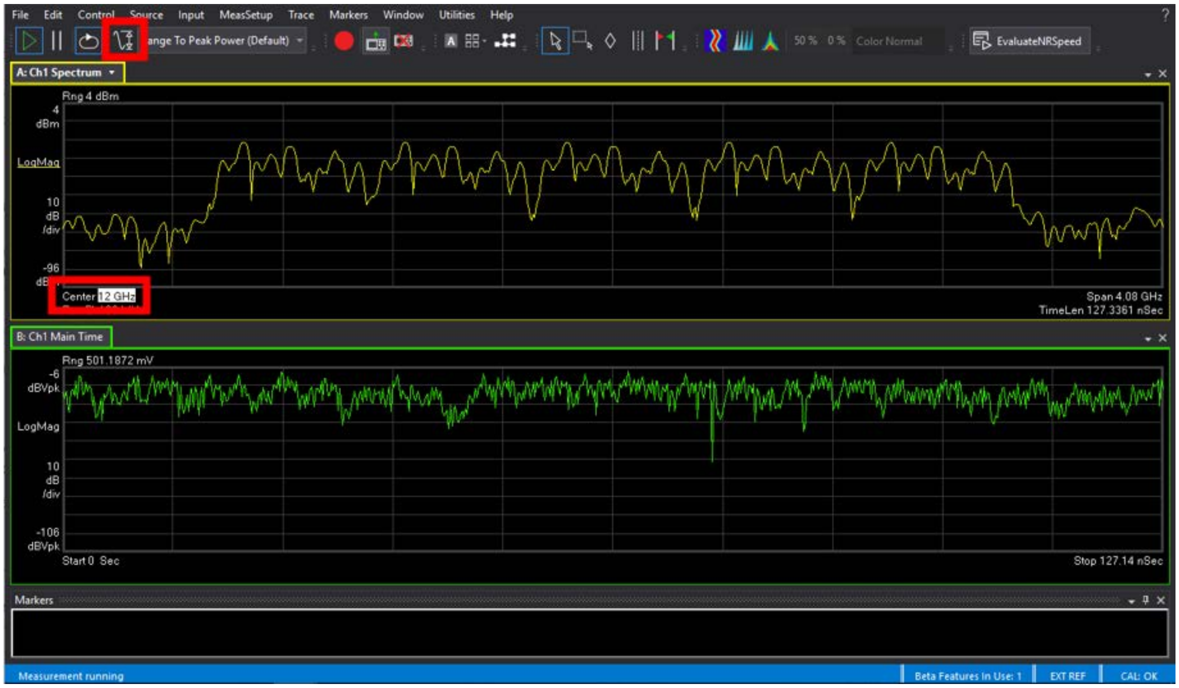


2. Open the VSA software by selecting **Mode Meas** > **Launch VSA**.

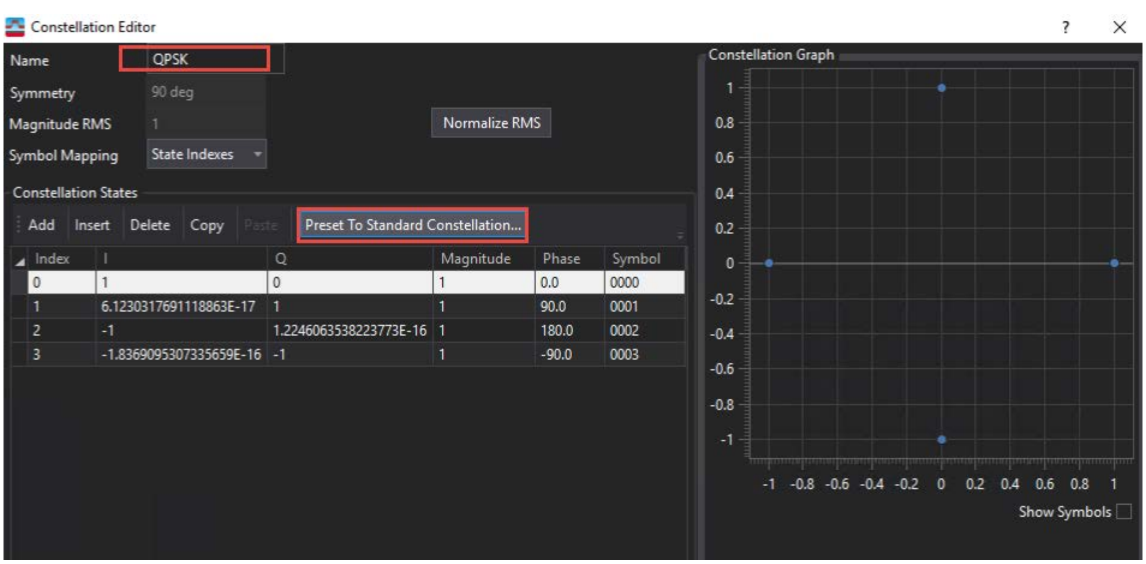
NOTE

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.

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

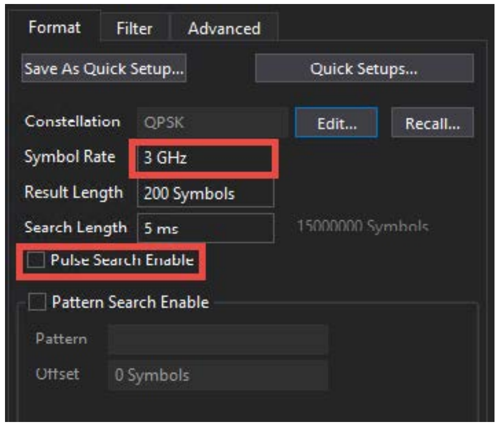


4. From the menu bar, select **MeasSetup** > **Measurement Type** > **General Purpose** > **Custom IQ**.
5. From the menu bar, select **MeasSetup** > **Custom IQ Demod Properties**.
   a. Select the **Format** tab and select Constellation **Edit**.
   b. Select **Preset to Standard Constellation** >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

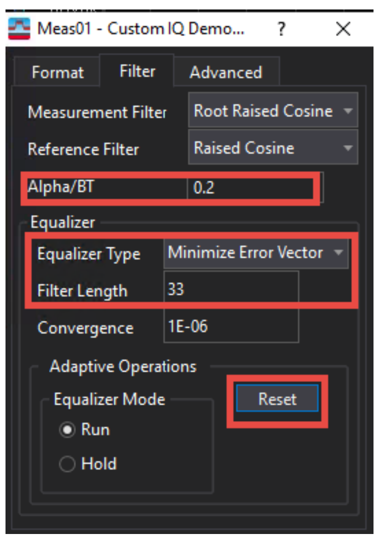


d. Turn off **Pulse Search Enable** (checkbox cleared).

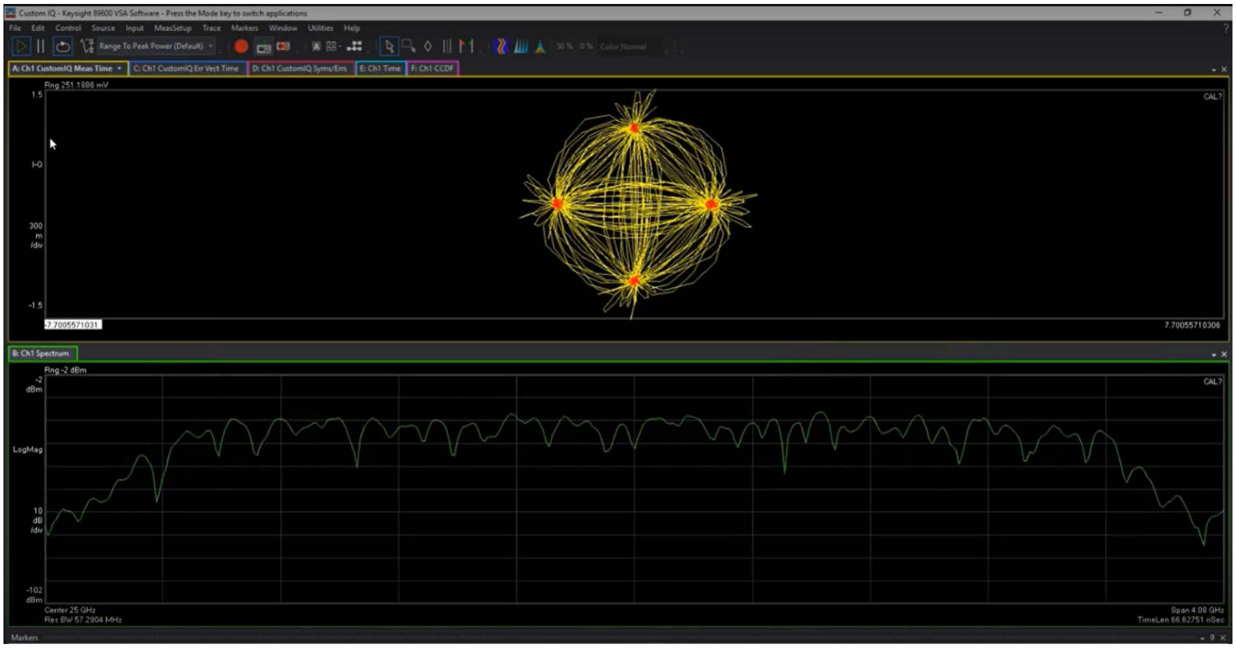
e. Set the Symbol Rate to **3 GHz**.



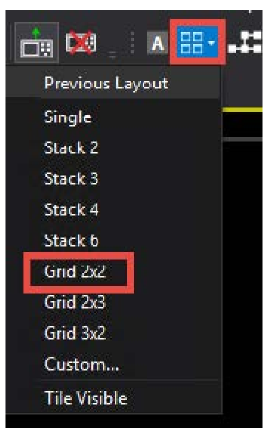
f. Select the **Filter** tab and set Alpha/BT to **0.2**, Filter Length to **33**, Equalizer Type to **Minimize Error Vector**, and **Reset** the Filter.



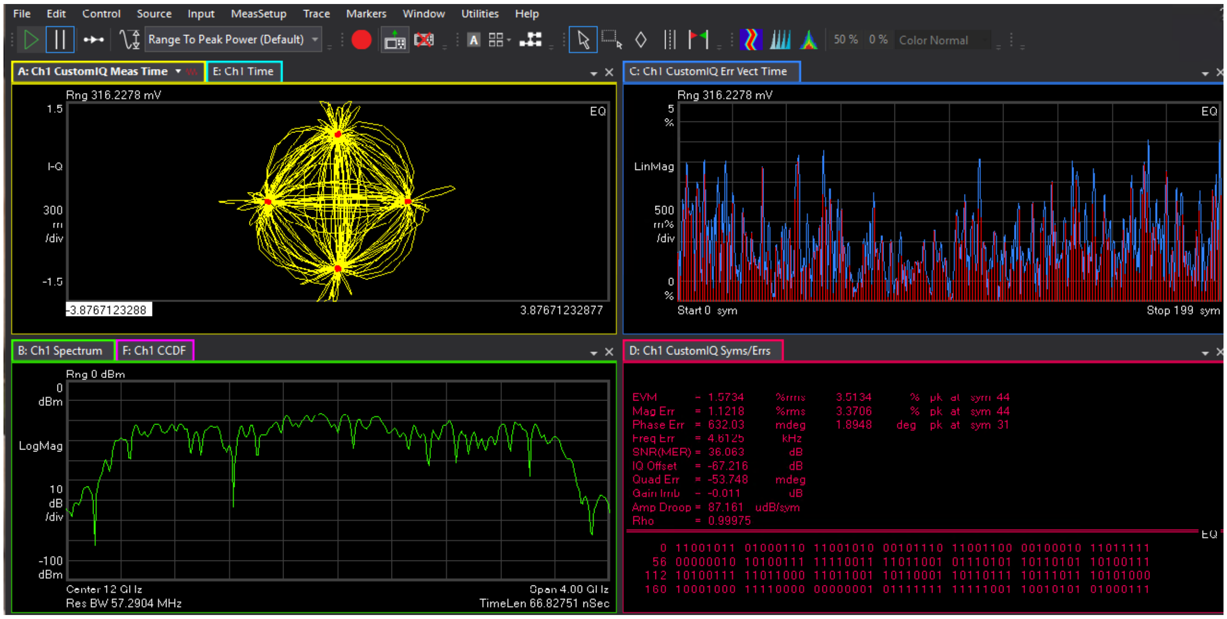
6. View the results.



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



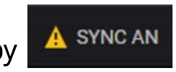
This allows you to view more measurement details like the EVM results, which for this example is ~1.6 %rms.


File Edit Control Source Input MeasSetup Trace Markers Window Utilities Help
Range To Peak Power (Default)
50 % 0 % Color Normal
A: Ch1 CustomIQ Meas Time
E: Ch1 Time
Rng 316.2278 mV
EQ
1.5
I-Q
300 m /div
-1.5
-3.8767123288
3.87671232877
C: Ch1 CustomIQ Err Vect Time
Rng 316.2278 mV
EQ
5 %
LinMag
500 m% /div
0 %
Start 0 sym
Stop 199 sym
B: Ch1 Spectrum
F: Ch1 CCDF
Rng 0 dBm
0 dBm
LogMag
10 dB /div
-100 dBm
Center 12 GHz
Res BW 57.2904 MHz
Span 4.00 GHz
TimeLen 66.82751 nSec
D: Ch1 CustomIQ Syms/Errs
EVM = 1.5734 %rms 3.5134 % pk at sym 44
Mag Err = 1.1218 %rms 3.3706 % pk at sym 44
Phase Err = 632.03 mdeg 1.8948 deg pk at sym 31
Freq Err = 4.6125 kHz
SNR(MER) = 36.063 dB
IQ Offset = -67.216 dB
Quad Err = -53.748 mdeg
Gain Imb = -0.011 dB
Amp Droop = 87.161 udB/sym
Rho = 0.99975
EQ
0 11001011 01000110 11001010 00101110 11001100 00100010 11011111
56 00000010 10100111 11110011 11011001 01110101 10110101 10100111
112 10100111 11011000 11011001 10110001 10110111 10111011 10101000
160 10001000 11110000 00000001 01111111 11111001 10010101 01000111

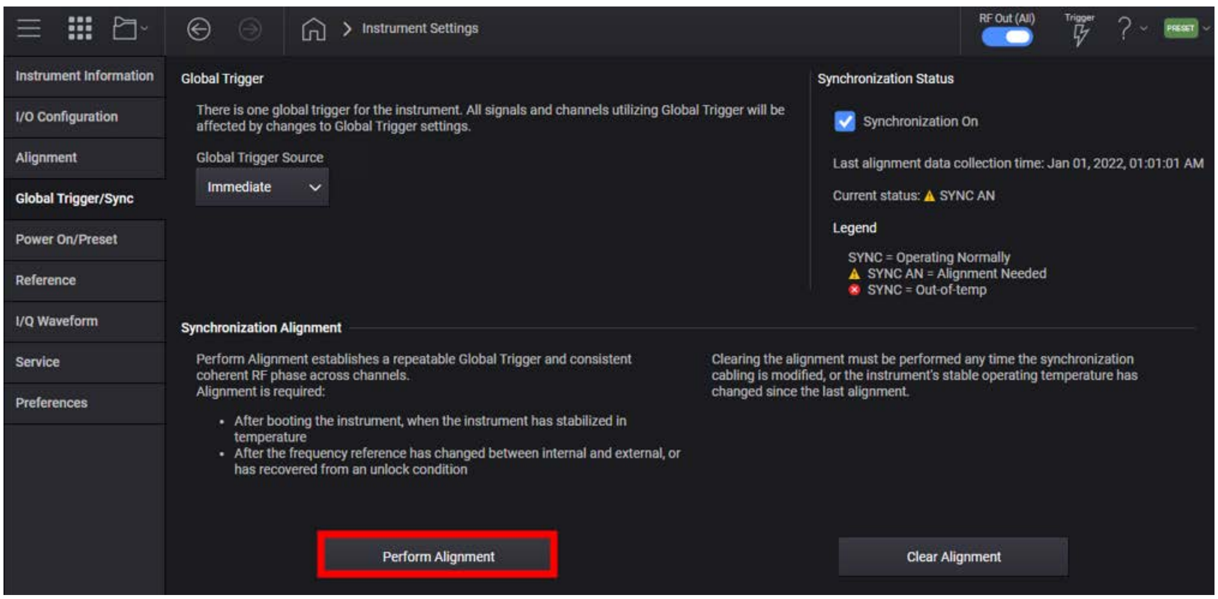
Generating a 5G NR Waveform

On the VXG:

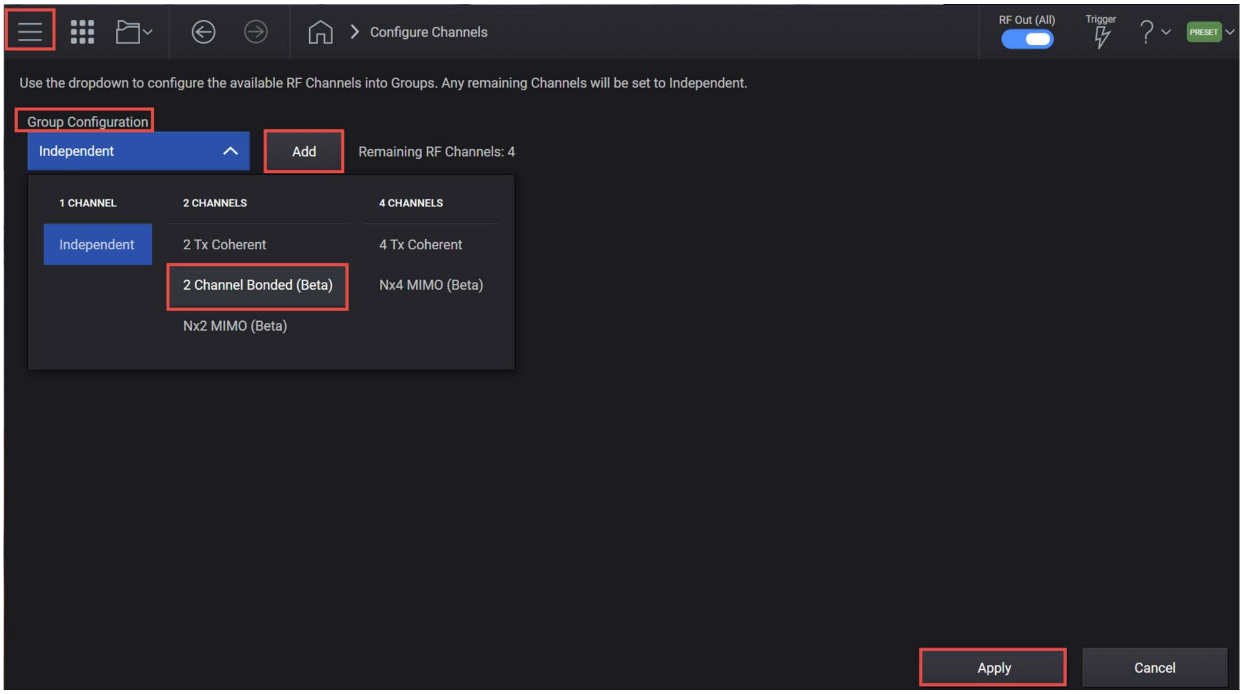
1. Connect the equipment as shown in Figure 3-1 on page 93.
2. Select **Preset** > **Preset** to set the VXG to a known state.

   If a Synchronization Alignment is required, indicated by 

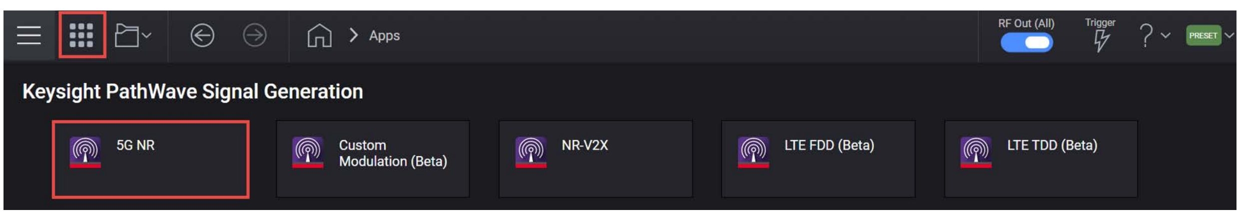
 in the bottom left corner, tap or click the warning message and choose **Perform Alignment** before proceeding.



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** > **Add** (for 4 channel instruments only) > **Apply** > **Apply**.

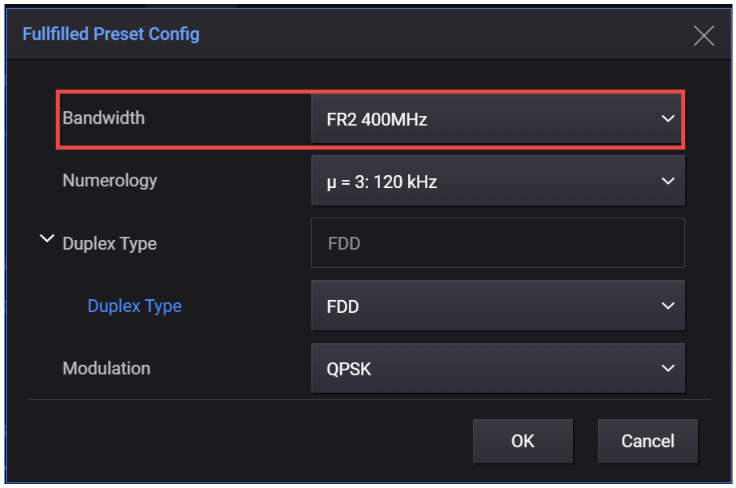


4. Set the Center Frequency to **12 GHz** and Power to **0 dBm**.
5. Select the **Apps** block to open, then select **5G NR**.



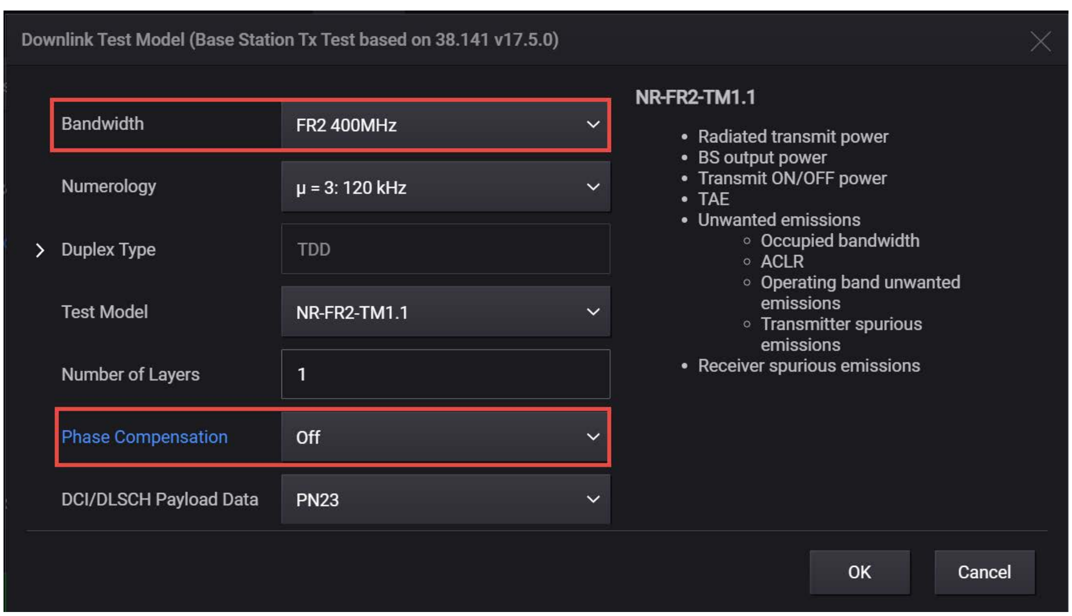
6. Select the **Carrier** tab.

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

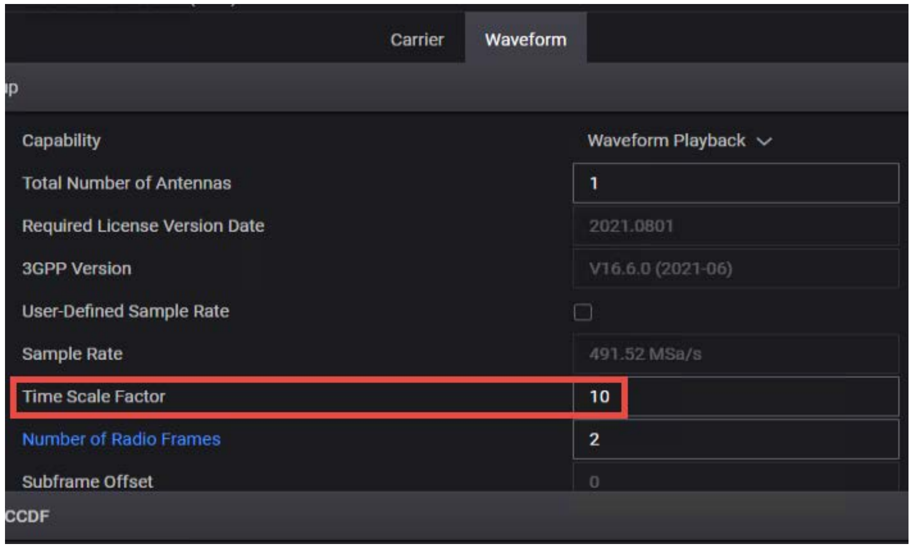


Full Filled Configurations is a great place to start creating your waveform. You can select FR, bandwidth, and modulation format with a fully allocated PDSCH data channel. This would represent a spectrally correct signal that is typically used in power amplifier measurements. You can modify the RB allocations and Slot allocations if fully allocated data channels are not desired.

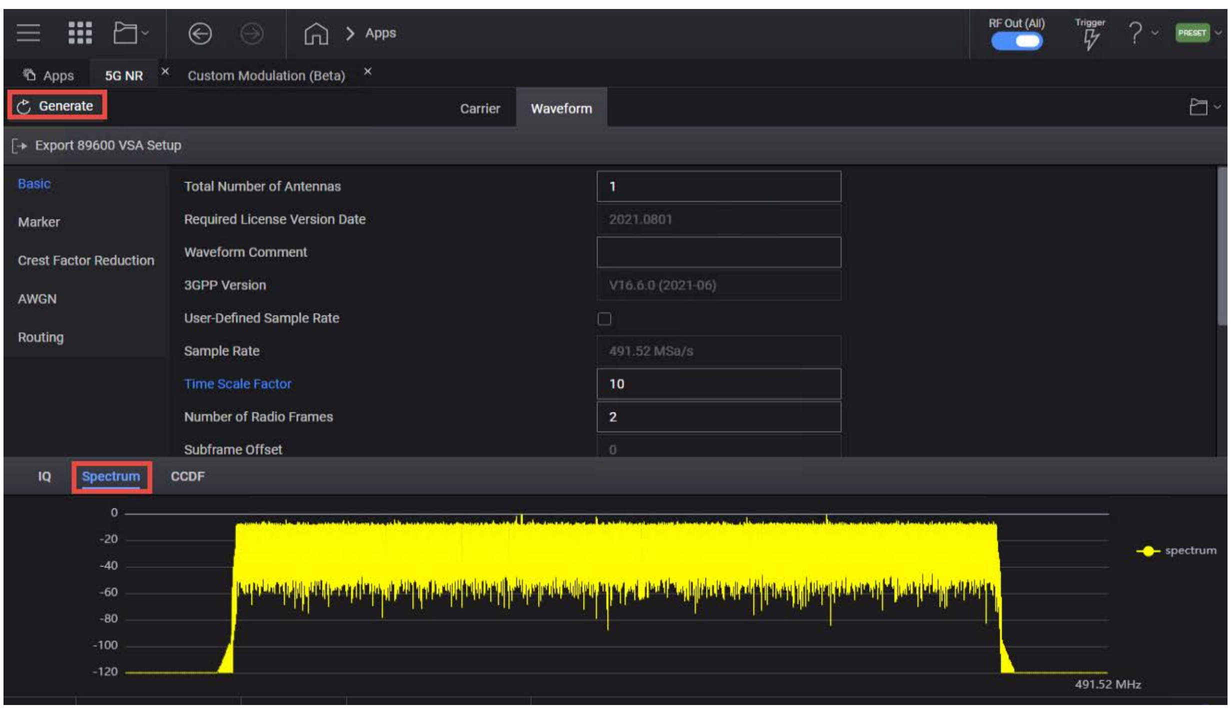
8. Select **DL Test Model** to open. set Bandwidth to **FR2 400 MHz** and set Phase Compensation to **Off**, and then select **OK**.



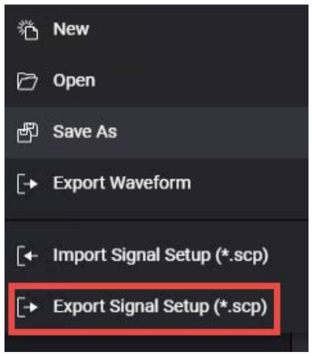
9. Select the **Waveform** Tab, and set the Time Scale Factor to **10**.



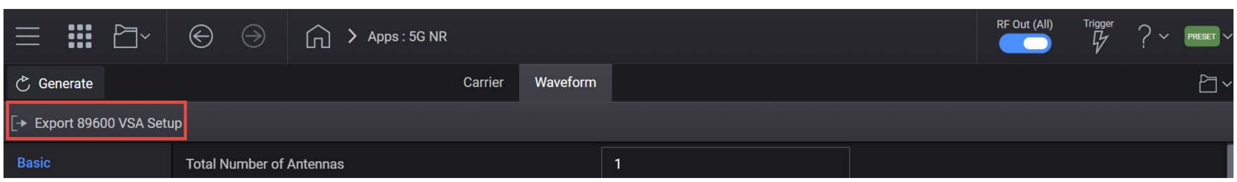
10. **Generate** the waveform and select the **Spectrum** tab from the bottom pane. The waveform will take a moment to finish generating.



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 UXA.



12. 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:

a. Select the **System** menu icon (triple bar), then **Switch to Windows**.

b. Select the **Windows** icon (bottom left corner), open **File Explorer** and navigate to the setup files and **Copy** both files.

c. On the UXA, select the **Windows** icon, open **File Explorer** and **Save** the two setup files.

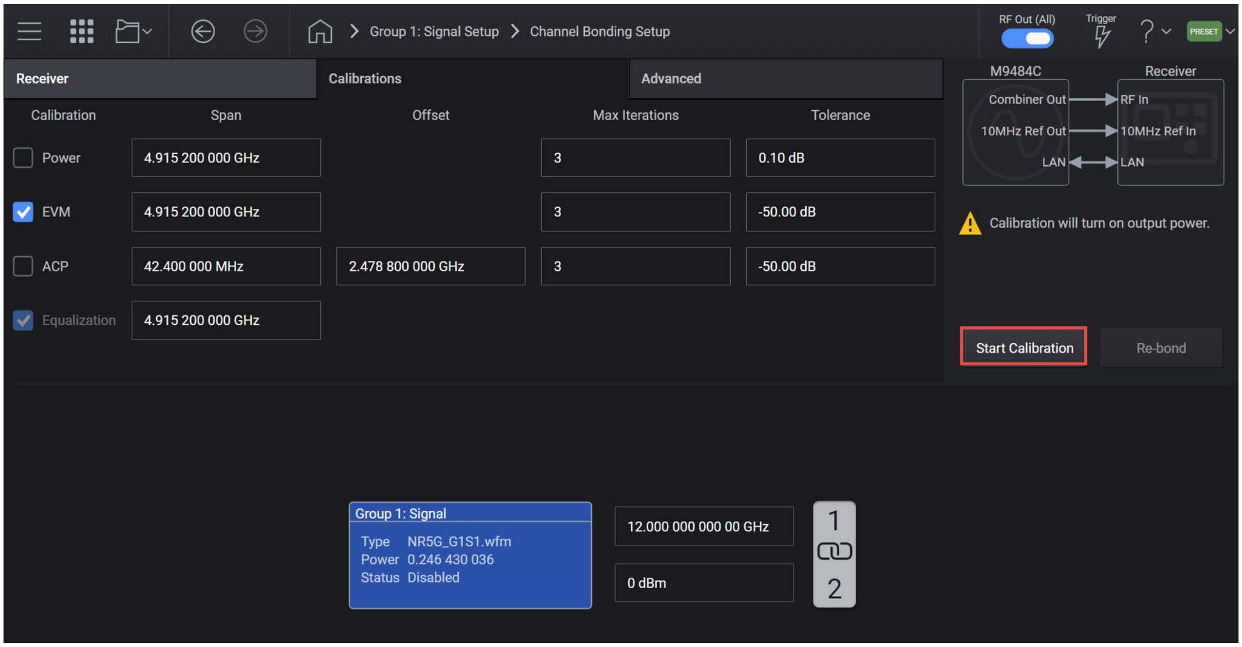
d. On the VXG, select the PathWave SG icon in the Desktop to restore the PathWave application.

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:

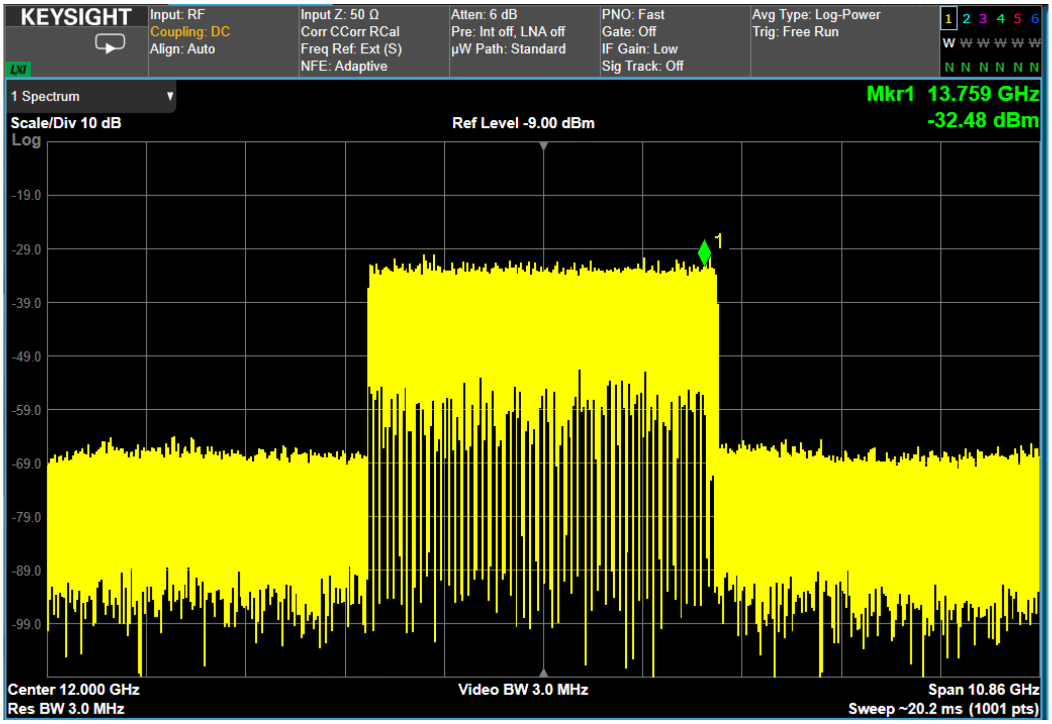
Below are two methods for viewing the results of the 5G NR wideband waveform.

— 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.

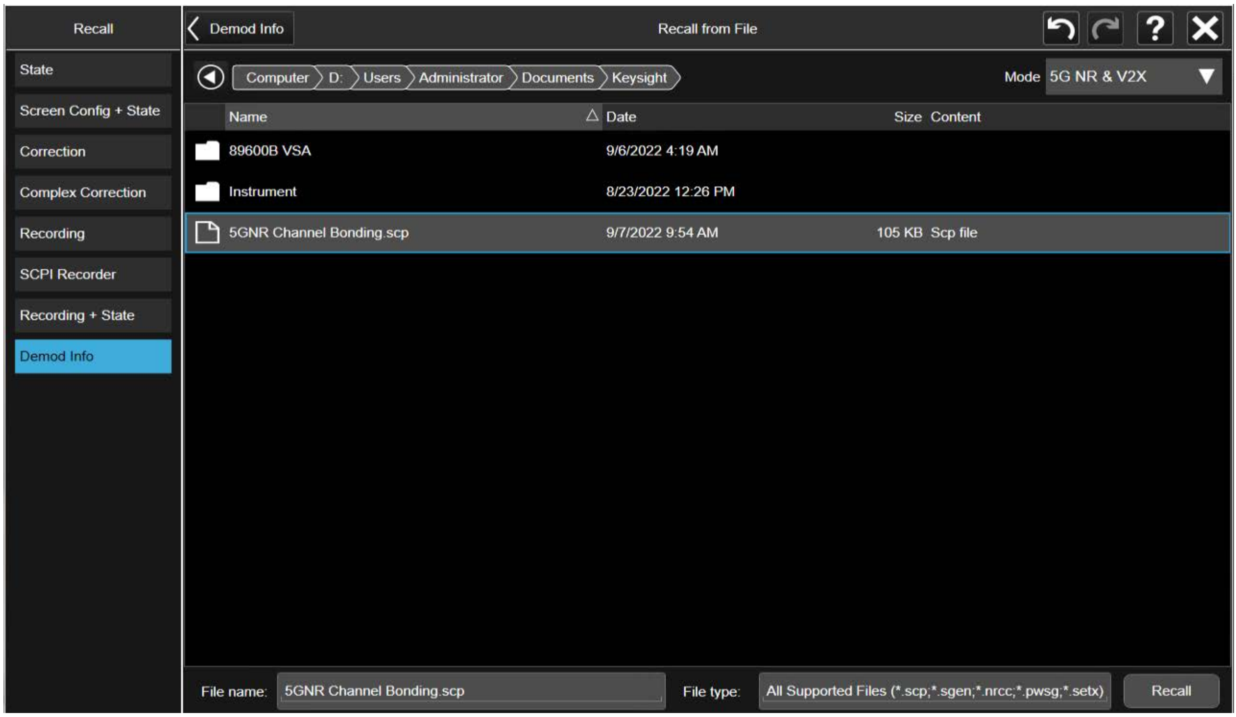


2. From the N9042B select **Mode/Meas** > **5G NR &V2X** Mode > **OK**.

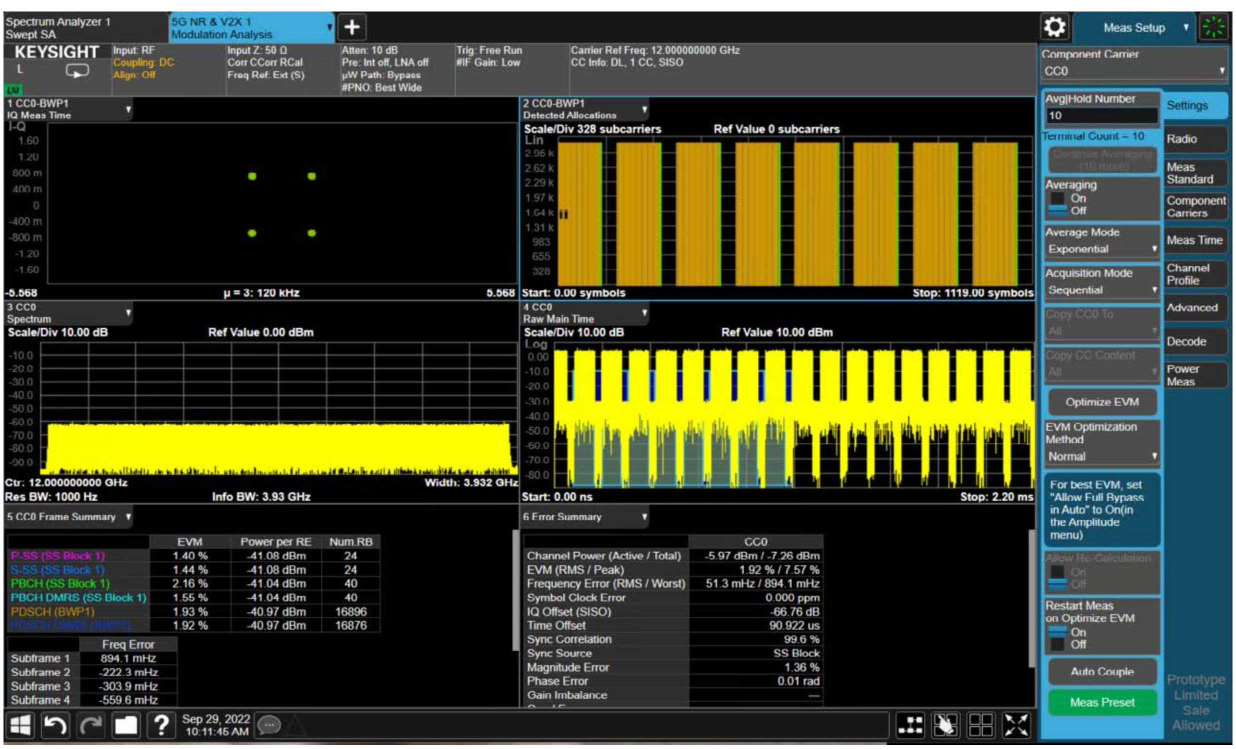
NOTE If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top left of the display) to open the Mode/Measurement/View Selector window.

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%.

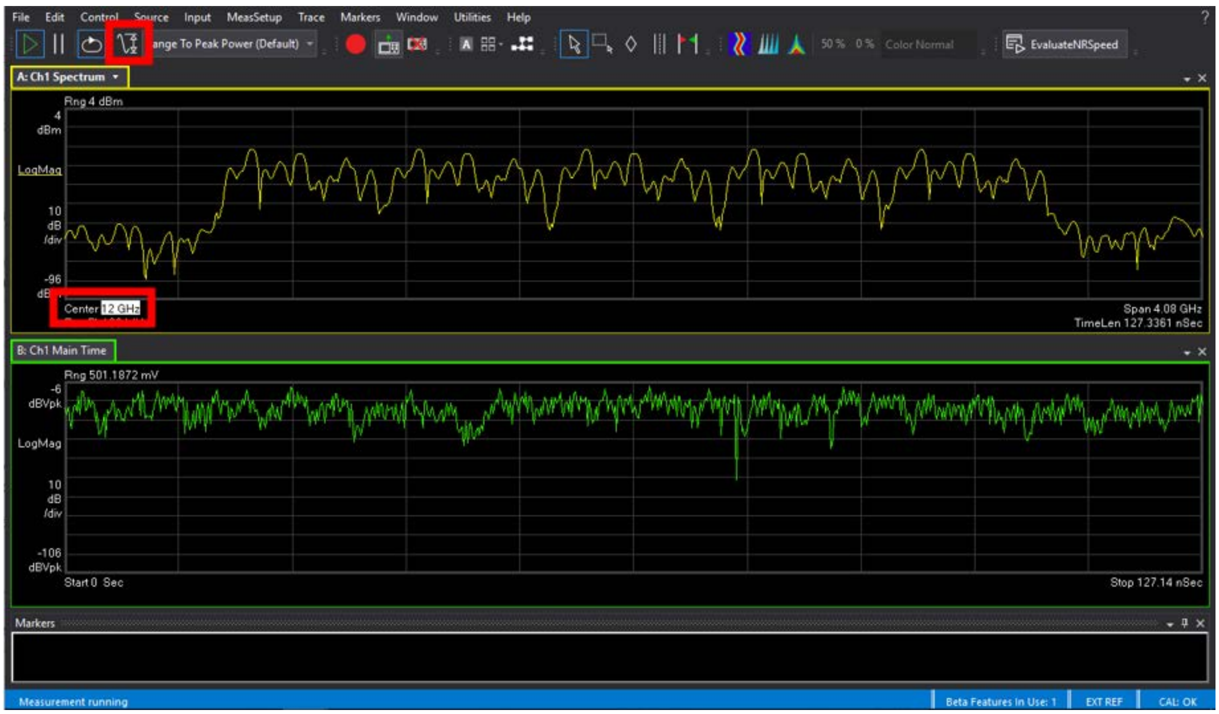


Using 89600 VSA

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.

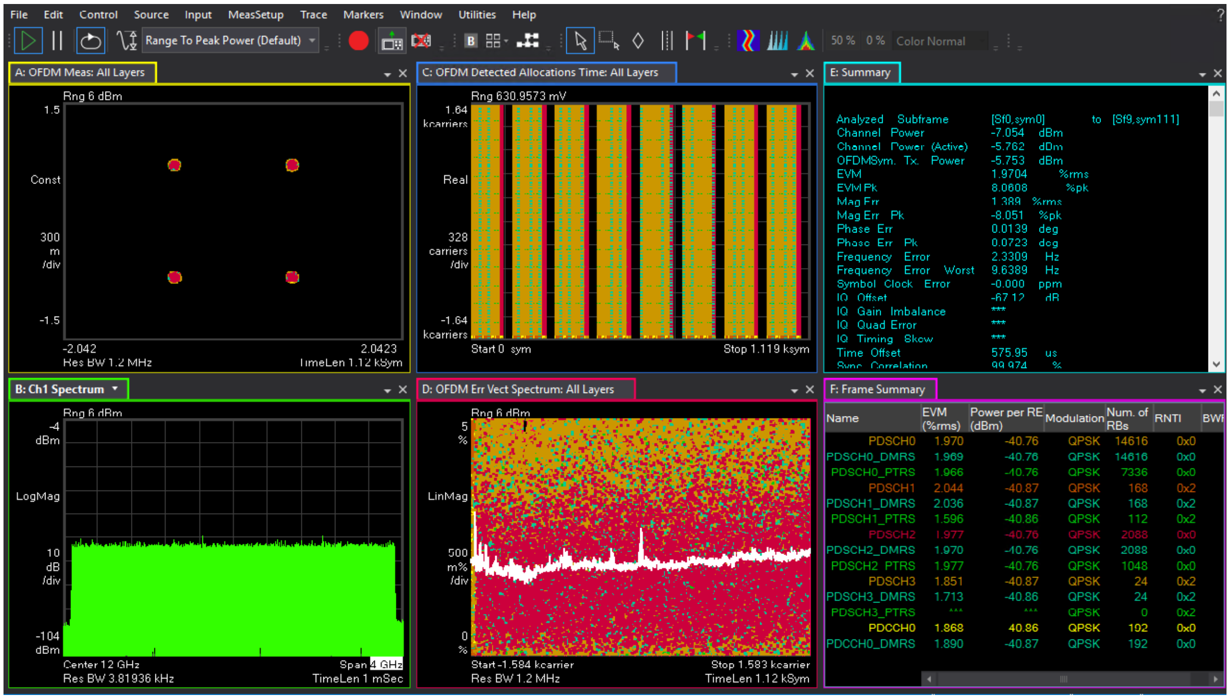
2. In the Spectrum window, set the Center Frequency to **12 GHz** and **Auto-range**.



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.

5. 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.

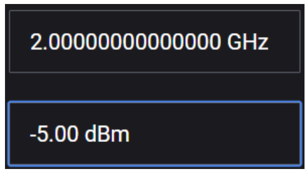
NOTE **The VXG must have Option M9484C-8SG (8 virtual signal generators) installed.**

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

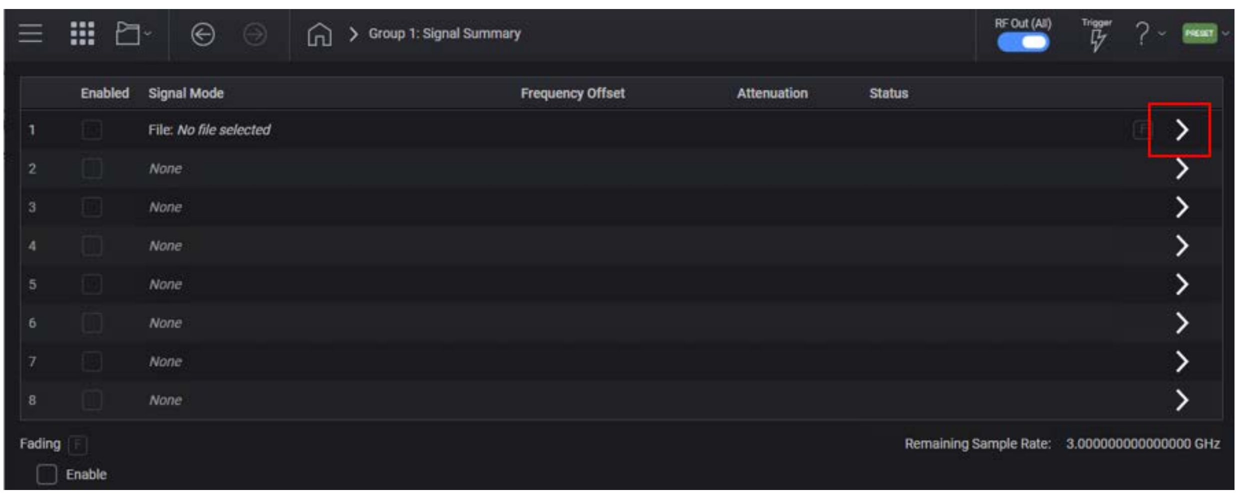
On the VXG:

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**.



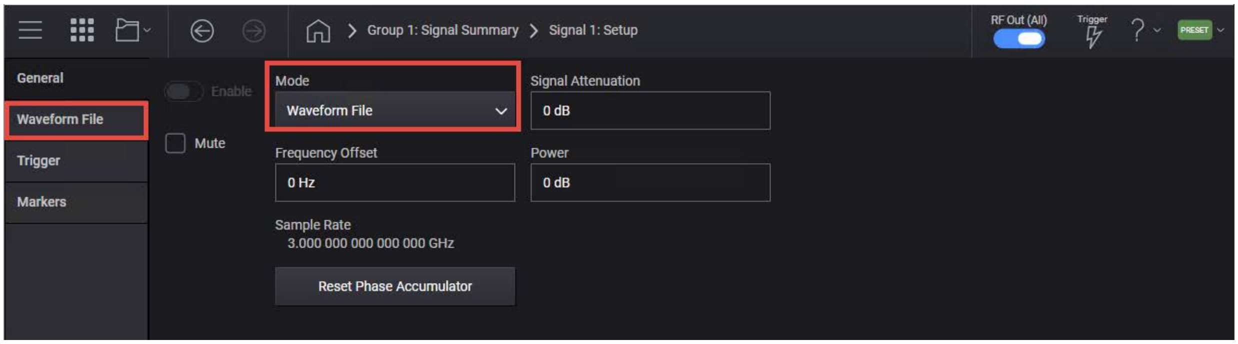
3. Select the arrow for Signal 1 to open the Signal Setup window.

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.



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

5. Select the **Mode** drop down menu and select **Waveform File** and then select the **Waveform File** tab on the left side.

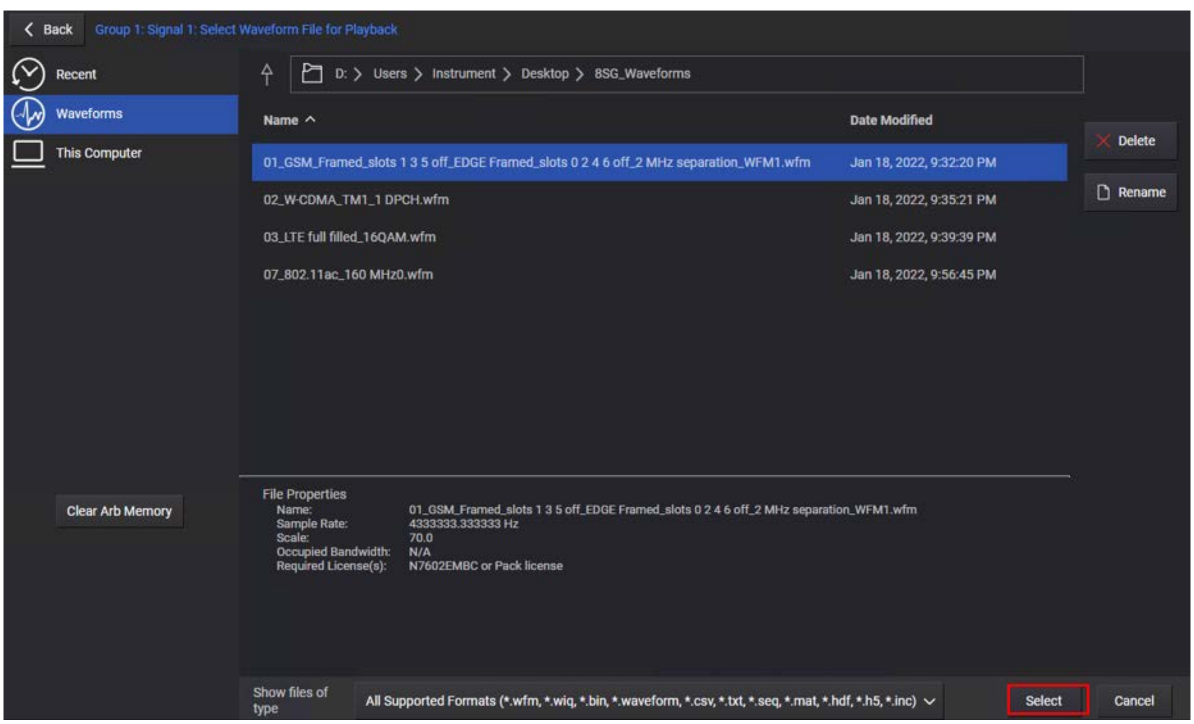


6. In the Waveform Playback Setup area, use File **Select** to navigate to:

```
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

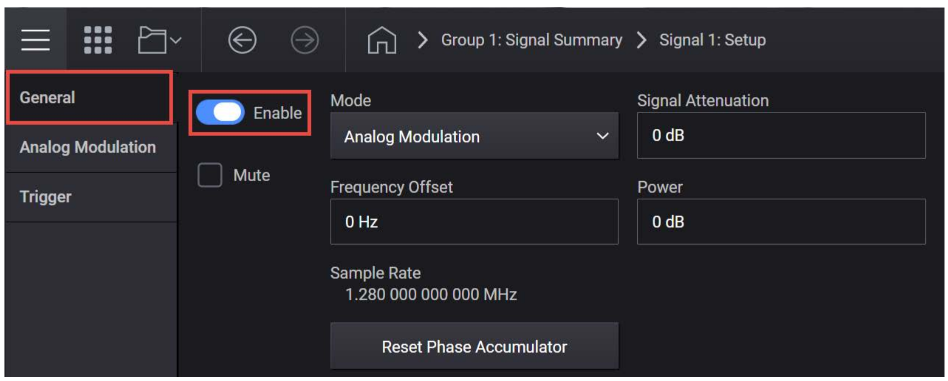
Whenever you enable a particular waveform file that is not currently enabled in another IQ path, it uploads prior to playback. If the file is already enabled in one or more other IQ paths, an upload does not occur and the waveform plays directly.

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**.

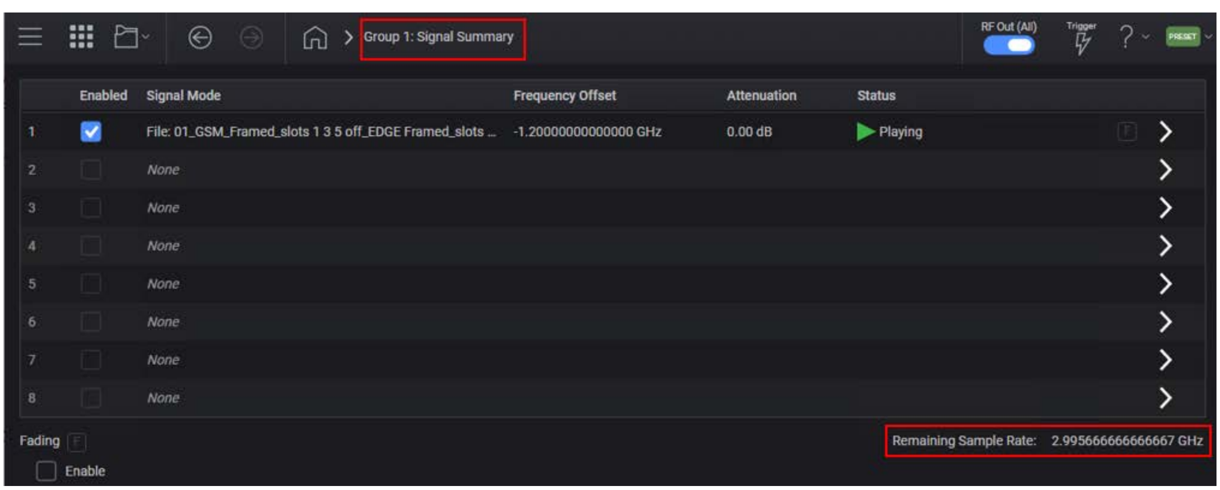
   The Frequency Offset is the distance from the channel's RF center frequency (set in step 2) to the center frequency of the signal. You can adjust the signal attenuation for each signal to allow scaling the signal down without disrupting the output.

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



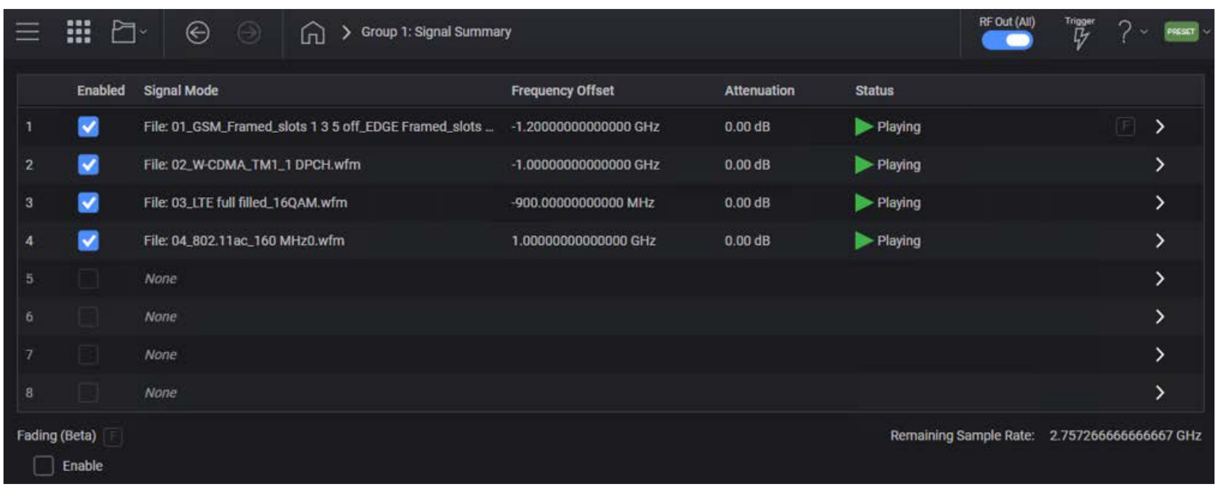
9. From the Menu/Tool & Navigation bar, select **Group 1: Signal Summary**.

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

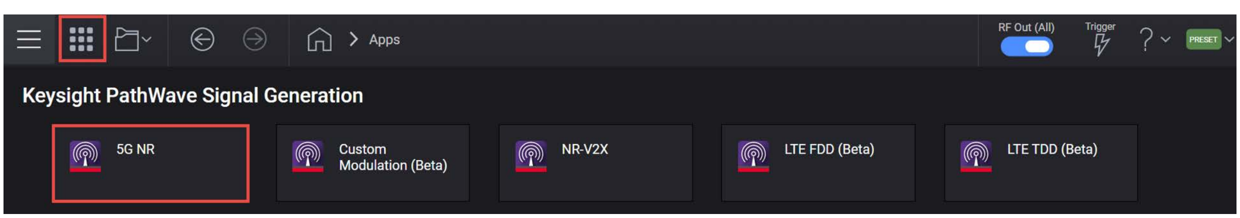


10. Repeat step step 5 through step 9 for Signal 2, Signal 3, and Signal 4 with the following changes.

- 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**

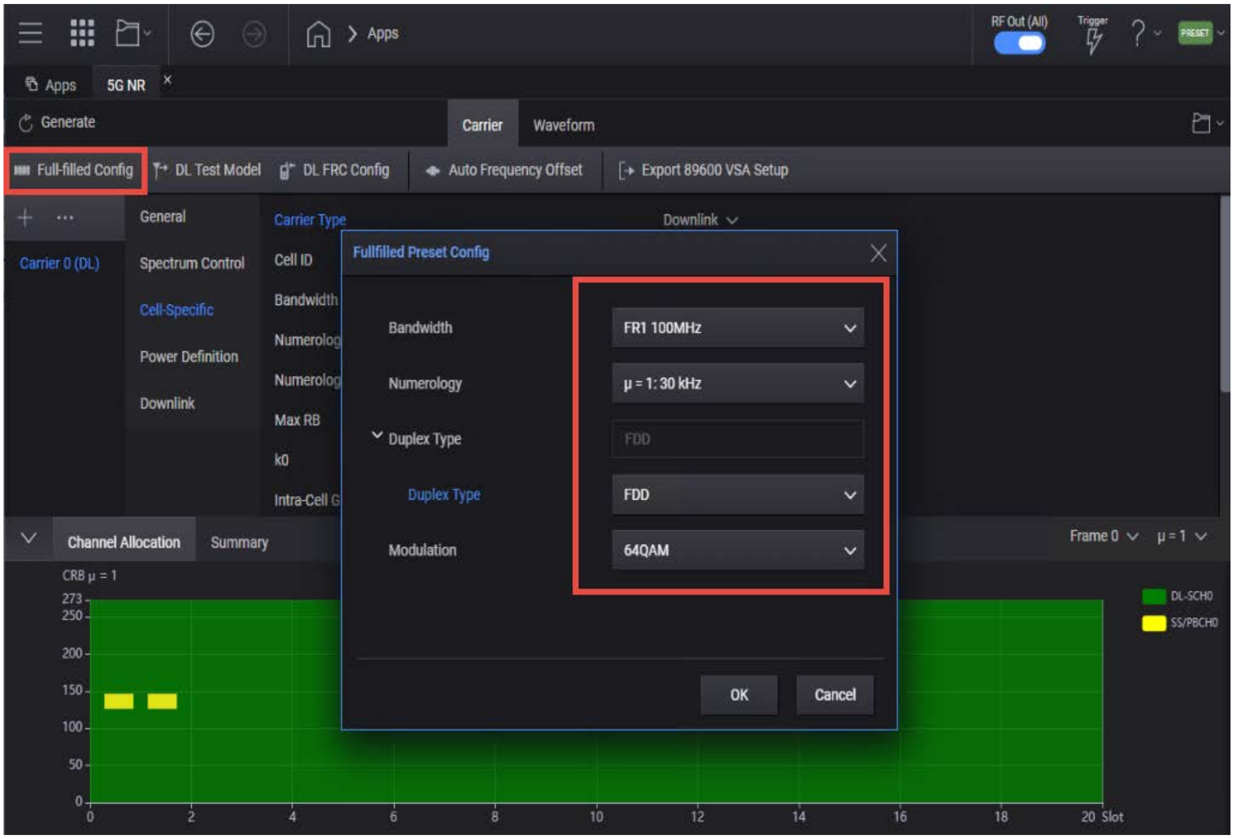


11. Signals 5 -7 will be configured using the embedded PathWave Signal Generation for 5G NR (N7631APPC). Select the **Radio Apps** icon in the top left of the window, and then select **5G NR**.

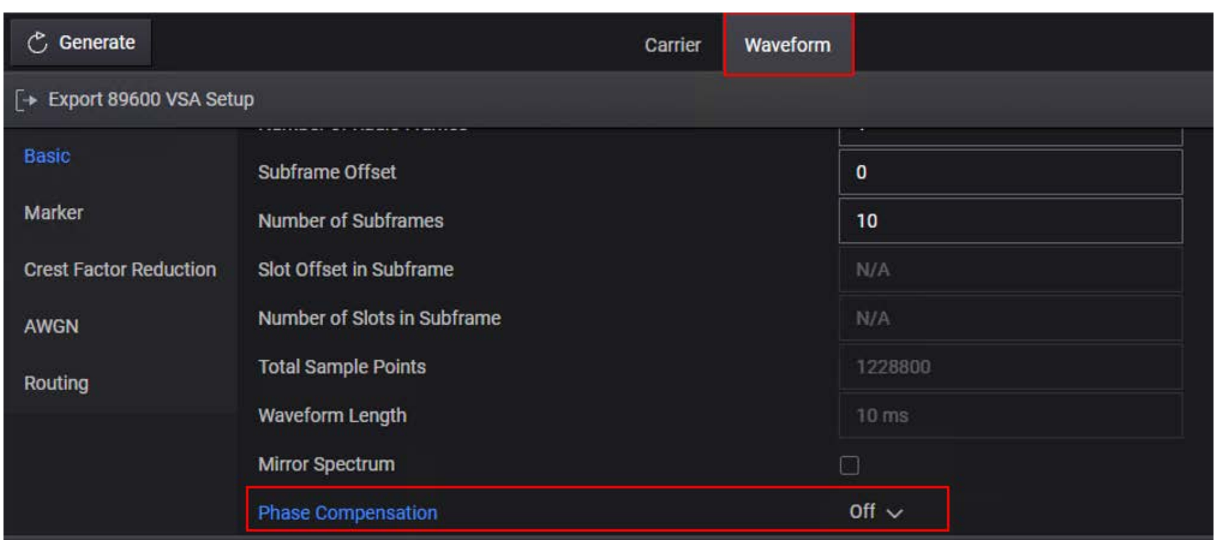


12. To create signal 5, select the **Carrier** tab > **Full-filled Config** and set
    - Bandwidth to **FR1 100 MHz**

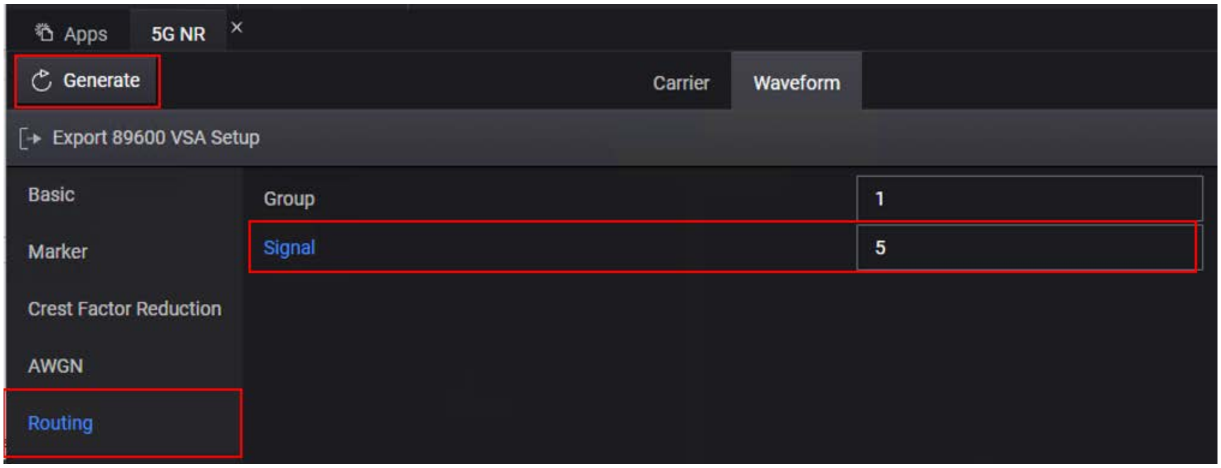
- Duplex Type to **FDD**
- Modulation to **64QAM**, then select **OK**



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**.

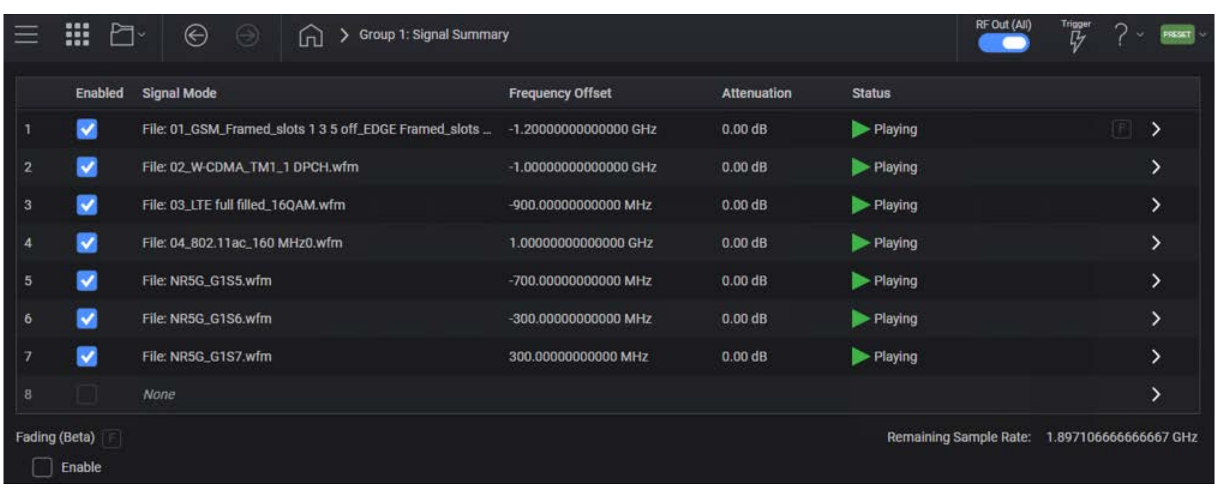
18. Select the **Waveform** tab, then from the left pane, select the **Routing** tab, set the signal number to **7**, and then **Generate**.

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

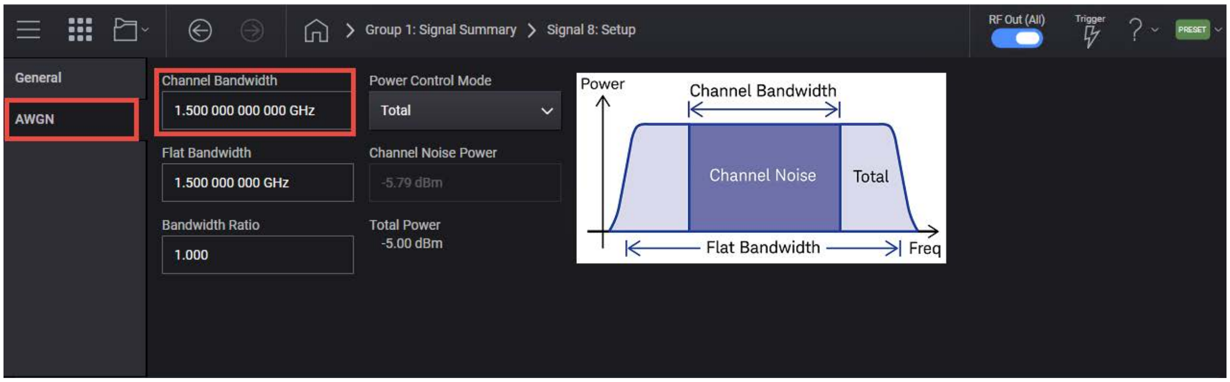
   – Signal 6 to –300 MHz

   – Signal 7 to 300 MHz

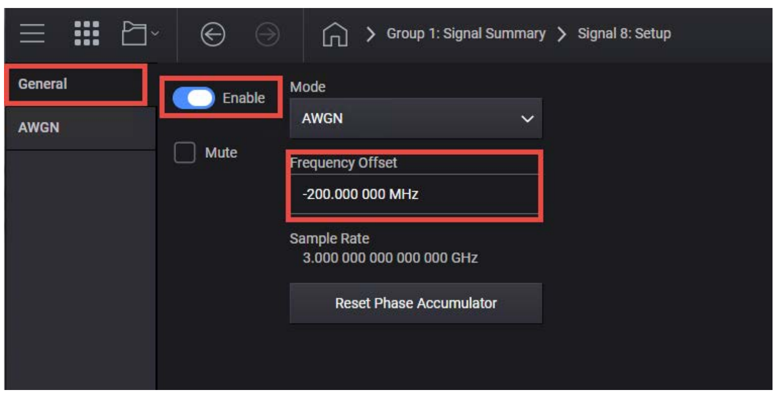


20. Select the arrow for Signal 8.

21. Select the **Mode** drop down and select **AWGN**. Select the AWGN tab and set Channel Bandwidth to **1.5 GHz.**

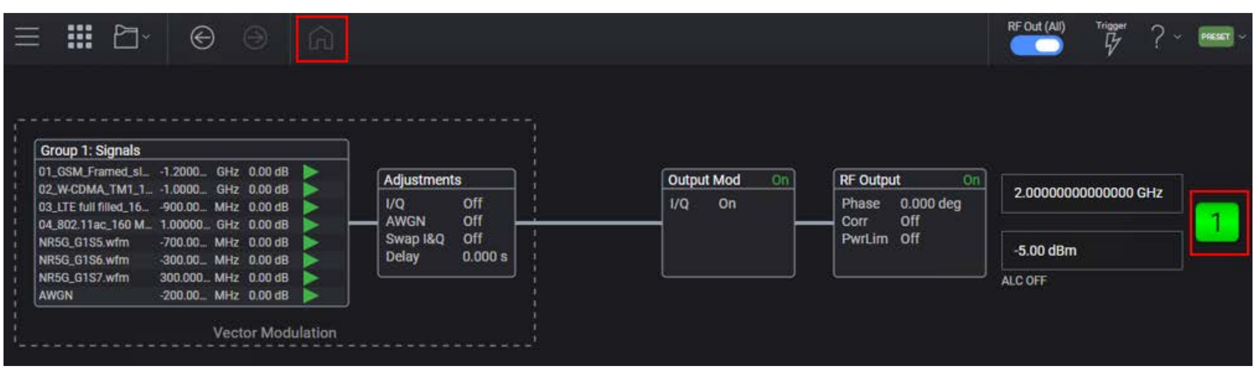


22. Select the **General** tab and set Frequency Offset to **-200 MHz** and **Enable** the AWGN signal.

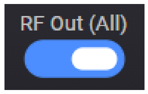


23. Select the **Home** icon and set RF Out to **On** by selecting the numbered channel indicator switch.

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.

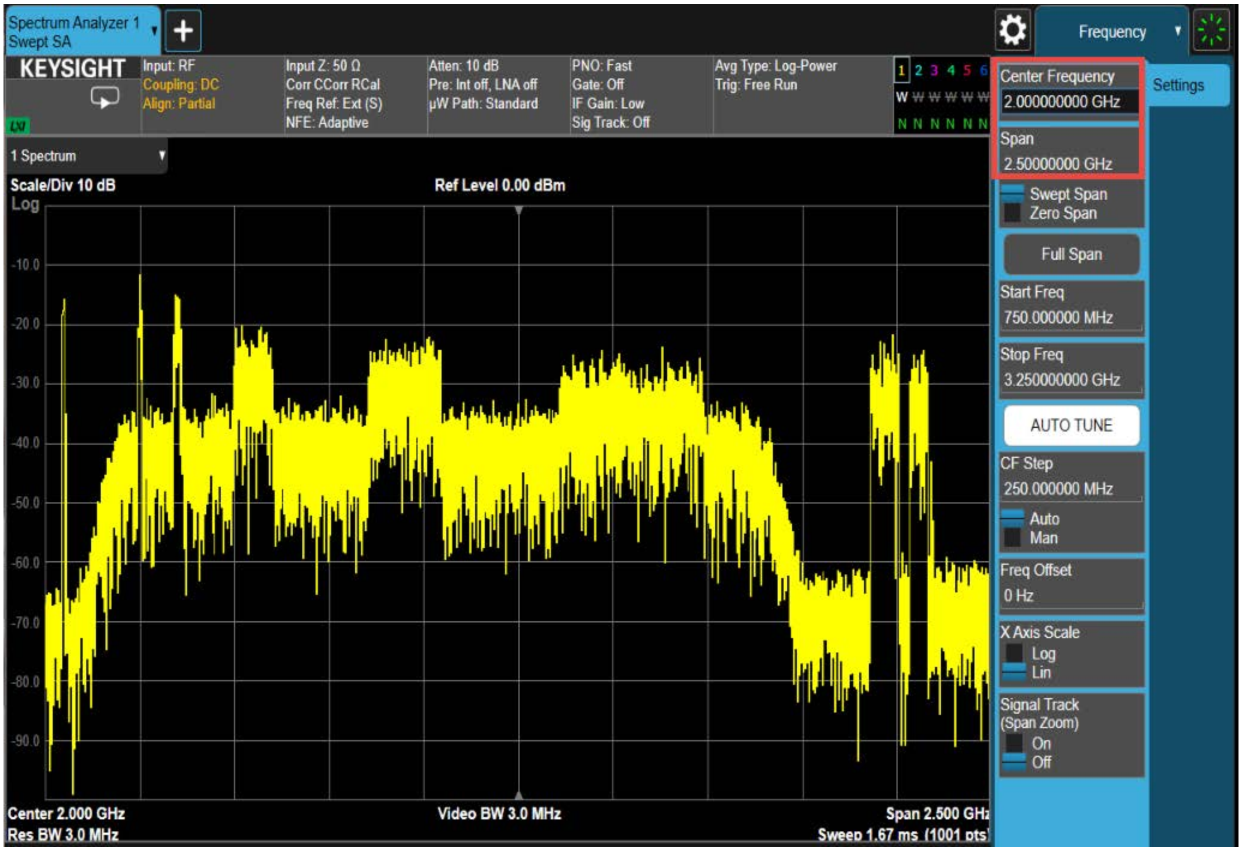
On the Signal Analyzer:

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.

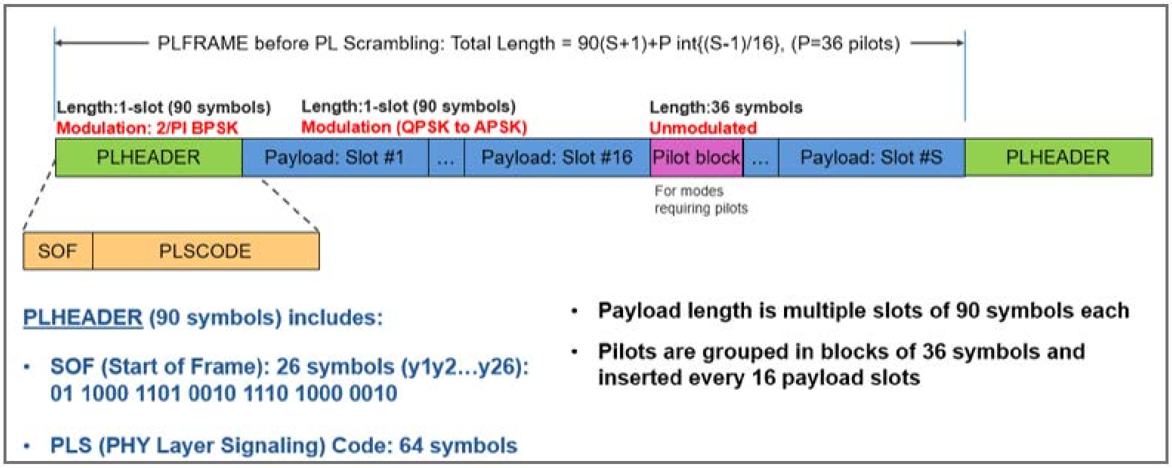
For this example, we will use the following equipment:

– 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.

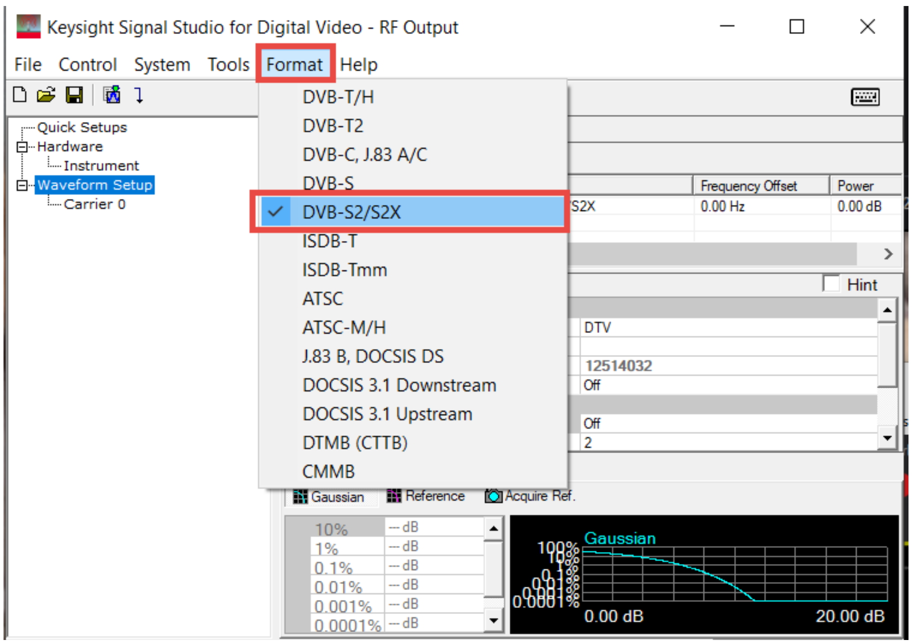
N7623C Signal Studio for Digital Modulation	N7608C Signal Studio for Custom Modulation	89601AYAC Flex Frame
256APSK 29/45	256APSK 116/180	256APSK 116/180
256APSK 2/3	256APSK 20/30	Not supported
256APSK 31/45	256APSK 124/180	256APSK 124/180
256APSK 32/45	256APSK 128/180	256APSK 128/180
256APSK 11/15	256APSK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

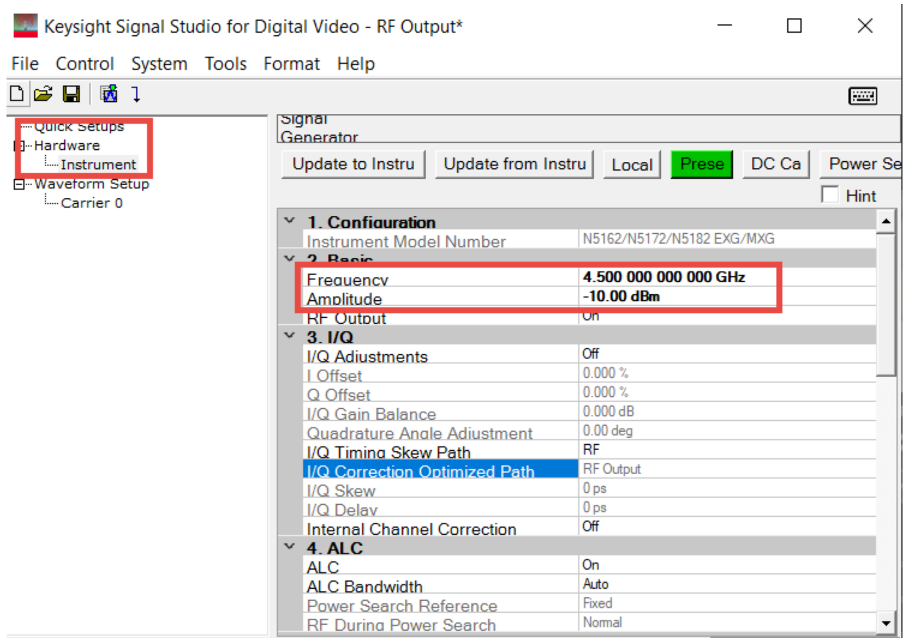
Setting Up the Waveform in Signal Studio for Digital Video

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**

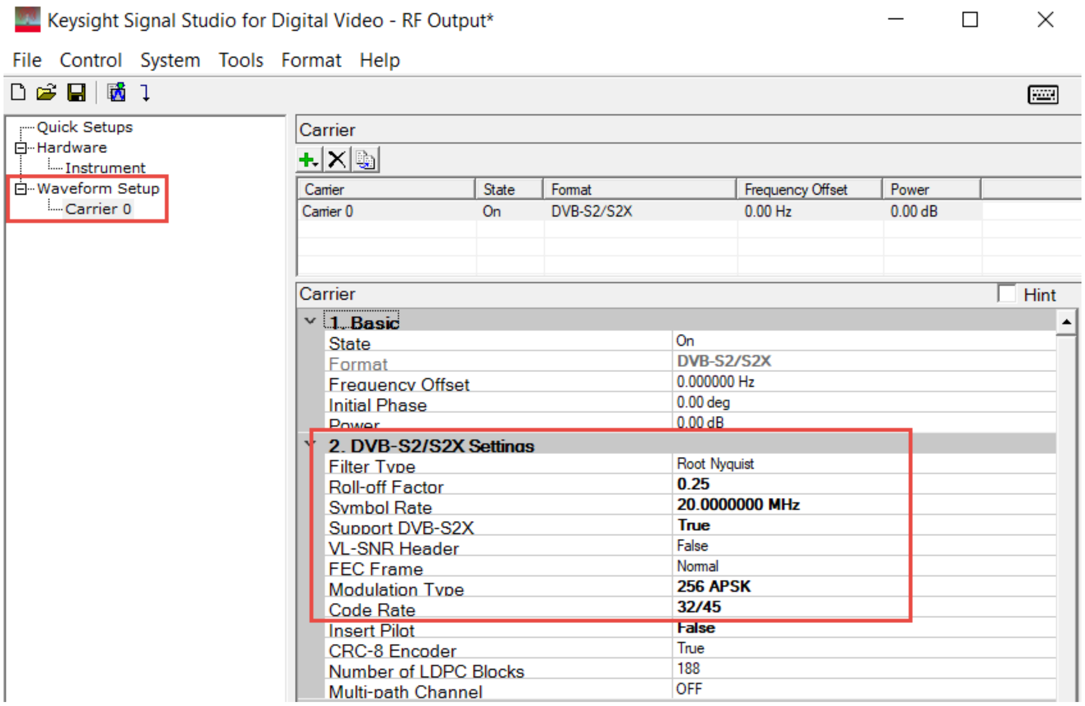
   – Symbol Rate to **20 MHz**

   – Support DVB-S2X to **True**

   – Modulation Type to **256 APSK**

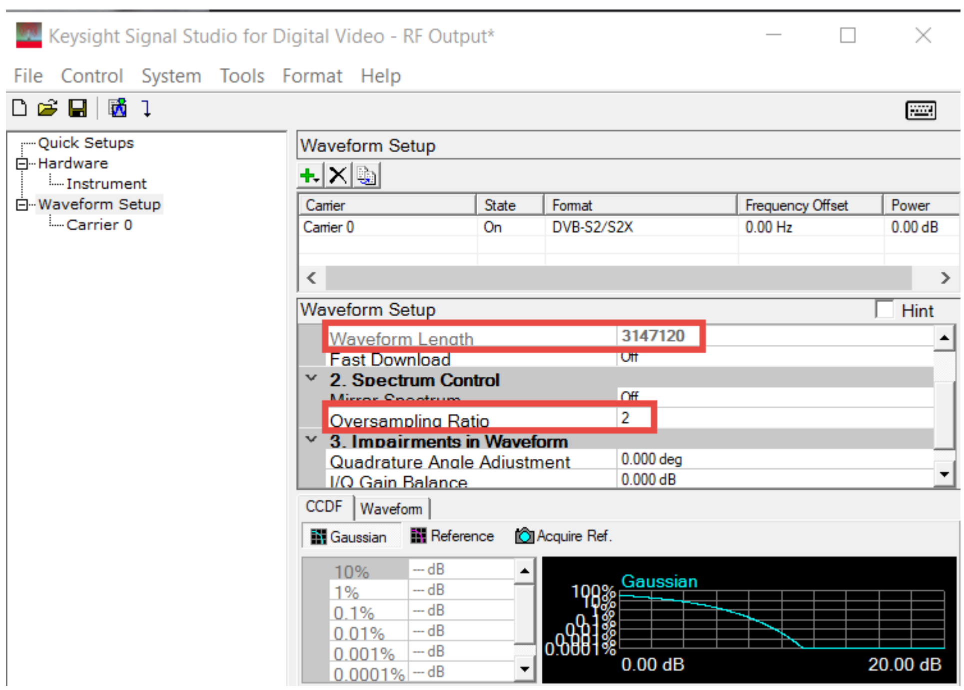
   – Code Rate to **32/45**

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.

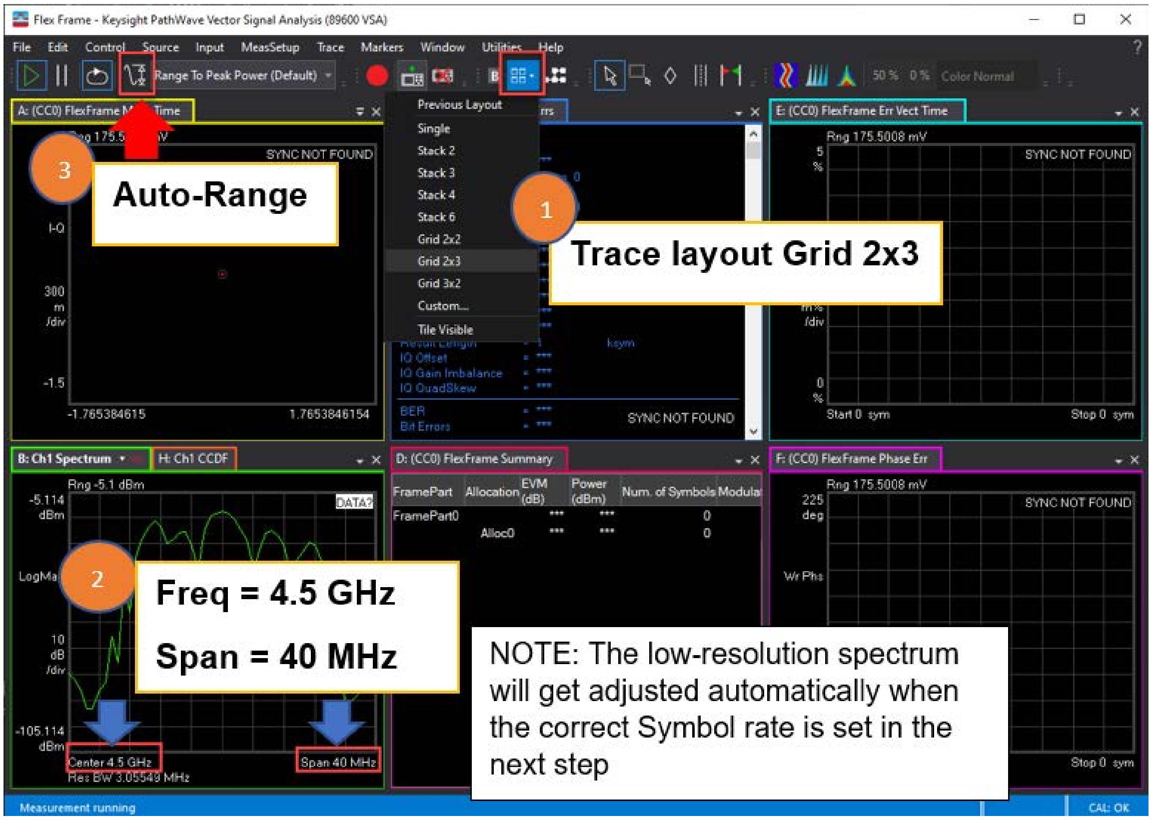
Setting up and Analyzing the Signal Using VSA Flex Frame

NOTE

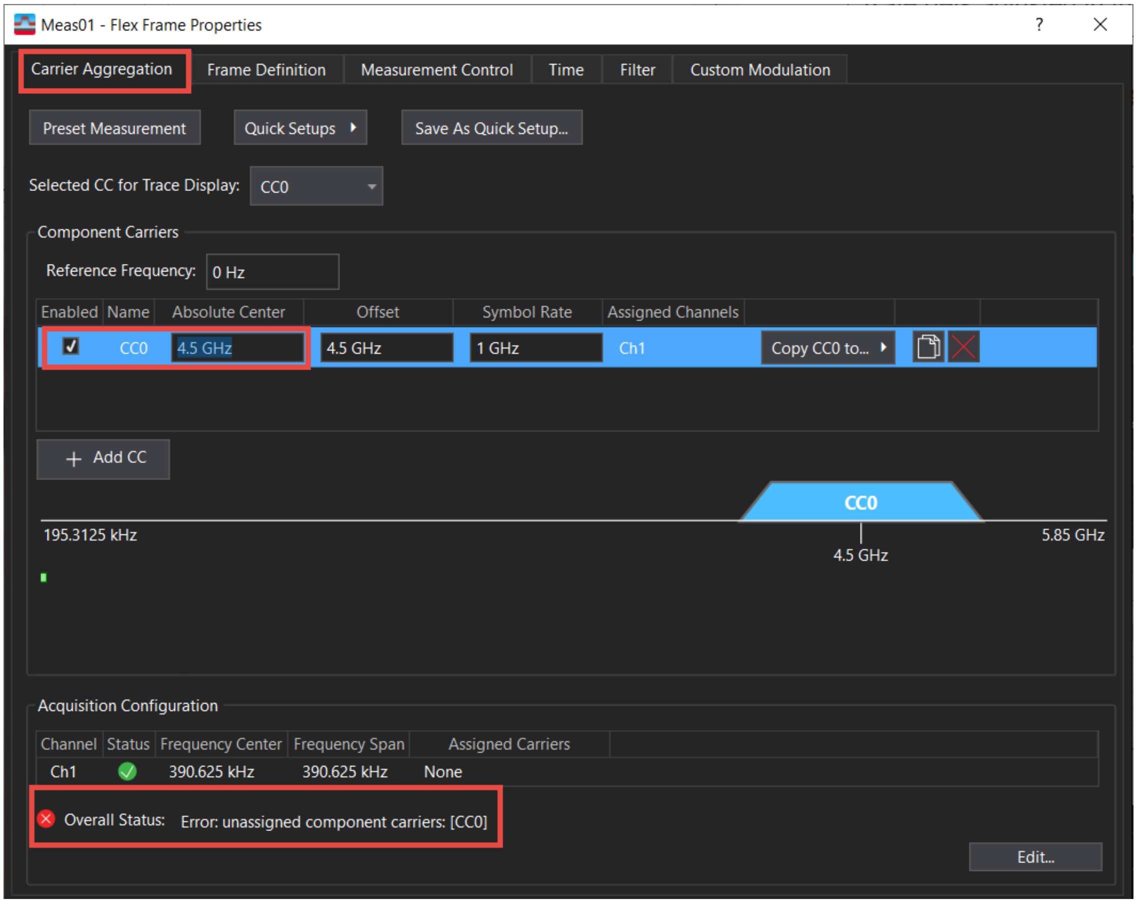
Changing settings on the VSA can take longer to take affect than expected. Wait to change the next setting until the previous setting has been updated.

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**

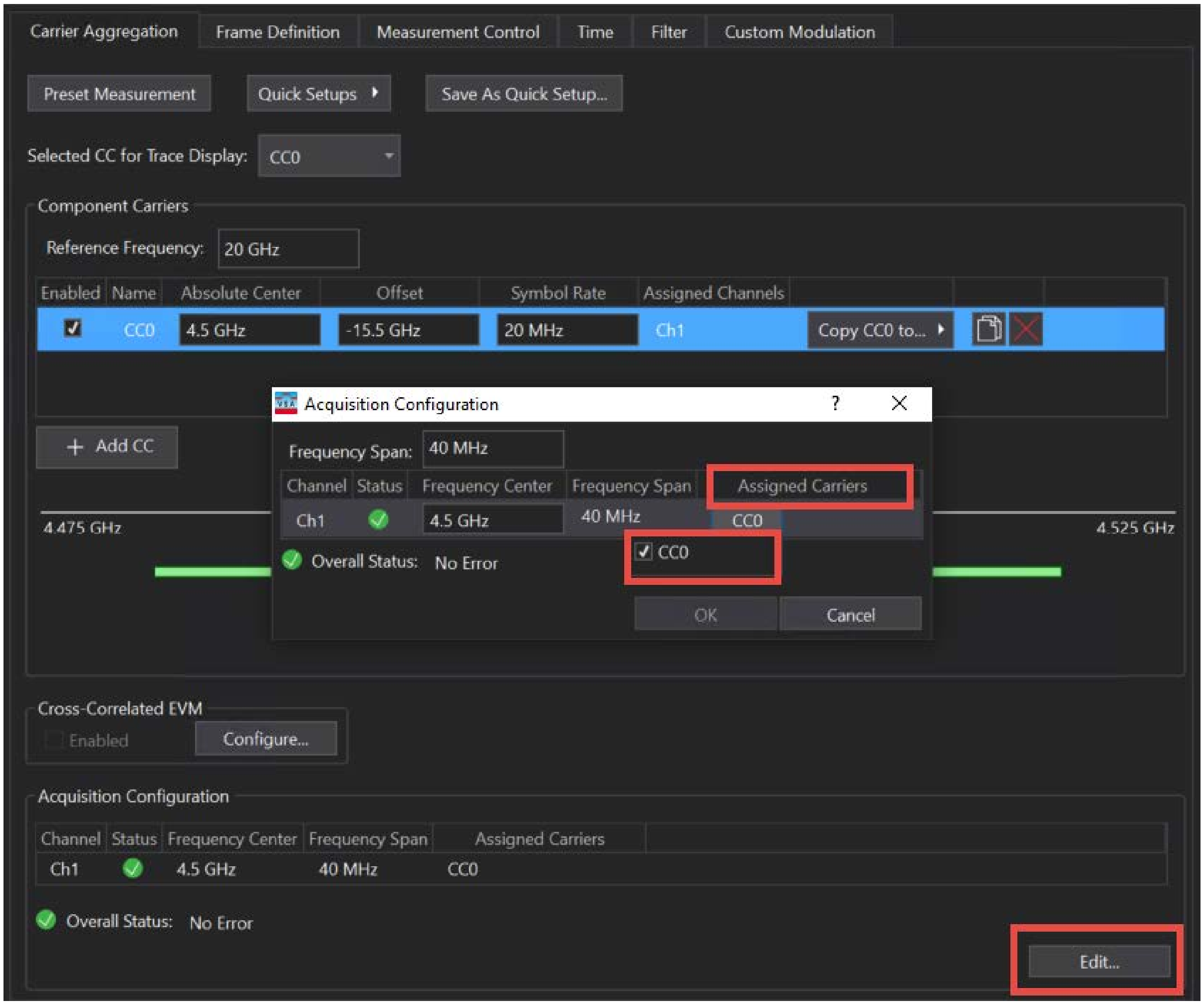

Auto-Range
Trace layout Grid 2x3
Freq = 4.5 GHz
Span = 40 MHz
NOTE: The low-resolution spectrum will get adjusted automatically when the correct Symbol rate is set in the next step

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 **CCO**.



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

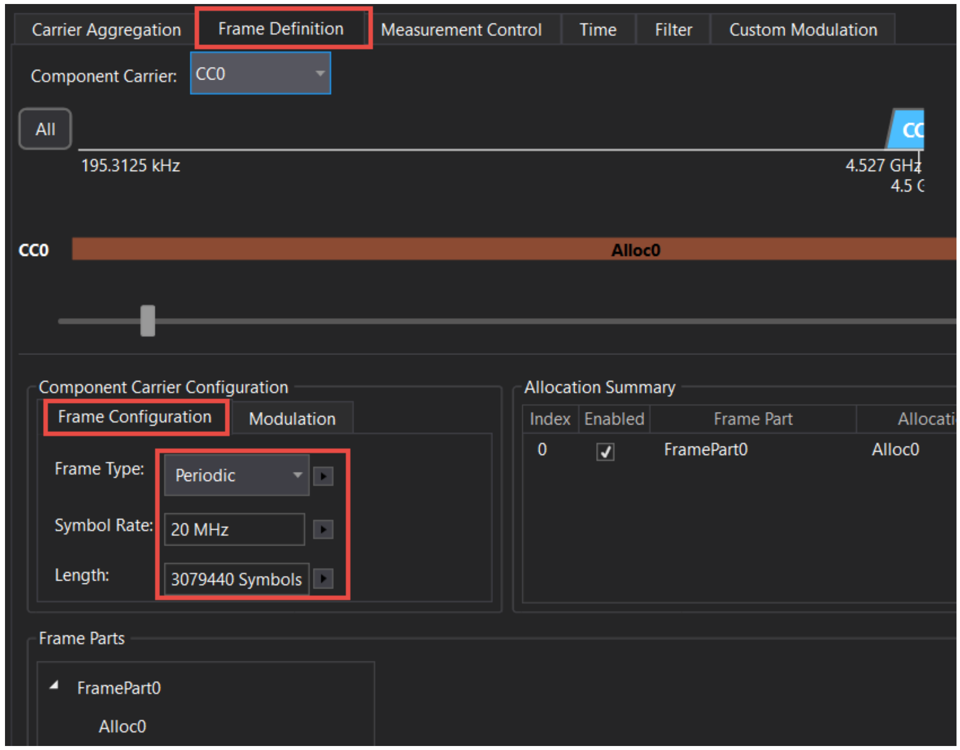
   – Frame Type to **Periodic**

   – 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**.

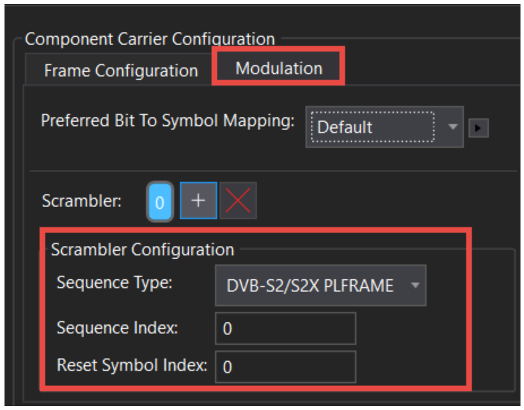
   When testing a DUT, if the bit mapping into constellation point is as defined by DVB-S2X, DVB-RCS2 or 802.11ad/ay standard, selecting the correct standard under "Bit To Symbol Mapping" is required for accurate Tx BER measurement. When using Signal Studio, leave it as Default.

   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.

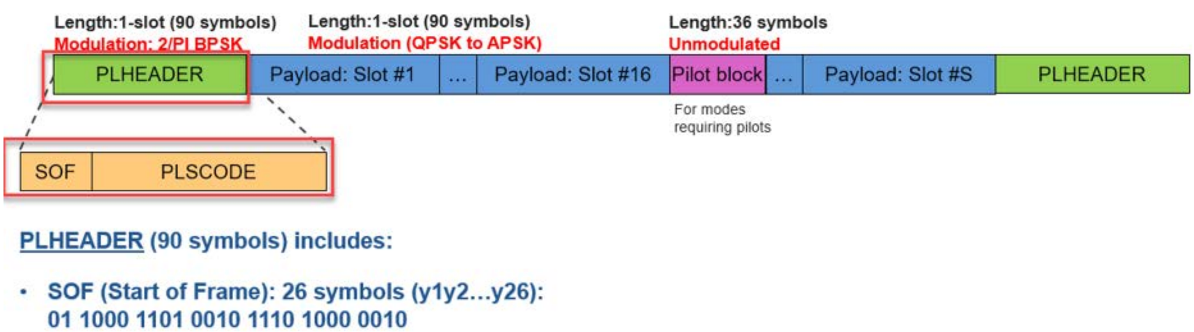
7. Set the Sequence Type to **DVB-S2/S2X PLFRAME**.

   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)



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 π/2BPSK**

     – Enter the 26 symbols **01100011010010111010000010**

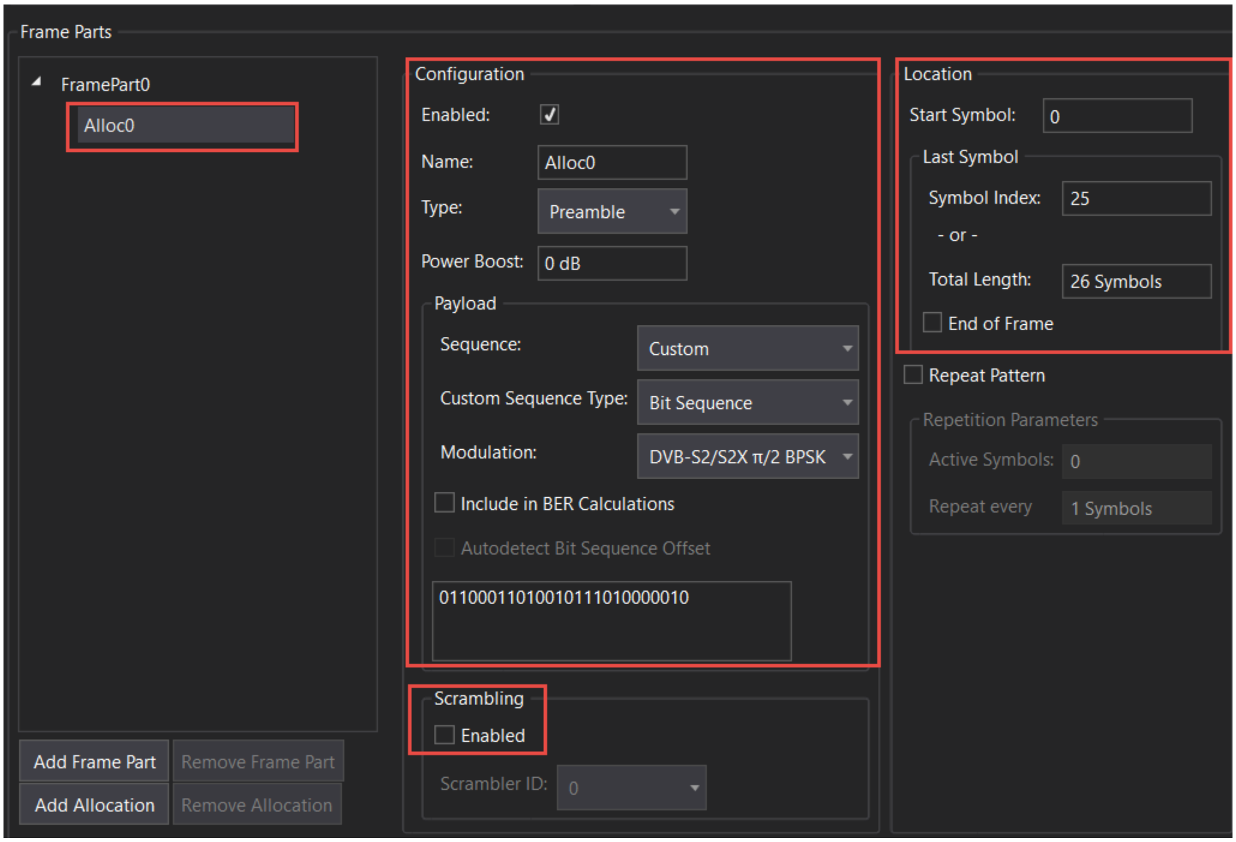
       (011 000 110 100 101 110 100 000 10)

   – 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.



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:

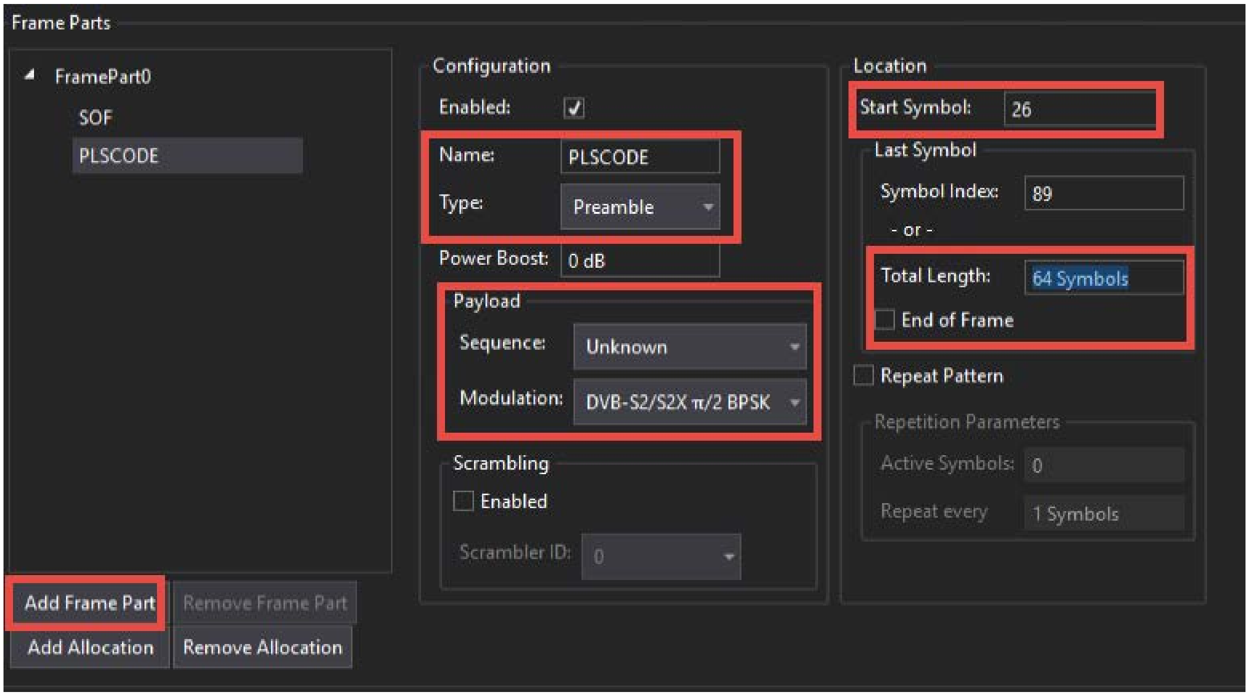
– Name to **PLSCODE**
– Type to **Preamble**
– Sequence to **Unknown**
– Modulation to **DVB-S2/S2Xπ/2 BPSK**

Notice that Scrambling is not applied to Preamble.

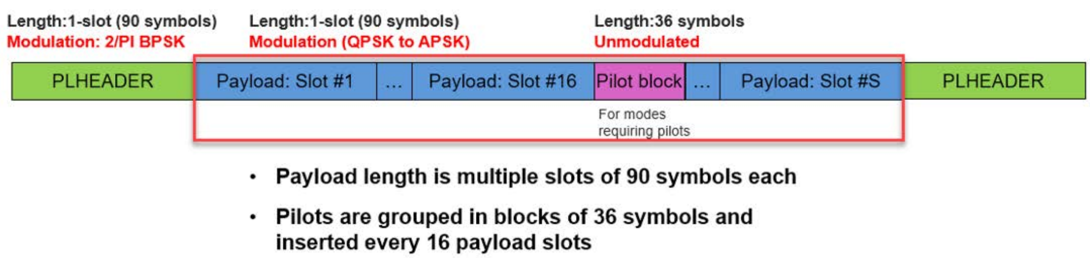
12. In the Location area, set:

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

– Total Length to **64 Symbols**



Configure the Payload



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**

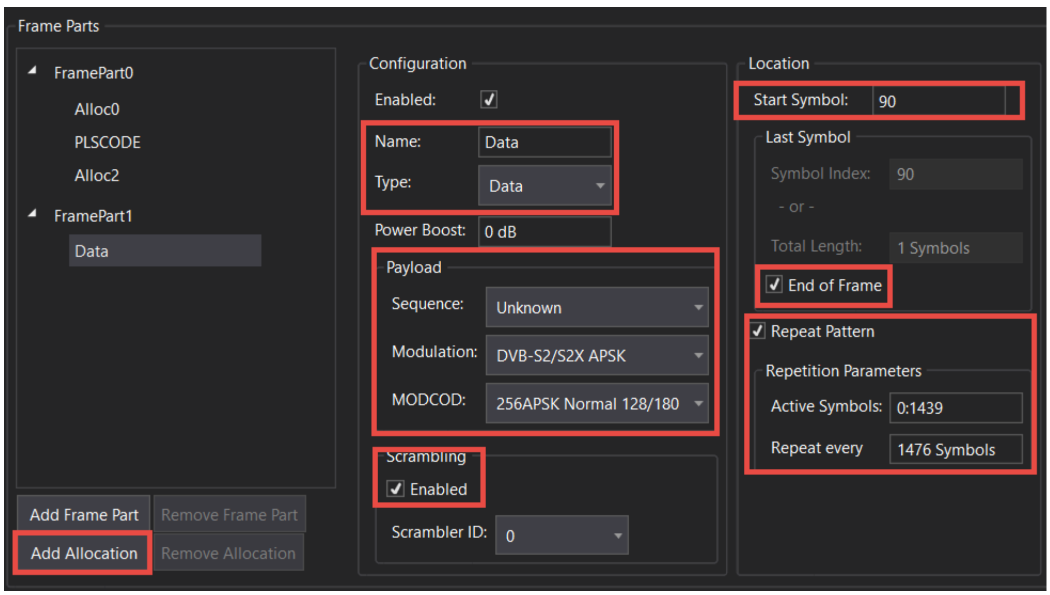
– Select **Repeat Pattern**

– 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.



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**

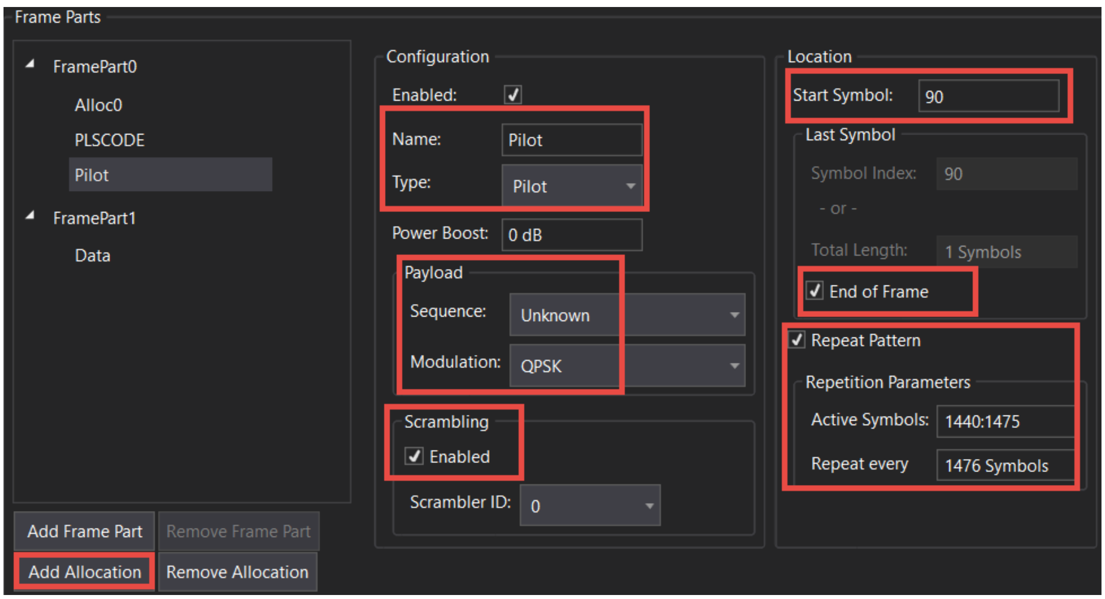
18. In the Location area, set:

- 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.



Configure Synchronization and Equalization

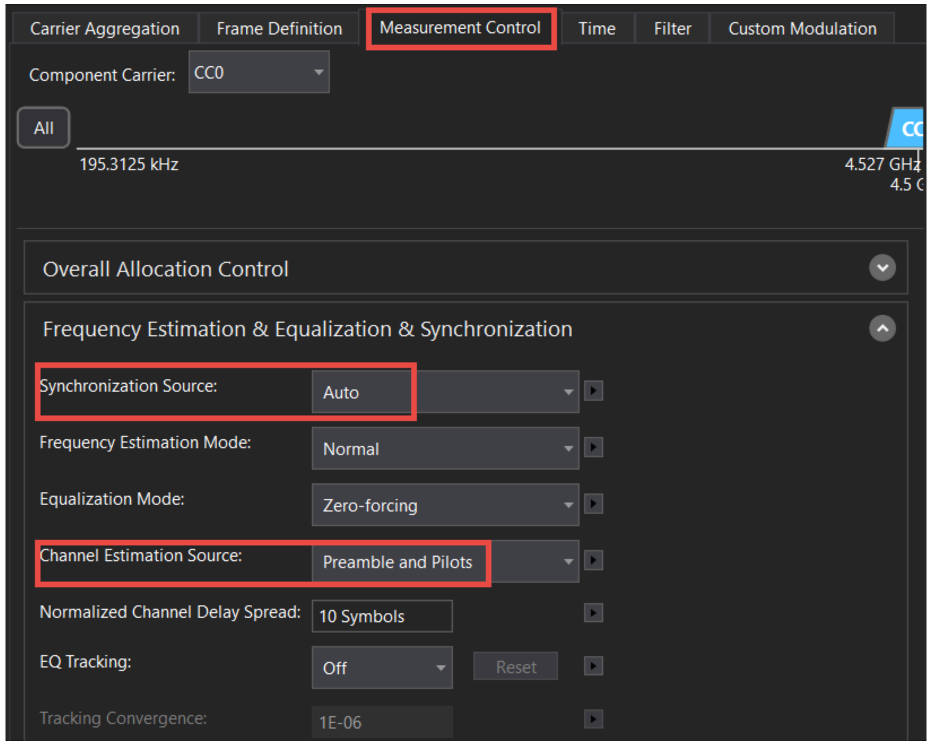
19. Select the **Measurement Control** tab, and set:

- 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**

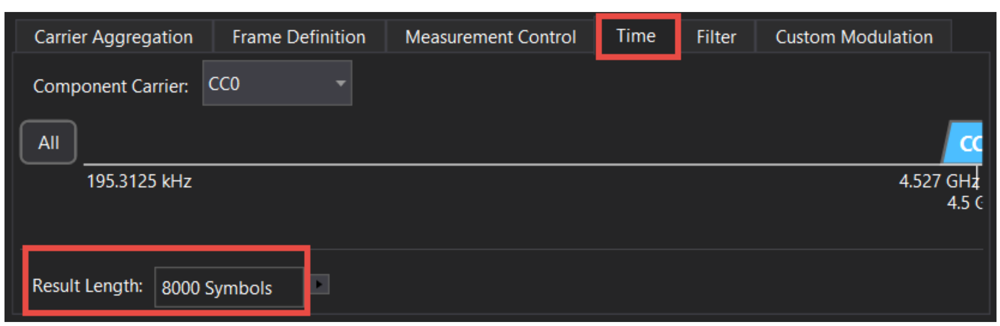
Equalization is off by default. You can choose the different frame parts for channel estimation and equalization.



Configure the Analysis Region

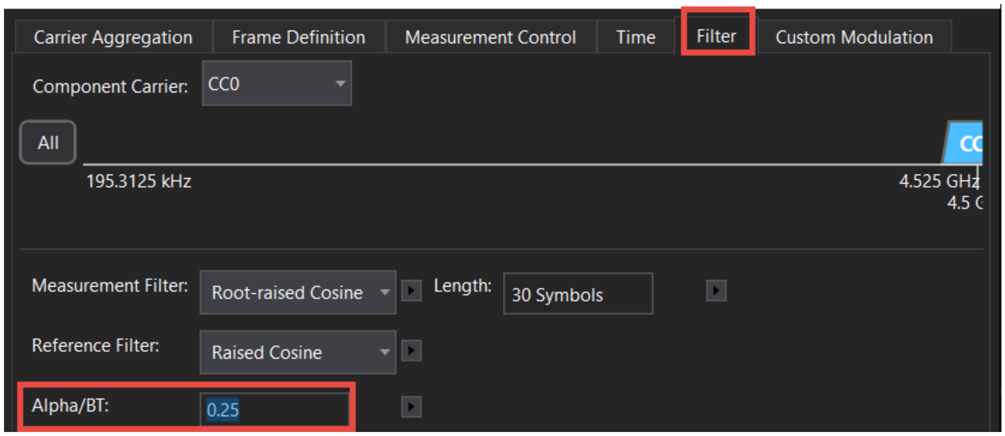
20. Select the **Time** tab, set the Result Length to **8000 Symbols**.

Setting the result length to ≤ 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

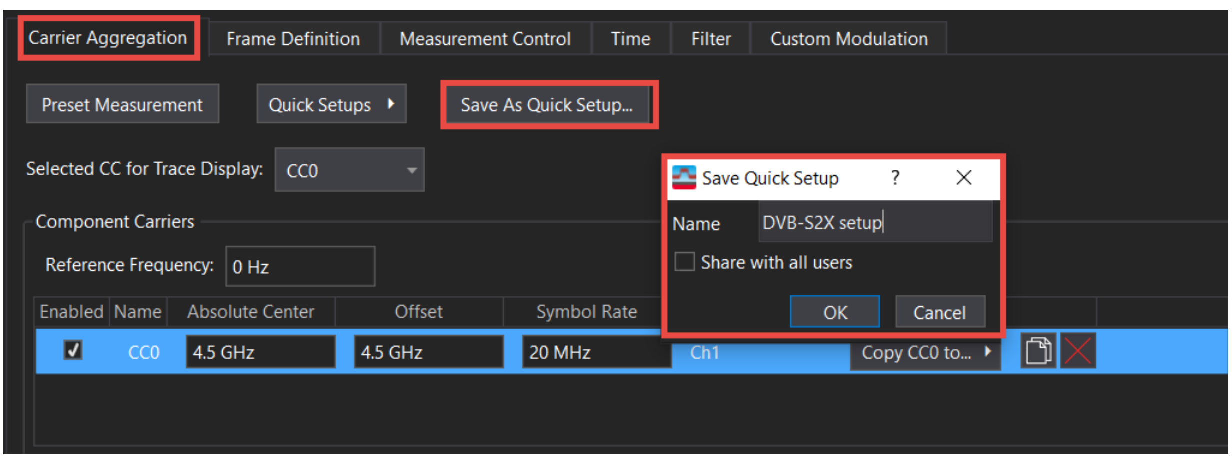
21. In the **Filter** tab, set Alpha/BT: to 0.25.



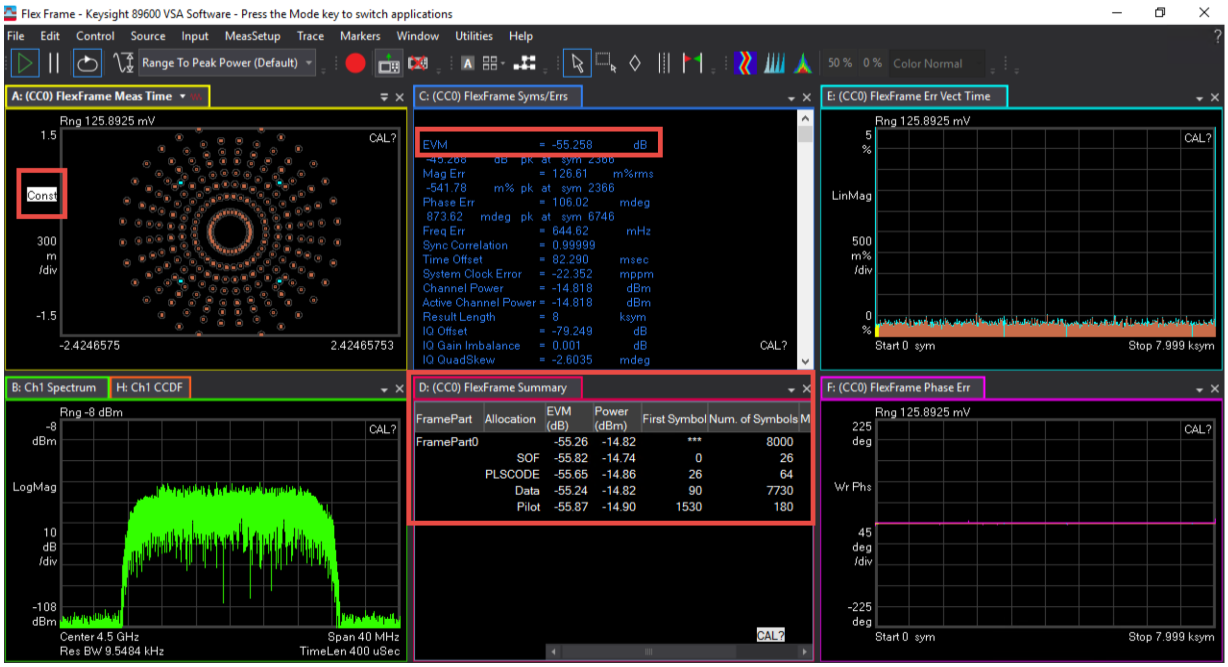
Save the Configuration as a Quick Setup

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.



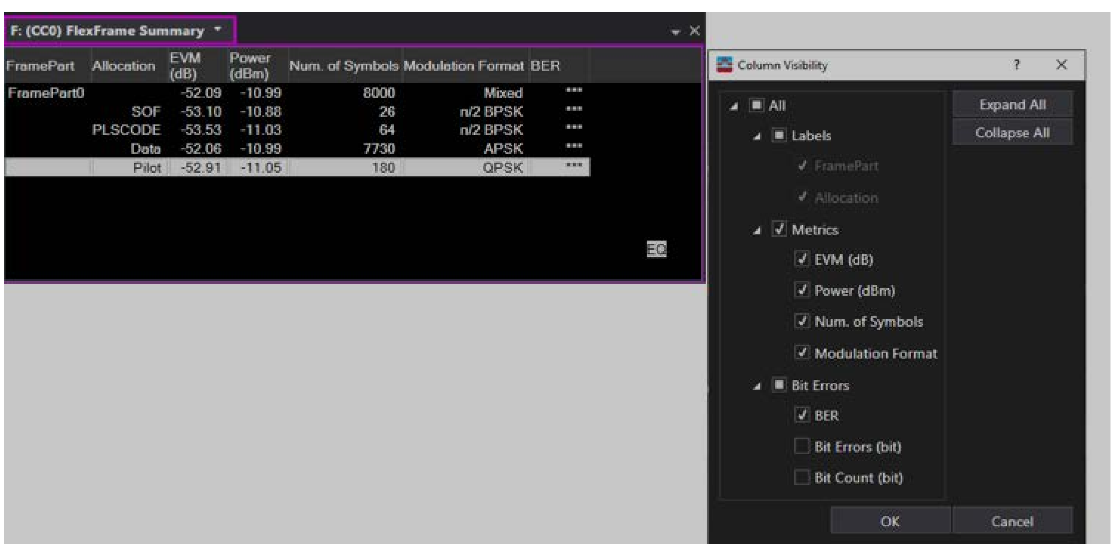
23. Close the Properties window and change Trace A to a Constellation Diagram, then view the results.



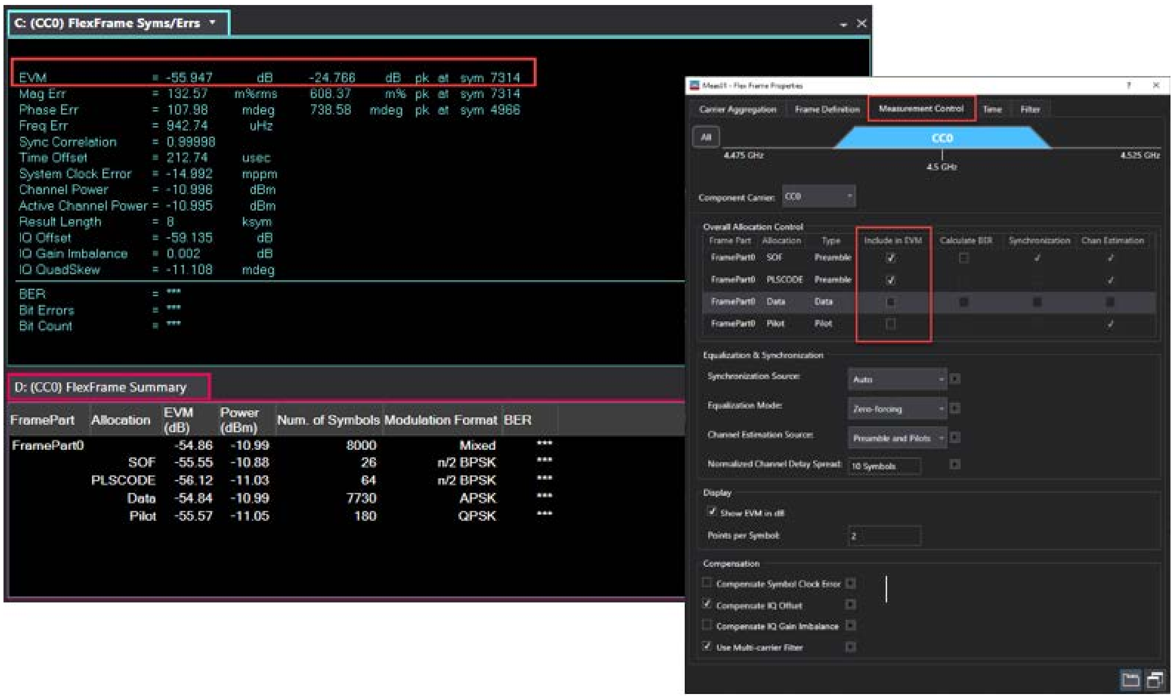
You should see a successful demodulation with very low EVM. Multiple traces and tables are available including Error Vector Spectrum, Error Vector Time, demod, and BER Bits.

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.



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.



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

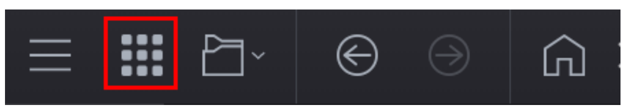
For this example, we will use the embedded N7608APPC application on the M9484C VXG.

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

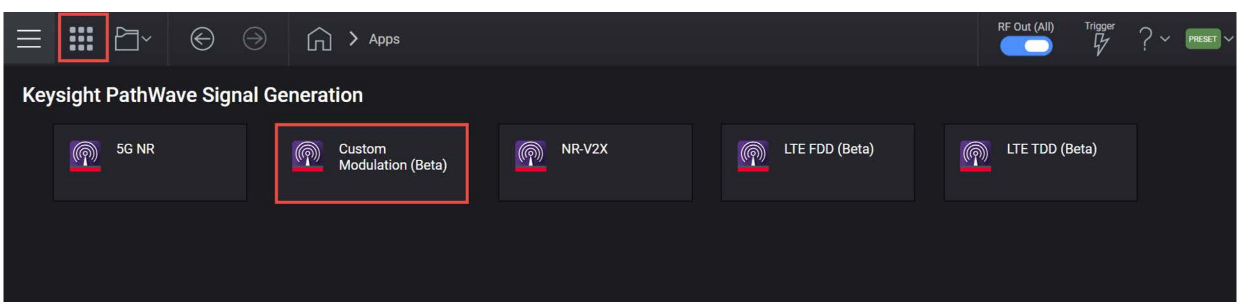
Setting Up the Waveform in PathWave Custom Modulation

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**.

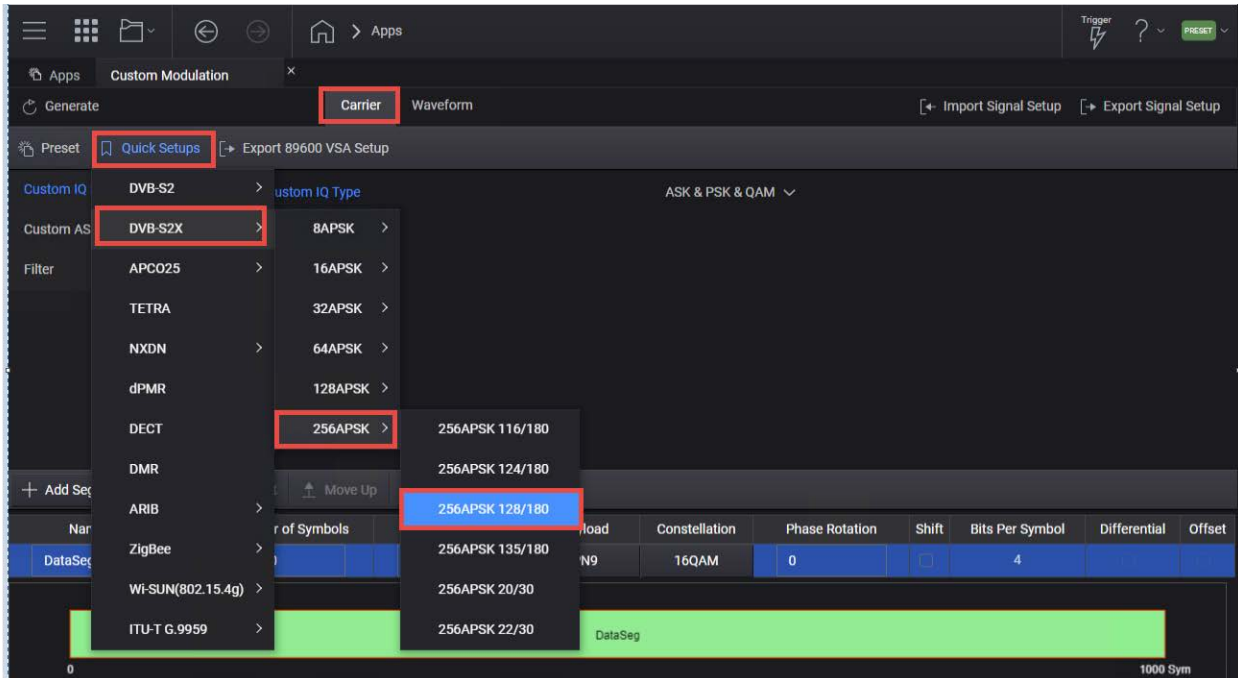
3. Select the **Radio Apps** block to open the Vector Modulation Signal Setup panel.



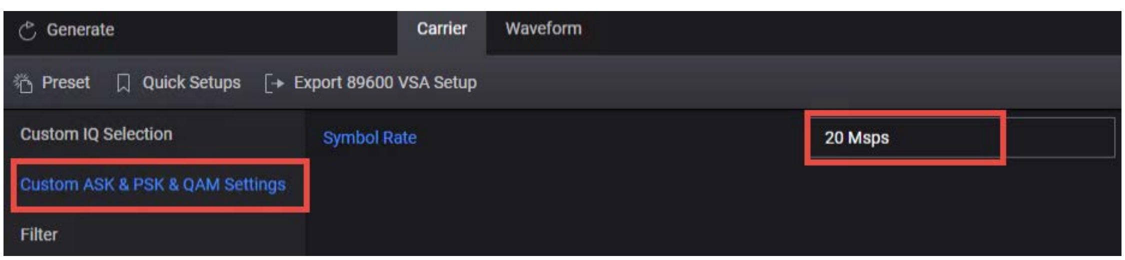
4. Select **Custom Modulation** to enter Custom Modulation Signal Mode.



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

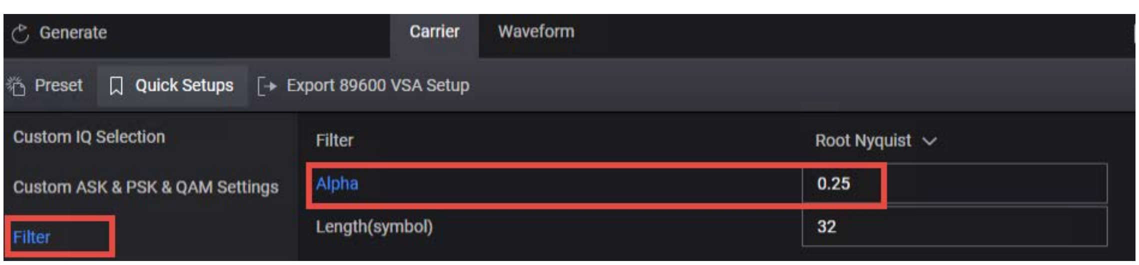


6. From the left pane, select **Custom ASK & PSK & QAM Settings** and set the Symbol Rate to **20 Msps** per channel.



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

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



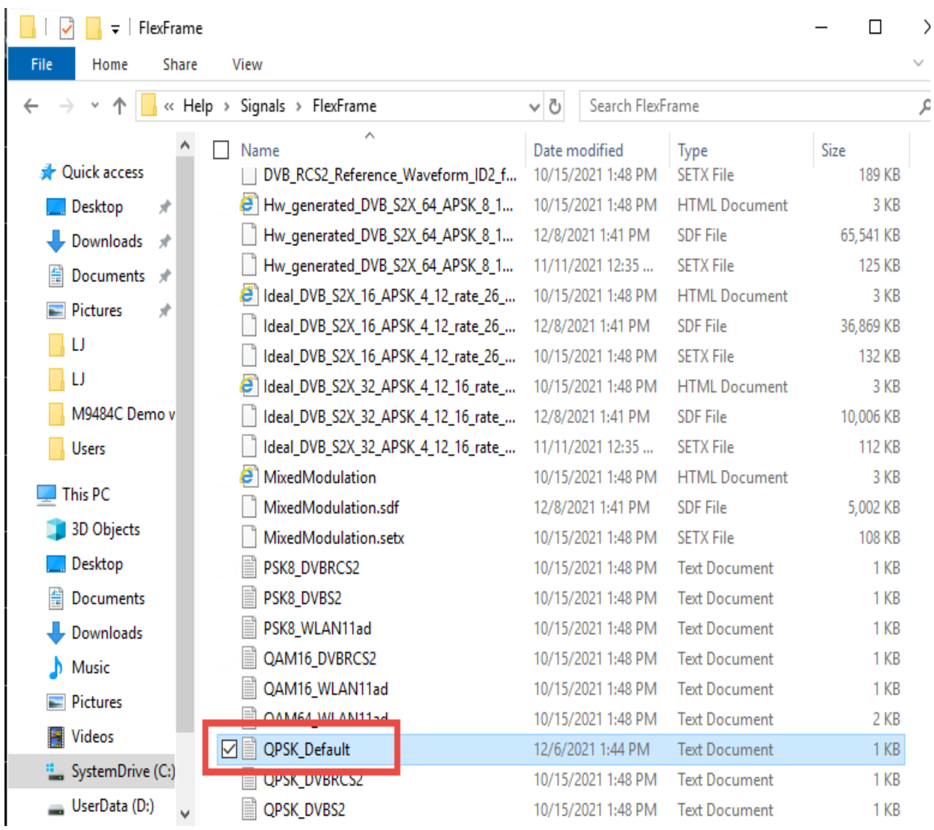
Configure the PLHEADER (Preamble)

In Part 1, the PLHEADER using π/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 52 symbols for the SOF. Since N7608C doesn't support π/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.

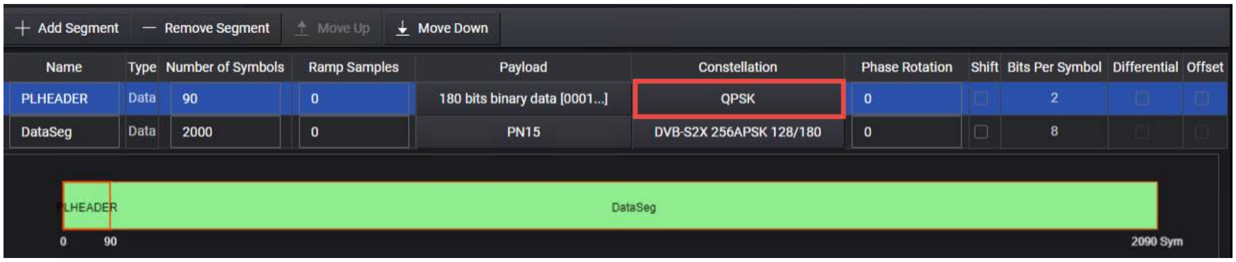


NOTE

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

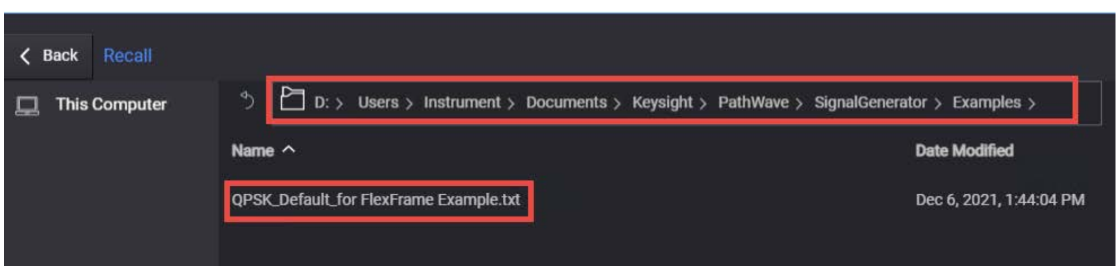
```
D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples\QPSK_Default_for FlexFrame Example
```

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

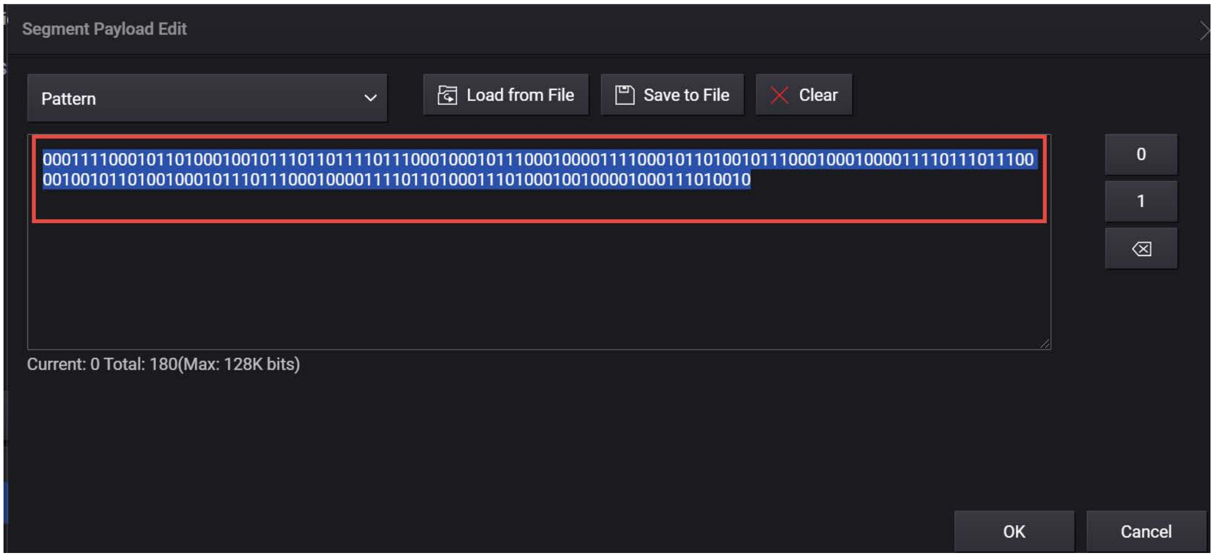


9. In the Constellation Edit dialog, select **Recall**.

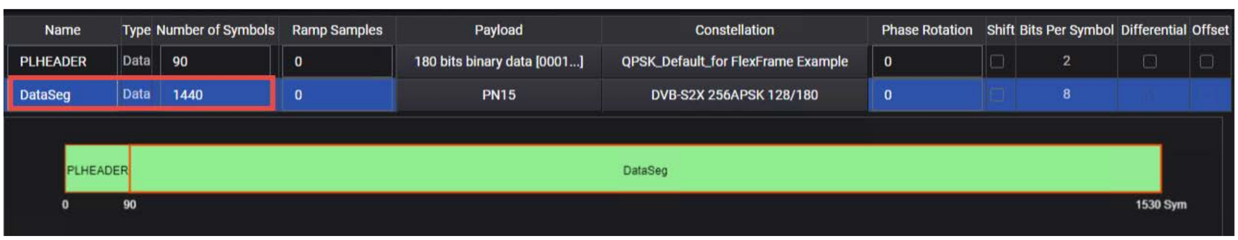
10. Navigate to the text file and choose **Select**. Select **OK** to Close the Constellation Edit dialog.



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. Select OK to close the dialog box.



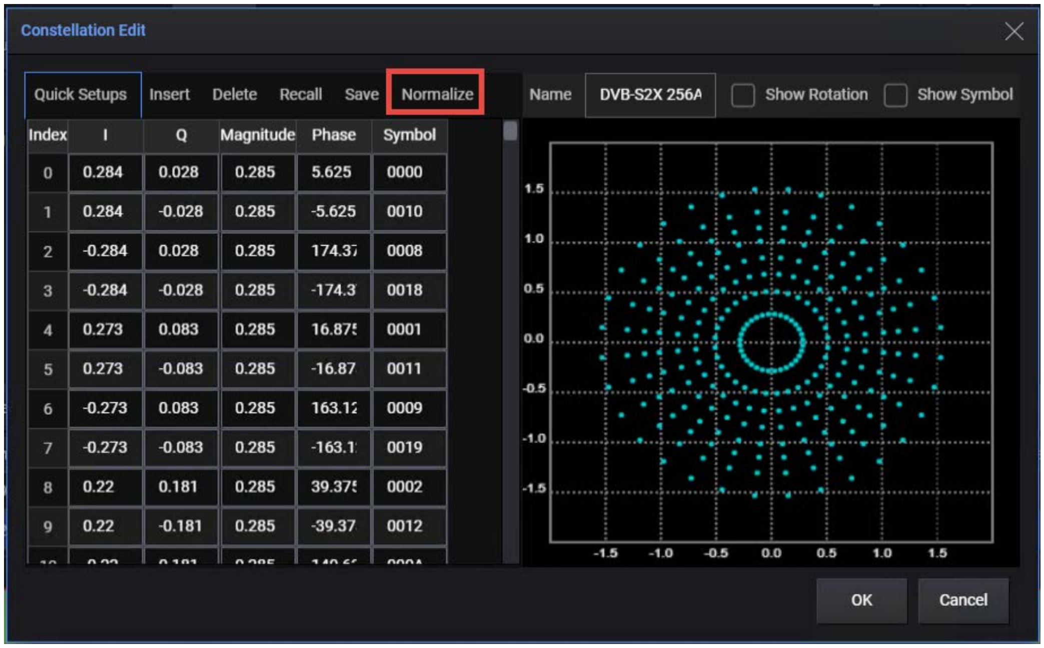
12. To configure the Payload, from the DataSeq row, set the Number of Symbols to **1440**.



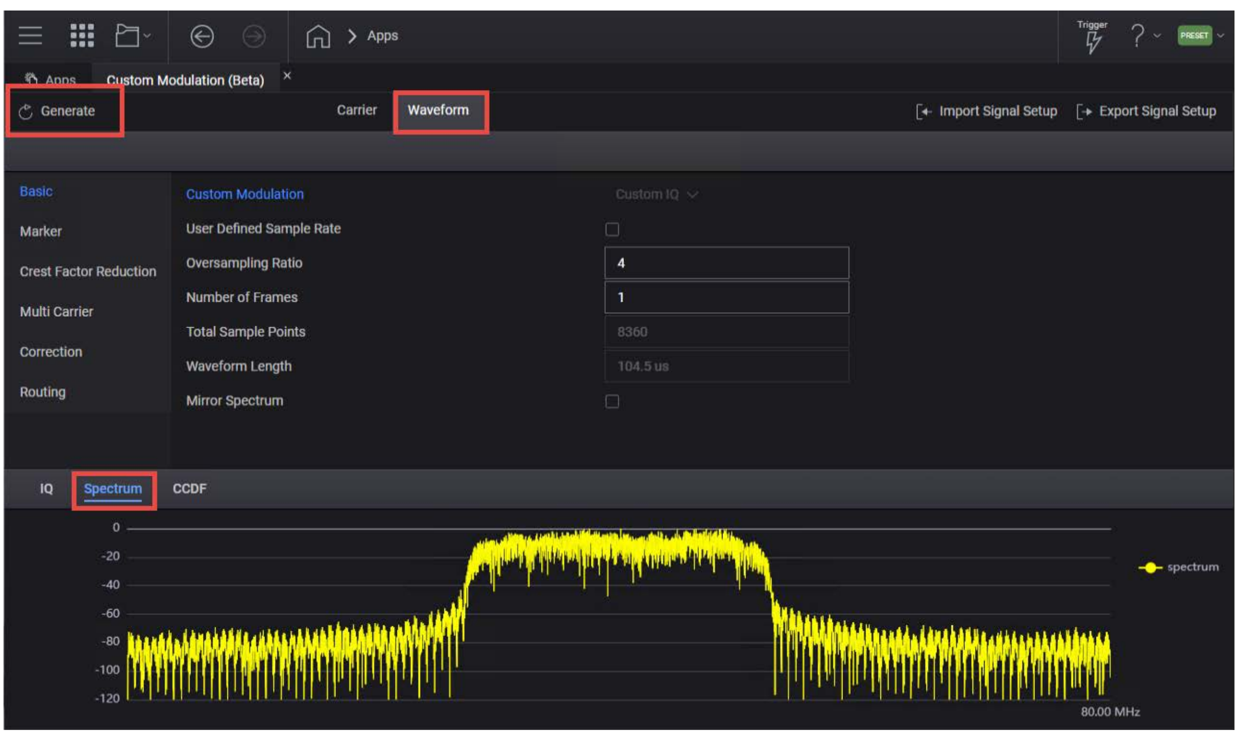
Use 16 payload slots (90 symbols/slot) for the radio frame. These are the slots prior to Pilot. Pilots are optional and not generated (See part 1 of this demo guide for a frame with pilot segment).

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

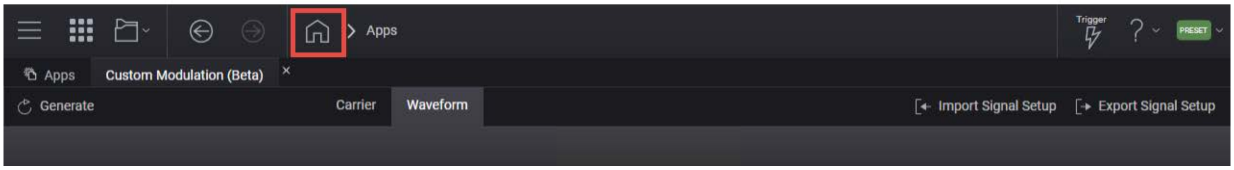
It is a good idea to normalize the power. Difference power levels between data and preamble can result in high EVM.



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



15. Select **Home** to exit the setup panel.



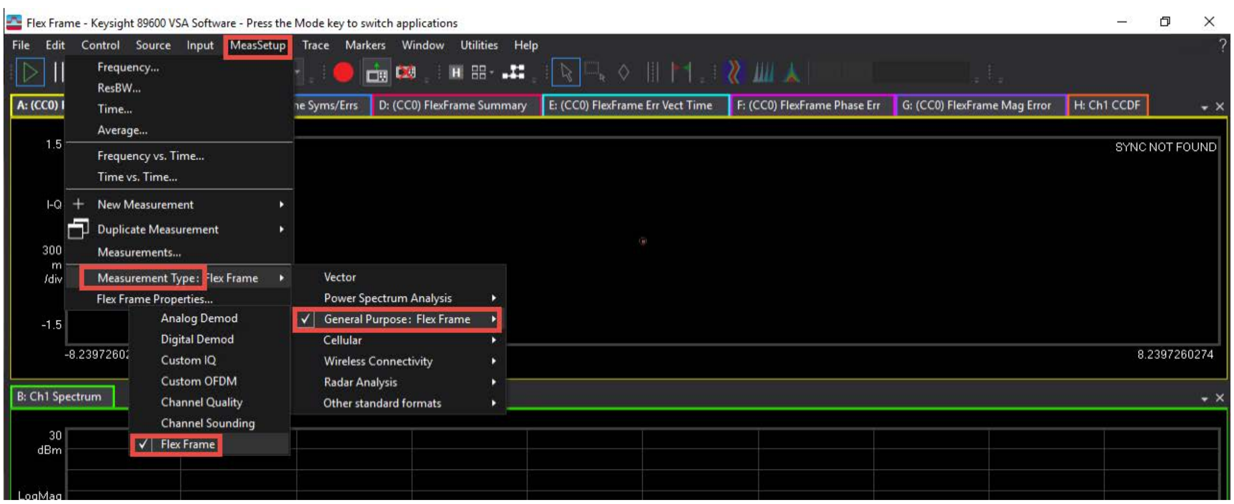
16. Set RF Out to **On** by selecting the numbered channel indicator switch.

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

Setting up 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** > **General Purpose** > **Flex Frame.**



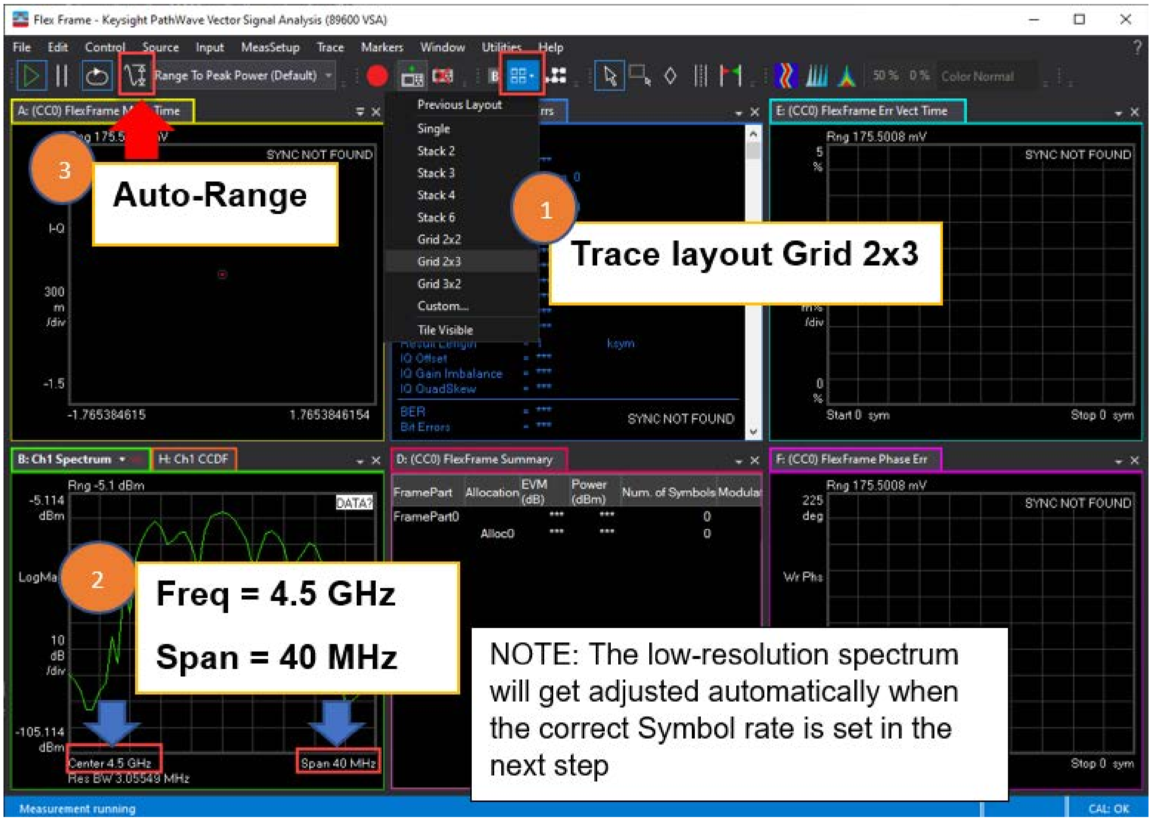
2. Set the correct frequency, span, and input range. For this example, set:

   – Change the Trace Layout Grid to 2 x 3.

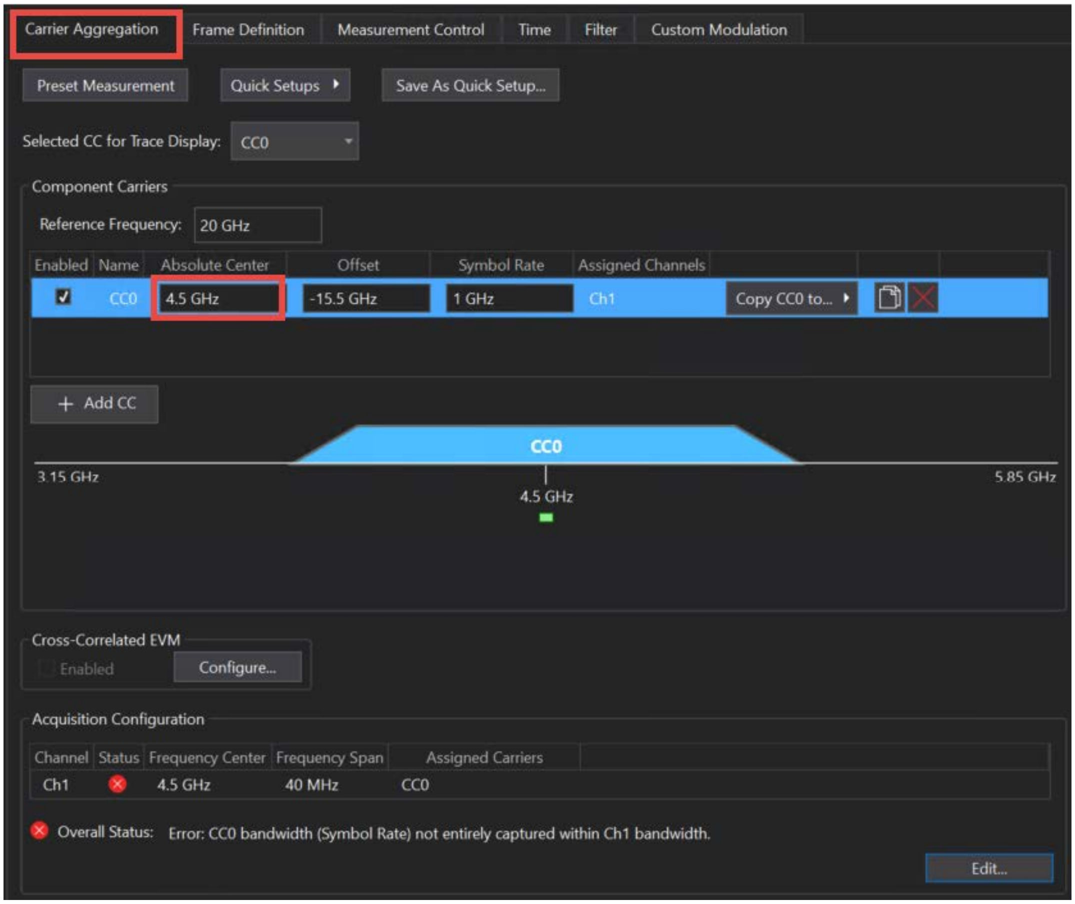
   – Change Trace B to **Ch1 Spectrum**, and set Center Frequency to **4.5 GHz**

   – Span to **40 MHz**

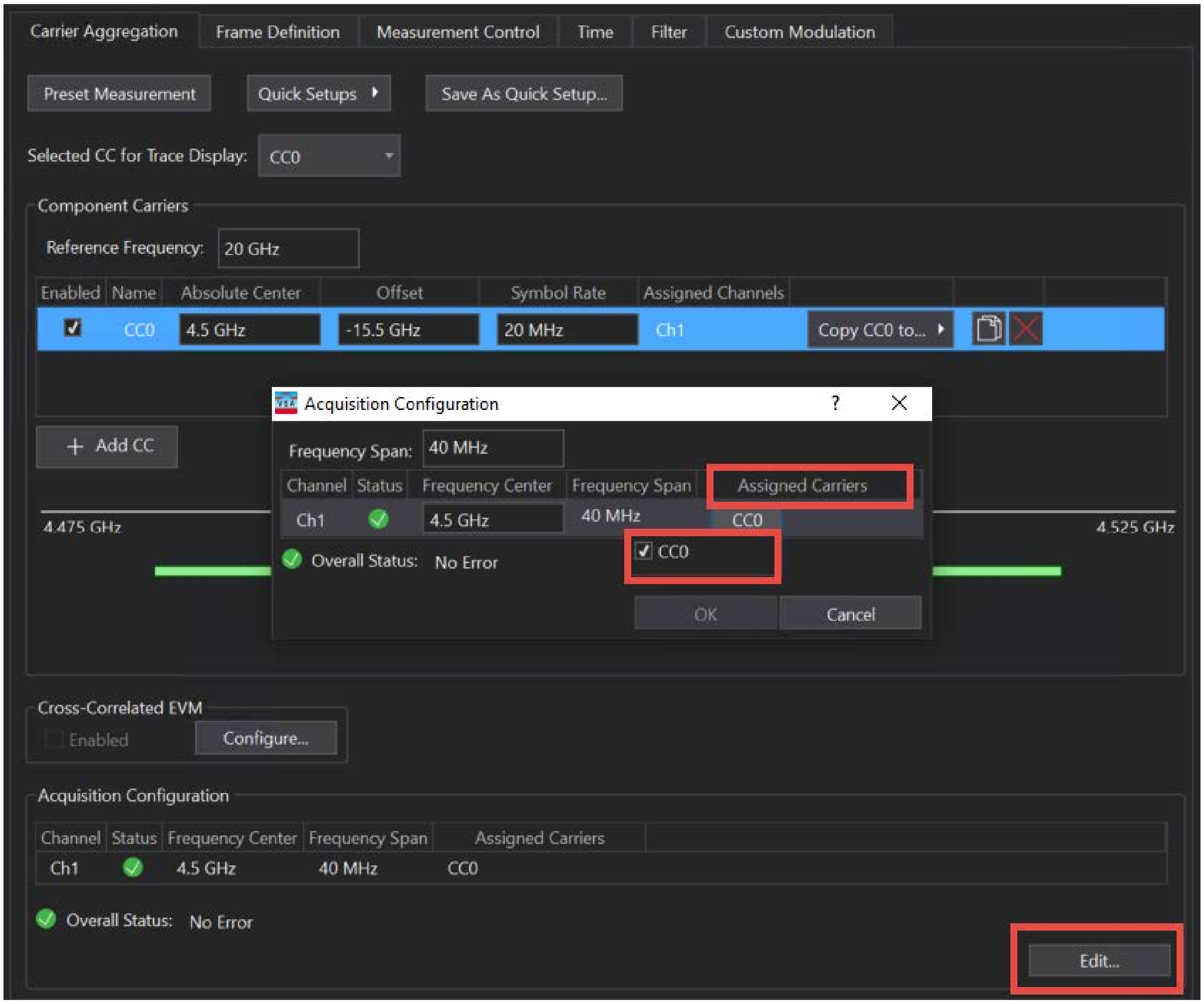
– **Autorange**


Flex Frame - Keysight PathWave Vector Signal Analysis (89600 VSA)
Auto-Range
Trace layout Grid 2x3
Freq = 4.5 GHz
Span = 40 MHz
NOTE: The low-resolution spectrum will get adjusted automatically when the correct Symbol rate is set in the next step
Previous Layout
Single
Stack 2
Stack 3
Stack 4
Stack 6
Grid 2x2
Grid 2x3
Grid 3x2
Custom...
Tile Visible
Center 4.5 GHz
Span 40 MHz
Measurement running
CAL: OK

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



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



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

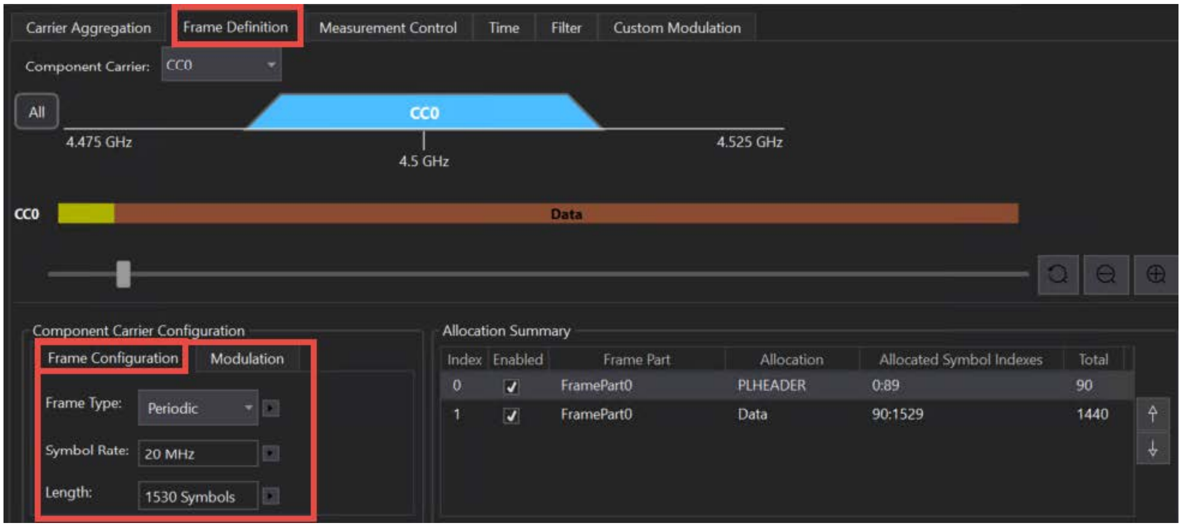
– Frame Type to **Periodic**

– 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**

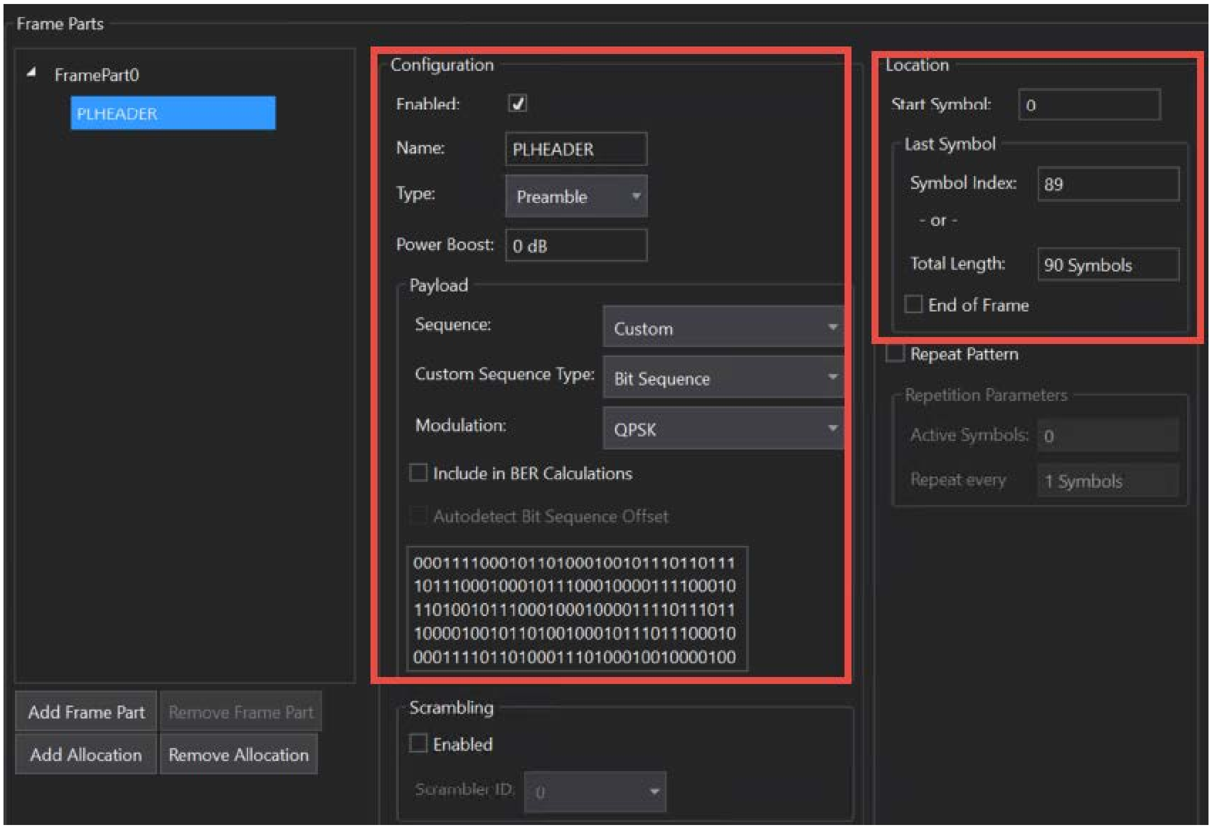
     – Enter the 180 symbols you copied over from the Custom Modulation PLHEADER Payload setup in step 11.

   – In the Location area,

     – Clear the End of Frame checkbox

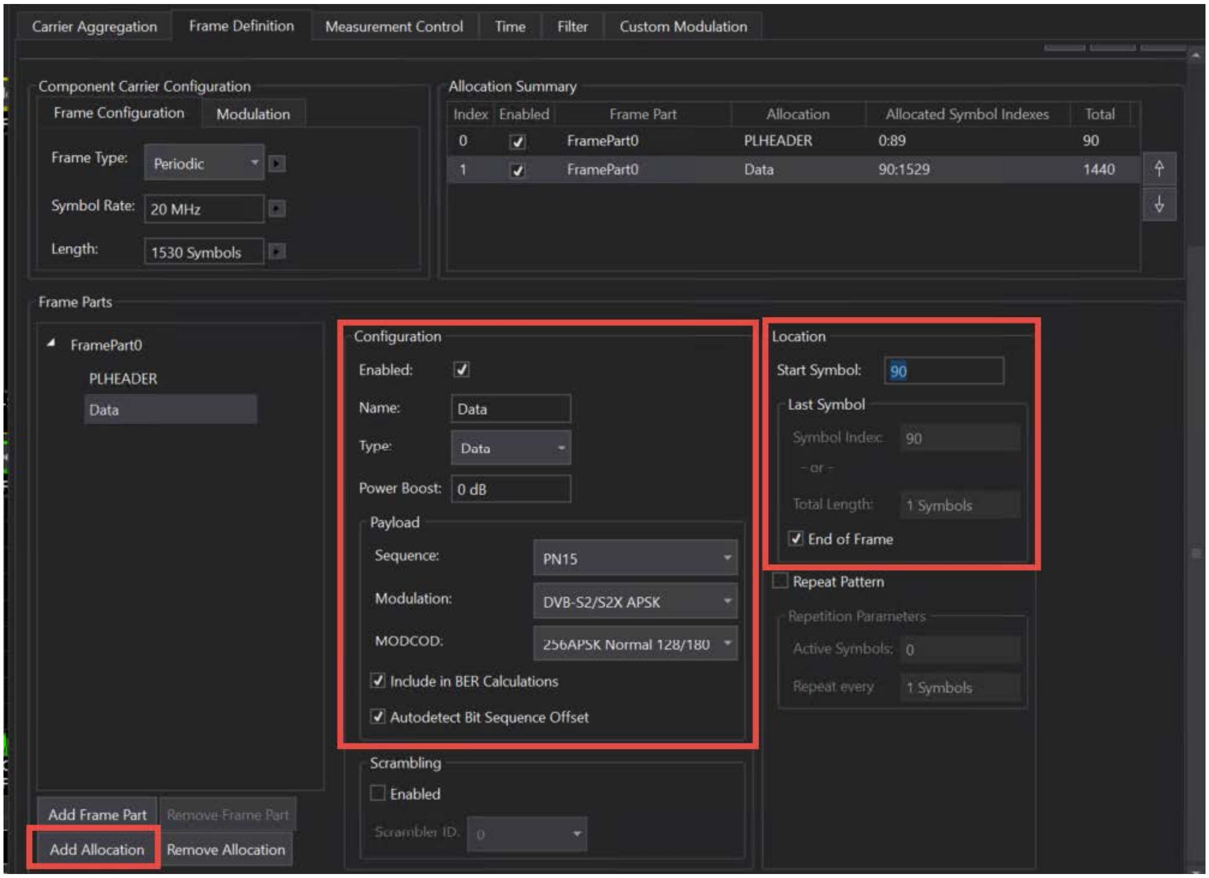
     – Start Symbol to **0**

– Total Length to **90**



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**



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

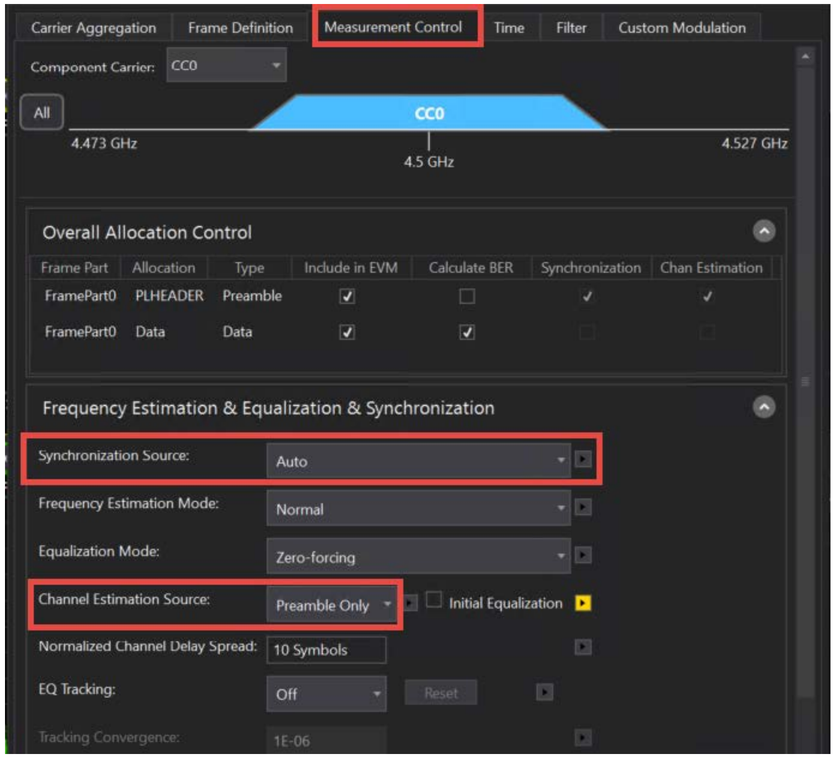
10. Select the **Measurement Control** tab, and set:

– 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**

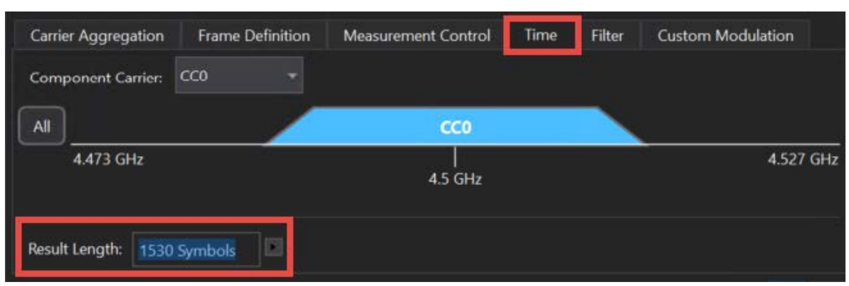
Equalization is off by default. You can choose the different frame parts for channel estimation and equalization.



Configure the Analysis Region

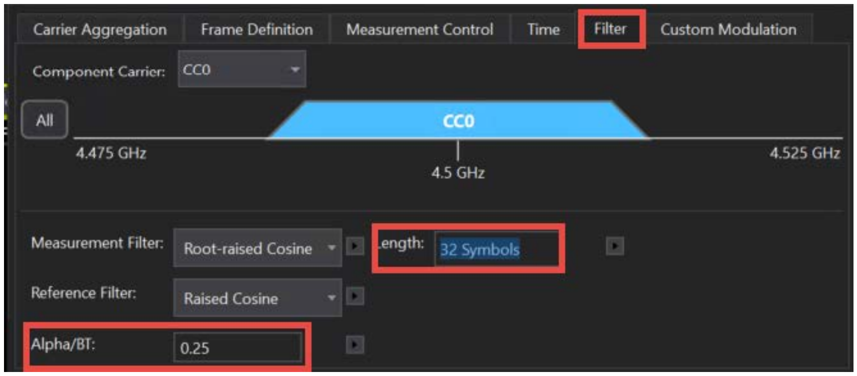
11. Select the **Time** tab, set the Result Length to **1530 Symbols**.

90 for the preamble plus 1440 for the data.



Configure the RRC filter

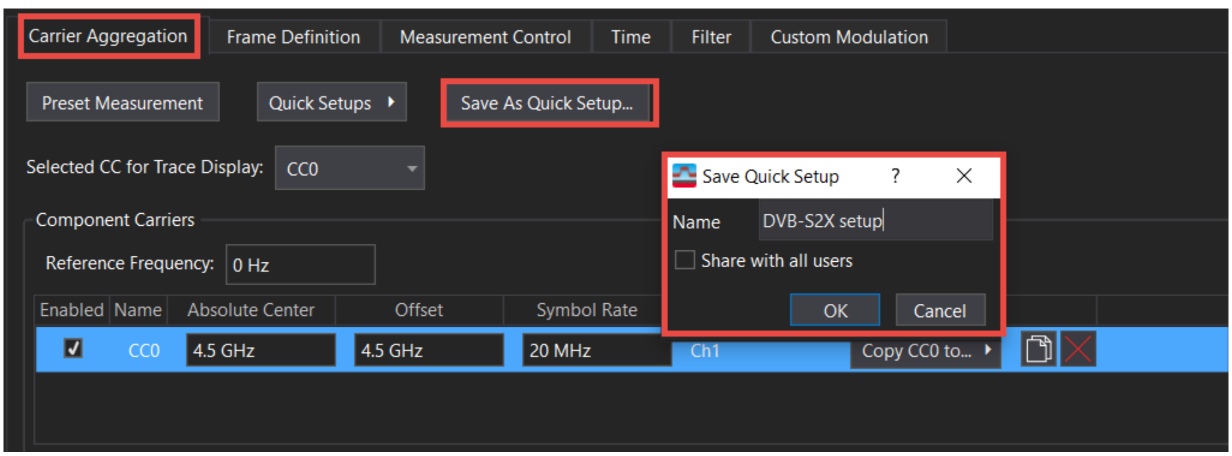
12. In the **Filter** tab, set Alpha/BT: to **0.25** and Length to **32 Symbols**.



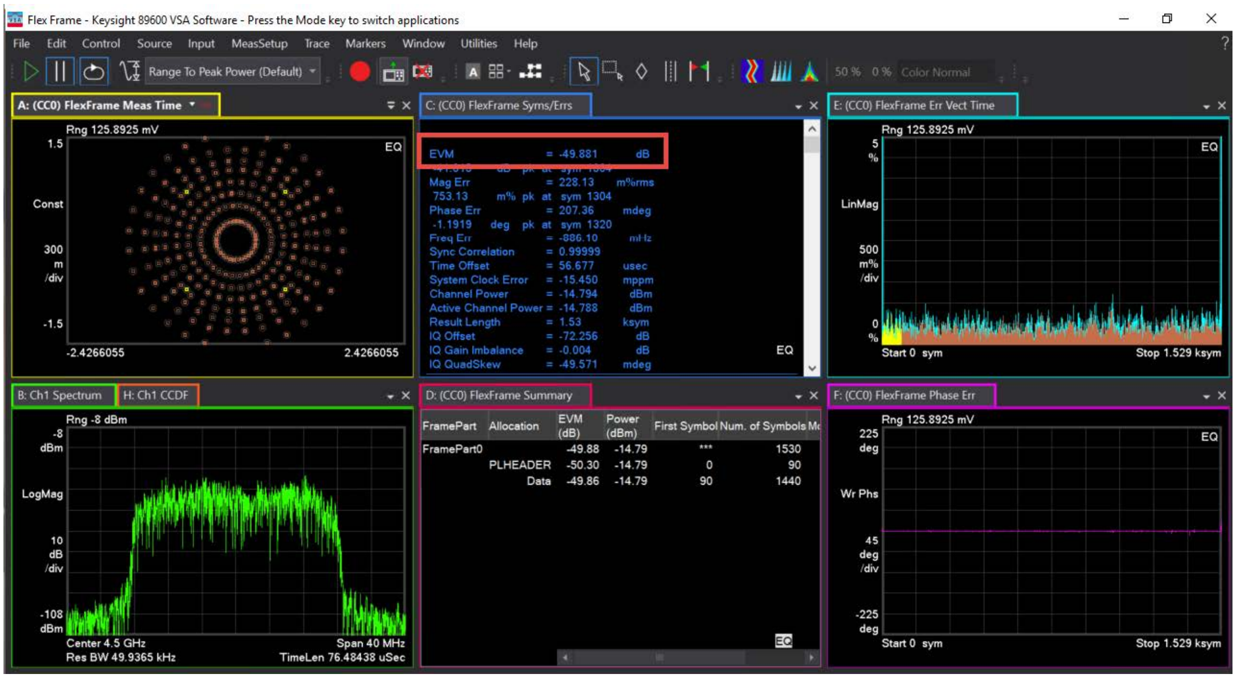
Save the Configuration as a Quick Setup

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.

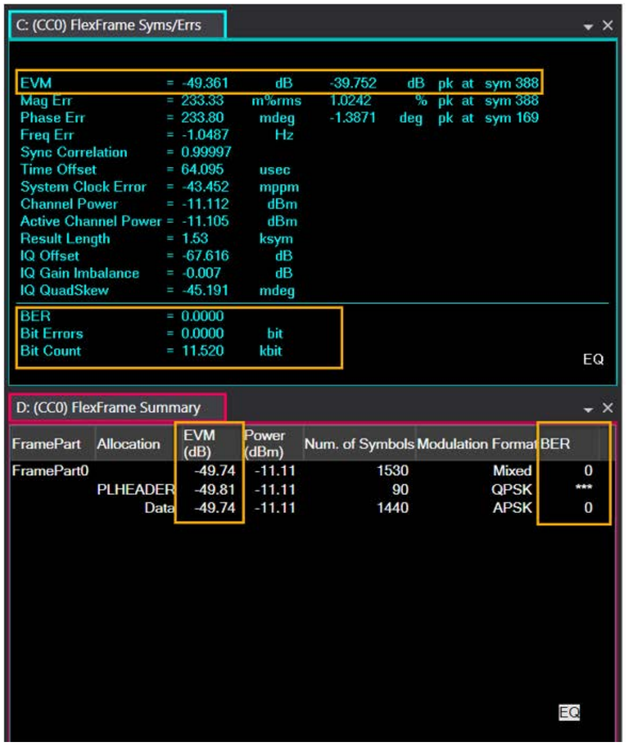


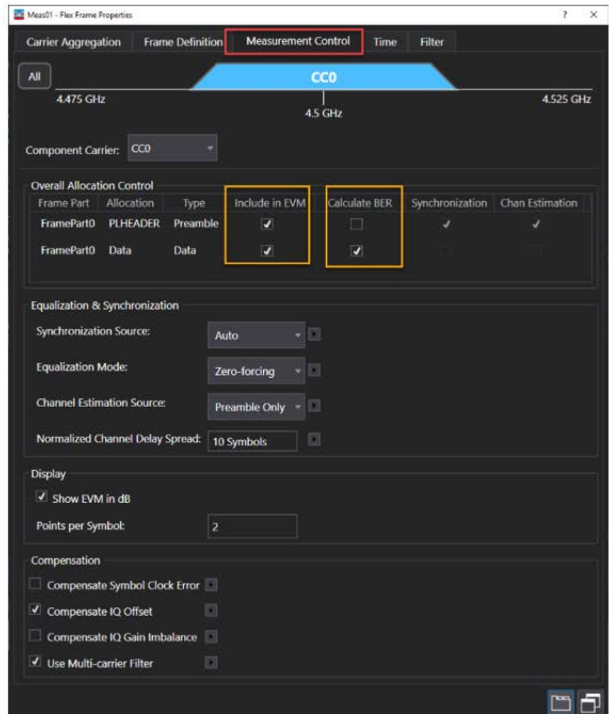
14. Close the Properties window and change Trace A to a Constellation Diagram, then view the results.



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.

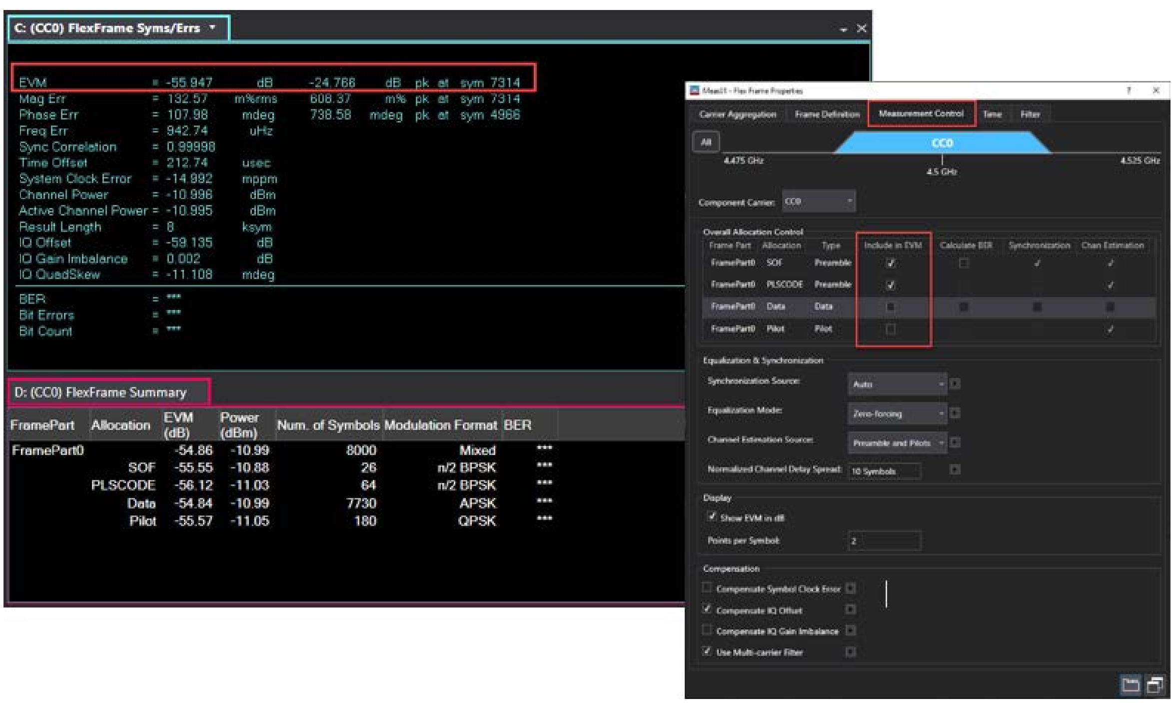




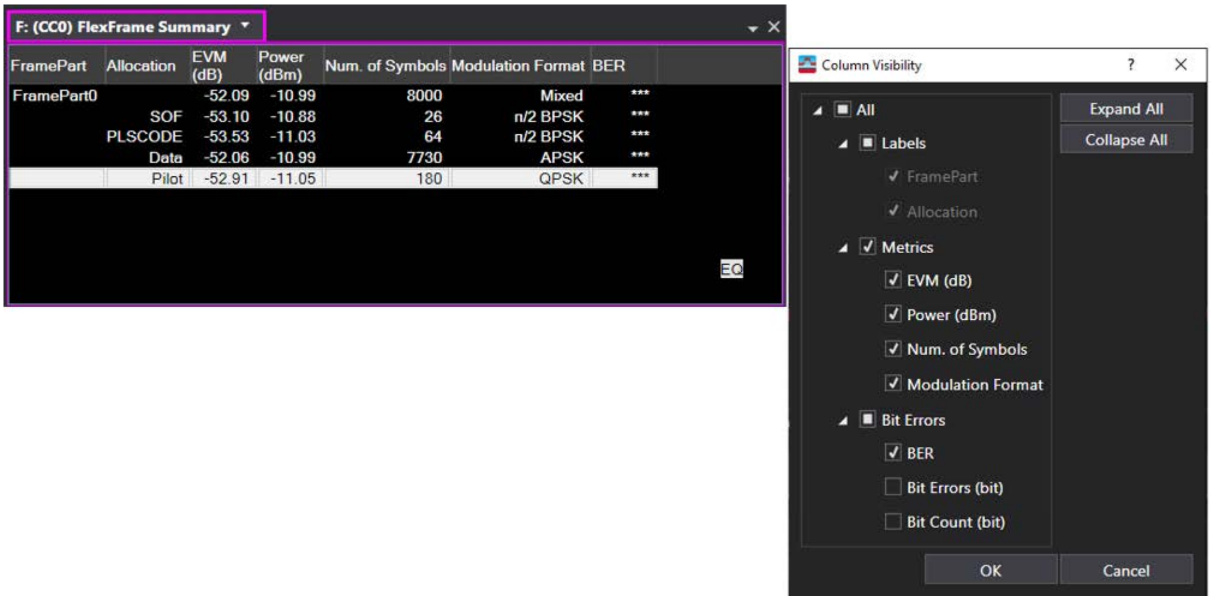
TxBER/RawBER is returned for the Data segment. NOTE: BER is supported if the allocation's payload sequence is either a PN type or a Custom bit sequence. Reference and measured bits are returned.

- 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).

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.



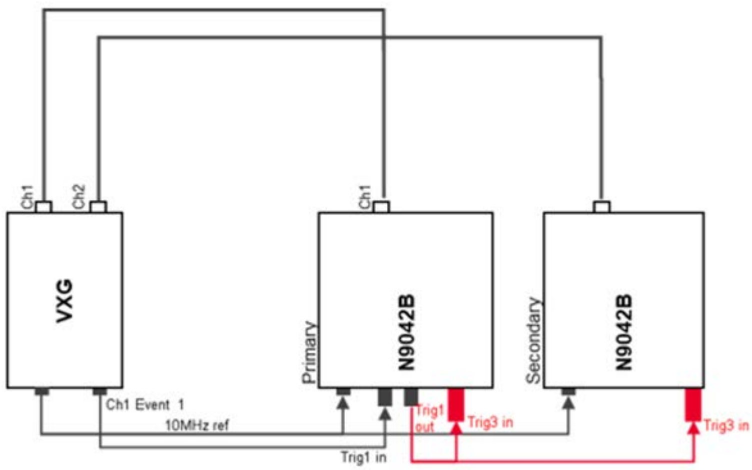
FlexFrame Summary table is a type of Matrix Table that provides sortable rows by column, selectable column visibility, and copy/paste and export functionality to share rows of content or complete tables to applications like email, text editing or spreadsheet programs. Right click the column header to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



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.

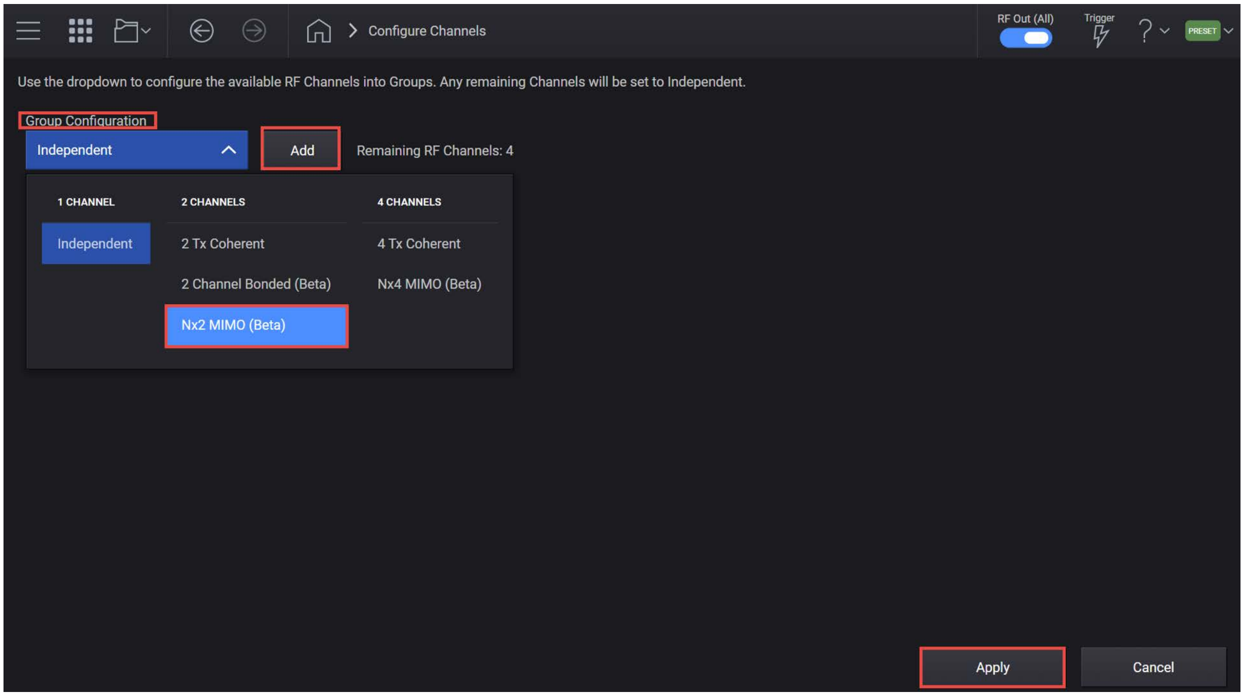
The hardware setup includes a 2-channel VXG and two N9042B UXAs.



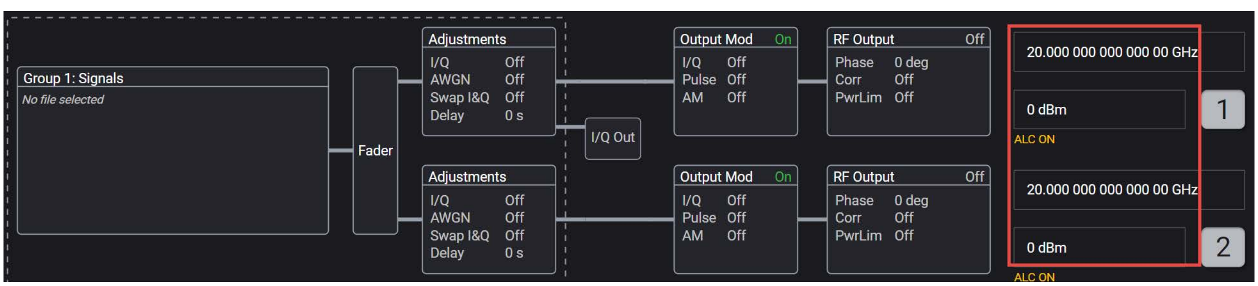
M9484C VXG	N9042B UXA
Required Options – RF bandwidth of 160 MHz or above – Two-channel configuration	Required Options – UXA 1 N9042MMOB Multi-box Synchronization for MIMO, Analysis Bandwidth of 160 MHz or above – UXA 2 Analysis Bandwidth of 160 MHz or above
Required Software – M9484C Firmware version A.11.01 or higher – 7631APPC PathWave Signal Generation for 5G NR	Recommended Software – 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

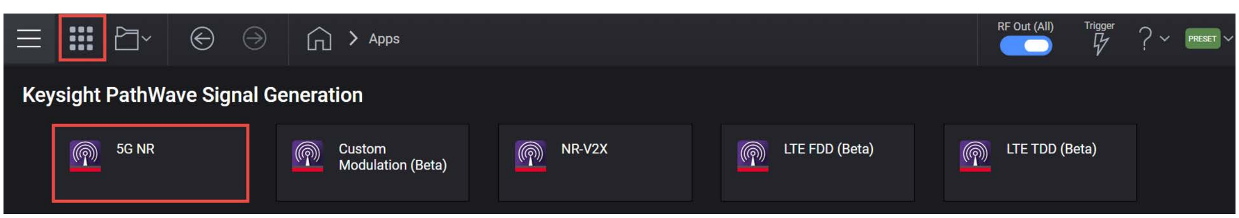
1. Connect the equipment as shown above.
2. Select **Preset** > **Preset** to set the VXG to a known state.
3. Select the System menu (triple bar icon at the top left of the window), and then select **Configure Channels** > **Nx2 <MIMO** > **Add** > **Apply** > **Apply**.



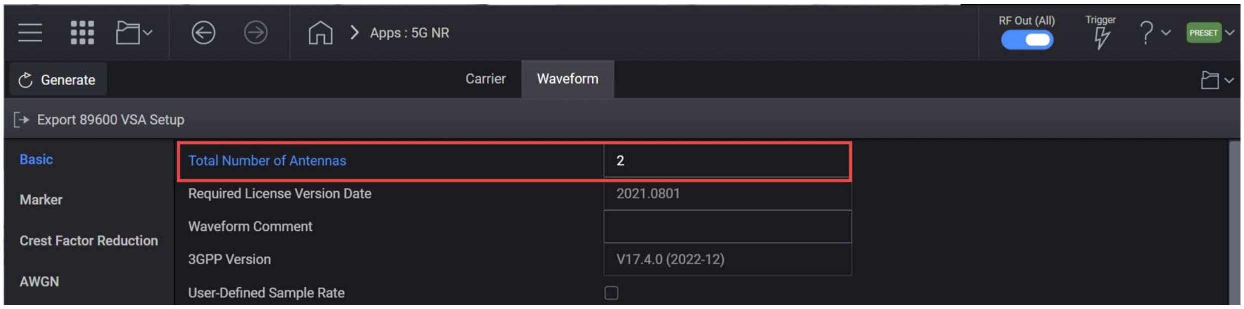
4. Set the Frequency to **20 GHz** and Power to **0 dBm**.



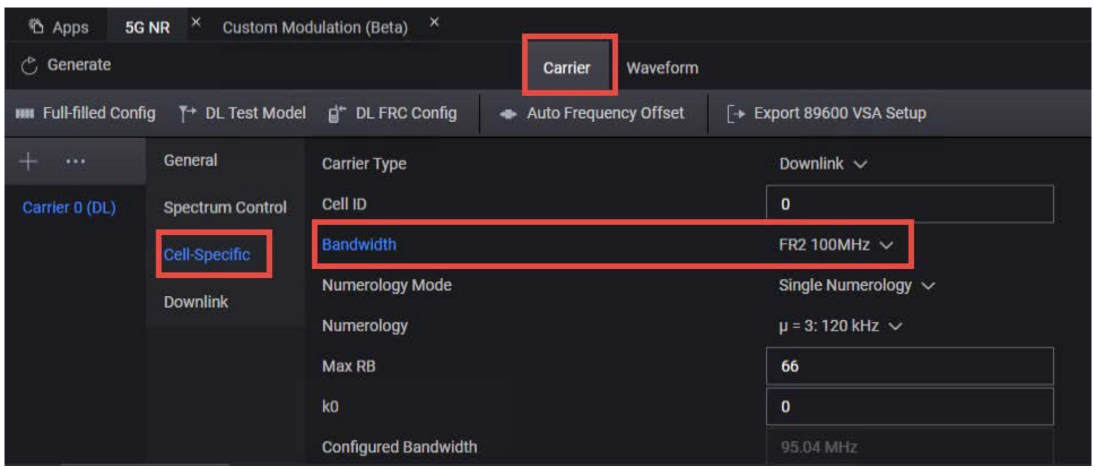
5. Select the **Apps** block to open, then select **5G NR**.



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

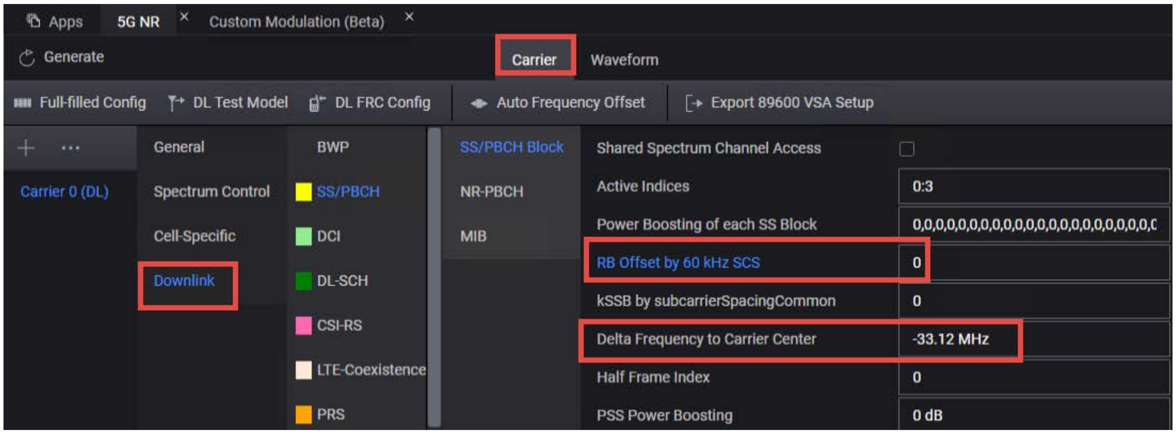


7. Select the **Carriers** tab > **Cell Specific** node, and set Bandwidth to **FR2 100 MHz.** Keep the rest of the default settings.



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

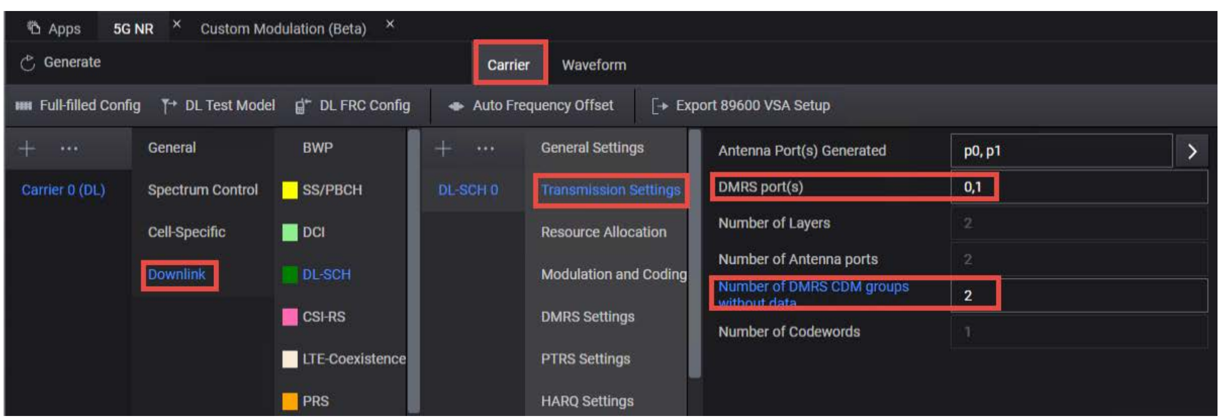
This automatically changes the Delta Frequency to Carrier Center to -33.12 MHz. Using 0 RB Offset puts the SSB at the lower edge of the carrier.



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**.

   Number of DMRS CDM groups without data is used to determine how many resource elements are reserved for DMRS. When this parameter is changed, the DMRS power boosting is automatically coupled based on table 4.1-1 of 38.214.

   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).



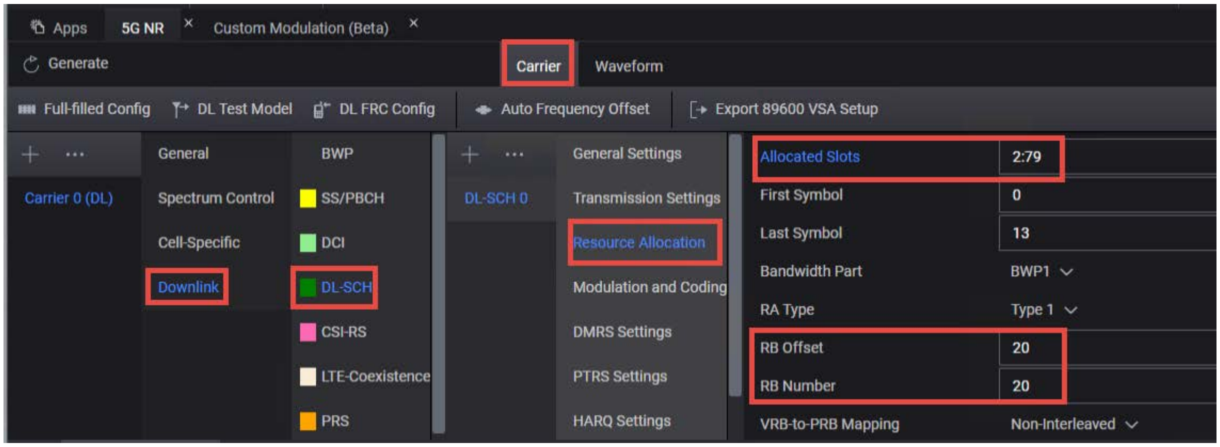
10. Select the **Resource Allocation** node and set:

   – 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.

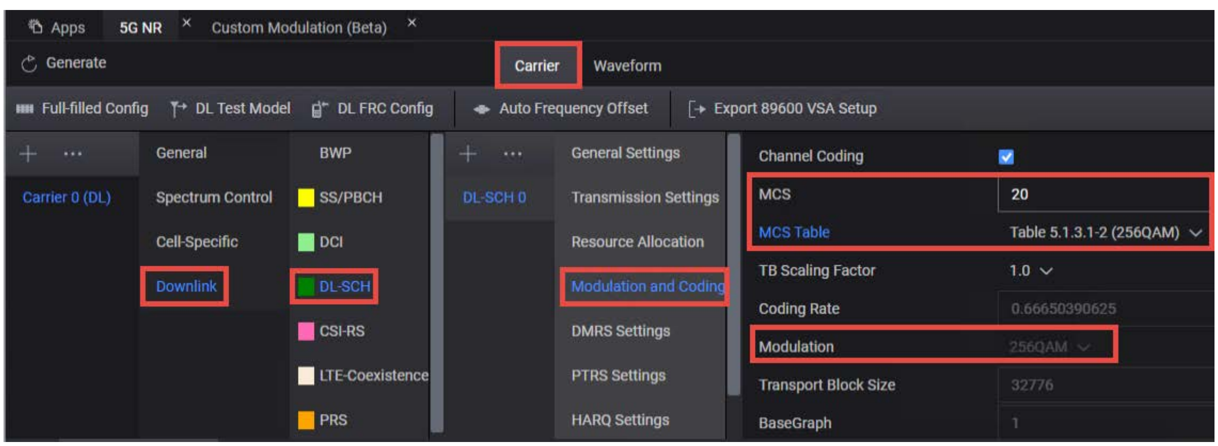


11. Select the **Modulation and Coding** node and set:

   – MCS to **20**

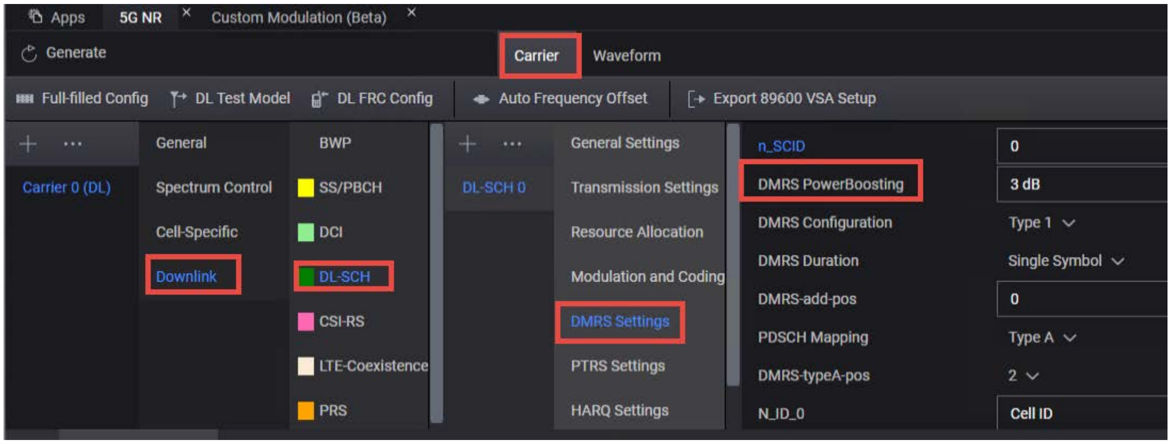
   – MCS Table to **5.1.3.1-2 (256 QAM)**

   Notice that modulation is updated to 256 QAM.

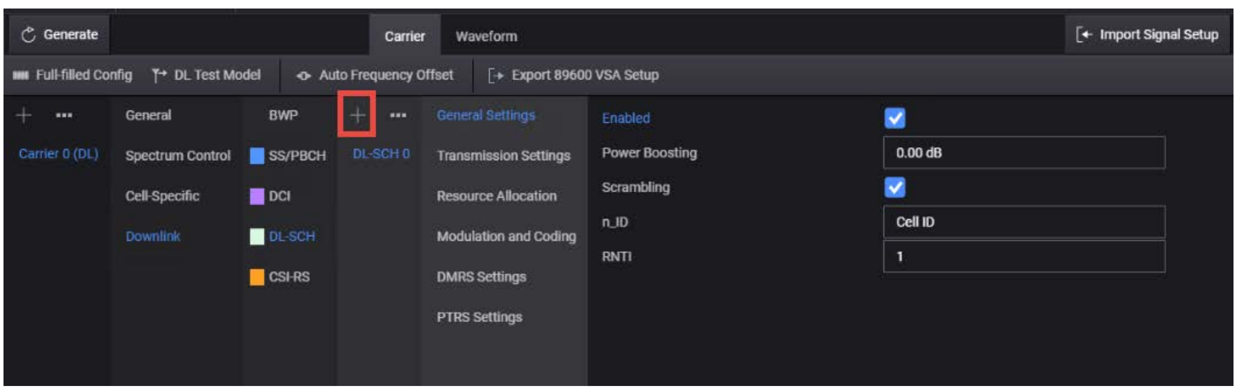


12. Select the **DMRS Settings** node and set DMRS Power Boosting to **3 dB**.

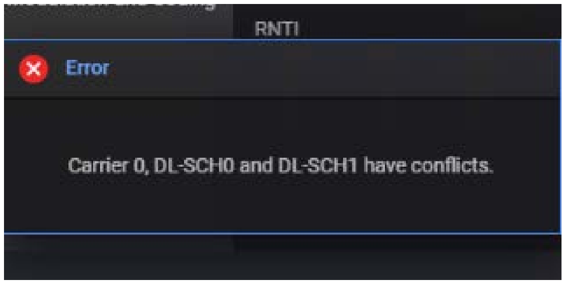
When CDM Group Number is 2, DMRS power boosting becomes 3 dB per 3GPP.

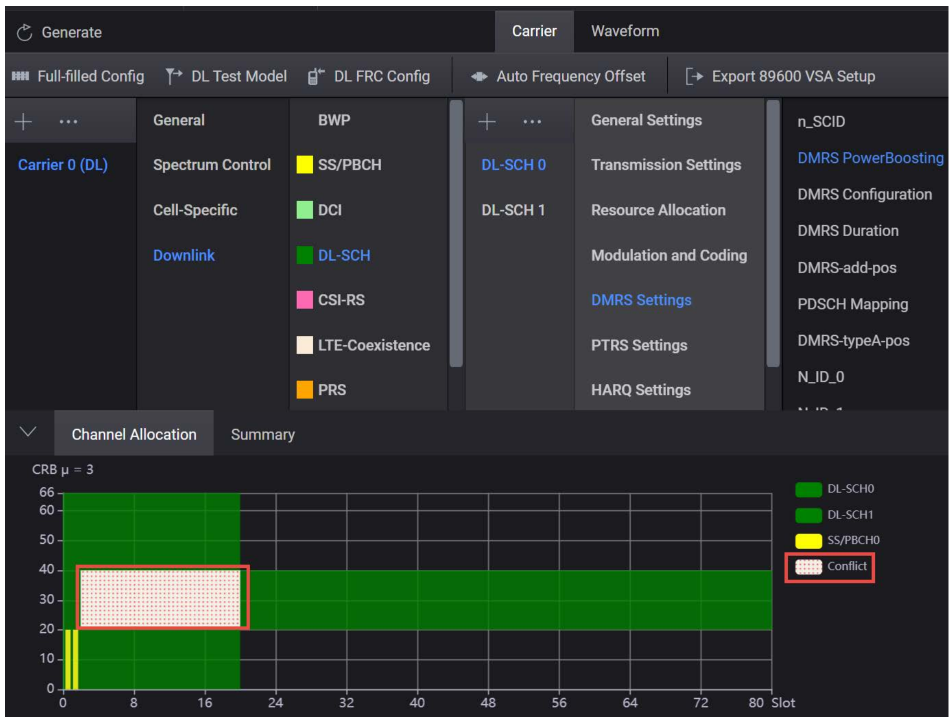


13. Under the DL-SCH 0 node, select the + icon to add a new **+DL-SCH** (DL-SCH1).



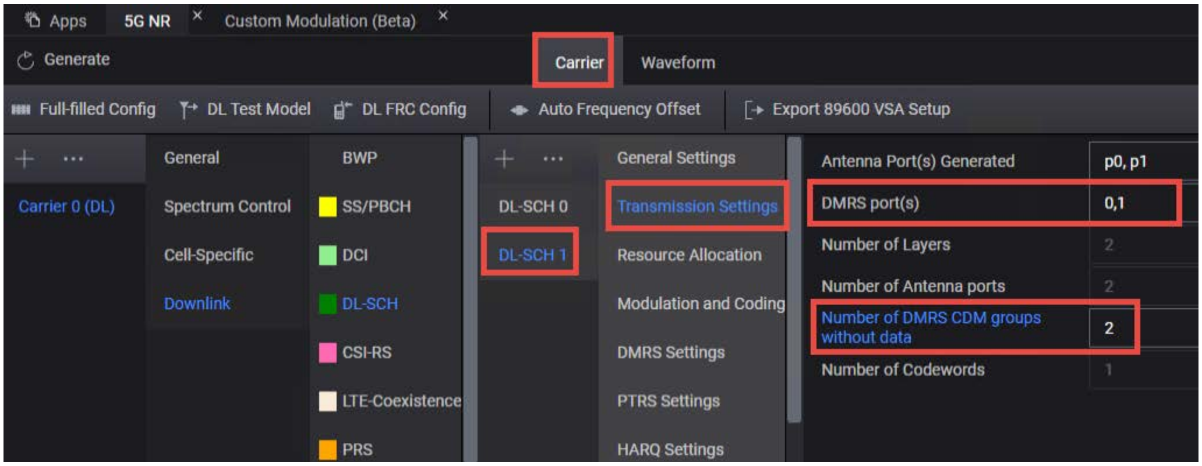
NOTE This will create a conflict between DL-SCH0 and DL-SCH1. This will be resolved in a later step.





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.**

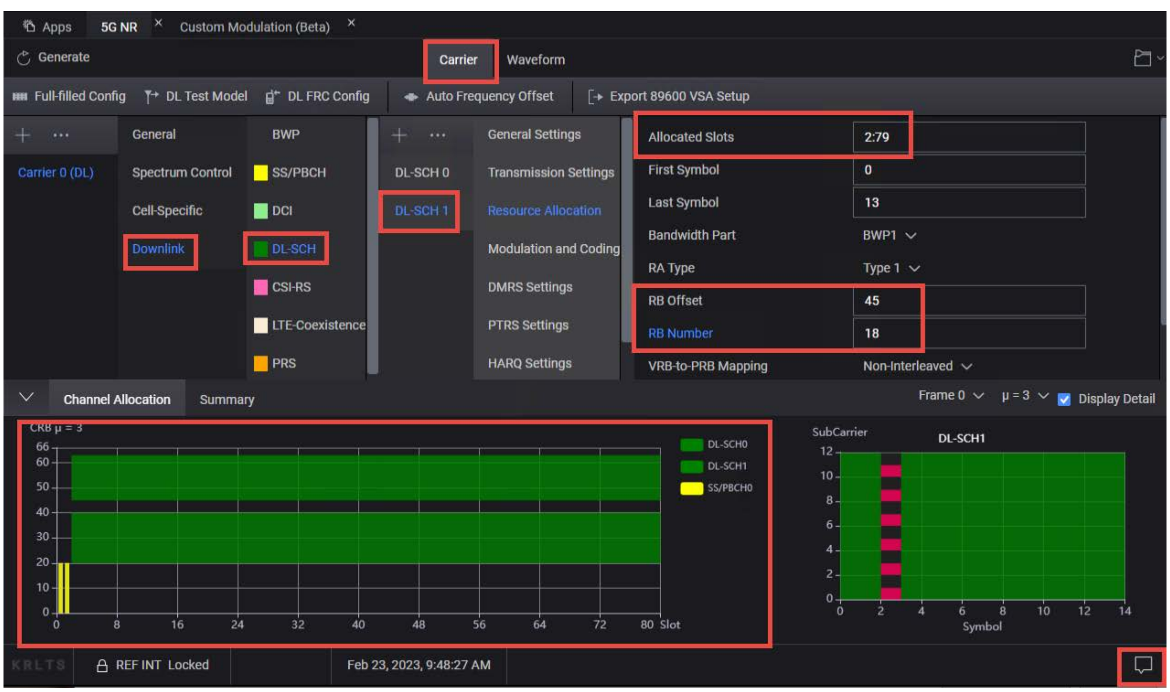
Notice that Number of Layers is updated to 2 and each layer is assigned with a particular DMRS port. Antenna Ports Generated is automatically assigned P0,P1, which will map generated multiple antenna port signals to different antennas (instruments).



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

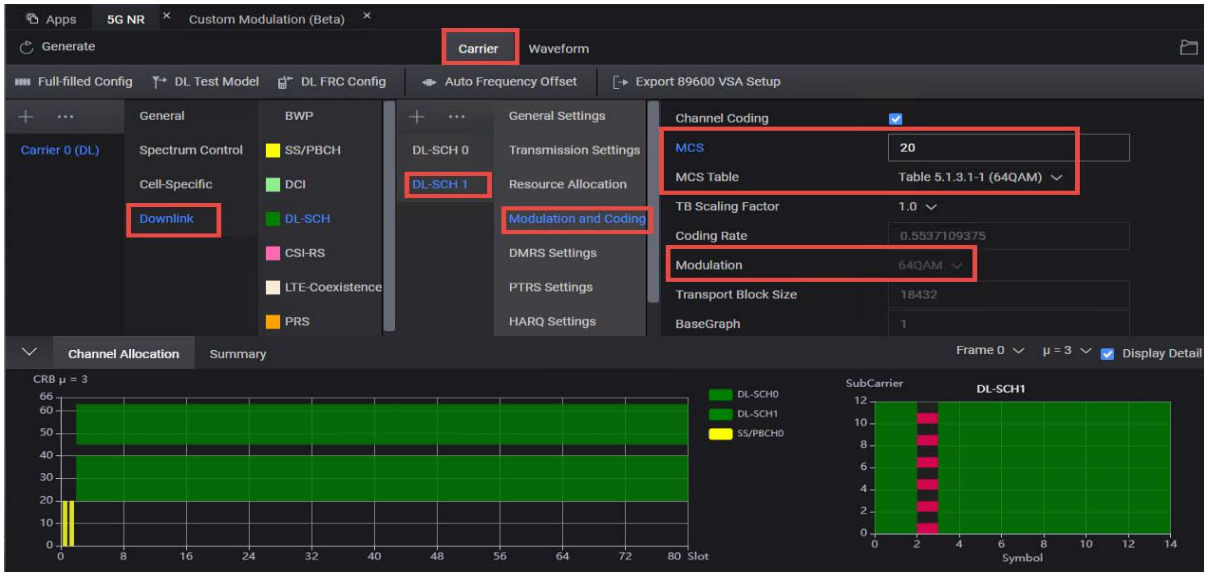
- Allocated Slots to **2:79**
- RB Offset to **45**
- RB Number to **18**

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.

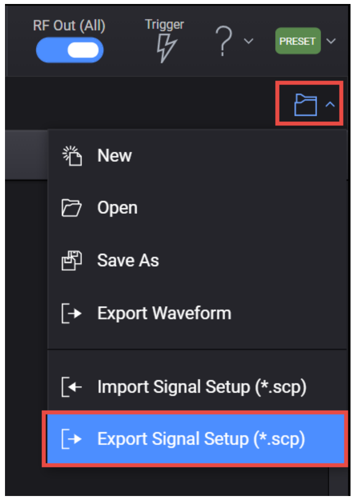


17. Select the **Waveform** tab > Select **Generate**.

View the waveform by selecting Spectrum on the bottom display.

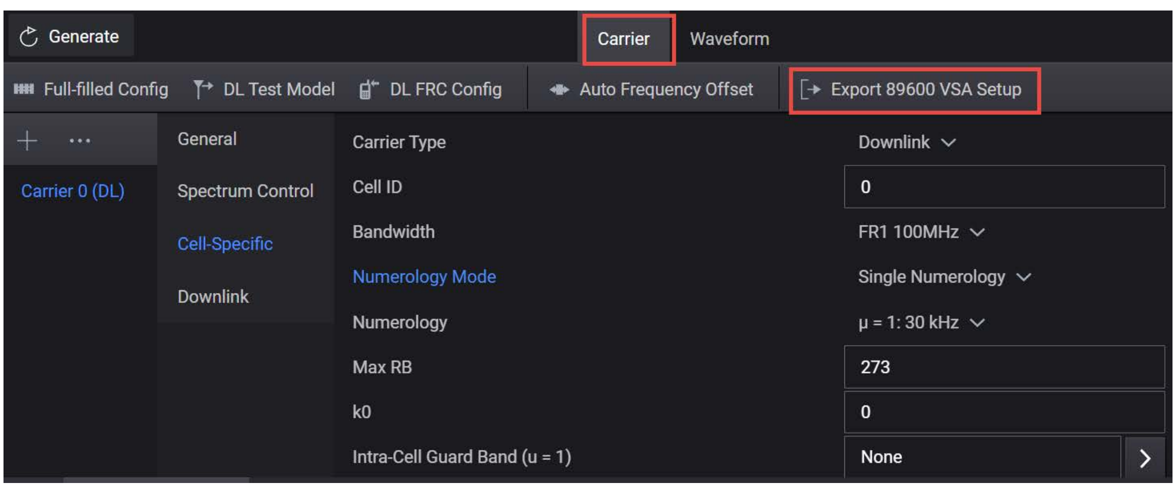
18. Select the **File** icon on the top right and select Export Signal Setup (*.scp), and save the file.

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

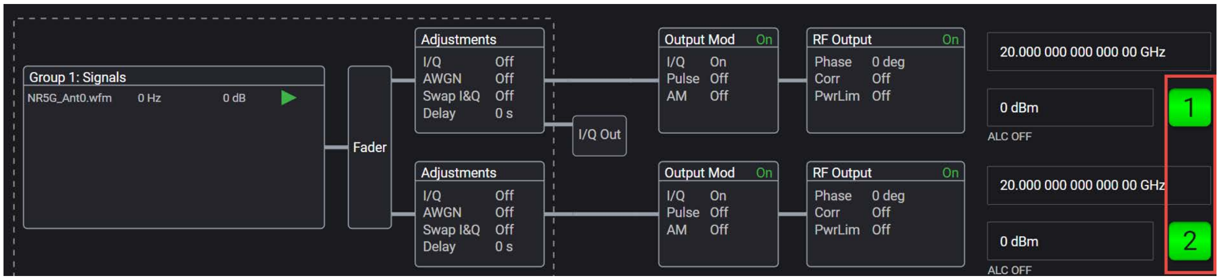


19. Select the **Carrier** tab and select **Export 89600 VSA Setup** and save the file.

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.

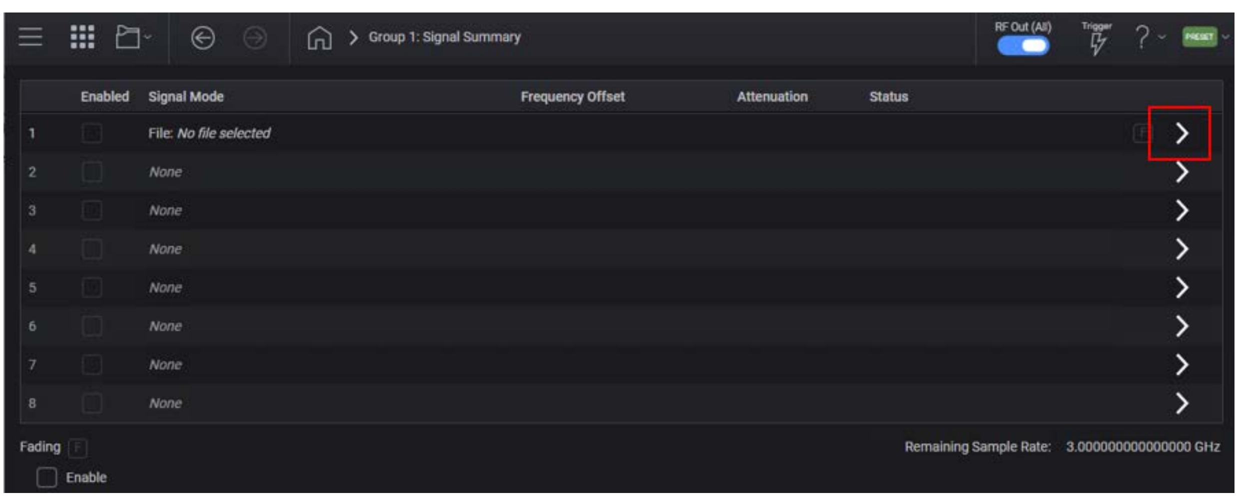


21. Select the **Signal** block to open.

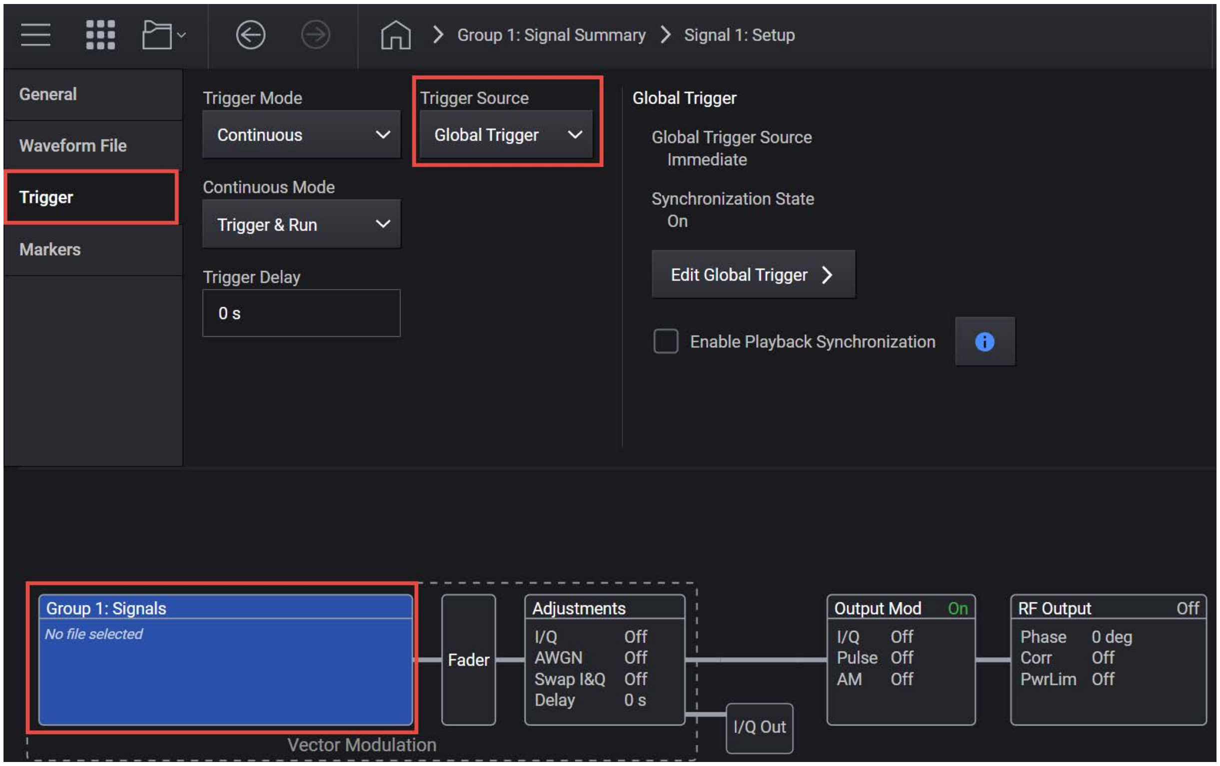
22. Select the arrow for Signal 1 to open the Signal Setup window.

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.



23. Select the **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.

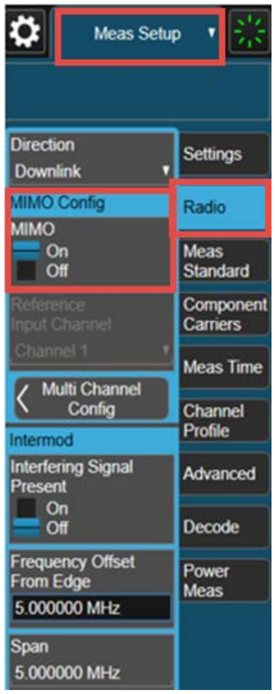
On the Primary UXA:

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.

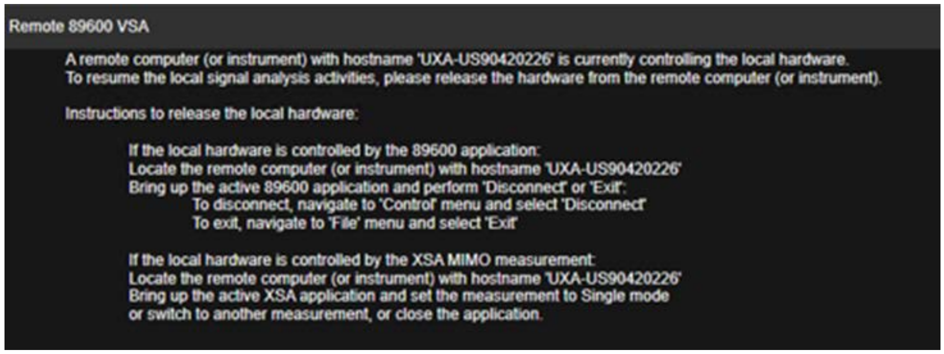
2. Select **Mode Preset** to set Spectrum Analyzer 5G NR mode to a known state.
3. From the N9042B Menu Panel (or the Screen tab), select **Mode/Meas** > **5G NR & V2X** Mode > **Modulation Analysis** Measurement > **OK**.

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



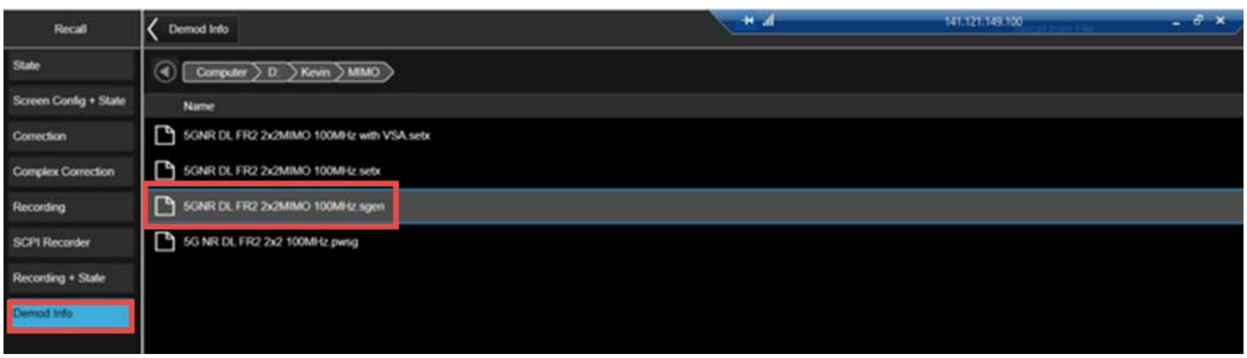
5. Select **Multi Channel Config** to open the Configuration dialog box.
   – Set Channel 1 IP Address to **Local**
   – Enter the IP address for Channel 2
   – Select **Locked** for both Channel 1 and Channel 2

Once MIMO mode is ON and both channels are locked, the secondary N9042B display changes as shown below.

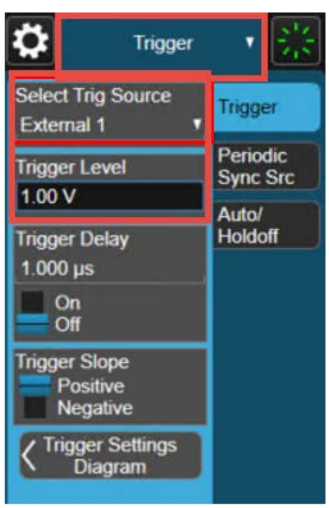


6. Select **Recall** (If accessing the signal analyzer remotely, select the Folder icon at the bottom of the display) > **Demod Info** > set Data Type to **CC Setup** > **Recall From** > and **Recall** the setup file.

   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**.

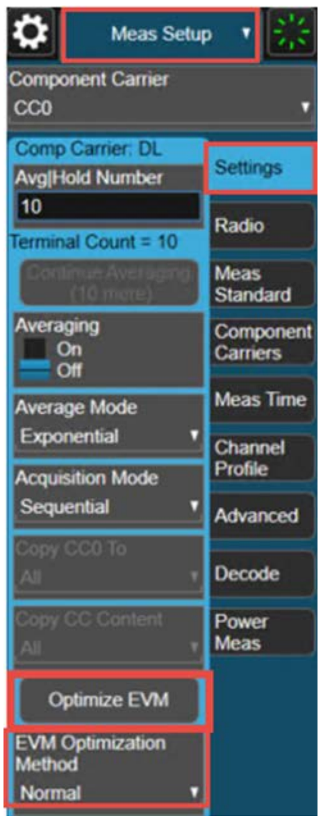


8. Select **Meas Setup** > **Settings** tab> **Optimize EVM**.

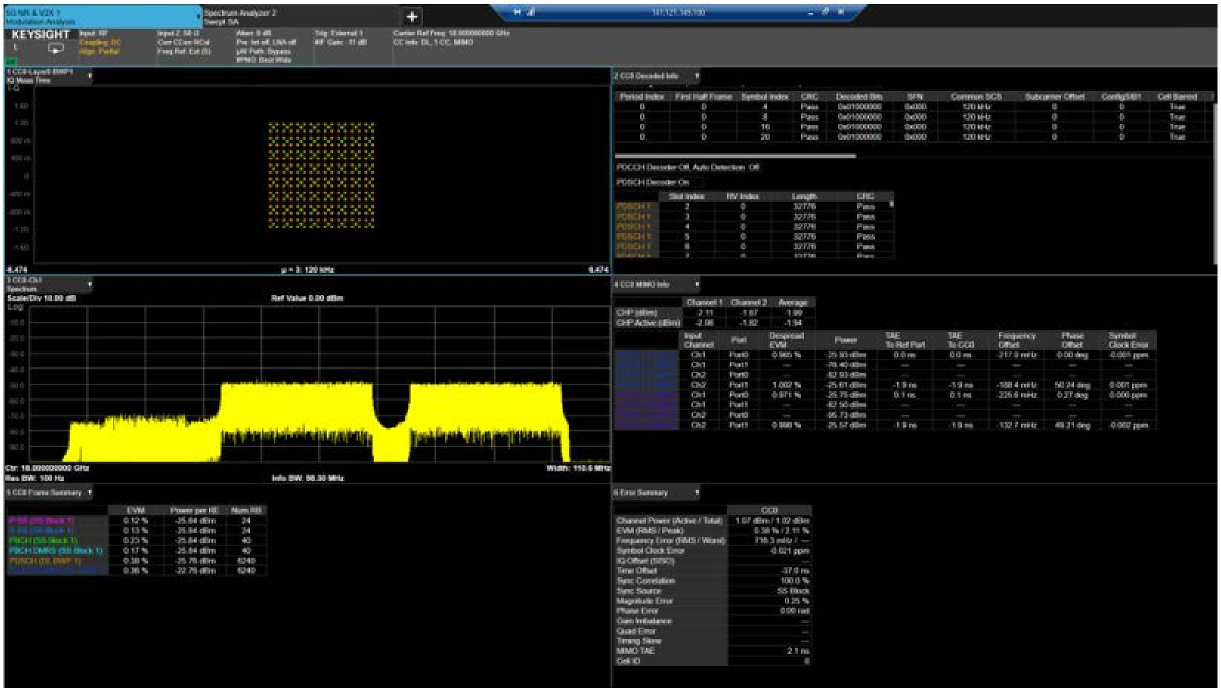
Optimize EVM is an immediate action to adjust the hardware settings to minimize EVM.

- 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).



View the results.



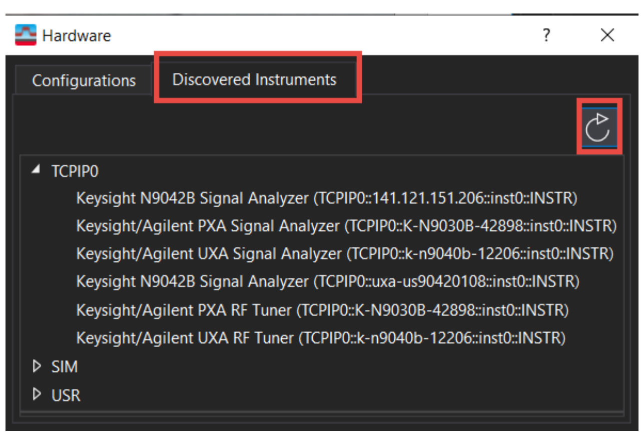
Demodulate the 5G NR 2x2 MIMO Using VSA:

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

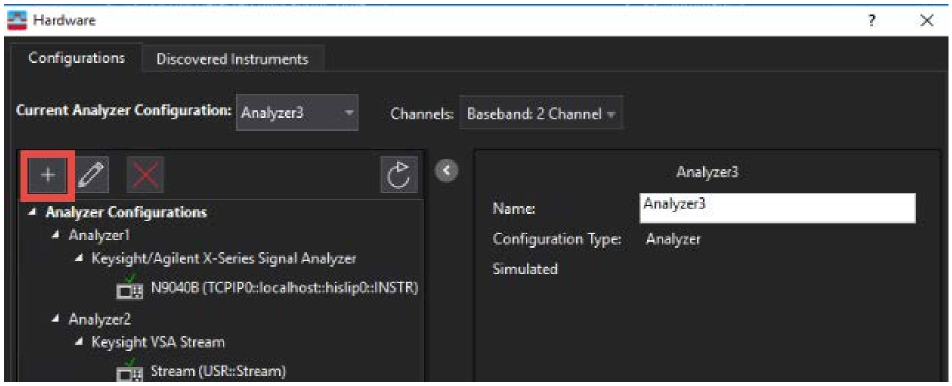
NOTE

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**.

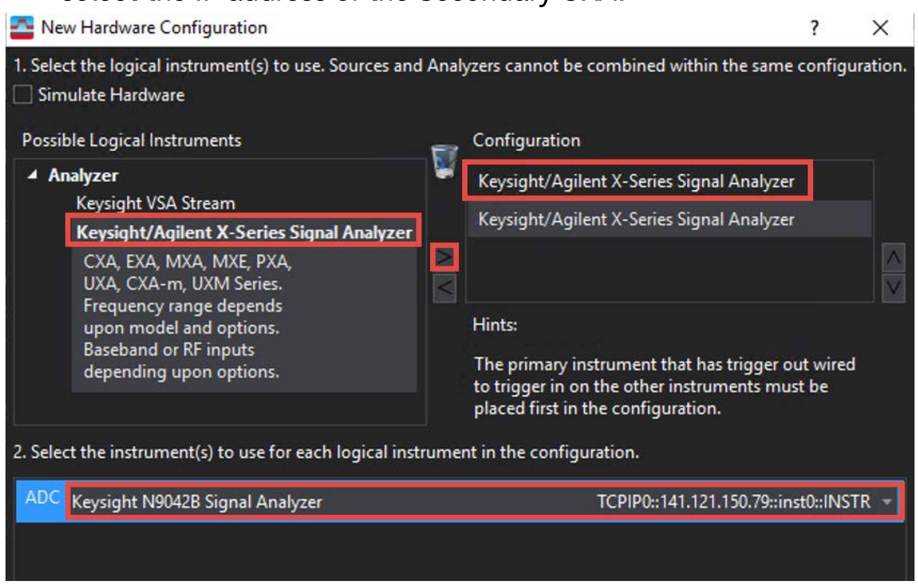


5. Scroll down the Possible Logical Instruments and select **Keysight/Agilent X-Series Signal Analyzer** twice.

   a. Select the first Keysight/Agilent X-Series Signal Analyzer and then press the right arrow to move it under the Configuration area.

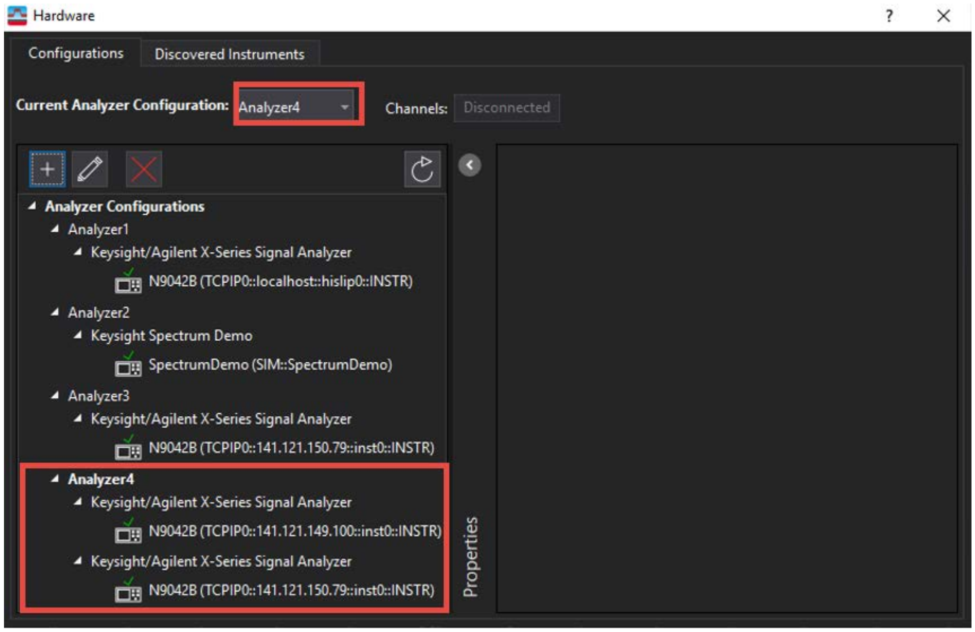
   b. From the middle of the dialog box, select the down arrow next to the Analyzer and select the IP address of the Primary UXA.

   c. Repeat the two steps above for the second signal analyzer but select the IP address of the Secondary UXA.

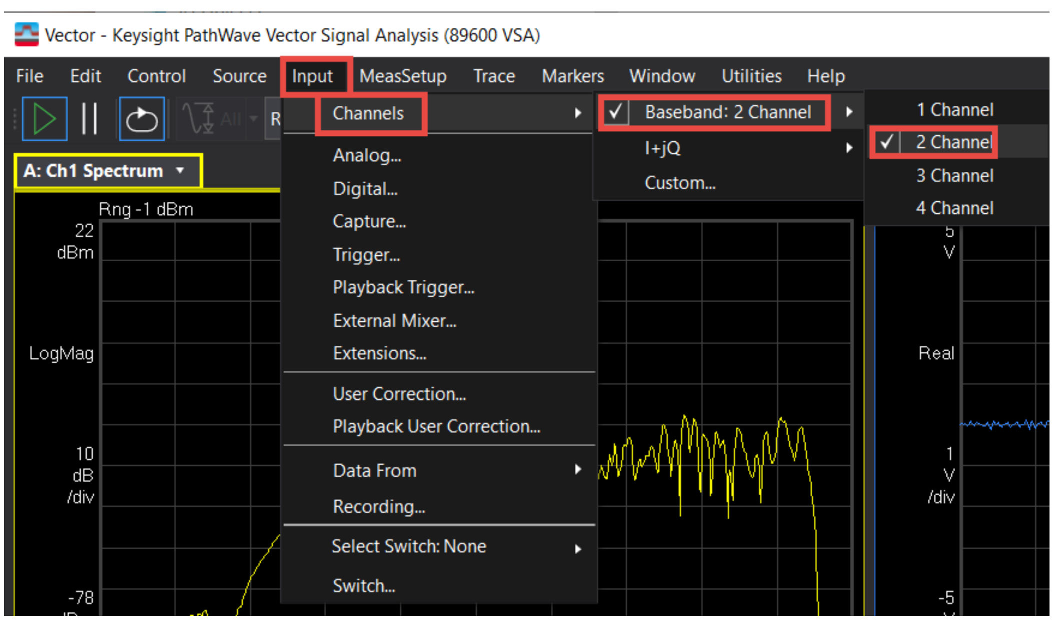


6. Select **OK** to create the new configuration.

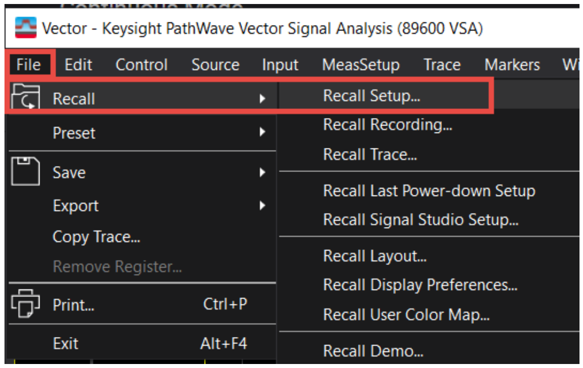
7. In the **Configurations** tab, set the Current Analyzer Configuration, select the Analyzer number for the new configuration. In this example **Analyzer 3**.



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



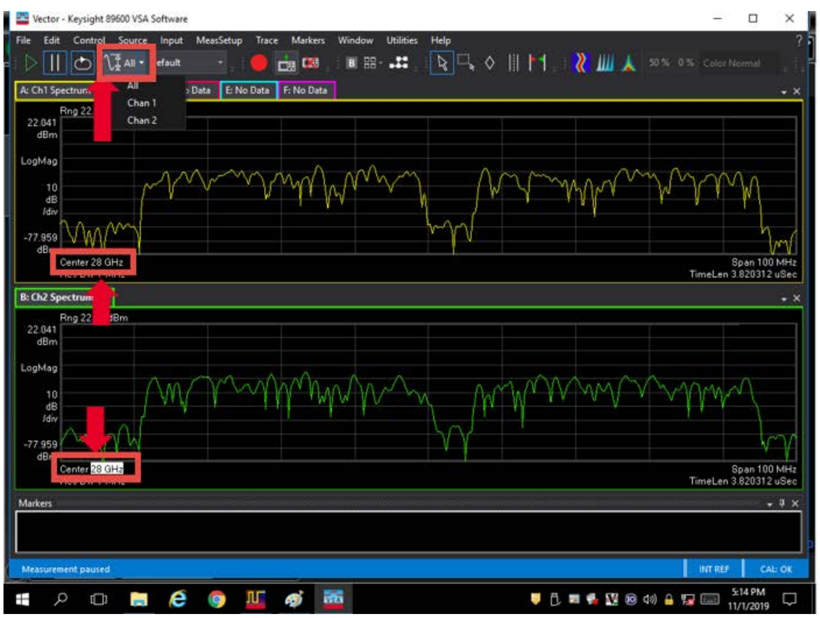
9. From the menu bar, select **File** > **Recall** > **Recall Setup** and navigate to the .setx file you save during the VXG waveform generation.

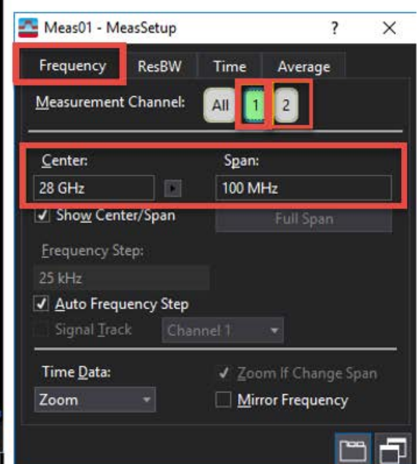


You can also set the frequency and span of both channels under Meas Setup > Frequency.

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.

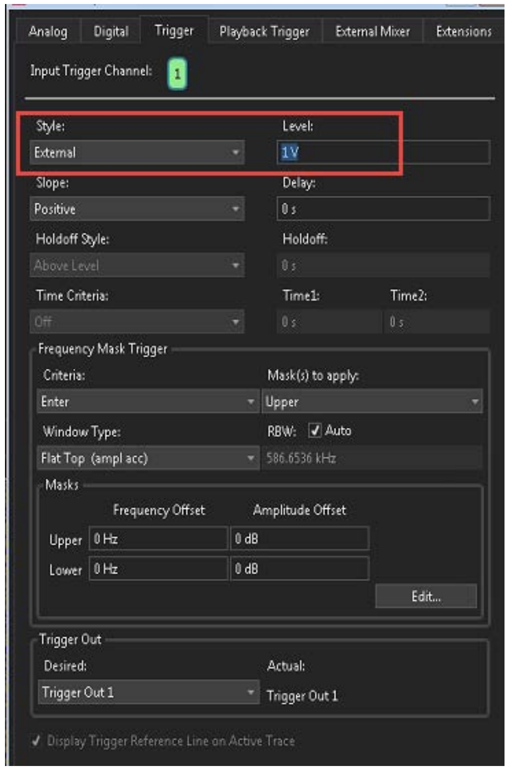




10. From the menu bar, select **Input** > **Trigger** and set:

– Style to **External**

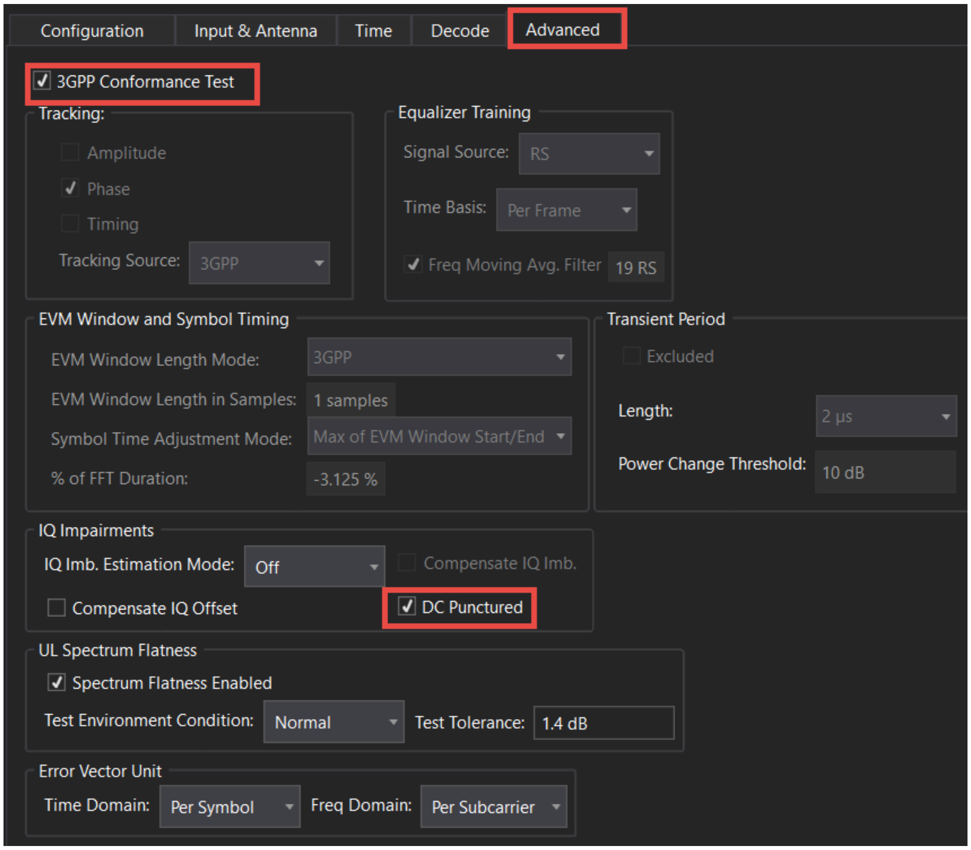
– Level to **1 V**



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.

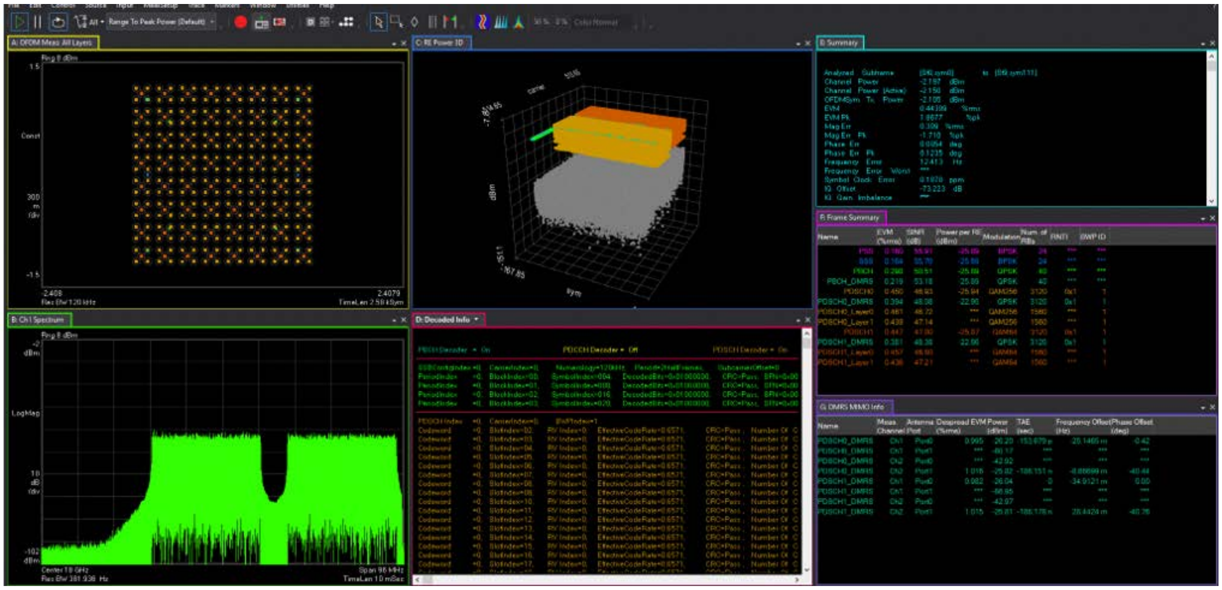


12. Close the 5G NR Properties dialog.

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

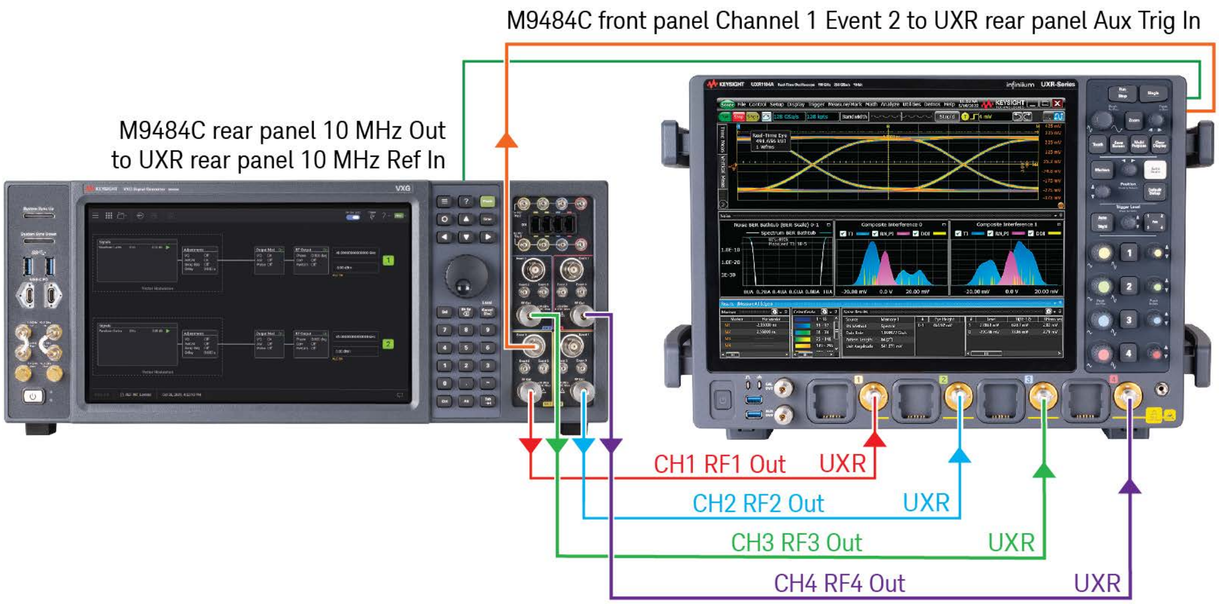
– EVM - Table or Algorithm Based performs EVM optimization based on prescribed table/algorithm instead of using EVM in the feedback loop. This method of EVM auto-range is normally faster than Meas Based Iteration, but may not achieve the most optimal setup for minimized EVM).

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



Creating and Analyzing a 4x4 MIMO using a UXR Running VSA Software

Equipment Setup

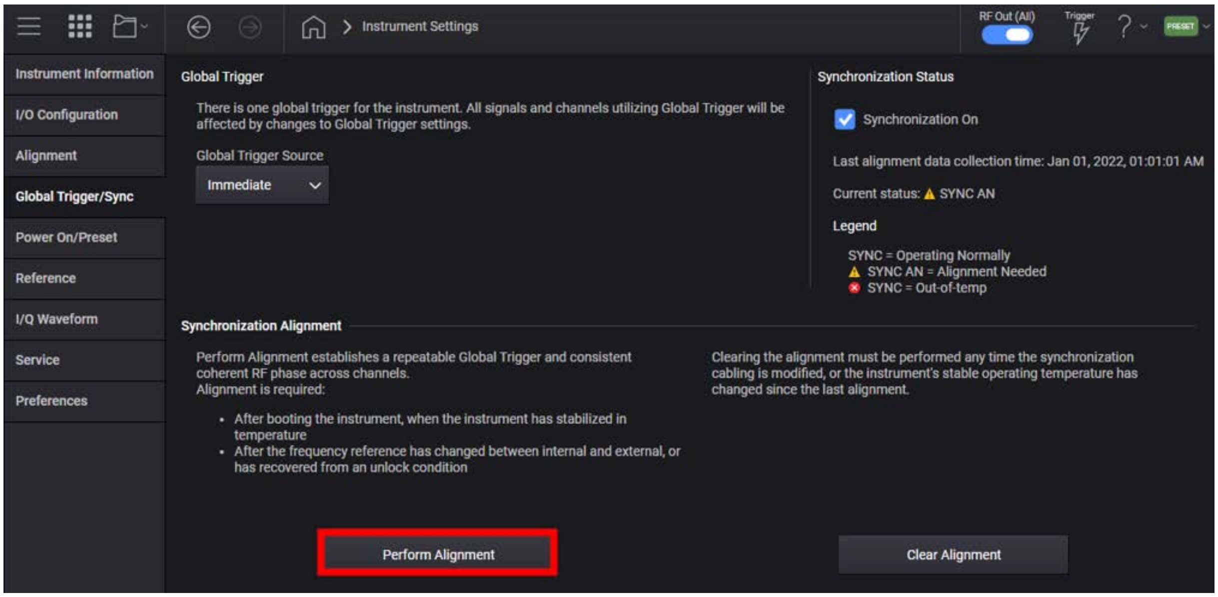


- M9484C
  - Four channels (M9484C-004)
  - N7631APPC PathWave Signal Generation for 5G NR
- UXR0334
  - UXR000-602: DDC option with 2 GHz BW
  - 89600 PathWave Vector Signal Analysis (VSA)

On the VXG:

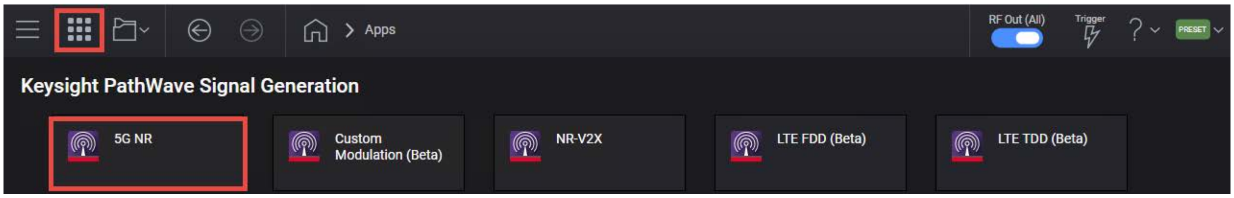
1. Connect the equipment as shown above.
2. Select **Preset** > **Preset** to set the VXG to a known state.

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

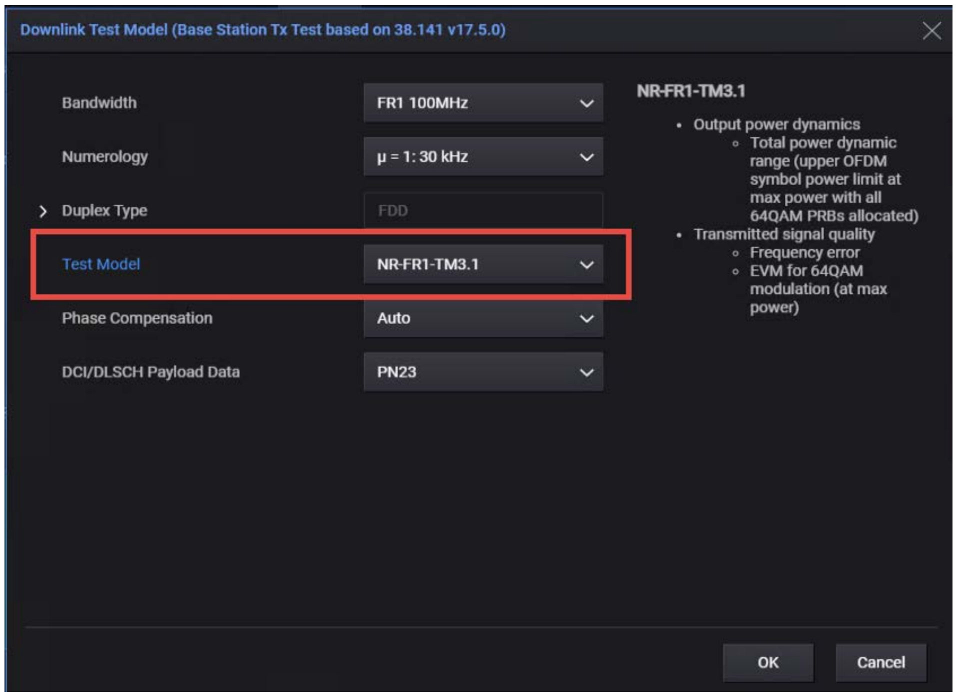


3. In the Output area for all four channels, set the Frequency to **5 GHz** and Power to **–10 dBm**.

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

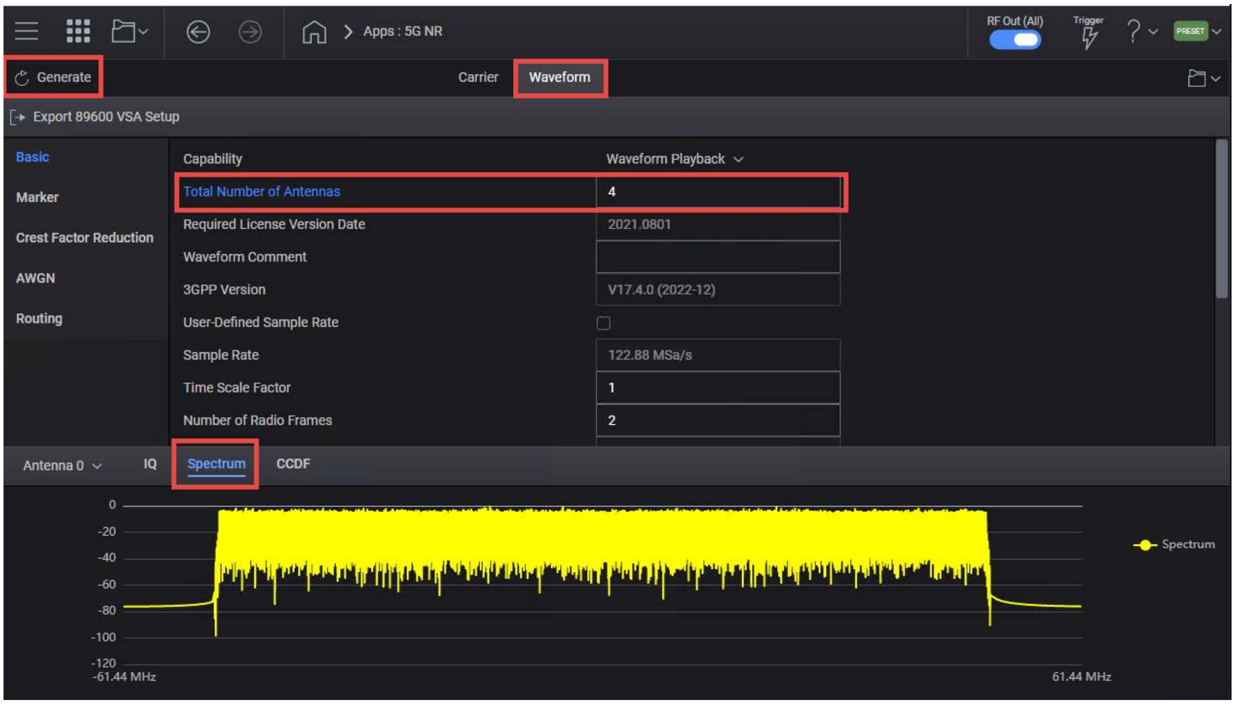


5. Select the **Carrier** tab > **DL Test Model** and set the Test Model to **NR-FR1-TM3.1.** Leave other settings as default and select **OK**.

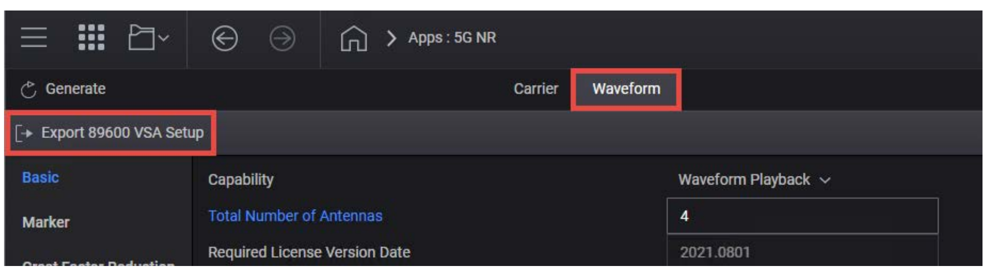


6. Select the **Waveform** tab and set the Total Number of Antennas to **4**. This indicates that two antenna port signals will be generated.

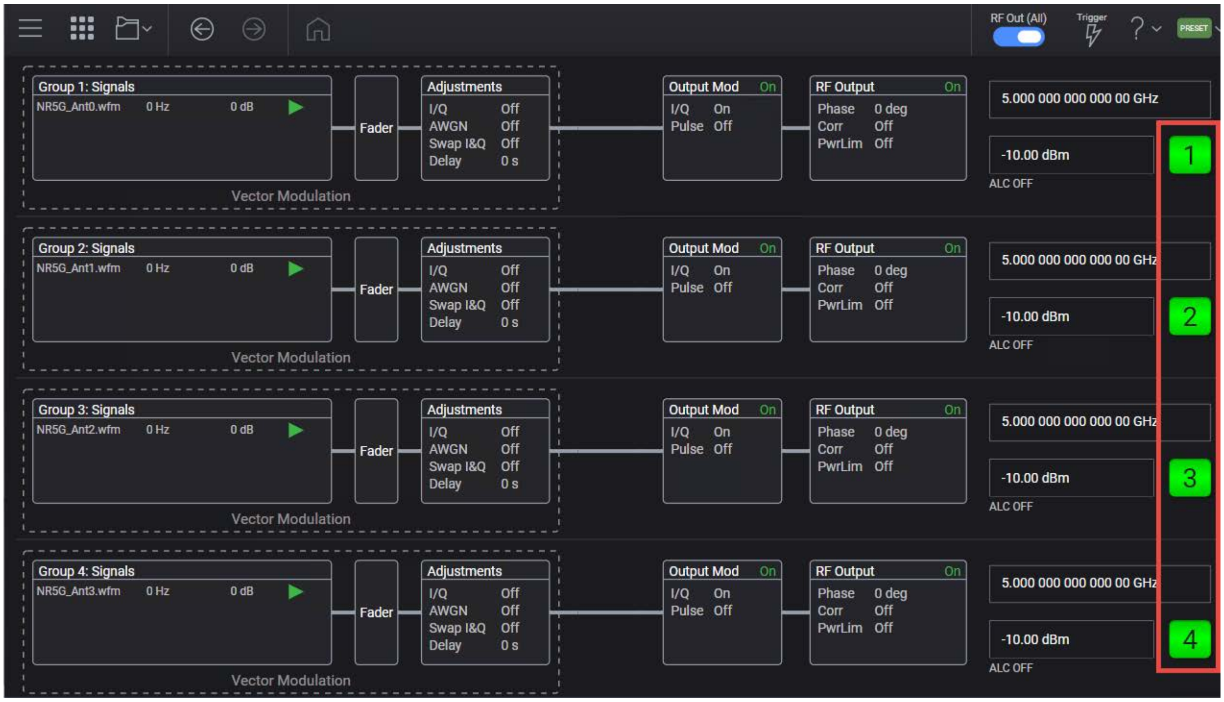
7. Select **Generate** to apply the signals to each channel. The expected spectrum can be observed in the bottom window.



8. To simplify analysis, select **Export 89600 VSA Setup** and save the file.



9. Select the **Home** icon to return to the main block diagram, and then select the gray **1**, **2**, **3**, and **4** to turn on each channel.



On the UXR

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.

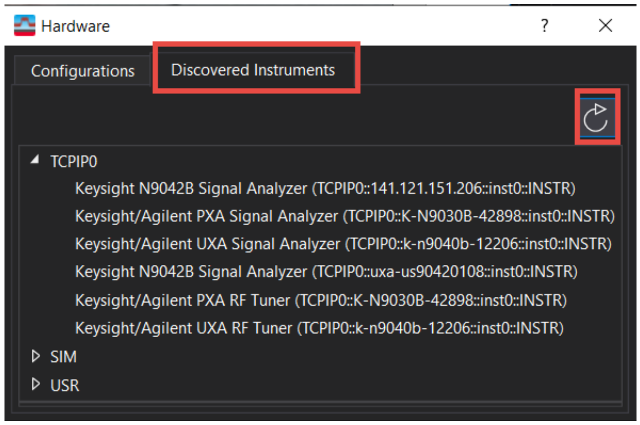
NOTE If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

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

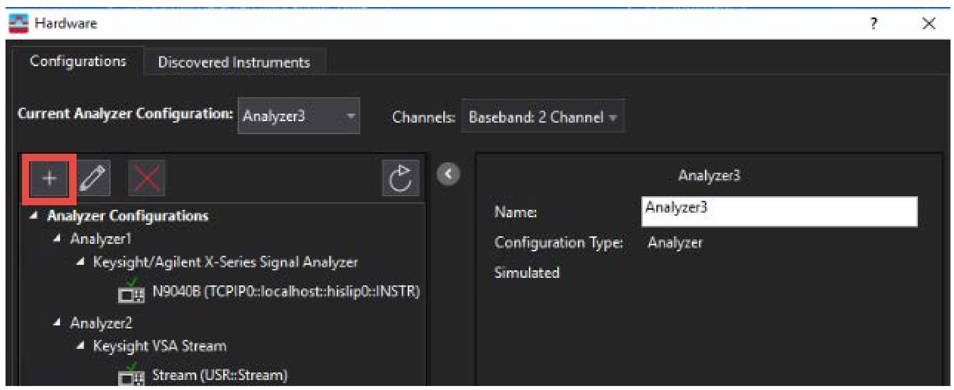
3. To configure the hardware, go to **Utilities** > **Hardware** > **Configurations**.

If it is already configured, go to step 10.

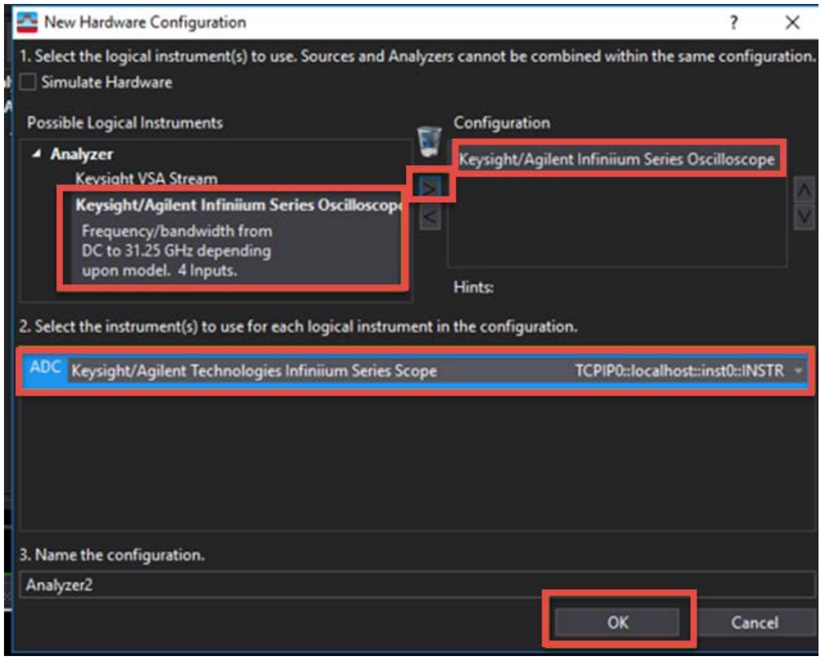
4. Open the **Discovered Instruments** tab and verify that the UXR is listed, if not, select the **Rediscover Instruments** icon.



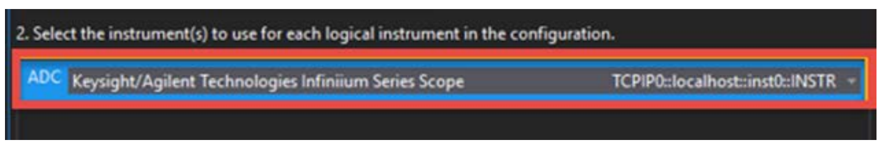
5. In the **Configuration** tab, select the **+ icon**.



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.

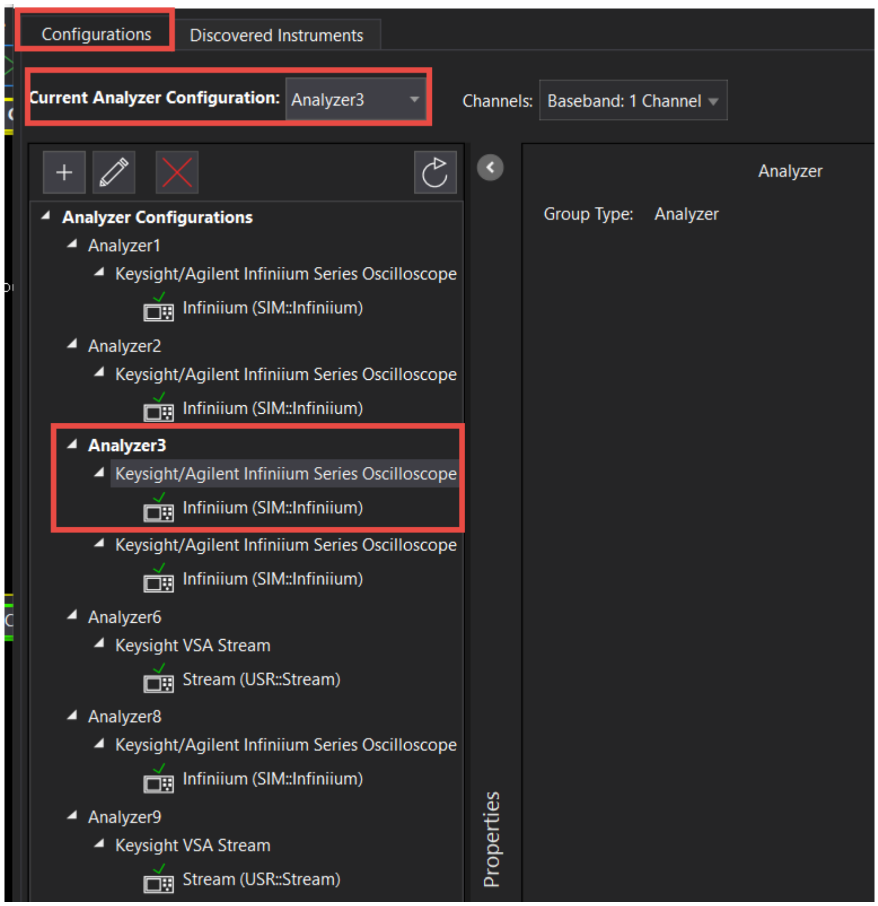


7. From the middle of the dialog box, select the UXR to be used.

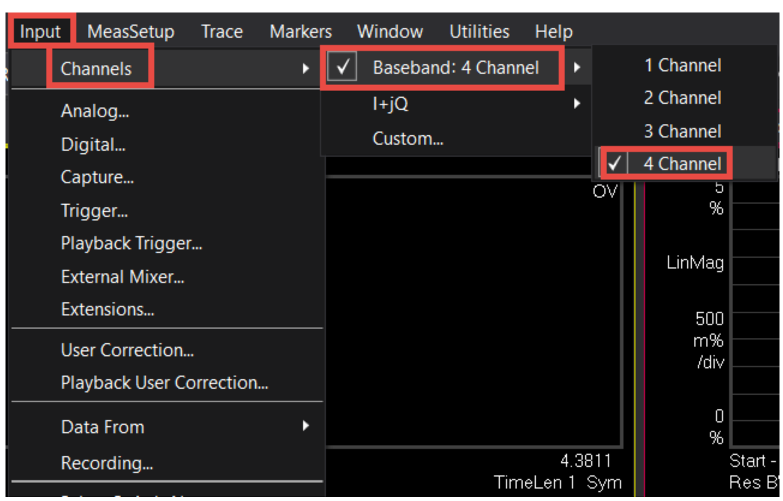


8. Select **OK** to create the UXR configuration.

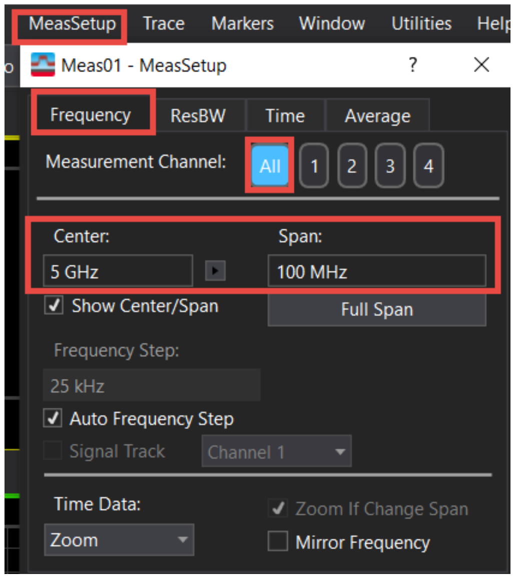
9. In the **Configurations** tab, set the Current Analyzer Configuration by selecting the Analyzer number for the new configuration. In this example **Analyzer 3**.



10. From the menu bar, select **Input** > **Channels** > **Baseband** > **4 Channels**.



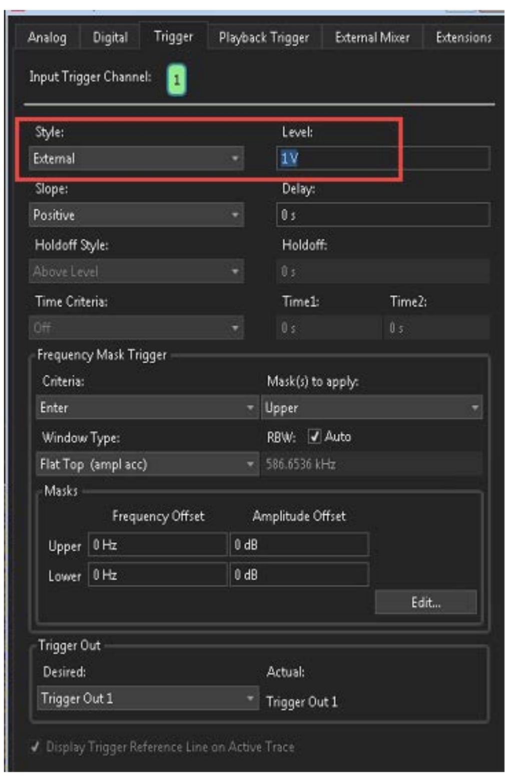
11. From the menu bar, select **MeasSetup** > **Frequency** and set the Center Frequency to **5 GHz** and Span to **100 MHz** on all four channels.



12. If External Trigger is available, it is recommended to use it to speed up the demodulation of the measurement. From the menu bar, select **Input** > **Trigger** and set:

– Style to **External**

– Level to **1 V**



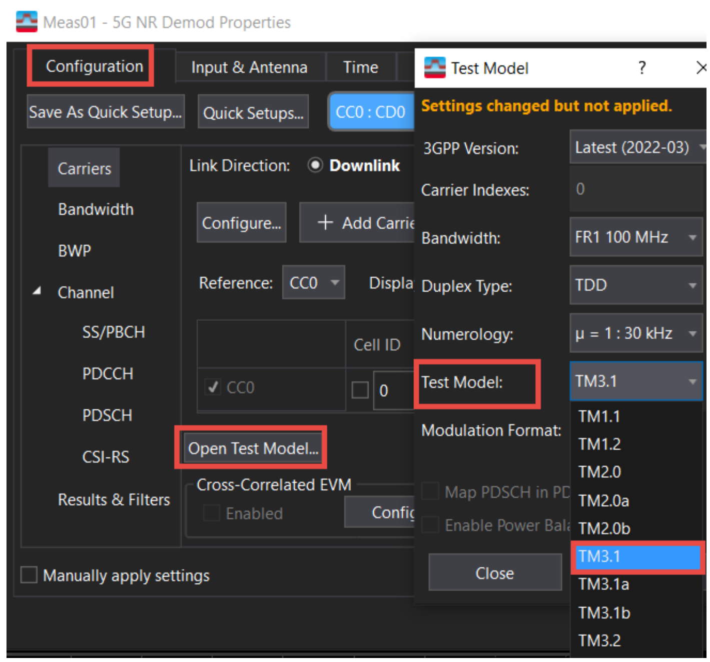
13. Select **File** > **Recall** > **Recall Setup** and navigate to the setup file you saved during the VXG 5G NR setup.

NOTE

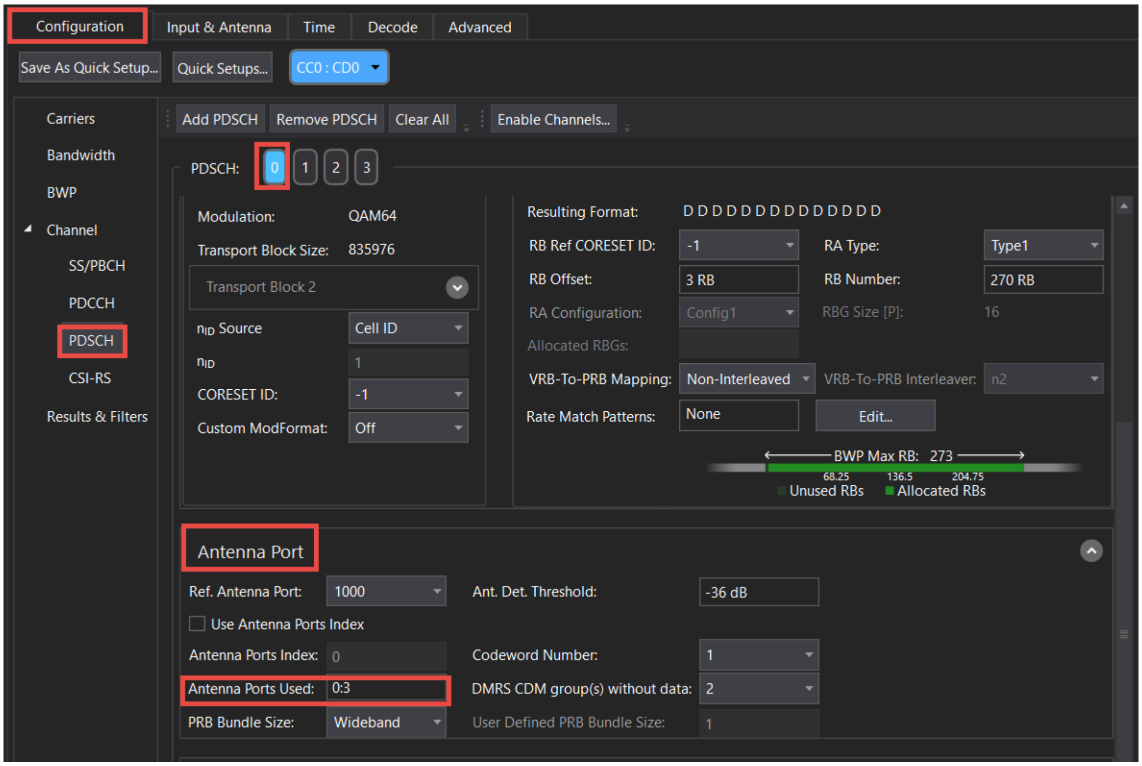
You will need to copy over the setup files to the X-Series Signal Analyzer or the PC running the VSA application, or continue with the settings below to setup the VSA manually.

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

15. To configure the Analysis region, select **MeasSetup** > **5G NR Demod Properties** > **Configuration** tab and select **Open Test Model** > **TM3.1** > **Apply** > **Close**.



16. Select the **PDSCH** tab, scroll down, open the **Antenna Port** tab and set Antenna Ports Used to **0:3**. Repeat for the remaining PDSCH channels by selecting the corresponding number at the top.



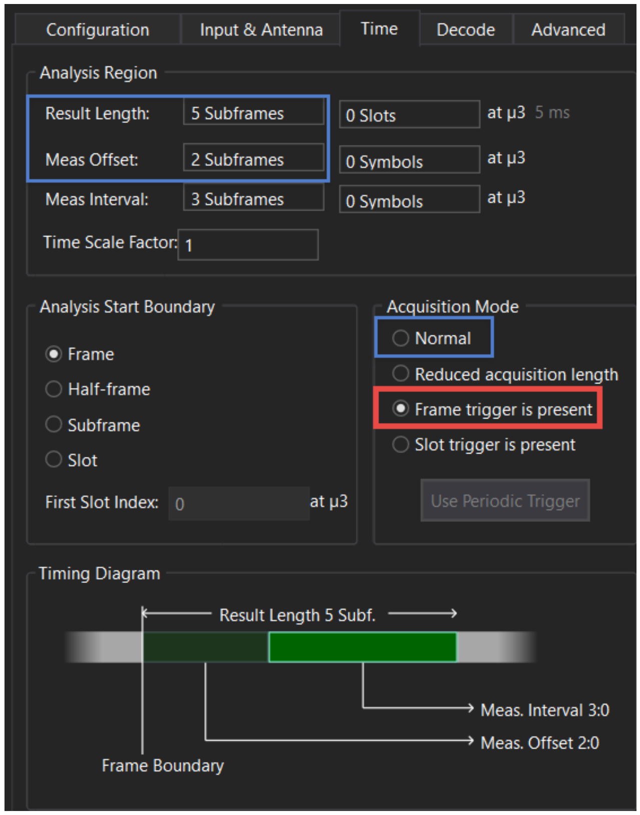
17. To reduce measurement time, select **MeasSetup** > **5G NR Demod Properties** >**Time** and set:

– Result Length to **5 Subframes**

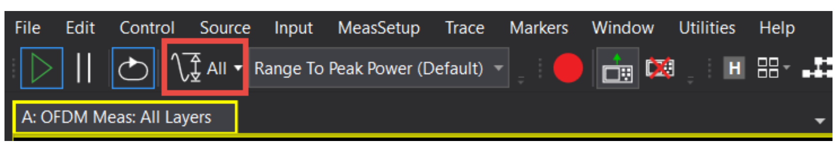
– Meas Interval to **2 Subframes**

– Enable **Frame Trigger is present.**

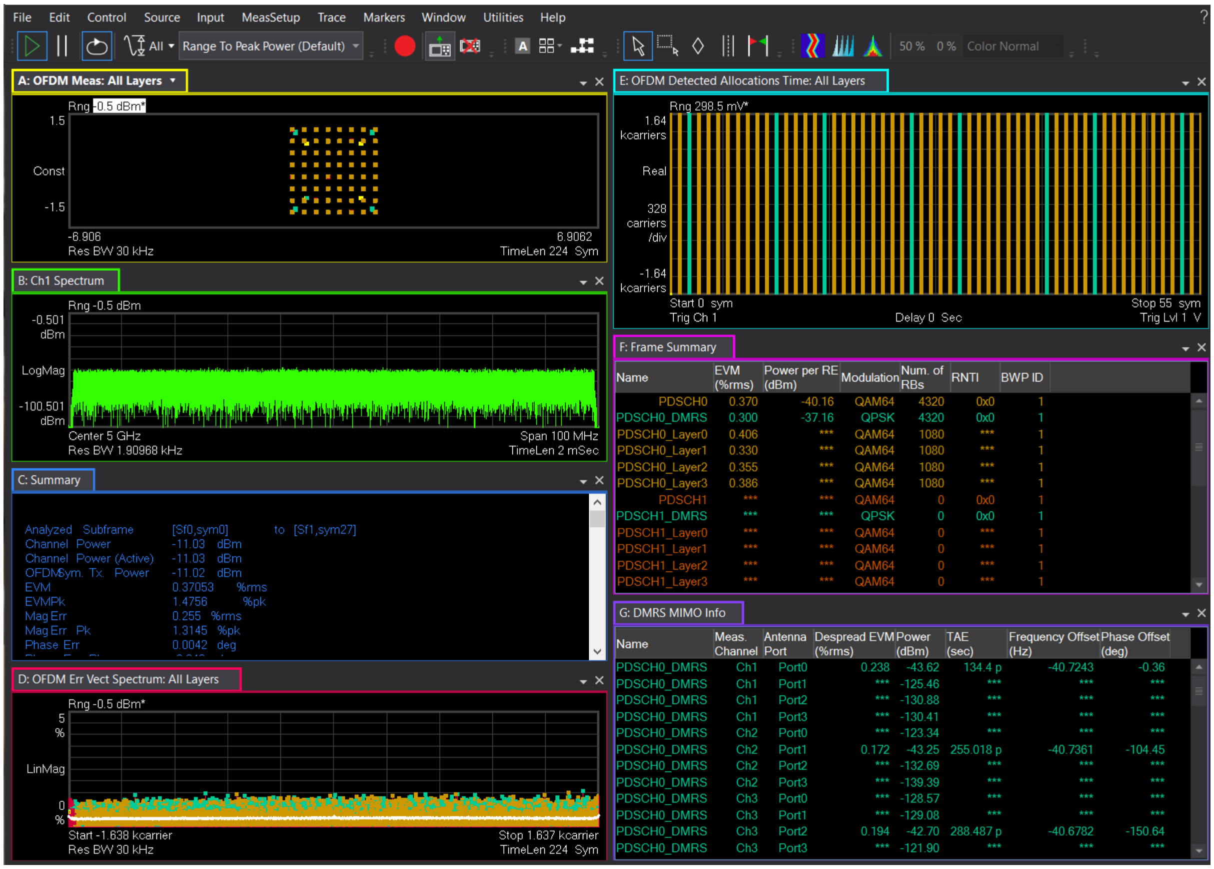
We are using an external trigger for this example so selecting Frame Trigger is Present will use the external trigger and will speed up the measurement significantly. If not using an external trigger, set to Normal.



18. At the top of the display, select **Autorange**.



19. Observe the demodulation 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.

– Trace G: 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.

4 Other X-Series Signal Analyzer Measurements

KEYSIGHT TECHNOLOGIES

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.

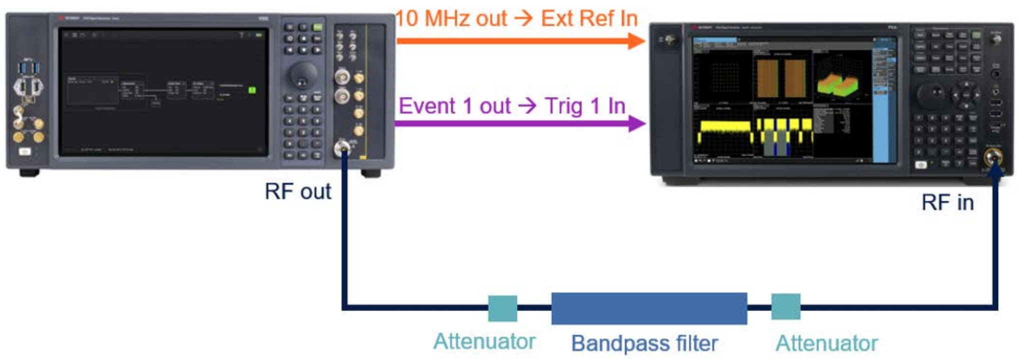
In this measurement example, we will use the M9484C VXG to generate a wideband modulated signal, drive this through a filter and the N9042B UXA will analyze the output signal and display the filter characteristics (gain, phase, and group-delay). Also, all settings to the VXG will be made via the Connection Management setup in the N9042B/N9056EM0E 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 my need to be adjusted for your filter.

For this example we are using the follow 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**.

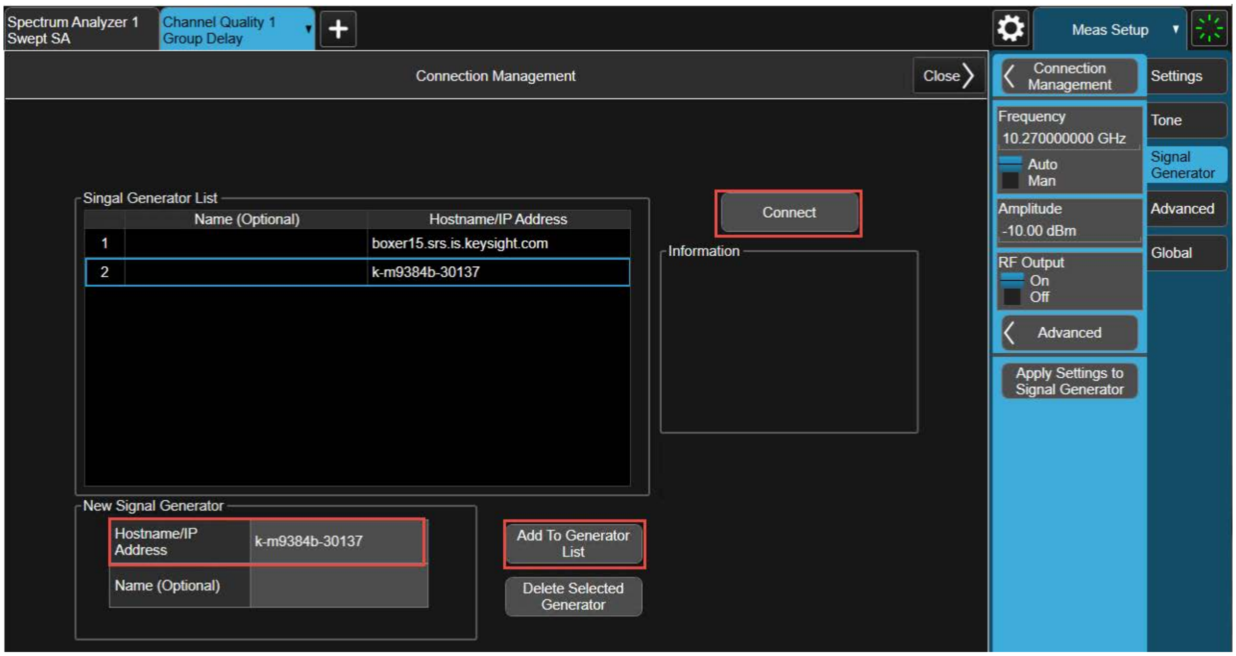
4. In the **Meas Setup** menu panel, select the **Signal Generator** tab and confirm the Center Frequency is set to **10.27 GHz** (the frequency of the filter) and set the Amplitude to **+10 dBm**.

   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**.

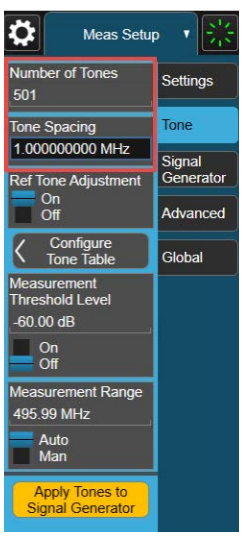
6. In the New Signal Generator area, specify the **Hostname or IP address** of the VXG, then select **Add to Generator List** > **Connect**.

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.

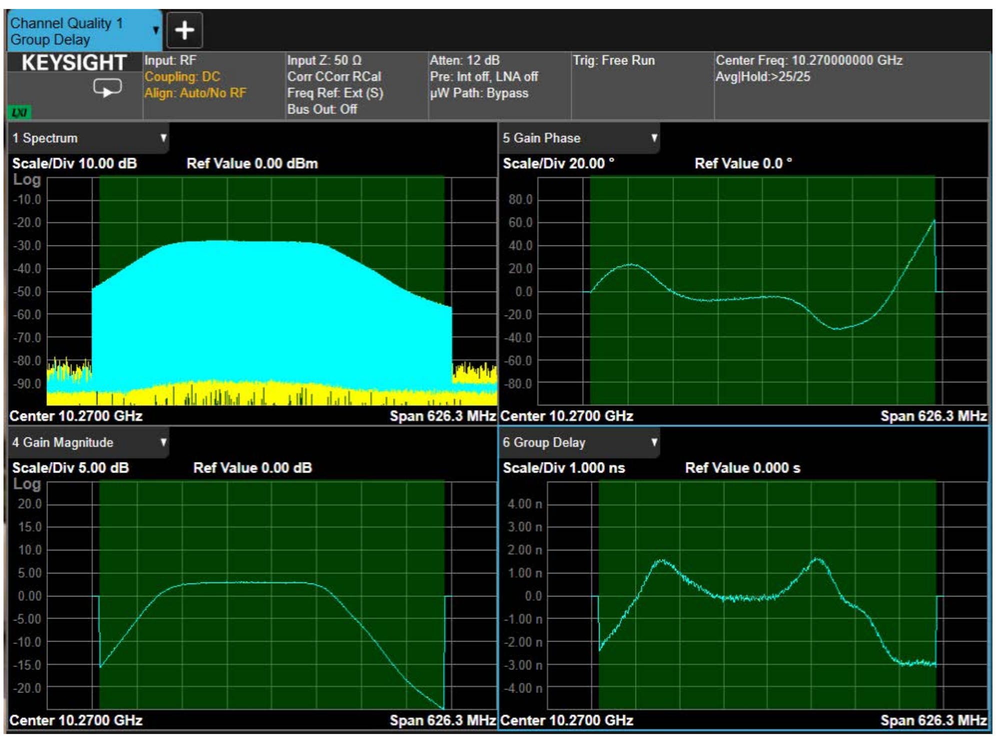
12. **Close** the Configure Tone table.

13. Select the **Calibration** tab > **Calibrate Tones.**

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

14. Once the calibration is complete, connect the filter between the two 3 dB attenuators to see the response of the filter.

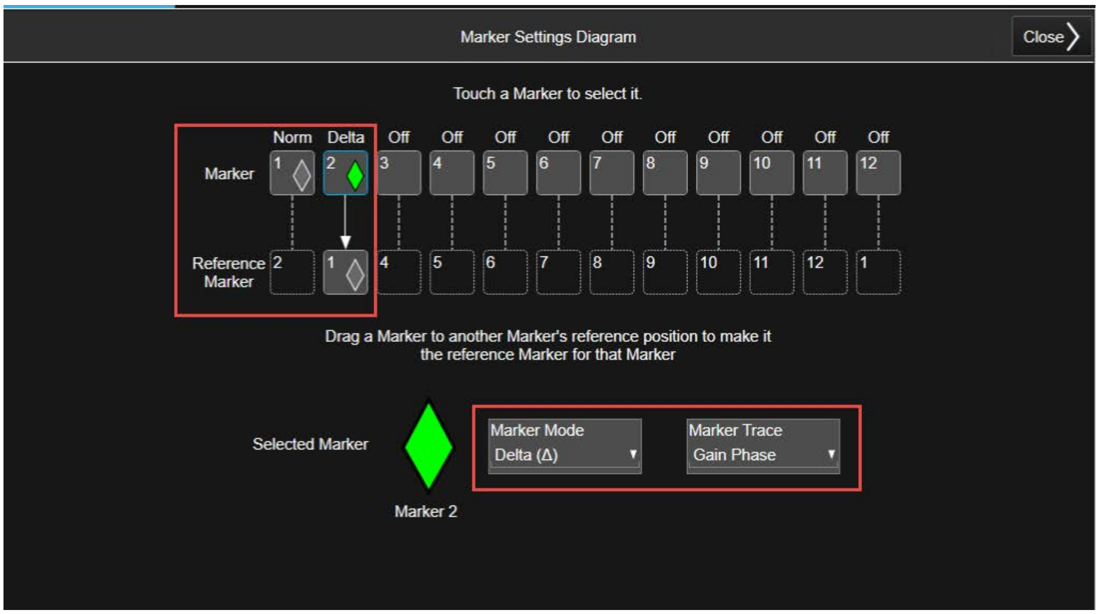
15. For this example, set the **Gain Magnitude Scale/Div to 5 dB** and the **Group Delay Scale/Div to 1 ns**. For your specific measurement adjust the screen settings to a value that allows you to get the best signal resolution on your measurement displays.



16. From the menu panel, select **Marker** > **Settings** > **Marker Settings Diagram**.

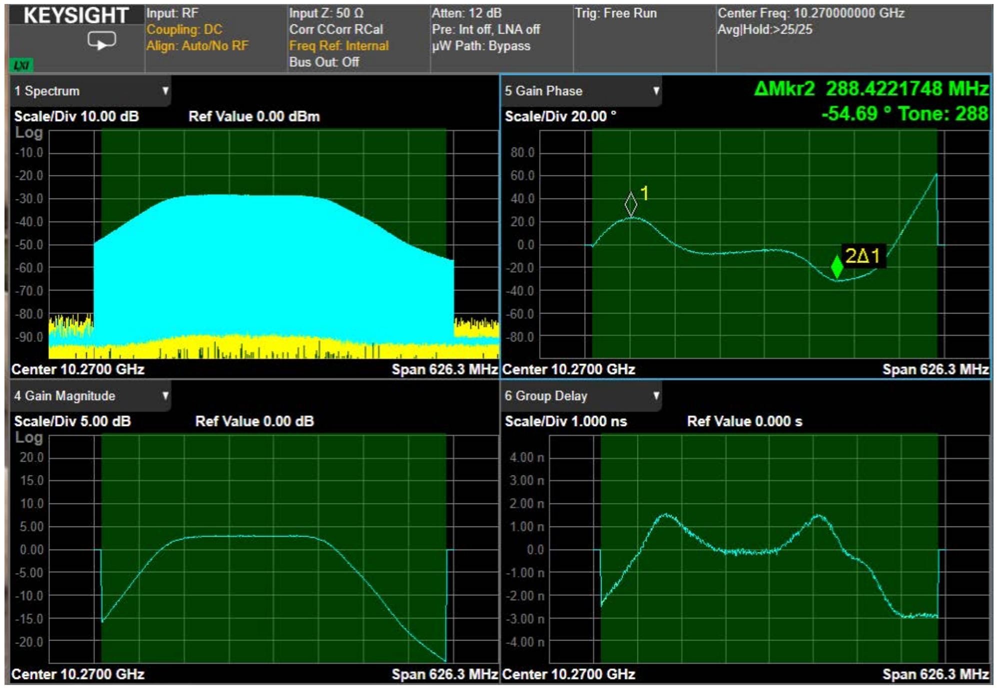
17. Activate Marker 1 by setting Marker Mode to **Normal** and set Marker Trace to **Gain Phase**. Click and drag Marker 1 to the Reference Marker 2 position.   Activate Marker 2 by setting Marker Mode to **Delta**, then set Marker Trace to **Gain Phase** to put the marker on the Gain Phase measurement, then **Close** the window.

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

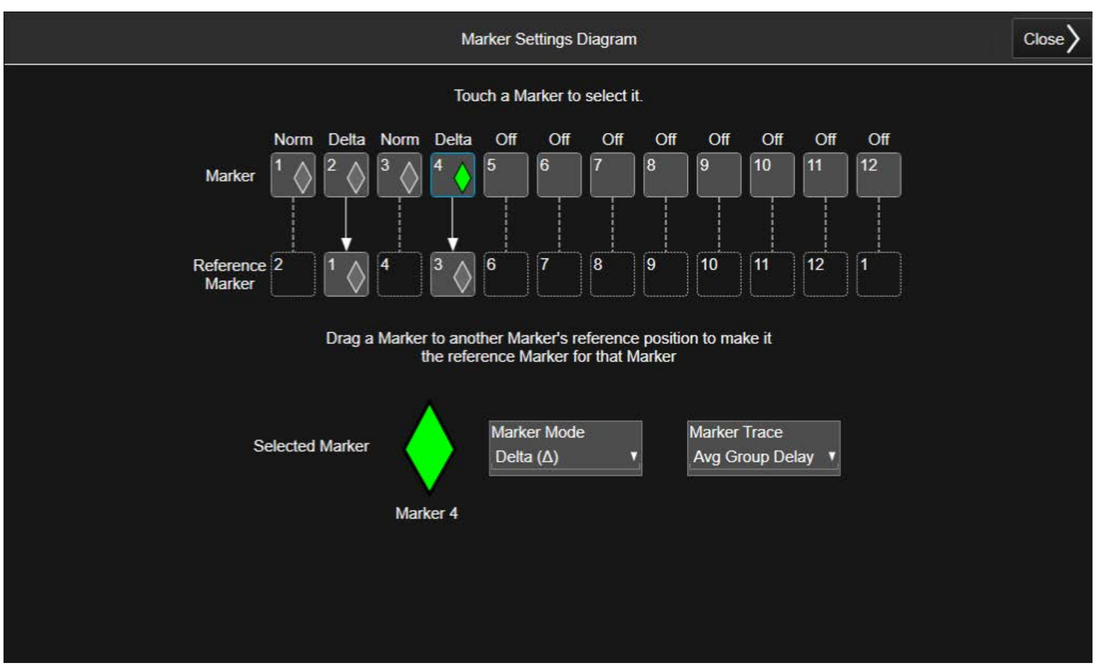


18. Move Marker 1 to the Peak of the Signal within the bandwidth range of the signal and Marker 2 to the minimum.

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 °.

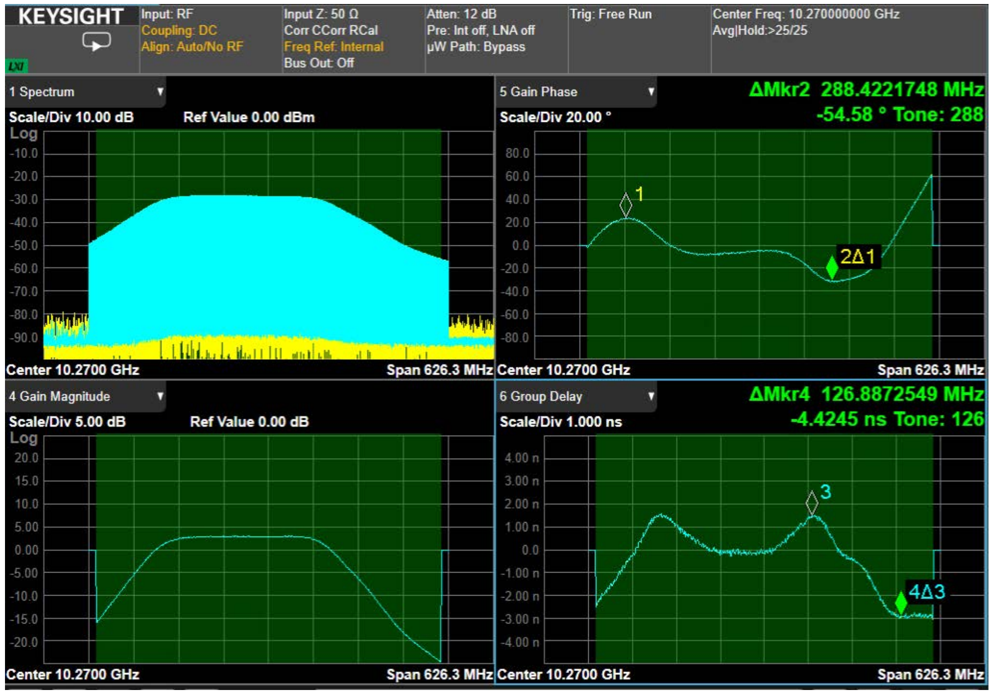


19. Go back into the **Marker** Menu and turn on Marker 3 and set Marker Mode to Normal and Marker Trace to **Avg Group Delay**. Drag Marker 3 to Marker 4's Reference Position. Turn on Marker 4 and set Marker Mode to **Delta** and Marker Trace to **Avg Group Delay**. **Close** the Marker Settings Diagram.

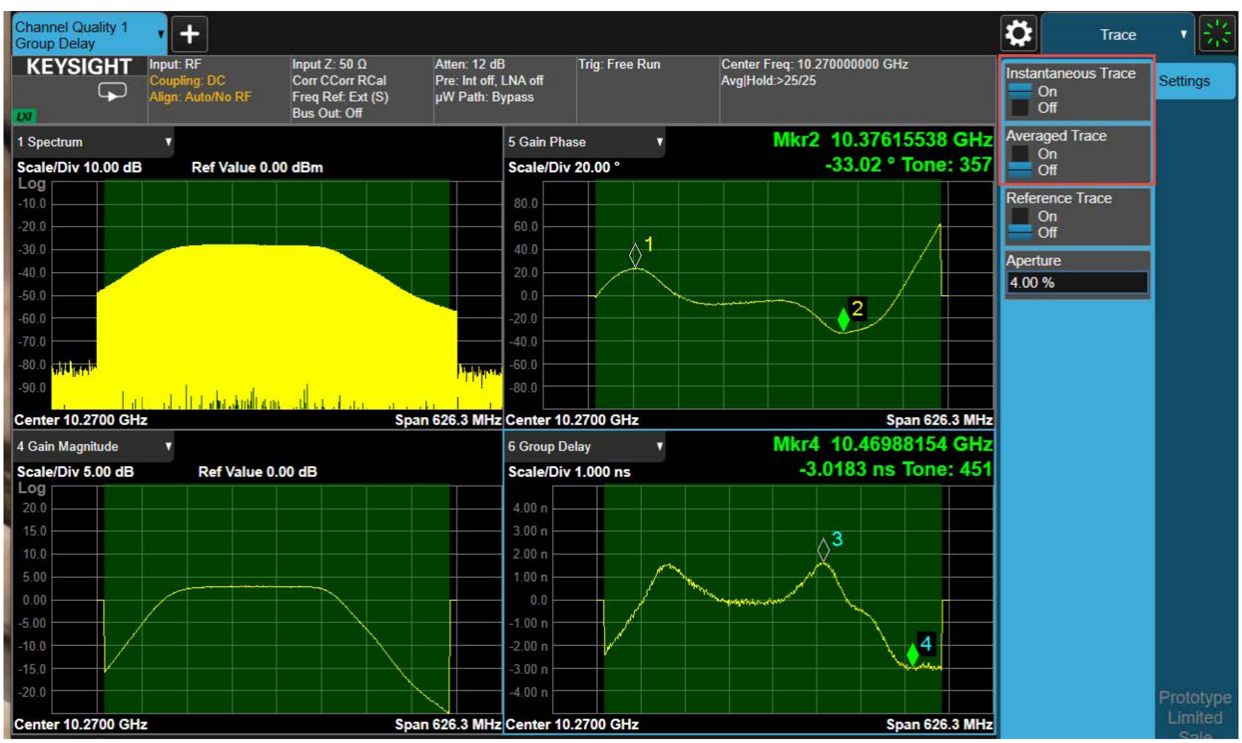


20. Move Marker 3 to the peak of the trace and Marker 4 to the minimum.

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

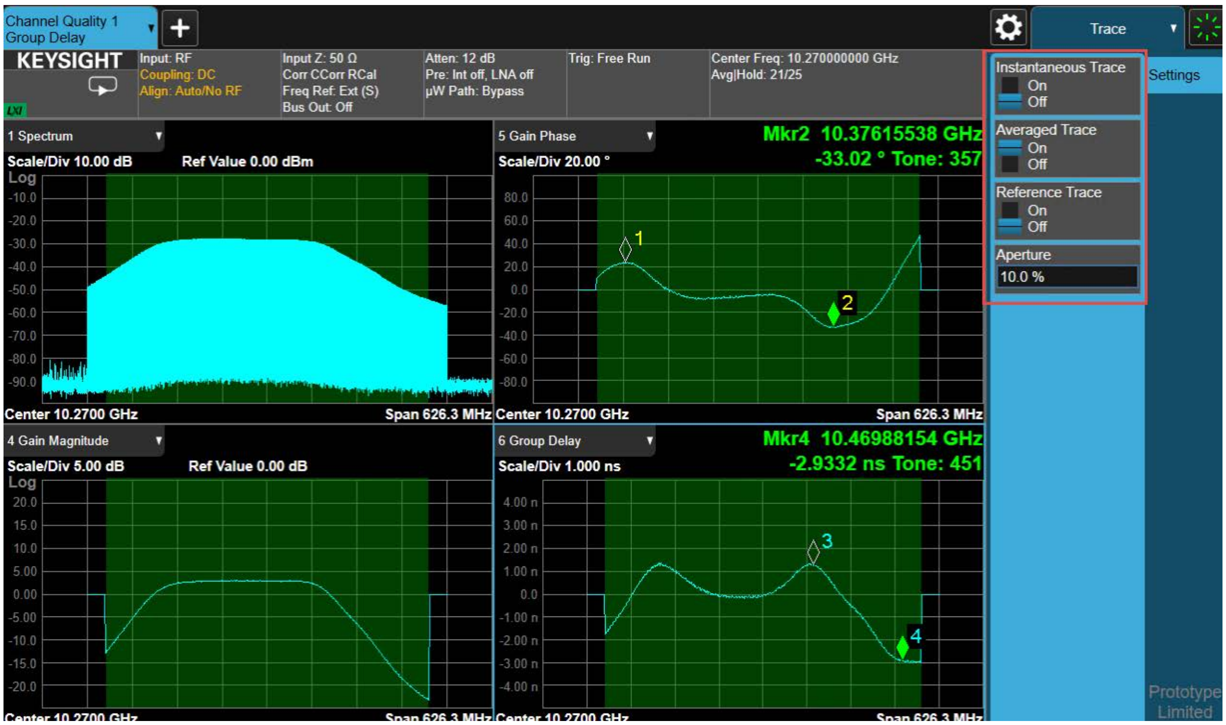


21. From the menu panel, select **Trace** > Averaged Trace **Off**. With Averaged Trace Off, you can capture smalls spurs that might occur on the trace.

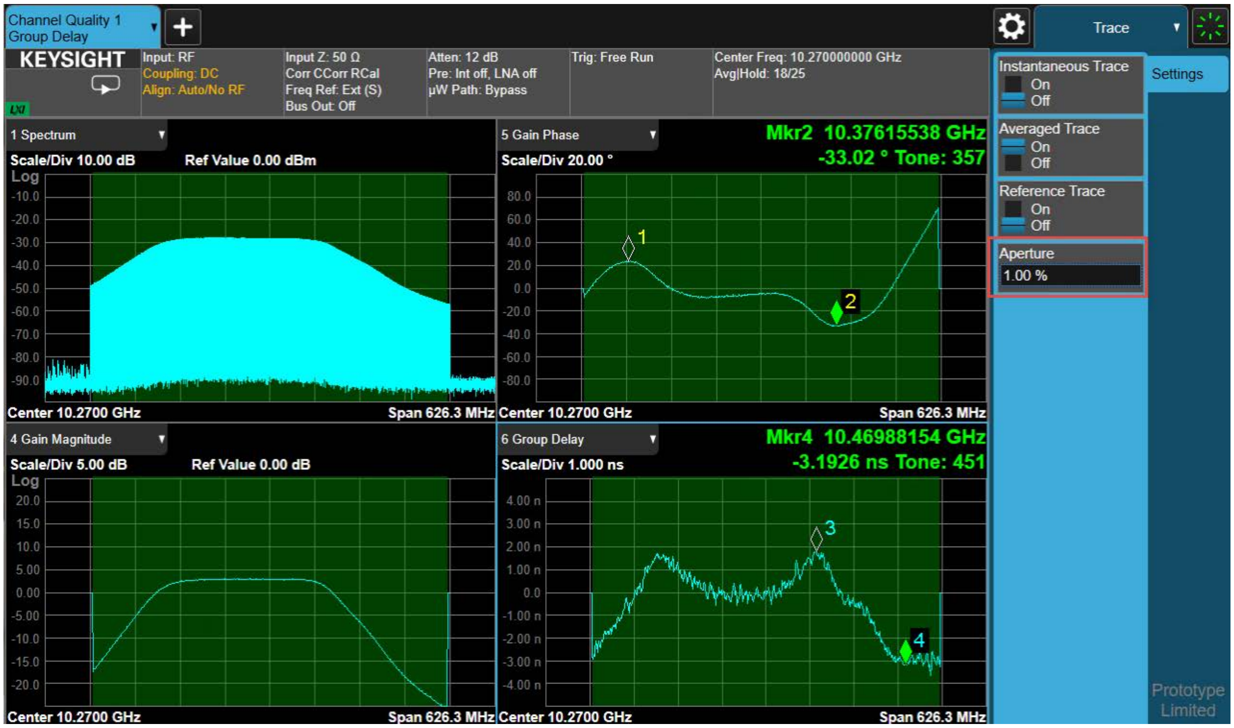


22. Turn Instantaneous Trace **Off** and Averaged Trace **On** then set the Aperture to **10%** to get a smoother result, but lose a little bit more at the beginning and the end of the 500 MHz band.

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



23. 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.



24. 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.

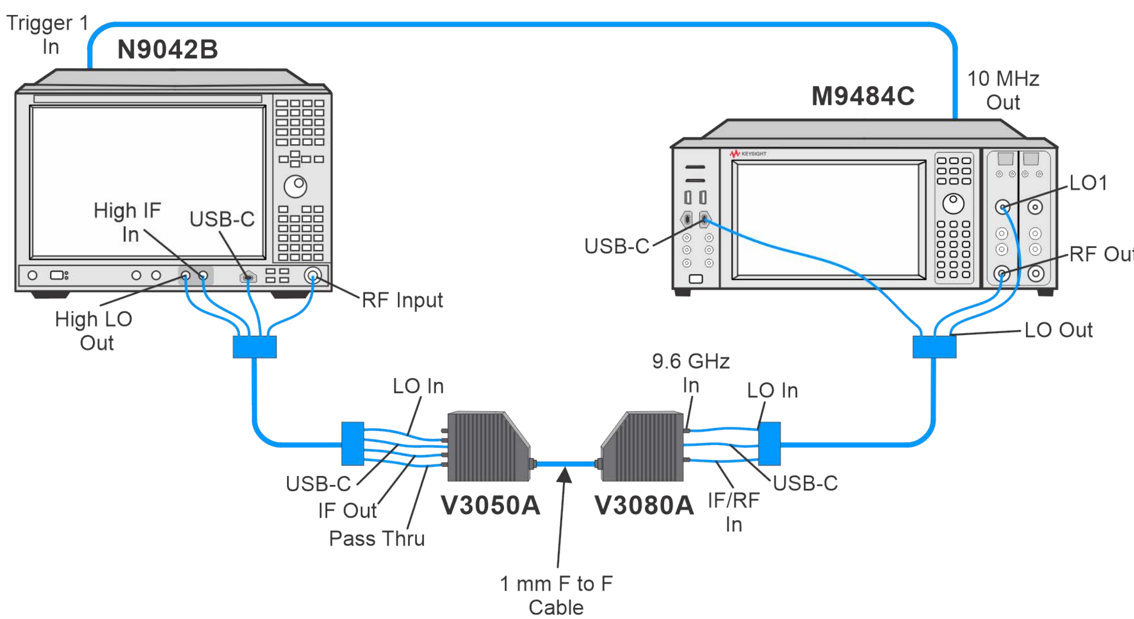

Channel Quality 1
Group Delay
KEYSIGHT
Input: RF
Coupling: DC
Align: Auto/No RF
Input Z: 50 Ω
Corr CCorr RCal
Freq Ref: Ext (S)
Bus Out: Off
Atten: 12 dB
Pre: Int off, LNA off
µW Path: Bypass
Trig: Free Run
Center Freq: 10.270000000 GHz
Avg|Hold:>25/25
1 Spectrum
Scale/Div 10.00 dB
Ref Value 0.00 dBm
Center 10.2700 GHz
Span 626.3 MHz
5 Gain Phase
Scale/Div 20.00 °
Mkr2 10.37615538 GHz
-33.03 ° Tone: 357
4 Gain Magnitude
Scale/Div 5.00 dB
Ref Value 0.00 dB
6 Group Delay
Scale/Div 1.000 ns
Mkr4 10.46988154 GHz
-3.1936 ns Tone: 451
3 RF Envelope
Scale/Div 10.00 dB
Ref Value 0.00 dBm
0.000 s
30.166 us
Meas Time 30.166 µs (23615 pts)
9 Metrics
Basic | Sample | Averaged
Signal Power | -4.17 dBm | -4.18 dBm
Frequency Error | 0 Hz | 0 Hz
Clock Error | 0.0001 ppm | 0.0009 ppm
Time Offset | 152.3146 ns | 595.5620 ns
Group Delay | Sample | Averaged | Max Hold
RMS | 67.1852 ps | 67.1886 ps

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 M9848C 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.

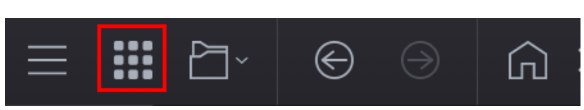


Setting up a 5G NR Millimeter-Wave Measurement

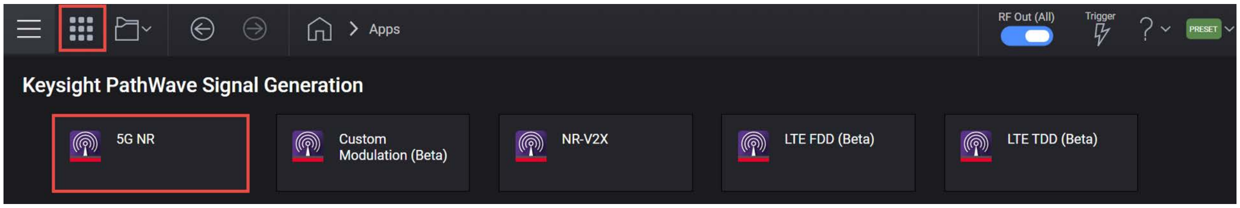
NOTE The VXG must have the N7631APPC Signal Generation for 5G NR license installed.

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.

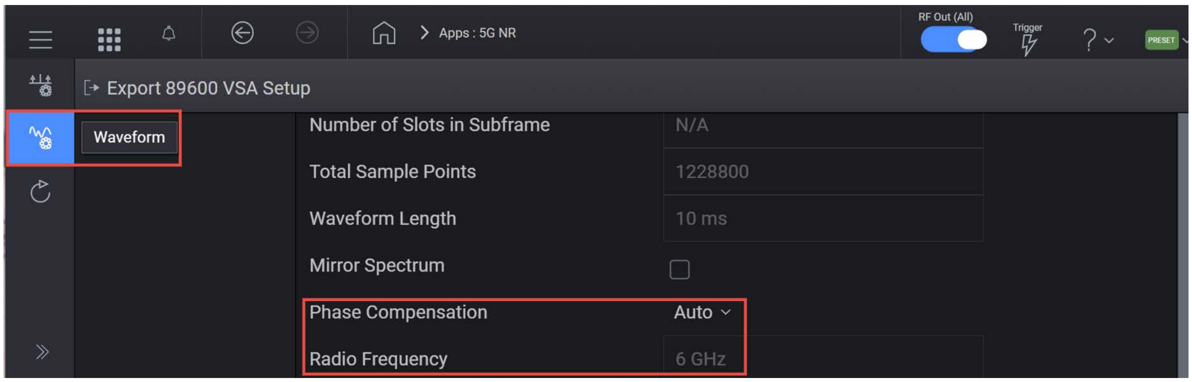


4. Select **5G NR** to enter the 5G NR signal mode.



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.



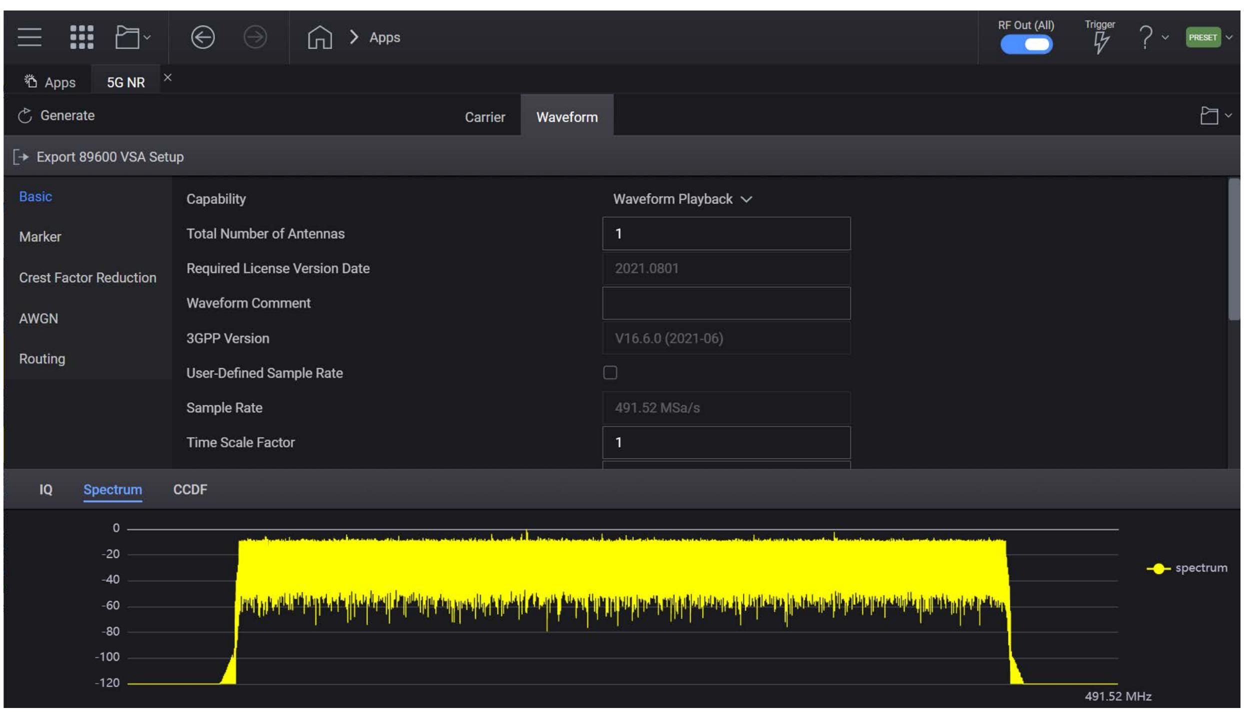
TIP Some applications, like power amplifier measurements use the same waveform at different frequencies and can be time consuming to generate a separate waveform for each frequency. In this case, you would turn Phase Compensation Off, so the waveform becomes independent from the carrier frequency. You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

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

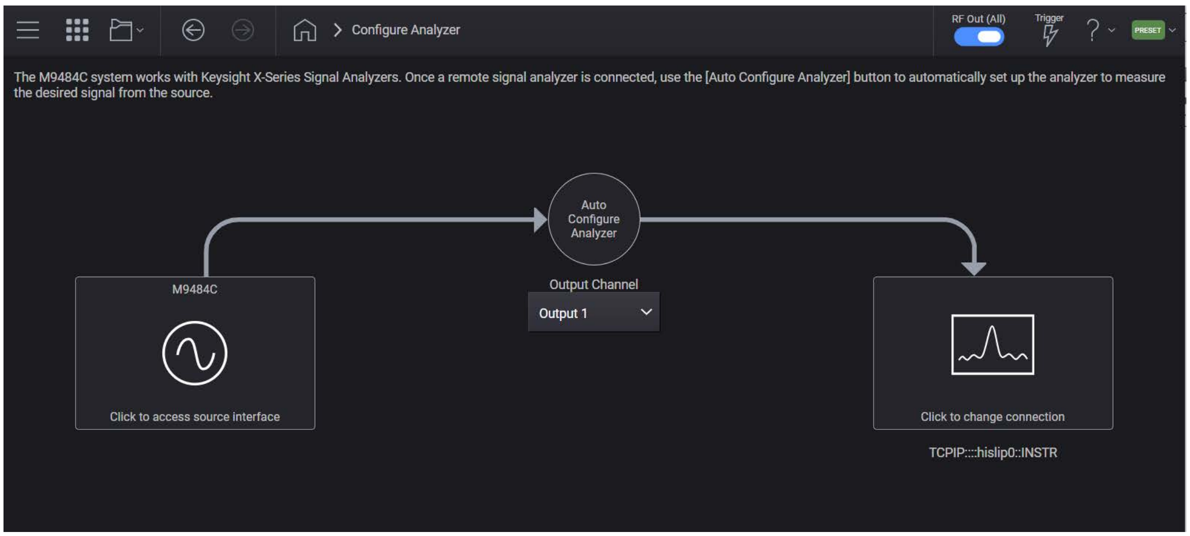
9. Select **Generate** to generate the Waveform, and then select **Home** to exit the setup panel.



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**.



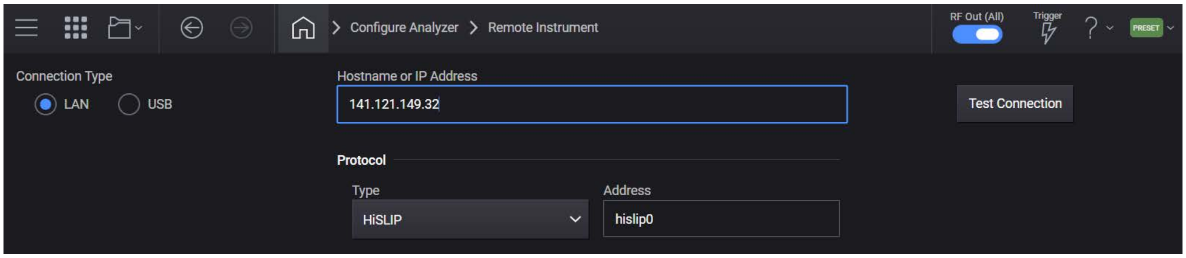
12. In the System Configuration setup, click on the Remote Signal Analyzer block (on far right) to setup the communication channel to the Keysight X-Series Signal Analyzer.

13. Set Connection Type to **LAN**.

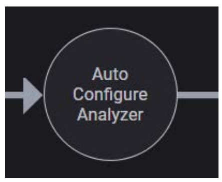
14. In the Connect Remote X-Series Signal Analyzer setup, enter the Hostname or IP Address for the signal analyzer.

15. Under Set Protocol, select **HiSLIP** and use the Remote name **hislip0**.

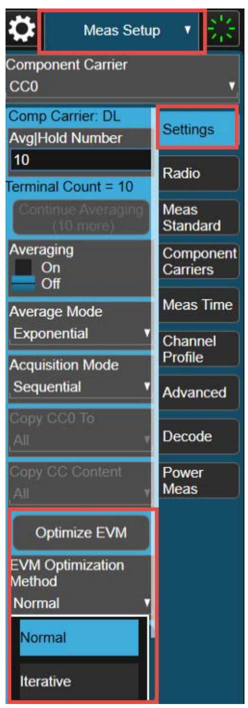
16. Select **Test Connection** to verify, then **Back**.



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



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



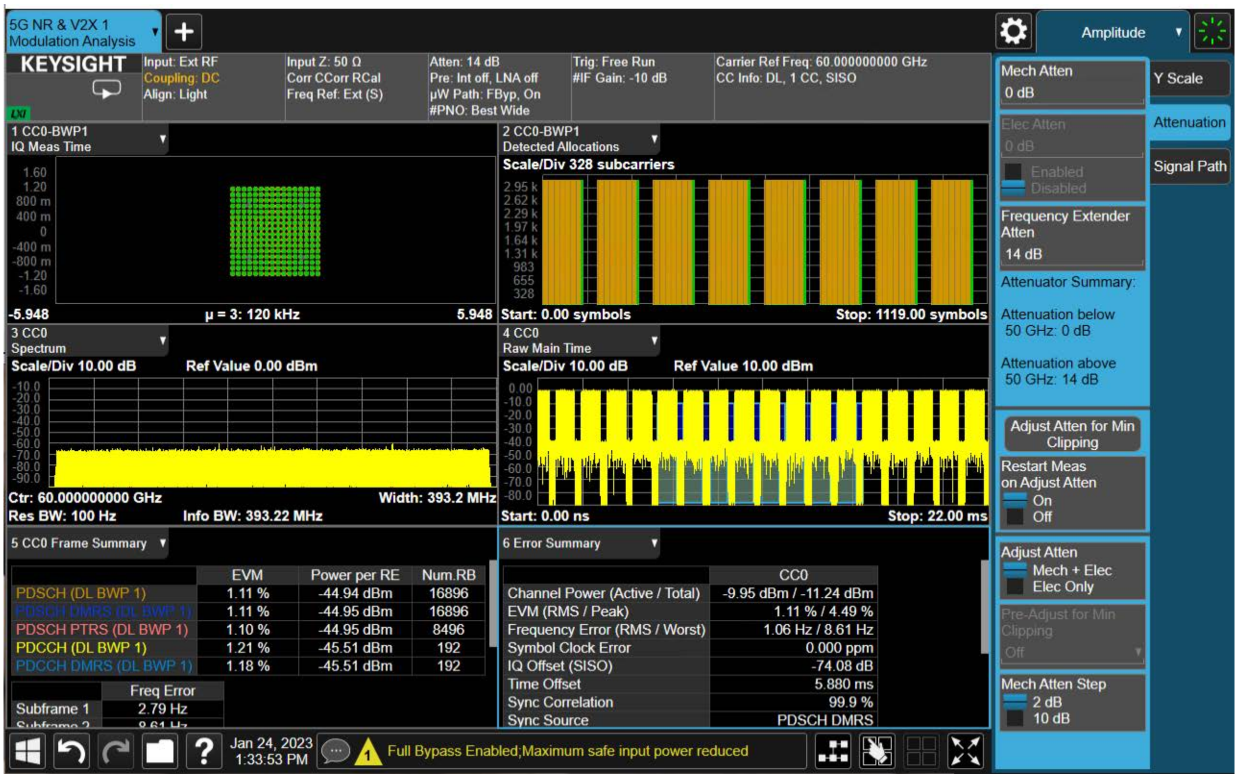
Optimize EVM is an immediate action to adjust the hardware settings to minimize EVM.

- 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.

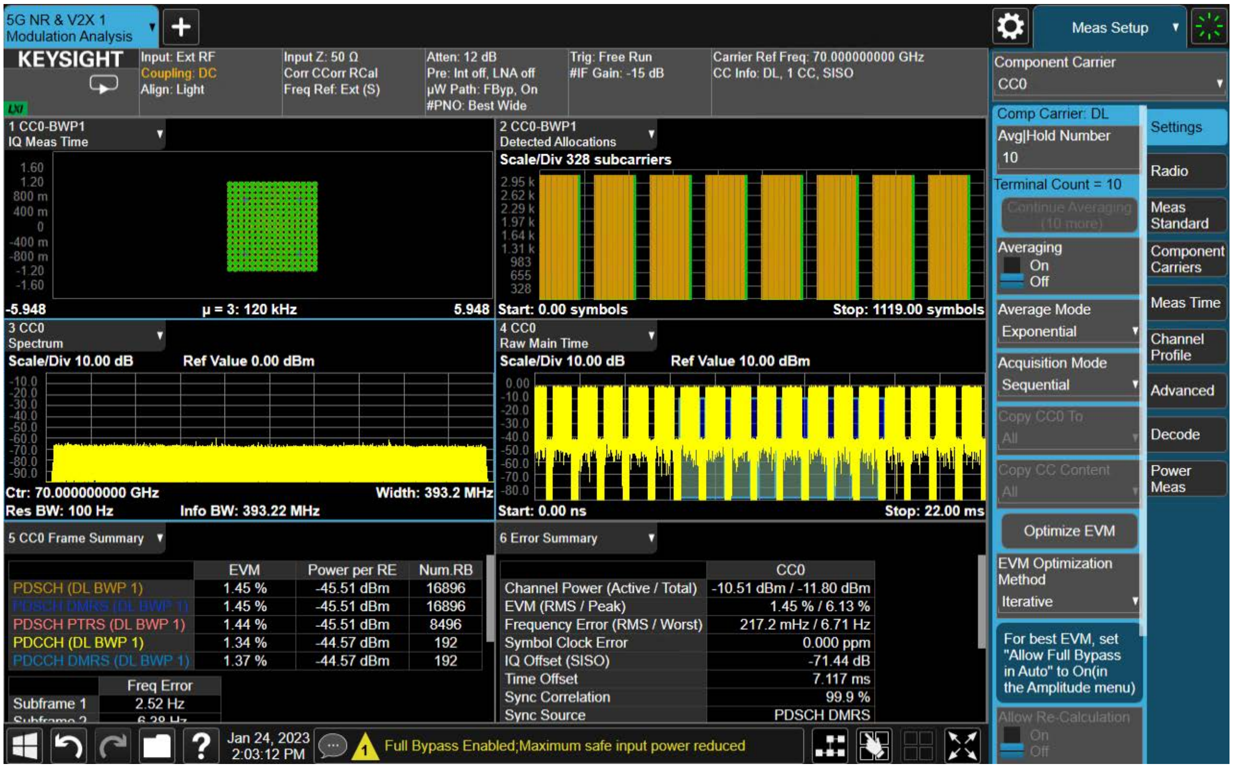
  For 5G NR signals, this method is much slower, than normal, but with achieve better EVM results. You can also manually adjust IF Gain, Frequency Extender Attenuation (use when measurement setup includes a V3050A frequency extender).

19. View the results on the signal analyzer.

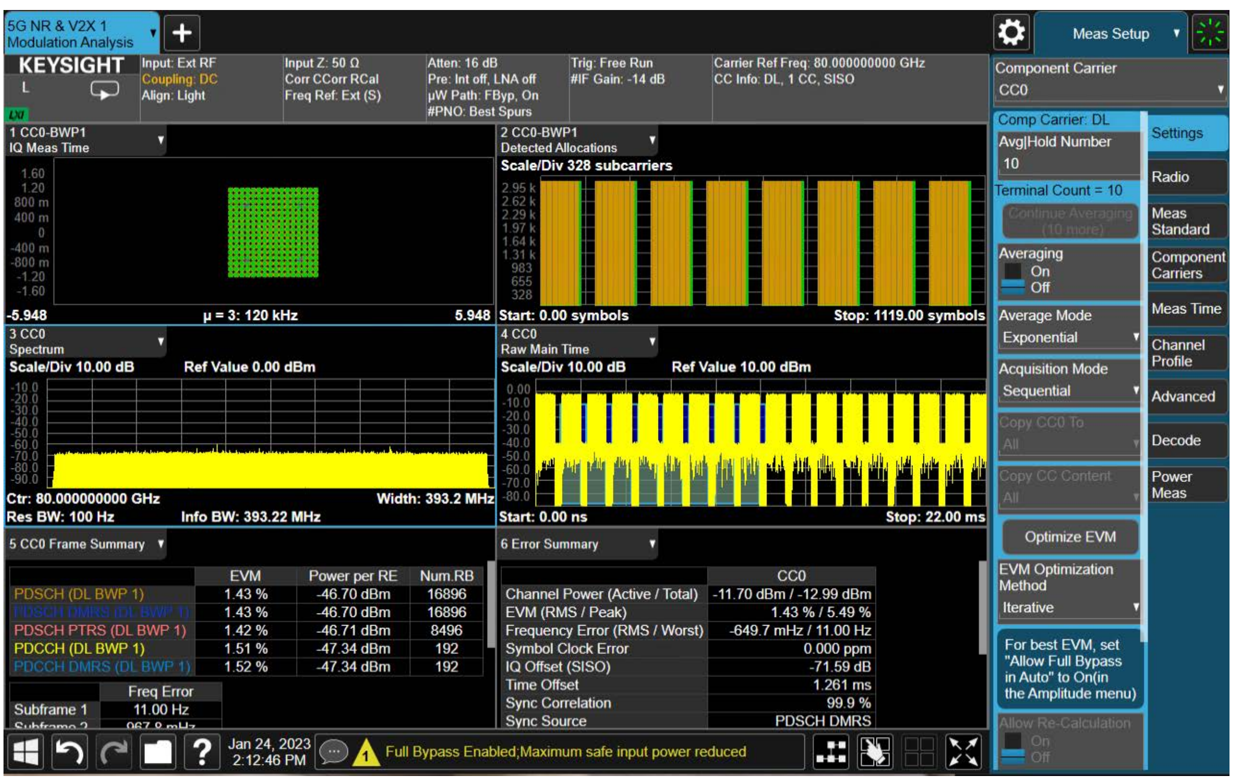


20. Change the frequency and power level of the M9484C and frequency of the N9042A to view other results. Remember to Optimize EVM after each change.

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



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



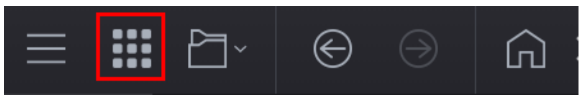
This measurement was done at 85 GHz, - 10 dBm.

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

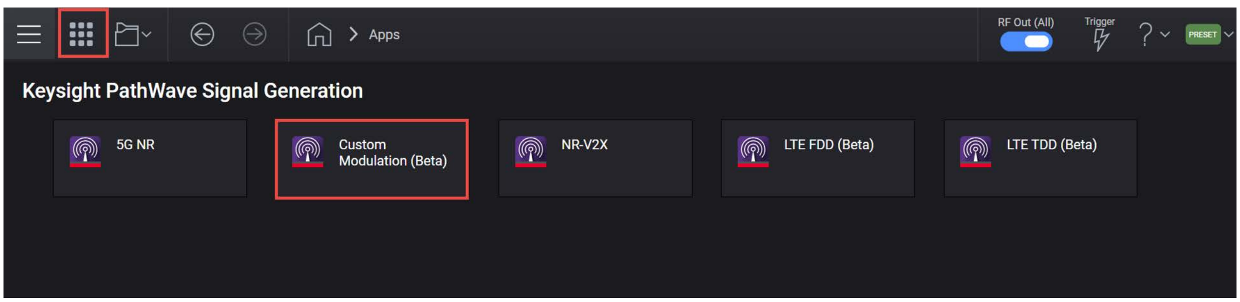
NOTE The VXG must have the N7608C Signal Studio for Custom Modulation license installed.

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.

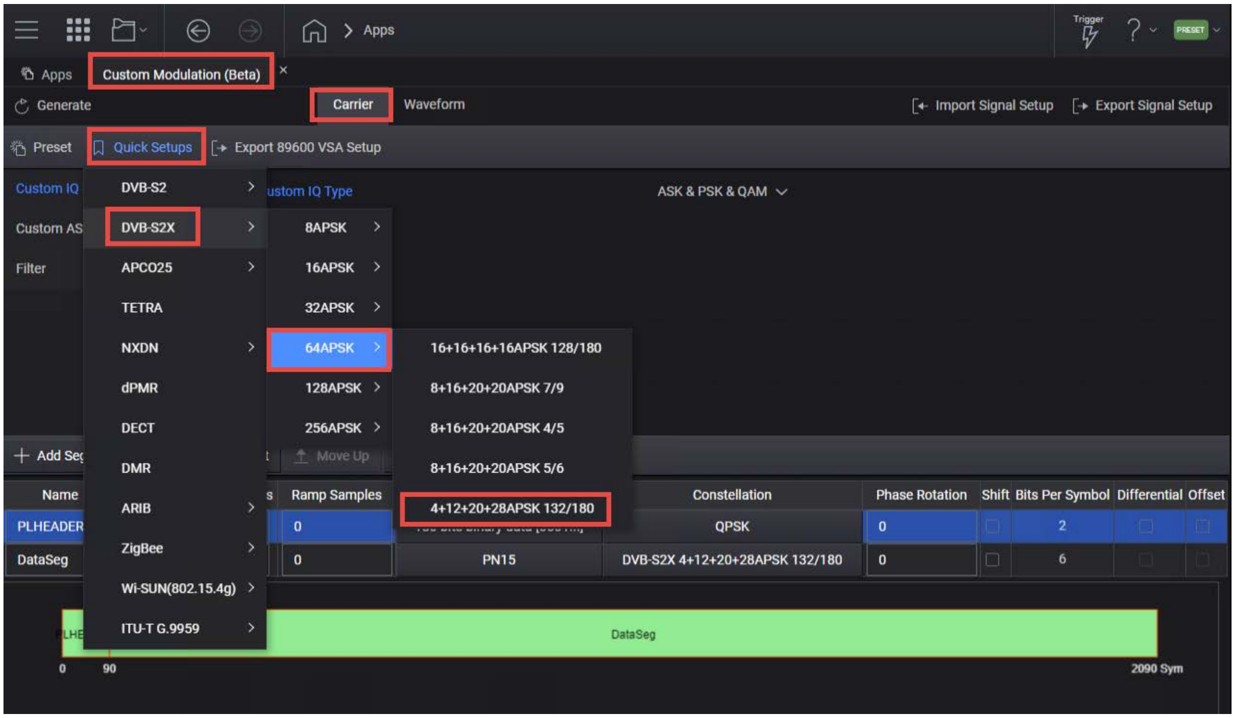


4. Select **Custom Modulation** to enter Custom Modulation Signal Mode.

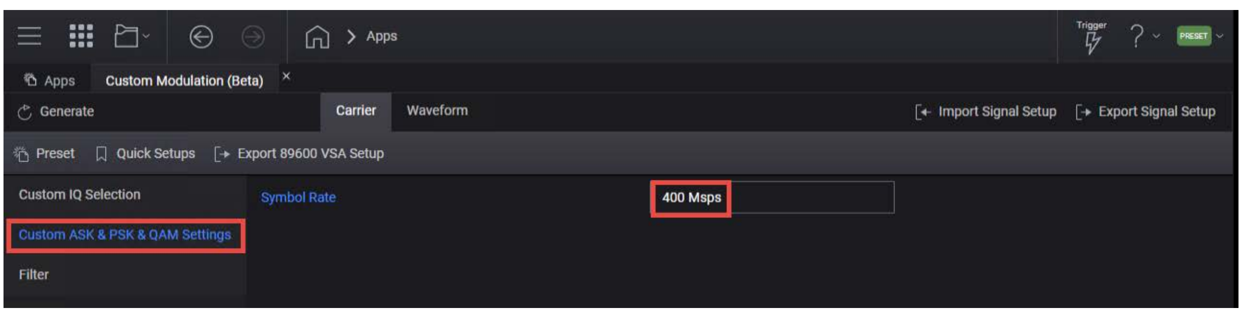


5. Select the **Carrier** tab.

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

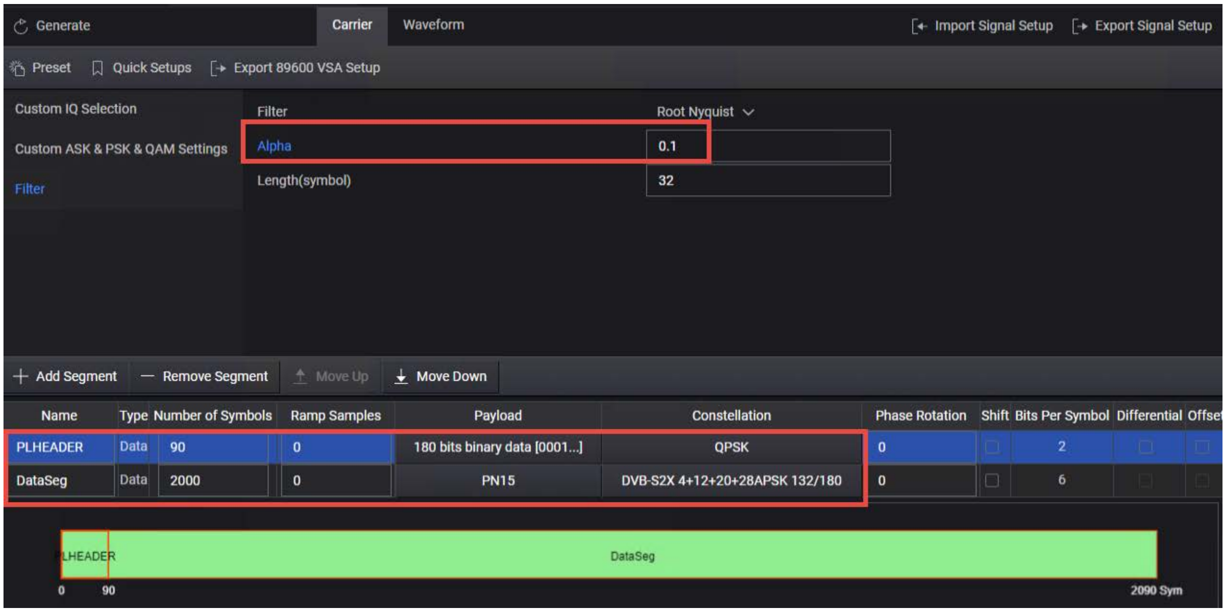


7. From the left pane, select **Custom ASK & PSK & QAM Settings** and set the Symbol Rate to **400 Msps** per channel.

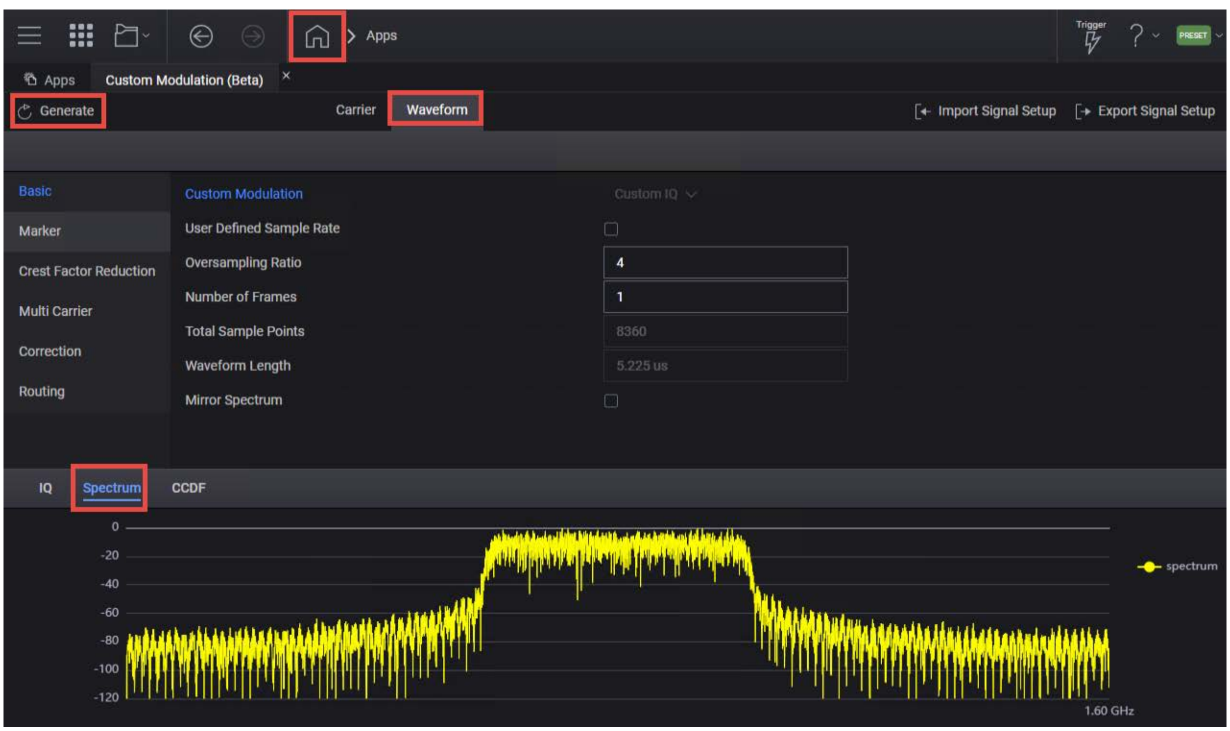


8. Select **Filter** > Alpha to **0.1**.

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.

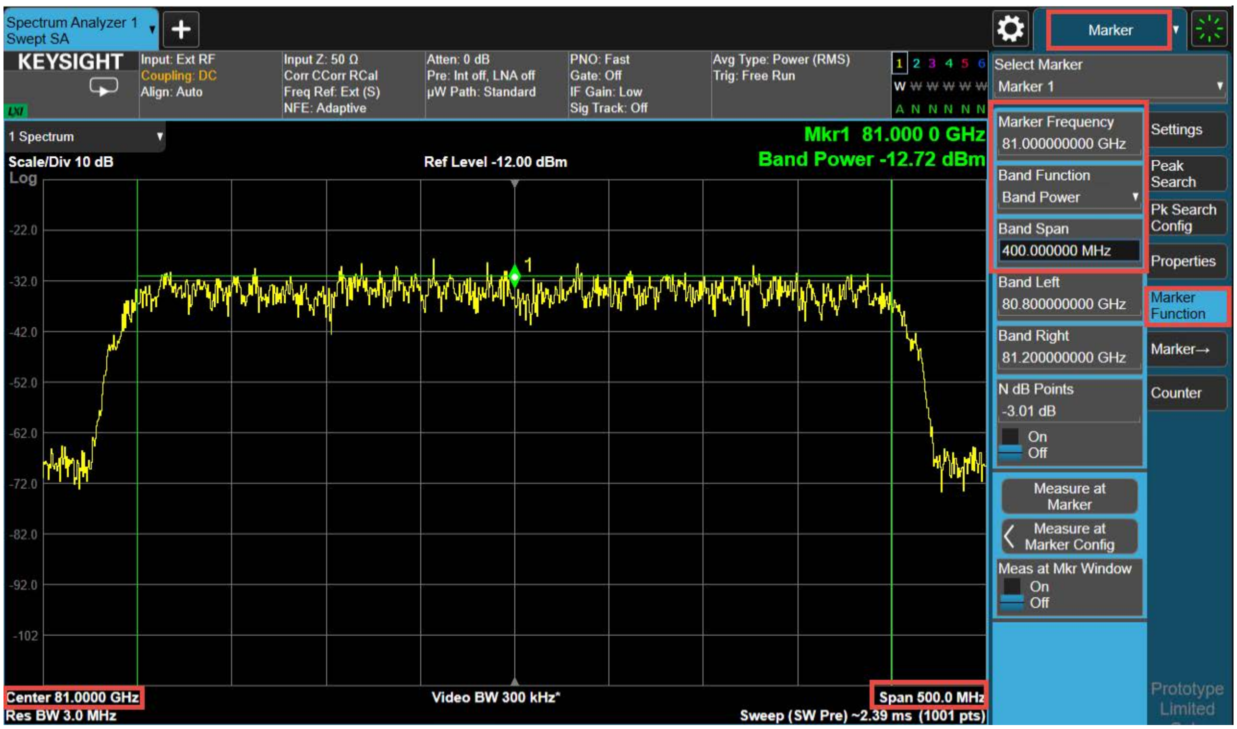


10. Set RF Out to **On** by selecting the numbered channel indicator switch.

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

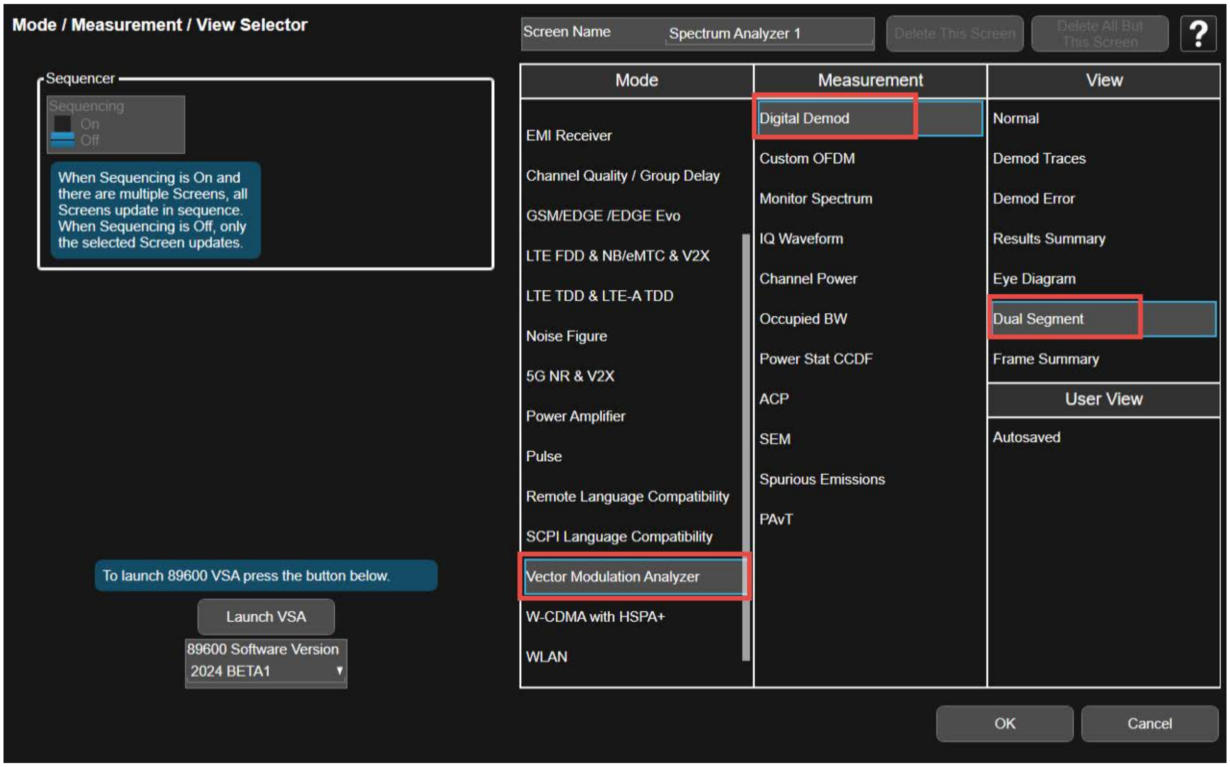
Setting Up the UXA Using X-Apps

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**.

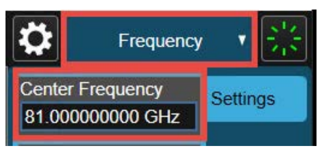


5. Select **Mode/Meas** > **Vector Modulation Analyzer** Mode > **Digital Demod** Measurement > **Dual Segment** View.

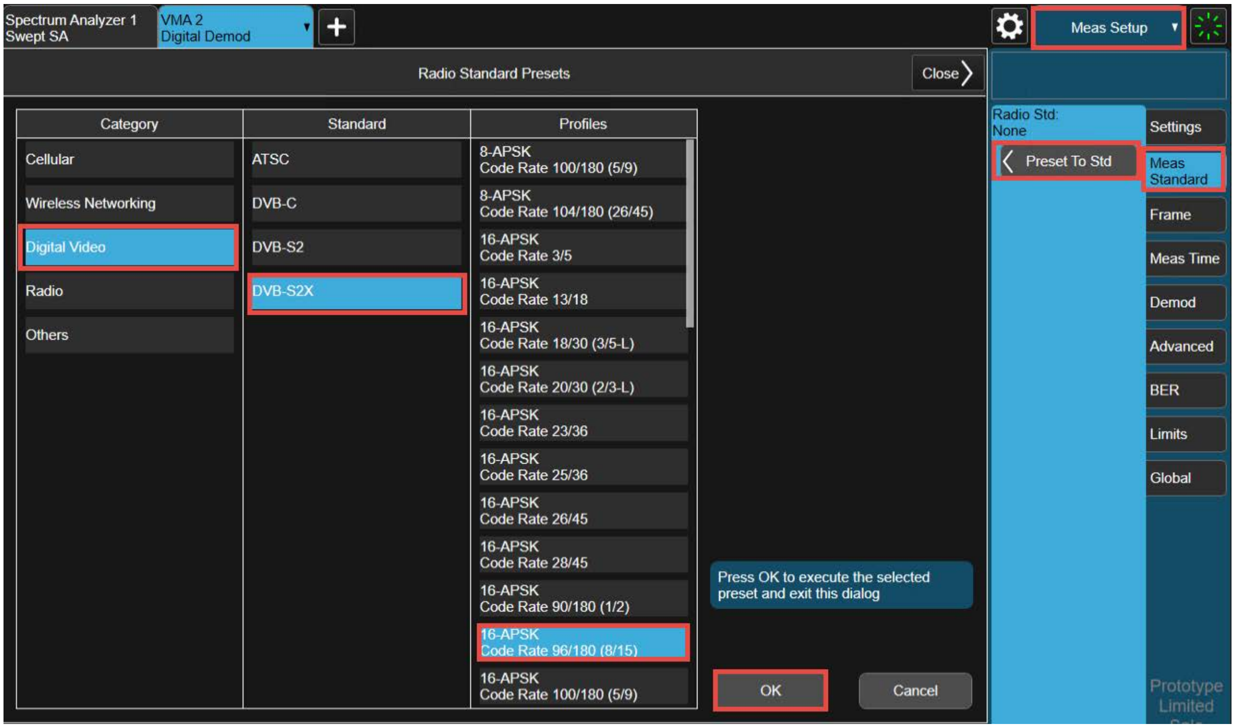
NOTE If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.



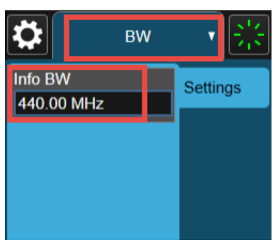
6. Select **Frequency** and set to **81 GHz**.



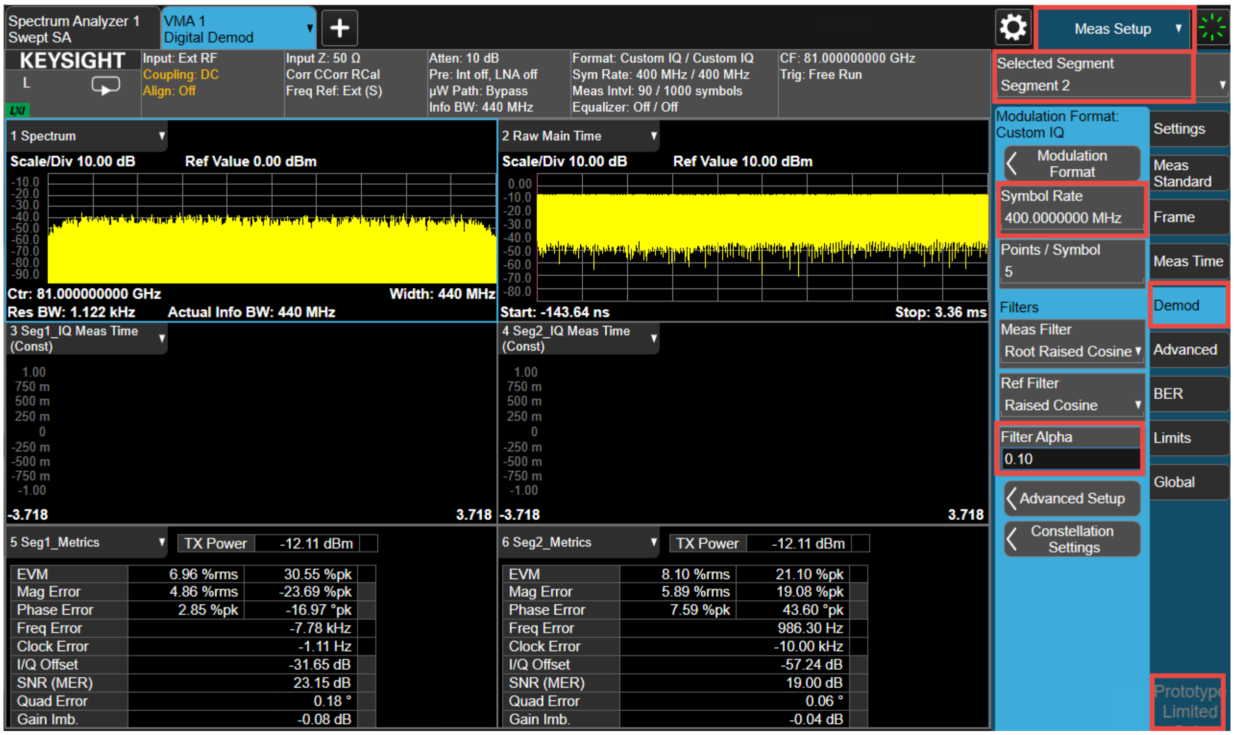
7. Select **Meas Setup** >**Meas Standard** tab > **Presel to Std**, and then select **Digital Video** > **DVB-S2X** > **64-APSK Code Rate 132/180 (11/15)**, then **OK** to close the window.



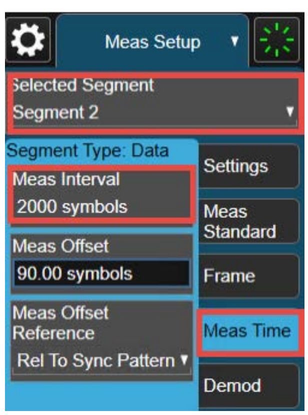
8. Select **BW** and set to Info BW to **440 MHz**.



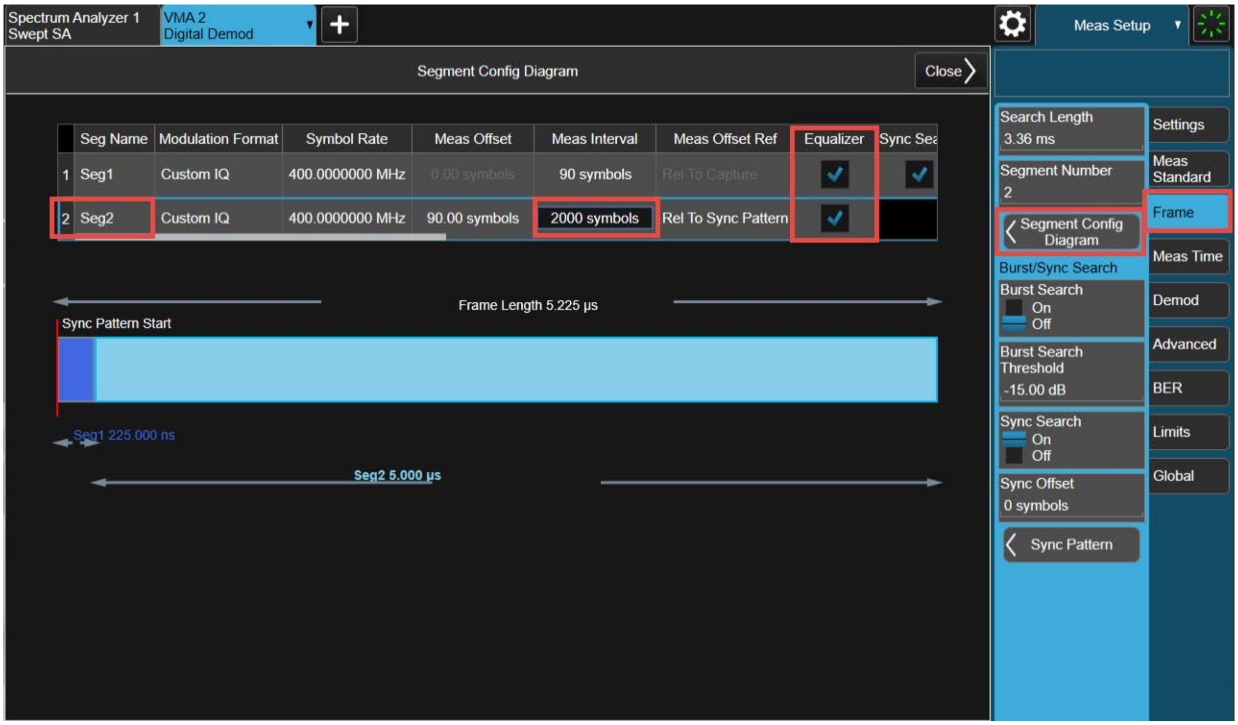
9. Select **Meas Setup** > **Demod** tab and set the Symbol Rate to **400 MHz** and Filter Alpha to **0.1** for both **Segment 1** and **Segment 2** to match the settings in the Custom Modulation Setup.



10. 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.

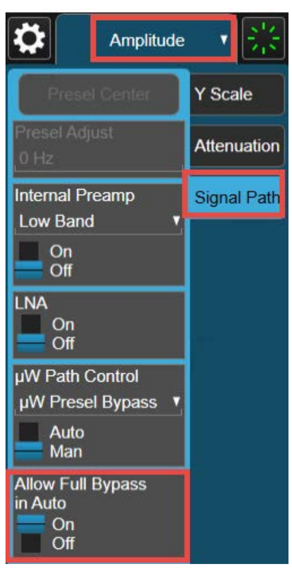


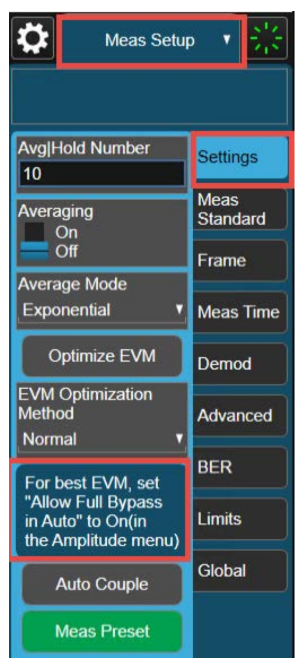
11. Select the **Frame** tab > **Segment Config Diagram** and set **Equalizer** to turn on for both **Segment 1** and **Segment 2**, then **Close** the window.



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

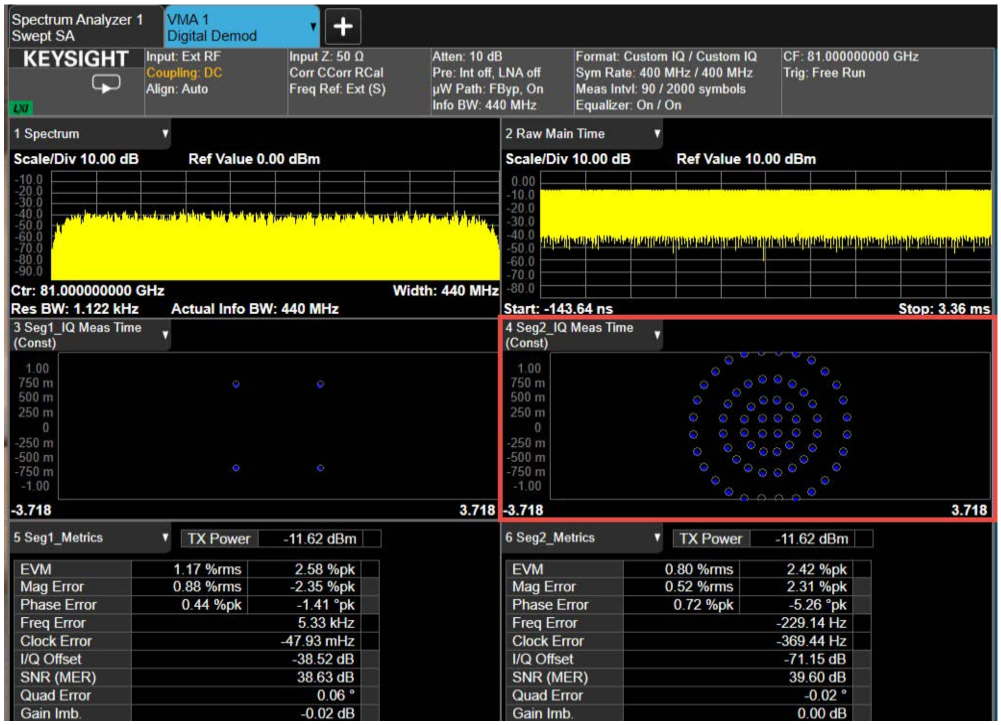
Notice that is recommended in the Meas Setup > Settings tab to turn this on for best EVM results.

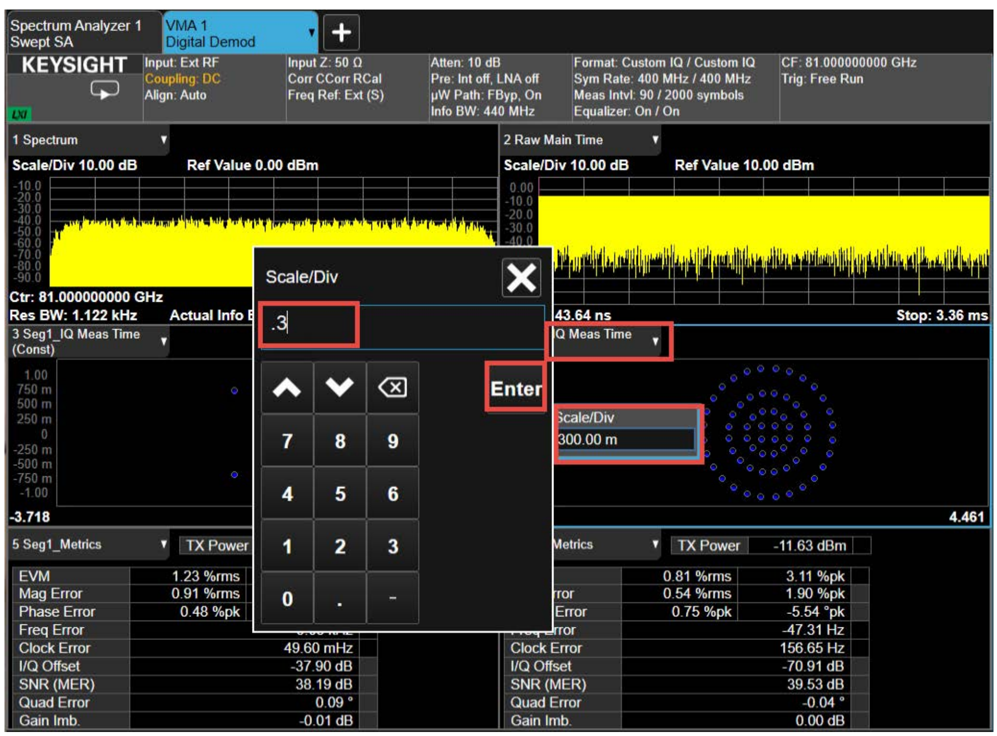




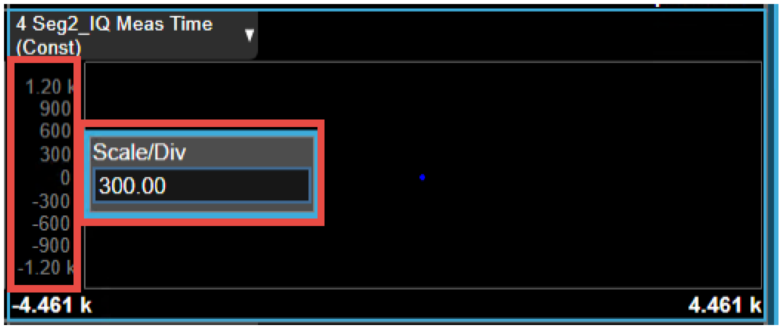
13. At the top of the display, select **Equalizer On/Off**. From the dropdown, select **Equalizer Reset**.

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**.



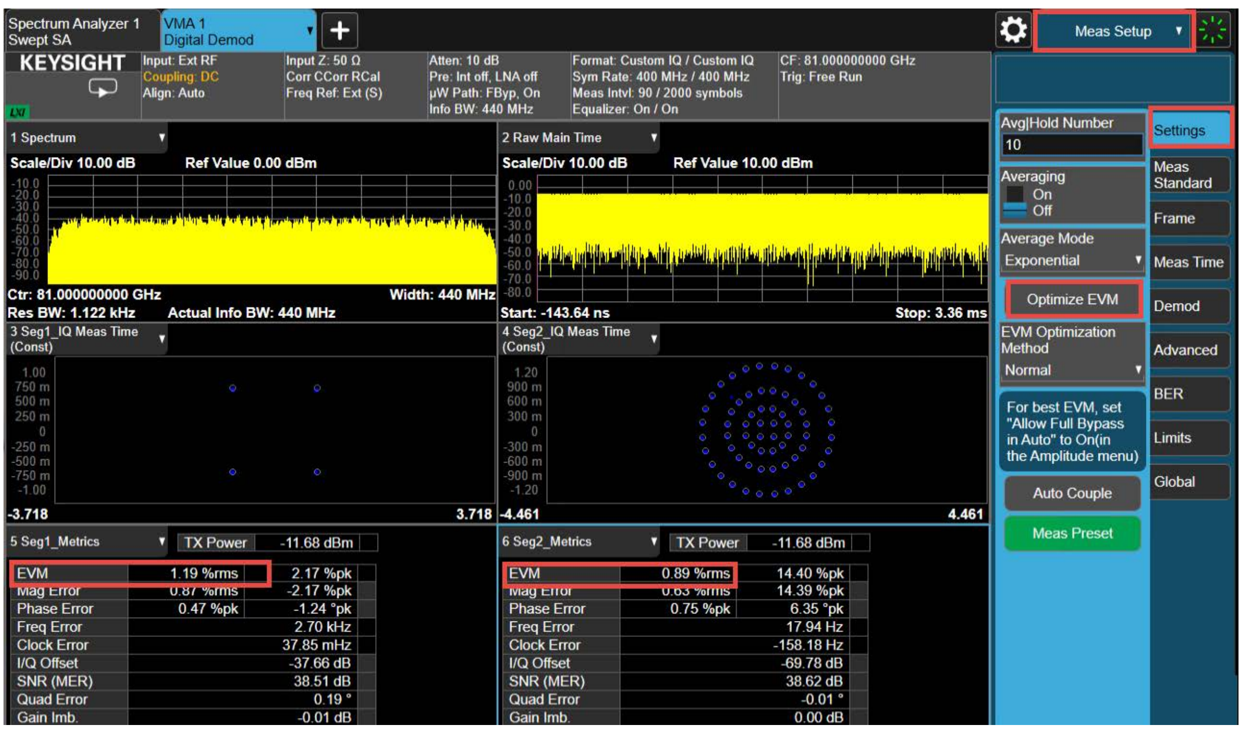


NOTE You must set this value to 300 instead of .3, the scaling gets changed to 250 k per division instead of 250 m per division.

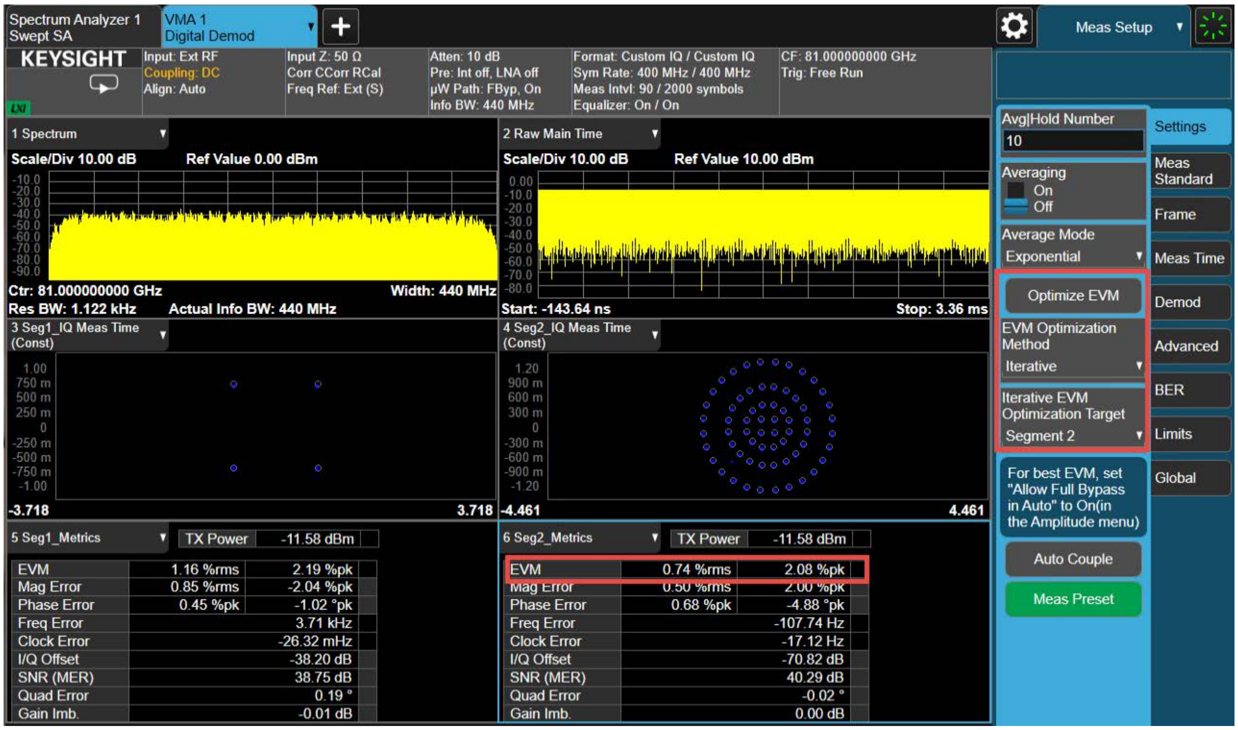


15. Select **Meas Setup** > **Settings** tab > **Optimize EVM**.

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

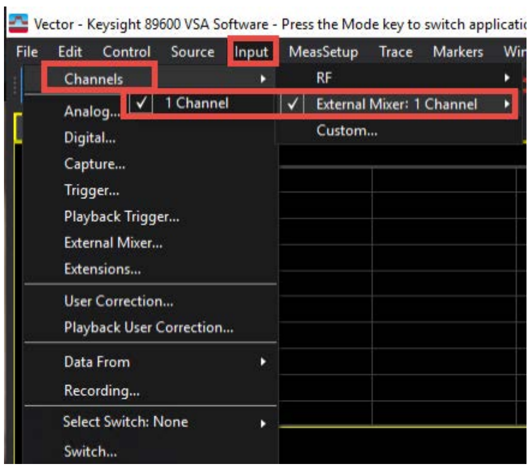
NOTE Changing settings on the VSA can take longer to take affect than expected. Pausing the measurement until all settings have been made will help speed up the time. Wait to change the next setting until the previous setting has been updated.

1. Open the VSA software.

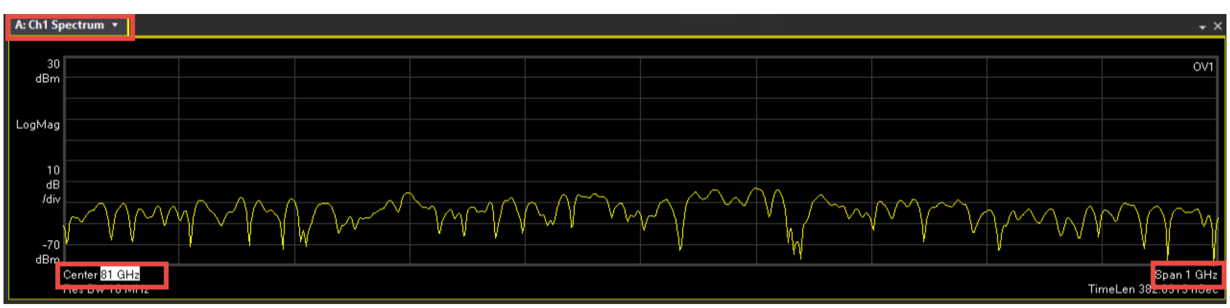
   To access the VSA software, go to the Windows Start menu and find Keysight 89600 Software (latest installed version) folder and run the software.

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**.



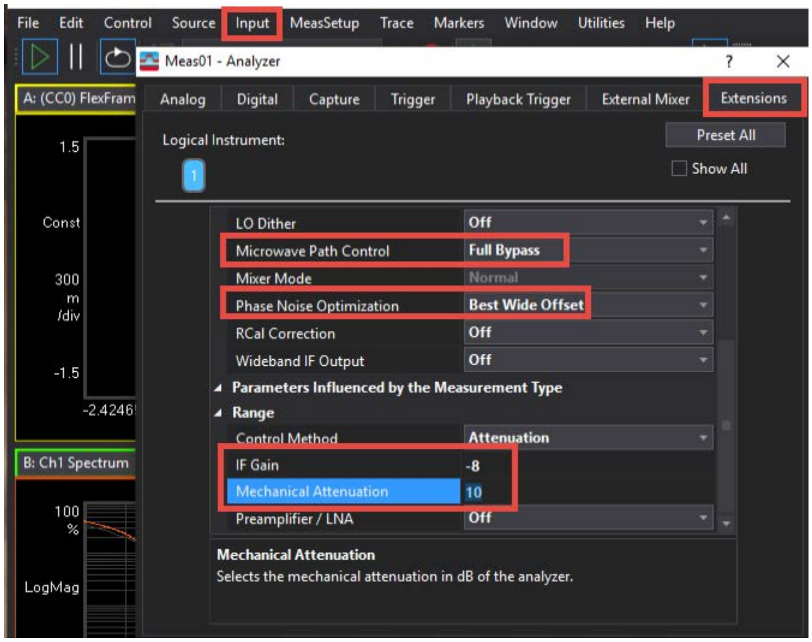
4. In the **Spectrum** window, select **Center** and set the Center Frequency to **81 GHz**. and Span to **1 GHz**.



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

   – Microwave Path Control to **Full Bypass**

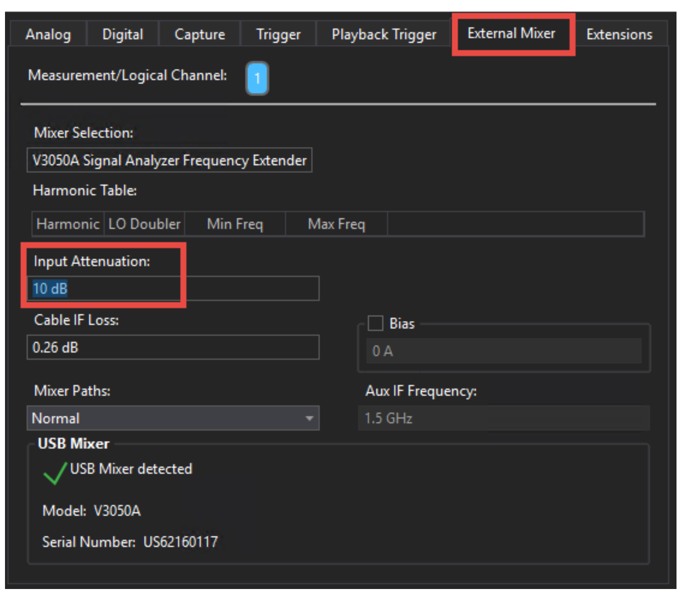
   – Phase Noise Optimization to **Best Wide Offset**



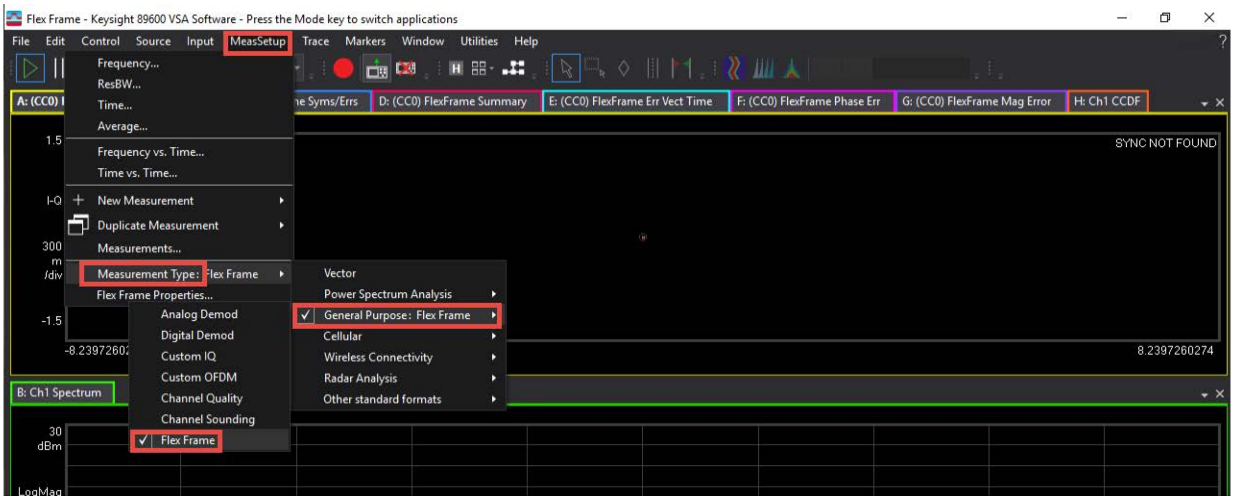
   – IF Gain to **-8 dB**

   – Select the External Mixer tab and set Input Attenuation to **10 dB**

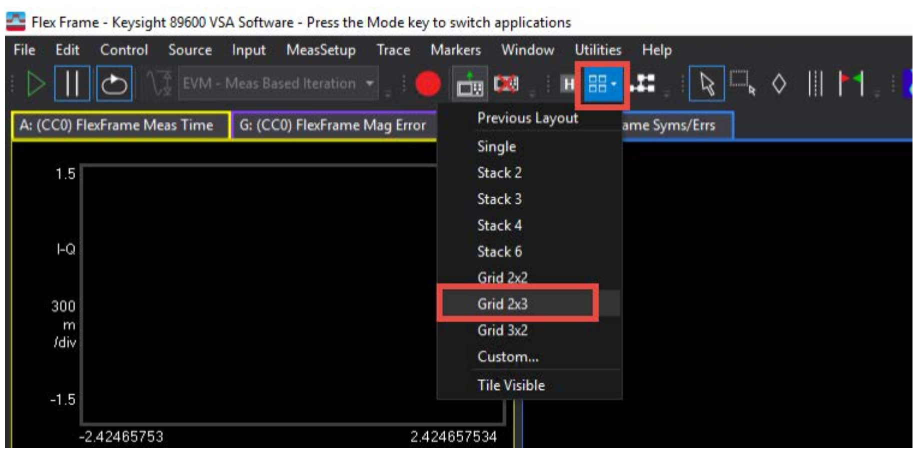
   These are the optimized settings we used in the X-Apps measurement.



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



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

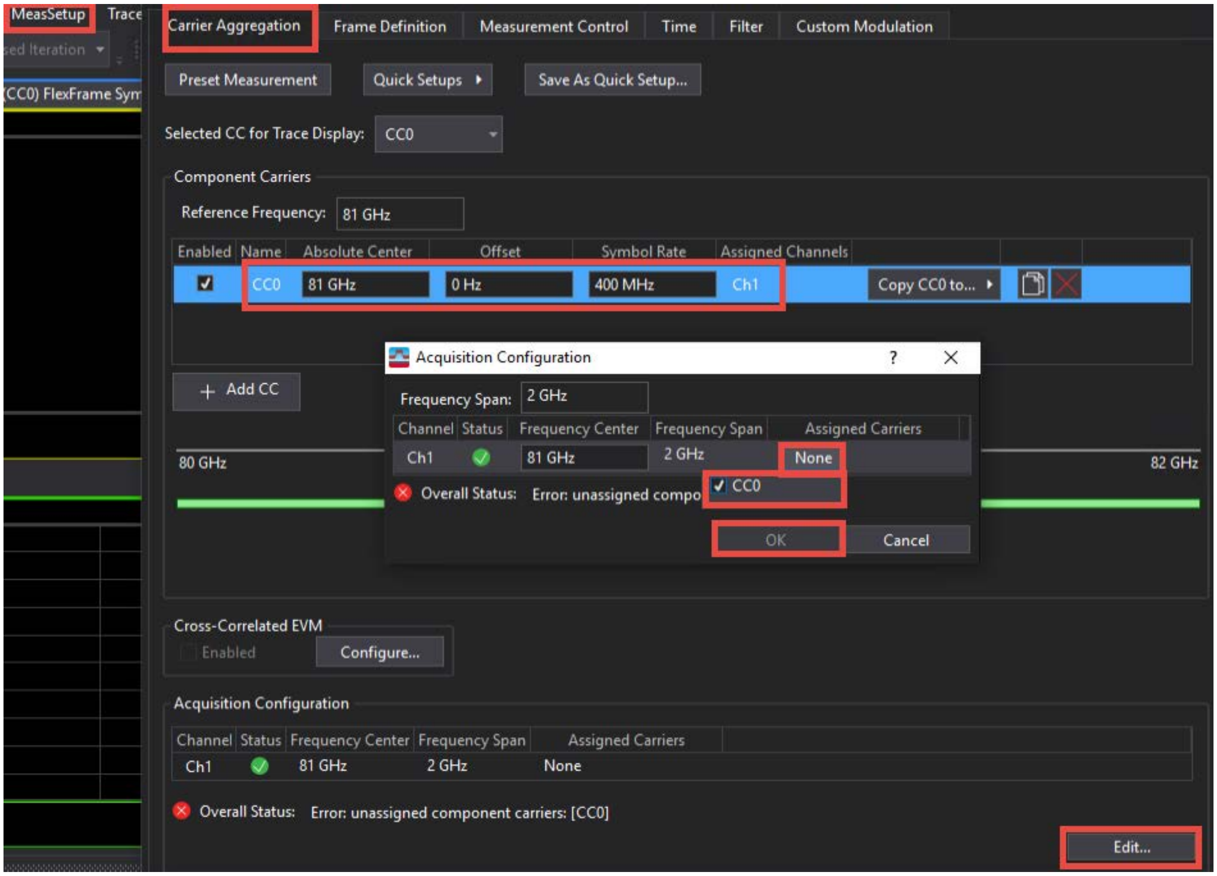


8. Select **MeasSetup** > **Flex Frame Properties** > **Carrier Aggregation** tab, and set:

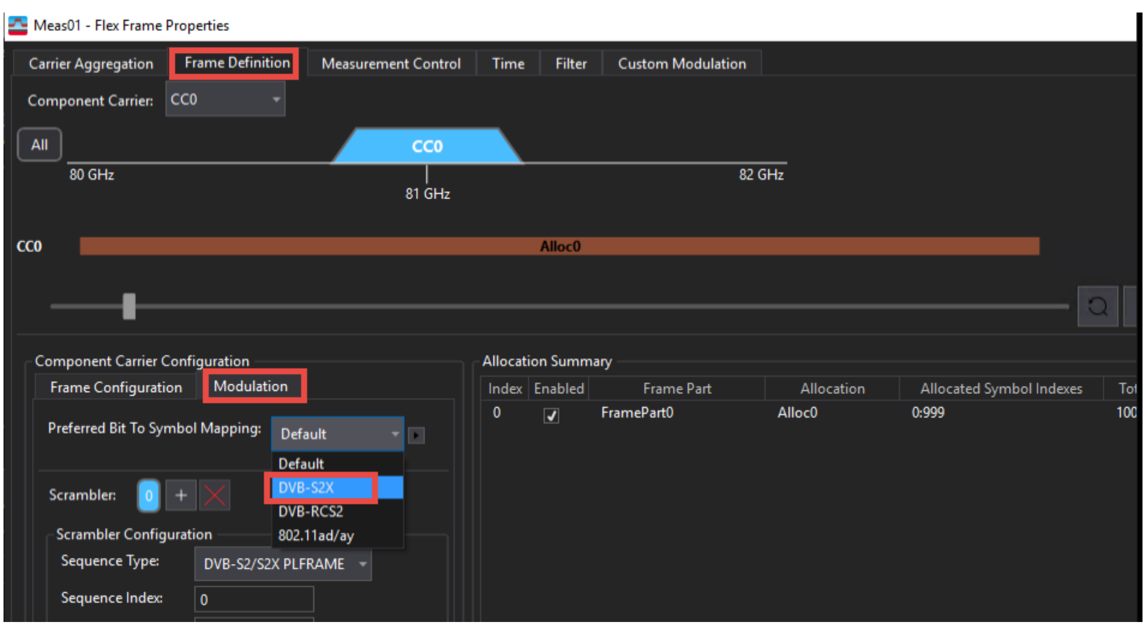
   – CCO Absolute Center frequency to **81 GHz**

   – Symbol Rate to **400 MHz**.

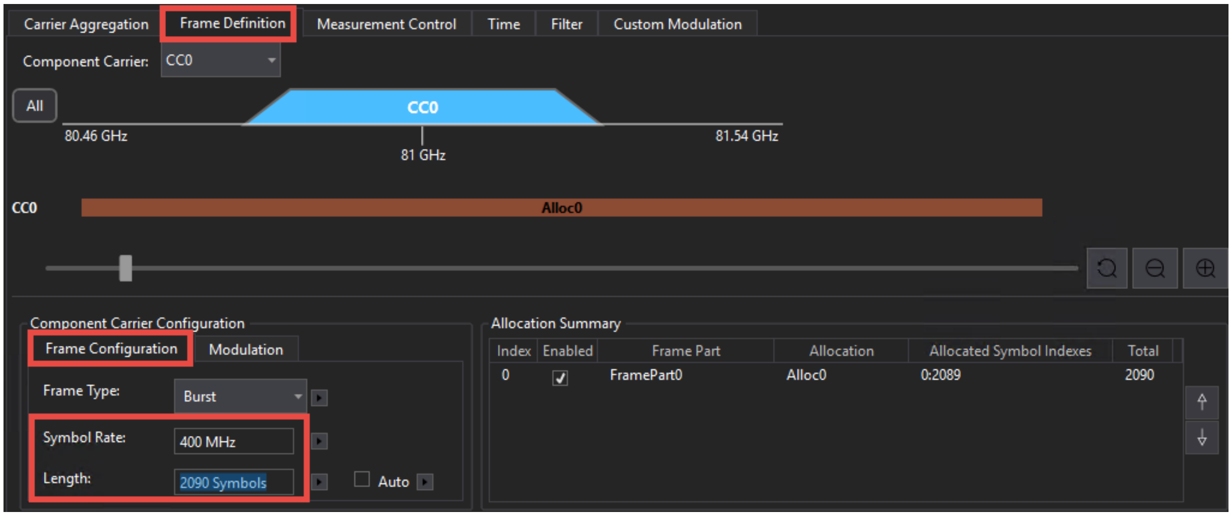
– **Edit** dropdown and set Assigned Carriers to **CC0**.



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**.



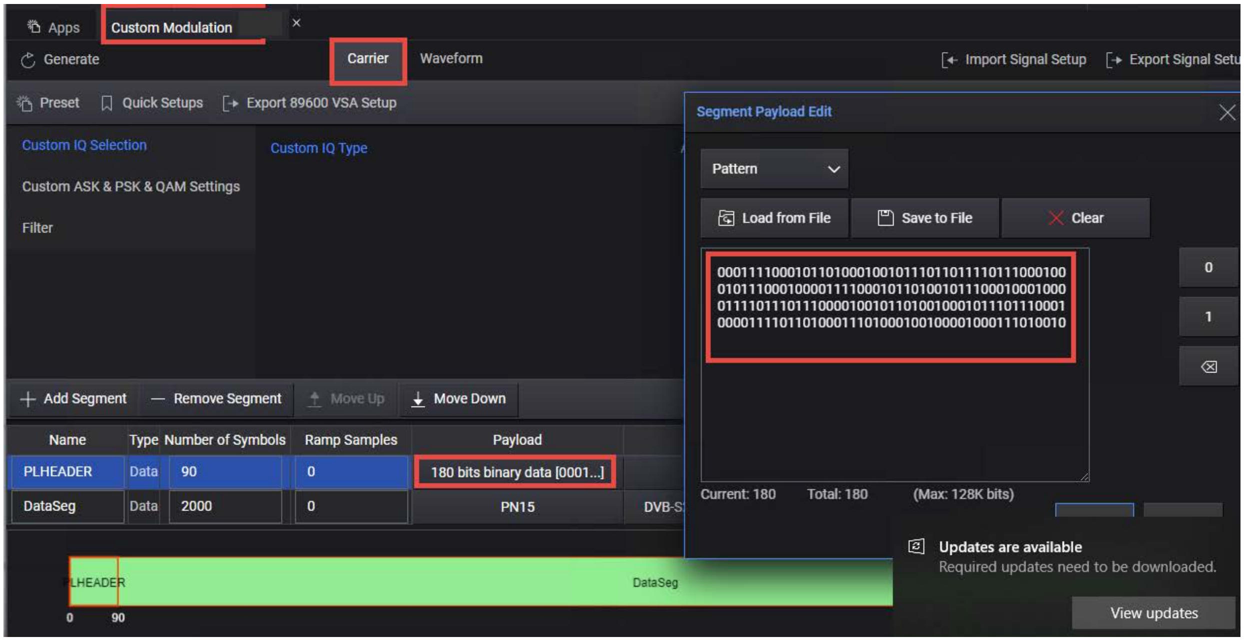
10. In the Frame Definition tab, under Component Carrier Configuration, select the **Frame Configuration** tab and set Symbol Rate to **400 MHz** and Length to **2090 Symbols**.



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**

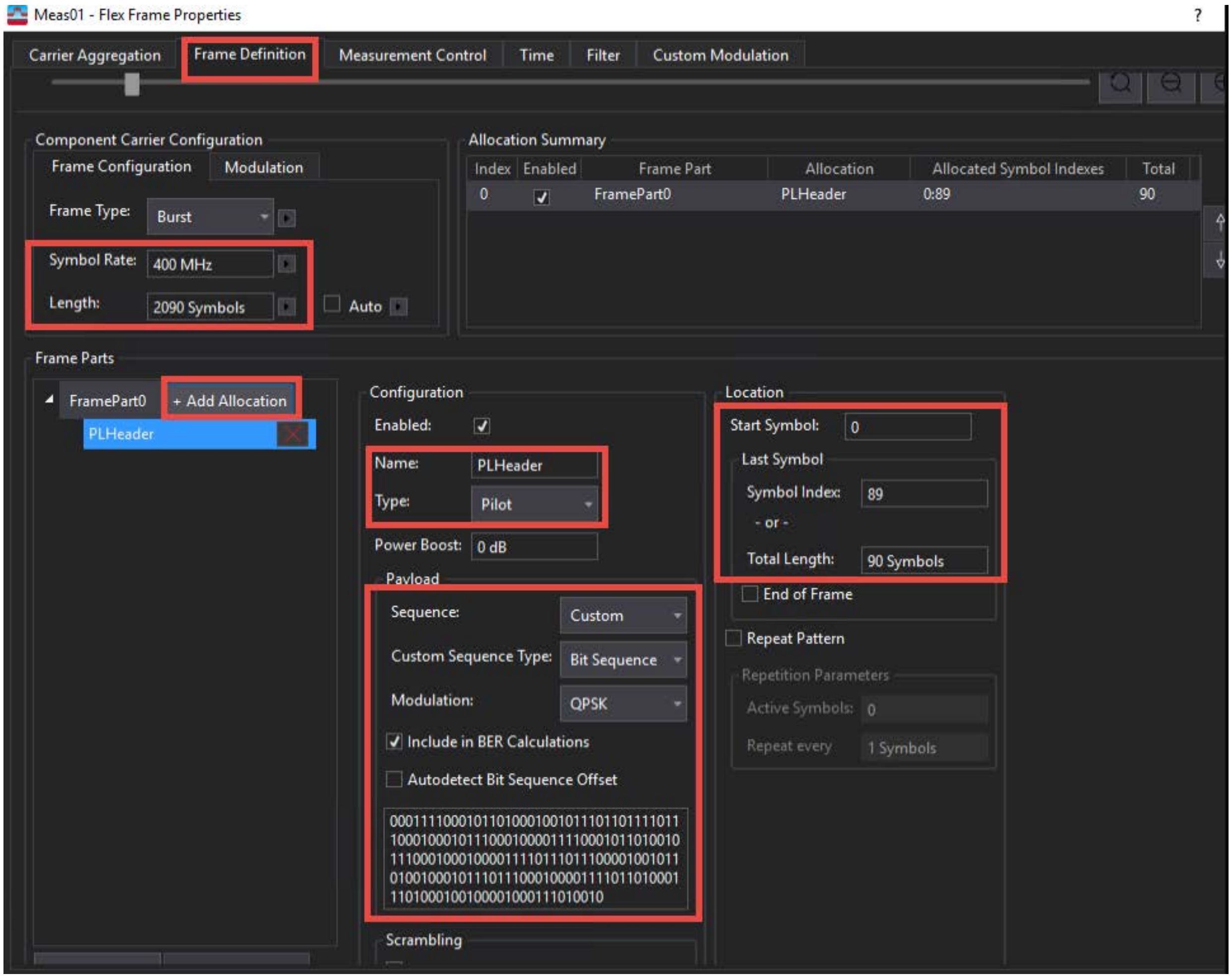
- Go back into the VXG Custom Modulation setup **Carrier** tab and select PLHEADER **Payload** to open and copy the symbols.



- 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**

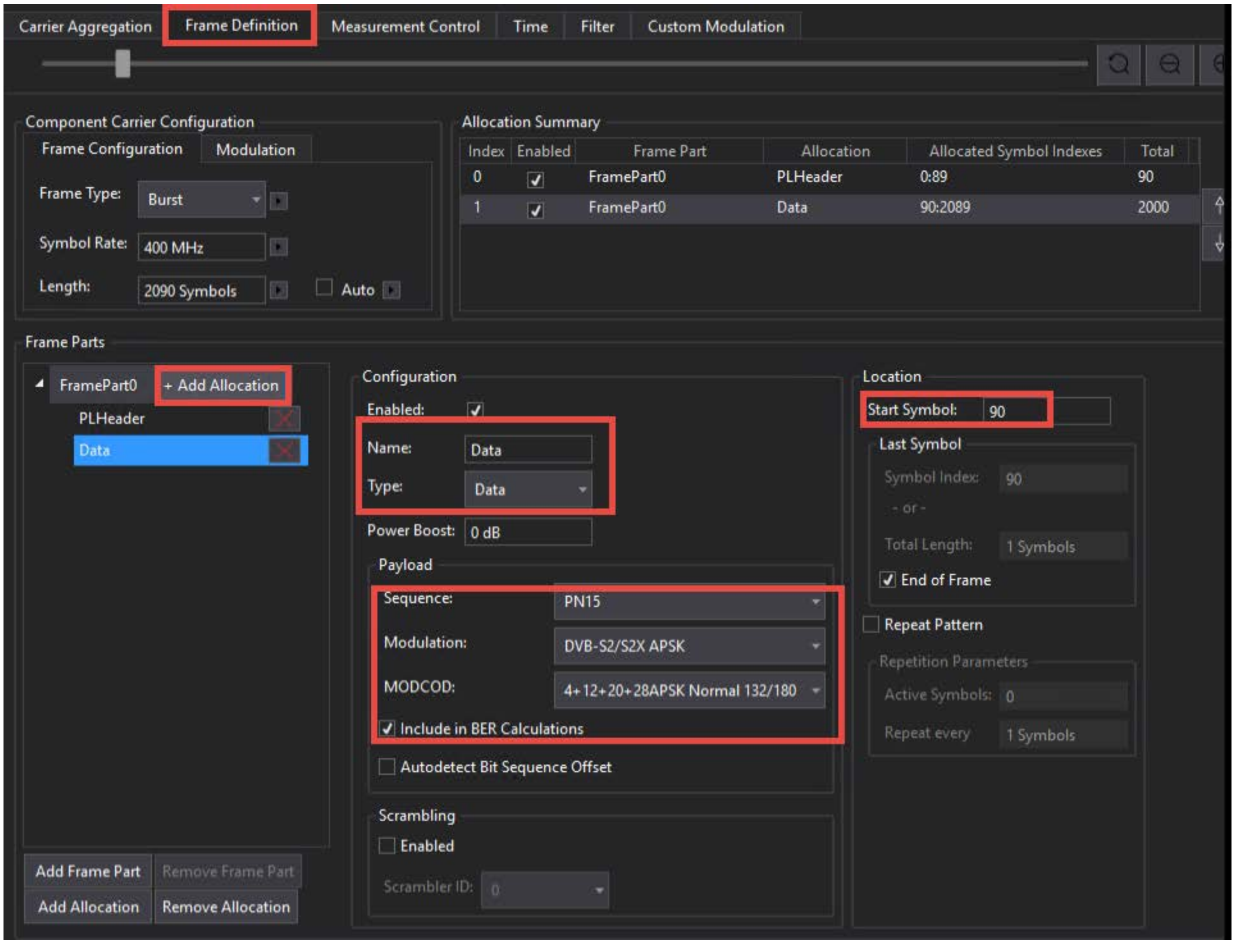
– Sequence to **PN15**

– 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**.



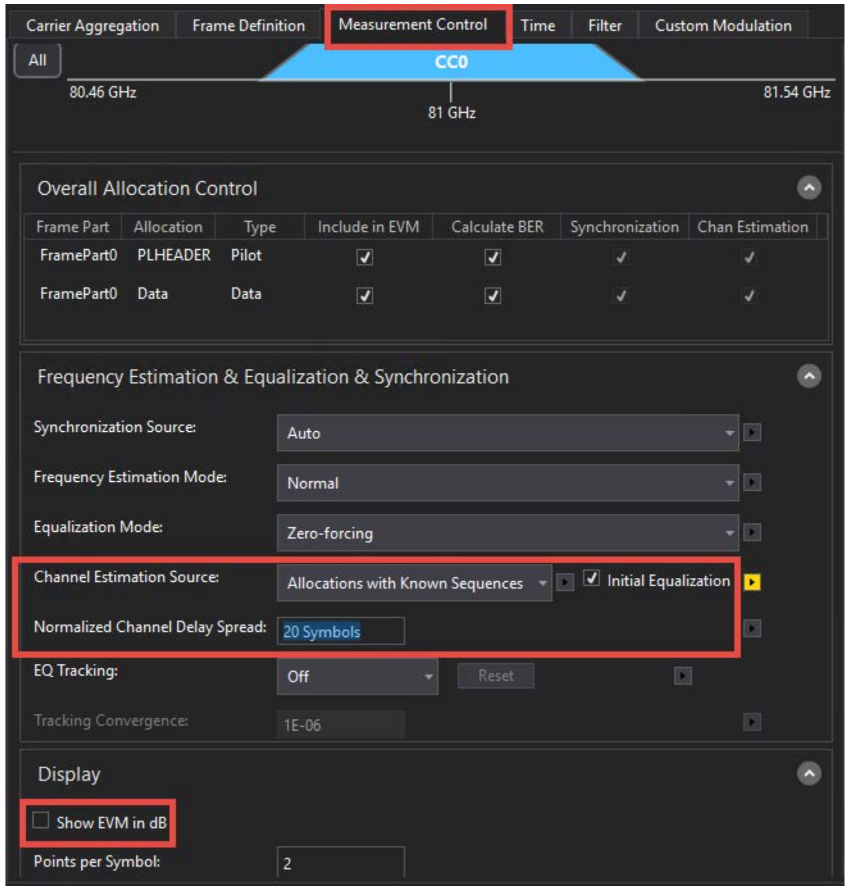
13. In the **Measurement Control** tab, and set:

– Channel Estimation Source to **Allocations with Known Sequences**

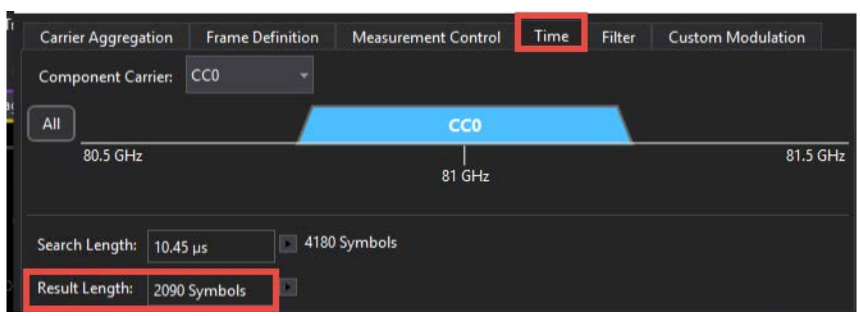
– Select **Initial Equalization**

– Normalized Channel Delay Spread to **20 Symbols**

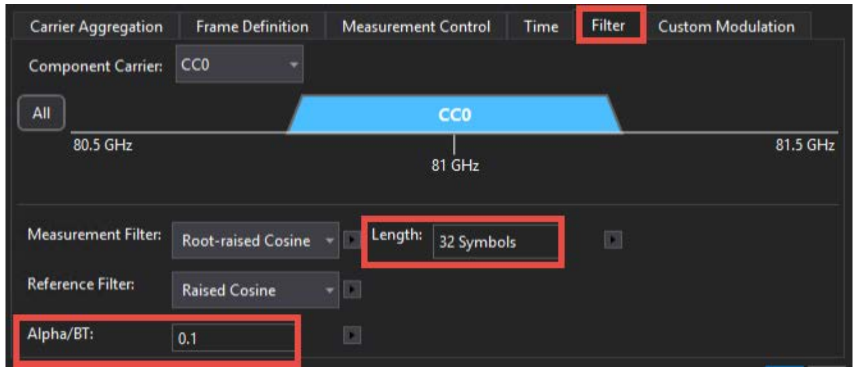
– Clear the **Show EVM in dB** checkbox



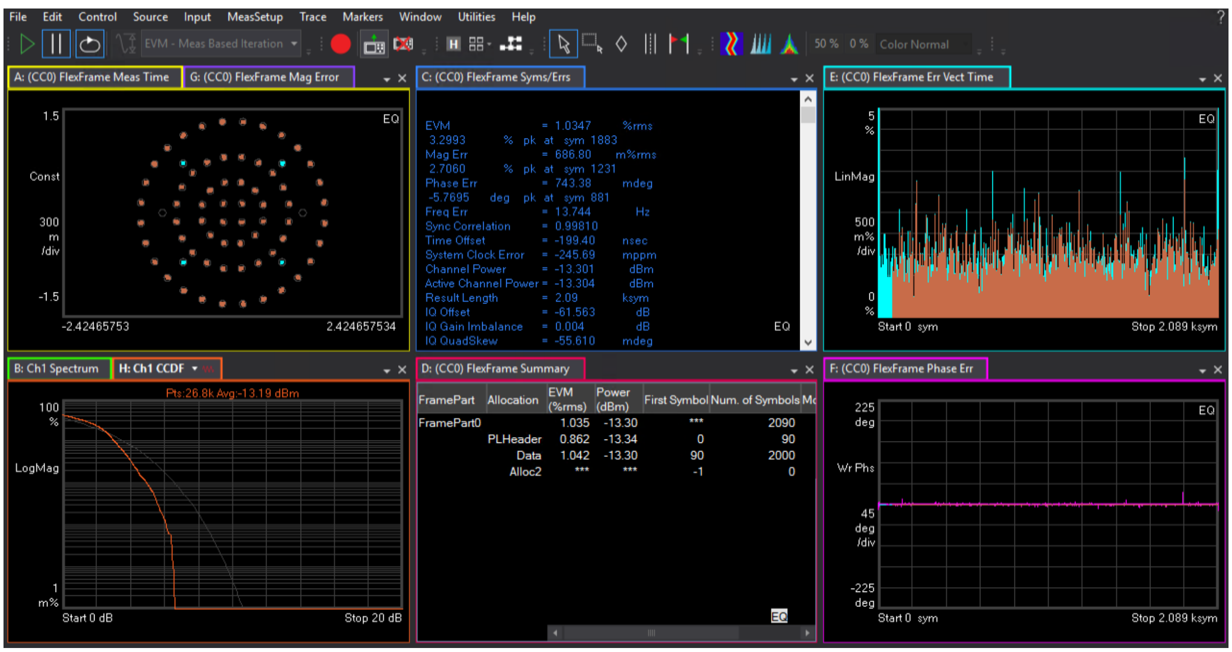
14. In the **Time** tab, set Result Length to **2090 Symbols**.



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

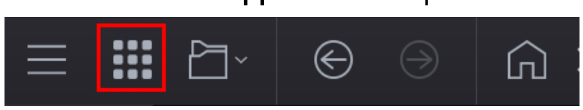
On the VXG:

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**.

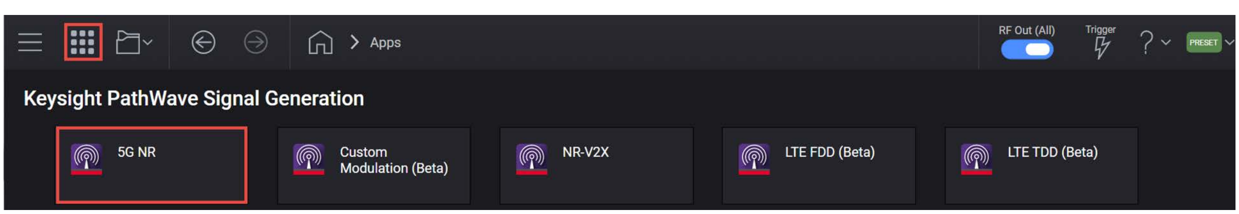
NOTE

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.

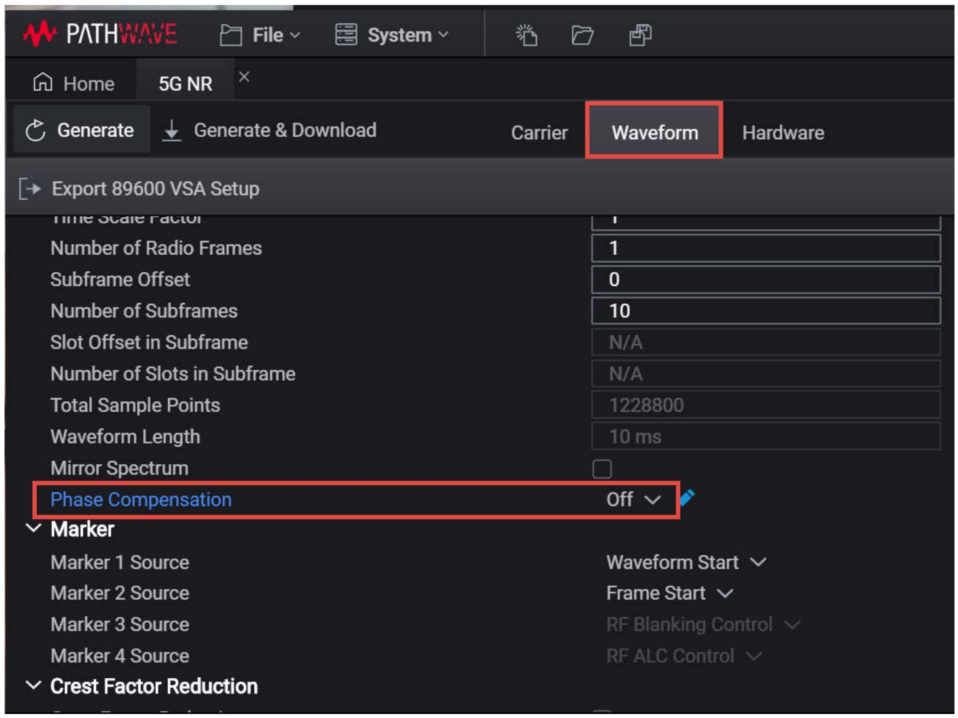


4. Select **5G NR**.



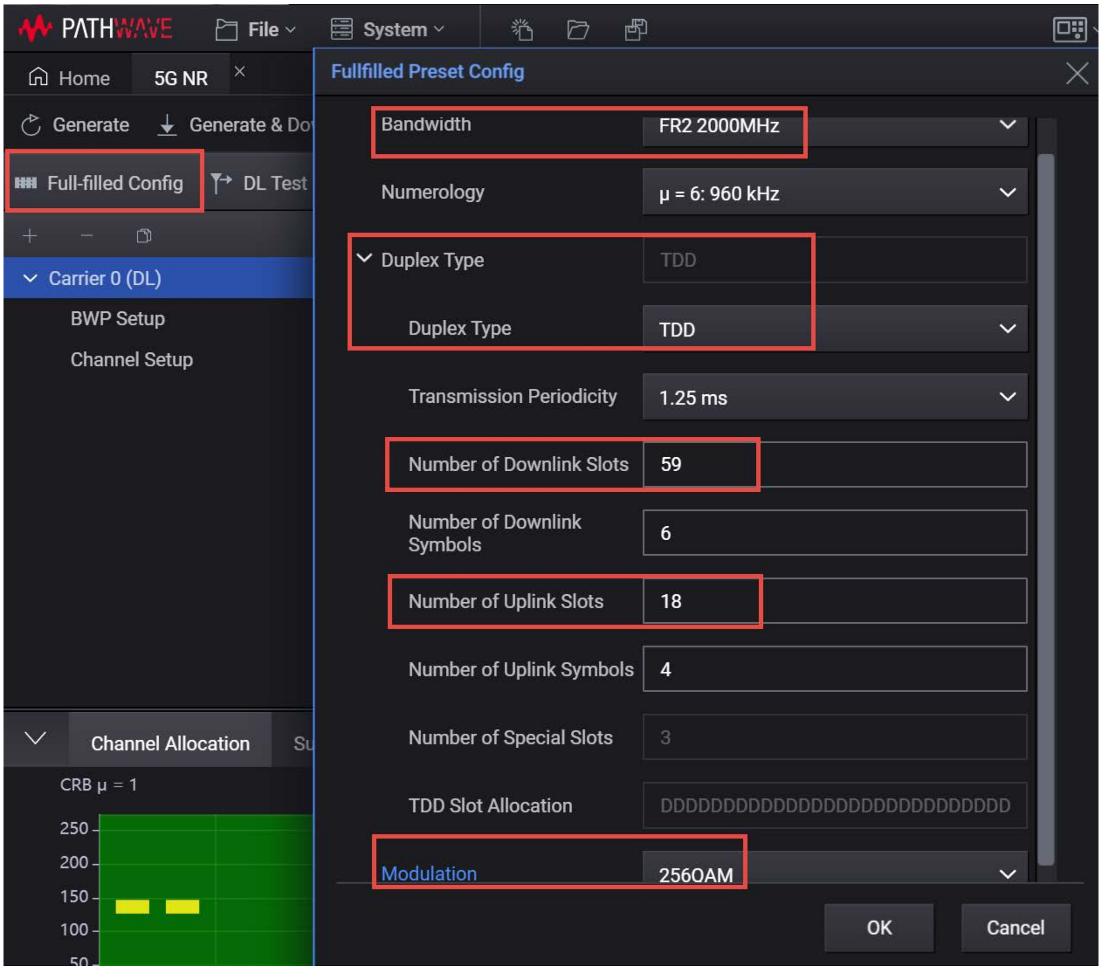
5. Select the **Waveform** tab and turn off **Phase Compensation** so the same waveform can be used at different frequencies.

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.

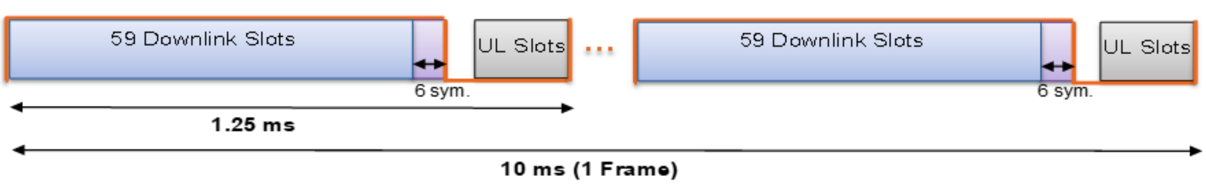


6. To configure the Downlink carrier, select the **Carrier** tab > **Full-filled Config** and set:
   - Bandwidth to **FR2 2000 MHz**
   - Duplex Type to **TDD**
   - Number of Downlink slots to **59**
   - Number of Uplink Slots to **18**
   - Modulation to **256 QAM**

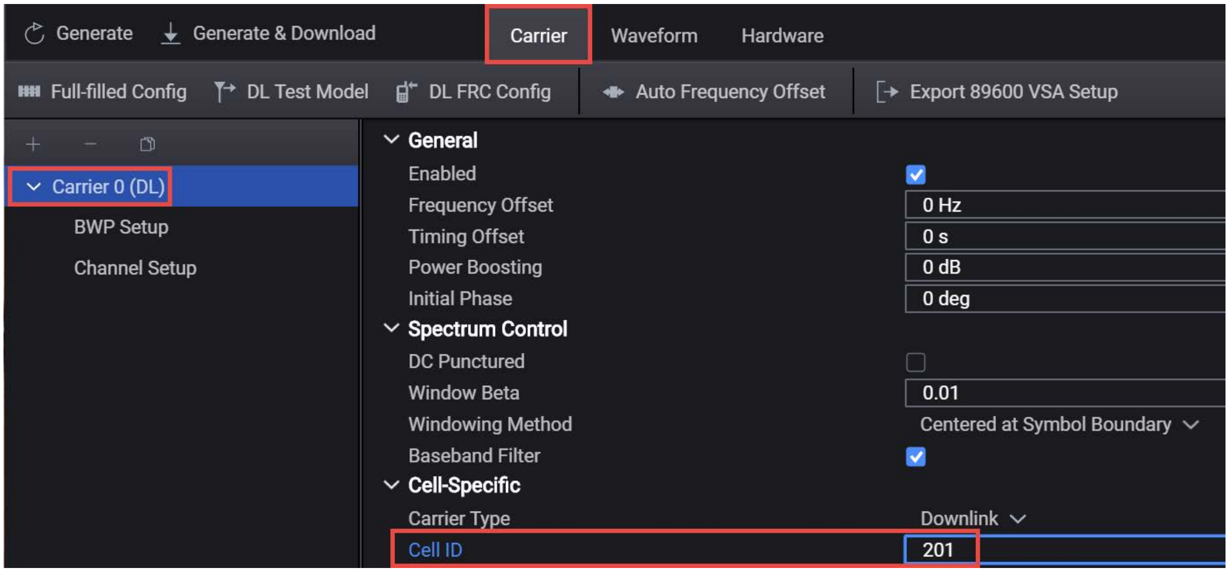
– Select **OK** to close the window.



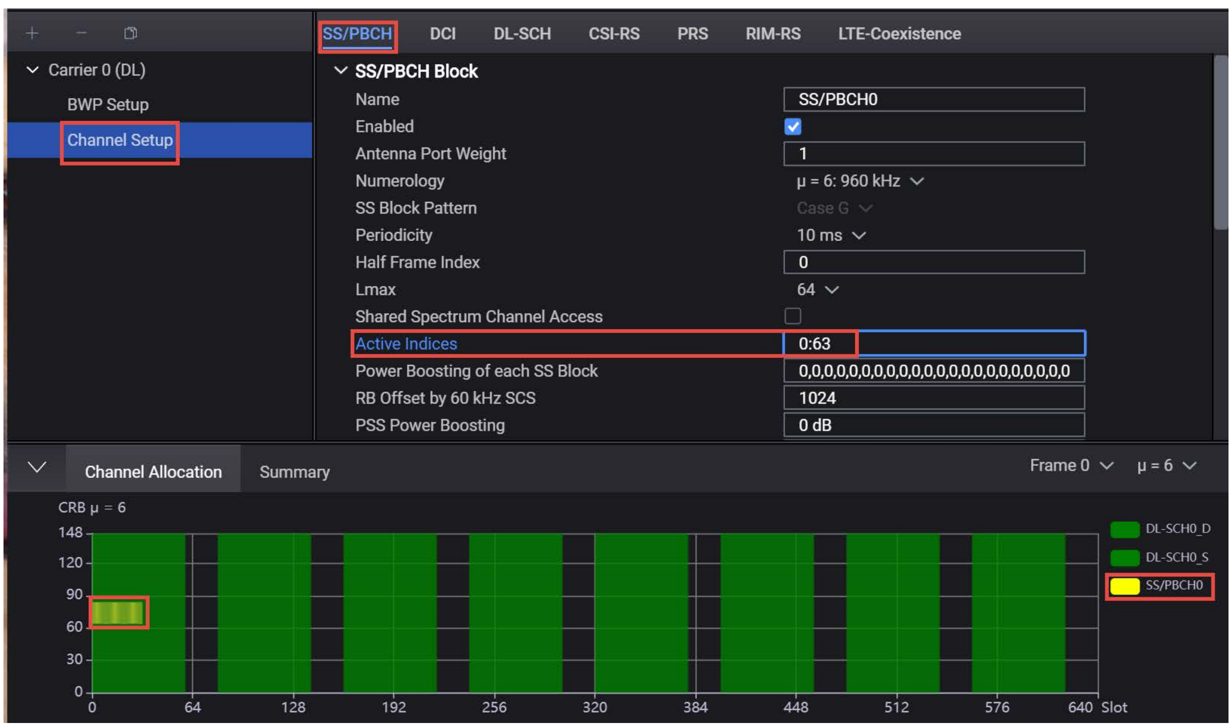
These parameters are based on 3GPP endorsed Test Model for 2000 MHz bandwidth.



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**.

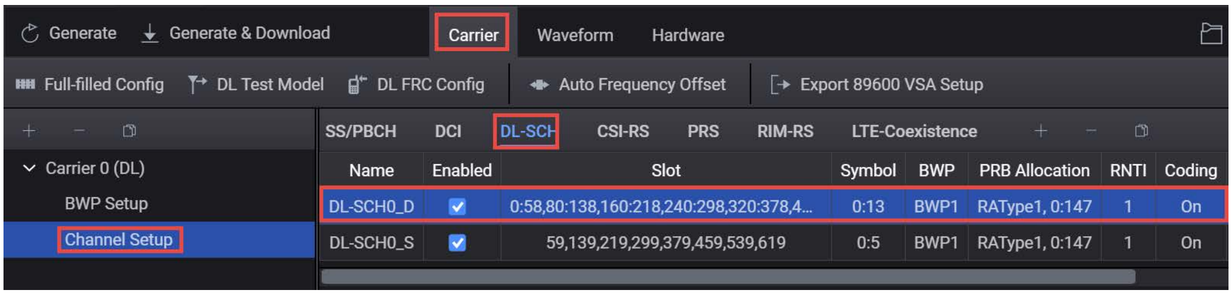


With RB Offset by 60 kHz SCS set to 1024 and kSSB by subcarrierSpacingCommon set to 0, the SSB is set to the center of the carrier. This is shown in the Channel Allocation graph at the bottom of the window. If you set it to 0, the SSB will be set in the lower band of the carrier.

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 were 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.

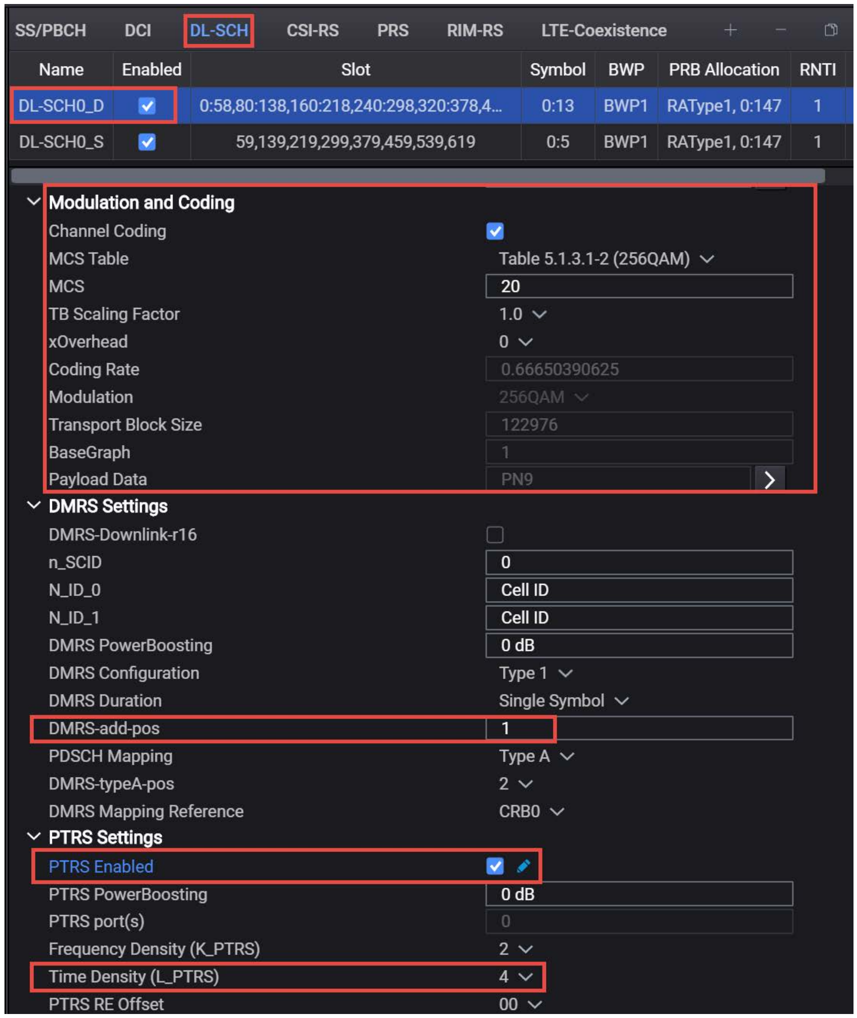


- Confirm Allocated Slots is set to **0:58,80:138,160:218,240:298,320:378,400:458,480:538,560:618**

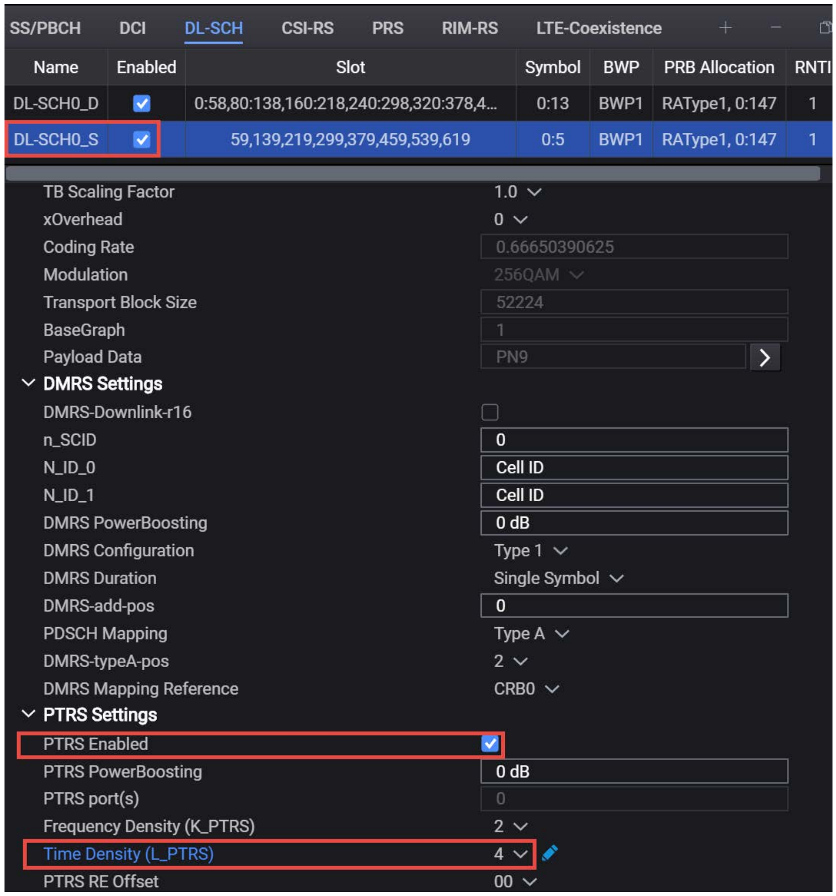
  These values will be used in the VSA/X-App. You can copy these values for easier setup later.

- 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.

– Set Time Density to **4**.

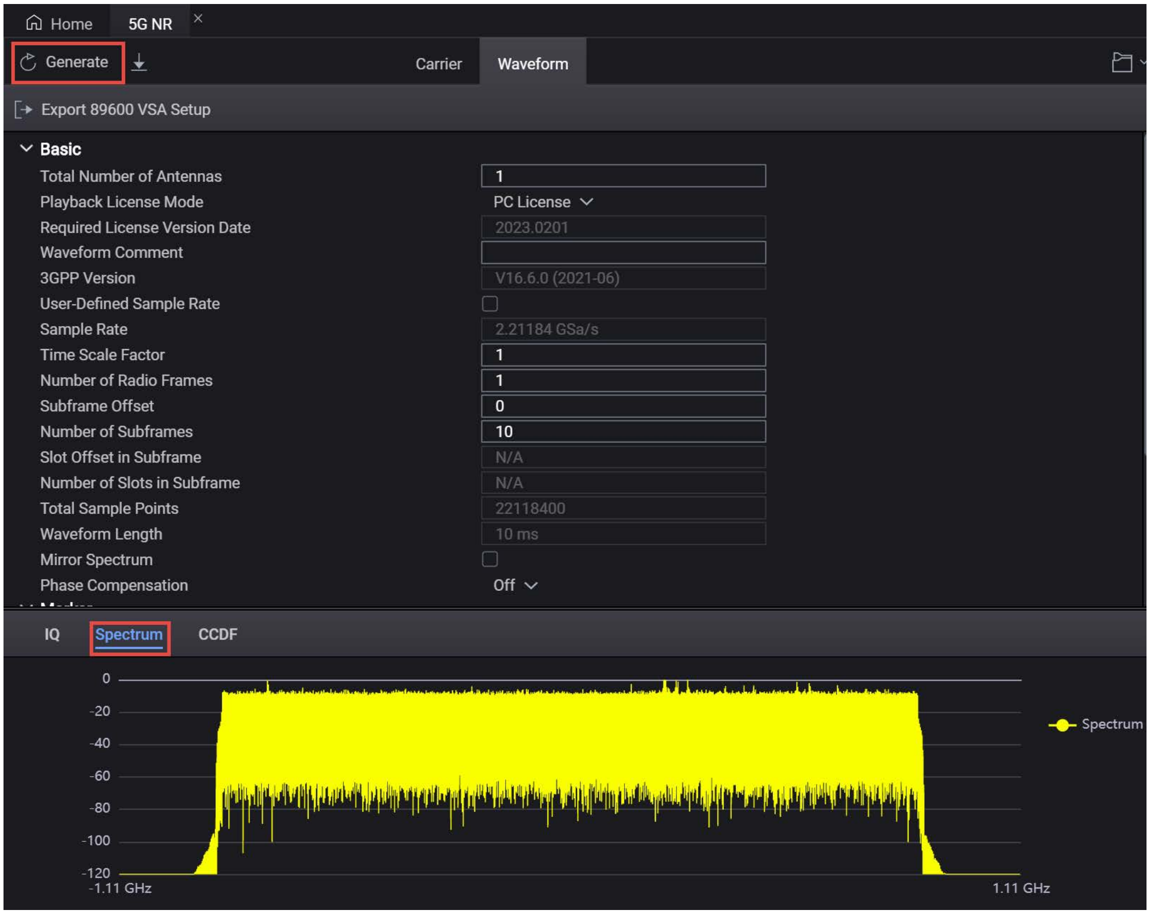


10. Select **DL-SCH0_S**. Set **PTRS Enabled** and Time Density to **4.** Confirm that Allocated Slots is set to **59,139,219,299,379,459,539,619**.



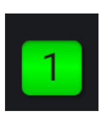
11. Select the Waveform tab, then **Generate** to generate the Waveform, and then select **Home** to exit the setup panel.

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

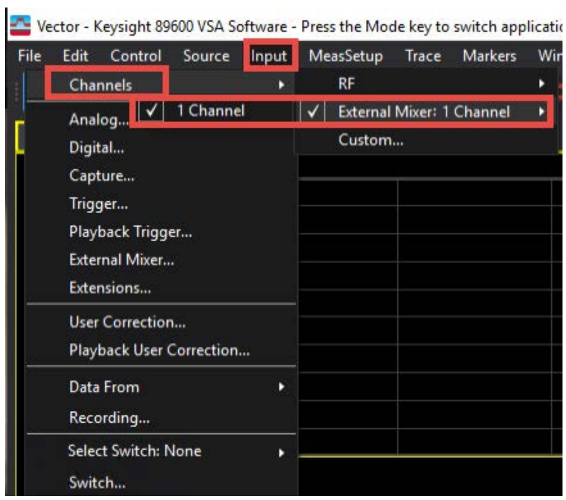
Changing settings on the VSA can take longer to take affect than expected. Stopping the measurement (Control menu > Stop) until all settings have been made will help speed up the setup time.

1. Open the VSA software.

NOTE

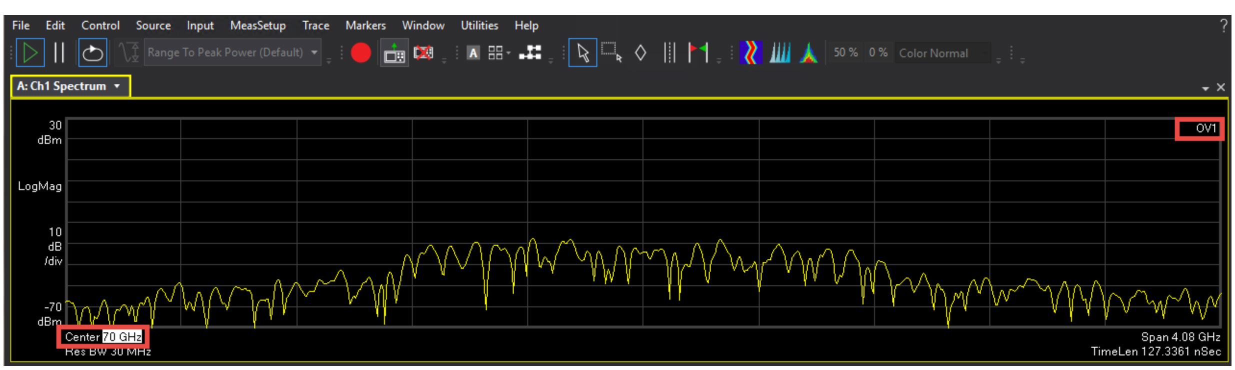
If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window, then select **Launch VSA**.

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**.



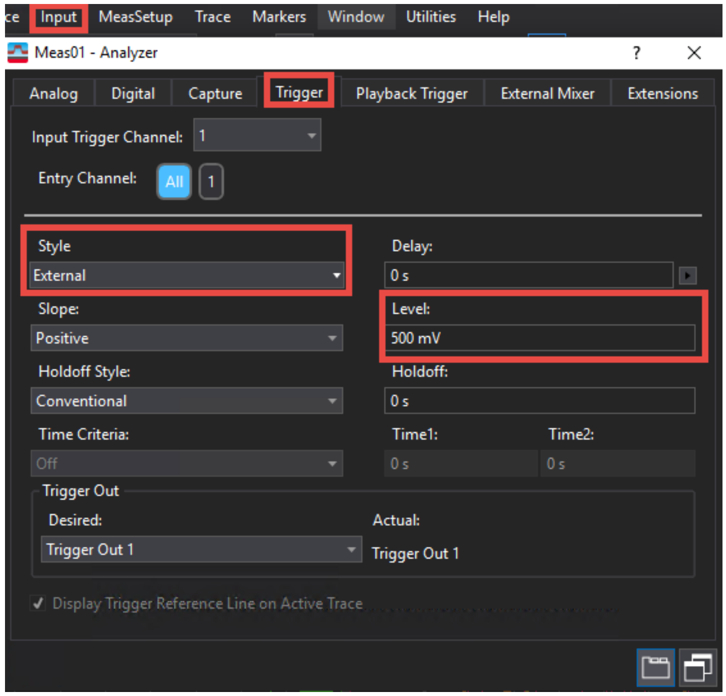
4. In the **Spectrum** window, select **Center** and set the Center Frequency to **70 GHz**.

   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.



5. 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.

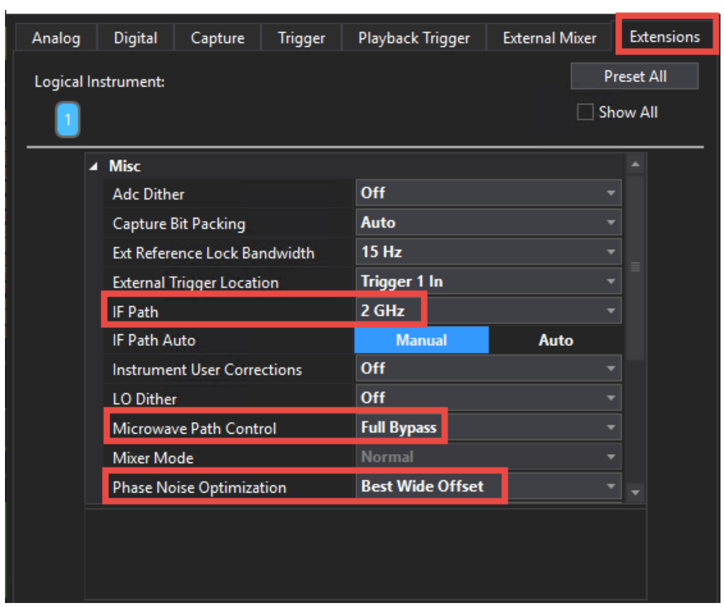


6. Select the **Extensions** tab and set:

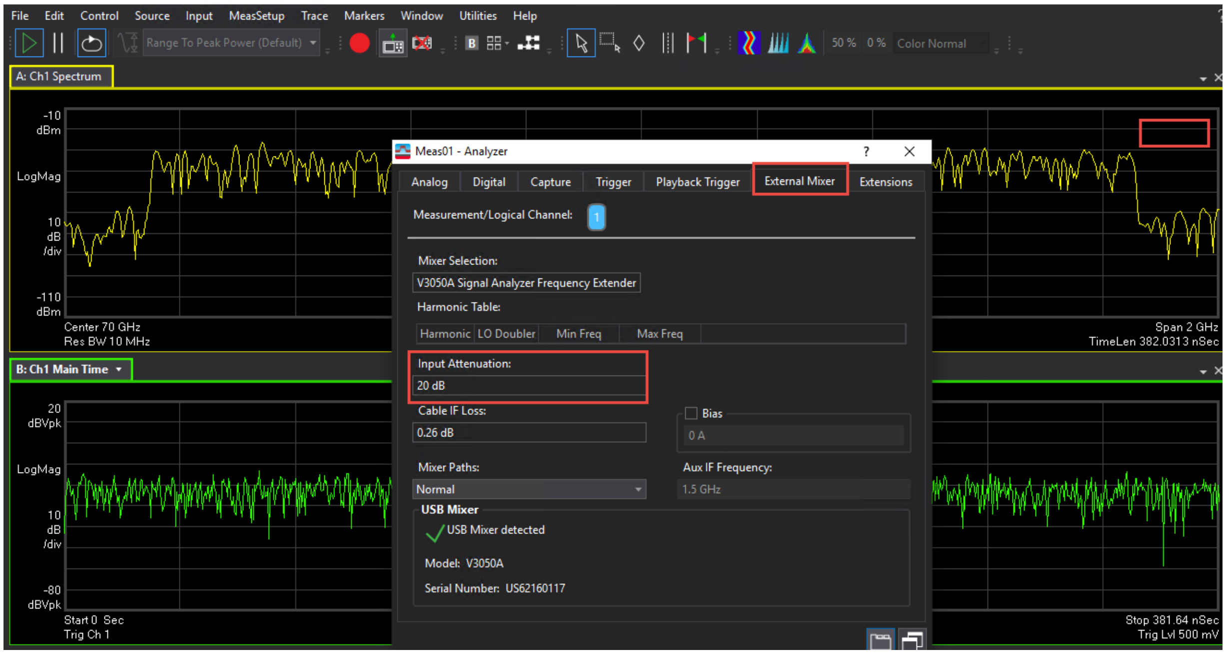
   – IF Path to **2 GHz**

   – Microwave Path Control to **Full Bypass**

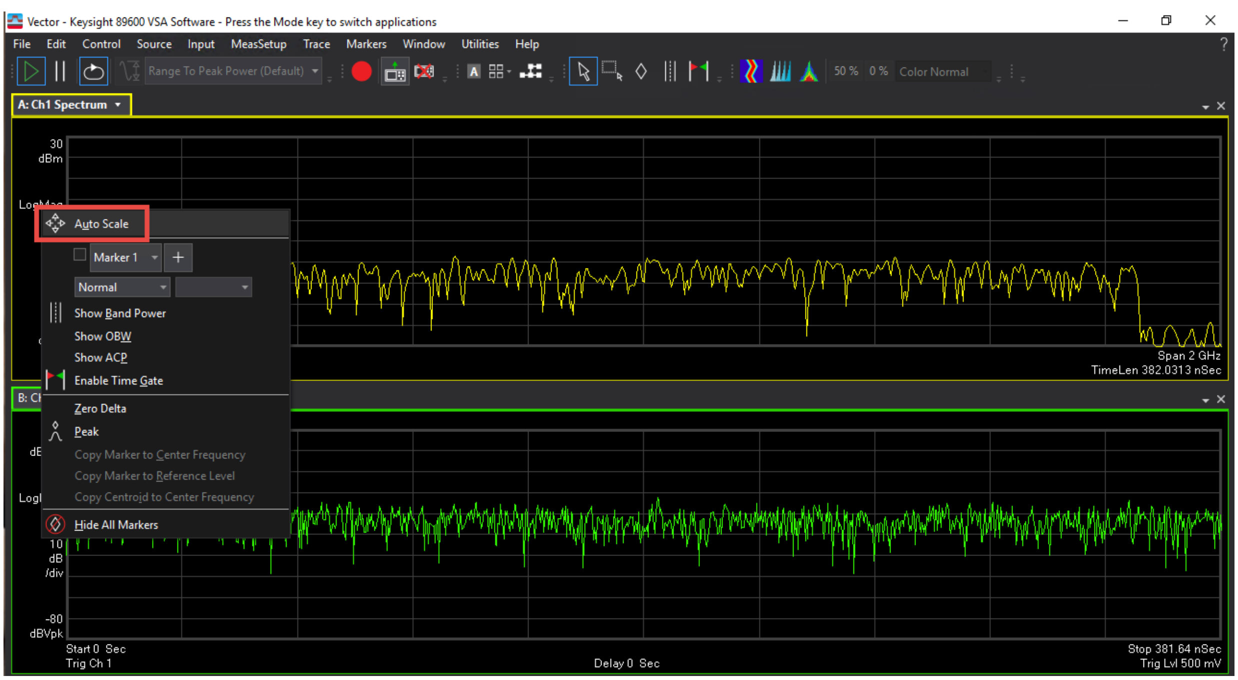
   – Phase Noise Optimization to **Best Wide Offset**



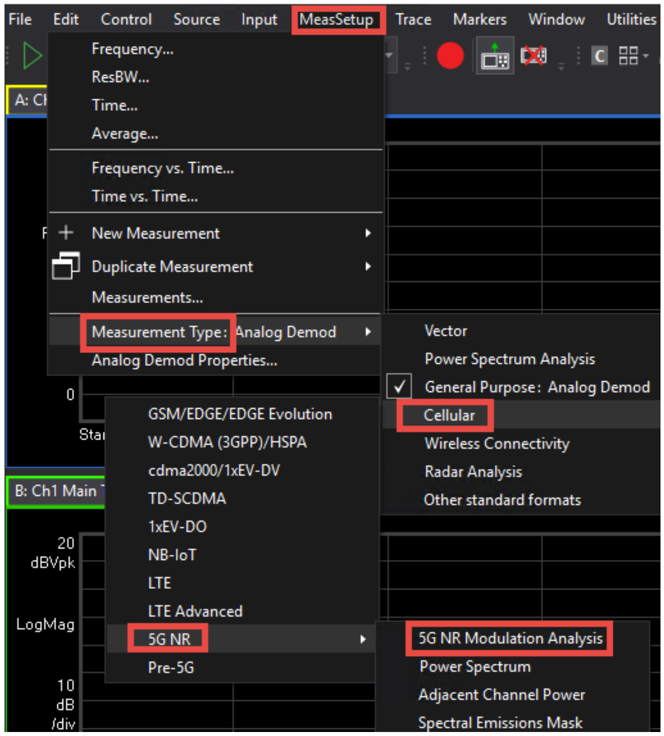
7. Select the **External Mixer** tab and set Input Attenuation to approximately **20 dB**, or a level where the overload flag disappears. This is to bring the waveform up on the spectrum display.



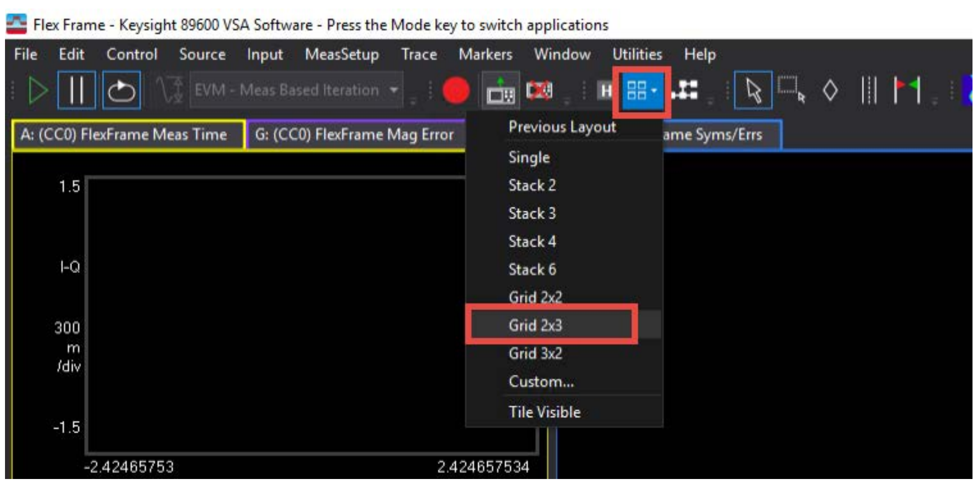
8. In the **Spectrum** window, right click on the Spectrum display and select **Auto Scale**.



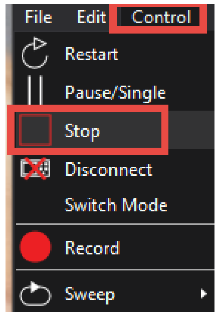
9. From the menu bar, select **MeasSetup** > **Cellular** > **5G NR** > **5G NR Modulation Analysis**.



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.



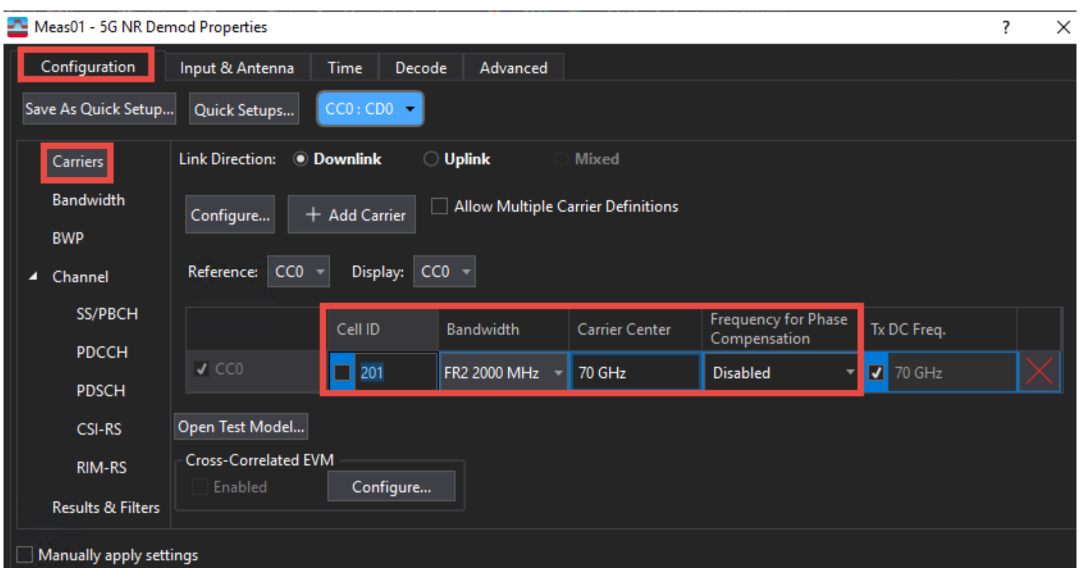
12. Select **MeasSetup** > **5G NR Demod Properties** > **Configuration** tab > **Carriers** panel and set:

   – Cell ID to **201** (or select the box to the right to Auto Detect the cell ID)

   – Bandwidth to **FR2 2000 MHz**

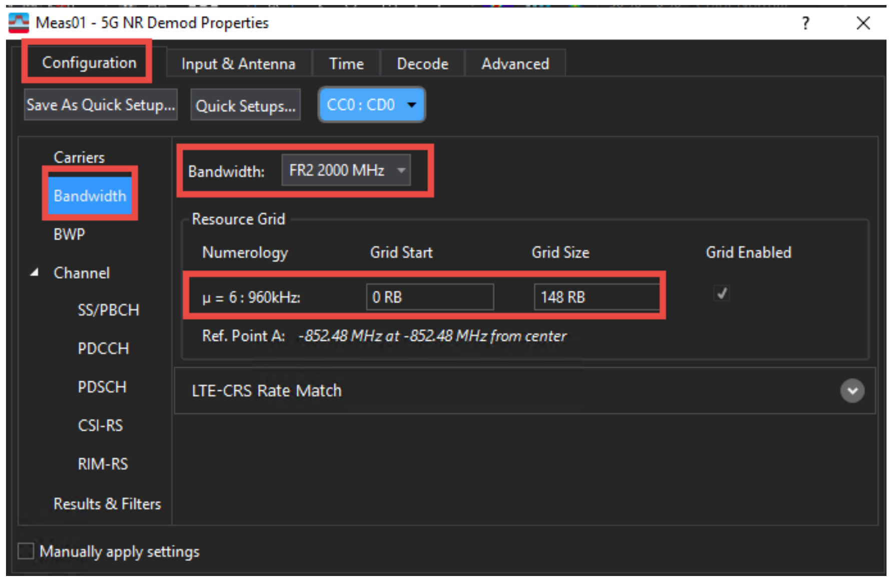
   – Frequency for Phase Compensation to **Disabled**.

   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.

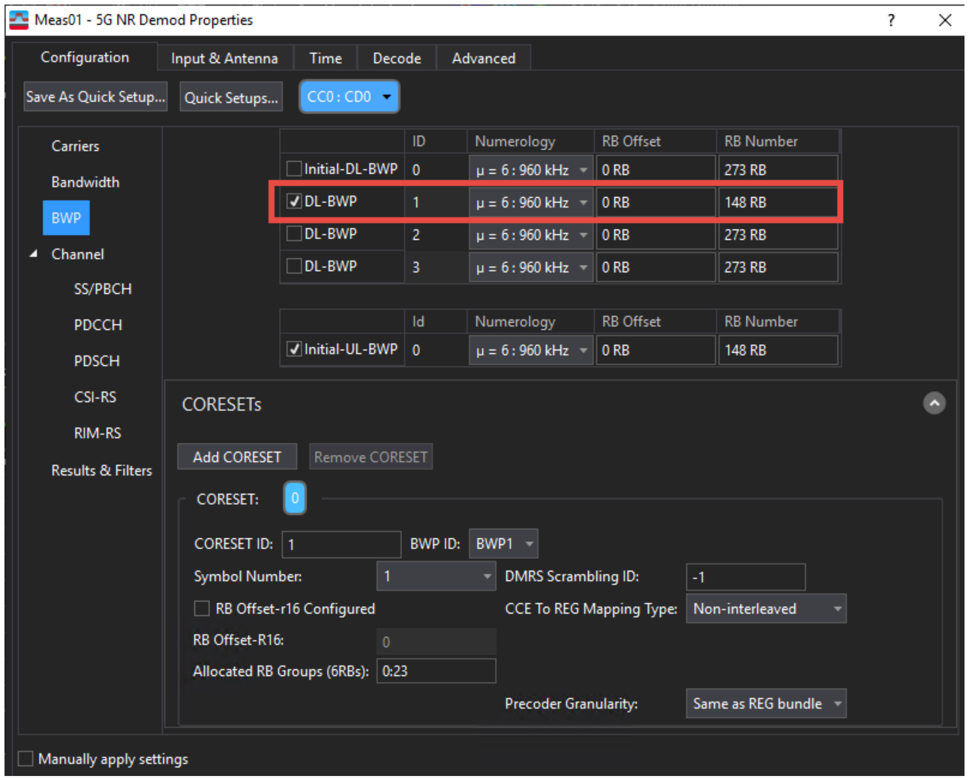


14. Select **MeasSetup** > **5G NR Demod Properties** > **Configuration** tab > **BWP** panel. We will use the default settings for DL-BWP 1.

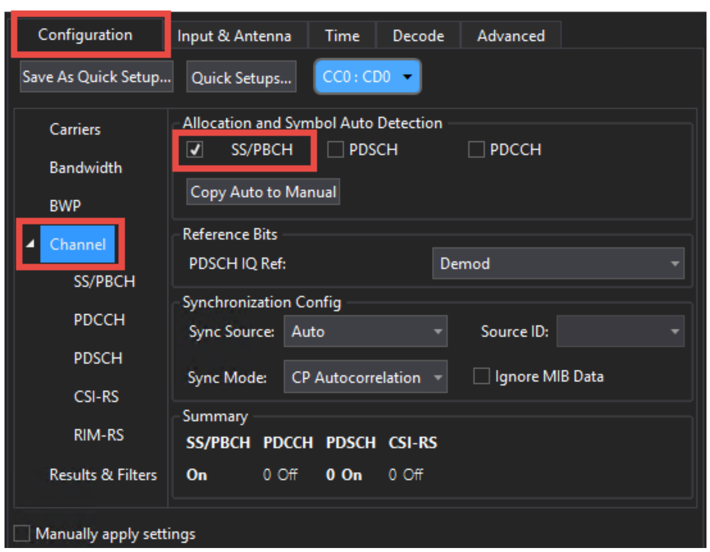
This section of the UI is to configure the DL BWP allocation within the component carrier and the control resource set (CORESET). CORESET is used for PDCCH configuration and there is no PDCCH in this measurement example, so we don't need to make changes.

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.

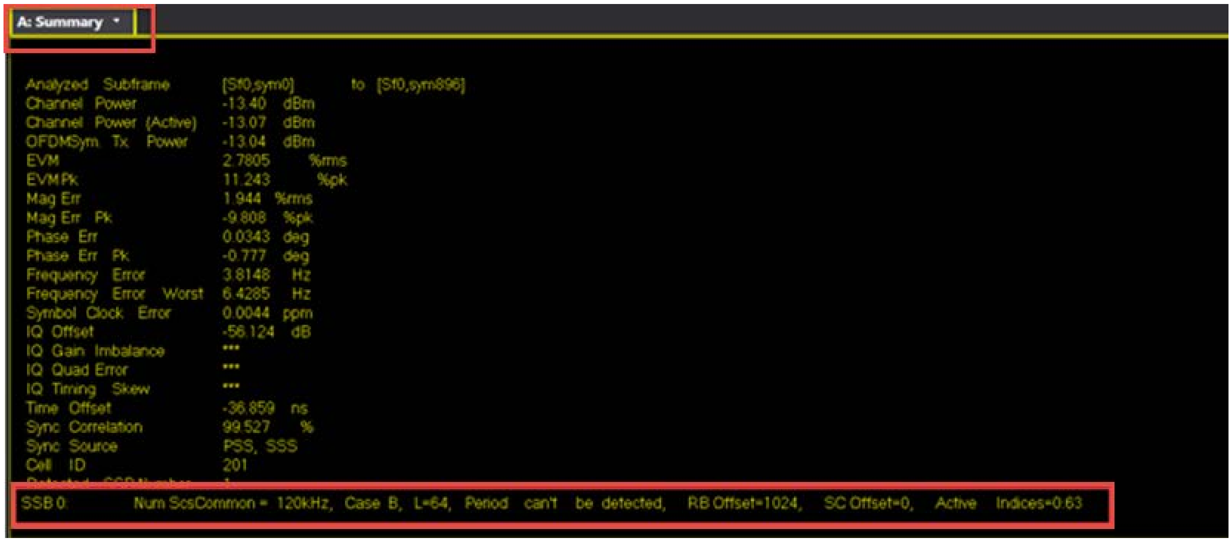


15. Select **MeasSetup** > **5G NR Demod Properties** > **Configuration** tab > **Channel** > **SS/PBCH**.



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.

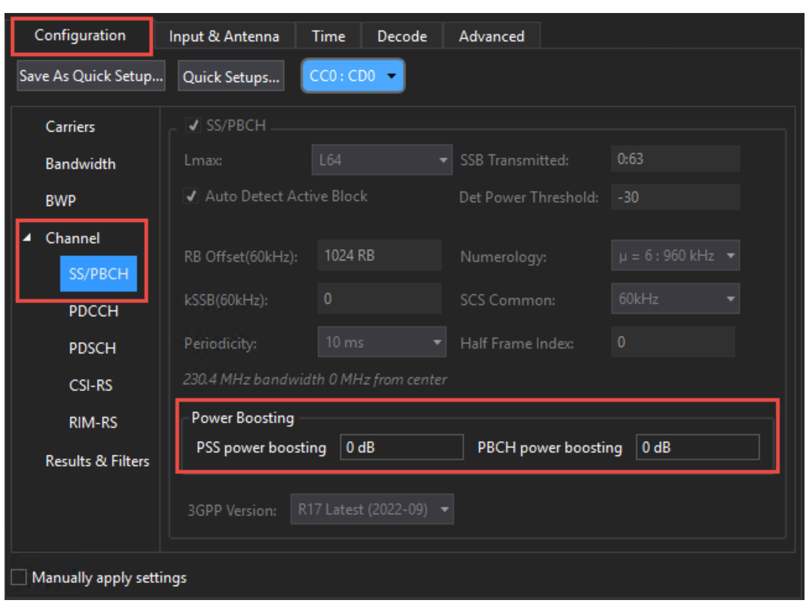
The auto detected SSB parameters are returned in the Summary table. "Copy Auto to Manual" will copy these detected parameters into the SS/PBCH settings.



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 SSBlock 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



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

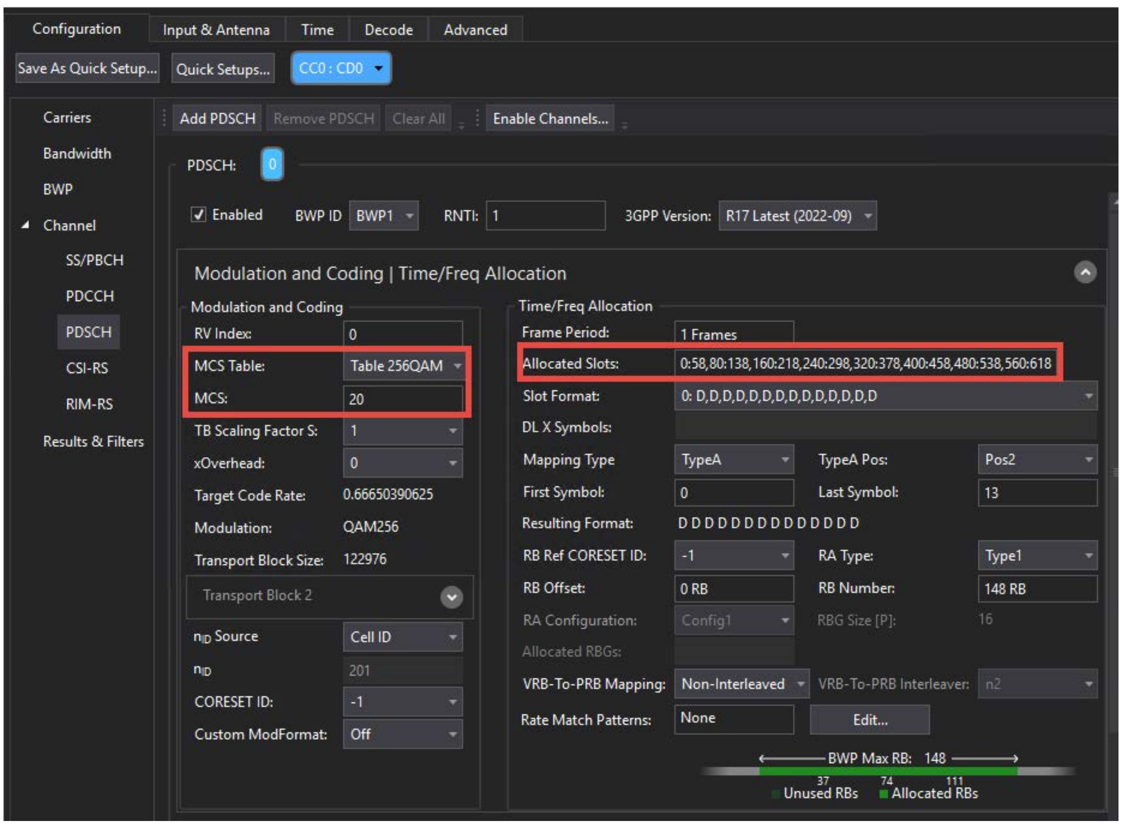
   – MCS Table to **Table 256QAM**

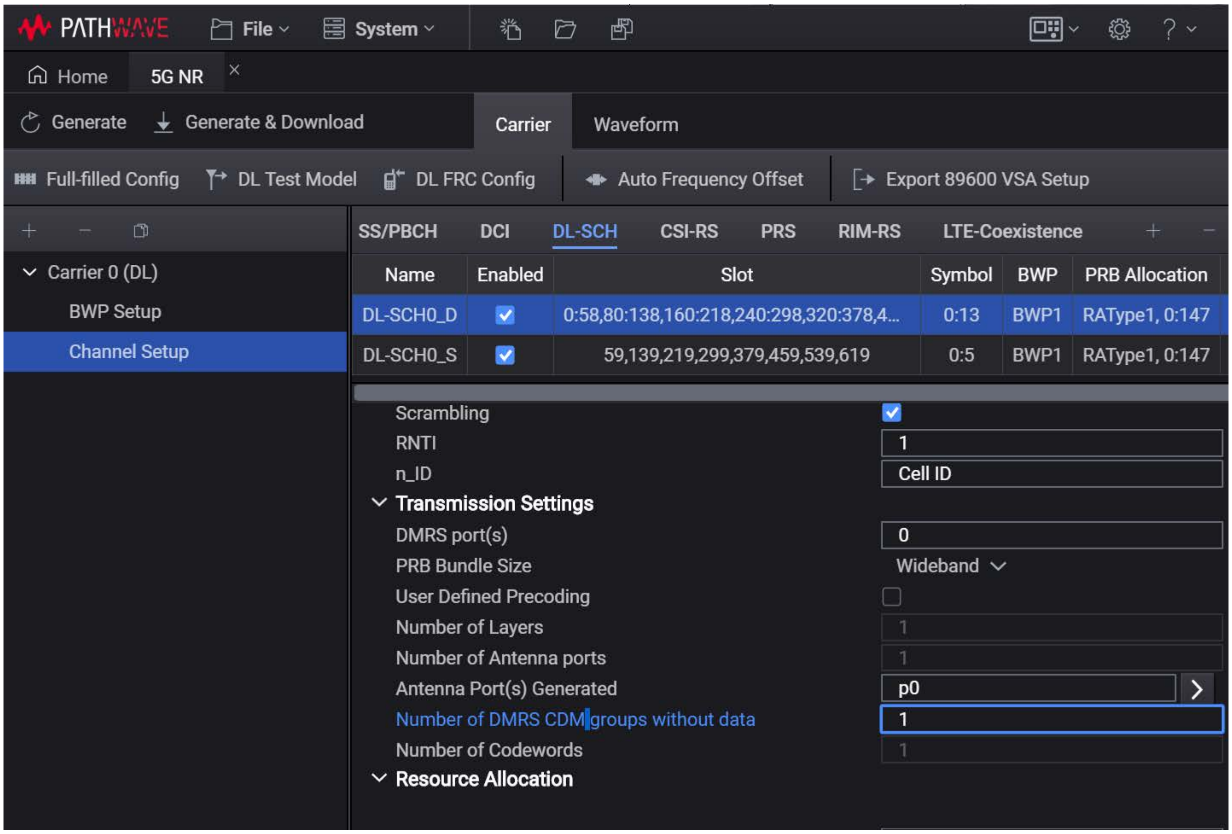
   – MCS to **20**

     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**.



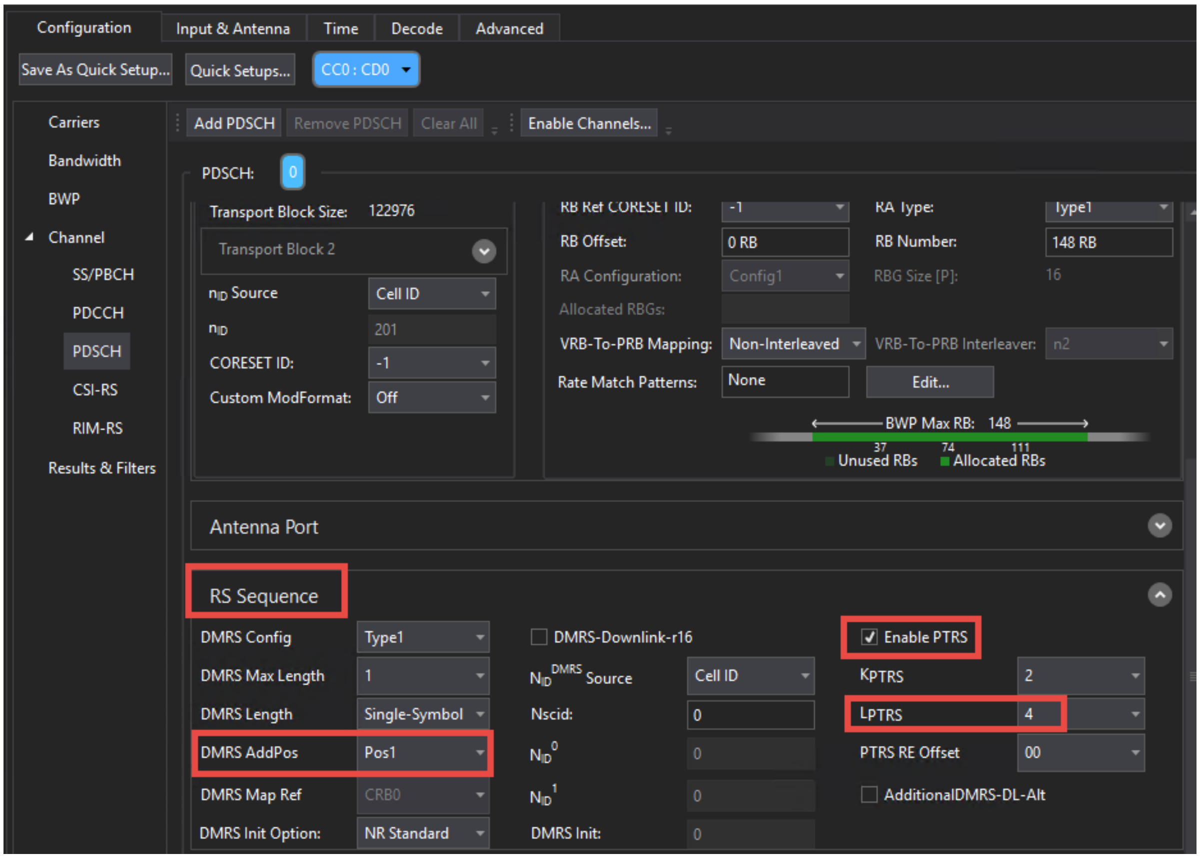


18. Scroll Down to **RS Sequence** and set:

– DMRS AddPos to **Pos1**

– Select **Enable PTRS**

– LPTRS to **4**



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

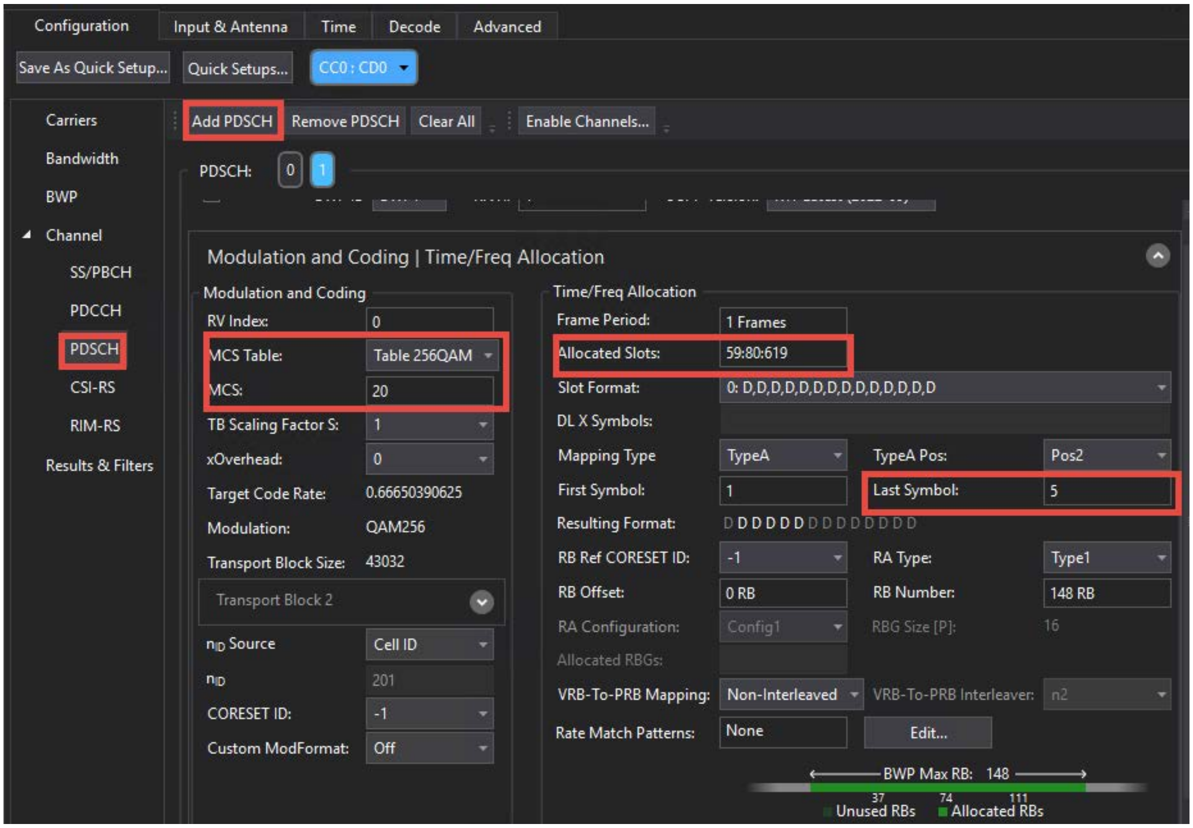
– MCS Table to **Table 256 QAM**

– 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**

– Last Symbol to **5**

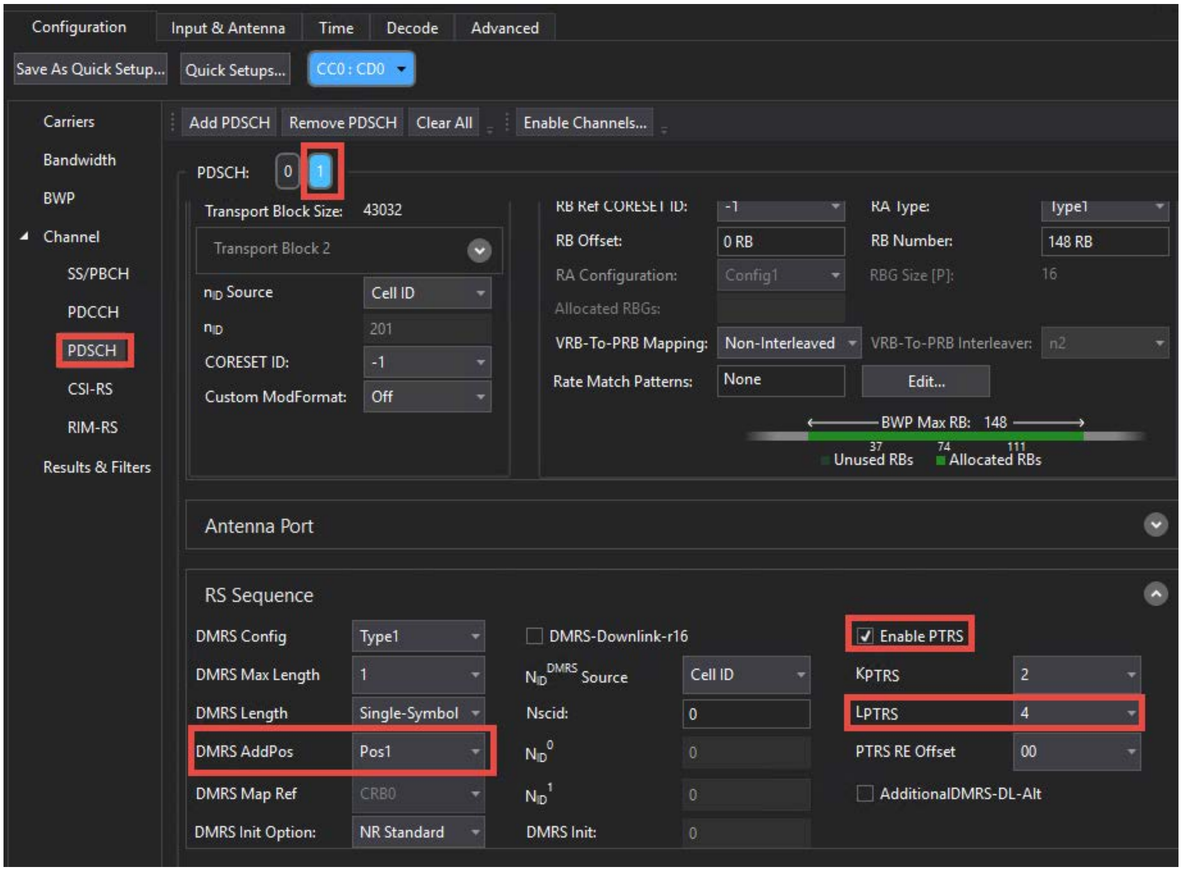


20. Scroll Down to **RS Sequence** and set:

– DMRS AddPos to **Pos1**

– Select **Enable PTRS**

– LPTRS to **4**



21. In the **Time** tab set:

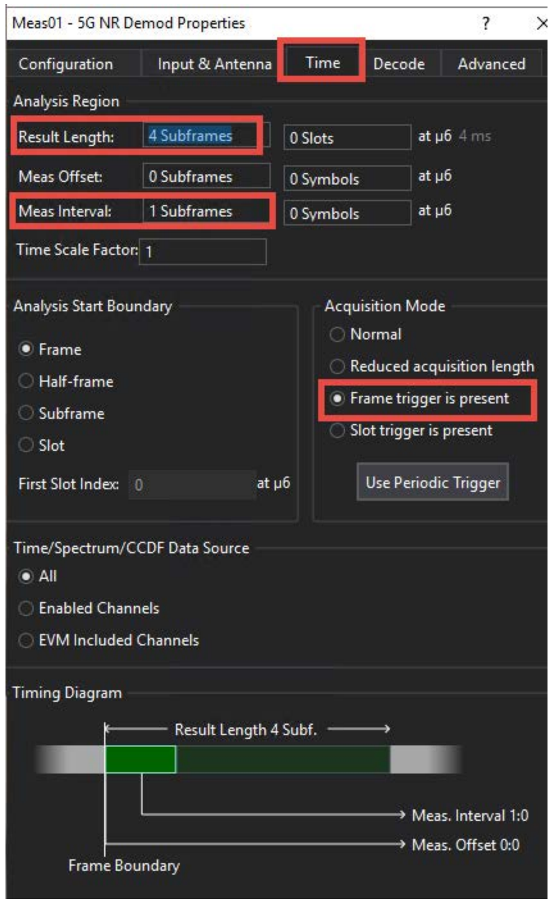
– Result Length to **4 Subframes**

– 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**

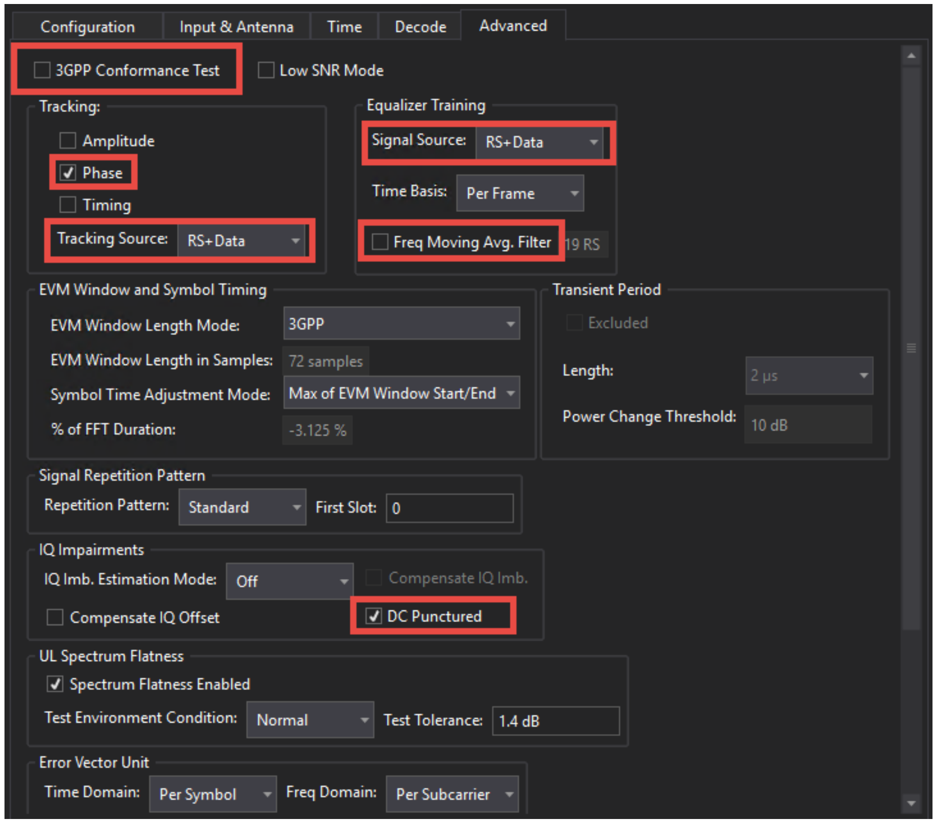
We are using an external trigger for this example, so selecting "Frame Trigger is Present" will use the external trigger and will speed up the measurement significantly.



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**.

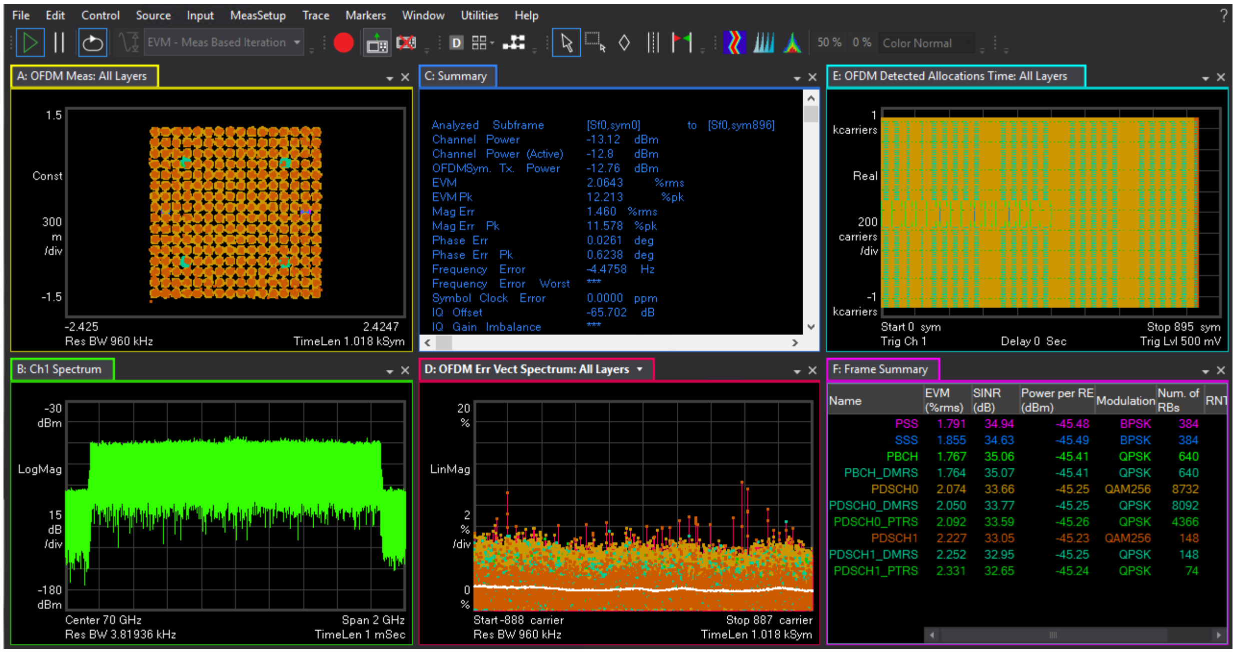
5G NR counts the DC subcarrier as a valid subcarrier for rate-matching purposes. High LO feedthrough will impact demodulation and EVM performance of the input.



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.


File Edit Control Source Input MeasSetup Trace Markers Window Utilities Help
EVM - Meas Based Iteration
A: OFDM Meas: All Layers
C: Summary
E: OFDM Detected Allocations Time: All Layers
Analyzed Subframe [Sf0,sym0] to [Sf0,sym896]
Channel Power -13.12 dBm
Channel Power (Active) -12.8 dBm
OFDMSym. Tx. Power -12.76 dBm
EVM 2.0643 %rms
EVM Pk 12.213 %pk
Mag Err 1.460 %rms
Mag Err Pk 11.578 %pk
Phase Err 0.0261 deg
Phase Err Pk 0.6238 deg
Frequency Error -4.4758 Hz
Frequency Error Worst ***
Symbol Clock Error 0.0000 ppm
IQ Offset -65.702 dB
IQ Gain Imbalance ***
Res BW 960 kHz
TimeLen 1.018 kSym
Start 0 sym
Stop 895 sym
Trig Ch 1
Delay 0 Sec
Trig Lvl 500 mV
B: Ch1 Spectrum
D: OFDM Err Vect Spectrum: All Layers
F: Frame Summary
Center 70 GHz
Span 2 GHz
Res BW 3.81936 kHz
TimeLen 1 mSec
Start -888 carrier
Stop 887 carrier
Name | EVM (%rms) | SINR (dB) | Power per RE (dBm) | Modulation | Num. of RBs
PSS 1.791 34.94 -45.48 BPSK 384
SSS 1.855 34.63 -45.49 BPSK 384
PBCH 1.767 35.06 -45.41 QPSK 640
PBCH_DMRS 1.764 35.07 -45.41 QPSK 640
PDSCH0 2.074 33.66 -45.25 QAM256 8732
PDSCH0_DMRS 2.050 33.77 -45.25 QPSK 8092
PDSCH0_PTRS 2.092 33.59 -45.26 QPSK 4366
PDSCH1 2.227 33.05 -45.23 QAM256 148
PDSCH1_DMRS 2.252 32.95 -45.25 QPSK 148
PDSCH1_PTRS 2.331 32.65 -45.24 QPSK 74

Using the X-Series Analyzer's SCPI Recorder Function

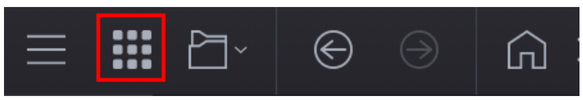
The SCPI Recorder feature allows you to view active recording content, and edit the content. Right-click or touch and hold on any UI control to display a menu allowing you to record the SCPI associated with the control. You can also record a series of commands. These commands can be viewed and edited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

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

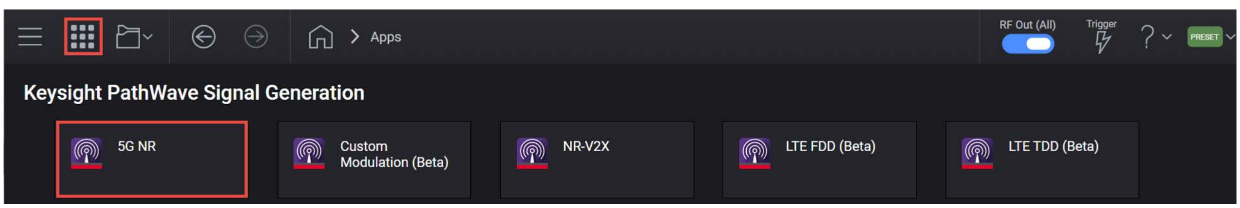
Using the graphical user interface

On the VXG:

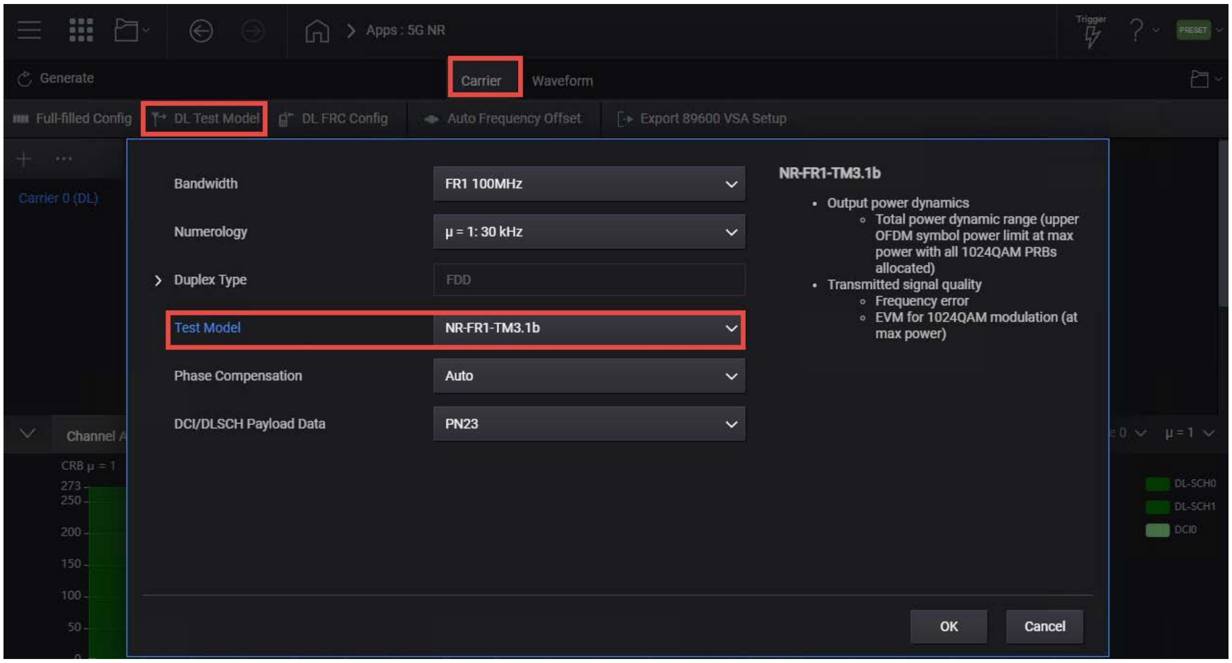
1. Select **Preset** > **Preset** to set the VXG to a known state.
2. In the Output area, set Frequency to **3.5 GHz** and Power to **0 dBm**.
3. Select the **Radio Apps** block to open the mode selection panel.



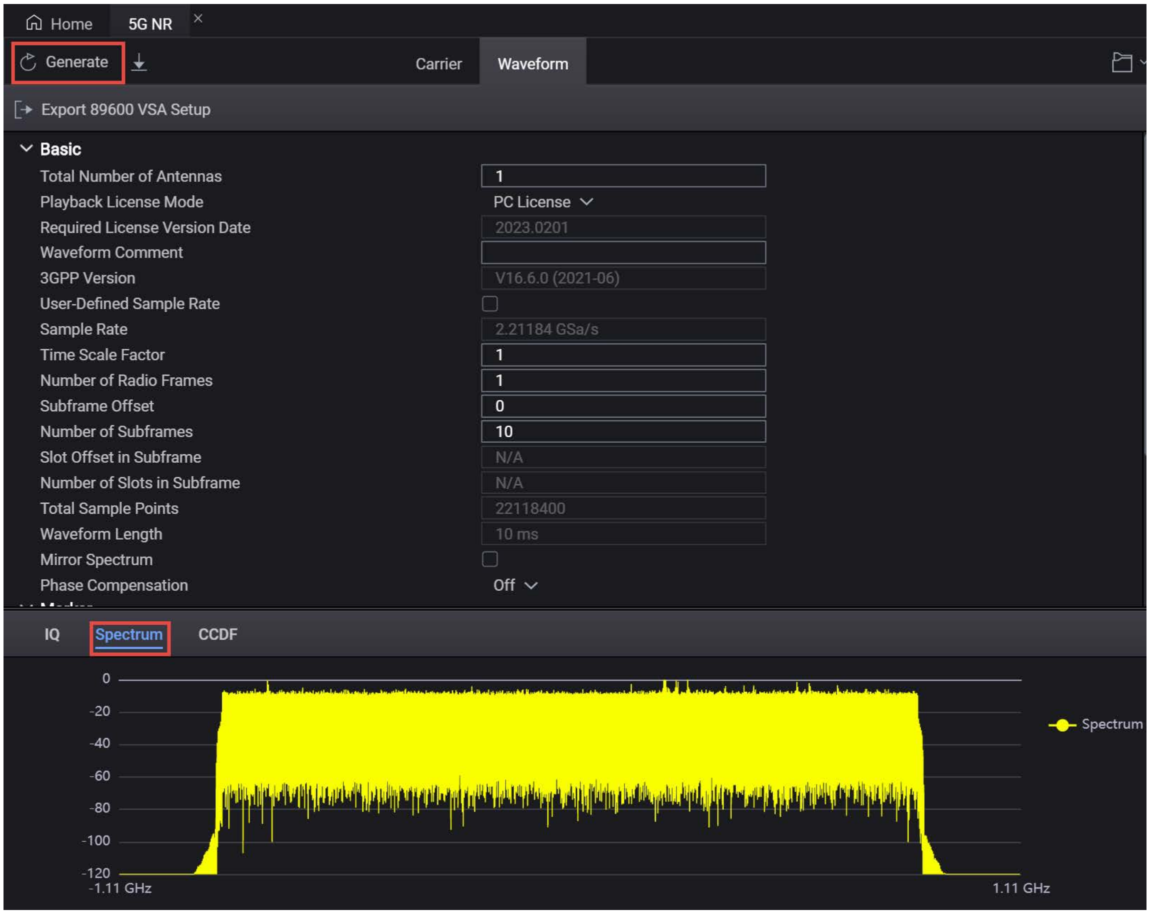
4. Select **5G NR**.



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**.

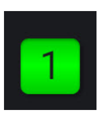


6. Select the **Waveform** tab, then **Generate** to generate the Waveform, and then select **Home** to exit the setup panel.



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**.

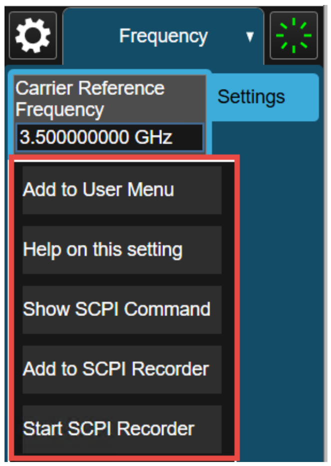
NOTE If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top left of the display) to open the Mode/Measurement/View Selector window.

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**.

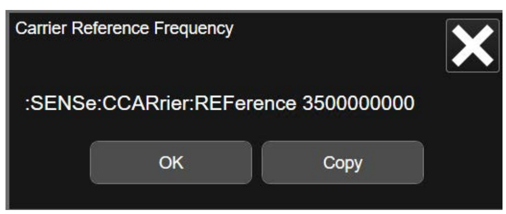
4. Select **Frequency** and set Carrier Reference Frequency to **3.5 GHz**.

   – 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.

Carrier Reference Frequency

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

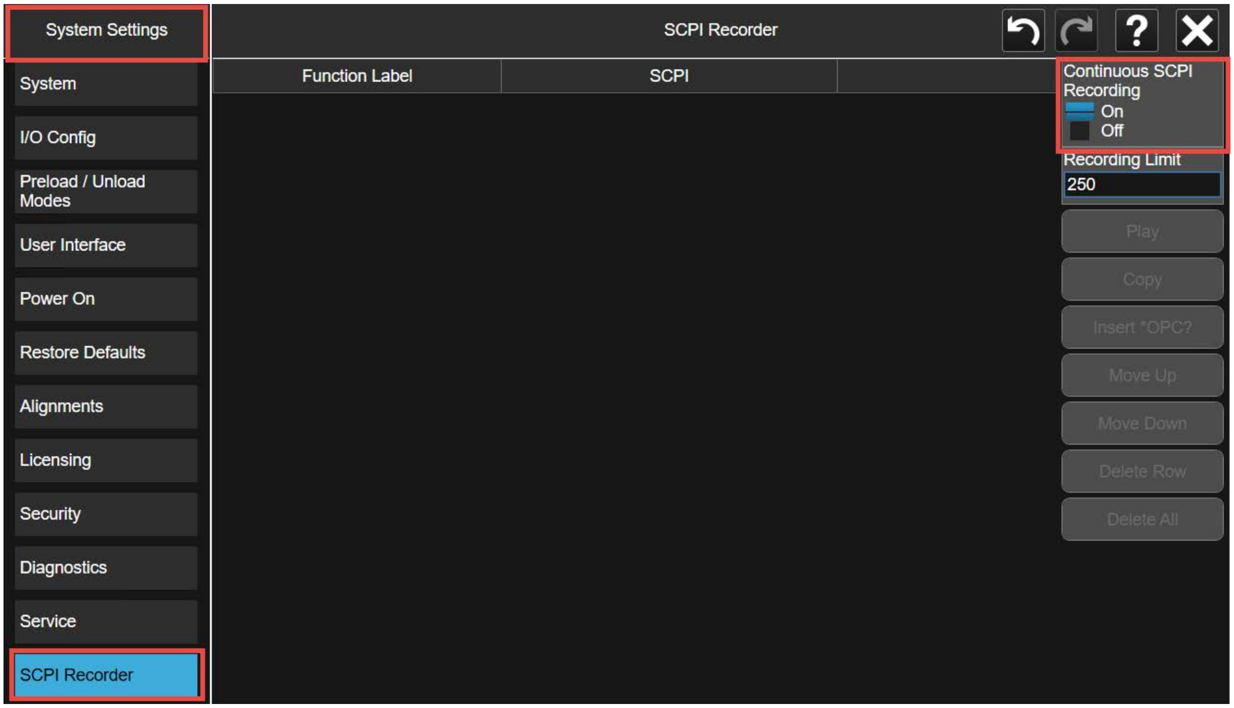
Remote Command	`[:SENSe]:CCARrier:REFerence <freq>` `[:SENSe]:CCARrier:REFerence?`
Example	`:CCAR:REF 2GHz` `:CCAR:REF?`
Preset	1 GHz
State Saved	Saved in instrument state
Min	Depends on instrument minimum center frequency. Same as Center Frequency
Max	Depends on instrument maximum center frequency.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

To Start Continuous SCPI Recording:

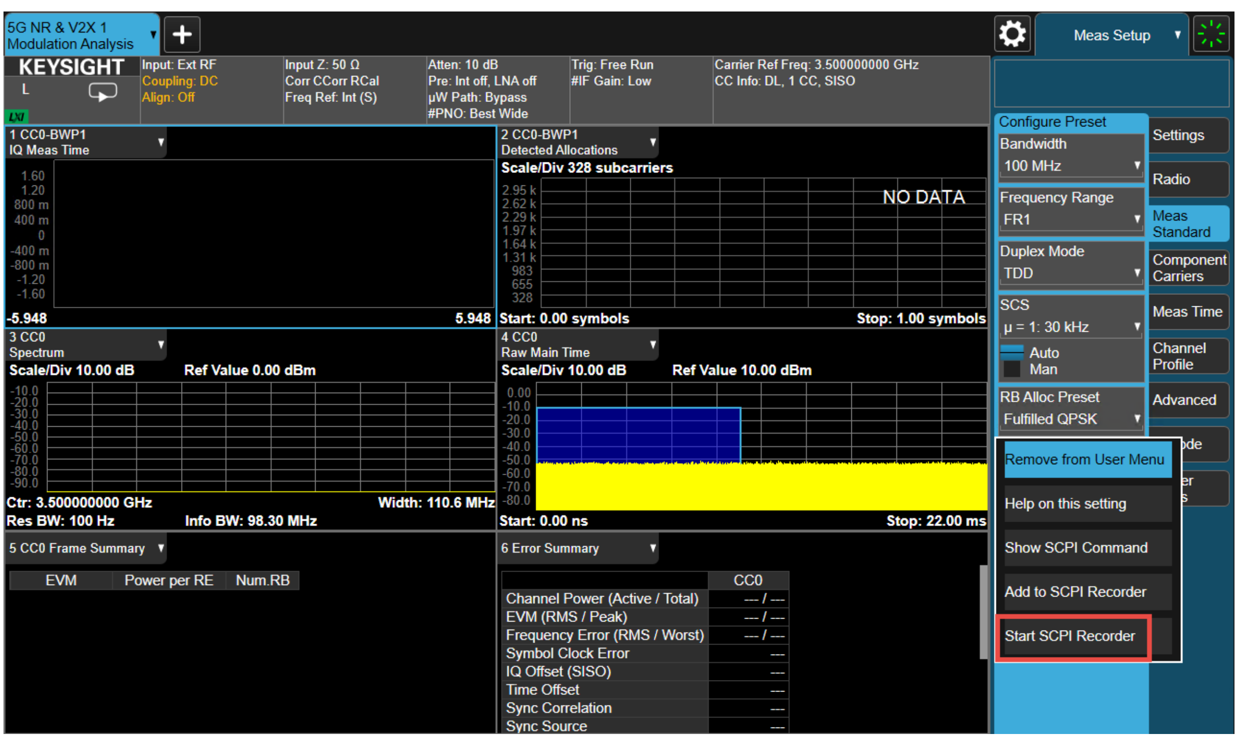
The SCPI Recorder supports an automatic mode of operation. In this mode, a series of manual operations can be added to the list automatically without any further user activity. You can start the recording process by enabling the Continuous SCPI Recording, then disable it to stop recording after completing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

There are two ways to start continuous SCPI recording:

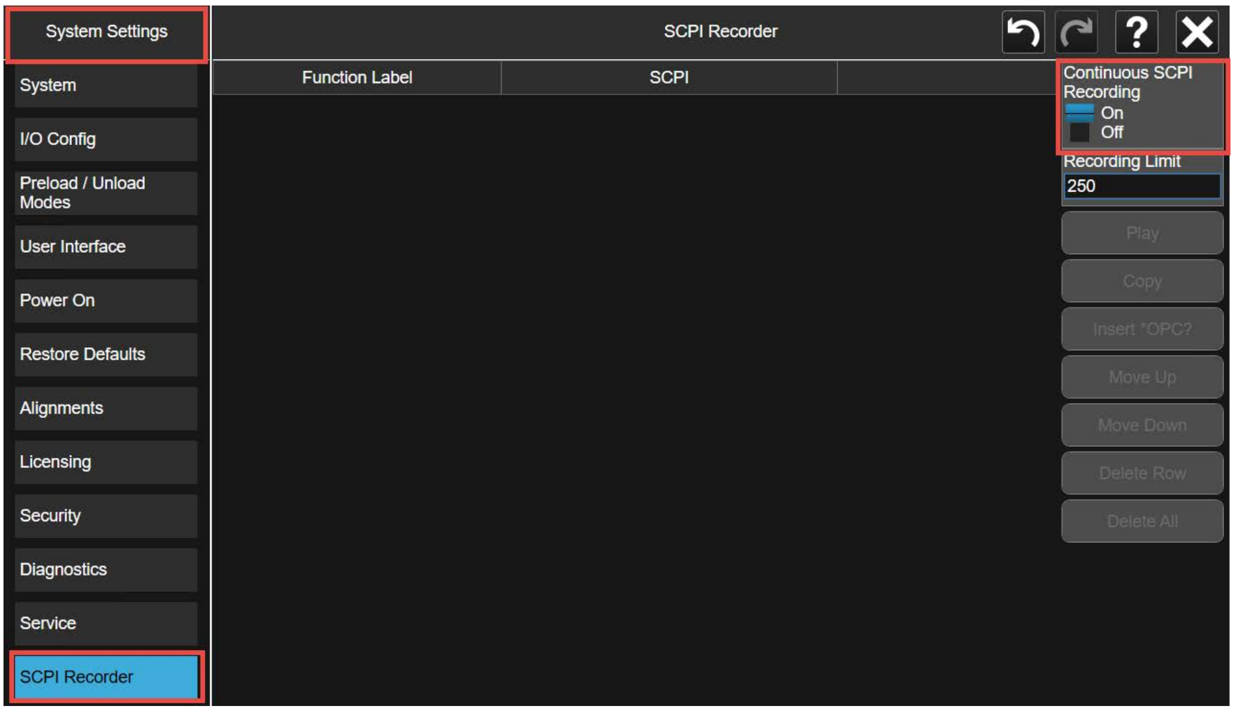
– From the System Settings > SCPI Recorder.



– From the context sensitive menu of the function key.



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

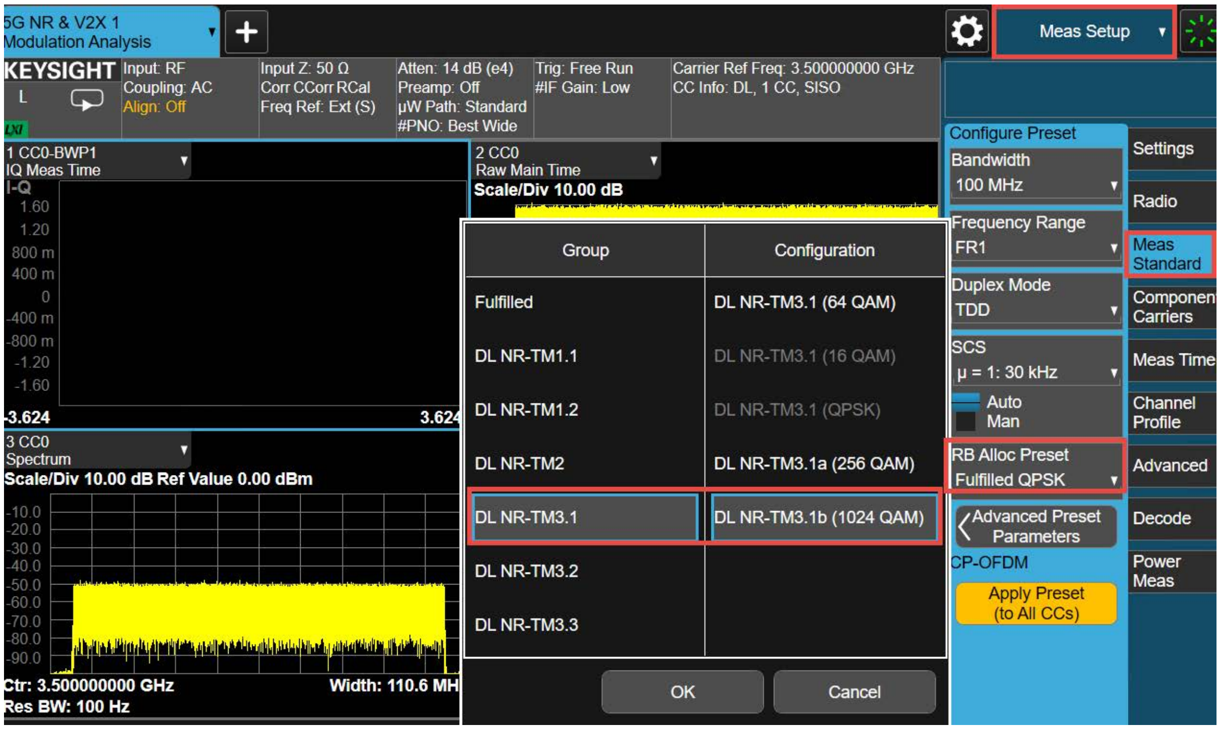


3. Select **Mode/Meas** > **5G NR &V2X** Mode > **Modulation Analysis** Measurement > **Normal** View > **OK**.

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

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

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

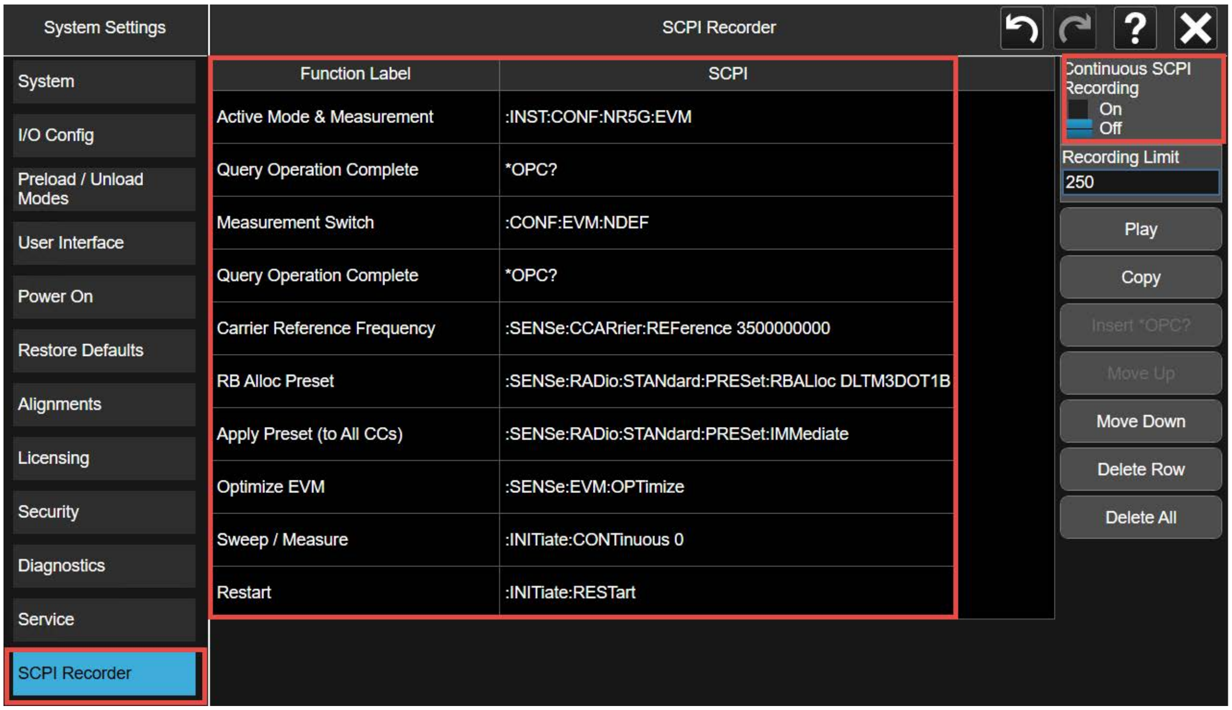


6. Select **Apply Preset (to All CCs)**.

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

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

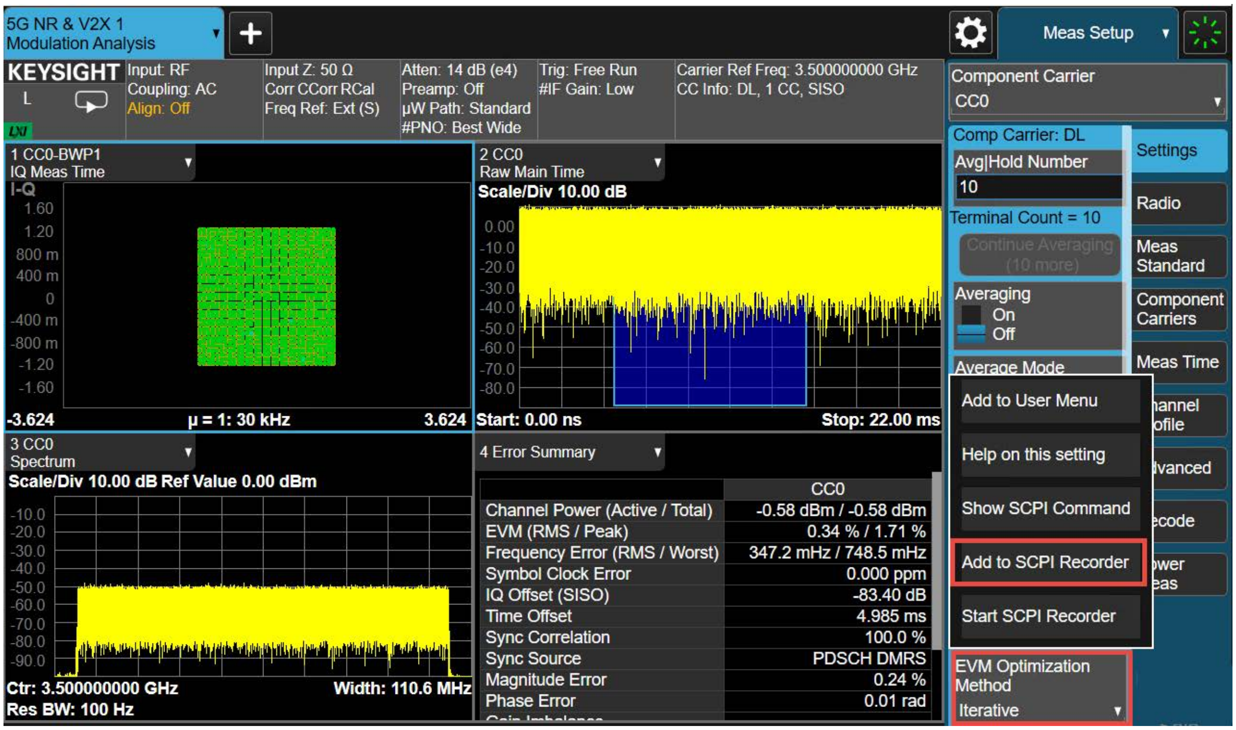
9. Select the **System Settings** icon (Gear wheel on top right of the display) > **SCPI Recorder** > **Continuous SCPI Recording Off**. Close the System Settings window by selecting the "X".



Manual Recording, Edit, Save and Play Functions

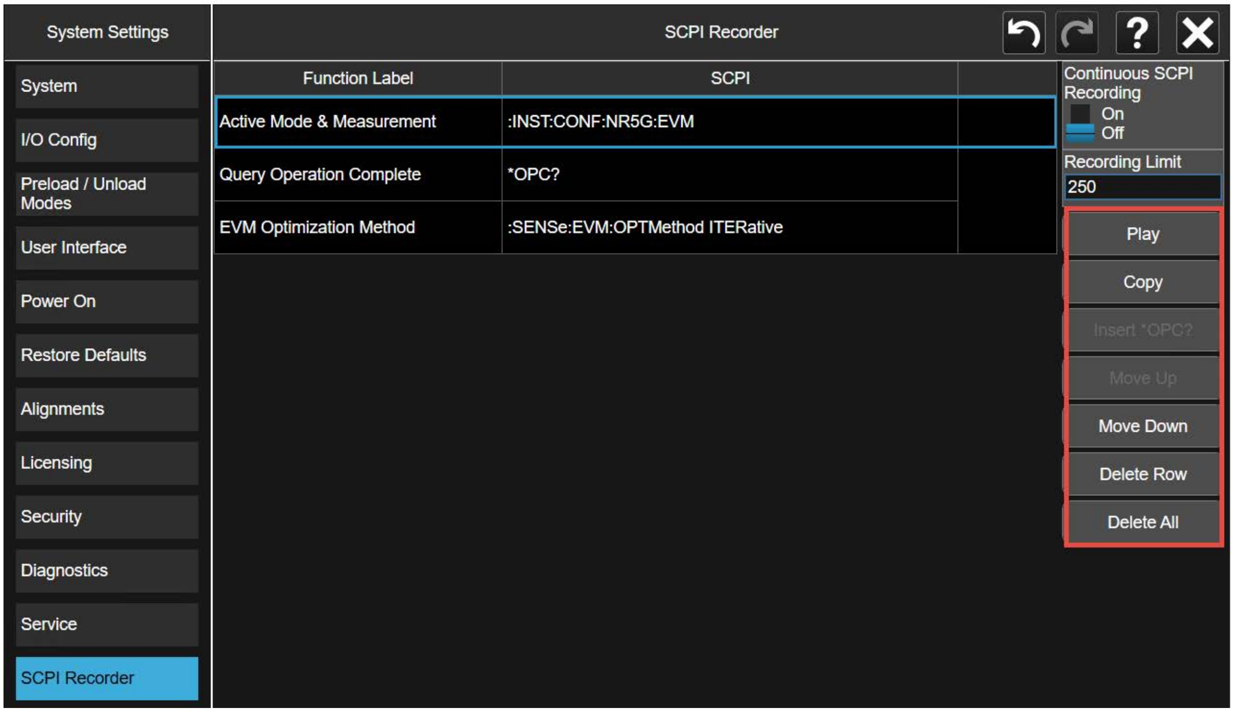
The SCPI Recorder supports manual recording of a list consisting of SCPI commands comprising any number of parameter variations when Continuous SCPI Recording is off. In this mode, the user can decide which SCPI commands should be added to the SCPI list. This mode of recording is helpful if a certain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

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

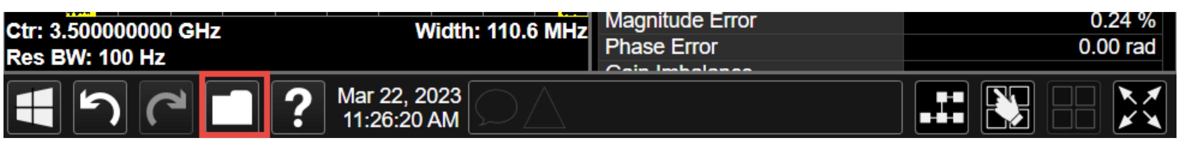


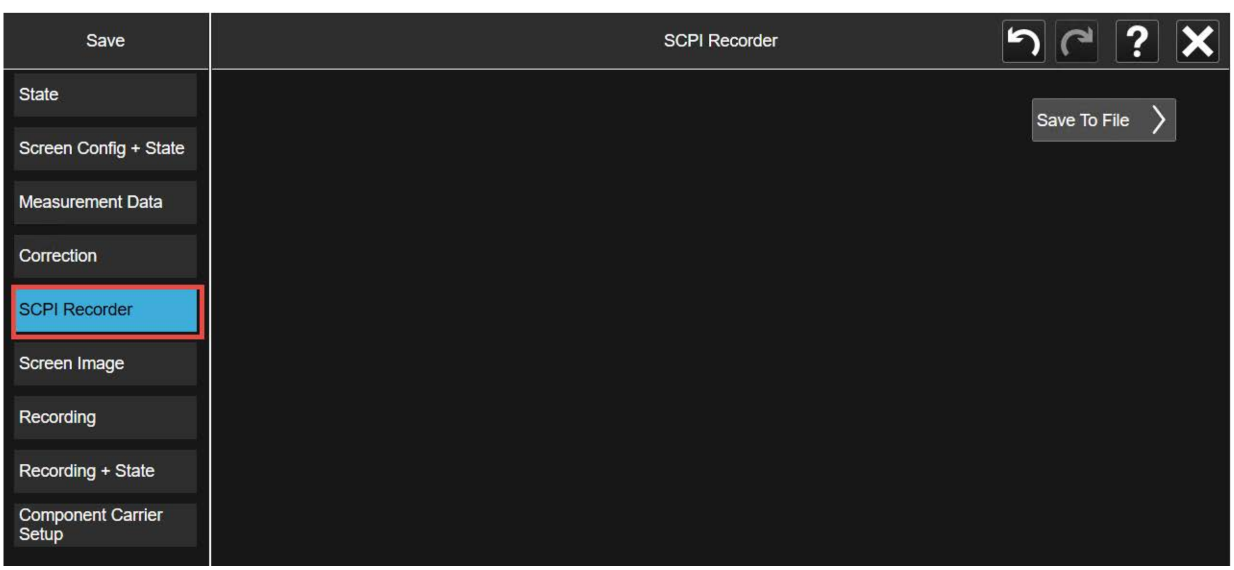
2. To view the newly added command, go to **System Settings** icon (Gear wheel on top right of the display) > **SCPI Recorder**.

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



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

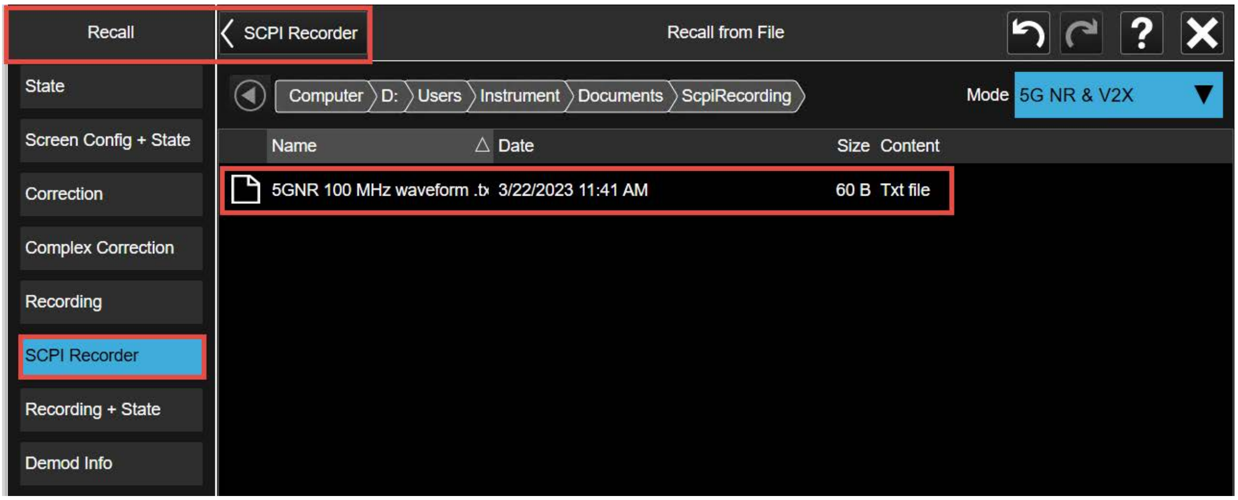




There are two ways to playback SCPI commands. One is recalling from a script file. And another one is pressing the 'Play' button in 'SCPI Recorder' tab view.

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

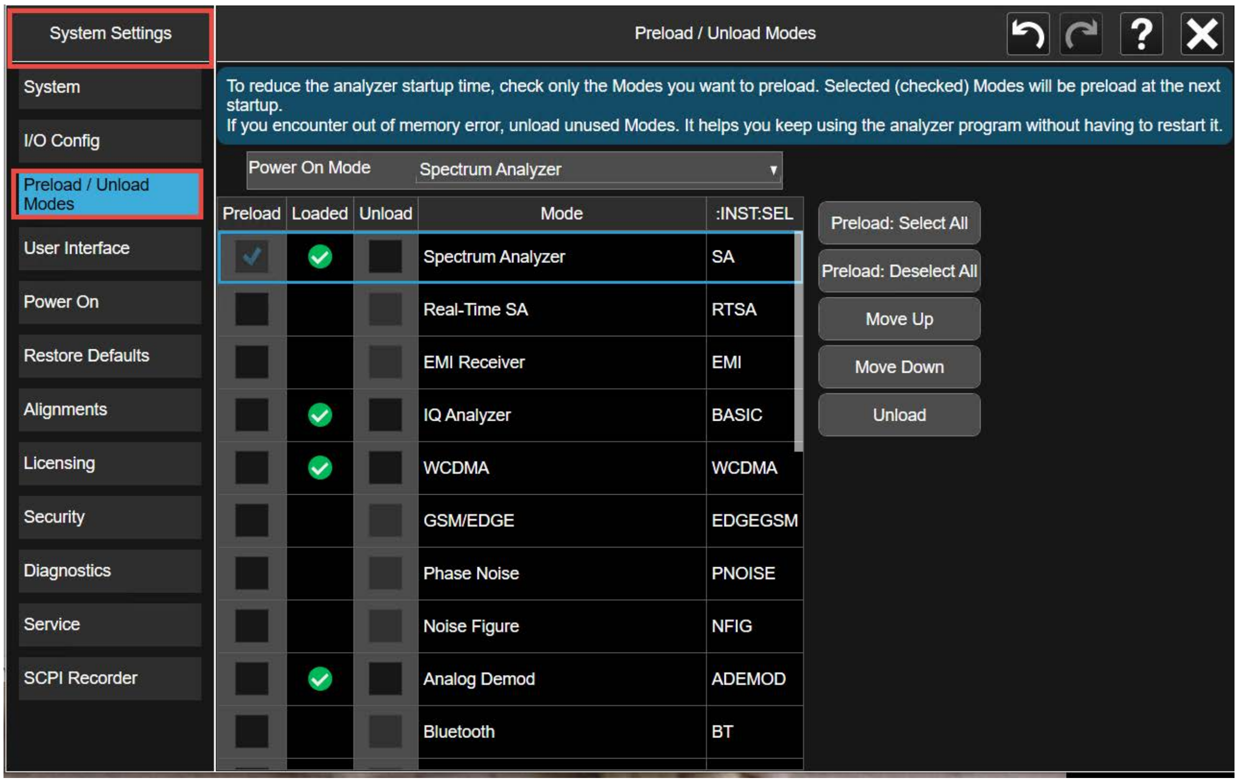
To recall the SCPI recording, go to Save/Recall and navigate to the saved file.



Using 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.

5 5G New Radio (NR) Measurements using X-Apps

This section includes the following topics:

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.

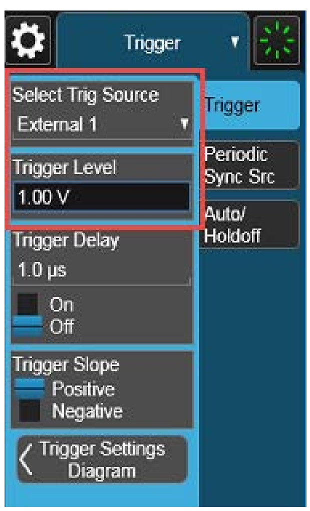
Setting Up Triggers on the X-Series Signal Analyzer

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:NR5G`

`SYSTem:PRESet`

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

`INSTrument:CONFigure:NR5G:EVM`

`TRIGger:EVM:SOURce EXTernal1`

`TRIGger:EXTernal1:LEVel 1V`

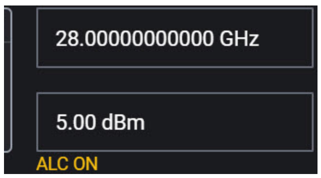
Setting Up a 1 CC 28 GHz EVM Measurement

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 292.

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**.

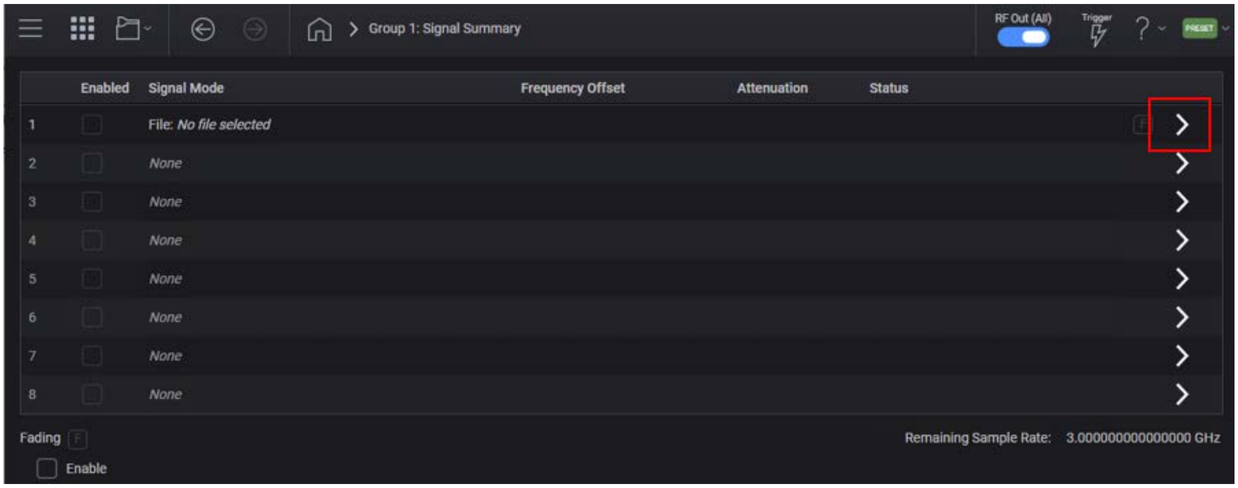


3. Select **Group 1: Signals** block to open.

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

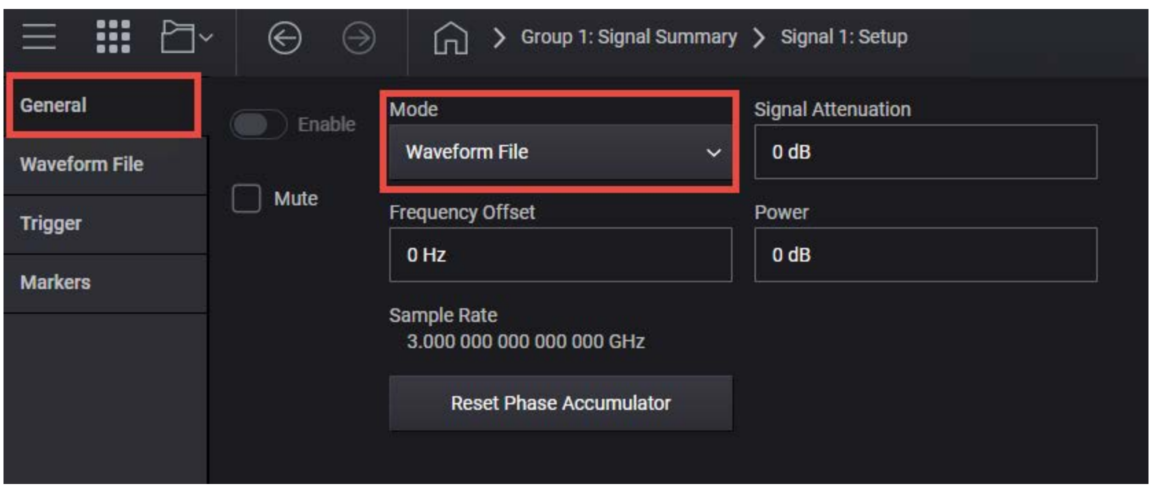
NOTE

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.



5. In the Vector Modulation Signal Setup:

   a. Select the **Mode** dropdown and set to **Waveform File**.

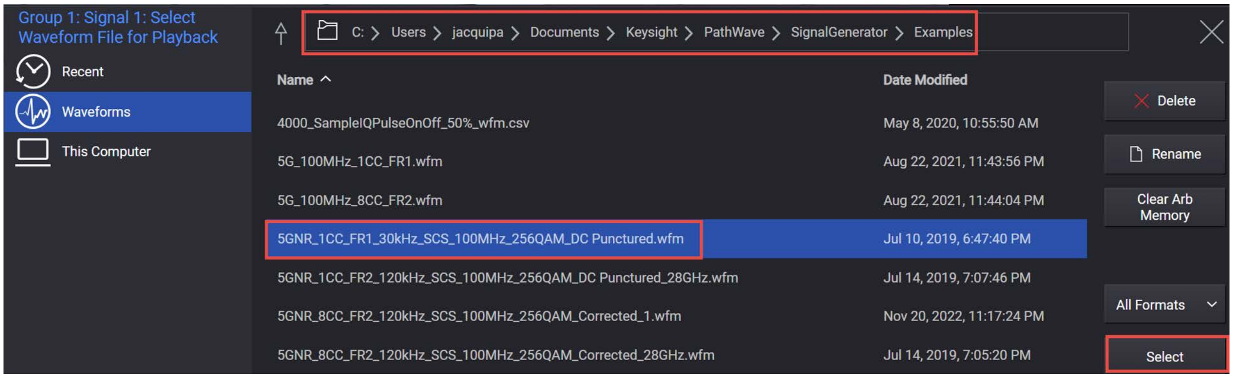


   b. In the left pane, select the **Waveform File** tab.

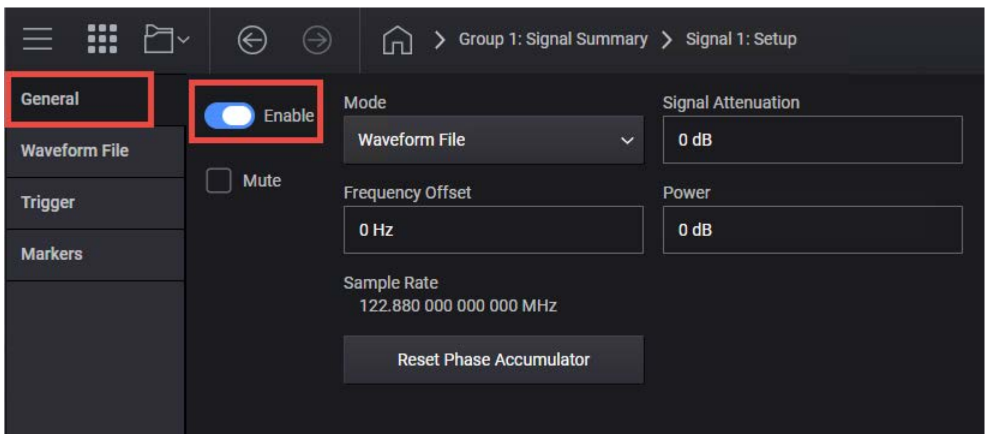
   c. Use **File Select** to navigate to:

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

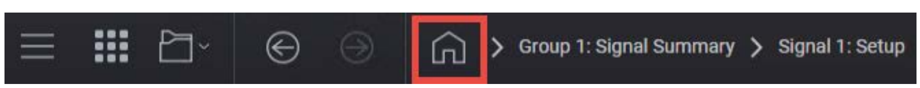
and choose `5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DCPunctured_28GHz.wfm` > **Select.**



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



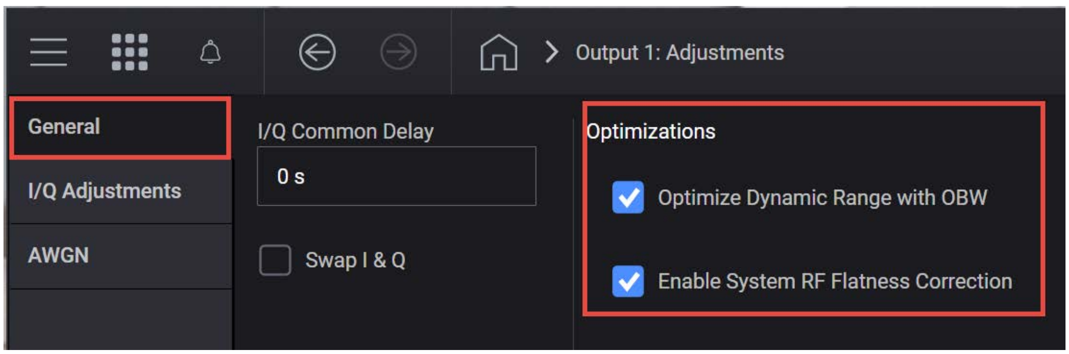
6. Close the Vector Modulation Signal Setup by selecting the **Home** icon at the top of the display.



7. 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.

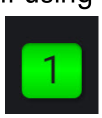
Enable System RF Flatness Correction - Disabling this function disables the factory calibrated RF channel flatness equalizer. Depending on the hardware channel response, this may hurt or improve the EVM. This is due to the dynamic range implications as it relates to signal to noise ratio. The greater 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.



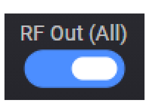
8. Close the Adjustments Setup by either selecting the **Back** or the **Home** icon at the top of the display.

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

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



10. **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:

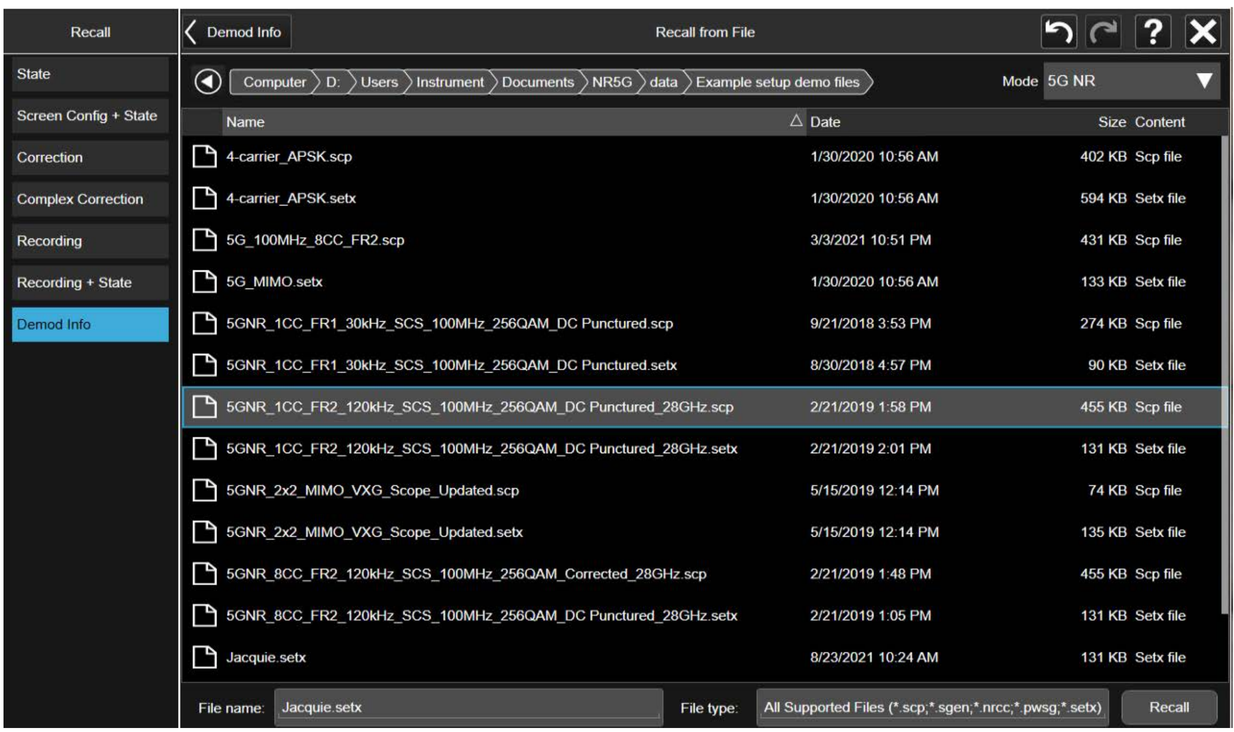
`D:\Users\Instrument\Documents\Keysight\PathWave \SignalGenerator\Examples`

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`

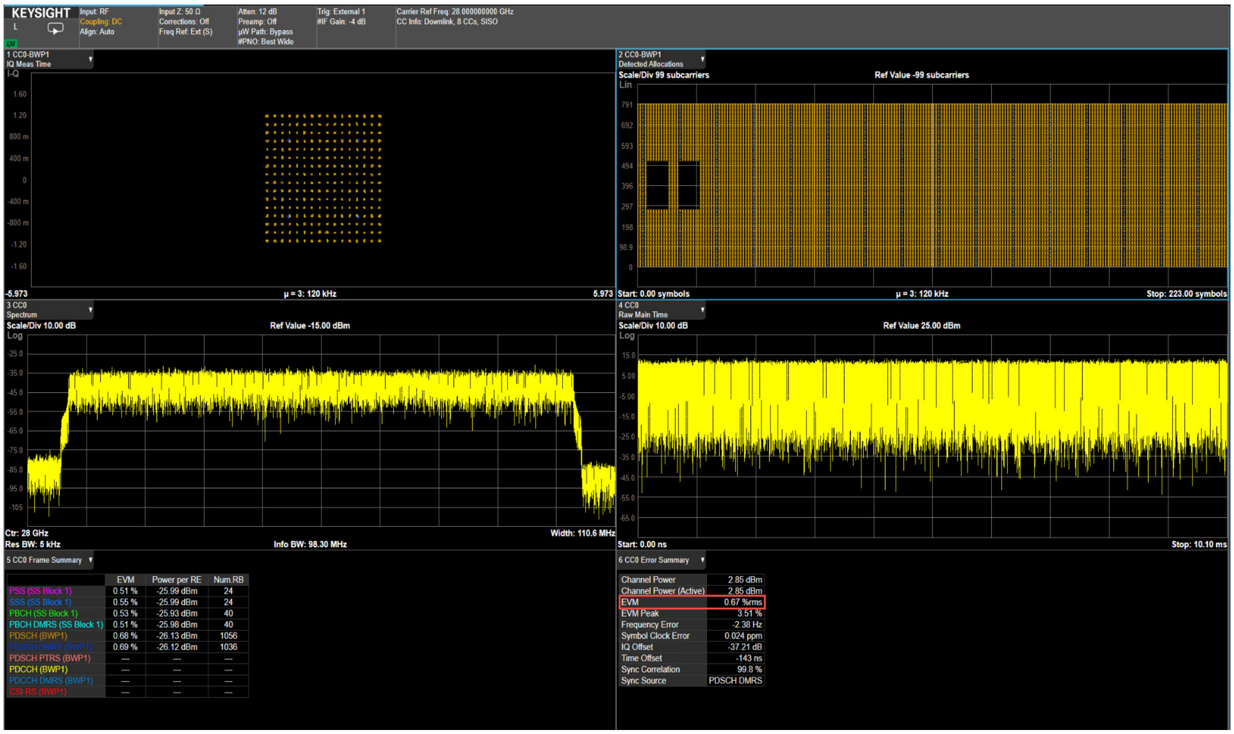
   Recall



2. Select **Meas Setup** > **Meas Time** and set:
   – Search Length to **10 ms**
   – Result Length to **2 Sub Frame**
   – Frame Trigger to **On**
3. 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.scp”
```

```
SIGNal1 ON
```

```
IQO:CORR:OPT:DYN:RANG:OBW ON
```

```
RF1:OUTPut ON
```

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

```
RFALl:OUTPut ON
```

On the X-Series Signal Analyzer:

NOTE

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.scp”
```

```
EVM:CCARrier0:TIME:LENGth:SEARch 10ms
```

```
EVM:CCARrier0:TIME:LENGth:RESult 2
```

```
EVM:CCARrier0:FRAMe:TRIGger ON
```

```
EVM:CCARrier0:DC:PUNCture ON
```

```
EVM:CCARrier0:PHASe:COMPensation:AUTO OFF
```

```
EVM:CCARrier0:PHASe:COMPensation:FREQuency 0 Hz
```

```
EVM:OPTimize
```

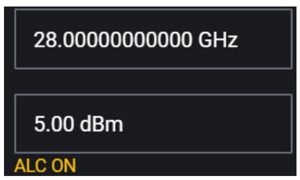
Setting up an 8 CC 28 GHz EVM Measurement

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 292.

On the VXG:

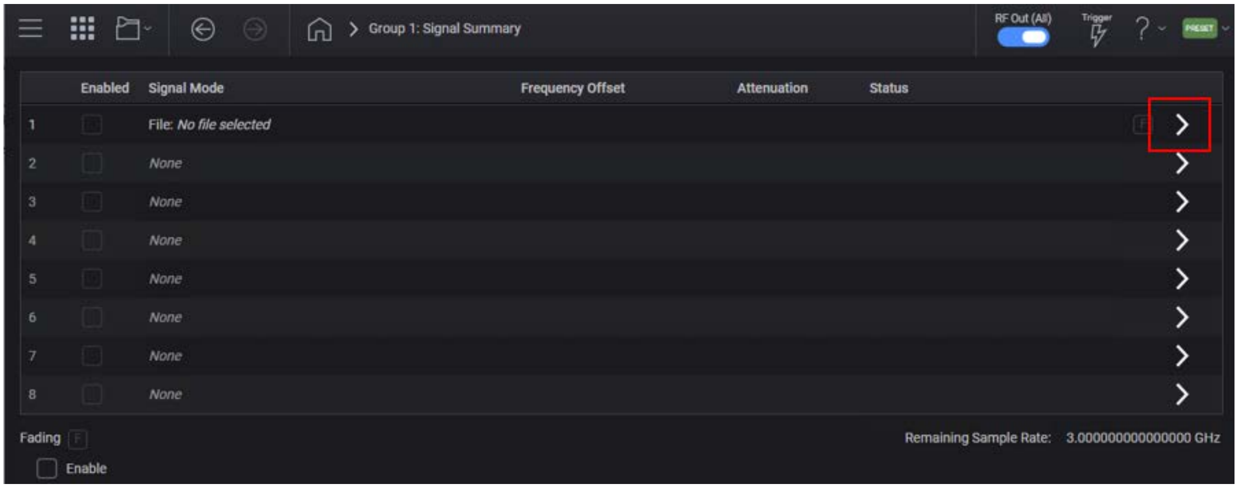
1. Select **Preset** > **Preset** to set the VXG to a known state.
2. Set Frequency to **28 GHz** and Amplitude to **5 dBm**.



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

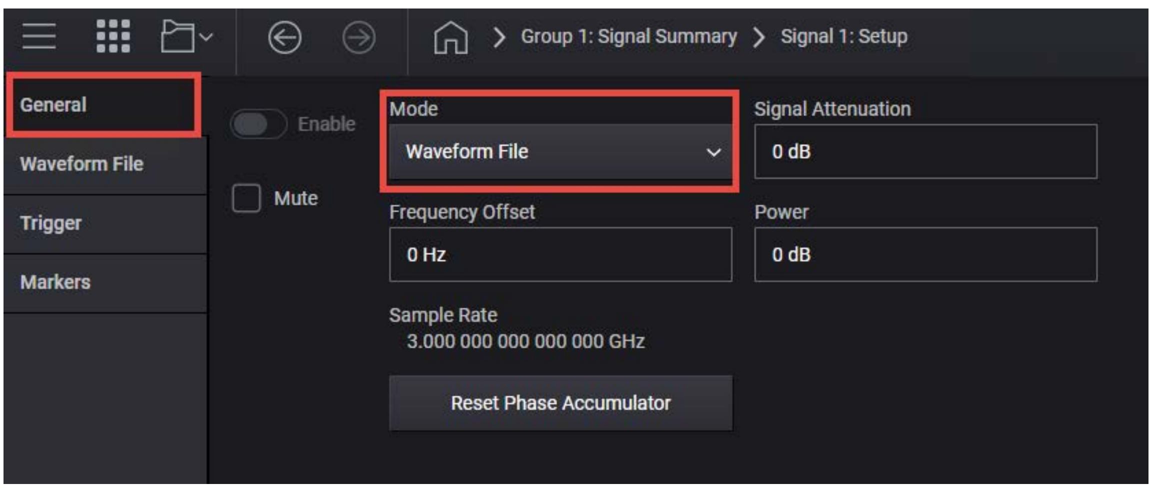
4. Select the arrow for Signal 1 to open the Signal Setup window.

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.



5. In the Vector Modulation Signal Setup:

   a. Select the **Mode** dropdown and set to **Waveform File**.

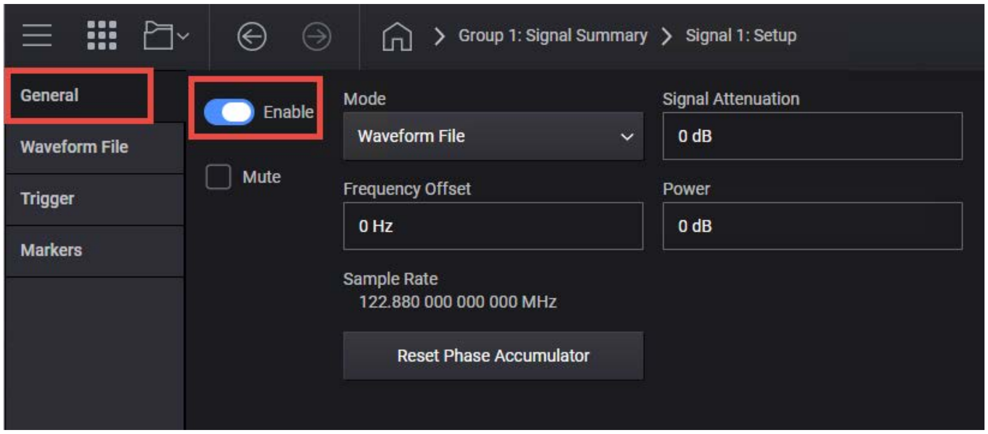


   b. In the left pane, select the **Waveform File** tab.

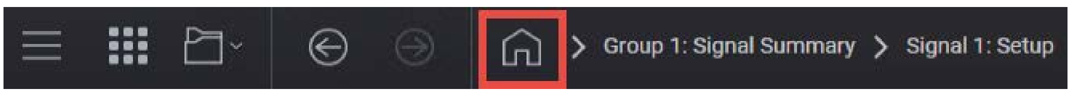
   c. Use **File Select** to navigate to:

      `D:\Users\Instrument\Documents\Keysight\PathWave\SignalGenerator\Examples`
      and choose
      `5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_28GHz.wfm`
      then **Select**.

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



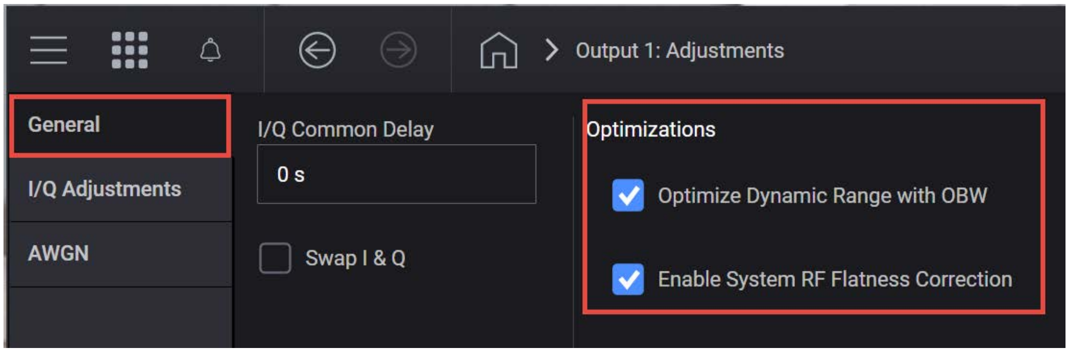
6. Close the Signal Setup by selecting the **Home** icon at the top of the display.



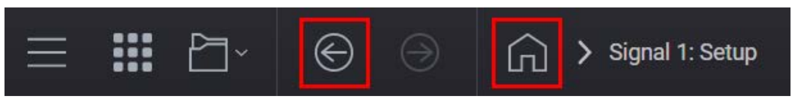
7. Select the **Adjustments** block and select **Optimize Dynamic Range with OBW** and **Enable System RF Flatness Correction.**

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.

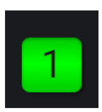


8. Close the Adjustments Setup by either selecting the **Back** or the **Home** icon at the top of the display.

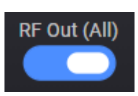


9. Set RF Out to **On** by selecting the numbered channel indicator switch.

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

NOTE

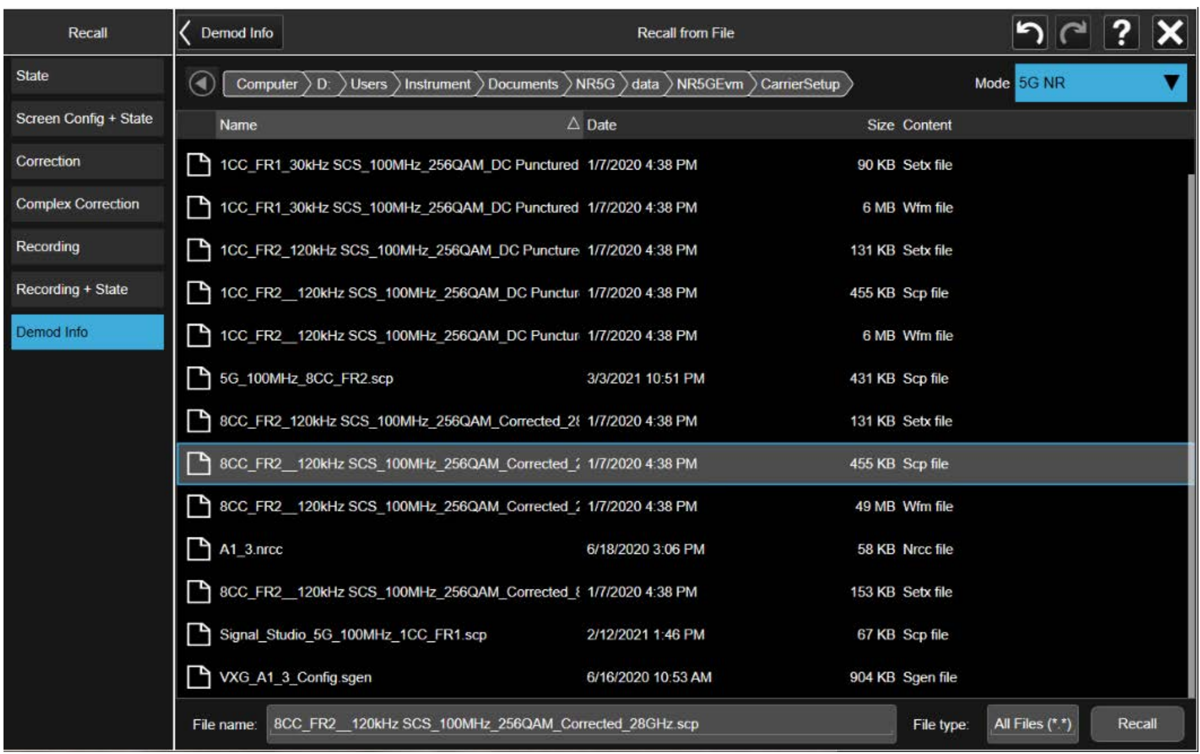
All example waveforms and setup files are located on the VXG at:

`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** > `5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_28GHz_34.scp` > **Recall.**

   You must be in the correct analysis mode (in this case, 5G NR & V2X1 >Modulation Analysis mode) to recall the .scp file.



2. Select **Meas Setup** > **Meas Time** tab and set:

   – Search Length to **10 ms**

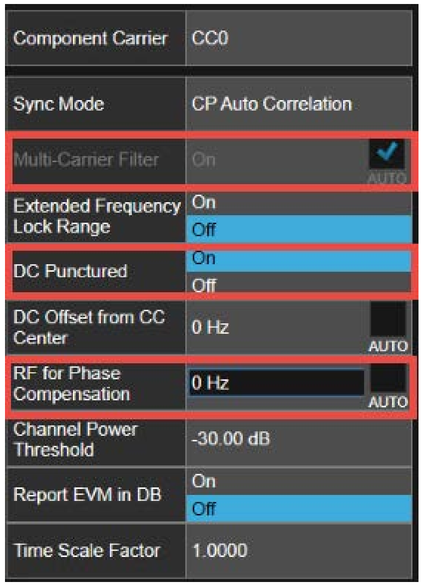
   – Result Length to **2 Sub Frame**

   – Frame Trigger to **On**

3. Select **Meas Setup** > **Advanced** tab > **Advanced Demod Setup** and verify that both **Multi-Carrier Filter** and **DC Punctured** are 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.



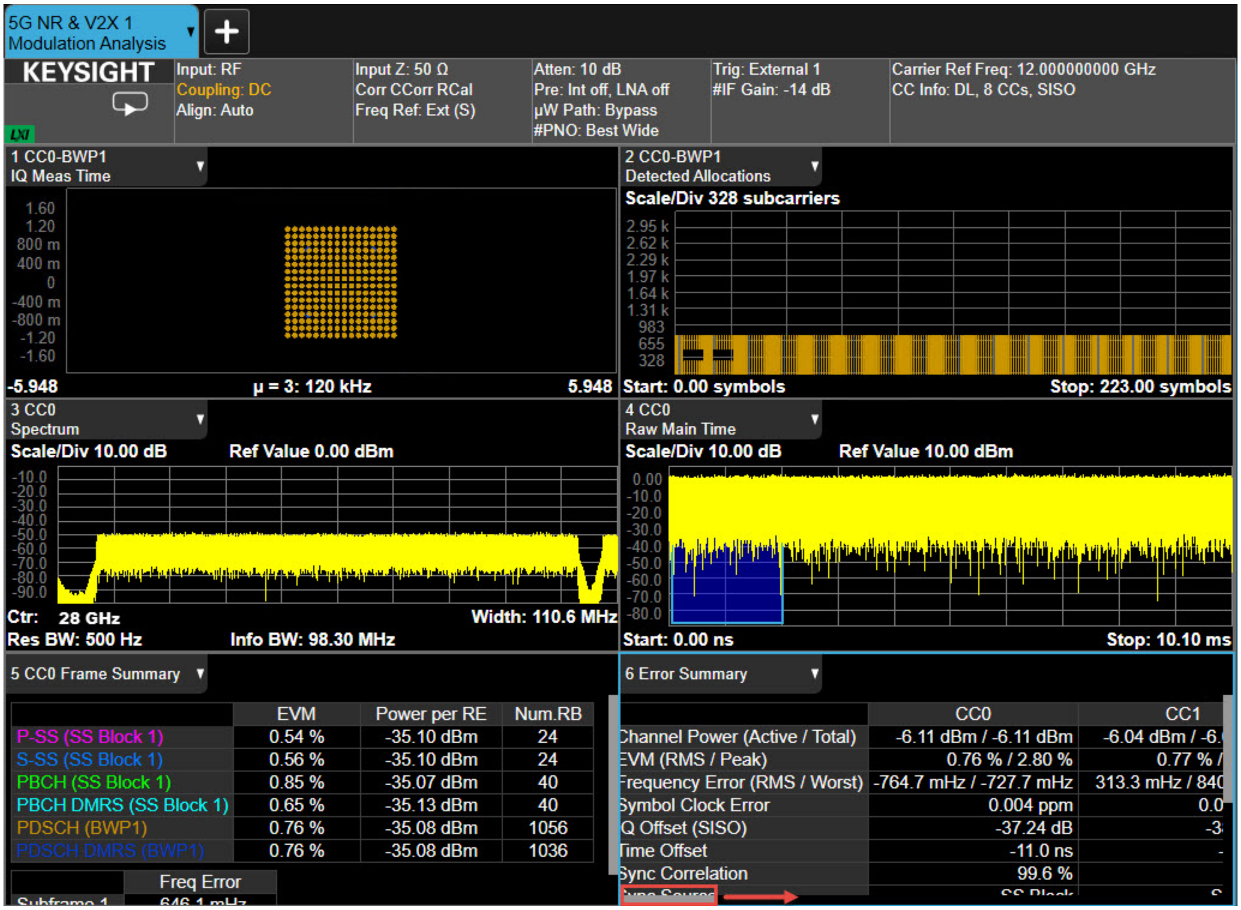
5. Select **Meas Setup** > **Settings** tab > **Optimize EVM**.

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

NOTE

If you are getting a "Sync Error; Sync not found" or "Input Overload - Detected; ADC over range" message), go to Amplitude > Attenuation > and increase the Mechanical Attenuation by 2 dB until the Sync Error is resold.

Notice that the Error Summary measurement has a scroll bar allowing you to view the results of all 8 component carriers.


5G NR & V2X 1
Modulation Analysis
KEYSIGHT
Input: RF
Coupling: DC
Align: Auto
Input Z: 50 Ω
Corr CCorr RCal
Freq Ref: Ext (S)
Atten: 10 dB
Pre: Int off, LNA off
µW Path: Bypass
#PNO: Best Wide
Trig: External 1
#IF Gain: -14 dB
Carrier Ref Freq: 12.000000000 GHz
CC Info: DL, 8 CCs, SISO
1 CC0-BWP1
IQ Meas Time
μ = 3: 120 kHz
2 CC0-BWP1
Detected Allocations
Scale/Div 328 subcarriers
Start: 0.00 symbols
Stop: 223.00 symbols
3 CC0
Spectrum
Scale/Div 10.00 dB
Ref Value 0.00 dBm
Ctr: 28 GHz
Width: 110.6 MHz
Res BW: 500 Hz
Info BW: 98.30 MHz
4 CC0
Raw Main Time
Scale/Div 10.00 dB
Ref Value 10.00 dBm
Start: 0.00 ns
Stop: 10.10 ms
5 CC0 Frame Summary
EVM
Power per RE
Num.RB
P-SS (SS Block 1) 0.54 % -35.10 dBm 24
S-SS (SS Block 1) 0.56 % -35.10 dBm 24
PBCH (SS Block 1) 0.85 % -35.07 dBm 40
PBCH DMRS (SS Block 1) 0.65 % -35.13 dBm 40
PDSCH (BWP1) 0.76 % -35.08 dBm 1056
PDSCH DMRS (BWP1) 0.76 % -35.08 dBm 1036
Freq Error
6 Error Summary
CC0
CC1
Channel Power (Active / Total) -6.11 dBm / -6.11 dBm
EVM (RMS / Peak) 0.76 % / 2.80 %
Frequency Error (RMS / Worst) -764.7 mHz / -727.7 mHz
Symbol Clock Error 0.004 ppm
IQ Offset (SISO) -37.24 dB
Time Offset -11.0 ns
Sync Correlation 99.6 %

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.

```
RFALl: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
```

To Optimize EVM for Multi-Carrier Waveforms

```
POWer:ATTenuation 0dB
```

```
[POWer:ATTenuation 2dB], …
```

```
EVM:IF:GAIN:LEVel 0dB
```

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
```

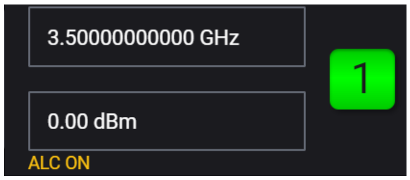
Setting Up a 1 CC 3.5 GHz ACP Measurement

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 292.

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**.

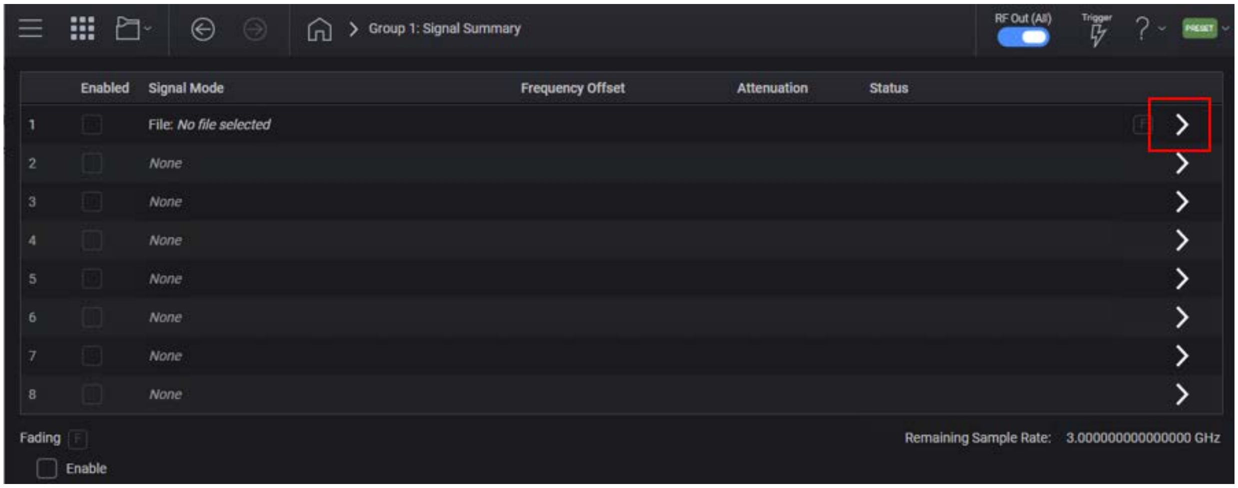


3. Select **Group 1: Signals** block to open.

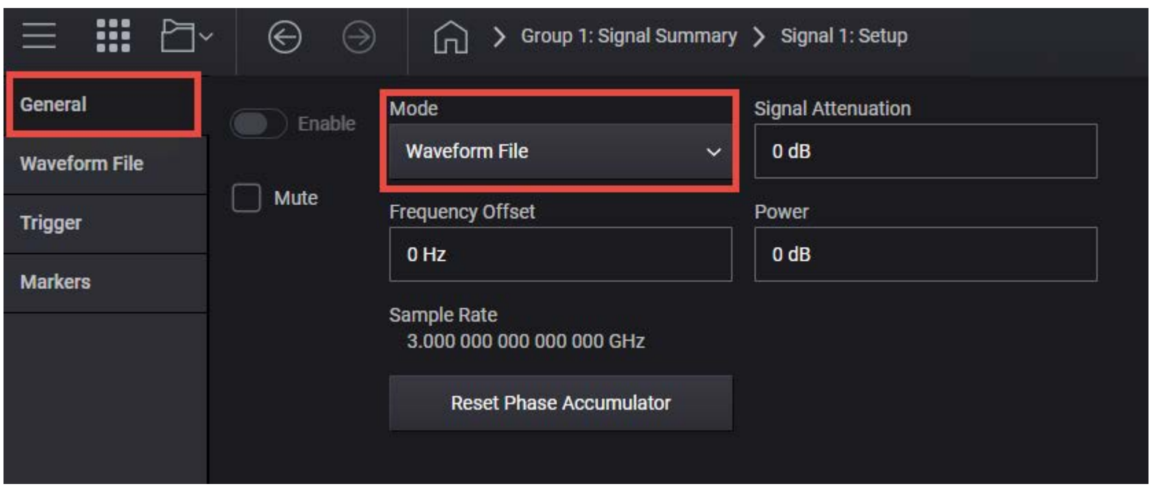
4. Select the arrow for Signal 1 to open the Signal Setup window.

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.



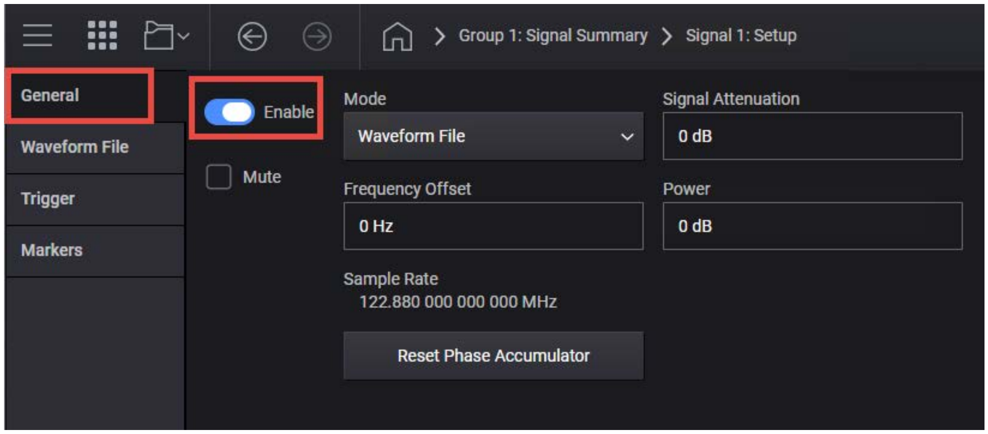
5. In the Vector Modulation Signal Setup:
   a. Select the **Mode** dropdown and set to **Waveform File**.



   b. In the left pane, select the **Waveform File** tab.
   c. Use **File Select** to navigate to:

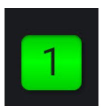
      `D:\Users\Instrument\Documents\Keysight\PathWave\SignalGenerator\Examples`
      and choose
      `5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DCPunctured.wfm`
      then **Select**.

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

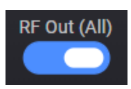


6. Set RF Out to **On** by selecting the numbered channel indicator switch.

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



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



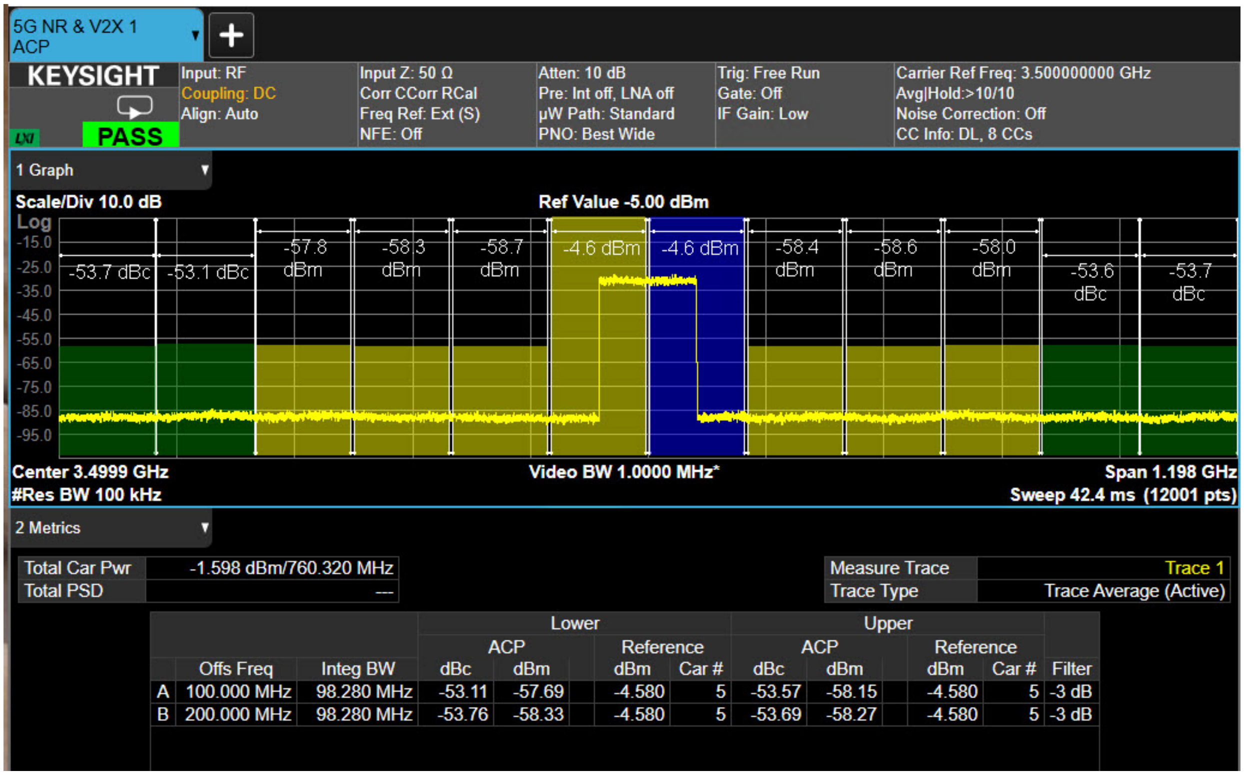
NOTE In order to turn on RF for any channel, both the RF Out for the specific channel (for example, Channel 1 or Channel 2), and RF Out All must be turned on.

On the X-Series Signal Analyzer:

1. Select **Mode Preset** to set 5G NR V2X mode to a known state.
2. Select **Mode/Meas** > **5G NR & V2X** Mode > **ACP** Measurement.

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

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



			Lower				Upper				
			ACP		Reference		ACP		Reference		
	Offs Freq	Integ BW	dBc	dBm	dBm	Car #	dBc	dBm	dBm	Car #	Filter
A	100.000 MHz	98.280 MHz	-53.11	-57.69	-4.580	5	-53.57	-58.15	-4.580	5	-3 dB
B	200.000 MHz	98.280 MHz	-53.76	-58.33	-4.580	5	-53.69	-58.27	-4.580	5	-3 dB

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.

```
RFALl: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

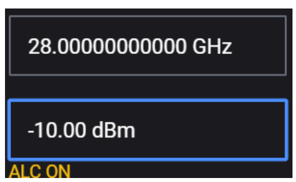
PathWave software tools can be used to create, download, and playback waveforms through the VXG.

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.

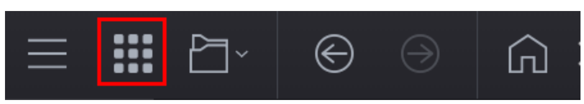
NOTE The VXG must have the N7631APPC Signal Generation for 5G NR license installed.

On the VXG:

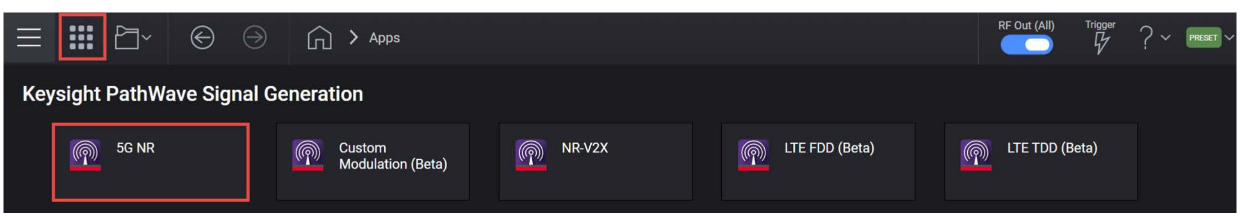
1. Select **Preset** > **Preset** to set the VXG to a known state.
2. In the Output area, set Frequency to **28 GHz** and Power to **-10 dBm**.



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

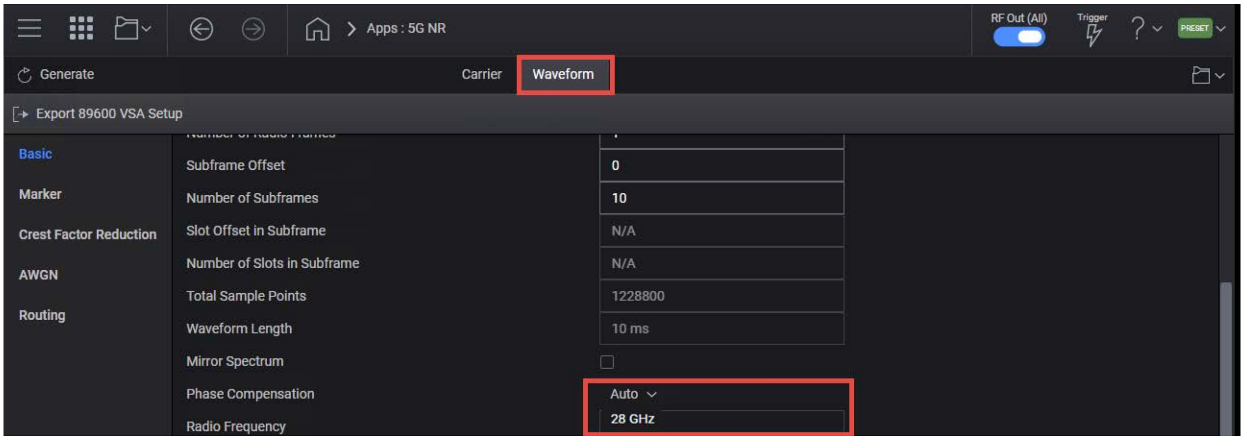


4. Select **5G NR** to enter the 5G NR signal mode.



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

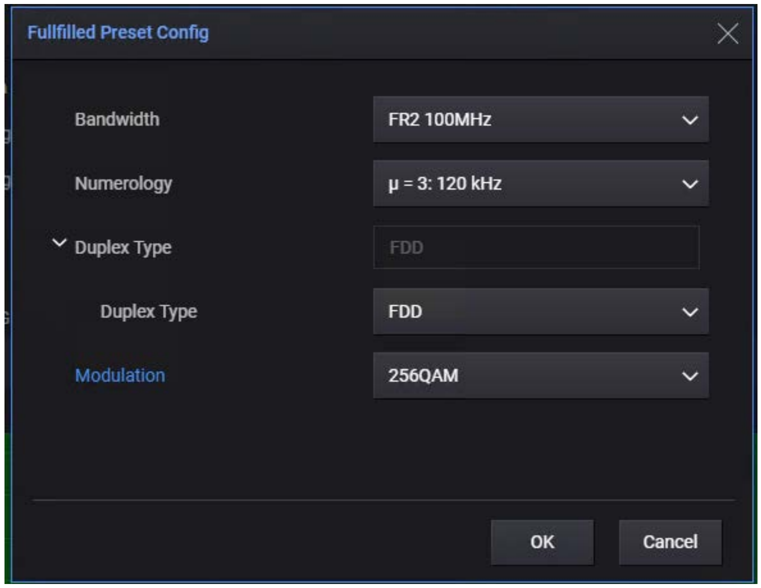
Some applications, like power amplifier measurements use the same waveform at different frequencies and can be time consuming to generate a separate waveform for each frequency. In this case, you would turn Phase Compensation Off, so the waveform becomes independent from the carrier frequency. You need 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 **μ= 3:120 kHz**, and 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.

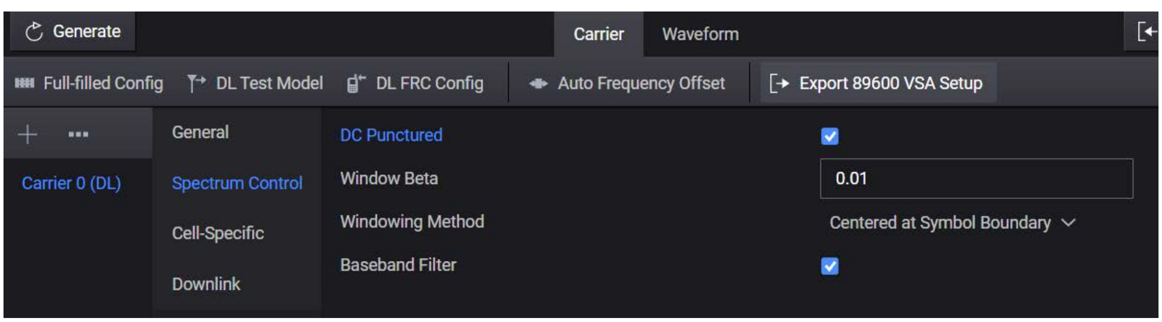
Full Filled Configurations is a great place to start creating your waveform. You can select FR, bandwidth, and modulation format with a fully allocated PDSCH data channel. This would represent a spectrally correct signal that is typically used in power amplifier measurements. You can modify the RB allocations and Slot allocations if fully allocated data channels are not desired.



8. Select **OK** to exit the Full Filled Config setup.

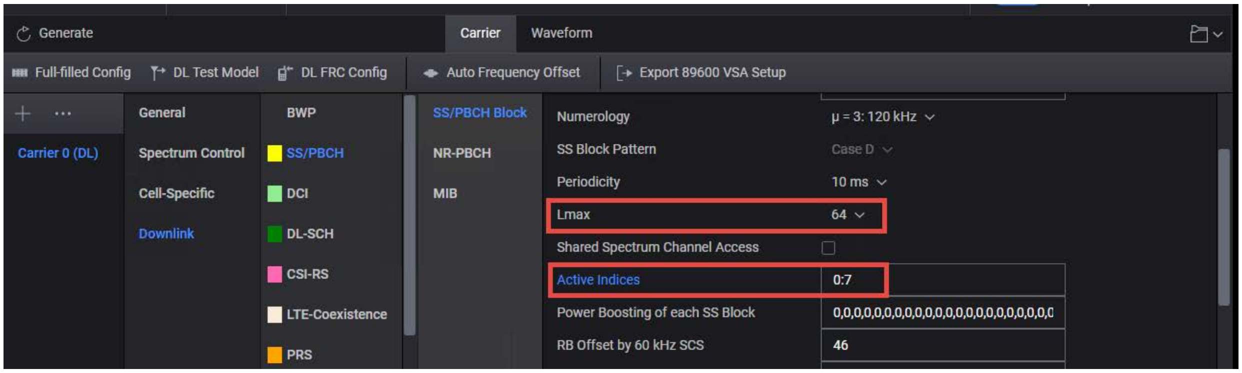
9. From the Carrier panel (in the left pane), select **Spectrum Control** > **DC Punctured On**.

   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**.

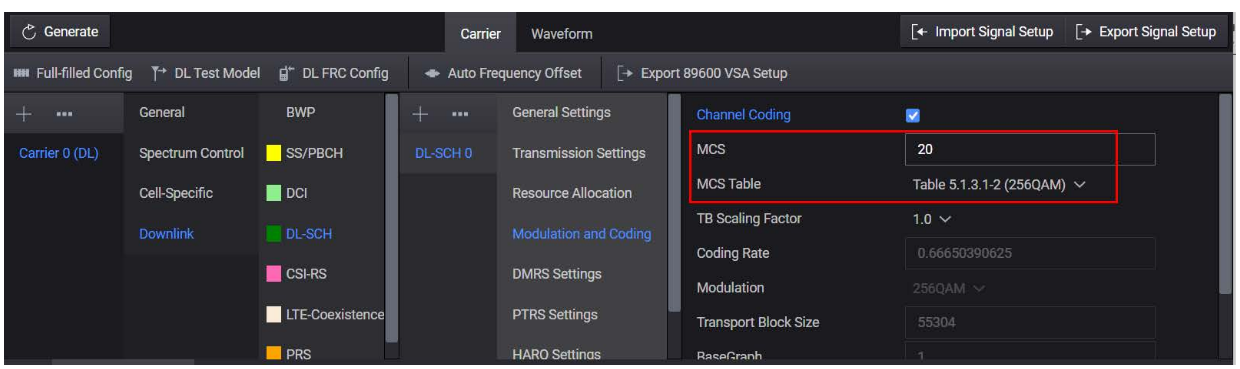
Instead of transmitting all 64 beams, we enable only 8 of them by setting Active Indices to 0:7.



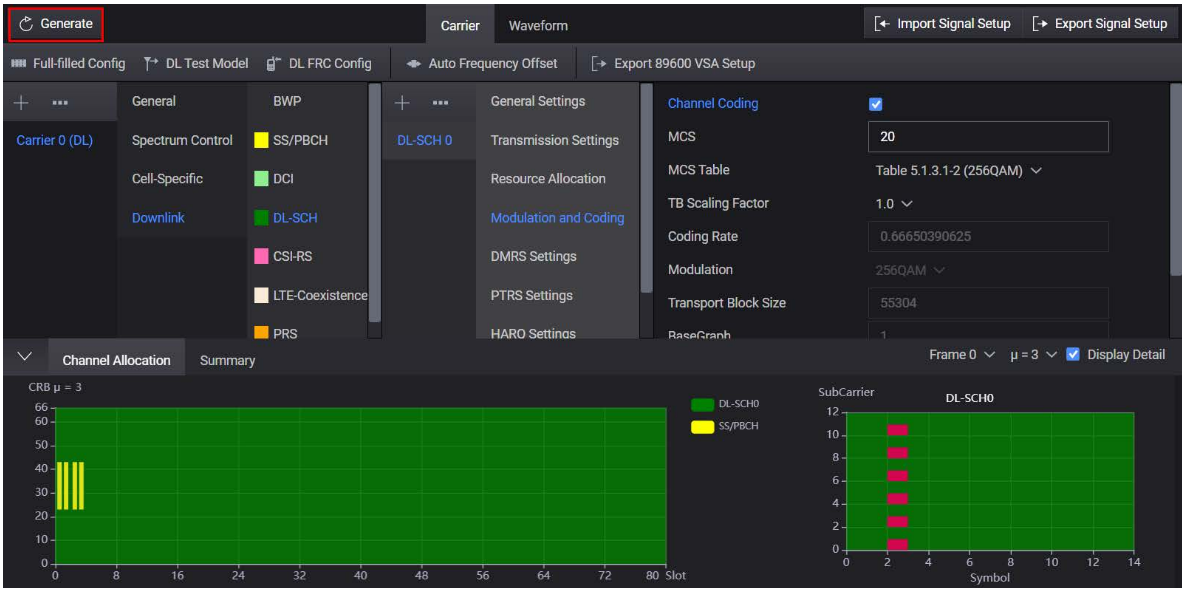
NOTE Lmax sets the maximum number of possible SS/PBCH blocks in a transmission opportunity. This value is fixed for a given carrier bandwidth. Typically, higher frequency and bandwidth carriers use a larger set of SS/PBCH opportunities to support a larger set of antenna beams.Lmax is either 4 or 8 for 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.

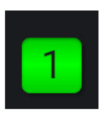


12. Select **Generate** to generate the Waveform, and then select **Home** to exit the setup panel.



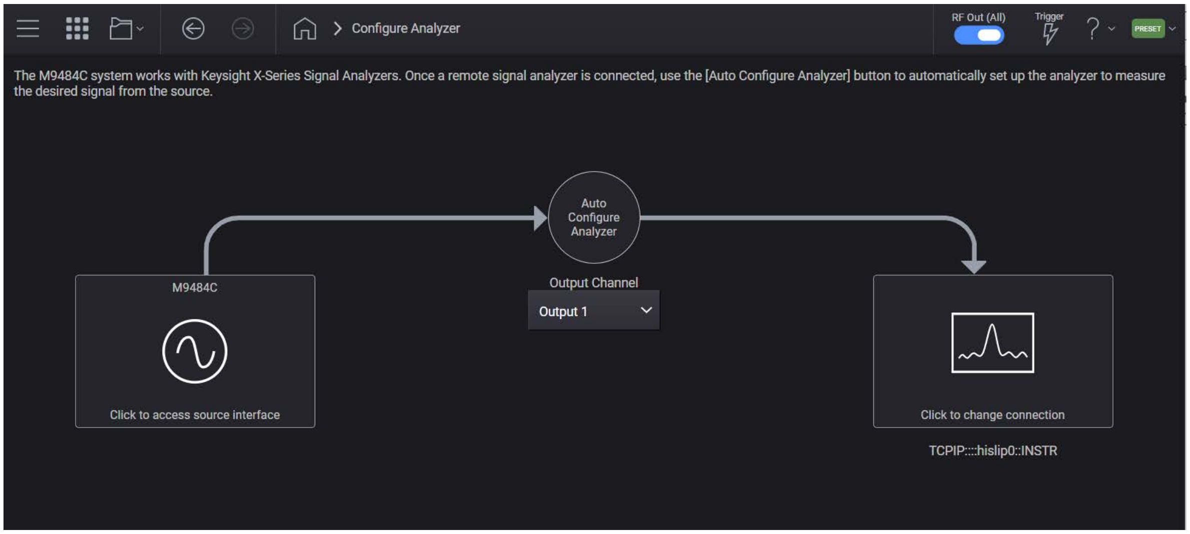
13. Set RF Out to **On** by selecting the numbered channel indicator switch.

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



Setup Auto Configure Analyzer

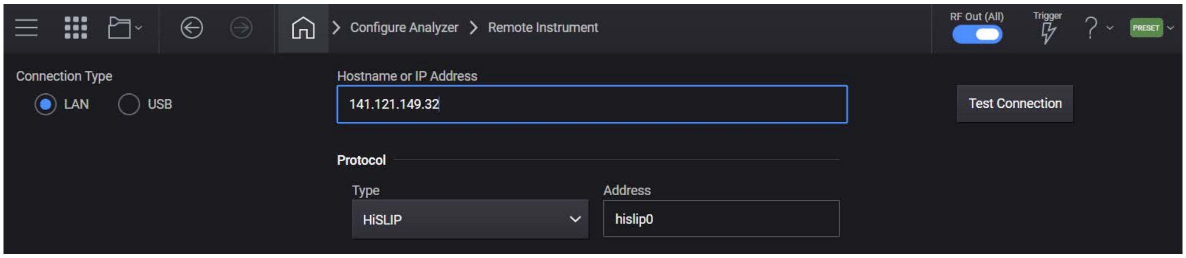
1. Select the **System** menu (triple bar tab at the top left of the window) to open the System Menu and then select **Configure Analyzer**.



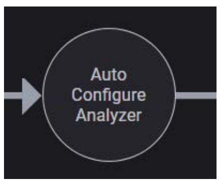
2. In the System Configuration setup, select the Remote Signal Analyzer block (on far right) to setup the communication channel to the Keysight X-Series Signal Analyzer.

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**.

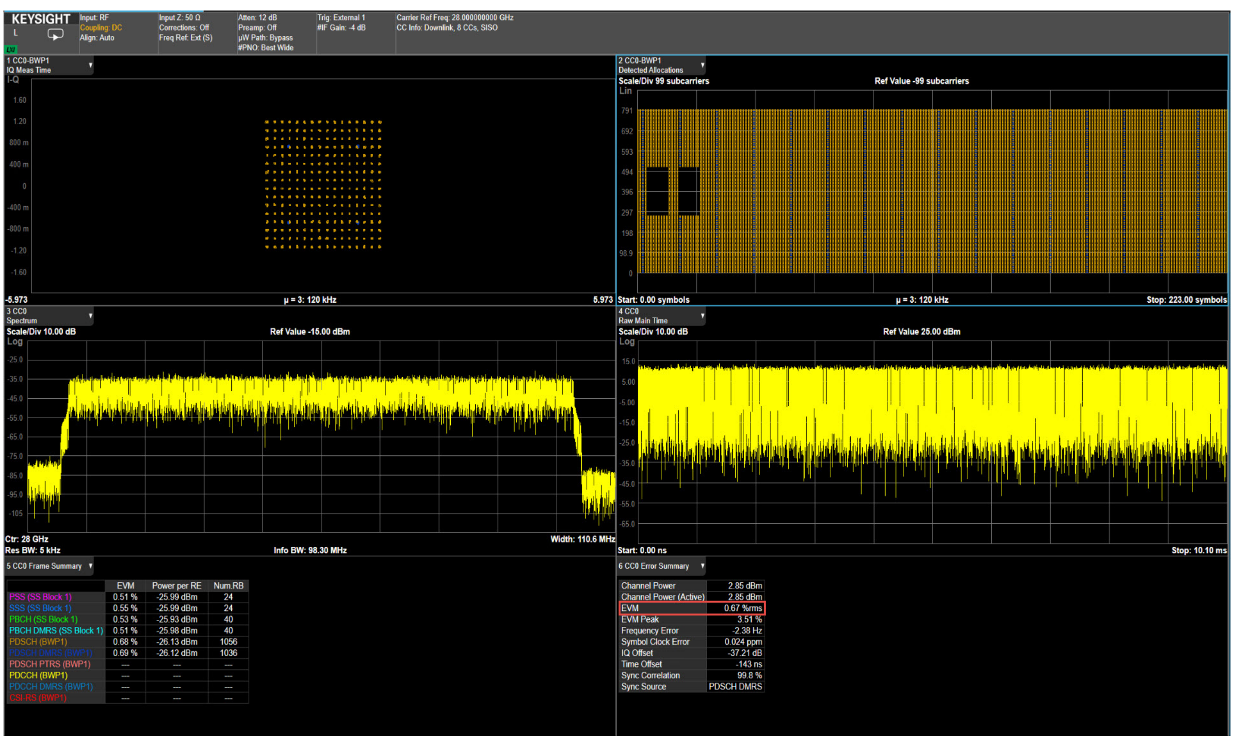
6. Select **Test Connection** to verify, then the **Back** icon to go back to the main Configure Analyzer display.



7. Select **Auto Configure Analyzer** to send the VXG settings to the analyzer.



8. 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 µ = 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:SIGNal1 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:

KEYSIGHT TECHNOLOGIES

5G Waveform and EVM Analysis Using VSA Software

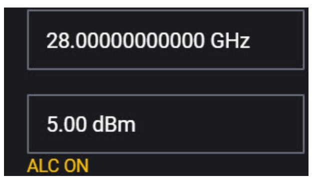
The VXG enables 5G testing with a low error vector magnitude (EVM) at high frequencies. The VXG has extremely good EVM at high power levels. However, not all signal analyzers can capture this low value. We will use the X-Series Signal Analyzer with the Vector Signal Analysis (VSA) software to observe 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:

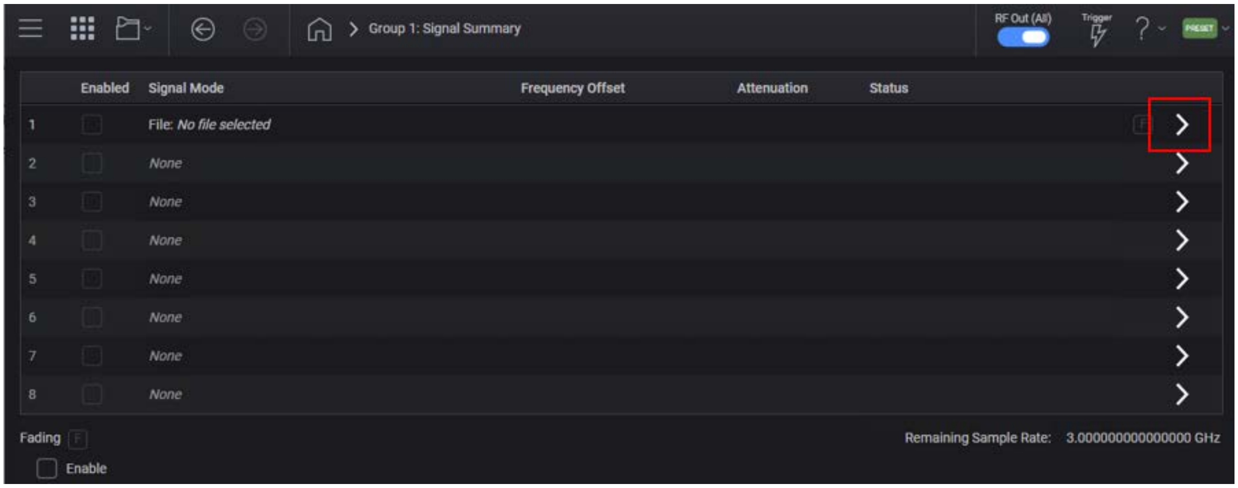
1. Select **Preset** > **Preset** to set the instrument to a known state.
2. In the Output 1 area, set Frequency to **28 GHz** and Power to **5 dBm**.



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

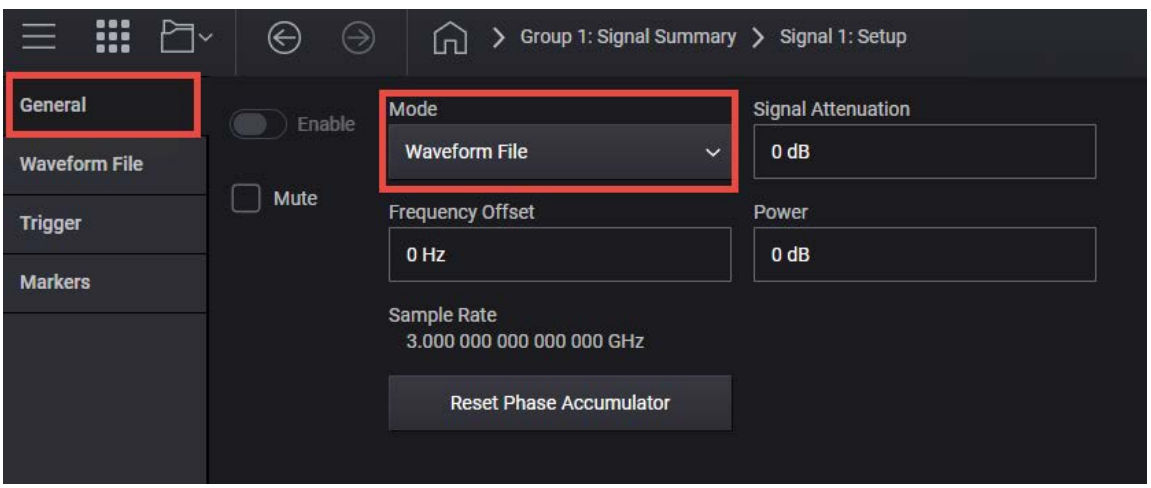
4. Select the arrow for Signal 1 to open the Signal Setup window.

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.



5. In the Vector Modulation Signal Setup:

   a. Select the **Mode** dropdown and set to **Waveform File**.



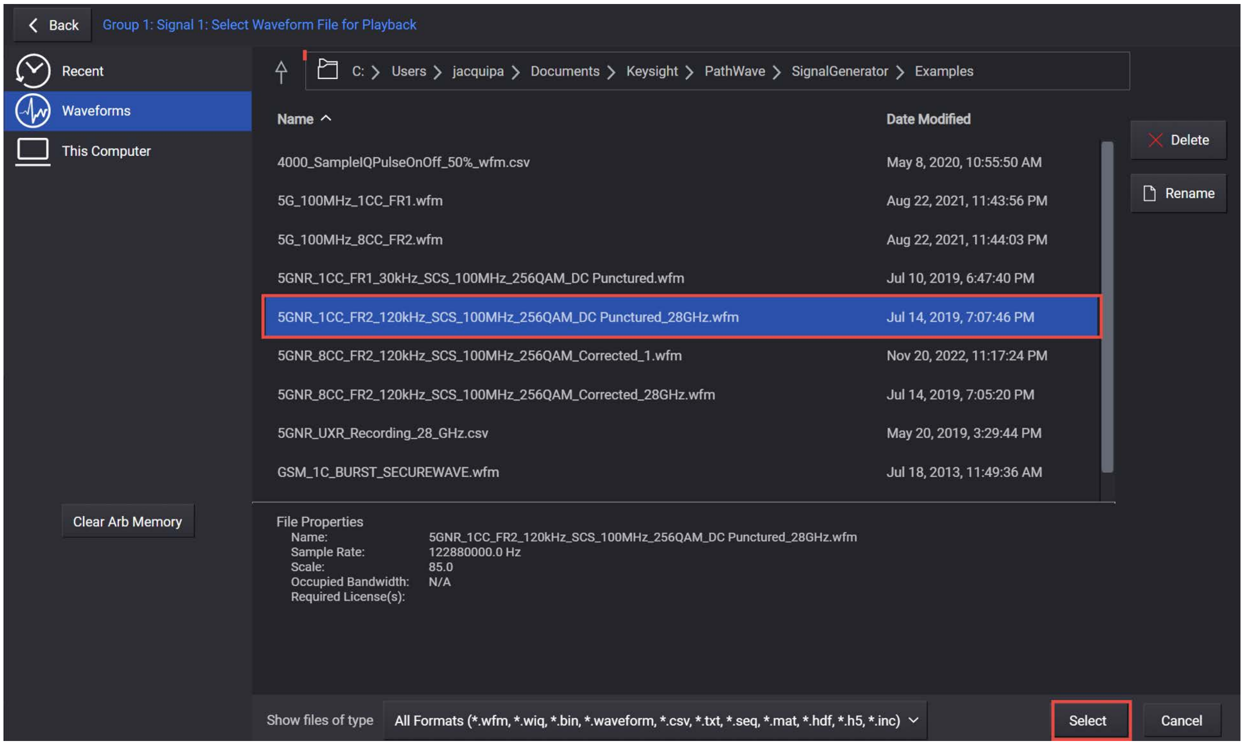
   b. In the left pane, select the **Waveform File** tab.

   c. Use **File Select** to navigate to:

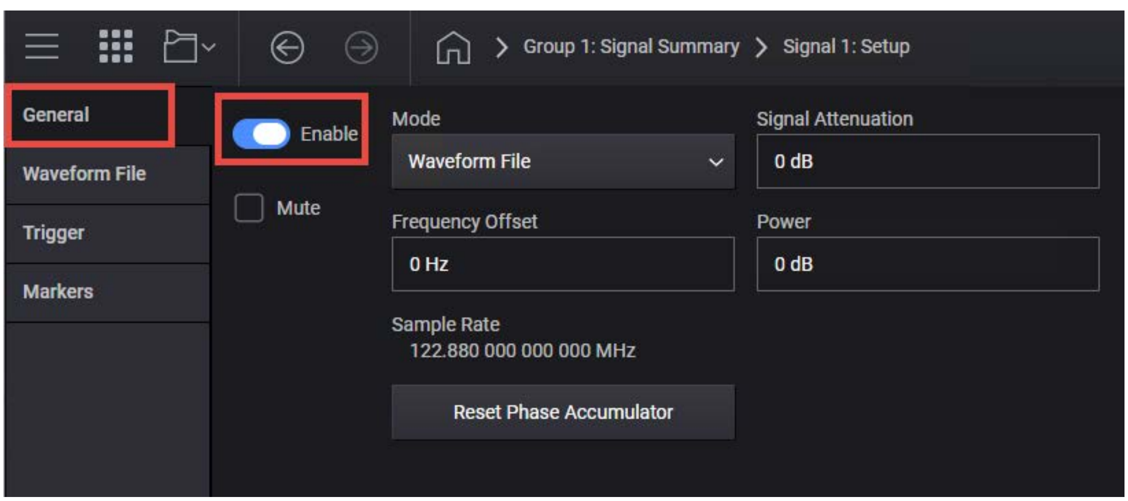
```
D:\Users\Instrument\Documents\Keysight\PathWave
\SignalGenerator\Examples
```

   and choose

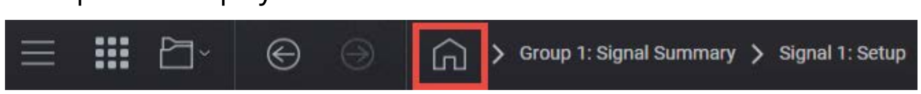
`5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DCPunctured_28GHz.wfm`
then **Select.**



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



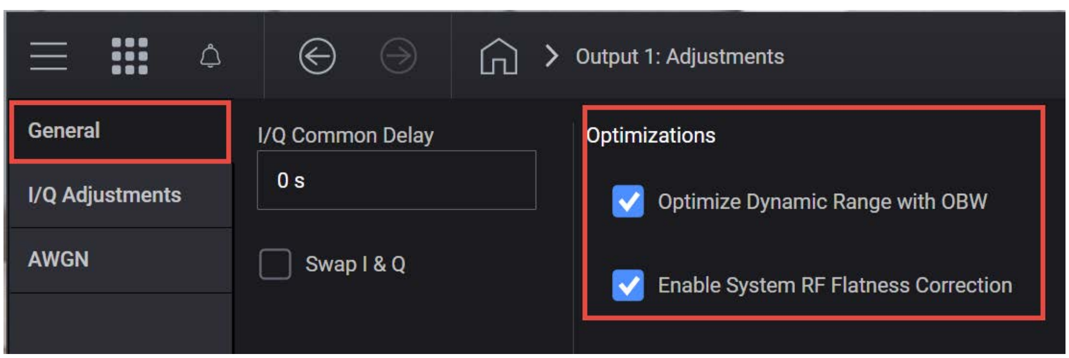
6. Close the Vector Modulation Signal Setup by selecting the **Home** icon at the top of the display.



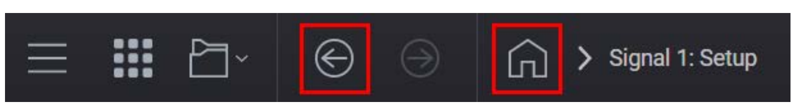
7. Select the **Adjustments** block and select **Optimize Dynamic Range with OBW** and **Enable System RF Flatness Correction**.

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.

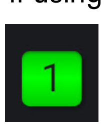


8. Close the Adjustments Setup by either selecting the **Back** or the **Home** icon at the top of the display.

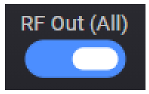


9. Set RF Out to **On** by selecting the numbered channel indicator switch.

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



10. **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:

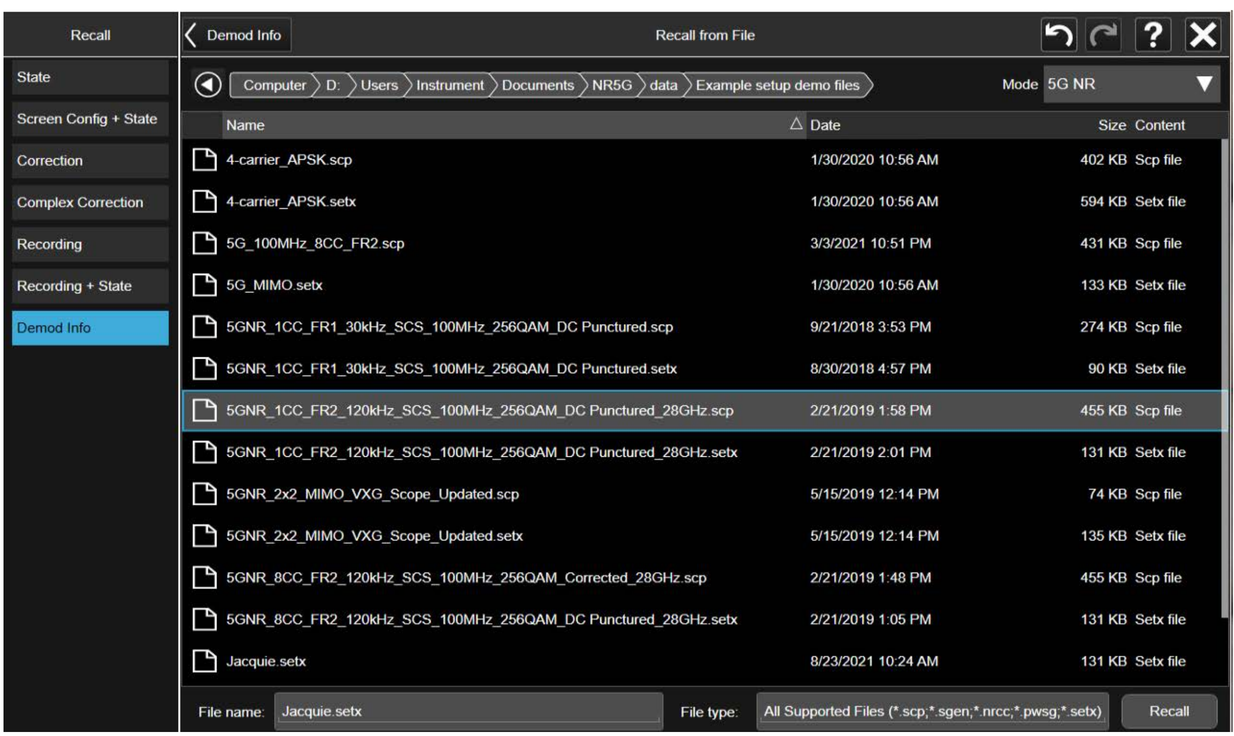
NOTE All example waveforms and setup files are located on the VXG at:

`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** >

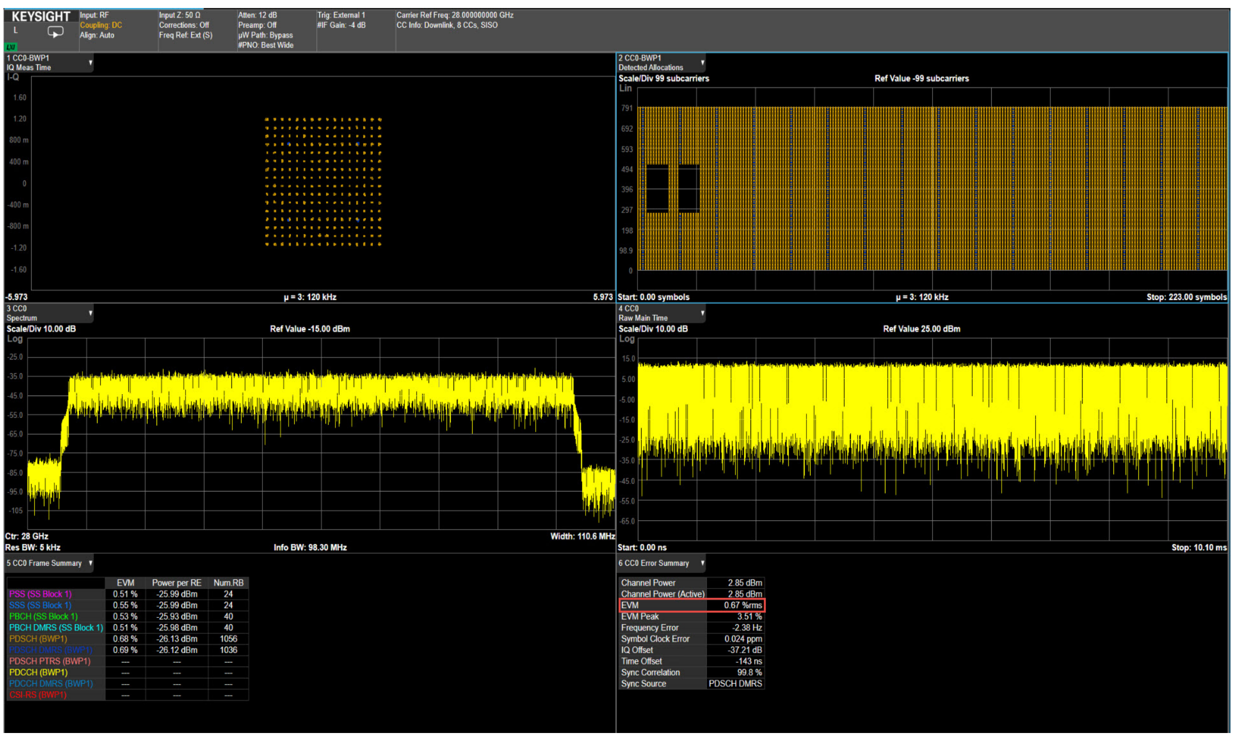
   `5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DC punctured_28GHz_34.scp` >**Recall**



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%.



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`

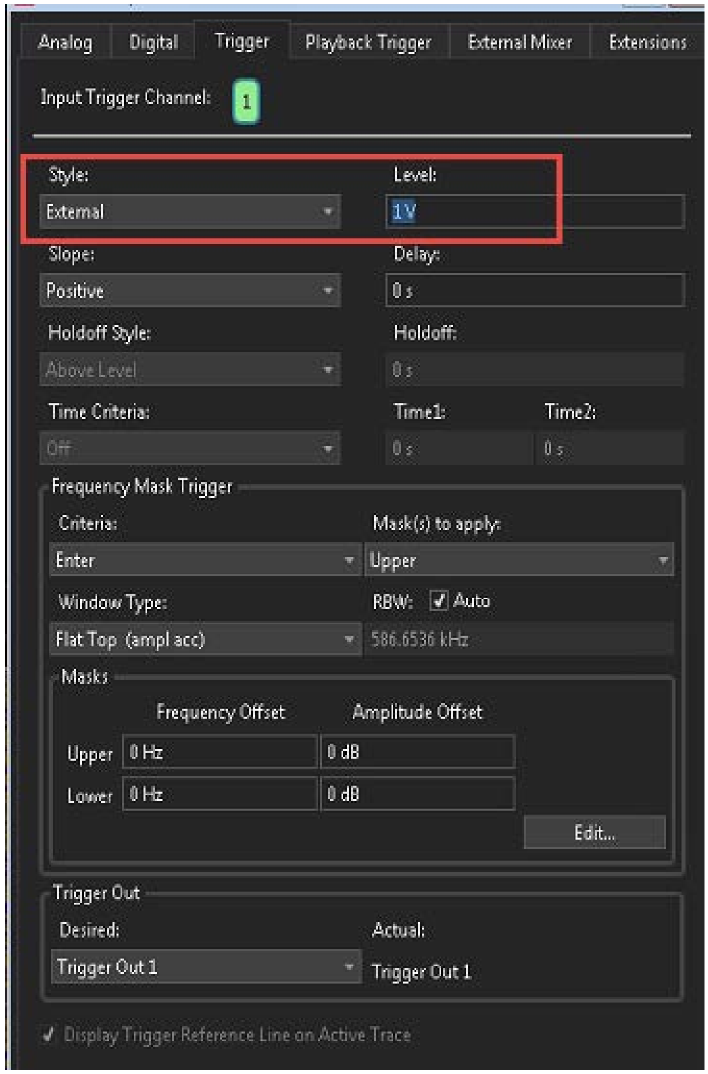
You will need to copy over the setup files to the X-Series Signal Analyzer or the PC running the VSA application.

2. Select **File** > **Recall** > **Recall Setup** and navigate to `5GNR_1CC_FR2_120kHz SCS_100MHz_256QAM_DC Punctured_28GHz.setx`

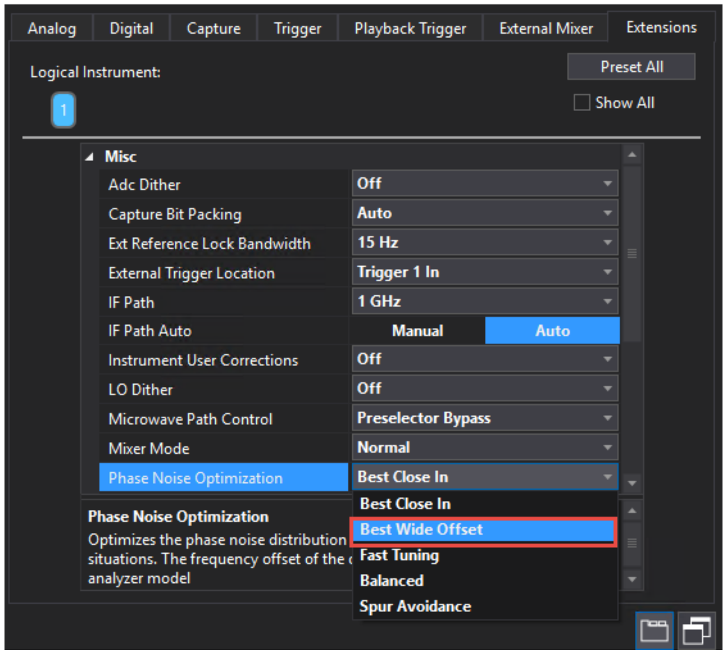
3. From the toolbar, select the **Pause** Icon. 

   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**.

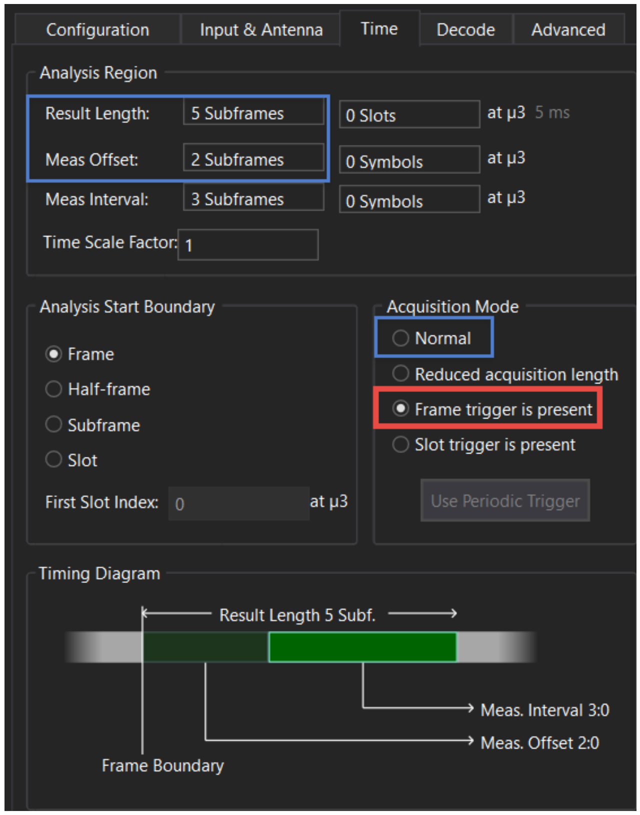


6. From the menu bar, select **MeasSetup** > **5G NR Demod Properties** > **Time** tab.

   – Set Result Length to **10 Subframes**.

   – Set Meas Interval to **2 Subframes**.

– Select **Frame Trigger is Present.**

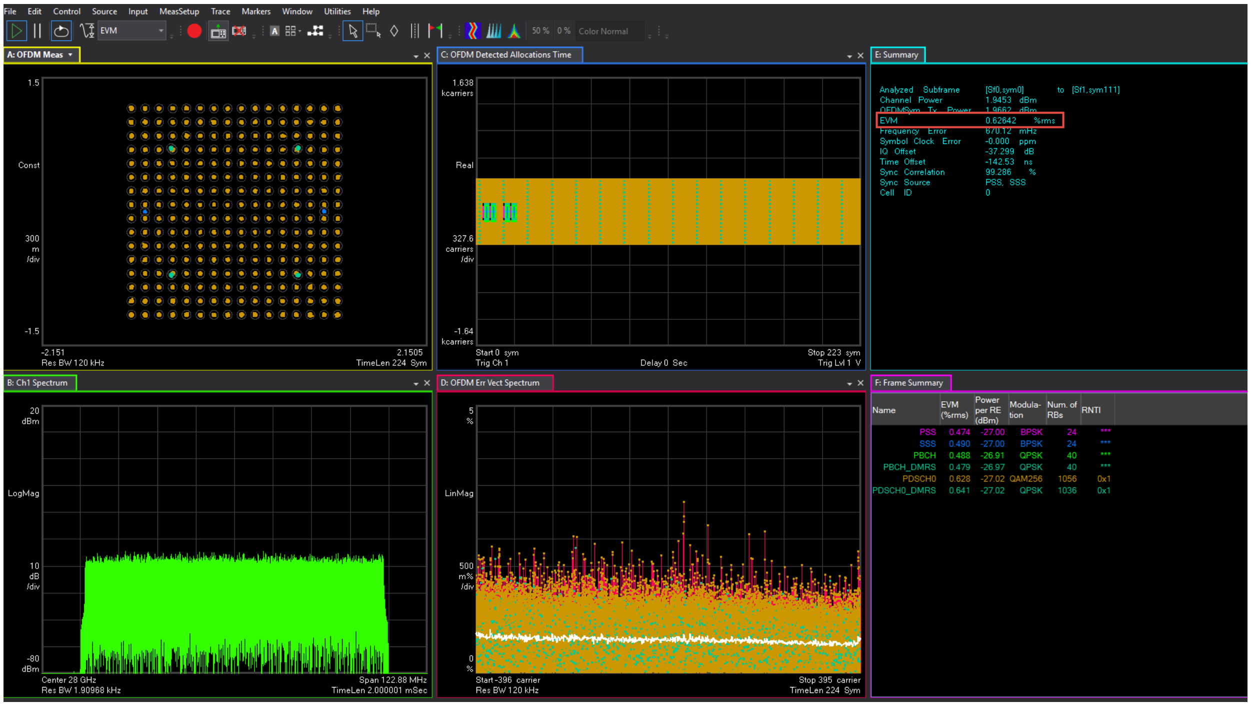


7. From the toolbar, select the **Auto-Rang**e dropdown and select **EVM-Table or Algorithm Based.**

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

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

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


File Edit Control Source Input MeasSetup Trace Markers Window Utilities Help
A: OFDM Meas
C: OFDM Detected Allocations Time
E: Summary
Analyzed Subframe [Sf0,sym0] to [Sf1,sym111]
Channel Power 1.9453 dBm
OFDMSym Tx Power 1.9662 dBm
EVM 0.62642 %rms
Frequency Error 670.12 mHz
Symbol Clock Error -0.000 ppm
IQ Offset -37.299 dB
Time Offset -142.53 ns
Sync Correlation 99.286 %
Sync Source PSS, SSS
Cell ID 0
B: Ch1 Spectrum
Center 28 GHz
Res BW 1.90968 kHz
Span 122.88 MHz
TimeLen 2.000001 mSec
D: OFDM Err Vect Spectrum
Start -396 carrier
Res BW 120 kHz
Stop 395 carrier
TimeLen 224 Sym
F: Frame Summary
Name | EVM (%rms) | Power per RE (dBm) | Modula-tion | Num. of RBs | RNTI
PSS 0.474 -27.00 BPSK 24 ***
SSS 0.490 -27.00 BPSK 24 ***
PBCH 0.488 -26.91 QPSK 40 ***
PBCH_DMRS 0.479 -26.97 QPSK 40 ***
PDSCH0 0.628 -27.02 QAM256 1056 0x1
PDSCH0_DMRS 0.641 -27.02 QPSK 1036 0x1

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.

```
RFALl: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:

```
NR5G:RLENgth 10
```

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

Set the Acquisition Mode to “Frame Trigger is Present”

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

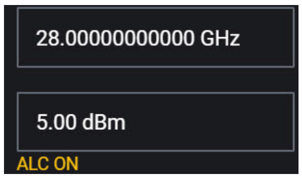
Setting Up an 8 CC 28 GHz EVM Measurement

NOTE Ensure the equipment and triggers are properly configured. Refer to “Equipment Setup” on page 11.

Using the graphical user interface

On the VXG:

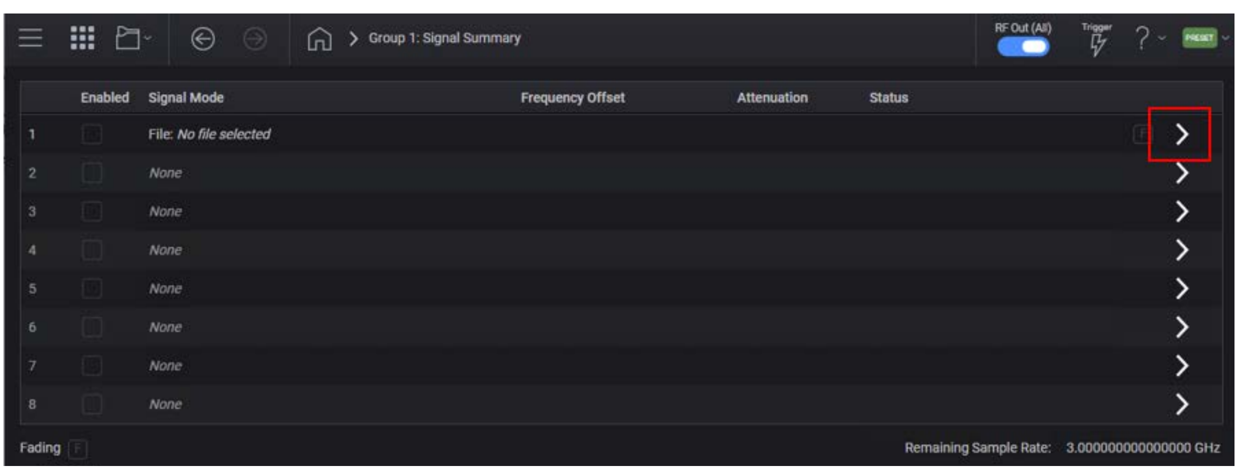
1. Select **Preset** > **Preset** to set the VXG to a known state.
2. Set Frequency to **28 GHz** and Amplitude to **5 dBm**.



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

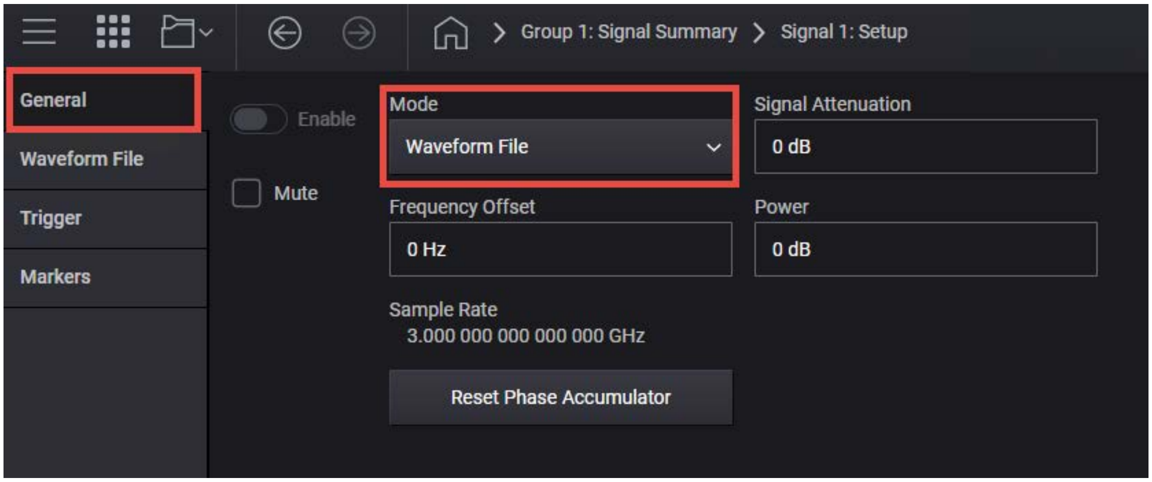
4. Select the arrow for Signal 1 to open the Signal Setup window.

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.



5. In the Vector Modulation Signal Setup:

   a. Select the **Mode** dropdown and set to **Waveform File**.

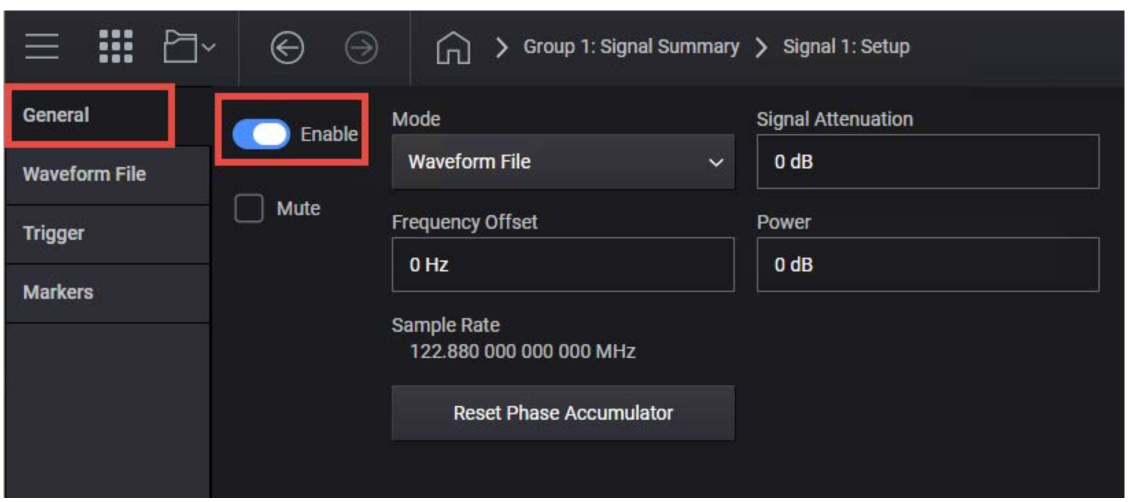


   b. In the left pane, select the **Waveform File** tab.

   c. 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**.

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

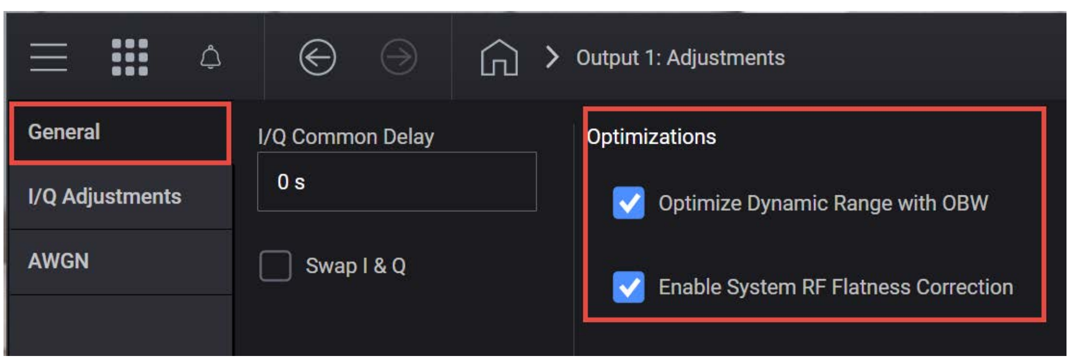


6. Close the Signal Setup by selecting the **Home** icon at the top of the display.

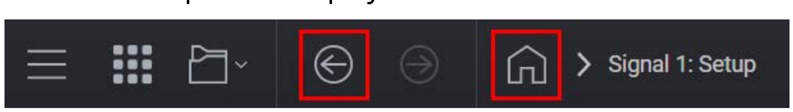
7. Select the **Adjustments** block and select **Optimize Dynamic Range with OBW** and **Enable System RF Flatness Correction**.

   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.



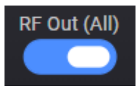
8. Close the Adjustments Setup by either selecting the **Back** or the **Home** icon at the top of the display.



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

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

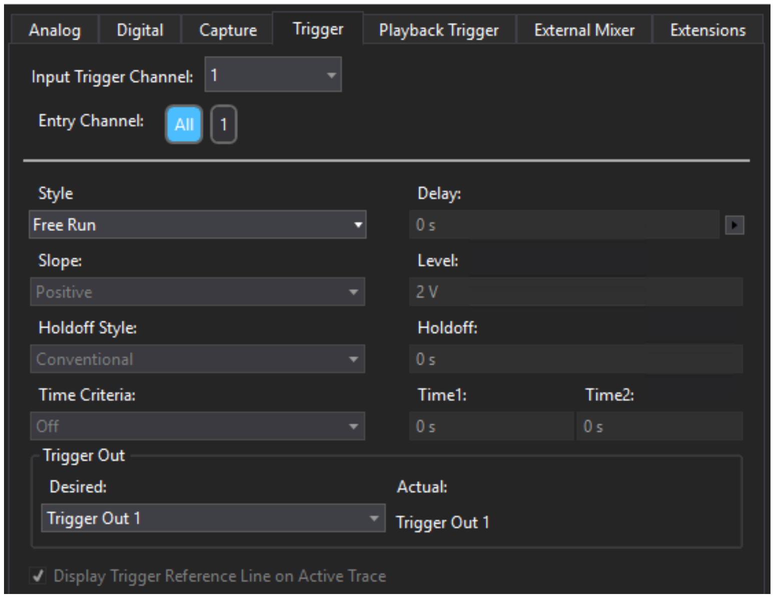
You will need to copy over the setup files to the X-Series Signal Analyzer or the PC running the VSA application.

---

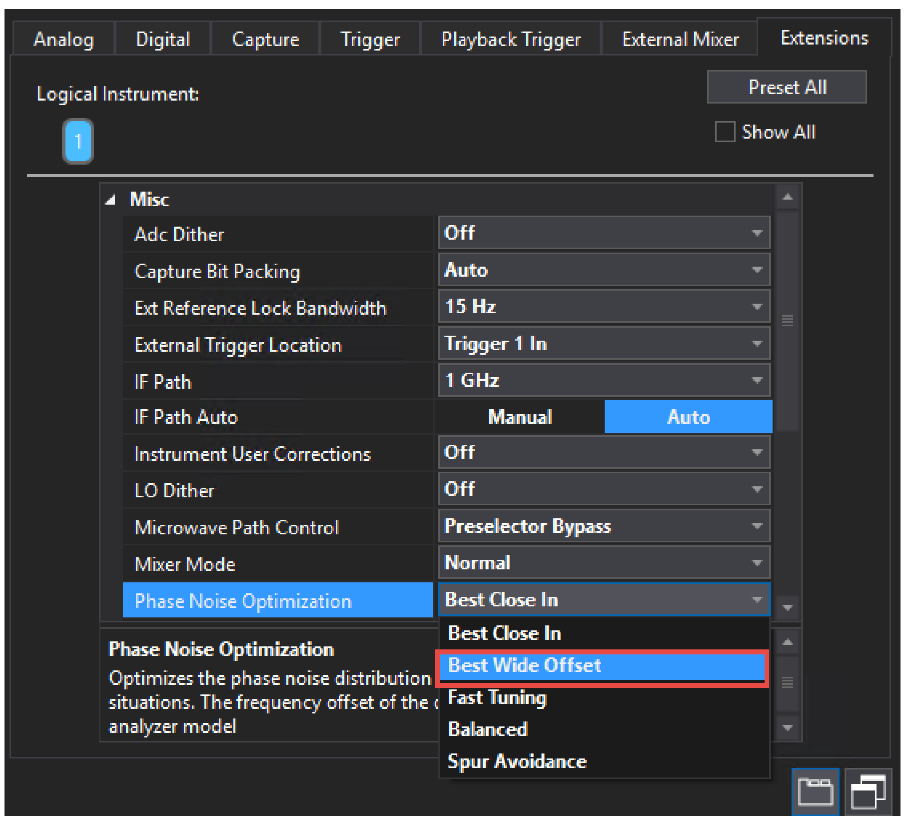
2. Select **File** > **Recall** > **Recall Setup** and navigate to D:Users\Instrument\Documents\NR5G\data\NR5GEvm\Carrier Setup, then open `5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_1.setx`
3. From the toolbar, select the **Pause** Icon. 

   Pausing the measurement will help to speed up the setup time.

4. From the menu bar, select **Input** > **Trigger** and set Style to **FreeRun**.



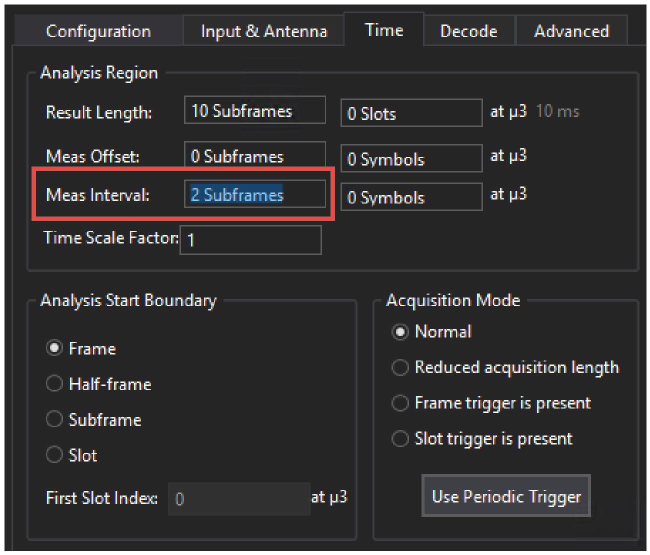
5. Select the **Extensions** tab and change Phase Noise Optimization to **Best Wide Offset**. (For an N9040B only, set External Trigger Location to Trigger 3 In.)



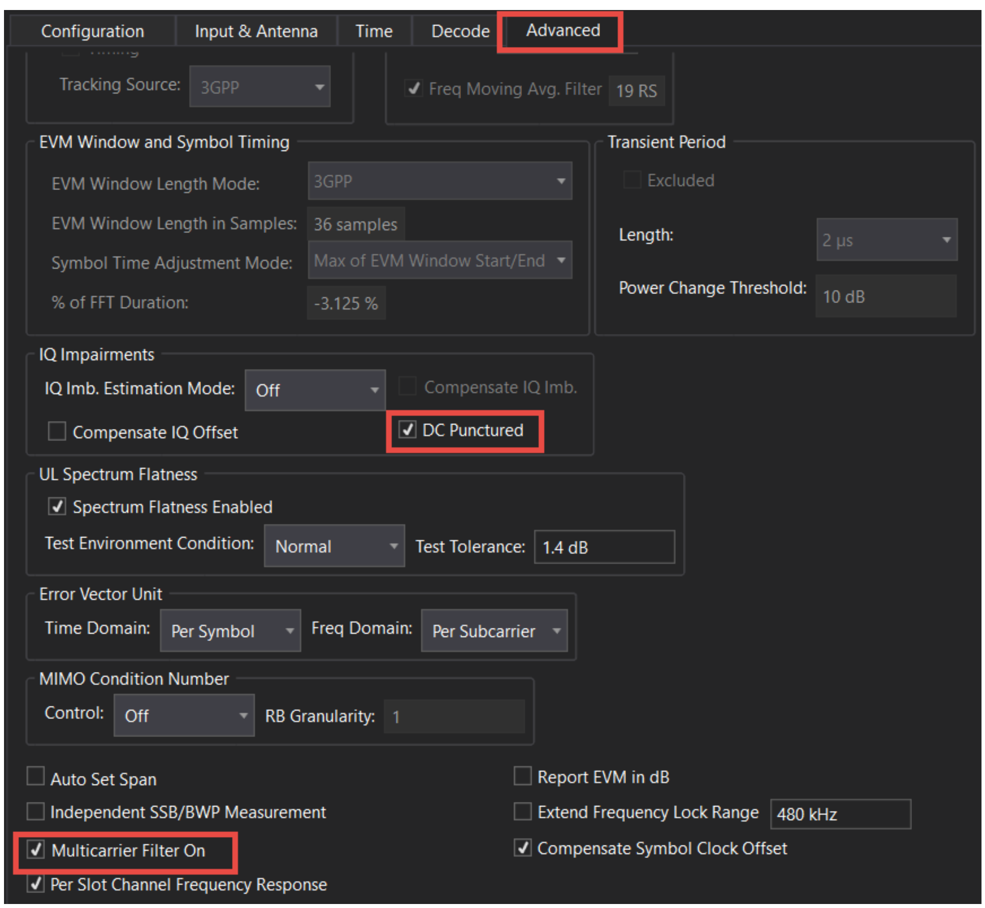
6. From the menu bar, select **MeasSetup** > **5G NR Demod Properties** > **Time** tab.

   – Set Result Length to **10 Subframes**.

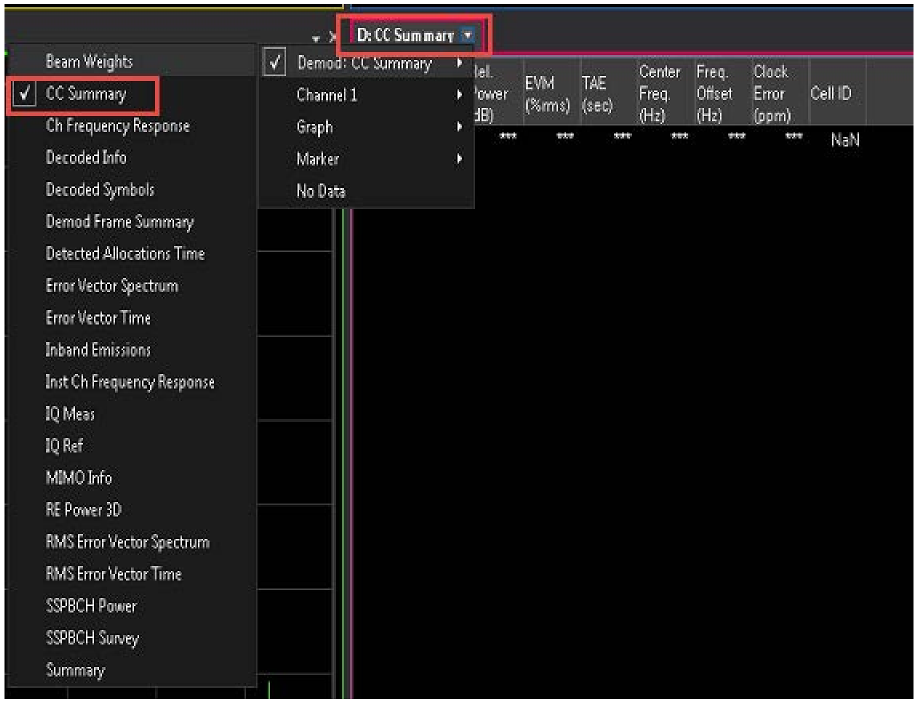
   – Set Meas Interval to **2 Subframes**.



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**.

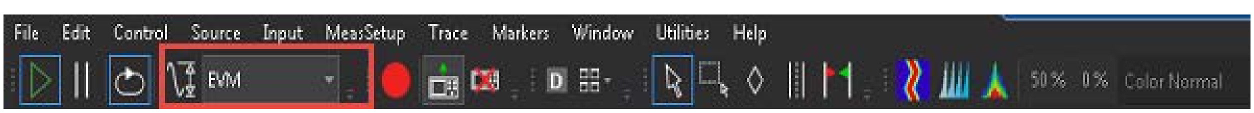


9. In the Spectrum trace window (bottom left window), select **Center** and change the frequency to **28 GHz**.

10. From the toolbar, select the **Autorang**e dropdown and select **EVM-Table or Algorithm Based**.

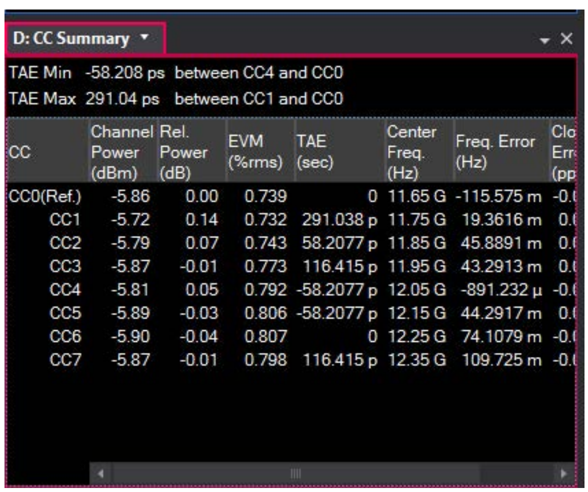
– EVM - Table or Algorithm Based performs EVM optimization based on prescribed table/algorithm instead of using EVM in the feedback loop. This method of EVM auto-range is normally faster than Meas Based Iteration, but may not achieve the most optimal setup for minimized EVM).

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



11. Select the **Autorange** icon to run the measurement for EVM optimization on all eight channels. This may take a few minutes to complete.


File Edit Control Source Input MeasSetup Trace Markers Window Utilities Help
EVM - Meas Based Iteration
A: (CC0) OFDM Meas: All Layers
C: (CC0) OFDM Detected Allocations Time: All Layers
E: (CC0) Summary
B: Ch1 Spectrum
D: CC Summary
F: (CC0) Frame Summary
Center 12 GHz
Span 768 MHz
Res BW 1.90968 kHz
TimeLen 2 mSec


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)
CC0(Ref.) -5.86 0.00 0.739 0 11.65 G -115.575 m
CC1 -5.72 0.14 0.732 291.038 p 11.75 G 19.3616 m
CC2 -5.79 0.07 0.743 58.2077 p 11.85 G 45.8891 m
CC3 -5.87 -0.01 0.773 116.415 p 11.95 G 43.2913 m
CC4 -5.81 0.05 0.792 -58.2077 p 12.05 G -891.232 µ
CC5 -5.89 -0.03 0.806 -58.2077 p 12.15 G 44.2917 m
CC6 -5.90 -0.04 0.807 0 12.25 G 74.1079 m
CC7 -5.87 -0.01 0.798 116.415 p 12.35 G 109.725 m

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.

```
RFALl:OUTPut ON
```

On the X-Series Signal Analyzer

```
INSTrument:SELect VSA89601

MMEMory:LOAD:DEMO
"D:\Users\Instrument\Documents\NR5G\data\NR5GEvm\CarrierSetup\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

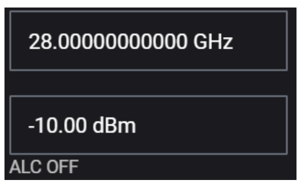
PathWave software tools can be used to create, download, and playback waveforms through the VXG.

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.

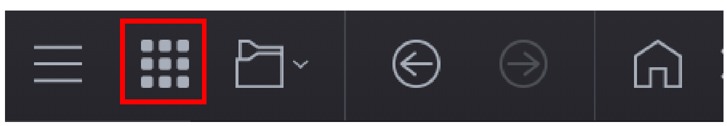
NOTE The VXG must have the N7631APPC Signal Generation for 5G NR license installed.

On the VXG:

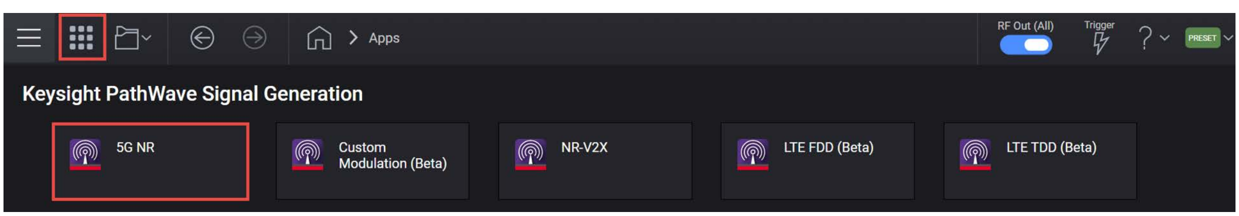
1. Select **Preset** > **Preset** to set the VXG to a known state.
2. In the Output area, set Frequency to **28 GHz** and Power to **-10 dBm**.



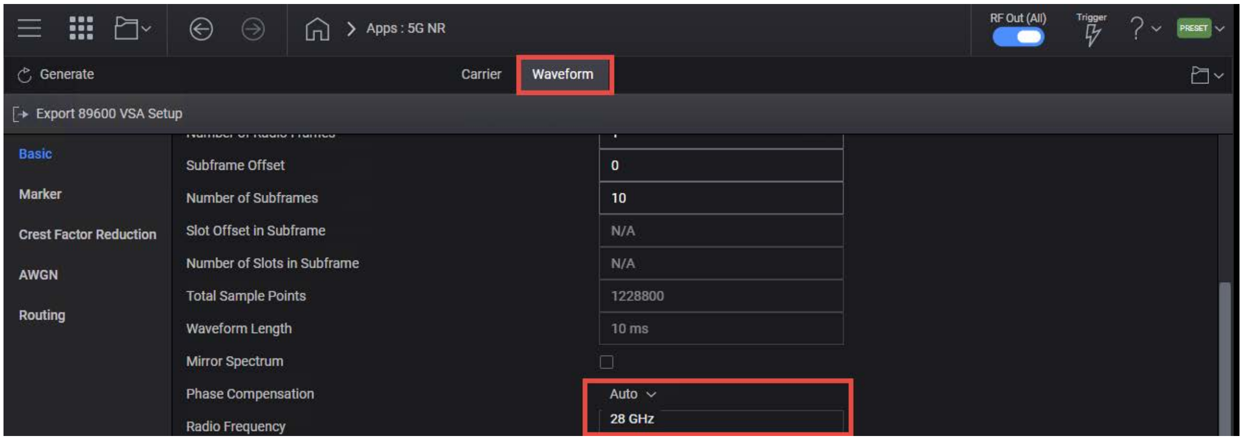
3. Select the **Radio Apps** block to open the Vector Modulation Signal Setup panel.



4. Select **5G NR** to enter 5GNR Signal Mode.



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.

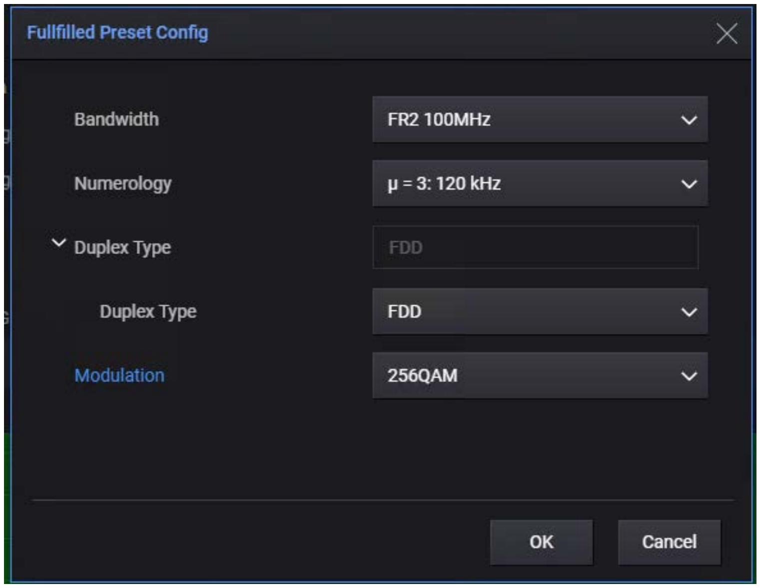
Some applications, like power amplifier measurements use the same waveform at different frequencies and can be time consuming to generate a separate waveform for each frequency. In this case, you would turn Phase Compensation Off, so the waveform becomes independent from the carrier frequency. You need 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 **μ = 3: 120 kHz**, and Modulation to **256QAM**.

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.

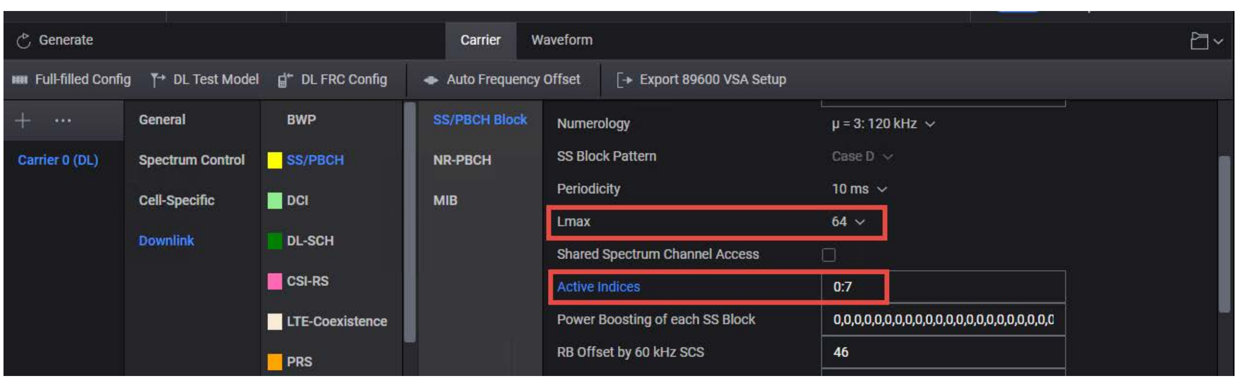
Full Filled Configurations is a great place to start creating your waveform. You can select FR, bandwidth, and modulation format with a fully allocated PDSCH data channel. This would represent a spectrally correct signal that is typically used in power amplifier measurements. You can modify the RB allocations 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**.

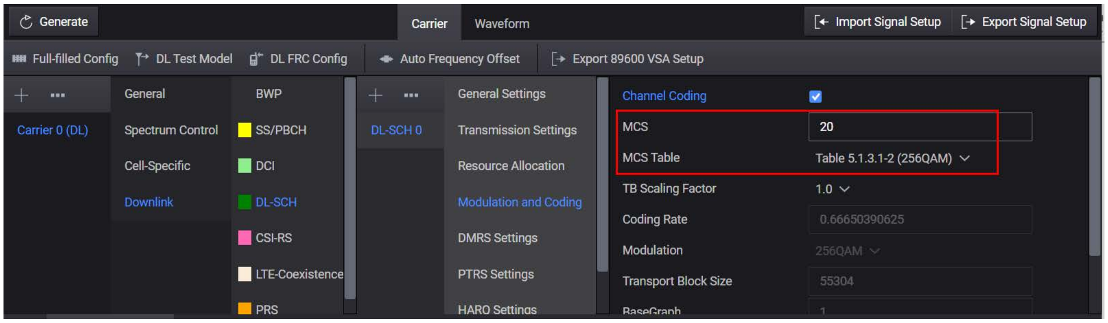
   Instead of transmitting all 64 beams, we enable only 8 of them be setting Active Indices to 0:7.



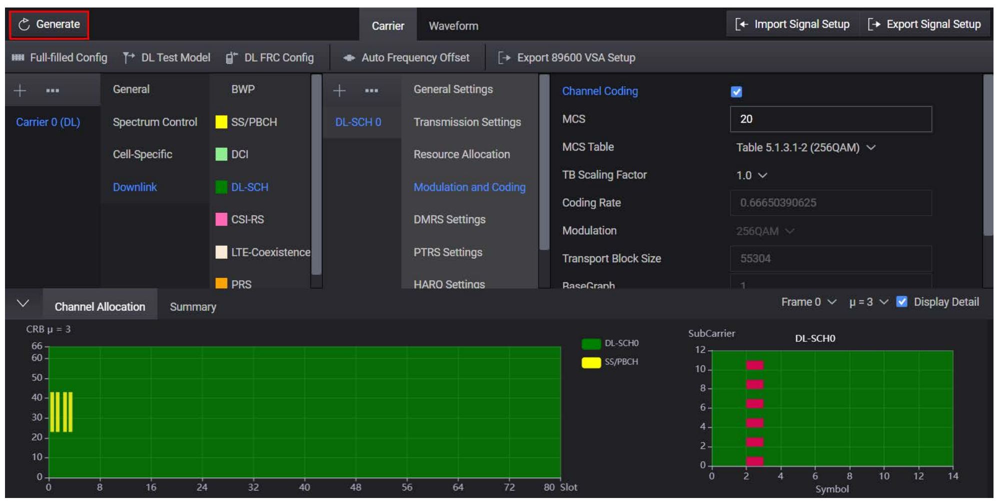
NOTE

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**.

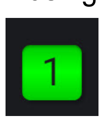


11. Select **Generate** to generate the Waveform.



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**.

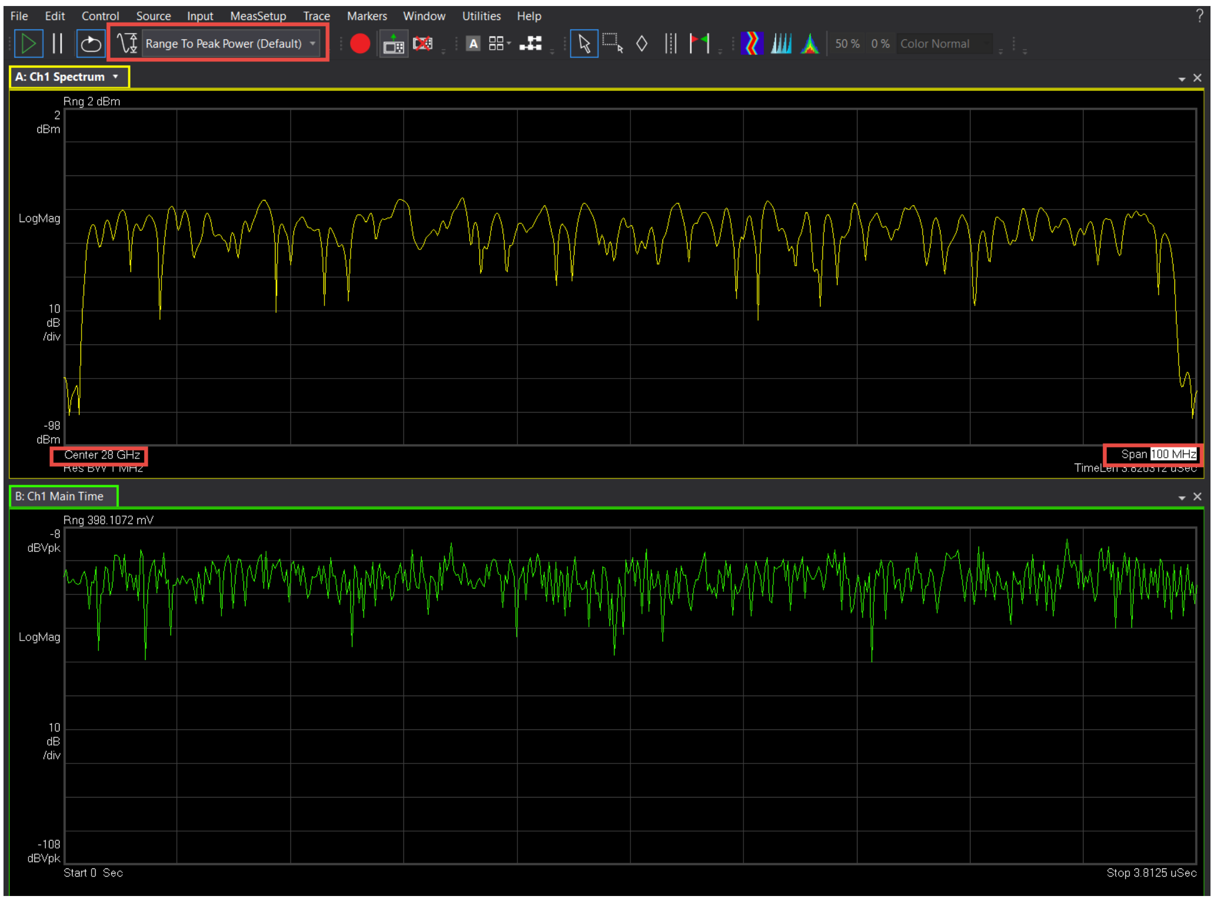
NOTE

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** > Span to **100 MHz**, then select **Auto Range.** 

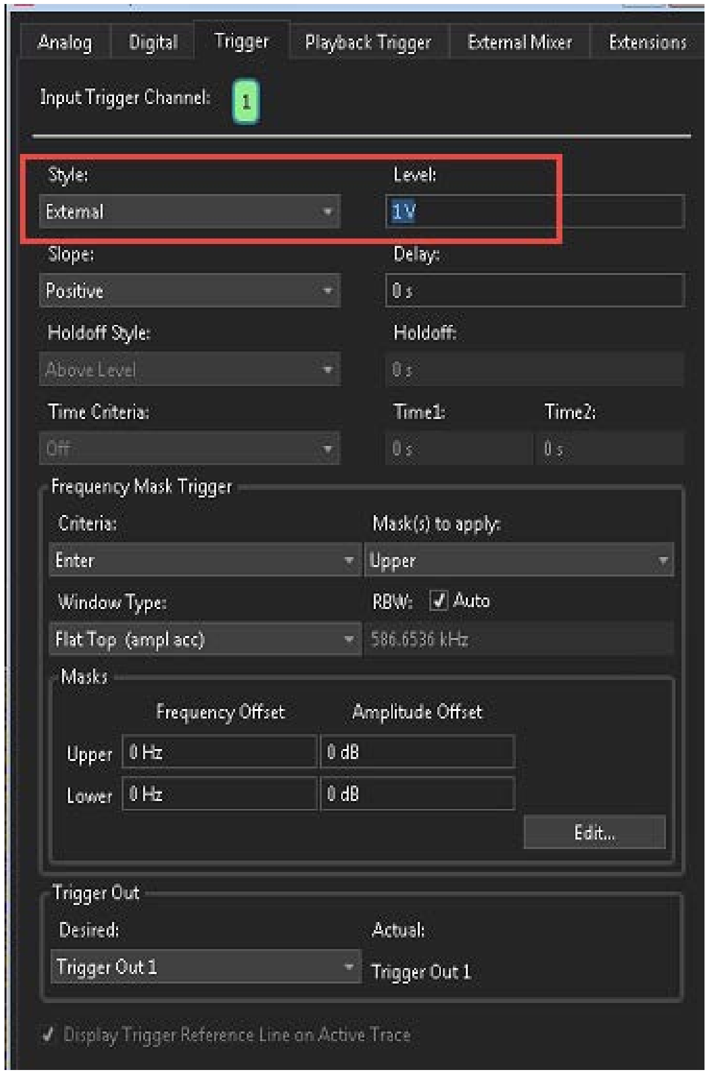
   Auto Range samples the current input signal and then sets the full scale input range to the minimum range that includes the peak voltage sample of the input signal.



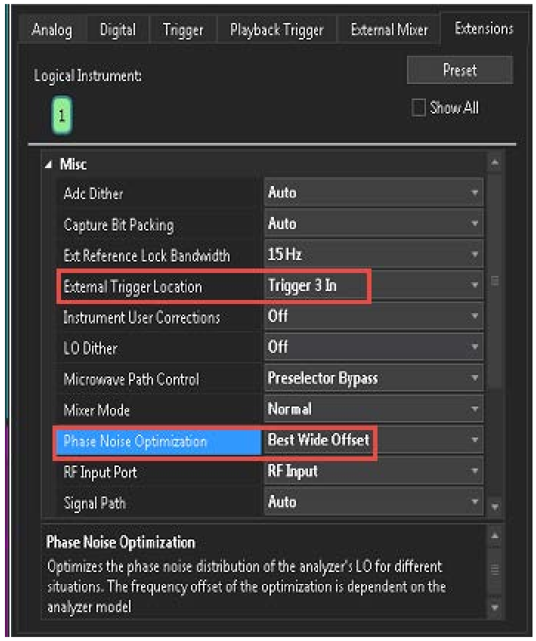
3. From the toolbar, select the **Pause** Icon. 

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**.

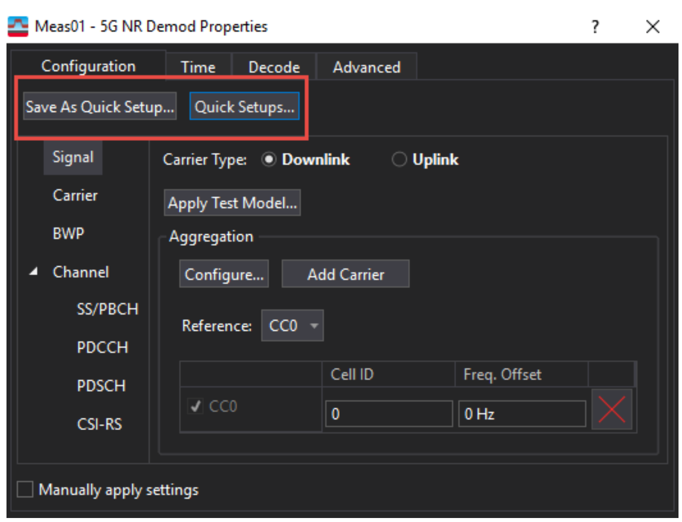


5. Select the **Extensions** tab and change the External Trigger location to **Trigger 1 In** or **Trigger 3 In** (Use Trigger 3 if your N9040B has Option H1G, 1 GHz BW) and set Phase Noise Optimization to **Best Wide Offset**.



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

7. From the menu bar, select **MeasSetup** > **5G NR Demod Properties** > **Configuration** tab.

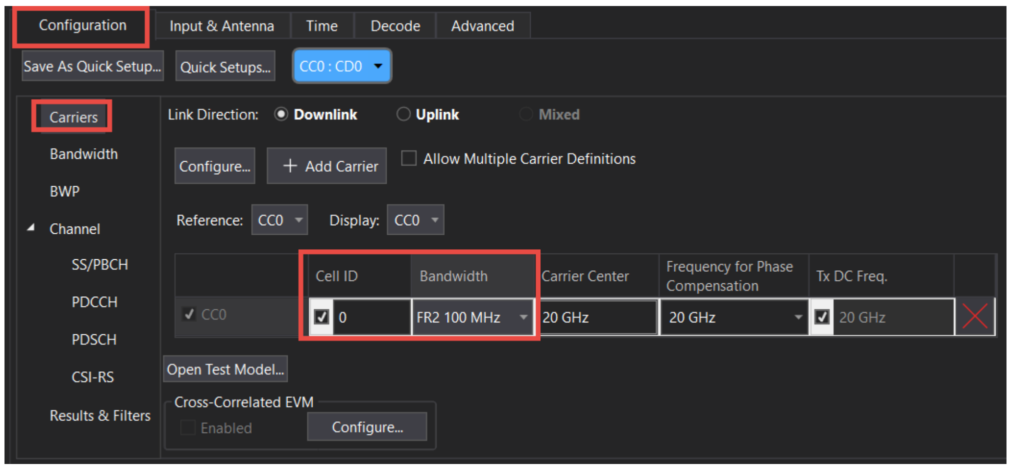


TIP Use Quick Setups for convenient saving and loading of common configurations. Quick Setups are factory supplied configurations and cannot be deleted by users. (This includes Signal Studio Downlink and Uplink defaults.)

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.

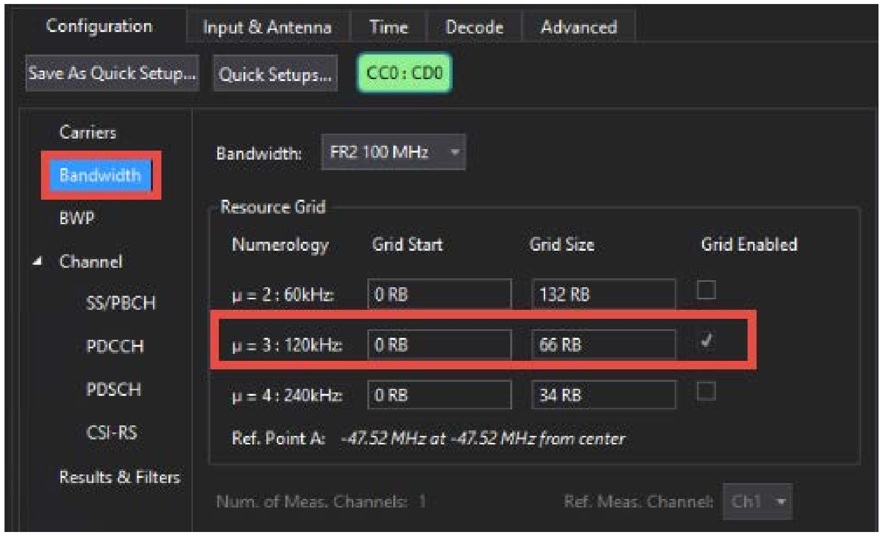
NOTE Cell ID is carried on PSS and SSS so the SS/PBCH must be transmitted and enabled for Auto Cell ID to work. It must also be a downlink since SS/PBCH is only transmitted on a downlink.

   – Set Bandwidth to **FR2 100 MHz**

9. Select the **Bandwidth** panel and set Numerology to μ = **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.

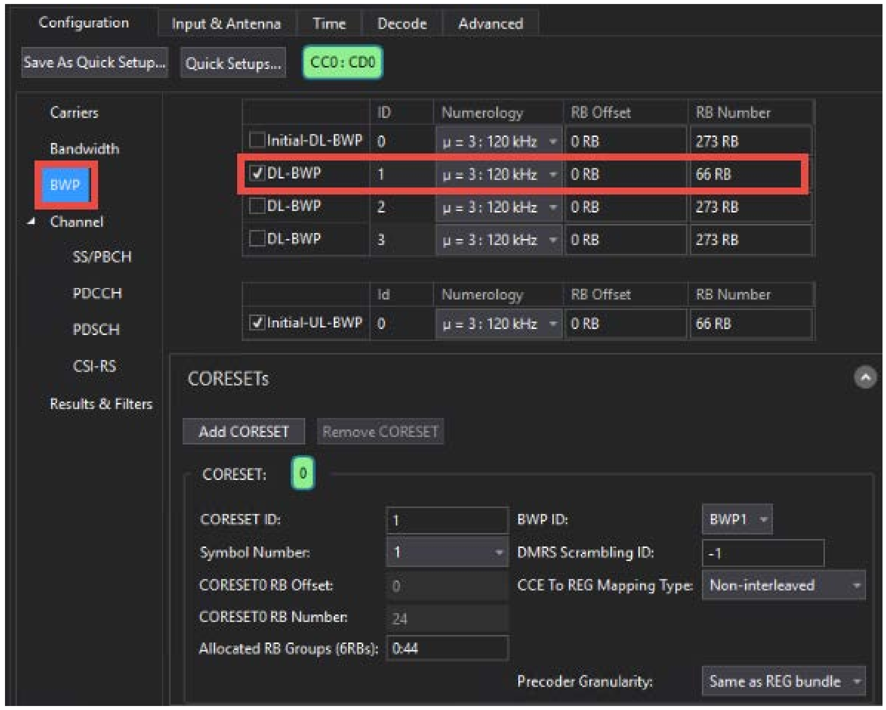


10. Select the **BWP** pane, then enable **DL-BWP**.

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 **μ= 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:

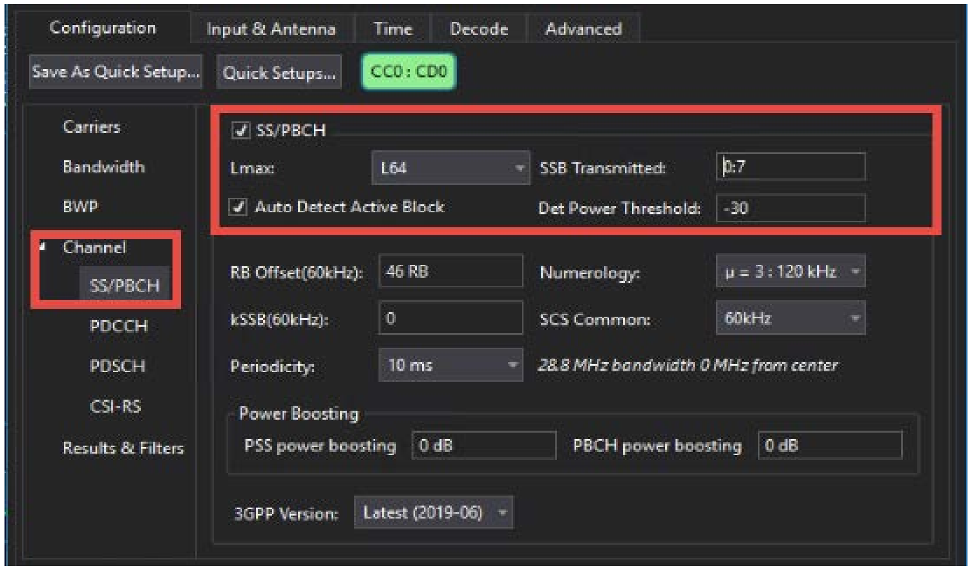
- Lmax to **L64**

  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

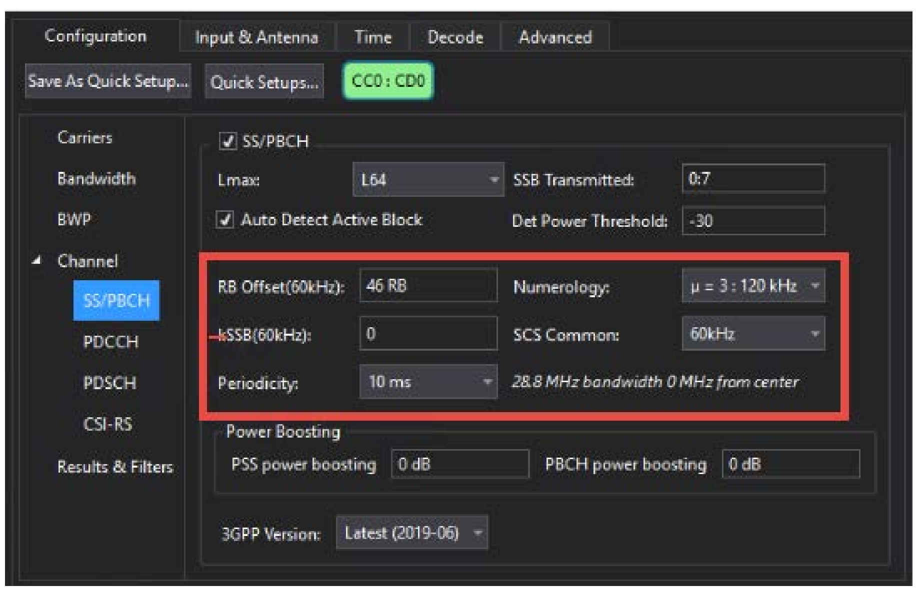
- SSB Transmitted to **0:7**

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 = **μ= 3 = 120 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

66RB/2 = 33 RB

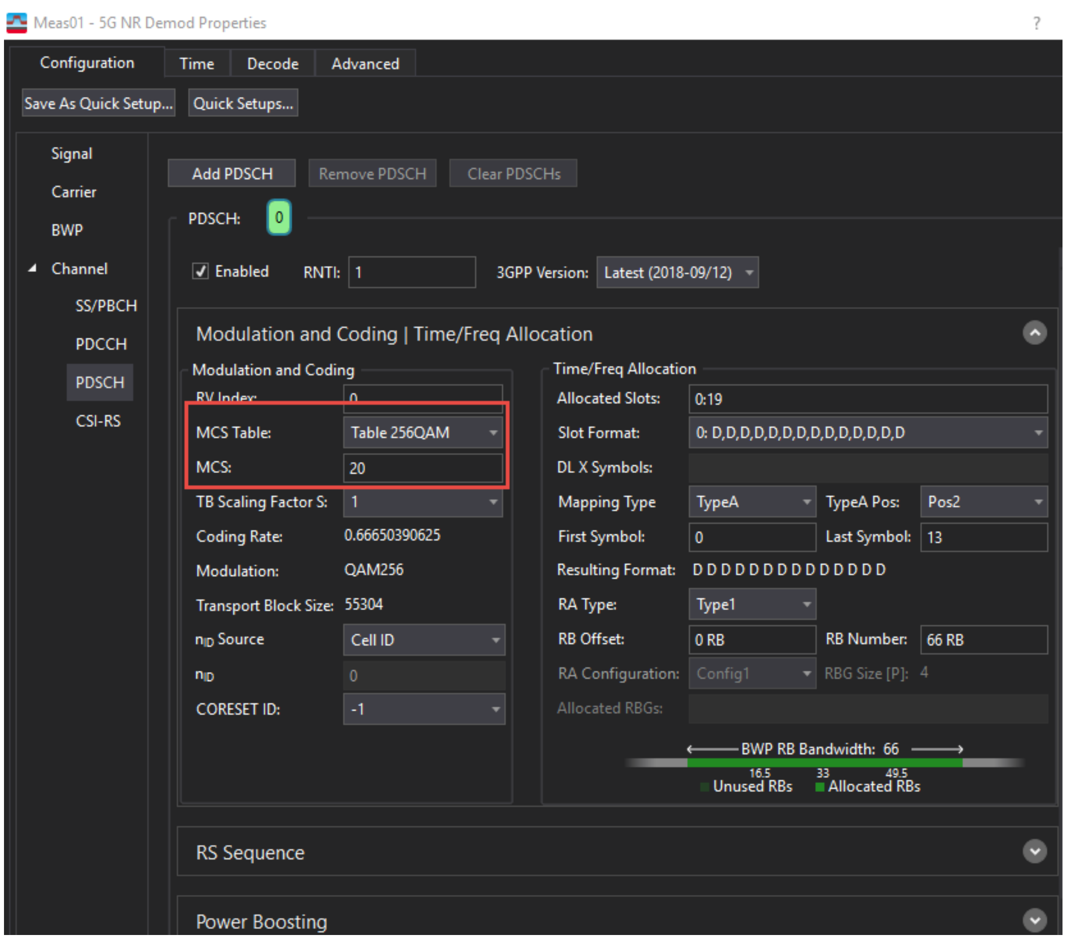
This is the center of the carrier bandwidth. However, the SS Block is 20 RB wide, so the start of the SS Block is 23 RB.

23 RB in 120 kHz is 23 * 2 = 46 RB in 60 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.

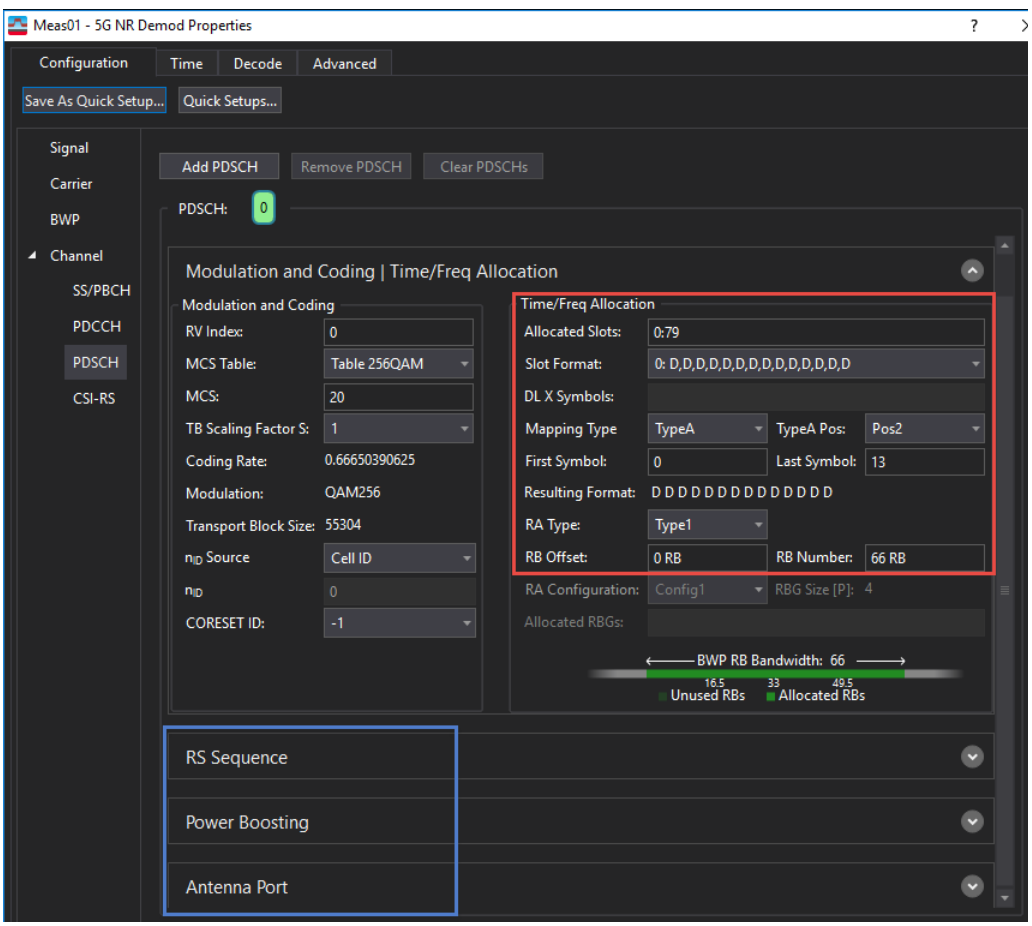
Table 5.1.3.1-2 has 256 QAM as maximum modulation

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.

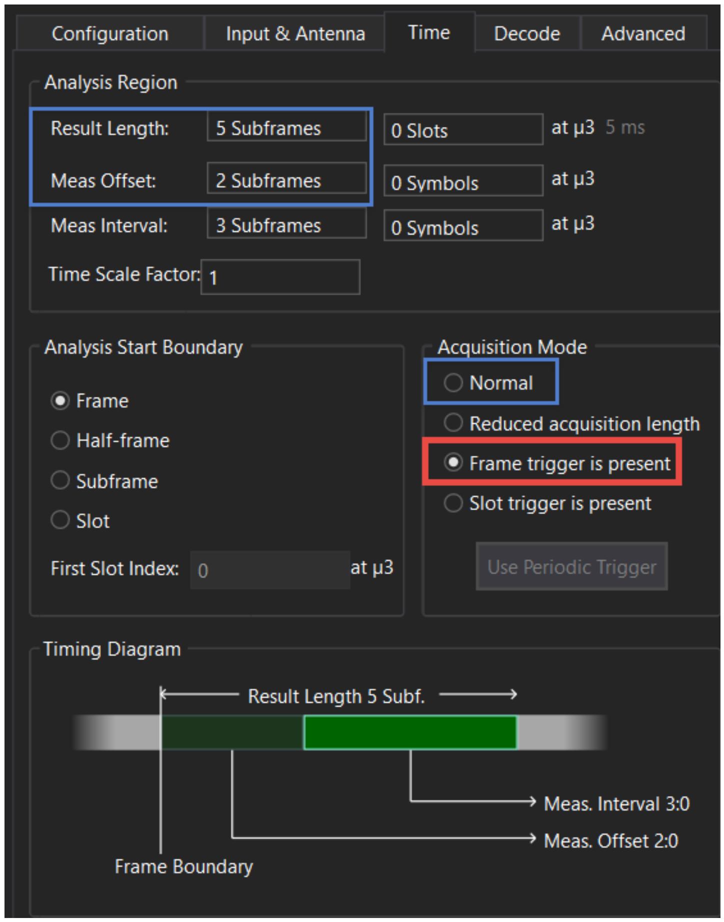
- Under the Time/Freq Allocation section, set
  - Allocated Slots to **0:79**
  - Slot Format to **0**
  - First Symbol to **0**
  - Last Symbol to **13**
  - RB Offset to **0 RB**
  - RB Number to **66 RB**



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**.



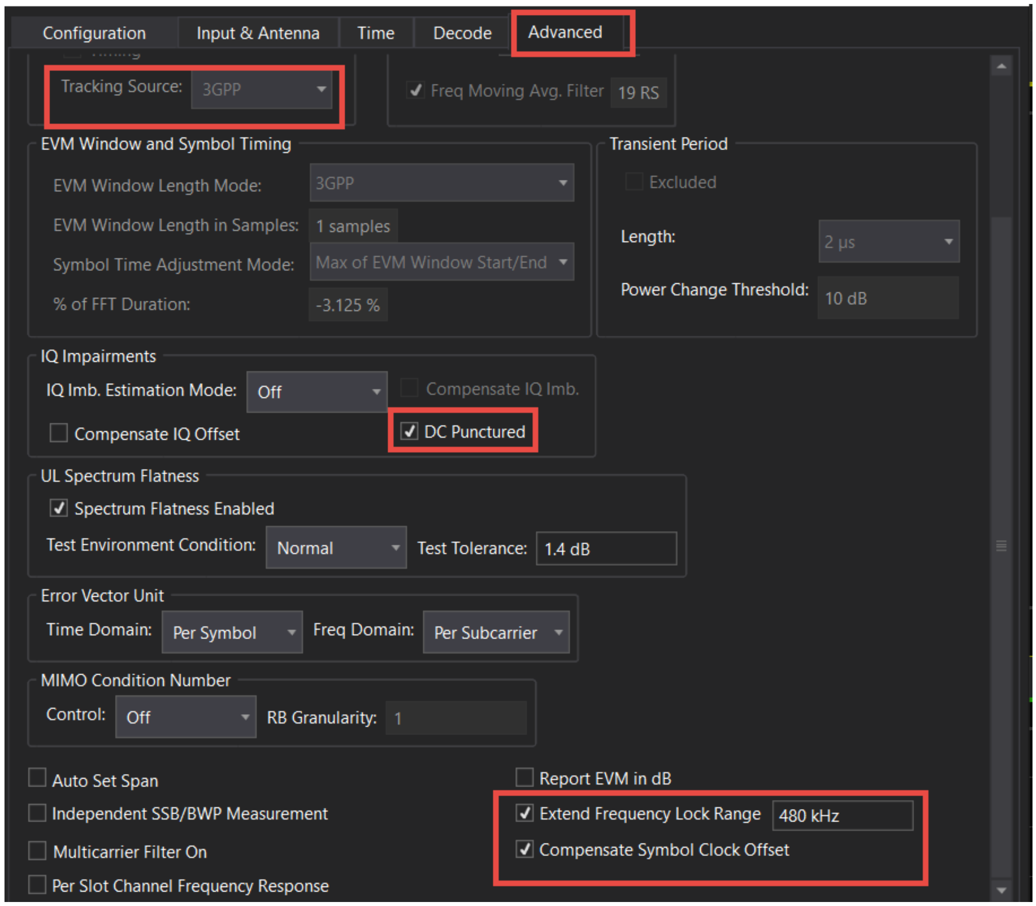
14. Select the **Advanced Settings** tab and select **DC Punctured**.

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.

3GPP Conformance Test > Phase 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.

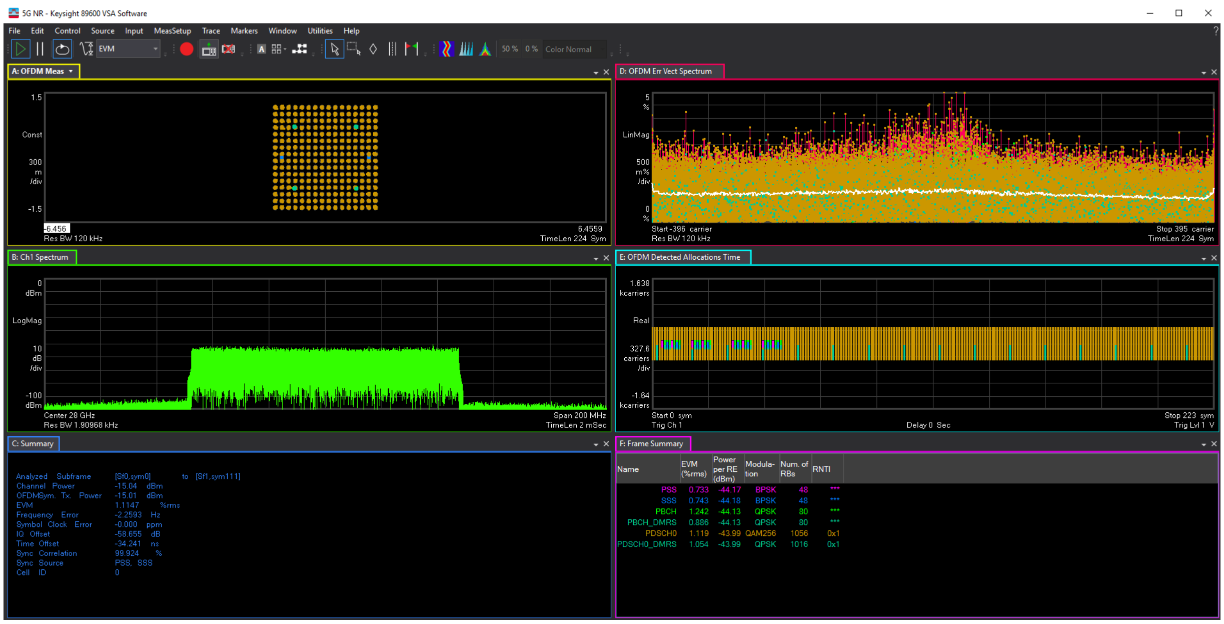


15. From the menu bar, select **Window** > **Trace Layout** > **Tile Visible**.

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

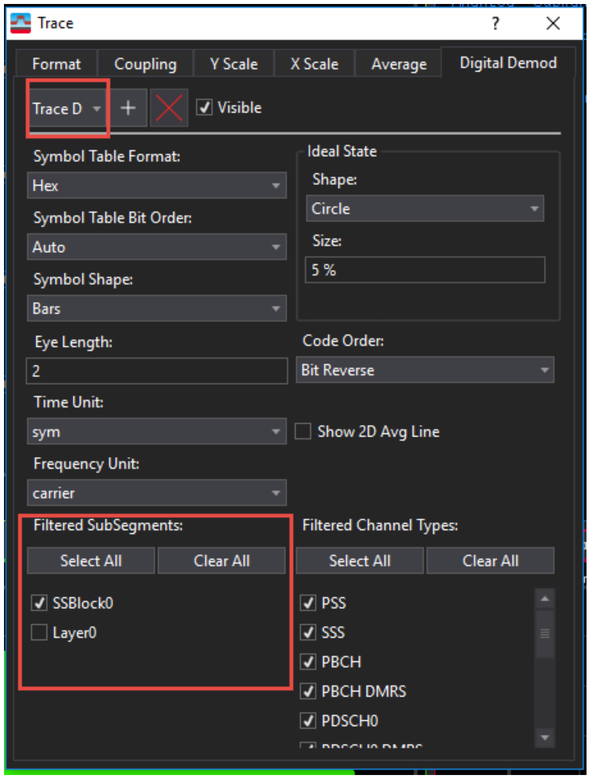
The rest of the traces do not support per-trace filtering.

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 alloys 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 (8slots/subframe). 66*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*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: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:SIGNal1 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
```

```
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.

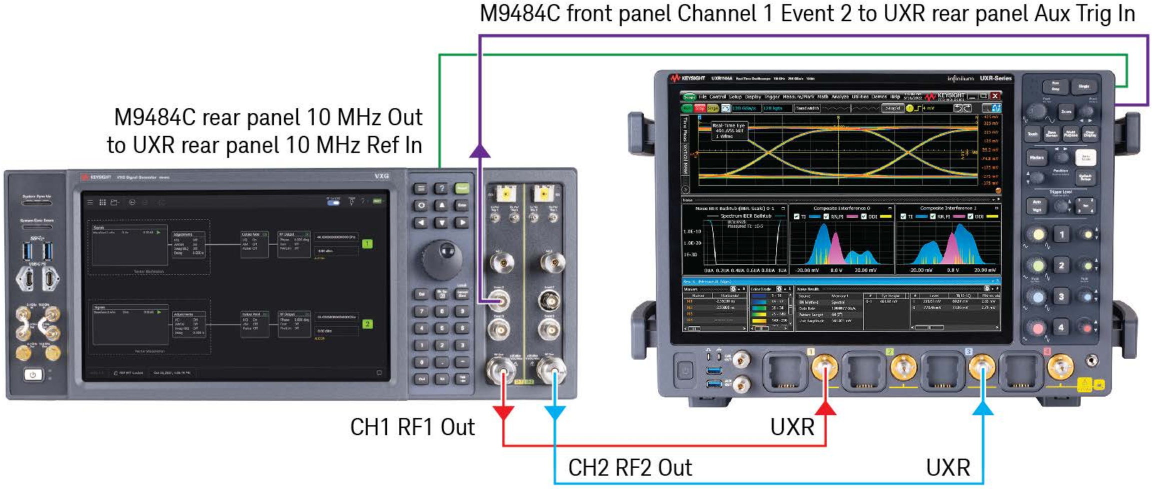
Software Requirements

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

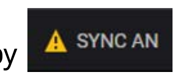
– M9484C rear panel 10 MHz Out to UXR rear panel 10 MHz Ref In.



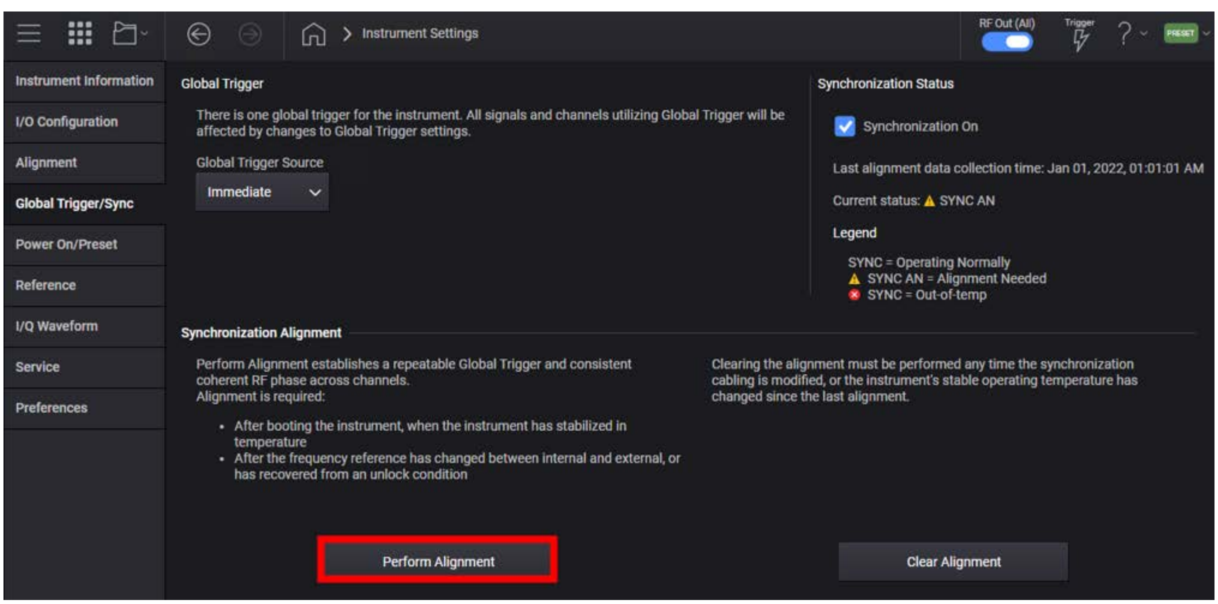
m9484c_UXR_4chan

On the VXG:

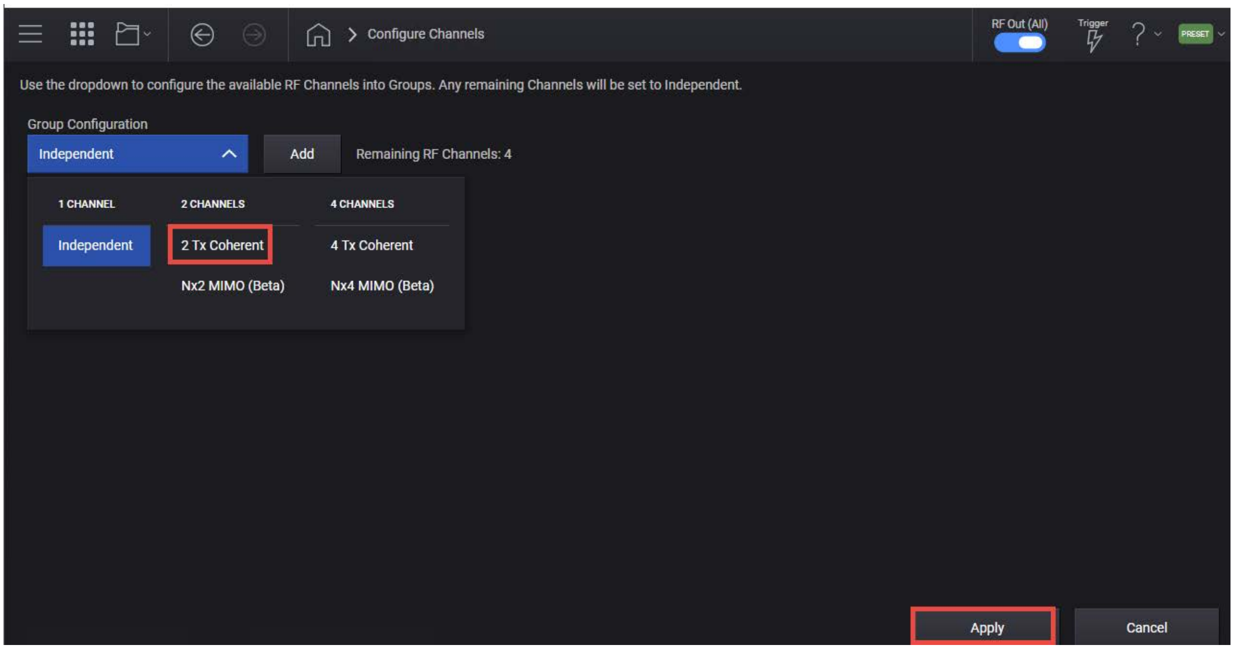
1. Select **Preset** > **Preset** to set the VXG to a known state.

   If a Synchronization Alignment is required, indicated by 

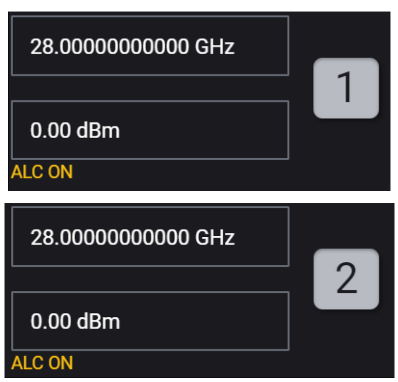
   in the bottom left corner, tap or click the warning message and choose **Perform Alignment** before proceeding.



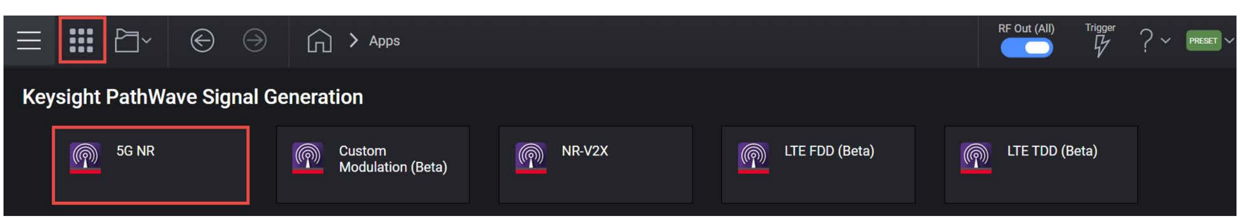
2. In the Menu/Tool Bar, select the Triple Bar icon (top left corner of the display, and then select **Configure Channels**. Change the signal configuration from Independent to **2 Tx Coherent** > **Add** > **Apply** > **Apply**.



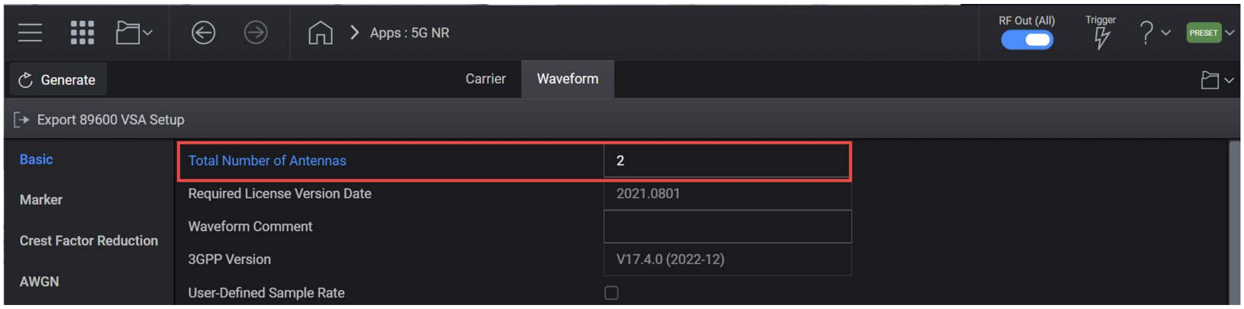
3. In the Output area for both Channel 1 and Channel 2, set Frequency to **28 GHz**, or the frequency you are using, and Power to **0 dBm**.



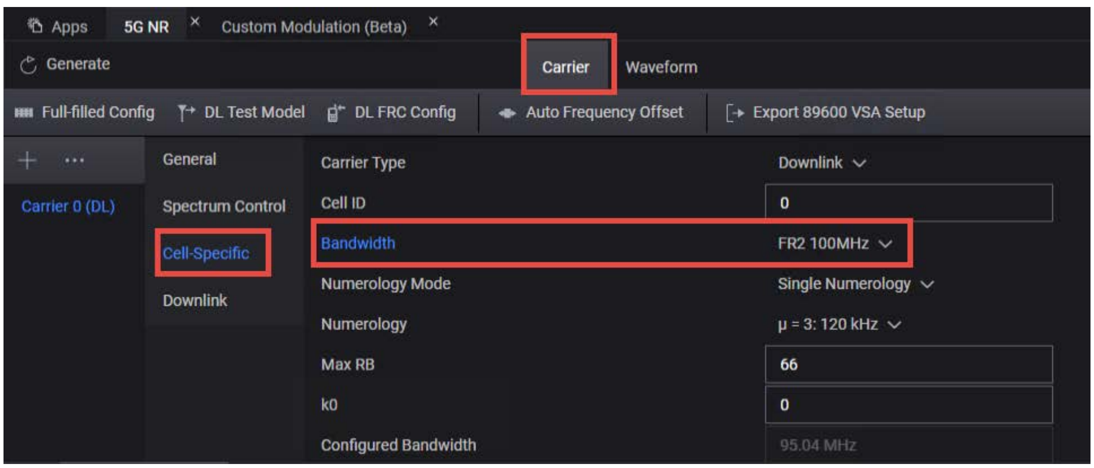
4. Select the **Apps** block to open, then select **5G NR**.



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

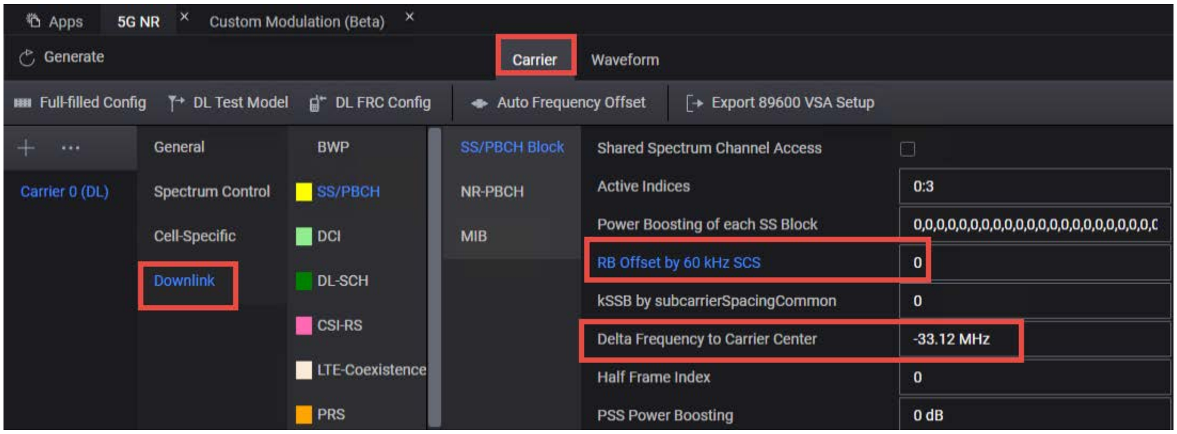


6. Select the **Carriers** tab > **Cell Specific** node, and set Bandwidth to **FR2 100 MHz.** Keep the rest of the default settings.



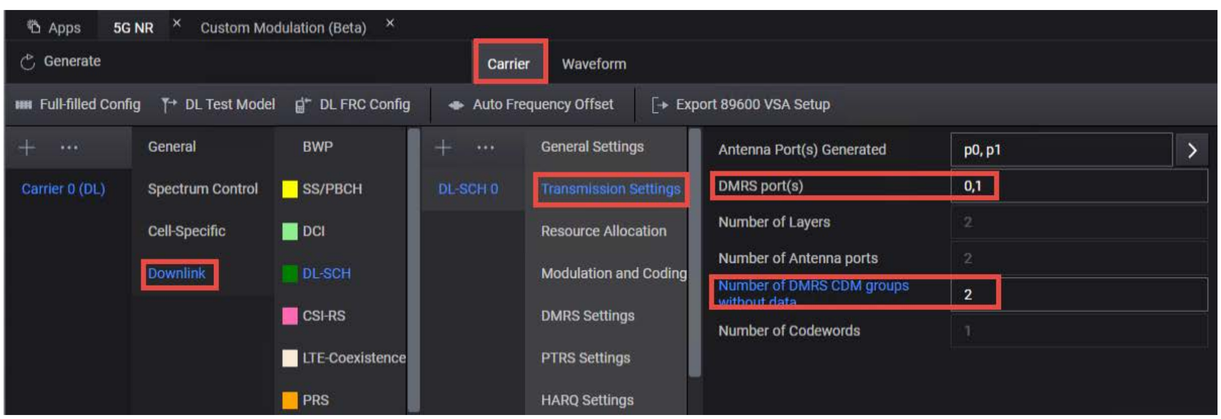
7. Select the **Downlink** node > **SS/PBCH** > **RB Offset by 60 kHz SCS** and set to **0.**

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.



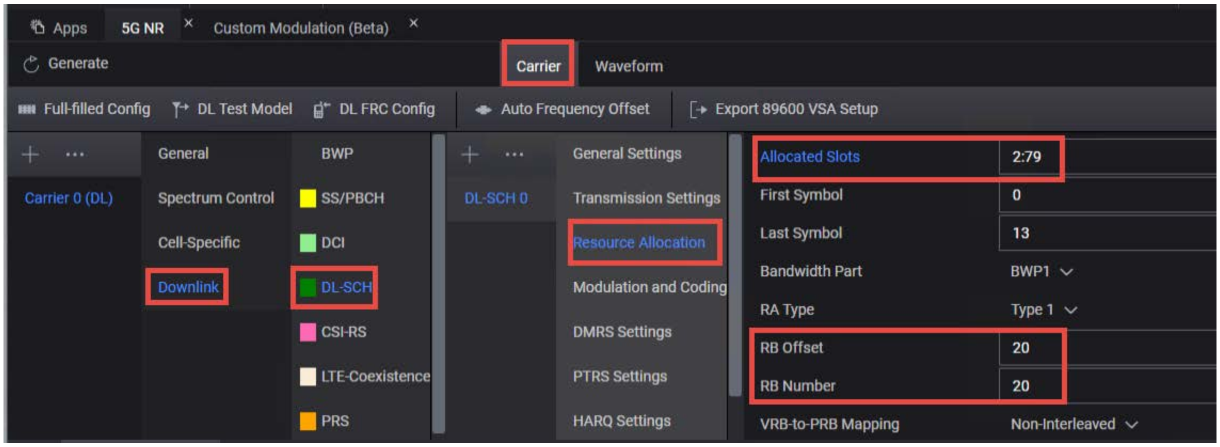
8. Select the **Downlink** node > **DL-SCH**> **Transmission Settings** and confirm DMRS ports is set to **0,1**. Set Number of DMRS CDM groups without data to **2**.

   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).



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.

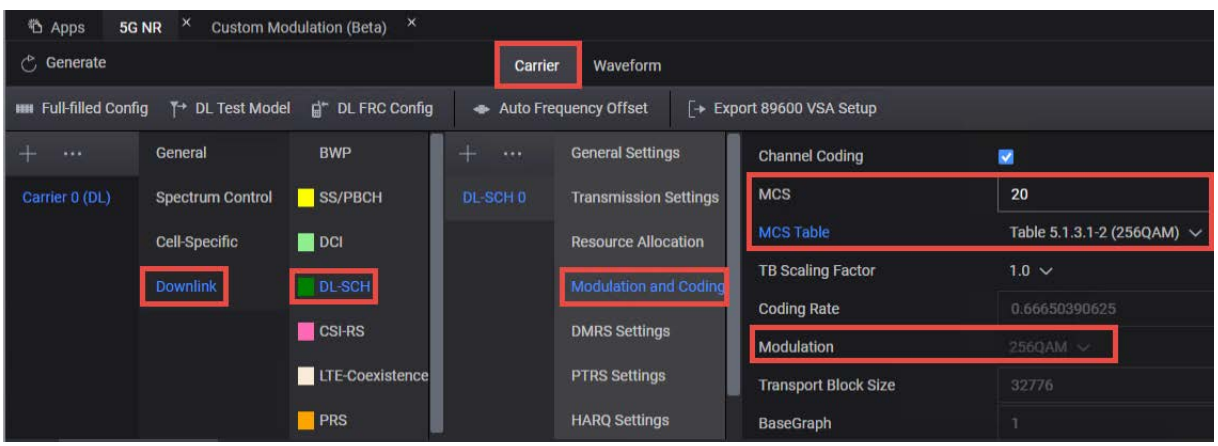


10. Select the **Modulation and Coding** node and set:

– MCS to **20**

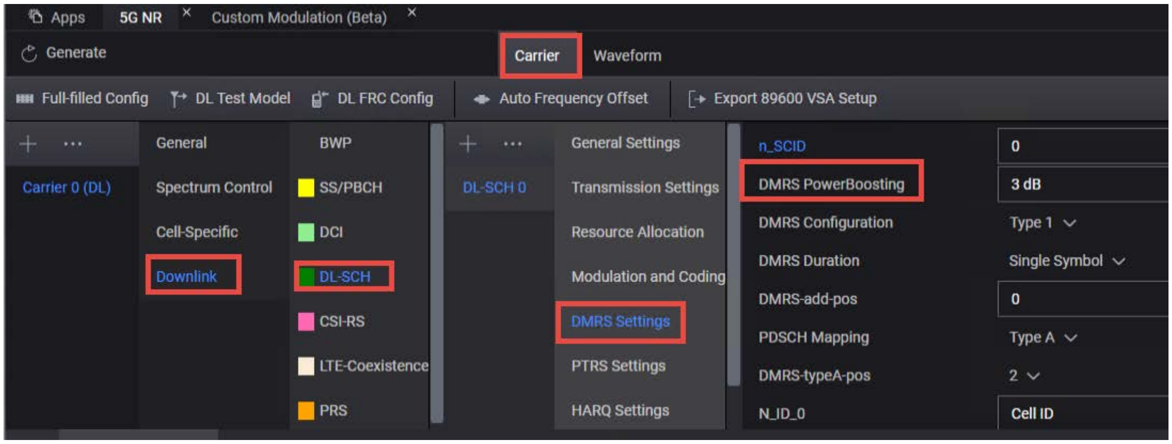
– MCS Table to **5.1.3.1-2 (256 QAM)**

Notice that modulation is updated to 256 QAM.

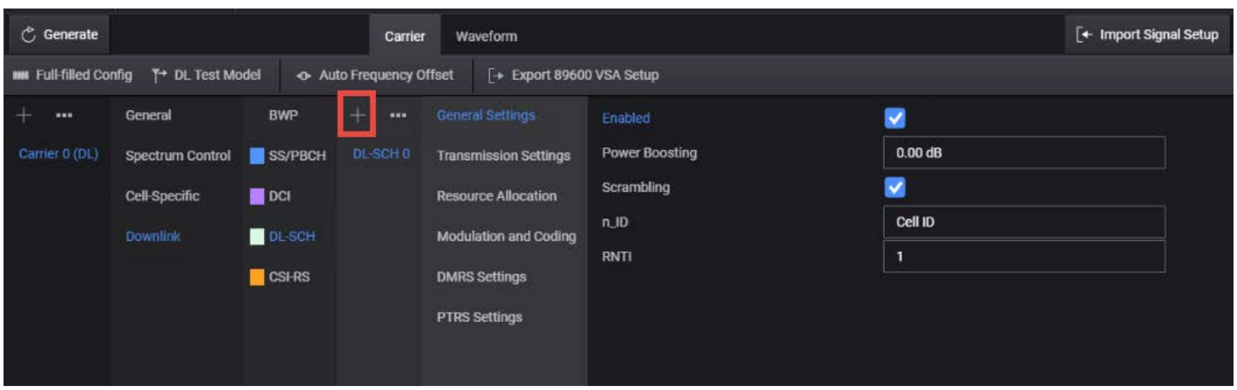


11. Select the **DMRS Settings** node and notice that DMRS Power Boosting is set to **3 dB**.

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

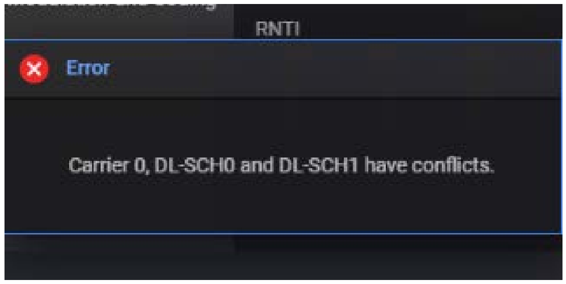


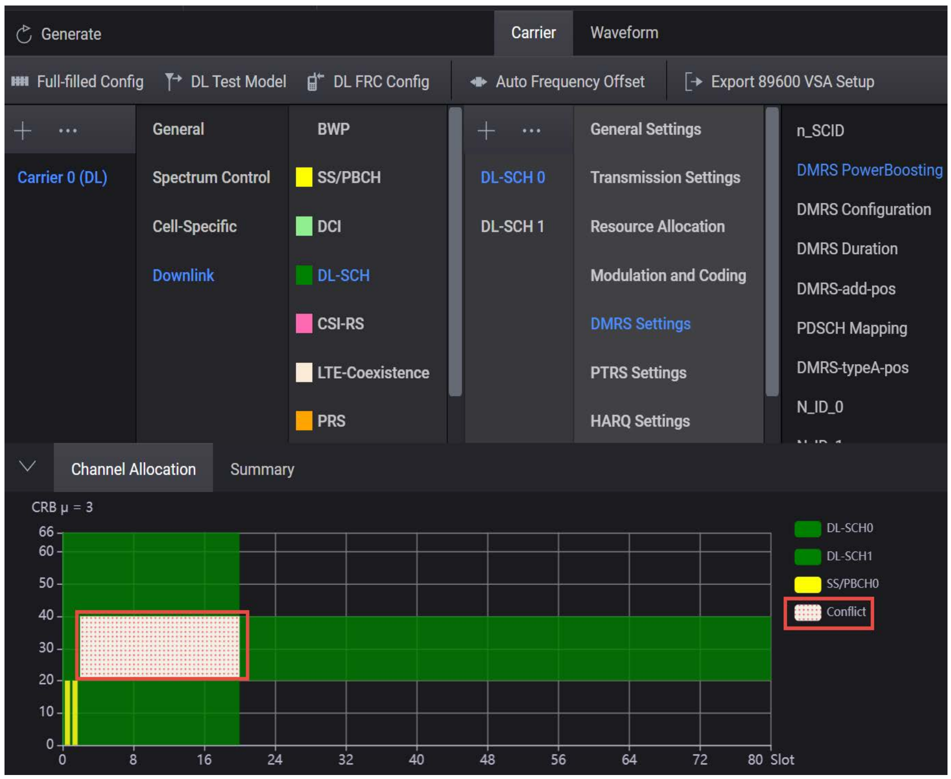
12. Under the DL-SCH 0 node, select the + icon to add a new **+DL-SCH** (DL-SCH1).



NOTE

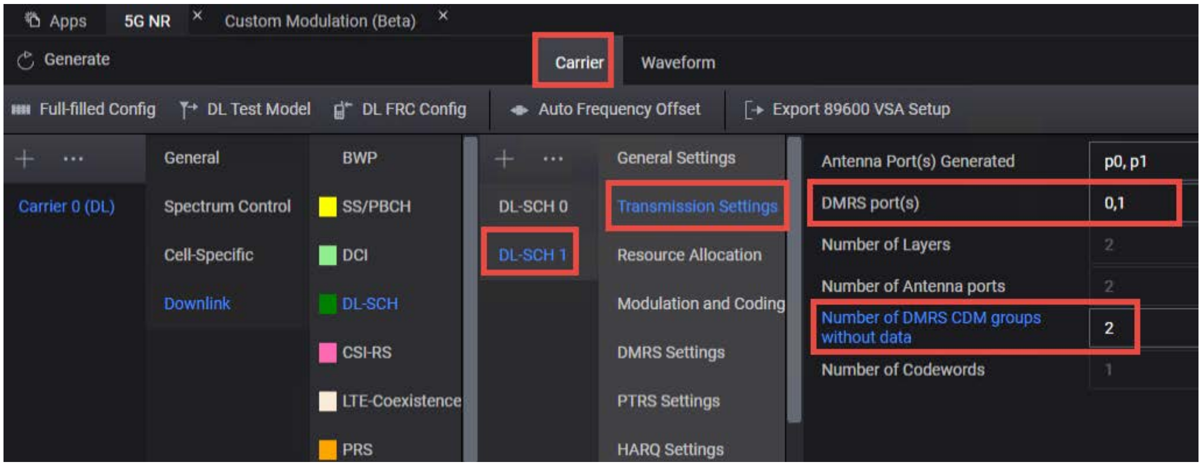
This will create a conflict between DL-SCH0 and DL-SCH1. This will be resolved in a later step.





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**.

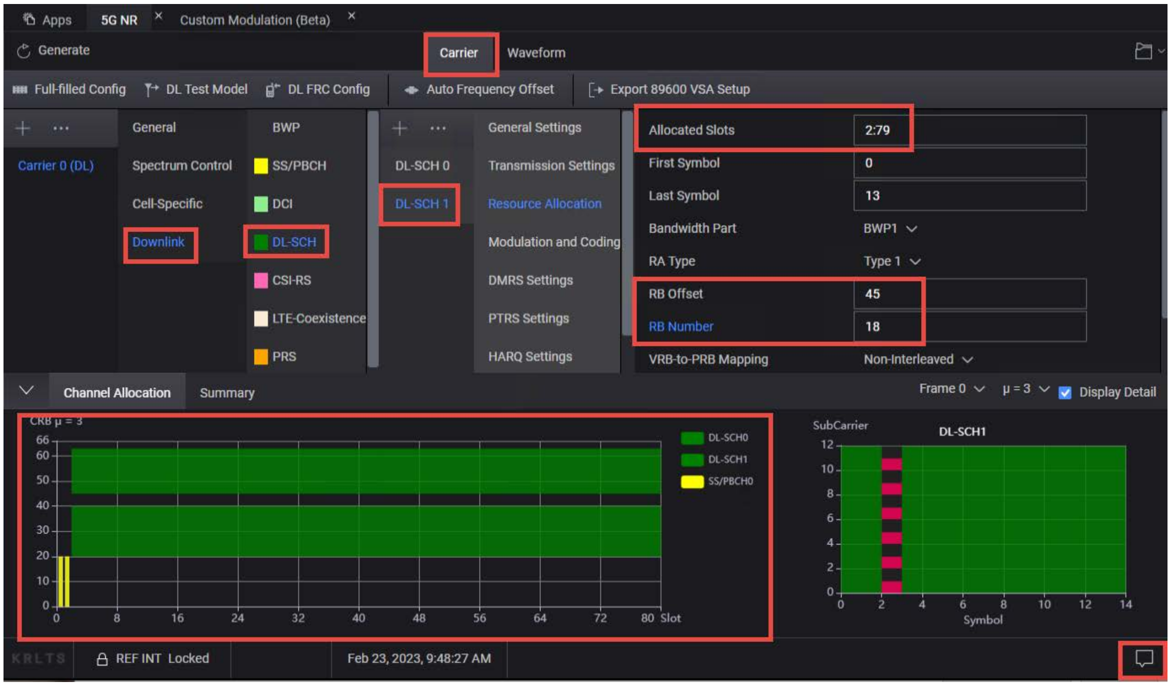
Notice that Number of Layers is updated to 2 and each layer is assigned with a particular DMRS port. Antenna Ports Generated is automatically assigned P0,P1, which will map generated multiple antenna port signals to different antennas (instruments).



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

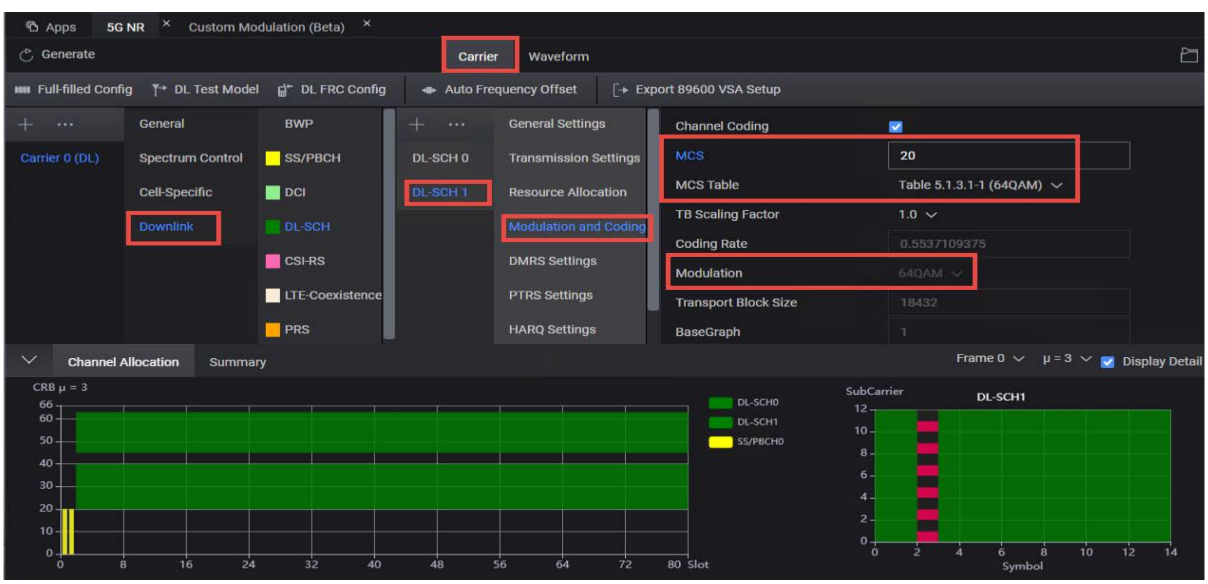
- Allocated Slots to **2:79**
- RB Offset to **45**
- RB Number to **18**

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**.

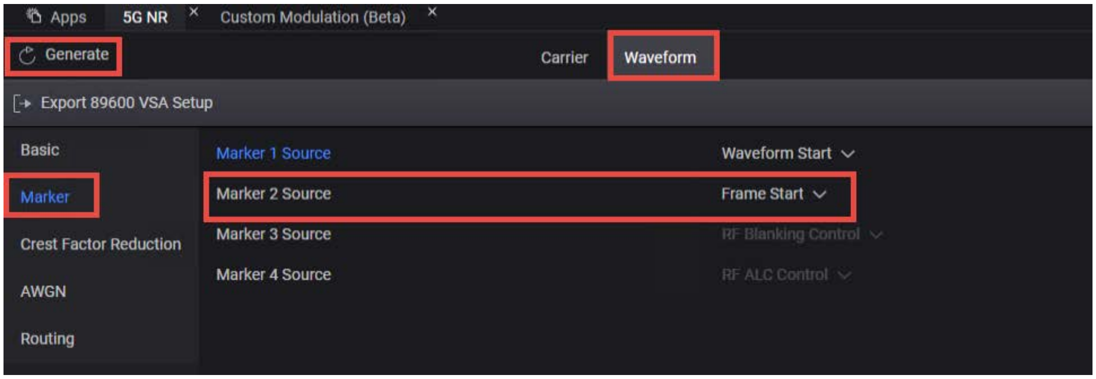


15. Select the **Modulation and Coding** node, and set MCS to **20**.

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

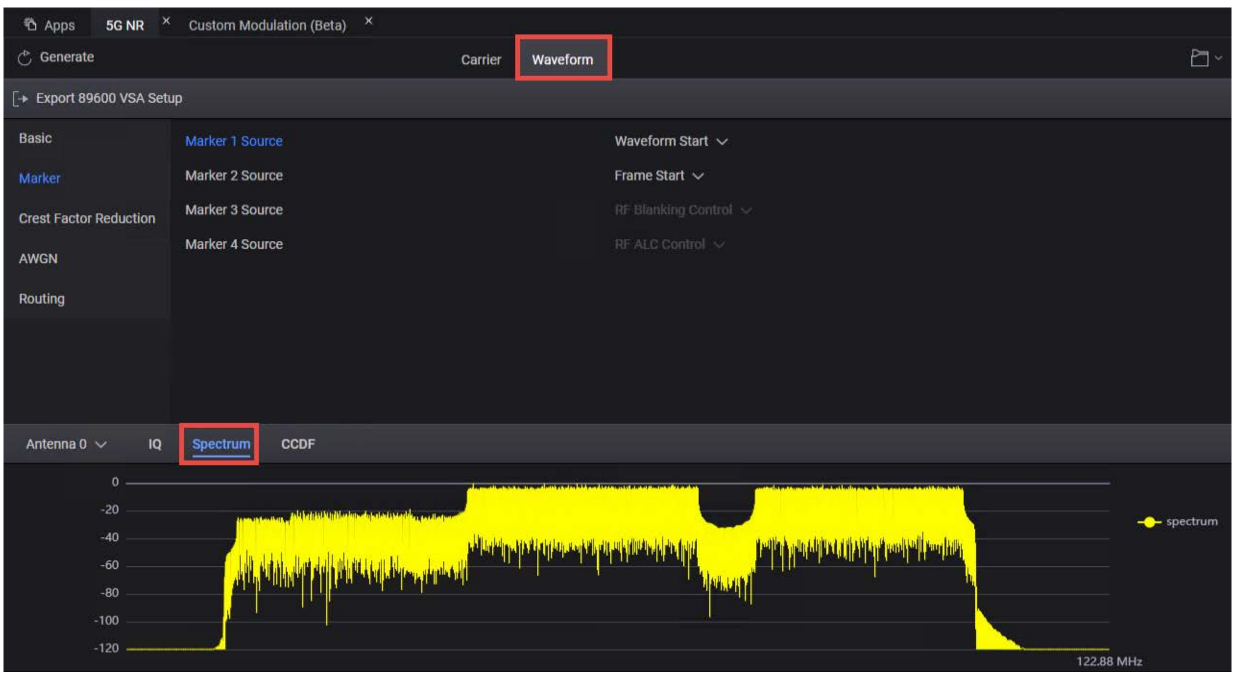


16. Select the **Waveform** tab > **Marker** and notice that Marker 2 Source is set to **Frame Start**. Select **Generate**.



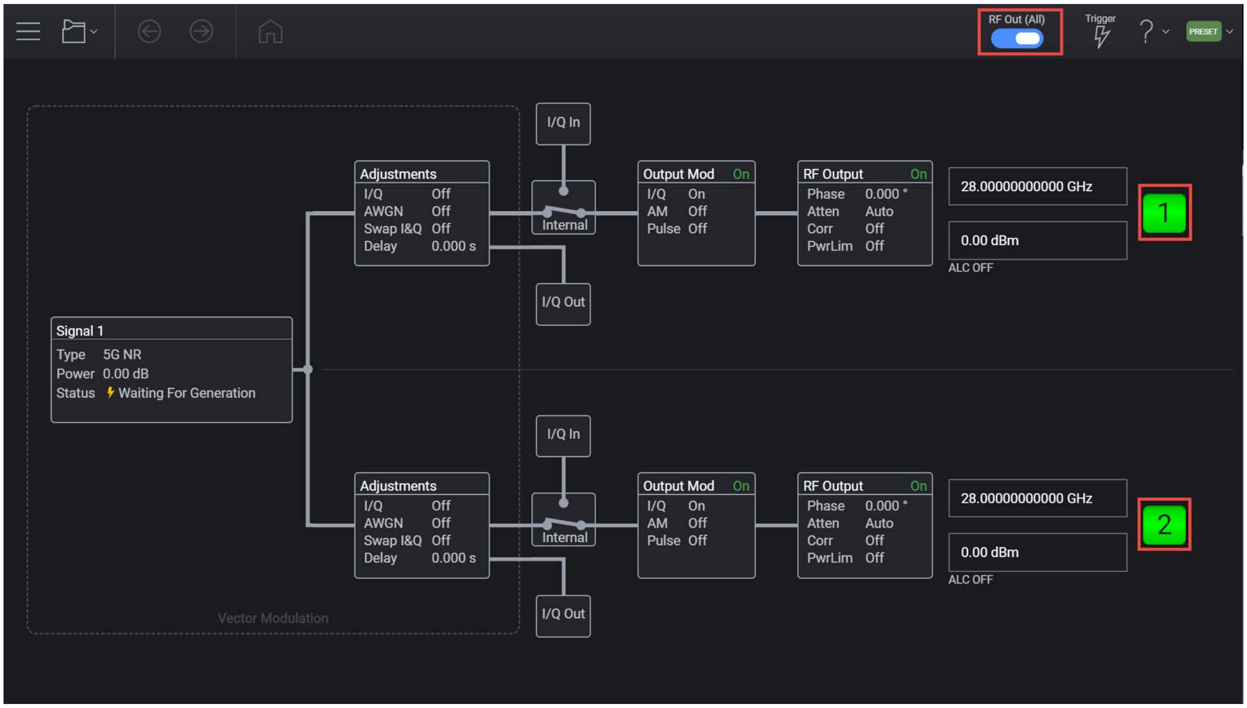
17. In the bottom panel, select **Spectrum**.

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 401

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

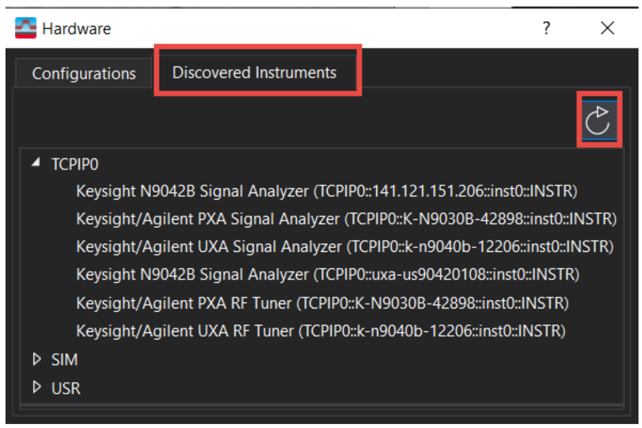
If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

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

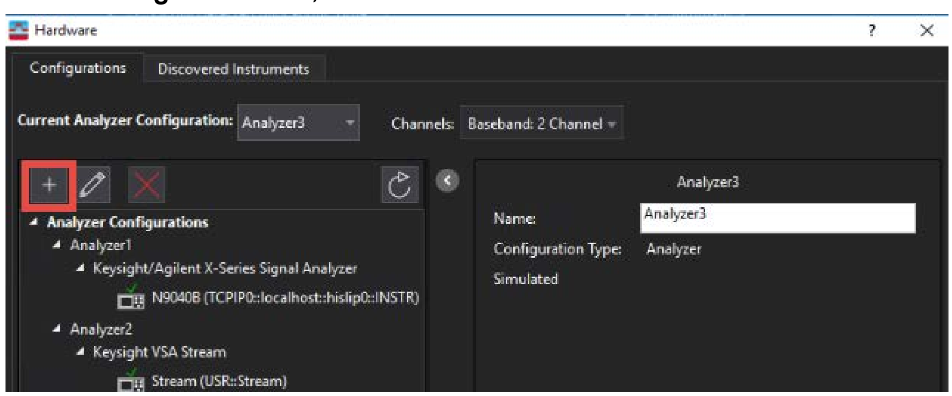
3. To configure the hardware, go to **Utilities** > **Hardware** > **Configurations**.

   If it is already configured, go to step 10.

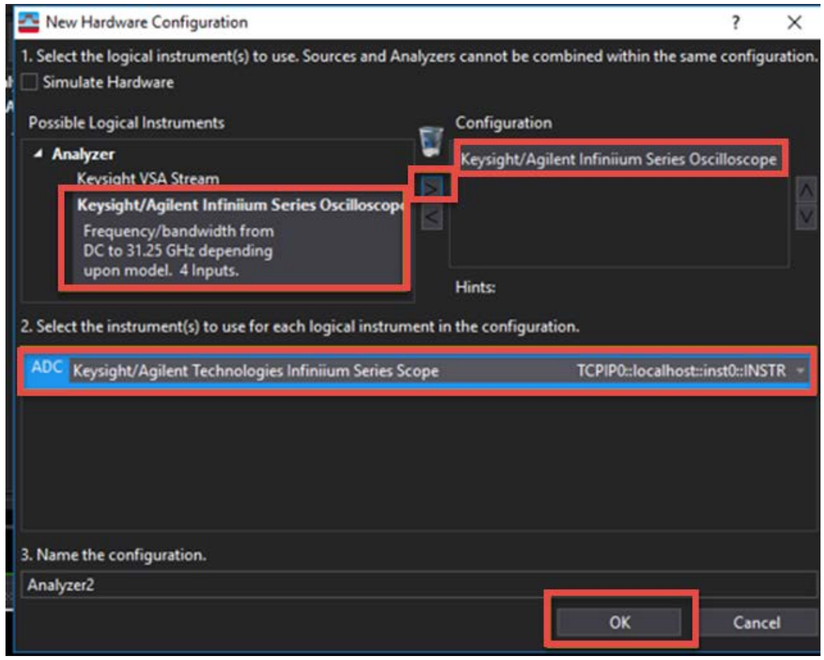
4. Open the **Discovered Instruments** tab and verify that the UXR is listed, if not, select the **Rediscover Instruments** icon.



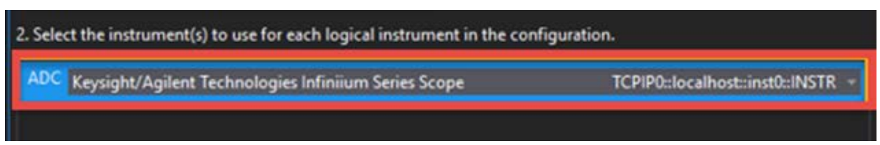
5. In the **Configuration** tab, select the **+ icon**.



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.

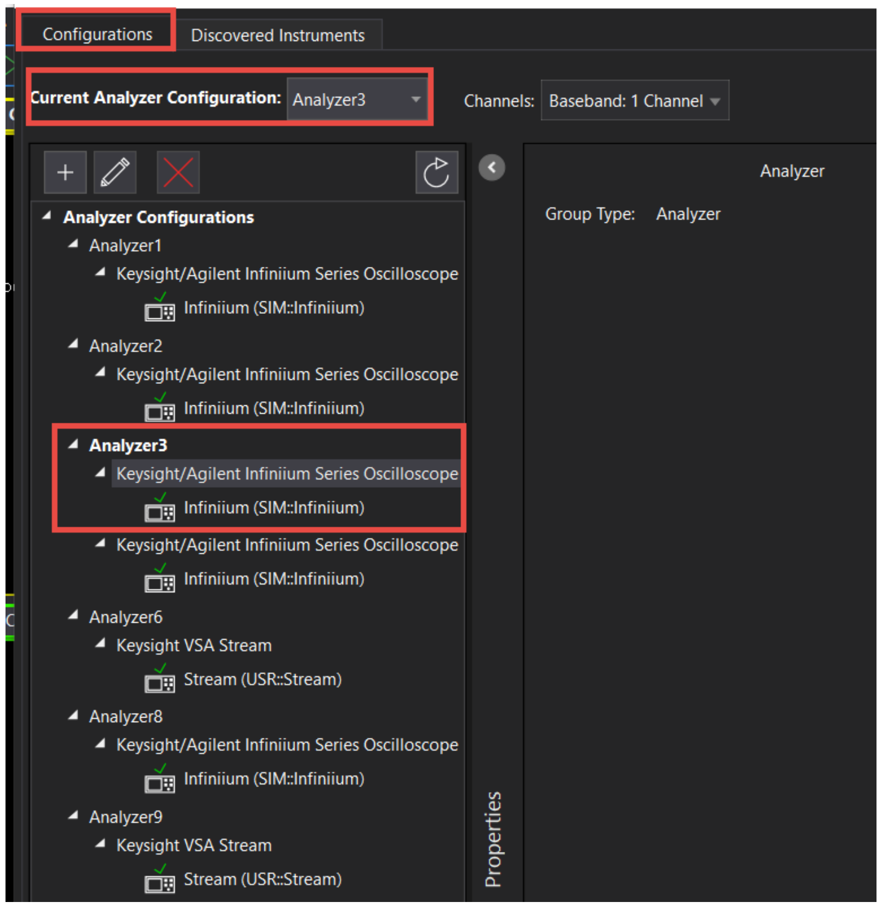


7. From the middle of the dialog box, select the UXR to be used.



8. Select **OK** to create the UXR configuration.

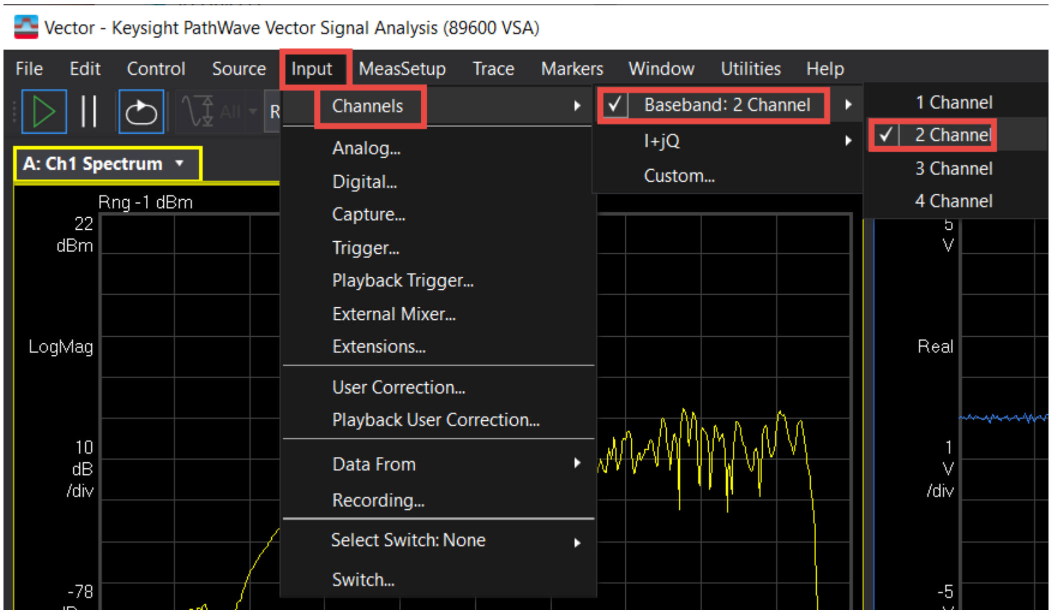
9. In the **Configurations** tab, set the Current Analyzer Configuration, select the Analyzer number for the new configuration. In this example **Analyzer 3**.



NOTE

The following steps perform the exact same function as loading the setup file you exported the VSA Setup File. At this point you can follow the steps below, or simply select File > Recall > Recall Setup and select the file you saved to the VXG.

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

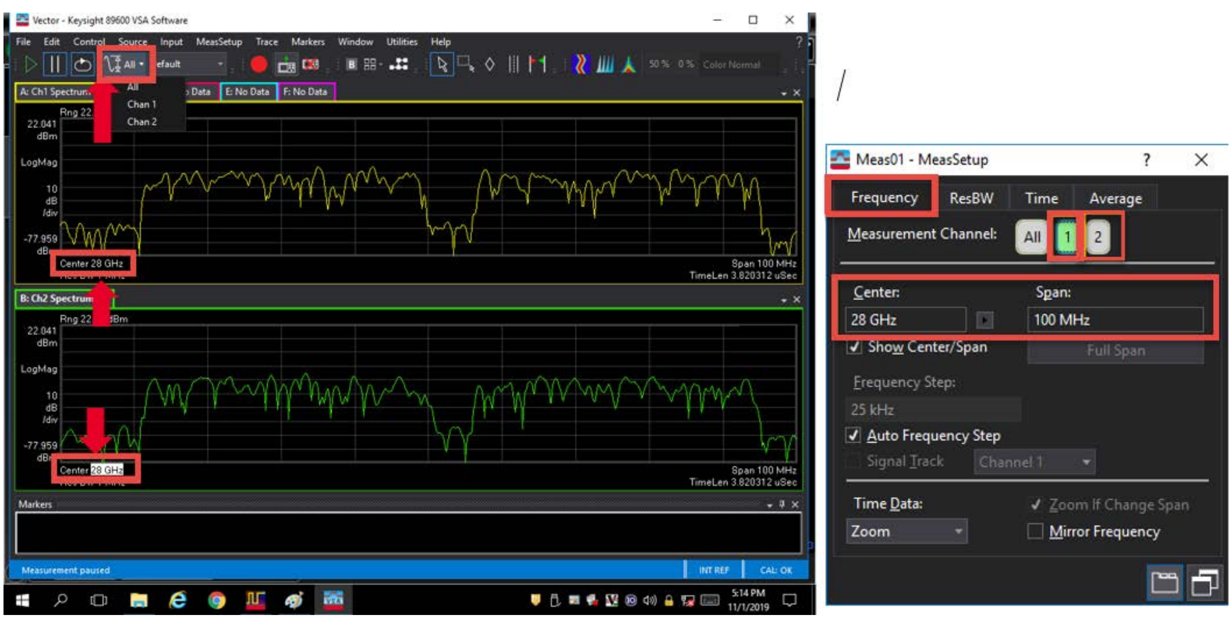


11. Set the center frequency of both channels to **28 GHz**, or the frequency you are using, and span to **100 MHz**.

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

If you are using a UXR, Select Autorange .

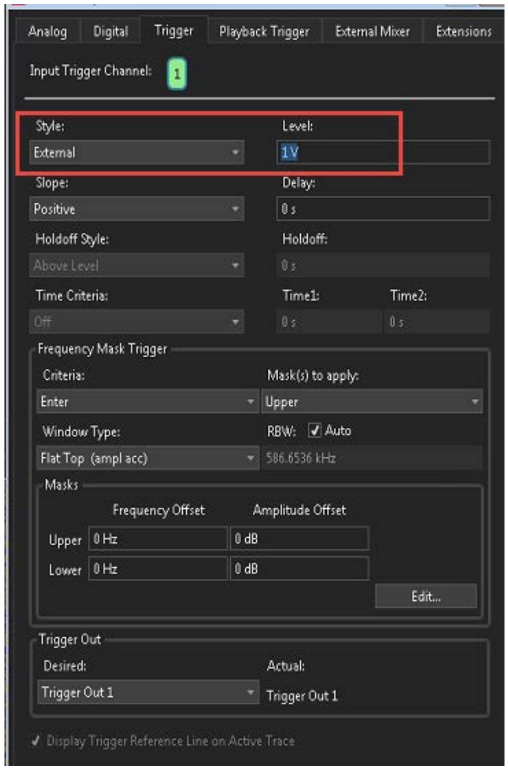
Auto Range samples the current input signal and then sets the full scale input range to the minimum range that includes the peak voltage sample of the input signal.



12. From the menu bar, select **Input** > **Trigger** and set:

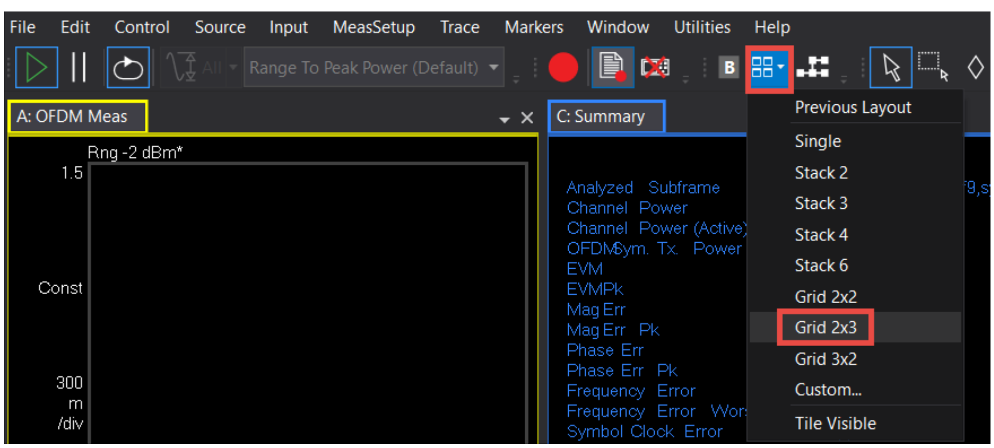
– Style to **External**

– Level to **1 V**



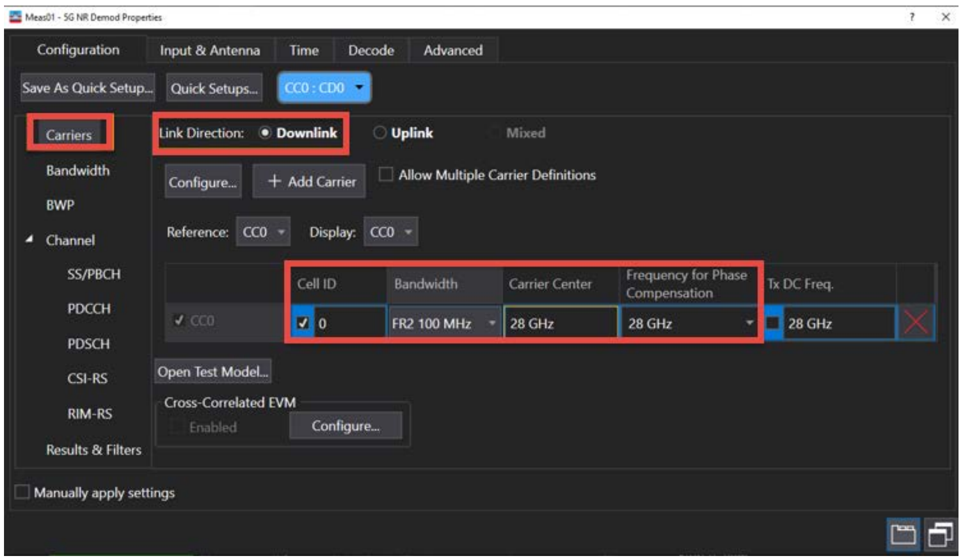
13. From the menu bar, select **MeasSetup** > **Measurement Type** > **Cellular** > **5G NR** > **5G NR Modulation Analysis.**

14. 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.**

15. 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.

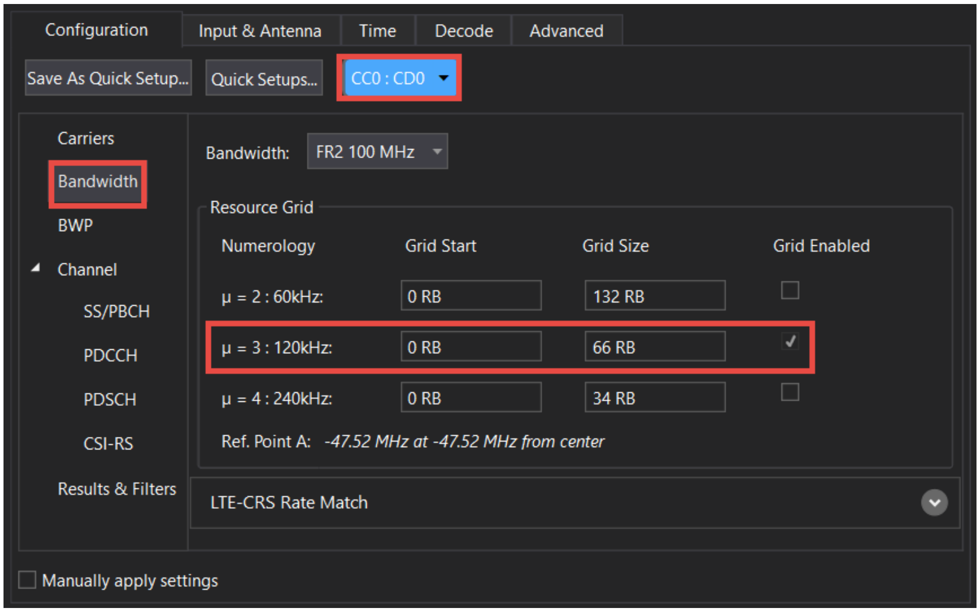


Cell ID is carried on PSS and SSS so that SS/PBCH must be transmitted and enabled for Auto Cell ID to work and must be a Downlink since SS/PBCH is only transmitted in the DL.

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.

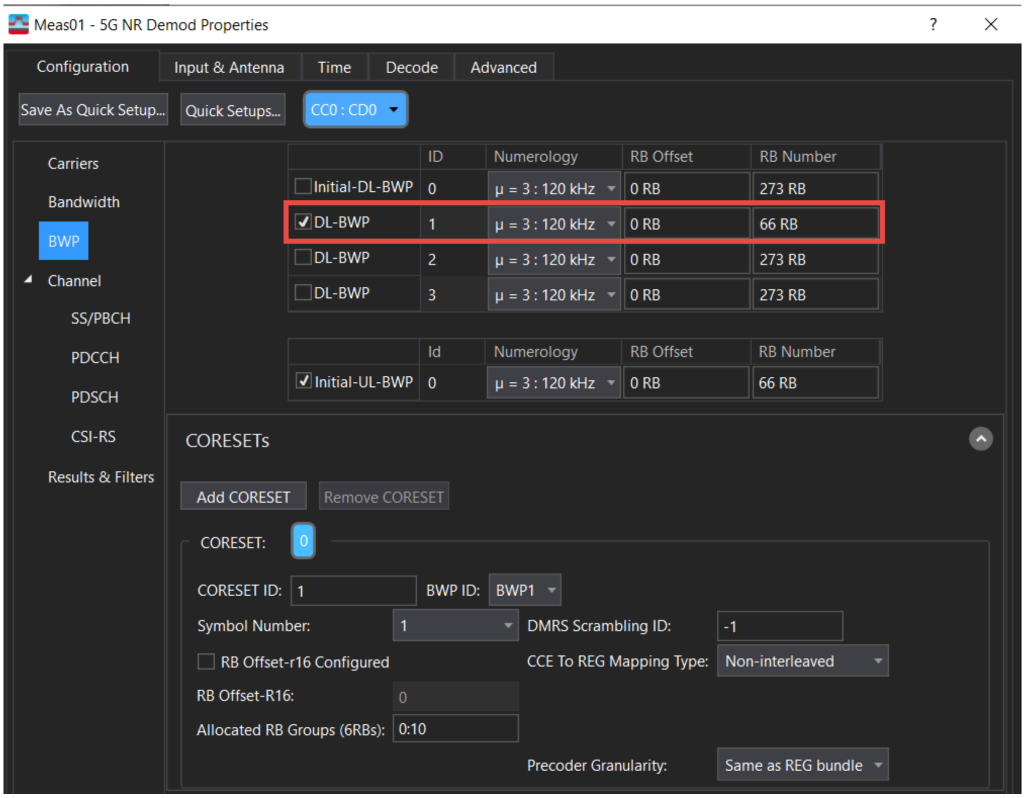
16. Select the **Bandwidth** pane and confirm that numerology is set to **μ= 3:120 kHz**.

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.



17. Select the **BWP** pane and confirm that **DL-BWP ID 1** is enabled.

For each BWP allocation, configure the numerology (µ) and 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.



18. Select the **Channel** pane > **SS/PBCH** and set:

  a. RB Offset (60 kHz) to **0 RB**

  b. Periodicity to **10 ms**

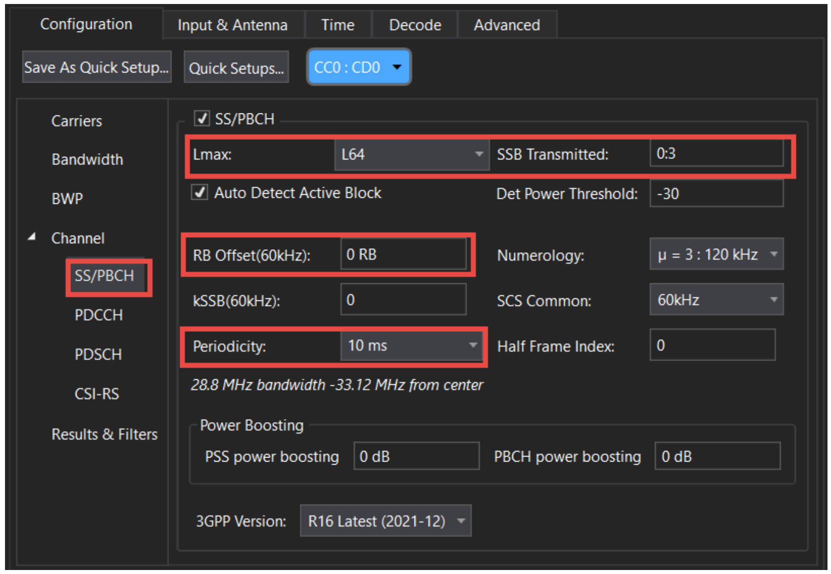
  c. Lmax to **L64**

  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 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.



19. 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 264QAM as max modulation

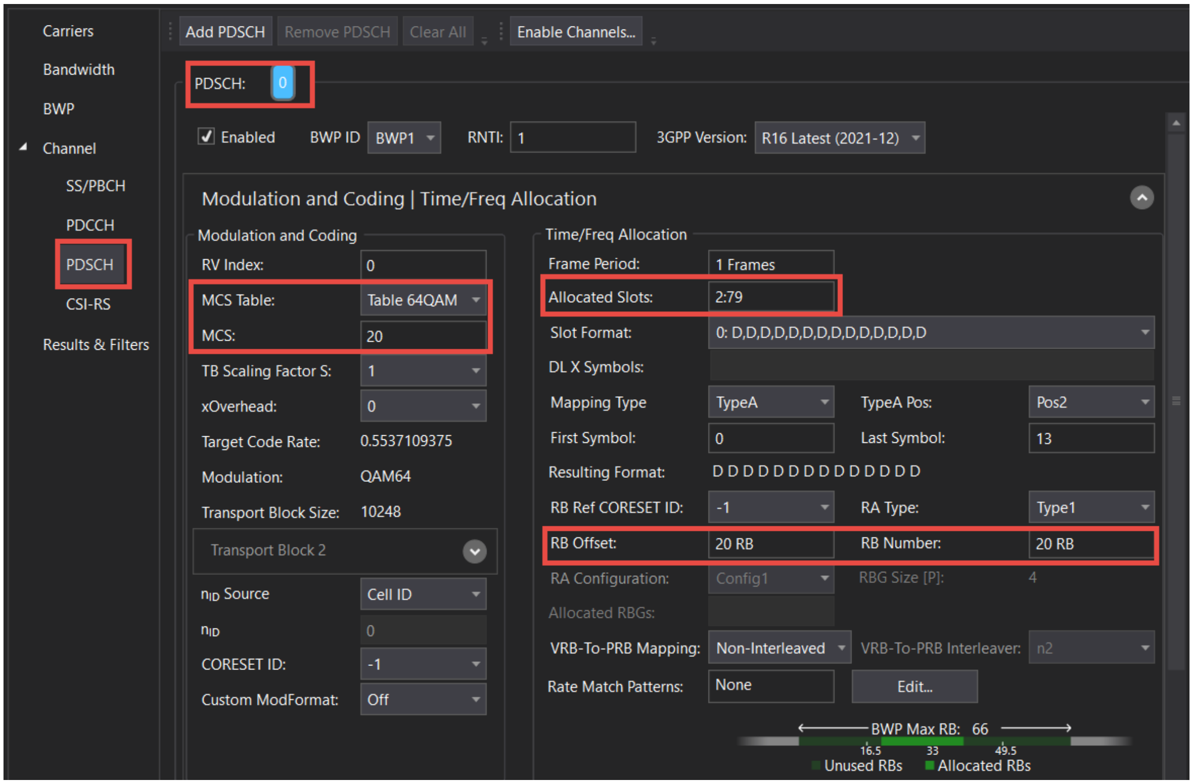
  – Table 5.1.3.1-4 has 1024QAM as max modulation

  – 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**



20. Scroll down and select the Antenna Port dropdown and set:

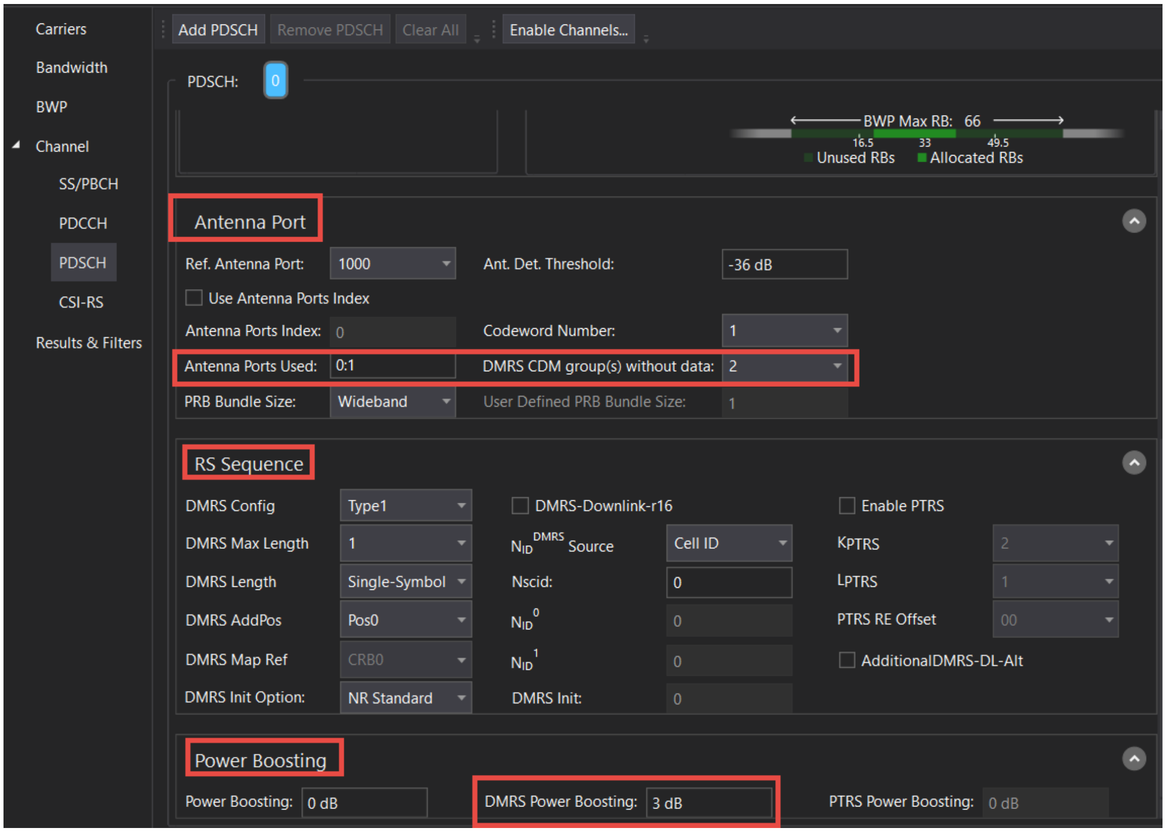
– Antenna Ports Used,1 to **0:1**

– DMRS CDM Group(s) without data to **2** (to match the PathWave setup)

21. 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.

22. 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.



23. To add and configure PDSCH1, select **Add PDSCH**.

24. Select **PDSCH1** and set:

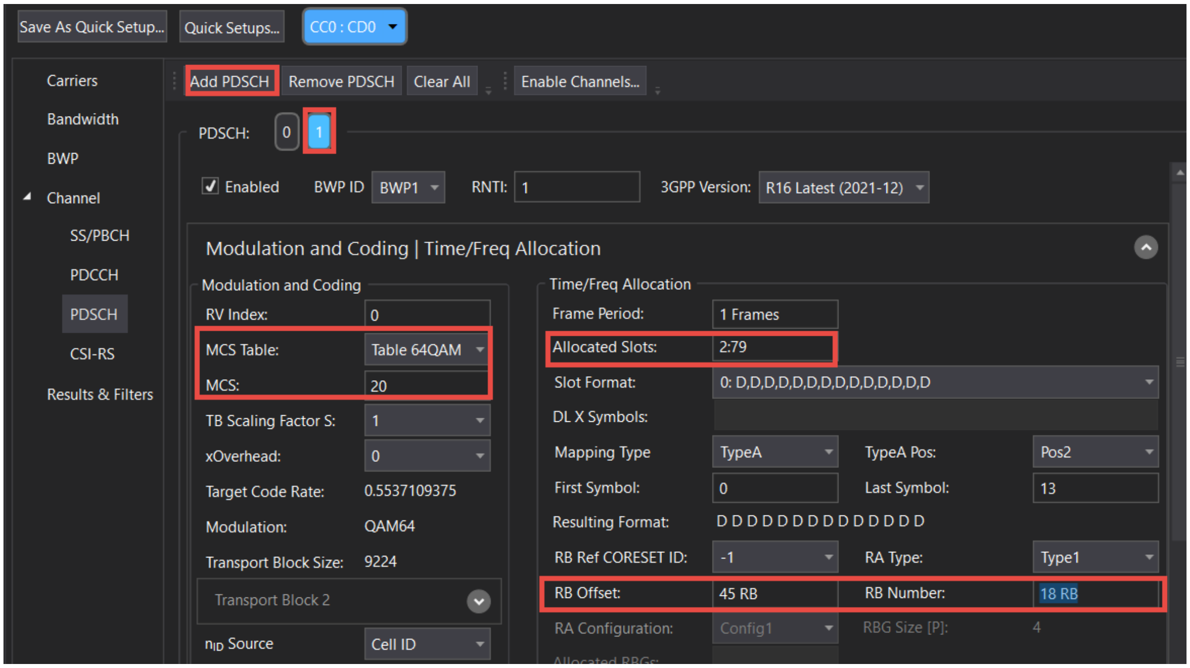
– MCS Table to T**able 64 QAM**

– MCS to **20**

– Allocated Slots to **2:79**

– RB Offset to **45 RB**

– RB Number to **18 RB**

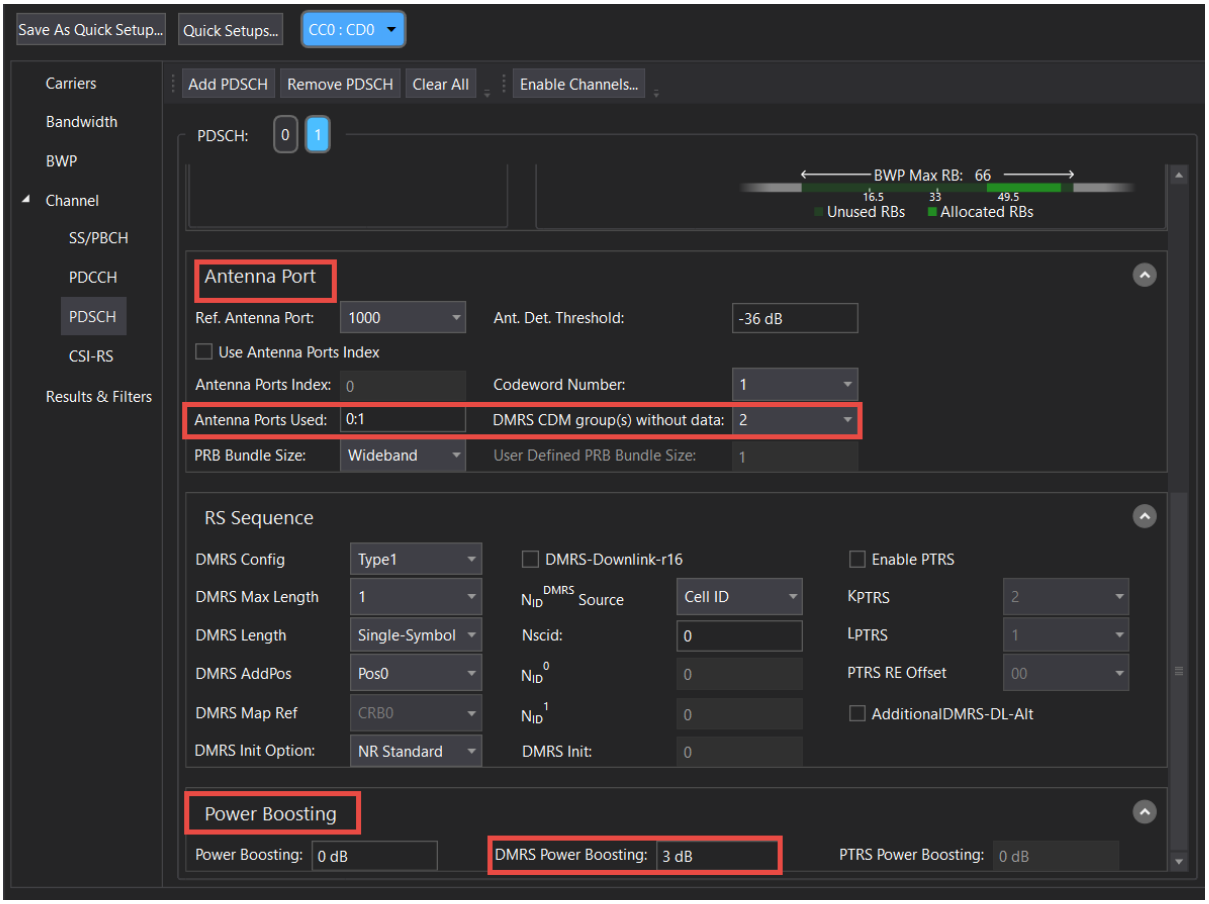


25. Scroll down and open the **Antenna Port** dropdown and set:

– Antenna Ports Used to **0:1**

– DMRS CDM group(s) without data to **2**.

26. 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.

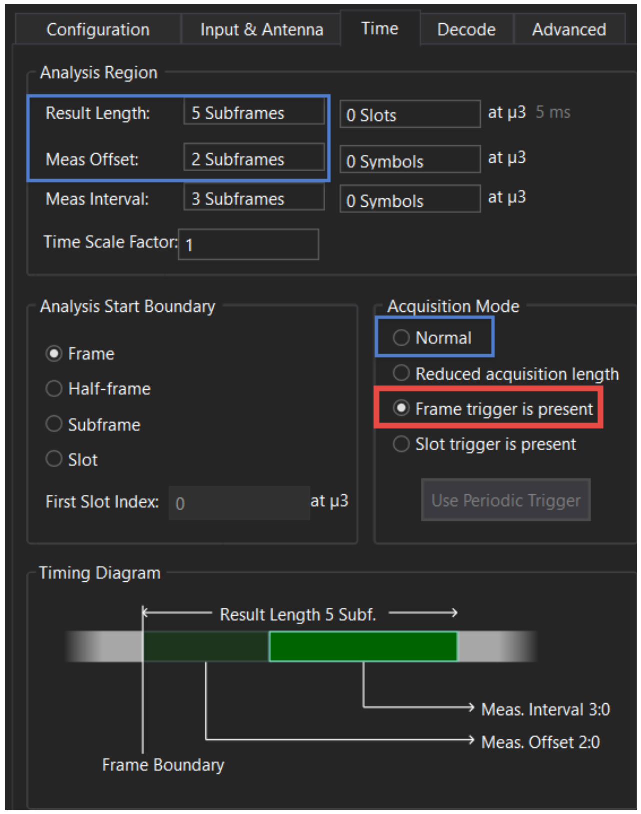
27. To configure the Analysis region, select the **Time** tab and set:

– 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 ±50 µs 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.

28. 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)

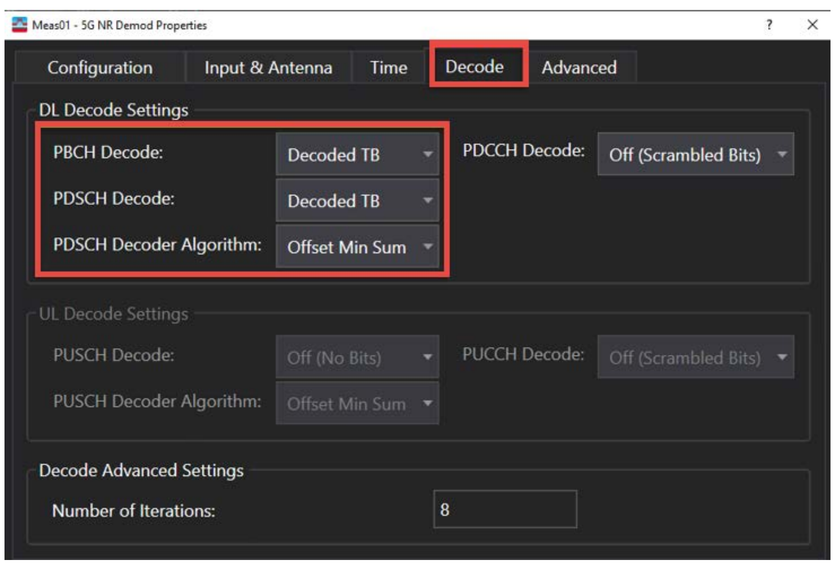
NOTE

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.

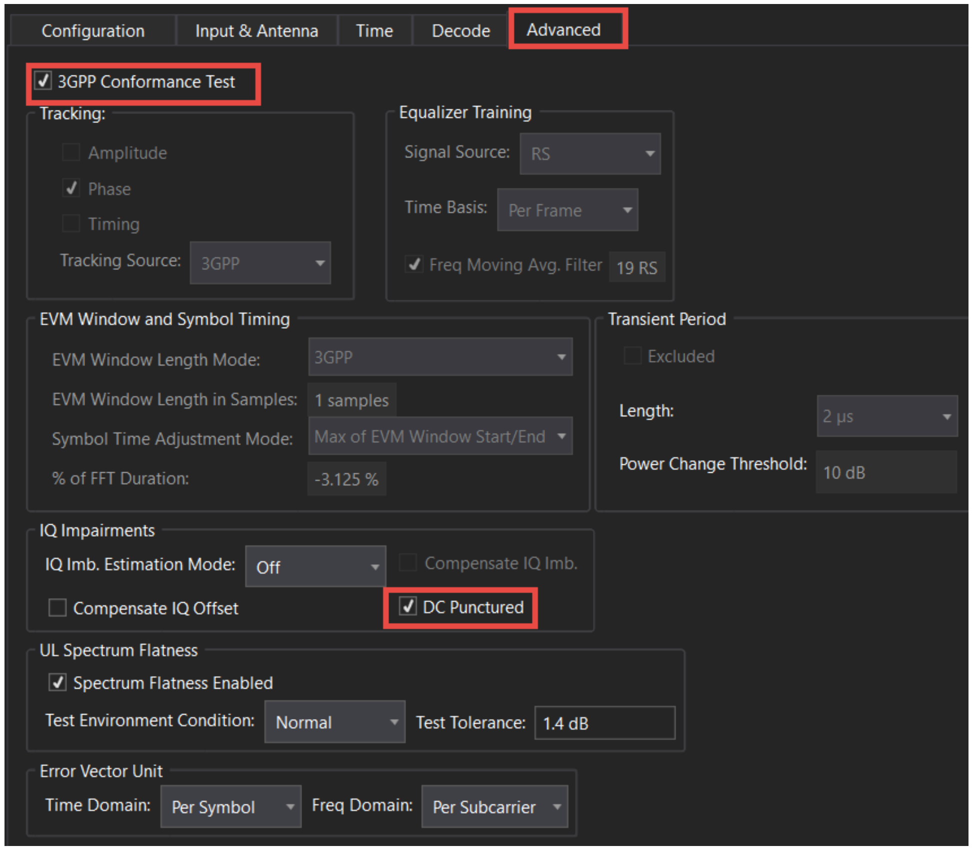
For successful PDSCH decoding (i.e. CRC pass), make sure the RNTI values (used for scrambling) and Transport Block Size matches between the transmitted signal and VSA. (Transport block size depends on MCS table, MCS value, TB Scaling Factor S, and xOverhead under PDSCH channel setting).



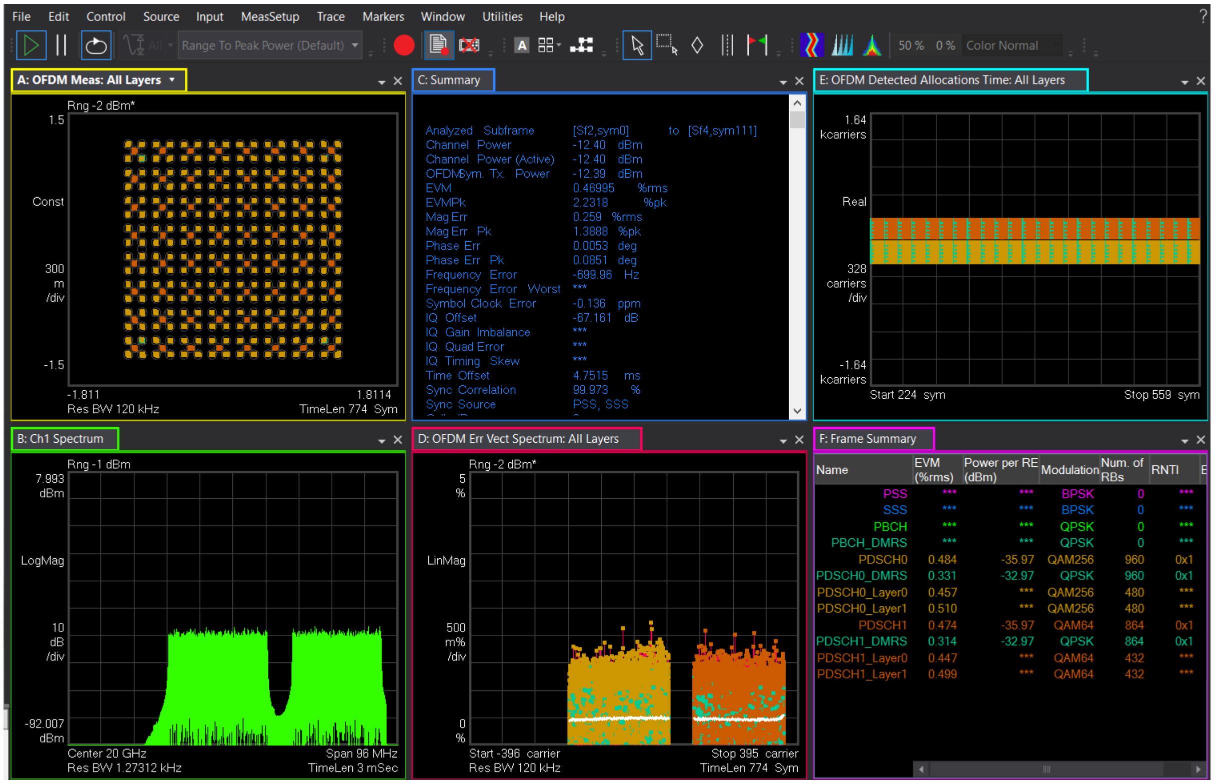
29. Select the **Advanced** tab and select the **DC Punctured** check box.

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.



30. Close the 5G NR Properties dialog, start and new sweep to update the display, then view the results.



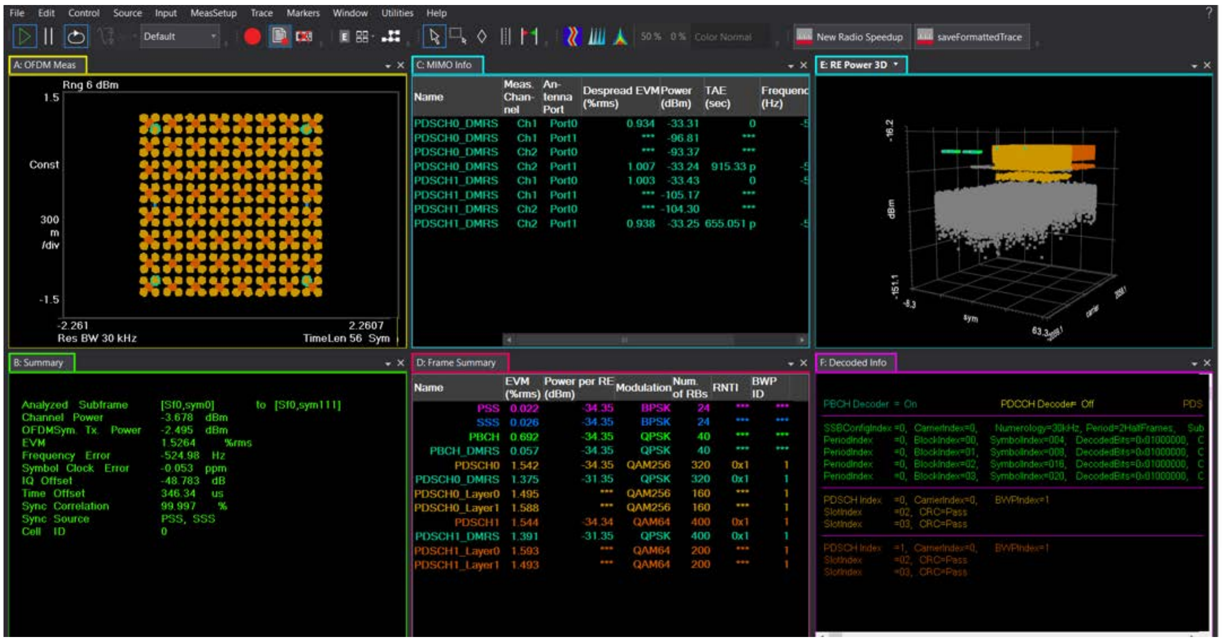
- Trace A: Composite constellation diagram showing different modulation formats for the different channels/signals present in the transmitted signal. See Trace F (Frame Summary) for the list of channels and modulation formats.
- Trace C: Summary trace showing composite error metrics.
- Trace D: Error 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.

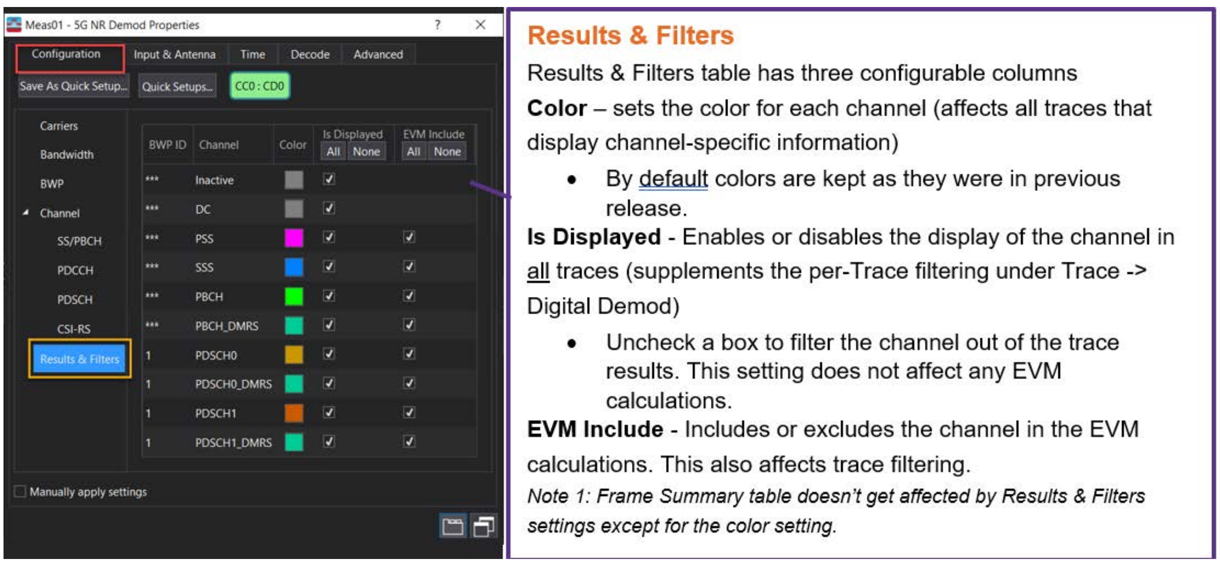
  - Use right click to auto scale, enable the marker, and change the display to different axes.

- 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

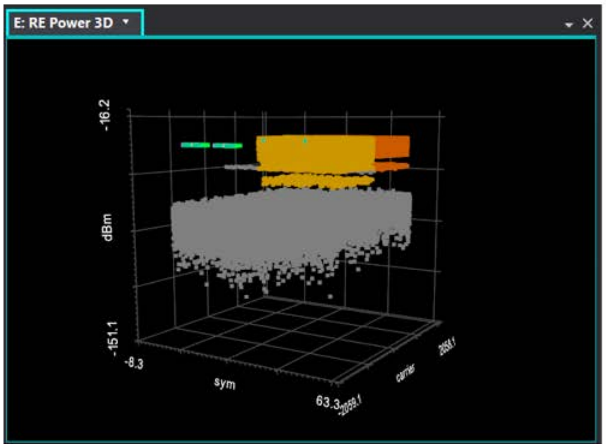
Meas Setup > NR Demod Properties > Configuration tab > Results & Filters panel.



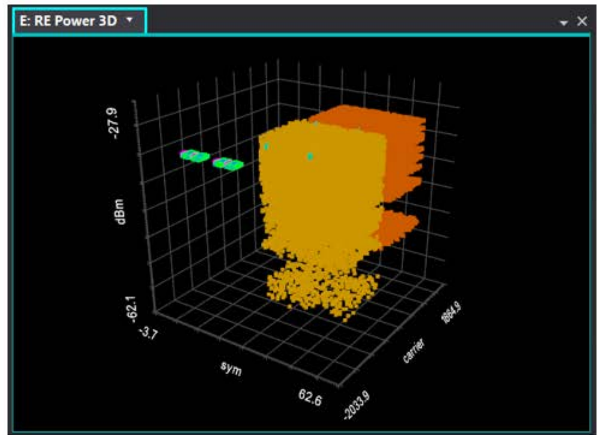
You can try to change colors of some of the channels, and/or filtering out all channels/signals except for SSBlock (PSS, SSS & PBCH) etc.

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

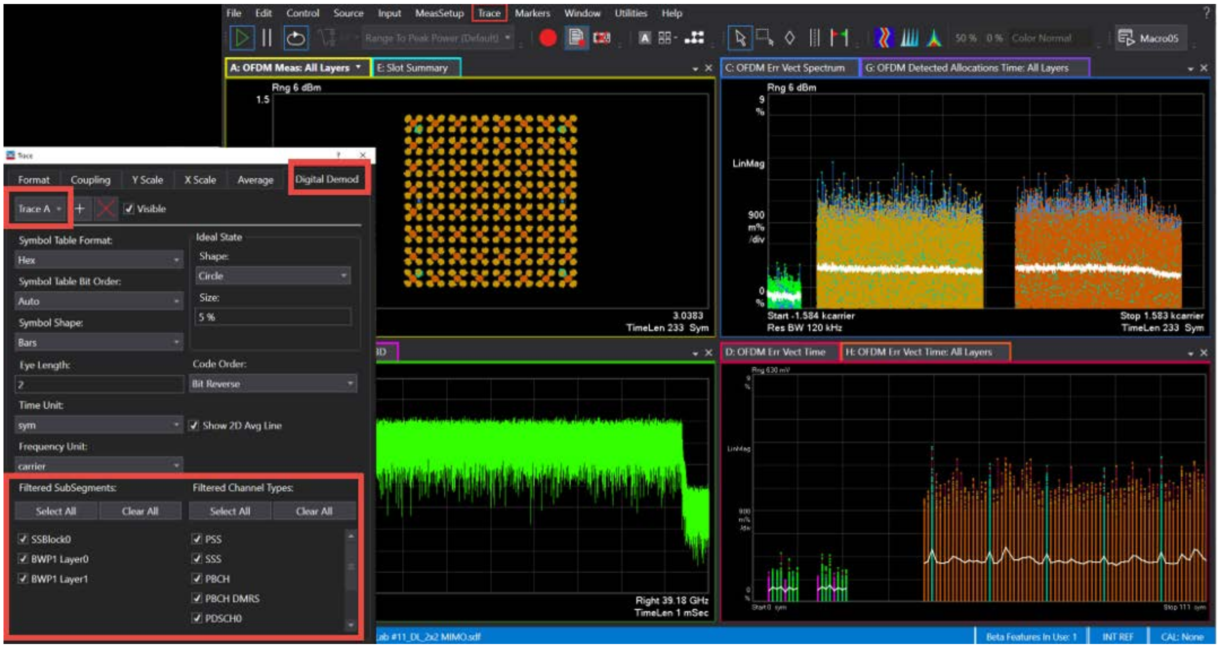
Trace > Digital Demod

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.

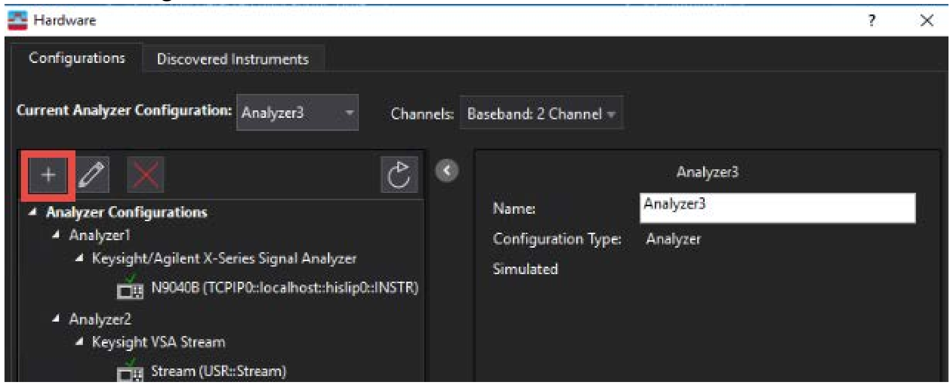
NOTE If accessing the instrument via a Remote Desktop connection, select the Screen tab (at the top of the display) to open the Mode/Measurement/View Selector window.

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

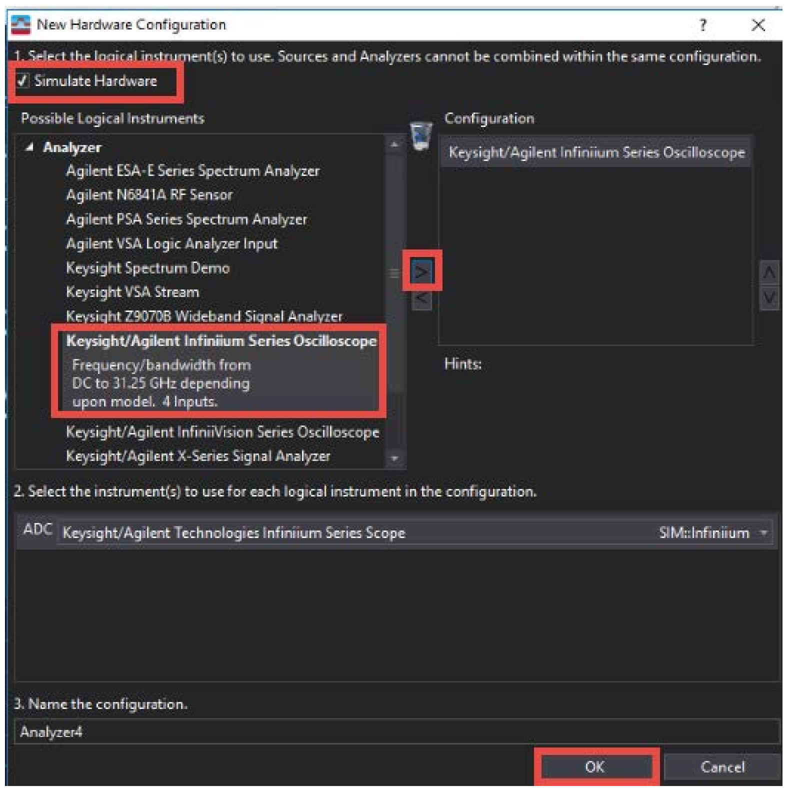
3. To configure the hardware, go to **Utilities** > **Hardware** > **Configurations.**

   If it is already configured, continue with step 9.

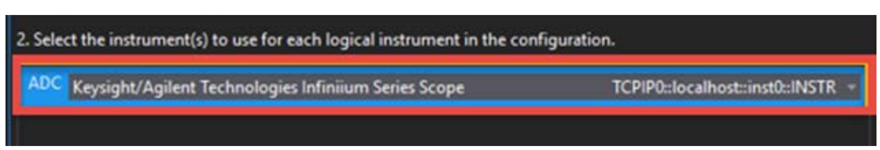
4. In the **Configuration** tab, select the **+ icon**.



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.

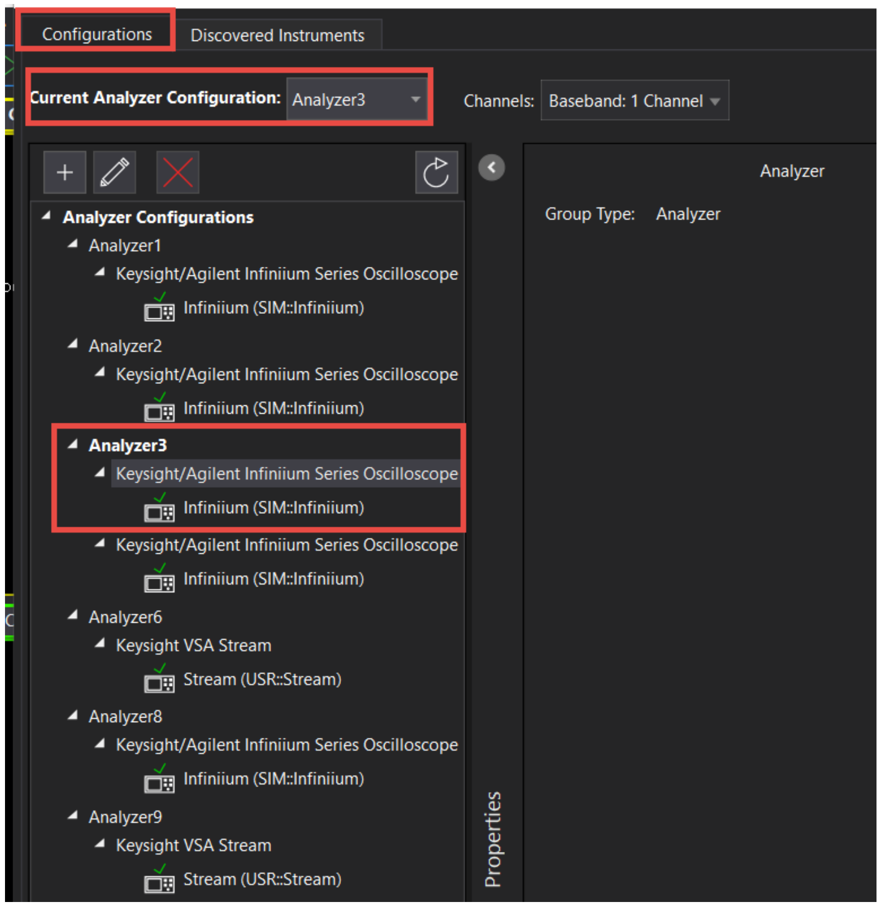


6. From the middle of the dialog box, select the UXR to be used.



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`

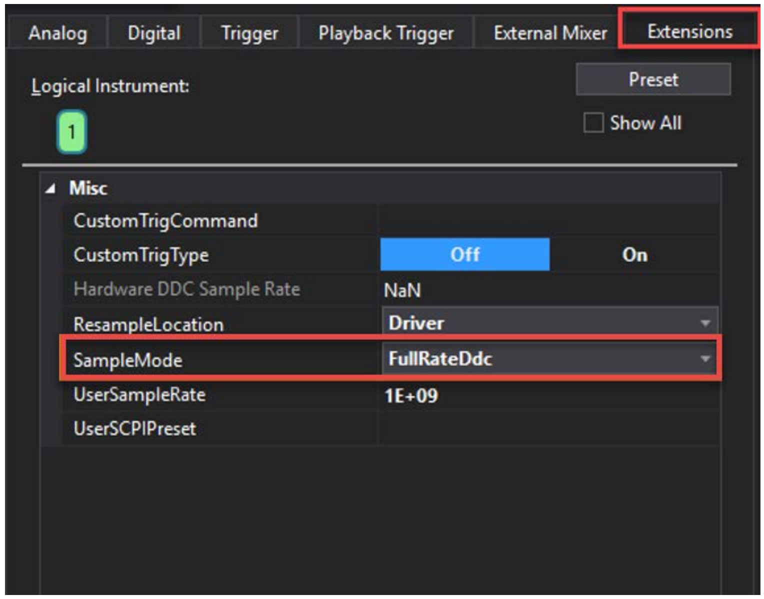
   Copy the **MIMO_UXR_Recording.sdf** file to the signal analyzer or the PC running the VSA application.

10. From the Menu Bar, select **File** > **Recall** > **Recall Recording** and select `MIMO_UXR_Recording.sdf`.

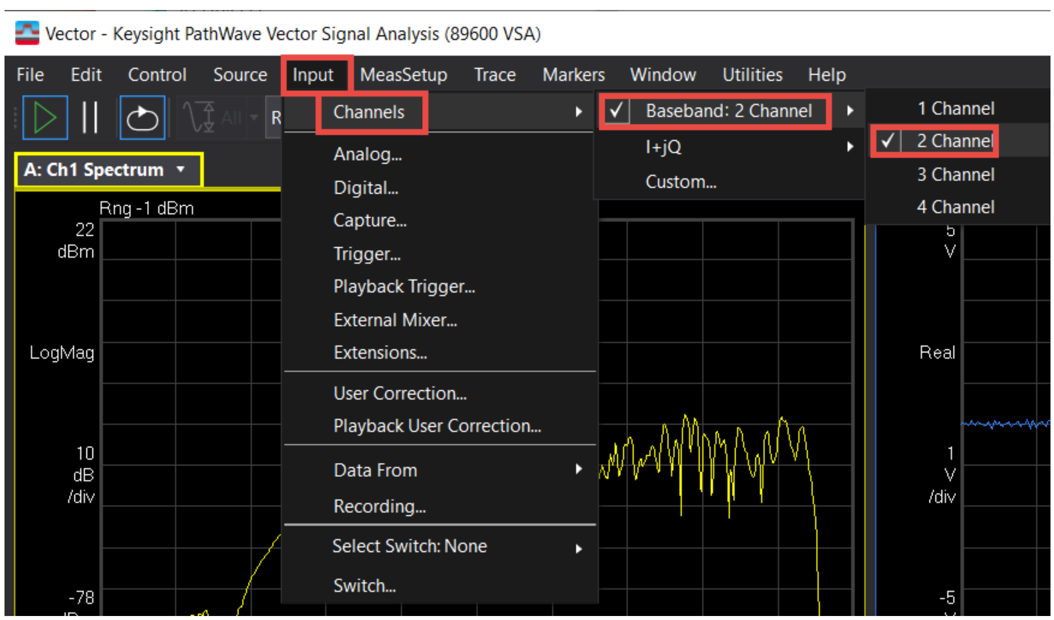
NOTE

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**.

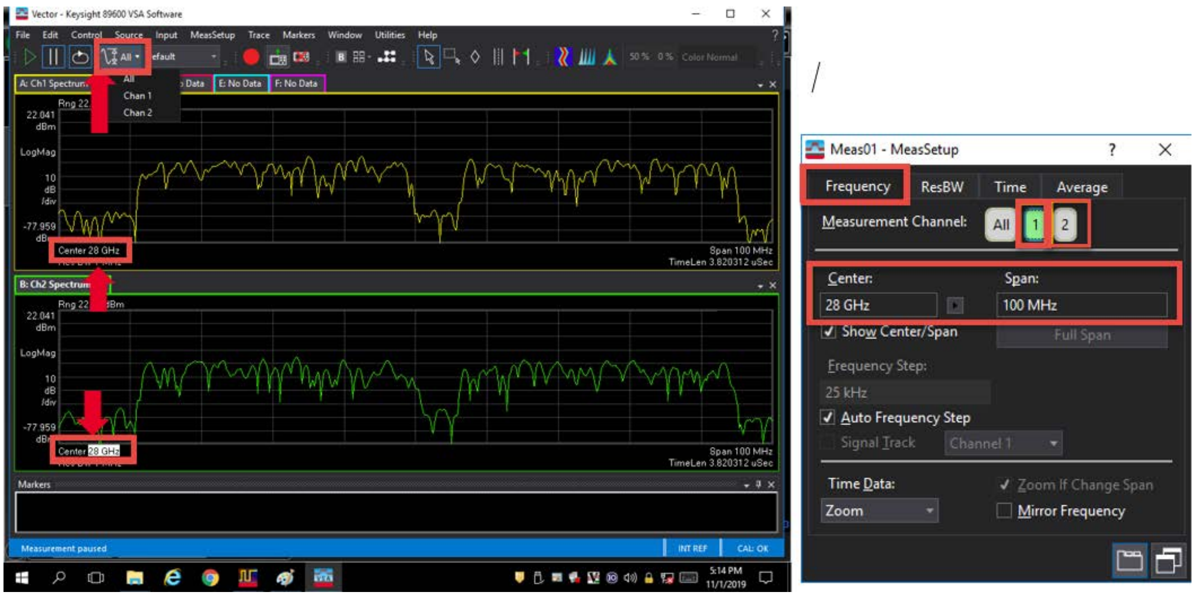
You can also set the frequency and span of both channels under Meas Setup > Frequency.

If you are using a UXR, Select Autorange .

NOTE

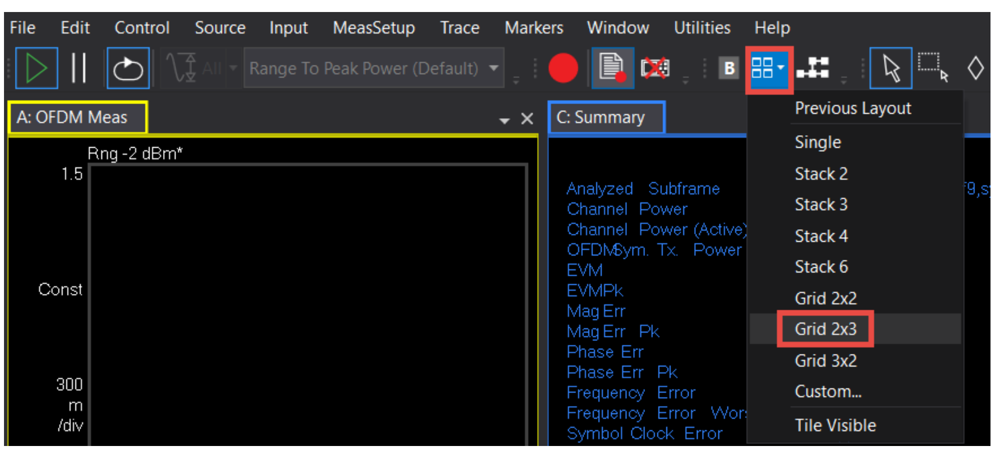
Autorange does not work if you are simulating the waveform with the UXR recording. Continue with the next step.

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.

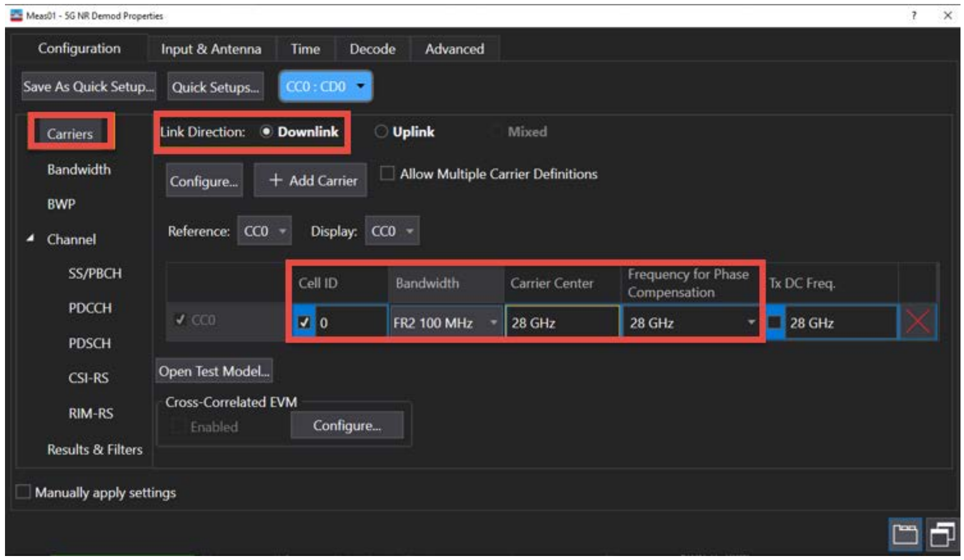


14. From the menu bar, select **MeasSetup** > **Measurement Type** > **Cellular** > **5G NR** > **5G NR Modulation Analysis**.

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.

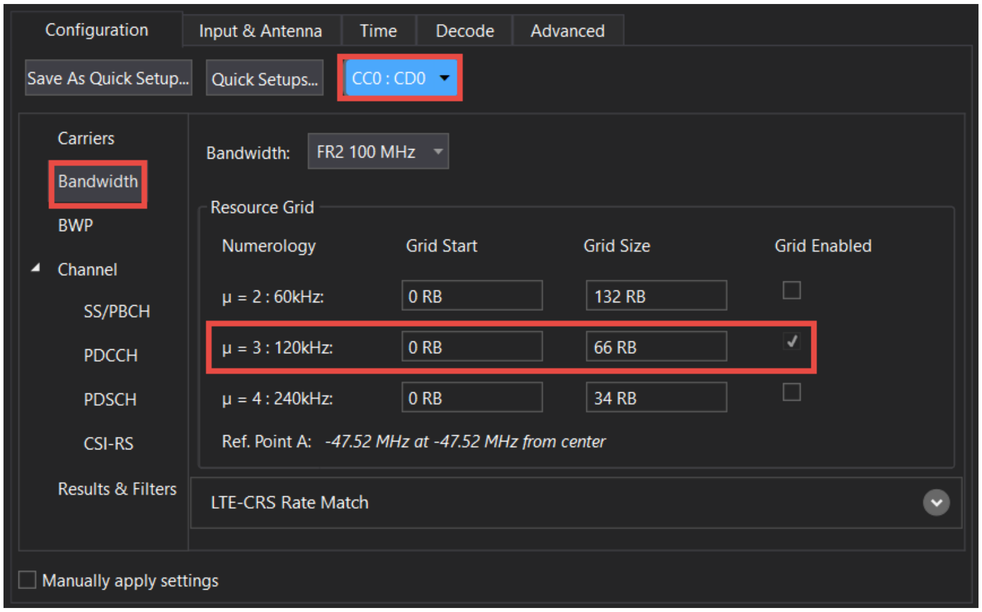


Cell ID is carried on PSS and SSS so that SS/PBCH must be transmitted and enabled for Auto Cell ID to work and must be a Downlink since SS/PBCH is only transmitted in the DL.

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.

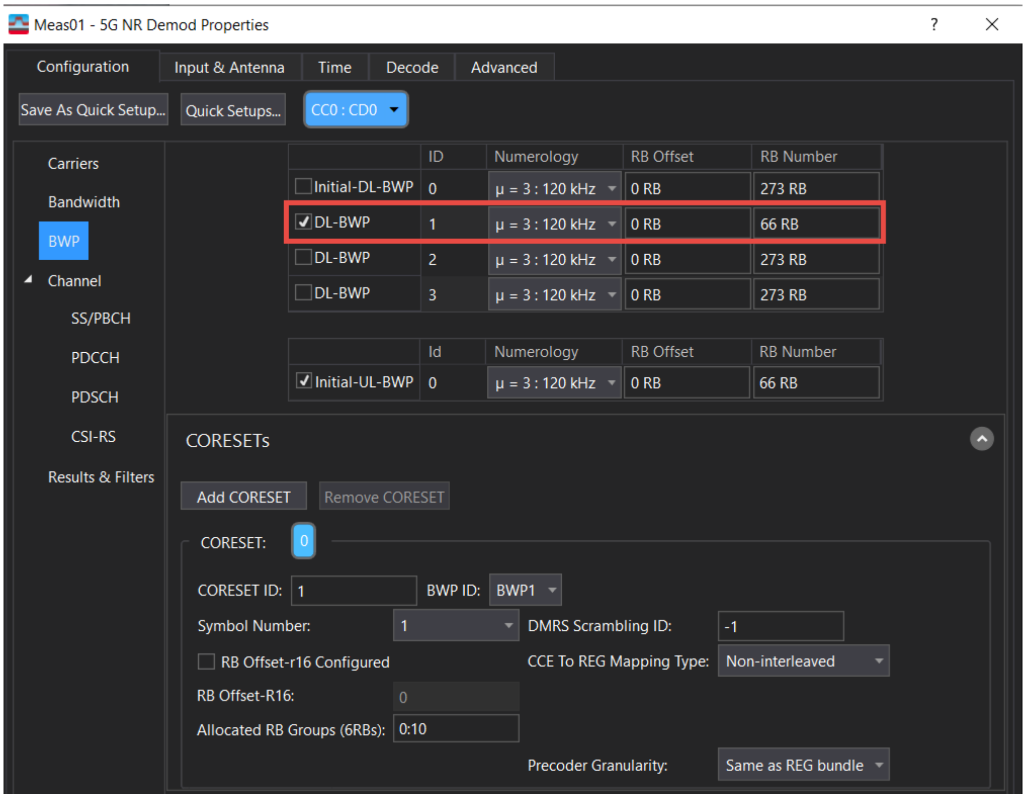
17. Select the **Bandwidth** pane and confirm that numerology is set to **μ= 3:120 kHz**.

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**

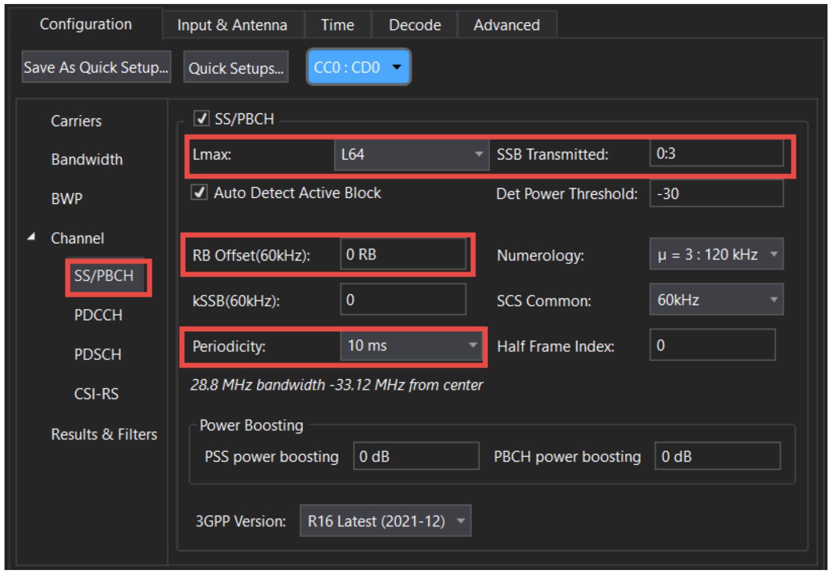
For this example we will use 4 of the 64 SS/PBCH Blocks (beams). In an SSBlock, the period is different fr the different numerologies.

– 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 264QAM as max modulation

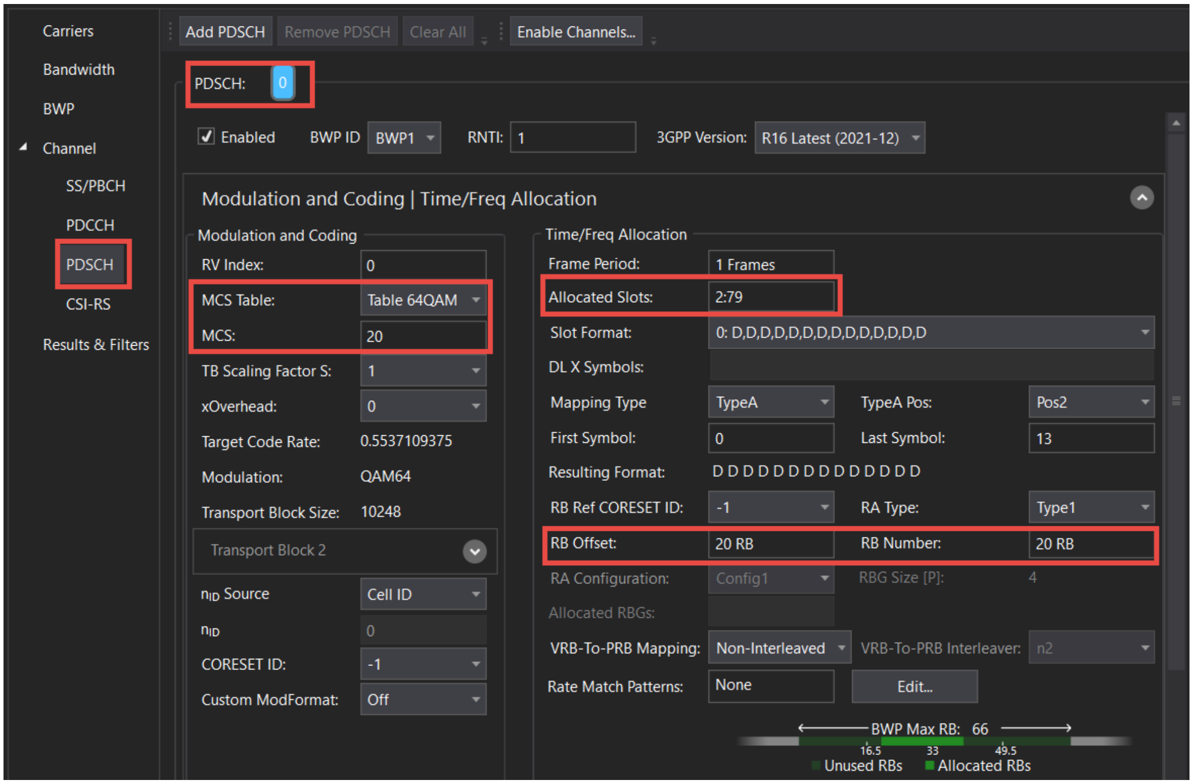
  – Table 5.1.3.1-4 has 1024QAM as max modulation

  – 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:

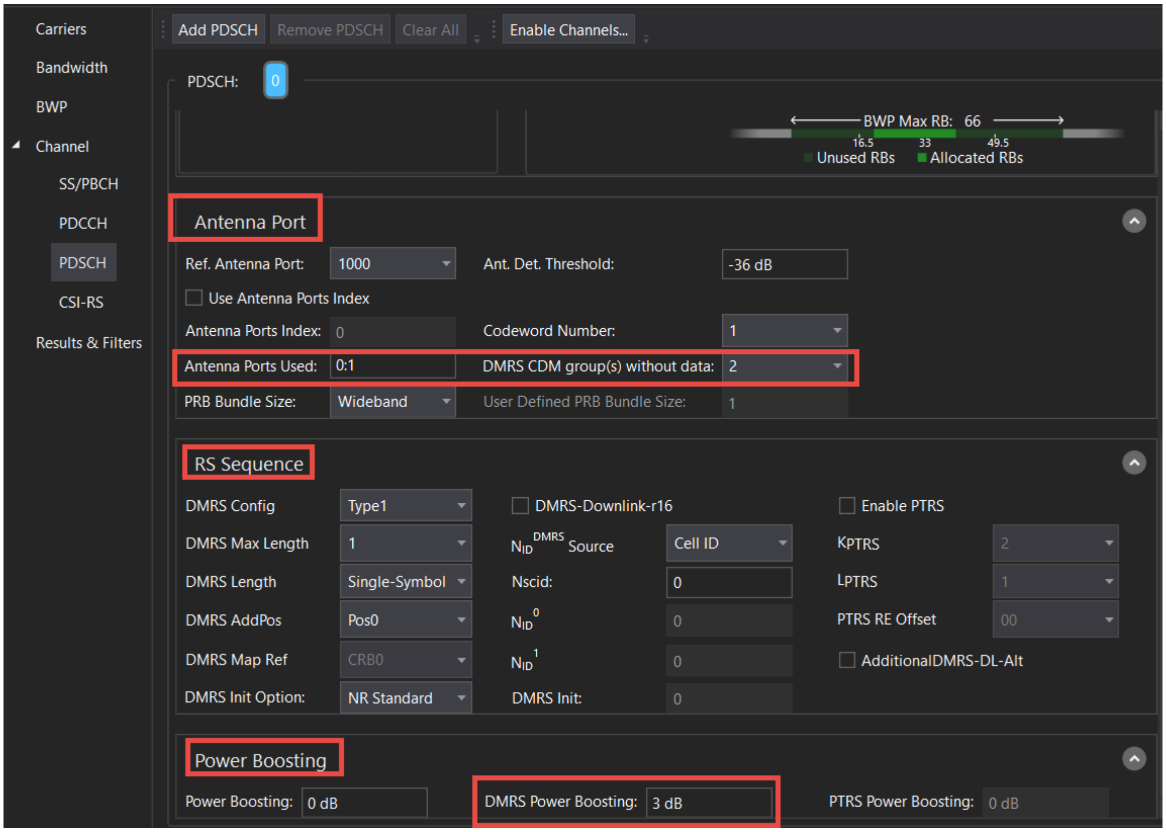
– Antenna Ports Used,1 to **0:1**

– 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.

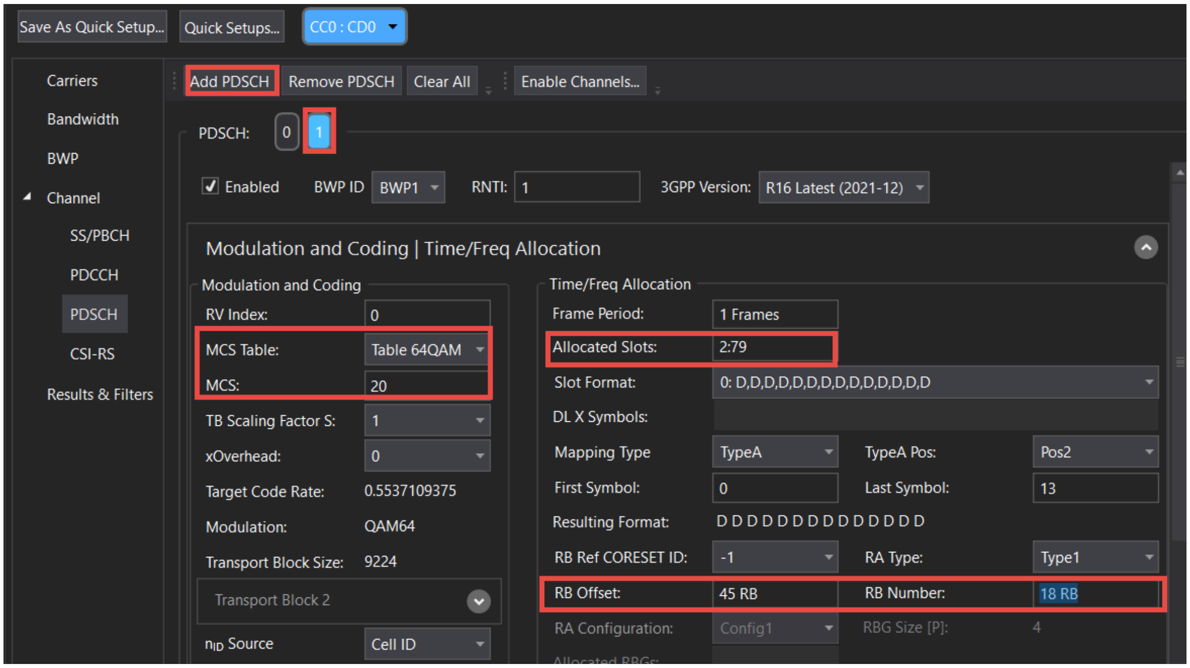


24. To add and configure PDSCH1, select **Add PDSCH**.

25. Select **PDSCH1** and set:

- MCS Table to T**able 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**.

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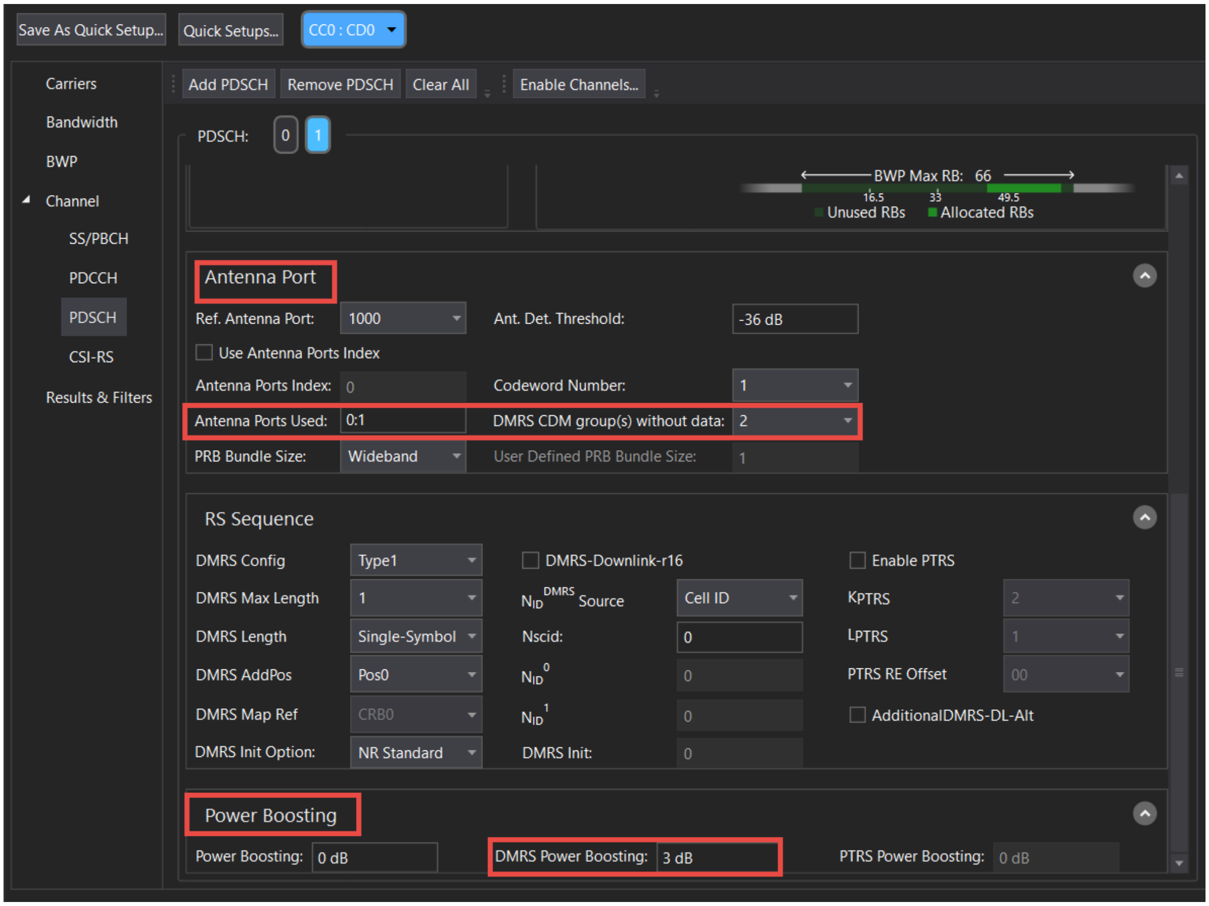
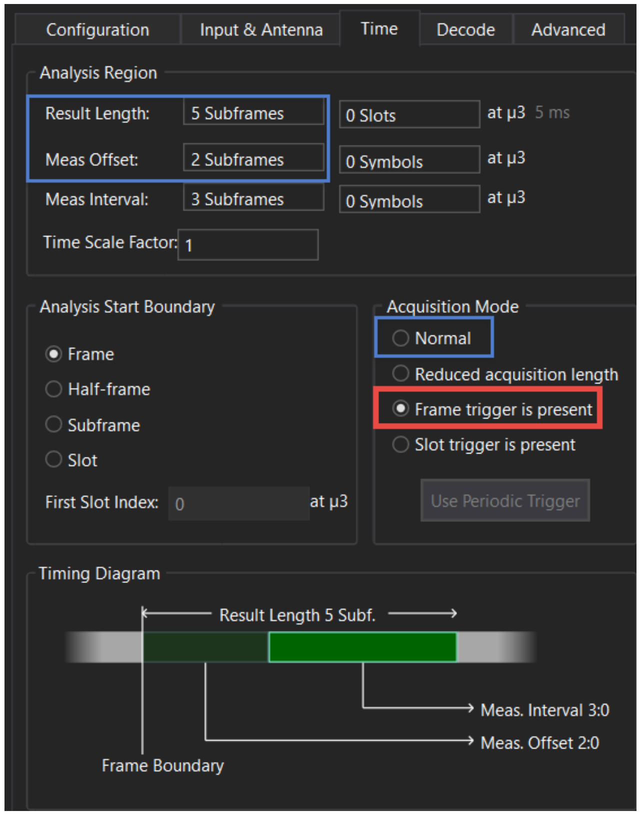


28. To configure the Analysis region, select the **Time** tab and set:

- 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.



TIP

To improve setup speed

Live measurement:

- Use external frame trigger and enable Frame trigger is present. The real frame boundary must be within ±50 µs 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)

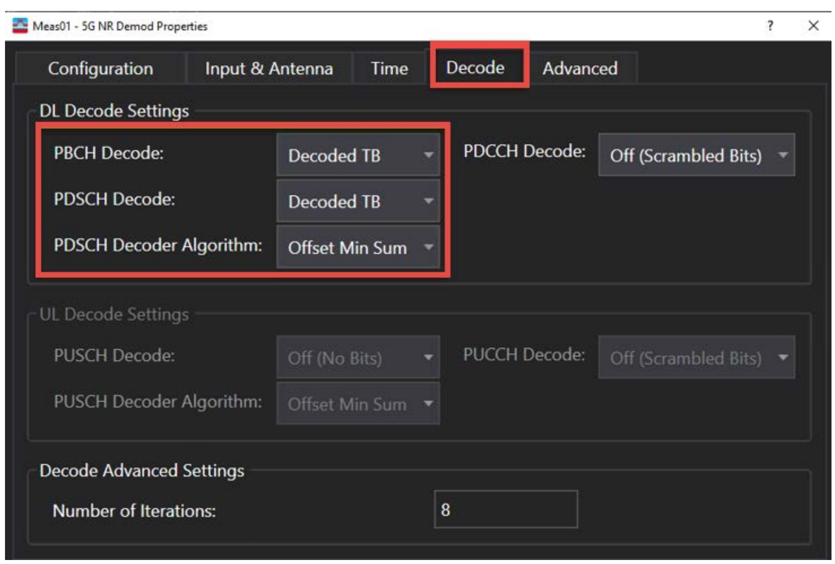
NOTE

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).



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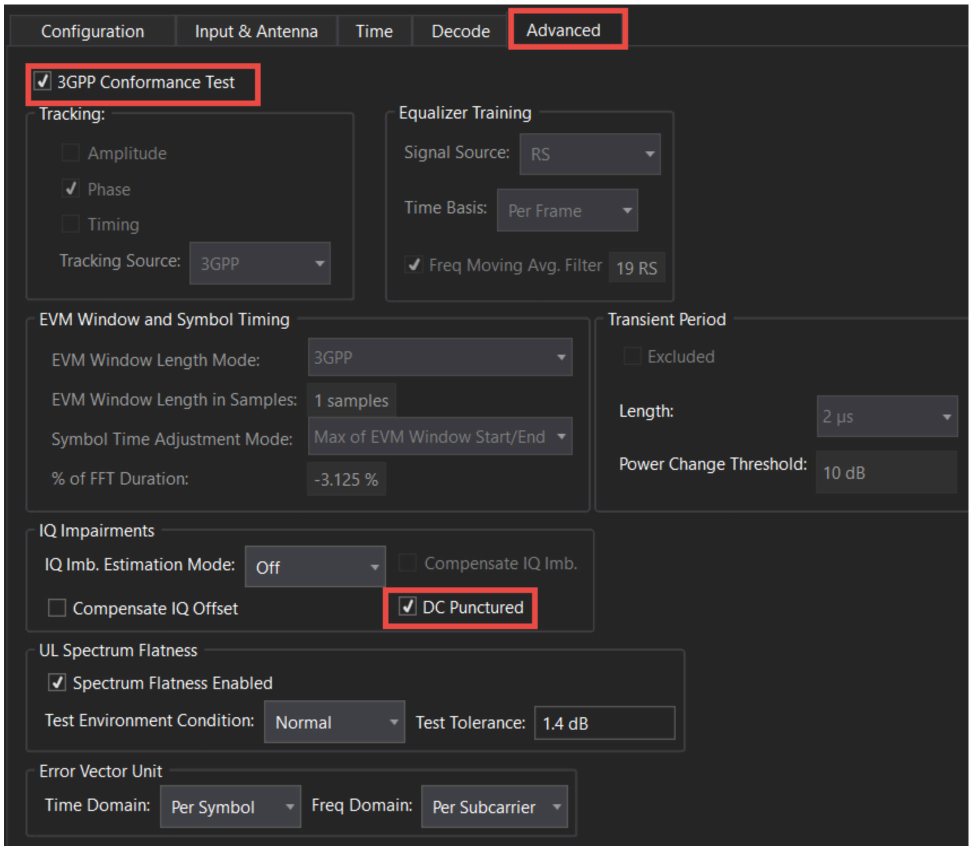
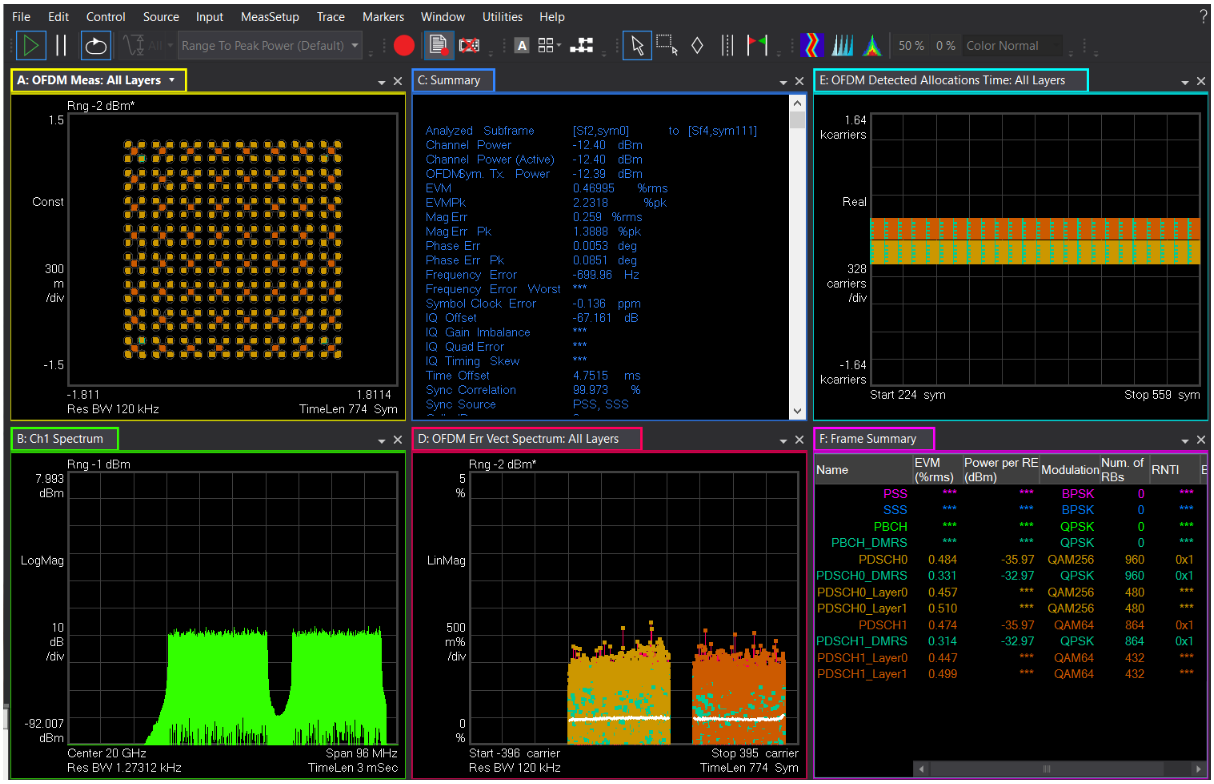


31. Close the 5G NR Properties dialog to view the results.



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- Trace C: Summary trace showing composite error metrics.
- Trace D: Error Vector Spectrum showing EVM versus subcarrier and symbol.
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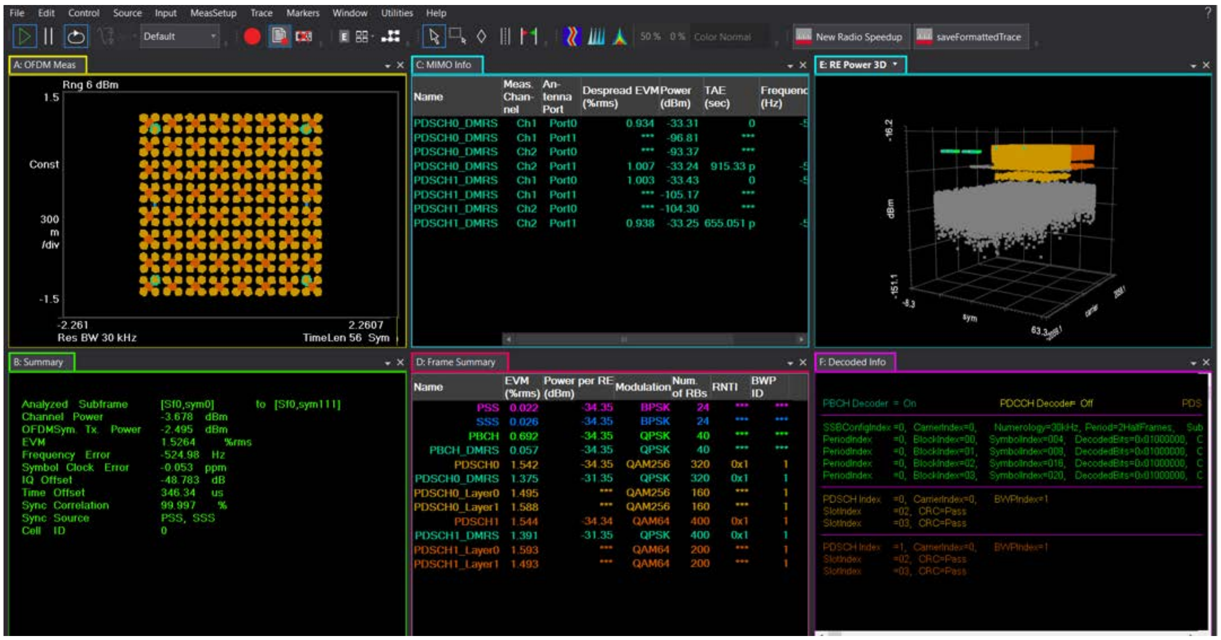
Right click on Trace D and select **Peak**. The exact symbol associated with this peak EVM can now be understood in terms of time domain symbol index, frequency domain subcarrier number, channel type, modulation format, IQ magnitude, and phase values. Other parameters are shown in the Marker window.

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

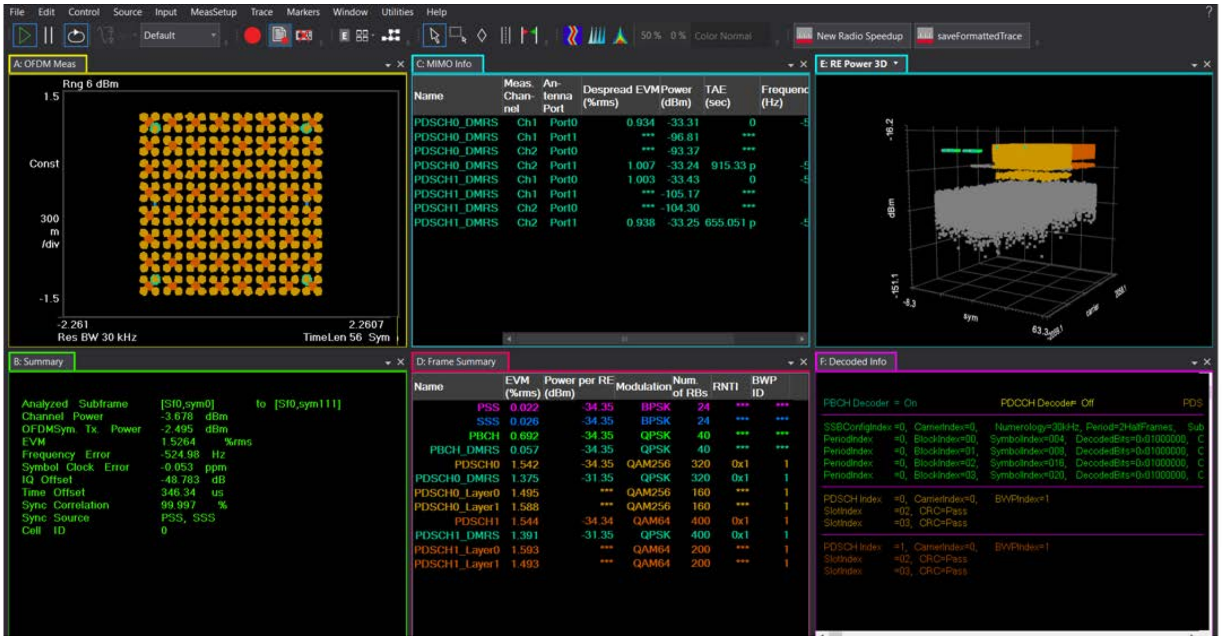
- Trace A: Composite constellation diagram showing different modulation formats for the different channels/signals present in the transmitted signal. See Trace F (Frame Summary) for the list of channels and modulation formats.
- Trace C: Summary trace showing composite error metrics.
- Trace D: Error 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.

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.

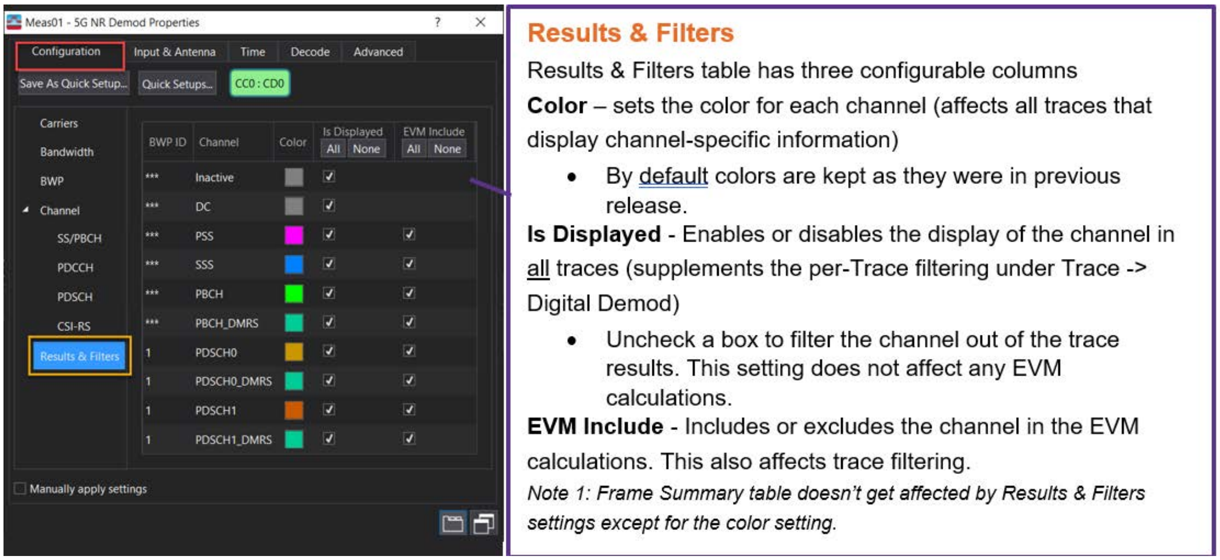
  – Use right click to auto scale, enable the marker, and change the display to different axes.

– 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

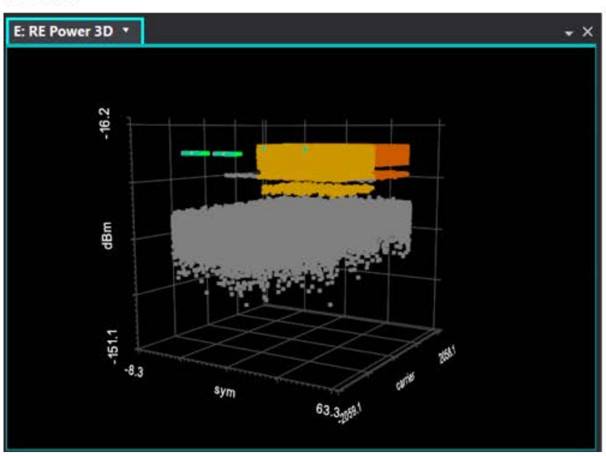
Meas Setup > NR Demod Properties > Configuration tab > Results & Filters panel.



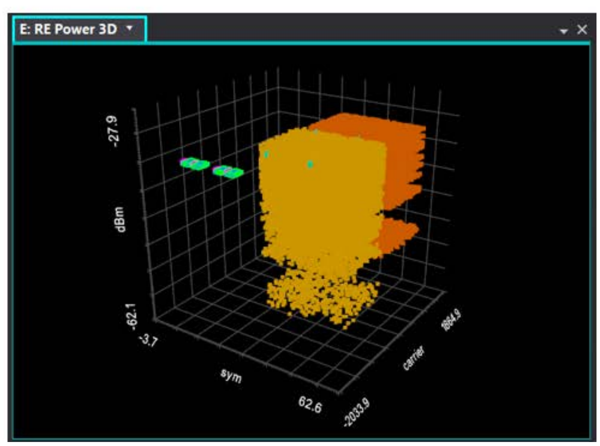
You can try to change colors of some of the channels, and/or filtering out all channels/signals except for SSBlock (PSS, SSS & PBCH) etc.

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.

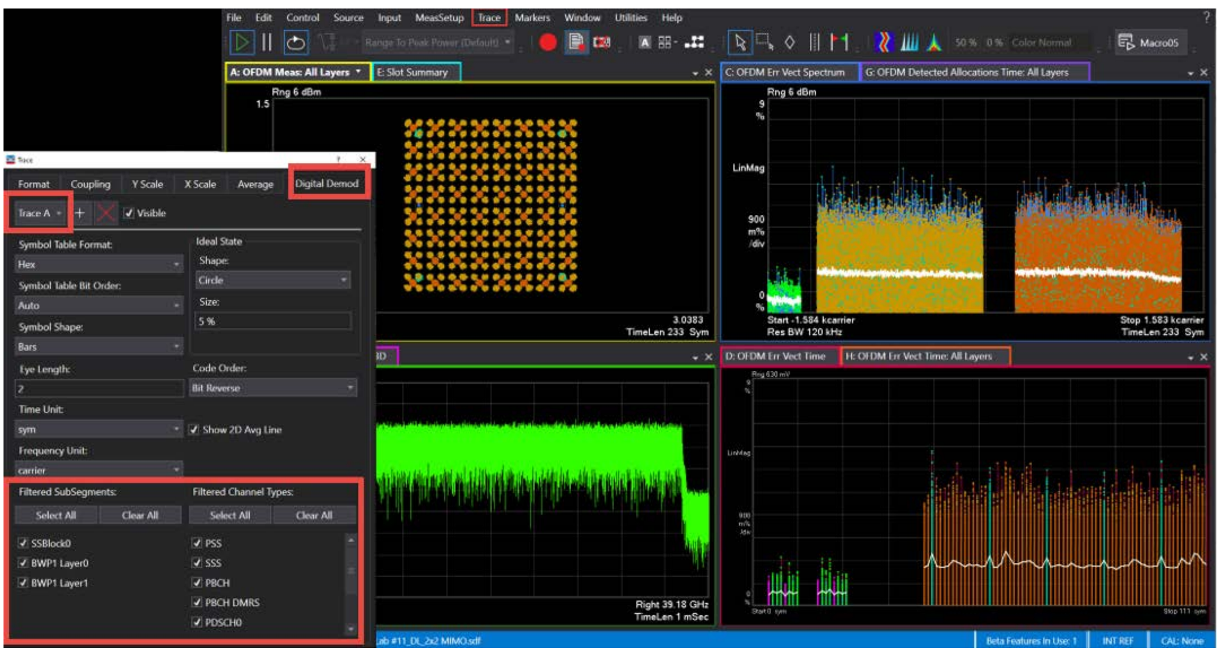
Per-Trace Filtering

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
```

```
SIGNal:NR5G:WAVeform:GENerate

SIGNal ON

SIGNal: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:SSBLock:ENABled 1

NR5G:SSBLock:ROFFset 0

NR5G:SSBLock: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
```

```
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
```