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.



MEASUREMENT GUIDE

Notices

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Where to Find the Latest Information

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

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

Information on preventing instrument damage can be found at:

http://keysight.com/find/PreventingInstrumentRepair

Is your product software up-to-date?

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

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

1. M9484C VXG Basic Measurements

Overview	10
Equipment Setup	11
Required Software	12
Setting Up Triggers on the X-Series Signal Analyzer	13
Basic Measurements	14
Generating a Continuous Waveform (CW)	14
Generating Amplitude Modulation	19
Generating Frequency Modulation	24
Generating Phase Modulation	28
Generating Synchronized Pulse (IQ + Analog) Modulation	33
Generating a Multitone Signal	37
Setting Up Waveform File Vector Modulation	42

2. Corrections

Corrections/De-embedding Using PathWave N7653APPC Software	52
Adding Fixture Blocks using s2p Files	52
Using a Spectrum Analyzer to Make the Corrections Measurement	58
Using a Power Meter to Make the Corrections Measurement	65
Using the equivalent SCPI commands	69
Instrument Nonlinear Correction	71
Setting Up an INC 1CC 4 GHz, 10 dBm EVM Measurement	71
Setting Up an INC 8CC 28 GHz, 10 dBm EVM Measurement	82

3. Advanced Measurements

Channel Bonding	92
Generating a Multi-Carrier DVB-S2X Signal for Satellite TV	93
Generating a Wide Band QPSK)7
Generating a 5G NR Waveform 11	6
Setting Up 8 Virtual Signal Generators	26
On the VXG:	27
On the Signal Analyzer:	34
Using the VSA Flex Frame to Create a DVB-S2X Signal	36
DVB-S2X PHY Layer Framing	37
Part 1: Generating a DVB-S2X Waveform Using N7623C Signal Studio for Digital	
Modulation	38
Part 2: Generating a DVB-S2X Waveform Using the N7608APPC Signal Studio for Custor Modulation	n 55
Creating & Analyzing a 5G NR DL 2x2 MIMO Measurement Using Two UXAs	74
On the VXG	75
Demodulate the 5G NR 2x2 MIMO in X-Apps18	35

Demodulate the 5G NR 2x2 MIMO Using VSA:	.189
Creating and Analyzing a 4x4 MIMO using a UXR Running VSA Software	.196
Equipment Setup	.196

4. Other X-Series Signal Analyzer Measurements

Setting Up a Group Delay Measurement
Setting Up Millimeter-Wave Measurements
Setting up a 5G NR Millimeter-Wave Measurement
Setting-up a Millimeter-Wave DVB-S2X 64APSK Measurement
Setting-up a Millimeter-Wave 5G NR, 2 GHz BW FR2 Measurement
Using the X-Series Analyzer's SCPI Recorder Function
Using the graphical user interface
On the X-Series Signal Analyzer:
Using the X-Series Analyzer's Preload/Unload Function

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

5G Waveform, EVM, and ACP Analysis Using X-Applications	292
Setting Up Triggers on the Signal Analyzer using 5G NR Mode	292
Setting Up a 1 CC 28 GHz EVM Measurement	294
Setting up an 8 CC 28 GHz EVM Measurement	301
Setting Up a 1 CC 3.5 GHz ACP Measurement	311
Using PathWave N7631APPC to Create a Waveform File then Automatically Confi Analyzer to View the Results	igure the

6. 5G NR Measurements Using the VSA Software

5G Waveform and EVM Analysis Using VSA Software	
Setting Up a 1 CC 28 GHz EVM Measurement	
Setting Up an 8 CC 28 GHz EVM Measurement	
Creating a Basic 5G NR Signal Using PathWave N7631APPC Embedded Soft	ware349
Creating a DL MIMO Signal Using PathWave N7631APPC Signal Generation	

1 M9484C VXG Basic Measurements

- "Overview" on page 10
- "Equipment Setup" on page 11
- "Required Software" on page 12
- "Setting Up Triggers on the X-Series Signal Analyzer" on page 13
- "Basic Measurements" on page 14
 - "Generating a Continuous Waveform (CW)" on page 14
 - "Generating Amplitude Modulation" on page 19
 - "Generating Frequency Modulation" on page 24
 - "Generating Phase Modulation" on page 28
 - "Generating Synchronized Pulse (IQ + Analog) Modulation" on page 33
 - "Generating a Multitone Signal" on page 37
 - "Setting Up Waveform File Vector Modulation" on page 42



M9484C VXG Basic Measurements Overview

Overview

NOTE

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

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

M9484C VXG Basic Measurements Required Software

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.



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.

1.000000000000	GHz
0.00 dBm	

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.

- 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.

- 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.

- 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.

RFAL1: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.

III		∫∽ 🕞 🕞 Sroup 1: Signal Summ	nary		RF Out (All)	ngger ? ~ pseset ~
	Enabled	Signal Mode	Frequency Offset	Attenuation Status		
i		File: No file selected				
2		None				>
-8		None				>
4		None				>
5		None				>
6		None				>
7		None				>
8		None				>

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

General	Enable	Mode	Signal Attenuation
Analog Modulation		Analog Modulation 🛛 🗸 🗸	0 dB
Trigger	Mute	Frequency Offset	Power
		0 Hz	0 dB
		Sample Rate 1.280 000 000 000 MHz	
		Reset Phase Accumulator	

- 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.

	⊕ ⊝	Group 1: Signal Summary	> Signal 1: Setup
General	Fnable	Mode	Signal Attenuation
Analog Modulation		Analog Modulation 🛛 🗸 🗸	0 dB
Trigger	Mute	Frequency Offset	Power
		0 Hz	0 dB
		Sample Rate 1.280 000 000 000 MHz	
		Reset Phase Accumulator	

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.



- 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

SIGNall ON

RF1:OUTPut:STATe ON

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

RFAL1: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.

≡ ₩ ₽~	6	Group 1: Signal Summary	> Signal 1: Setup
General	Enable	Mode	Signal Attenuation
Analog Modulation	mui.	Analog Modulation 🗸 🗸	0 dB
Trigger	Mute	Frequency Offset	Power
		0 Hz Sample Rate 1.280 000 000 000 MHz	0 dB
		Reset Phase Accumulator	

- 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.

) Group 1: Signal Summary	> Signal 1: Setup
General Enable	Mode	Signal Attenuation
Analog Modulation	Analog Modulation 🛛 🗸 🗸	0 dB
Trigger Mute	Frequency Offset	Power
	0 Hz	0 dB
	Sample Rate 1.280 000 000 000 MHz	
	Reset Phase Accumulator	

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.



- 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

SIGNall ON

RF1:OUTPut:STATe ON

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

RFAL1: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.

	Enabled	Signal Mode	Frequency Offset	Attenuation	Status	
		File: No file selected				>
		None.				>
		None				>
		Nane				>
5		None				>
		None				>
7		None				>
		None				>

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

≡ ₩ ⊡~ © ©	Group 1: Signal Summary	> Signal 1: Setup
General Enable	Mode Analog Modulation ~	Signal Attenuation 0 dB
Trigger Mute	Frequency Offset 0 Hz Sample Rate 1.280 000 000 000 MHz Reset Phase Accumulator	Power 0 dB

- 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.

	Group 1: Signal Summary	> Signal 1: Setup
General Ena	ble Mode	Signal Attenuation
Analog Modulation Trigger Mute	Frequency Offset	Power
	0 Hz	0 dB
	Sample Rate 1.280 000 000 000 MHz	
	Reset Phase Accumulator	

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.

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

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

SIGNall ON

RF1:OUTPut:STATe ON

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

RFAL1: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.

^	Name	^ ~ ~	Date modified	Туре
	5GNR_1CC_FR1_30kH	z_SCS_100MHz_256QAM_DC	9/20/2018 10:53 PM	Text Document
	5GNR_1CC_FR1_30kH	z_SCS_100MHz_256QAM_DC	8/29/2018 11:57 PM	SETX File
	5GNR_1CC_FR1_30kH	Iz_SCS_100MHz_256QAM_DC	7/10/2019 1:47 AM	WFM File
	5GNR_1CC_FR2_120k	Hz_SCS_100MHz_256QAM_DC	2/20/2019 9:58 PM	Text Document
	5GNR_1CC_FR2_120k	Hz_SCS_100MHz_256QAM_DC	2/20/2019 10:01 PM	SETX File
	5GNR_1CC_FR2_120k	Hz_SCS_100MHz_256QAM_DC	7/14/2019 2:07 AM	WFM File
	5GNR_2x2_MIMO_VX	G_Scope_Updated.scp	5/14/2019 7:14 PM	Text Document
	SGNR_2x2_MIMO_VX	G_Scope_Updated.setx	5/14/2019 7:14 PM	SETX File
	5GNR_8CC_FR2_120k	Hz_SCS_100MHz_256QAM_Cor	2/20/2019 9:48 PM	Text Document
	5GNR_8CC_FR2_120k	Hz_SCS_100MHz_256QAM_Cor	7/14/2019 2:05 AM	WFM File
	5GNR_8CC_FR2_120k	Hz_SCS_100MHz_256QAM_DC	2/20/2019 9:05 PM	SETX File
	5GNR_UXR_Recording	g_28_GHz.csv	5/19/2019 10:29 PM	CSV File
	10GHzInDB.s2p		4/25/2019 5:38 PM	S2P File
	4000_SamplelQPulse	OnOff_50%_wfm.csv	5/8/2020 10:55 AM	CSV File
	4000_SamplelQPulse	DnOff_50%_wfm.wmk	6/3/2020 2:30 PM	WMK File
	GSM_1C_BURST_SEC	UREWAVE.wfm	7/17/2013 6:49 PM	WFM File
	simpleAt10GHzInDB.s	s2p	4/28/2019 4:52 PM	S2P File
	WCDMA_TM1_64DPC	CH_4C.wfm	1/14/2013 10:57 PM	WFM File

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.

Group 1: Signals	
File None selected	

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.

=	#	* © 🤤	Grou	p 1: Signal Summa	ry			RE Out (All)	Tragger ? -	-
	Enabled	Signal Mode			Frequency Offset	Attenuation	Status			
1		File: No file selected							4	>
2		None								$\mathbf{\Sigma}$
ġ		None								>
4		None							- 3	>
5		None							3	>
6		None							3	>
7		None								>
8		None							0	>
Fading	Enable						Re	maining Sample Rate:	3.0000000000000000000000000000000000000	00 GHz

5. Select the Mode dropdown and select Waveform File.

	Θ \Im	Group 1: Signal Summary	> Signal 1: Setup
General	Enable	Mode	Signal Attenuation
Waveform File		Waveform File 🗸 🗸 🗸	0 dB
Trigger	Mute	Frequency Offset	Power
Markers		0 Hz	0 dB
		Sample Rate 3.000 000 000 000 000 GHz	
		Reset Phase Accumulator	

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.

	~ © @ 6	Croup 1: Signal Summary > Signal 1: Setup		RF Out (All)	Trigger ? ~ Preset
General	File D:\Users\Instrum	ent\Documents\Keysight\PathWave\SignalGenerator\Examples\40	00_Sample/QPulseOnOff_50%_wfn	n.csv	Select >
Waveform File				Nonlinear Correction	
Trigger				Off	Configure >
Markers	Sample Rate	RMS Power	Scale	Occupied Bandwidth	
	2.000 000 000 kHz	1.412 667	100.00 %	0 Hz	

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

) Group 1: Signal Summary	> Signal 1: Setup
General Enable	Mode	Signal Attenuation
Analog Modulation	Analog Modulation 🛛 🗸 🗸	0 dB
Trigger	Frequency Offset	Power
	0 Hz	0 dB
	Sample Rate 1.280 000 000 000 MHz	
	Reset Phase Accumulator	

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) 4.0 s .
--	------------------

KEYSIGHT	Input: RF	Input Z: 50 Ω	Atten: 10 dB	PNO: Fast	Avg Type: Log-Power	1 2 3 4 5 6
L 🖵	Align: Off	Freq Ref: Ext (S)	µW Path: Standard	IF Gain: Low	nig. Hee Kuit	w ₩ ₩ ₩ ₩ ₩
LXI		NFE: Adaptive		Sig Track: Off		NNNNN
1 Spectrum	¥.					
Scale/Div 10 dB			Ref Level 0.00 dB	m		
209						
-10.0						
-20.0						
-30 0						
-40.0						
-50.0						
50.0						
-60.0						
-70.0						
-80.0						,
-90 0						
Center 1.000000	000 GHz		#Video BW 300 H	z		Span 0 Hz
Res BW 3.0 MHz					Swee	p 4.00 s (1001 pts)

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

NOTE

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

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.

Group 1: Signals	
File None selected	

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.

E	nabled	Signal Mode	Frequency Offset	Attenuation	Status	
		File: No file selected				>
		None				>
		None				>
		None				>
5		None				>
		None				>
		None				>
		None				>

5. Select the Mode dropdown and select Mutitone.

	Group 1: Signal Summary	> Signal 1: Setup
General Enable	Mode	Signal Attenuation
Multitone	Multitone 🗸 🗸 🗸	0 dB
Trigger	Frequency Offset	Power
	0 Hz	0 dB
	Sample Rate 60.000 000 000 kHz	
	Reset Phase Accumulator	

- 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.

= III 🖻]→ 🕞 💮 🏠 > Group 1: Signal Summary > S	Signal 1: Setup	
General	Tones		
Multitone	15		
Trigger	Tone Spacing		
	500.000 000 00 kHz		
	# of Points		
7. Select the General tab > Enable.

≡ ::: 4 ⊚ (Group 1: Signal Setup	
General Enable	Mode	Signal Attenuation
Multitone	Multitone ~	0 dB
Trigger	Frequency Offset	T
	0 Hz	
	Reset Phase Accumulator	

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.



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

SIGNall ON

RF1:OUTPut:STATe ON

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

RFAL1: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.

Group 1: Signals	
File None selected	

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.

=	III 🖻	× ⊜ ∋	Group	1: Signal Summary				RF Out (All)	Trager C	? - 100
	Enabled	Signal Mode			Frequency Offset	Attenuation	Status			
1		File: No file selected								>
		None								>
		None								>
		None								>
		None								>
		None								>
		None								>
		None								>
Fading	Enable						Remaining Sa	ample Rate:	3.000000	000000000 GHz

5. In the Vector Modulation Signal Setup:

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

	Θ	Group 1: Signal Summary	> Signal 1: Setup
General	Fnable	Mode	Signal Attenuation
Waveform File		Waveform File 🗸 🗸 🗸	0 dB
Trigger	Mute	Frequency Offset	Power
Markers		0 Hz	0 dB
		Sample Rate 3.000 000 000 000 000 GHz	
		Reset Phase Accumulator	

- **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.

General	Enable	Mode	Signal Attenuation
Waveform File		Waveform File 🗸 🗸 🗸 🗸 🗸	0 dB
Trigger	Mute	Frequency Offset	Power
Markers		0 Hz	0 dB
		Sample Rate 122.880 000 000 000 MHz	
		Reset Phase Accumulator	

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.

=	III 🖻	* © 🤅	۵,	Group 1: Signal Sun	nmary				RF Out (All)	Tragger G	?- 🖻	-
	Enabled	Signal Mode			Frequency Offs	et	Attenuation	Status				
1		File: No file selected									>	
		None									X	
		None									>	
		None									>	
		None									>	
		None									>	
		None									>	
		None									>	
Fading	Enable							R	emaining Sample Rate:	3.0000000	00000000	GHz

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

≡ ₩ ₽~	0	Group 1: Signal Summa	ry 📏 Signal 1: Setup	RF Out (All)	Trigger G	? ~ PRESET ~
General		Mode	Signal Attenuation			
Waveform File		Waveform File 🗸 🗸	0 dB			
Trigger	Mute	Frequency Offset	Power			
Markers		0 Hz	0 dB			
		Sample Rate 3.000 000 000 000 000 GHz				
		Reset Phase Accumulator				

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

General				
File	D:\Users\Instrument\Documents\Keysight\PathWave	\SignalGenerator\Examples\02_W-CDMA_TM1_1	DPCH.wfm	Select >
Waveform File Use in	stalled Signal Studio to create waveforms			Nonlinear Correction
Trigger Cust	om Modulation 2023	V Launch		Off Configure >
Markers Sampl	e Rate	RMS Power	Scale	Occupied Bandwidth
7.68	0 000 000 000 MHz	0.606 600	86.40 %	7.680 000 MHz

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

K Back Dunpur 2 Signal 7, Sei	ect Waveform File for PloyIsack		
Recent	👌 🛅 D. > Users > Instrument > Documents > Keysight > PathWave > S	SignalGenerator 🗦 Examples	
Waveforms	Name *	Date Modified	
This Computer	5G_100MHz_1CC_FR1.wfm	Aug 22, 2021, 7:43:56 AM	Delete
	5G_100MHz_BCC_FR2.wfm	Aug 22, 2021, 7:44;04 AM	C) Rename
	SGNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC Punctured.wfm	Aug 23, 2021, 3:19:46 AM	
	5GNR_1CC_FR2_120kHz_SCS_100MHz_2560AM_DC Punctured_28GHz.wfm	Aug 23, 2021, 3:19:46 AM	
	5GNR_BCC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_28GHz.wfm	Aug 23, 2021, 3:19:46 AM	
	5GNR_UXR_Recording_28_GHz.csv	Aug 23, 2021, 3:19:52 AM	
	GSM_1C_BURST_SECUREWAVE.wfm	Aug 23, 2021, 3:19:52 AM	
	UserCorr-2022-01-14_001.csv	Jan 14, 2022, 7:51:43 AM	
	WCDMA_TM1_64DPCH_4C.wfm	Aug 23, 2021, 3:19,52 AM	
Clear Arb Memory	File Properties Name: WCDMA_TM1_640PCH_4C.wfm Sample Rate: 95930000.0 Hz Scale: 99,900002 Signal Attemution: 0.952698 dB Occupied Bandwidth: N/A Required License(s):		
	Show files of type All Supported Formats (* wfm, * wig, *.bin, *.csv, *.bxt, *.seg, *.mat, *.hr	df, *.h5, *.inc) ∨ Select	Cancel

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"

SIGNall ON

RF1:OUTPut:STATe ON

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

RFAL1: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"

SIGNall ON

RF1:OUTPut:STATe ON

On the X-Series Signal Analyzer:

ACPower: BANDwidth 620 Hz

FREQuency:SPAN 30MHZ

2 Corrections

- "Corrections/De-embedding Using PathWave N7653APPC Software" on page 52
 - "Using a Spectrum Analyzer to Make the Corrections Measurement" on page 58
 - "Using a Power Meter to Make the Corrections Measurement" on page 65
 - "Adding Fixture Blocks using s2p Files" on page 52
- "Instrument Nonlinear Correction" on page 71
 - "Setting Up an INC 1CC 4 GHz, 10 dBm EVM Measurement" on page 71
 - "Setting Up an INC 8CC 28 GHz, 10 dBm EVM Measurement" on page 82



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

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.

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

TIP

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.

Corrections Corrections/De-embedding Using PathWave N7653APPC Software

E		• ©	<u>ن</u>	Group 1: Signal Sur	nmary			RF Out (All)		? - 🔤 -
	Enabled	Signal Mode			Frequency Offset	Attenuation	Status			
i.		File: No file selected								>
		None								>
		None								>
		Nane								>
		None								>
		None								>
		None								>
		Nane								>
Fading	Enable						Re	maining Sample Rate:	3.000000	000000000 GHz

6. Select the Mode dropdown and select Multitone.

	Group 1: Signal Setup	
General Enable	Mode	Signal Attenuation
Multitone	Multitone 🗸 🗸 🗸	0 dB
Trigger	Frequency Offset	
	0 Hz	
	Reset Phase Accumulator	

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

		> Group 1: Signal Summary > Signal 1: Setup	
General	Tones		
Multitone	21		
Trigger	Tone Spacing		
	100.000 000 000 00 MHz		

8. Select the General tab > Enable.

۵ 🏭 🖻	€ ⊝	Group 1:	Signal Setup		
General	Enable	Mode		Signal Attenuation	
Multitone		Multitone	~	0 dB	
Trigger		Frequency Offset 0 Hz			
		Reset Phase Accu	umulator		

- **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

Corrections Corrections/De-embedding Using PathWave N7653APPC Software

- 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.

Enabled	Signal Mode	Frequency Offset	Attenuation	Status	
t	File: No file selected				>
	None				>
	None				>
4 ()	None				>
	None				>
	None				>
7	None				>
	None				>

7. Select the Mode dropdown and select Multitone.

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.

≡ Ⅲ 凸~	© 0	G > Group	1: Signal Summary	> Signal 1: Setup
General	Tones			
Multitone	501			
Trigger	Tone Spacing	_	1	
	4.000 000 000 00 M	Hz		

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:

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

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.

KEYS	IGHT Coupling: DC Align: Off	Input Z: 50 Ω Corrections: Off Freq Ref: Ext (S) NFE: Adaptive	Atten: 10 dB Preamp: Off µW Path: Standard	Trig: Free Run Gate: Off #IF Gain: Low	Center Freq: 12 Avg Hold:>10/10 Radio Std: None	000000000 GHz 3 3
1 Graph	č (†					
Scale/D	iv 10.0 dB		Ref Value -30.00 dl	Bm		,
-40.0						
-50.0						1
-60.0						
-70.0						
-80.0						Lange and and a second
-100						
-110						
-120						
Center	12.000 GHz	Ň	/ideo BW 50.000 N	lHz*	Sweet	Span 3 GH
2 Metrics	5 V				Once	5.00 ma (1001 pta
	Occupied Bandwidth					
	1.97	00 GHz		Total Power		-17.3 dBm
	Transmit Freq Error	-213.66 kH	Iz	% of OBW Pov	wer	99.00 %
	x dB Bandwidth	2.010 GH	IZ	x dB		-26.00 dB

NOTE

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.

≡ ₩ △ ⊕ ਭ	Gran > Output 1: RF Output	RE Out (All) Trigger
General C	orrections On Absolute Power Corrections Only	Block A Properties Stable
Corrections/De-embedding Optimizations Add fro		Add from Measurement

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**.

Overview	Configure Sensor	Power Measurement De	e Spectrum Analyzer				
Configure Sensor		Spectrum Analyzer 🗸	Connection Type	Hostname o	r IP Addre	288	
	Start Frequency	Power					Test Connection
Measure Corrections	1.000 000 000 000 00	GHz -10.00 d	n	Protocol		Address	
	Stop Frequency	Number o	teps	HiSLIP	~	hislip0	
	2.000 000 000 000 00	GHz 10					

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.

	🕞 🕤 🖒 🔾 Output	1: RF Output 🗲 Measure	Corrections			RF Out (All)	Trigger G	? ~ PRESET ~
Overview	Configure Sensor	leasurement Device	Spectrum Analyzer					
Configure Sensor	Spectr	rum Analyzer 🗸	Connection Type	Hostname or IP	Address			
	Start Frequency	Power	🔘 LAN 🔵 USB				Test	t Connection
Measure Corrections	11.000 000 000 000 00 GHz	-10.00 dBm		Protocol	Add	iress		
	Stop Frequency	Number of Steps		Hislip	~ h	islip0		
	13.000 000 000 000 00 GHz	101						
								=
					Cancel	< Back	Next >	Finish

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

Overview Configure Sensor	Configure Sensor Power Measurement Device Spectrum Analyzer ~		Spectrum Analyzer Connection Type	Hostname or IP A	ddres	1 5		
	Start Frequency	Power O LAN USB		uxa-us90420008			Test Co	onnection
Measure Corrections	11.000 000 000 00 MHz	-10.00 dBm		Protocol		Address		
	Stop Frequency Number of Steps	Number of Steps		HISLIP	~	пізіро		

- **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.

$\equiv \Box \circ \Theta$	G > Output 1: RF Output > Corrections Setup > Measure Corrections	RE Duit (All) Trisser ? - 📼 -
Overview	Correction File Name: JgnelGenerationExamples\UserCorr-2021-08-17.001.csv Change >	
Configure Sensor	Measure Correction Data	
Measure Corrections		
	Correction measurement in progress	
	Abort	

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.

Factory Cal Add lack A Model & Common and	1 000 000 000 GHz 0.00 Fixt connections, likeds can be accord into the fourne analysis, network analyses) series f My Fishers Charged 2 52 th	dom 2 2 UTC possed has comuted (stips, case with the finance) to get started.	icoo coo coo chiz	5.00 dBm	r ©v ?v mo ? ♥ Corrections Co
Recently in User	ion	cture Block	k		
L HEF HAT COLD April 9, 201	6 21135PM	Second Street Second	and the second		Ģ

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.

≡ Ⅲ △ ⊚ ⑧	🛱 > Output 1: RF Output	RF Out (All) Trigger ? ~ Mean ~
General Correct	tions On Absolute Power Corrections Only	🚯 Block A Properties 💽 Enable
Freq and Amp Adjustment		File
Optimizations	A or Embed	Add from Measurement
Add from File	e <= Alove Left - Hove Toght } - Delete Blocs	

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

≡ Ⅲ ↔	C Output 1: RF Output > Measure Corrections	RF Out (All)	Trigger	? ~ meat ~
Overview	Overview This wizard will guide you through the simple process of measuring an external network of cables, connectors and other connected between this source and the device under test.	passive components		
Configure Sensor Measure Corrections	SOURCE Cables/Connectors/Fixtures to be characterized Cables/Connectors/Fixtures to be characterized Power meter or spectrum analyzer			
	Connect the equipment (power meter or spectrum analyzer) as shown in the diagram above. Once the desired topology h effects can be removed from the output signal, moving the effective reference plane to the point at which the measuring Can	nas been characterize device was connecte cel Back	ed, its ed. Next	Finlah

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

Overview	Power Measurement Device Power Meter 🗠]		
Configure Sensor	Start Frequency	11.0000000000 GHz		Stop Frequency	30.0000000000 GHz
Measure Corrections	Number of Steps	20		Power	5.00 dBm

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

- **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.

$\equiv \Box \circ \odot$	Output 1: RF Output	Corrections Setup Measure Corrections		RE Dut (All)	тидон ? - нис -
Overview	Correction File Name:	enerator/Examples/UserCom-2021-08-17_001.csv	Change >		
Configure Sensor	Measure Correction Data				
Measure Corrections					
			_		
		Correction measurement in progress	1		
		Abort			

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.

E Constant	5 C 1 4	odo odo odo GHz chars, Blocks can be adde unalyzer, netwick adalyzer)	ixture	2 2	2 2003 SOID DOD GAHE	-5.00 dBm meet using one of (%-	° [™] ©~ ?* = ~ ? ♥ Correttion Dr
	A Control of the second	B My Fathers Charme	00 4 2 1	C in Abure Charonal 1 200	Delta		
Filebook B Per File My F Type: S2P Apply: Dev	User Correctio	0 our	Fixture	e Bloc	k		
L HERE	Ports	135 PM		Delete Block			Ģ

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

Corrections Corrections/De-embedding Using PathWave N7653APPC Software

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

SIGNall ON

RF1:OUTPut:STATe ON

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

RFAL1:OUTPut ON

On the X-Series Signal Analyzer:

SYSTem:PRESet FREQuency:CENTer 10GHZ FREQuency:SPAN 3GHZ

On the VXG:

Set the path to the s2p data as block 2 (you can use 1 through 4). CORRection:BLOCk2:FILE "FixtureChannel2" CORRection:BLOCk2 ON Add block C with the same file. CORRection:BLOCk3:FILE "FixtureChannel2" Change Block C to Embed. CORRection:BLOCk3:APPLy EMBedding CORRection:BLOCk3 ON

Instrument Nonlinear Correction

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

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



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

On the VXG:

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

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

4.000 000 000 000 0	0 GHz
10.00 dBm	1
ALC ON	

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.

	Enabled	Signal Mode	Frequency Offset	Attenuation	Status	
1		File: No file selected				>
		None				>
		None				>
		None				>
		None				>
		None				>
		None				>
8		None				>
Fading	Enable				Remaining Sample Rate:	3.00000000000000 GHz

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.

	🕞 🏠 🕻 Group 1: Signal Summary	> Signal 1: Setup
General	Mode	Signal Attenuation
Waveform File	Waveform File ~	0 dB
Trigger Mute	Frequency Offset	Power
Markers	0 Hz	0 dB
	Sample Rate 122.880 000 000 000 MHz	
	Reset Phase Accumulator	

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.
- 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

Recall	C Demod In	fo	Recall from File			うで	? ×
State	Con	nputer 〉D: 〉Users 〉Instrument 〉Documents 〉NR5G 〉data 〉NR5GEvm 〉Cam	ierSetup			Mode 5G NR	
Screen Config + State	Name			🛆 Date	Size Content		
Correction	5G_10	0MHz_8CC_FR2.scp		3/3/2021 10.51 PM	431 KB Scp file		
Complex Correction	Signal	_Studio_5G_100MHz_1CC_FR1.scp		2/12/2021 1:46 PM	67 KB Scp file		
Recording							
Recording + State							
Demoid Info							
	File name:	Signal_Studio_56_100MHz_1CC_FR1.scp			File type	All Files (* *)	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.

Advanced				General		う C ? Close
General	-					
EVM	Component Carrier	CC0				
UL Flatness & IBE	Sync Mode	CP Auto Correlation		Calculation	-	
Cross Carrier			1	Magnitude & Phase Error	Off	
	Extended Frequency	On	4413	IQ Imbalance	On Off	
	DC Punctured	On On			Commer	
	DC Offset from CC Center	0 Hz		Compensation Symbol Clock Error	On	
	RF for Phase Compensation			Compensation	Off	
	Channel Power Threshold	-30.00 dB				
	Report EVM in DB	On Off				

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]						
L Coupling L AlignOff	oc	Input Z50 Ω Corr CCorr RCal Freq RefExt (S)	Atten32 dB PreInt off, L μW PathBy #PNOBest	NA off pass Wide	TrigFree Run #IF Gain: -4 dB	Carrier Ref Freq4.00000000 CC InfoDL, 1 CC, SISO) GHz
1 CC0-BWP1				2 CC0-B	WP1		
IQ Meas Time				Detected	Allocations		
1.60 1.20 800 m 400 m -400 m -800 m -1.20 -1.60				2.95 k 2.62 k 2.29 k 1.97 k 1.64 k 1.31 k 983 655 328			
-5.948	µ = 1: 30 k	Hz	5.948	Start: 0.	00 symbols	Stop:	279.00 symbols
3 CC0 Spectrum Scale/Div 10.00 dB Re	ef Value 0.0	0 dBm		4 CC0 Raw Mai Scale/D	n Time ¥ iv 10.00 dB Re	f Value 10.00 dBm	
-20 0 -30 0 -50 0 -50 0 -70 0 -70 0 -90 0 -9	<mark>, and a factorial states and a state of a state</mark>	<mark>iji, kepterd tas electr, keita</mark> ya Wic	th: 110.6 MHz	-10.0 -20.0 -30.0 -40.0 -50.0 -60.0 -70.0 -70.0	and the second of the second	un la anticipation de la constituitan.	
Res BW: 100 Hz In	fo BW: 98.3	0 MHz		Start: 0.	00 ns		Stop: 22.00 ms
5 CC0 Frame Summary V				6 Error S	ummary 🔻		
P-SS (SS Block 1) S-SS (SS Block 1)	EVM 0.23 % 0.24 %	Power per RE -26.49 dBm -26 49 dBm	Num.RB 22 22	Channe EVM (F	el Power (Active / Tota RMS / Peak)	CC0 8 69 dBm / 8 69 dBm 0 32 % / 1 79 %	
PBCH (SS Block 1)	0.37 %	-26.49 dBm	42	Freque	ILLY ETTOL (KING / WOI:	st) -14.1 IIInz / 3/ V.V IIInz	
PBCH DMRS (SS Block 1)	0.27 %	-26.49 dBm	42	Symbol	Clock Error	0.000 ppm	
PDSCH (BWP1)	0.32 %	-26.45 dBm	5460	IQ Offs	et (SISO)	-84.81 dB	
PDSCH DMRS (BWP1)	0.32 %	-26.45 dBm	5439	Time O	ffset	3.314 ms	
Erea Error				Sync C	orrelation	99.6 %	
Cubframe 1 02.6 mLlz				Sync S	ource	SS Block	

To Measure ACP:

- a. Select Mode/Meas > 5GNR & V2X Mode > ACP > OK.
- **b.** Select Amplitude > Signal Path tab > and set μ W 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).

5G NR 1 ACP	+			-					0	Amplitude		器
	Input: RF Coupling: DC Align: Auto	Input Ζ: 50 Ω Corr CCorr RCal Freq Ref: Ext (S) NFE: Off	Atten: 8 dB Preamp: Off μW Path: LNP. On PNO: Best Wide	Trig: Free F Gate: Off IF Gain: Lo	lun W	Carrier Ref Fi Avg Hold >10 Noise Correct CC Info: DL, 1	eq: 4 00000000 /10 ion: Off I CC) GHz	Pres Presel A	sel Center djust	Y Sca	le
1 Graph		- Transiero							0 Hz		Atteni	uation
Scale/Div 10.0	dB		Ref Value 15.00 dt	Bm					Internal	Preamp	Signa	l Path
Log 5.00			7.0 dPm						Full Rar	ige i		
-5.00	-60.4 dBc	-51.0 dBc	r s dibiti		-51.0 (:Bc	-60	.6 dBc	On Off			
-15.0			i desta des propries de partes						uW Path	Control		
-35,0									LNP En	able		
-45.0									Aut			
-65.0									Mar	1		
-75.0	معيدة والعار وسوروا الجار ومادوه فالمحافظ المعري المعج	Name of Contract o				and the second se	-					
Center 4.0000 (#Res BW 100 k	GHz kHz		Video BW 1.0000 M	Hz^			Sweep 17.	Span 500 MHz ms (5001 pts)				
2 Metrics												
Total Car Pwr	7.925 dBm/9	8.280 MHz			Measure	Trace		Trace 1				
Total PSD					Trace Ty	pe	Trace Av	verage (Active)				
	Offe Erea	AC	Lower P Reference dPm dPm C	ce Sart dBe	Upp ACP	er Referer	nce Cartt Filter					
	A 100.000 MHz	98.280 MHz -50.98	43.05 7.925	1 -50.99	-43.06	7.925	1 -3 dB					
	B 200.000 MHz	98.280 MHz -60.40	-52.48 7.925	1 -60.58	-52.65	7.925	1 -3 dB					
											Proto	de/TDIE litteni
10	۲ 🚺 ? ای	in 30, 2021									Aller	na weg

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.

C:\Users\folipske.KEYSIGHT\Docum	ents\Keysight\PathWave\SignalGenerator\Examples\5G_10	0MHz_1CC_FR1.wfm
	Instrument Nonlinear Correction	
	To enable. Selected Waveform must be inc file. To generate inc file, measure or load correction.	
	Measure Correction Load Correction	
	DUT Nonlinear Correction	
	Mode: Lookup Table	

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.

		🕞 📏 Signal 1: Signal Setup	> Nonlinear Correction	> Instrument	Nonlinear Calibration	RF Out (All)	тория ? - 📼	
Receiver		Calibrations		Advanced		M93848	Receiver	
Connection Type	B.	Hostname or IP Address 141.121.149.32			Test Connection	RF Out	RF In 10MHz Ref In	
		Protocol Type Address HISLIP V hislip0				Calibration will	It ium on output power.	
						Start C	calibration	
A REF	INT Locked	Aug 17, 2021, 2:24:44 PM	Connection Test	to Remote Instrur	nent TCPIP:141.121.149.32;hi	slip0cINSTR Successful.	C.	

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

Receiver		Calibrations	Advanced	Advanced		
alibrations	Span	Offset	Max Iterations	Tolerance	RF Out	
Power	98.280 000 MHz		3	0.10 dB		
EVM	98.280 000 MHz		3	-50.00 dB	Calibration will turn on output	
ACP	98.280 000 MHz	98.280 000 MHz	3	-50.00 dB	power.	
Equalization	98.280 000 MHz				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.



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.

	Enabled	Signal Mode	Frequency Offset	Attenuation	Status	
		File: No file selected				>
		None				>
		None				>
		Nane				>
		None				>
		None				>
		None				>
		None				>
Fading					Remaining Sample Rate	3 00000000000000 GHz

- 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.

K Back Output 1: Signal 1:	Select Waveform File for Playback						
Recent		A D: > Users > Instrument > Documents > Keysight > PathWave > SignalGenerator > Examples					
Waveforms	Name A	Date Modified					
This Computer	4000_SampletQPulseOnOff_50%_wfm.csv	Aug 23, 2021, 3:19:46 AM	Delete				
	5G_100MHz_1CC_FR1.wfm	Aug 22, 2021, 7:43:56 AM					
	5G_100MHz_8CG_FR2.wfm	Aug 22, 2021, 7:44:04 AM	📋 Rename				
	strategies and the second dependence of a	i di marana ana					

7. Select the General tab > Enable.

≡ ₩ ₽~	⊕ ⊝	Group 1: Signal Summa	ry 📏 Signal 1: Setup
General	Enable	Mode	Signal Attenuation
Analog Modulation		Analog Modulation 🛛 🗸 🗸	0 dB
Trigger	Mute	Frequency Offset	Power
		0 Hz	0 dB
		Sample Rate 1.280 000 000 000 MHz	
		Reset Phase Accumulator	

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.

 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.

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

NOTE



- 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 μ W 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.

	× ⊖ ⊖ ∩ > Group 1: Signa	I Summary 📏 Signal 1: Setu	i.		RF Out (Ali)	Those ?~	-
General	File C:\Users\jacquipa\Documents\Keysight\	\PathWave\SignalGenerator\E	xamples\5G_100MHz_	8CC_FR2.wfm		Select	>
Waveform File	Use installed Signal Studio to create waveforms				Nonlinear Correction	000	-
Trigger	Digital Video 2020 Update 1.0		Launch		Off	Configure	>
Markers	Sample Rate	RMS Power	RMS Power		Occupied Bandwidth		
	983.040 000 000 000 MHz	0.102 340		85.00 %	983.040 000 MHz		

- 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.

	🖳 📏 Signal 1: Signal Setup	> Nonlinear Correction	> Instrument N	Ionlinear Calibration	RE Out (All)	
Receiver	Calibrations		Advanced		M93848	Receiver
Connection Type	Hostname or IP Address 141.121.149.32	Hostname or IIP Address 141.121.149.32			RF Out	RF In 10MHz Ref In LAN
	Protocol Type HiSLIP	Address histip0			Calibration will i	lum on output power.
	cked Aug 17, 2021, 2:24:44 PM	 Connection Test to 	Remote Instrum	nent TCPIP:141.121.149.32:his	lip0cINSTR Successful.	, e

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

= ## B	∃• ⊕ ⊙	Group 1: Signal Summ	ary 🗦 Signal 1: Setup 🍃 Nonlin	ear Correction 🗲 Instrument Calibra	lion RF Out (All) Trigger ? ~ PEET ~
Receiver		Calibrations	Advanced		M9484C Receiver
Calibrations	Span	Offset	Max Iterations	Tolerance	RF Out RF In
Power	983.040 000 MHz		3	0.10 dB	LAN 🗲 🕨 LAN
M EVM	983.040 000 MHz		3	-50.00 dB	Calibration will turn on output
ACP	758.480 000 MHz	870.760 000 MHz	3	-50.00 dB	power.
	983.040 000 MHz				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 μ W 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).



3 Advanced Measurements

- "Channel Bonding" on page 92
 - "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
- "Setting Up 8 Virtual Signal Generators" on page 126
- "Using the VSA Flex Frame to Create a DVB-S2X Signal" on page 136
- "Creating & Analyzing a 5G NR DL 2x2 MIMO Measurement Using Two UXAs" on page 174
- "Creating and Analyzing a 4x4 MIMO using a UXR Running VSA Software" on page 196



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



 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.

≡ ₩ 8~	⊕ ⊕	> Configure Channels			RF Out (All)	Trigger ? ~ most ~
Use the dropdown to co Group Configuration	nfigure the available RF Chann	els into Groups. Any remaining Channel Remaining RF Channels: 4	will be set to independent.			
1 CHANNEL	2 CHANNELS	4 CHANNELS				
Independent	2 Tx Coherent	4 Tx Coherent				
	2 Channel Bonded (Beta)	Nx4 MIMO (Beta)				
	Nx2 MIMO (Beta)					
				[Apply	Cancel

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.

≡ III	⊡~ €) Θ	Ω > ·	Apps :	Custom Mo	odulation (Beta)
🖒 Generate					Carrier	Waveform
Preset	🗍 Quick Setups	🕞 Expoi	rt 89600 VSA Set	up		
Custom IQ	DVB-S2		Туре			
Custom AS	DVB-S2X	>	BAPSK			
Filter	APC025		16APSK			
	TETRA		32APSK	3	4+12+	6APSK Normal 2/3
	NXDN		64APSK	×	4+12+	6APSK Short 2/3
	dPMR		128APSK		4+12+	6APSK Short 32/45
	DECT		256APSK		4+8+4	+16APSK 128/180
	DMR				4+8+4	+16APSK 132/180
+ Add Seg	ARIB	\$	± Move Up	*	4+8+4	+16APSK 140/180

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

+ Add Segment	— R	temove Segment	Move Lipi 🛓 Move Down						
Name	Туре	Number of Symbols	Payload	Constellation	Phase Rotation	Shift	Bits Per Symbol	Differential	Offset
PLHEADER	Data	90	180 bits binary data [0001]	QPSK	0				
DataSeg	Data	2000	PN15	DVB-S2X 4+8+4+16APSK 140/180	0		5		
PLHEAD	ER			DataSeg					
0	90							1090 Syr	m

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.

		S
卷 Apps 5G NR ×	Custom Modulation (Beta) $ imes$	
🖒 Generate	Carrier	Waveform
Basic	Custom Modulation	
Marker	User Defined Sample Rate	a
	The second second second second	

- 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.

+ Add	- Remove	×.c	lear	+ A	dd Rows
Carrier Index	Frequency C	Offset (MHz)	F	ower Offe	set (dB)
)	-1200		0		

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 \mathbf{OK} to close the Frequency Offsets dialog.

equency Off	sets	
$+ \mathrm{Add}$	— Remove 🗙 Clear	+ Add Rows
Carrier Index	Frequency Offset (MHz)	Power Offset (dB)
0	-1200	0
1	-600	0
2	0	0
3	600	0
4	1200	0

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

≡ ₩ ⊡ ∽ @	RF Out (All) Trigger ? ~ PRESET ~
10 Apps Custom Modulation (Beta) ×	
ල් Generate Carrier Waveform	[← Import Signal Setup [+ Export Signal Setup
Basic Multicarrier Enabled	
Marker Number of Carriers 5	
Crest Factor Reduction Carrier Phases Random V	
Payload Data Offset 0	
Frequency Offsets -1.2GHz;600MHz; >	
Correction Power Offsets 0,0,0,0,0 >	
Routing	
IQ Spectrum CCDF	
0 of the section of the secti	
⁻²⁰ <mark>թեղ հայ խահարկել ու հեղի բանել է</mark> ութ հեղ եզեն որ երեն հղվելու հայ խահարկել հետով էրեն հեղի հետ հետ հետ հետ հետ	n the spectrum
-60	
-100 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
-120	3.50 GHz

- **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**.

Vaveform Playback Setup			Triggering & Markers	
Enable Fileator\Do	cuments\Keysight\PathWave\SignalGenerator\Wavefc	orms\CustomMod_G1S1.wfm Select >	Trigger	
Sample Rate	Scale		Mode Continuous Continuous Free Run	
3.500 000 000 000 GHz 70.00 %		Configure Channel Bonding	Source Immediate	
RMS Power	Occupied Bandwidth		Markers	
0.328 625 952	3.000 000 000 000 GHz	Recall Calibrated State	Sync Marker 1	
	Court: Stend			
	Type CustomMod_G1S1.wfm	25.000 000 000 00 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.

= # P]- ⊕	<u>م</u>	> Group 1: Signal Setup	> Chan	inel Bonding Setup		RF Out (All) Trigger ?	V PRESET V
Receiver		C	librations		Advanced		M9484C Re	ceiver
Connection Type	Hostna	ame or IP Addre	55				Combiner Out RF In	
🔘 LAN 🔿	USB uxa-	us90420008				Test Connection	10MHz Ref Out 10MHz	Ref In
	Protoc	ol		Address				
	HiSL	IP	~	hislip0			Calibration will turn on out power.	put
							Start Calibration	
			Group 1: Signal Type CustomMod_G Power 0.325.538.612	1S1.wfm	12.000 000 000 00 GHz	1		
			Status Disabled		0.00 dBm	2		
	EF INT Locked	SYNC	Oct 10, 2022, 12:25:11	РМ	Connection Test to Remote Instru	ment TCPIP::uxa-us904200	08::hislip0::INSTR Successful.	Ş

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.

Receiver		Calibrations	Advanced		M9484C Receiver
alibrations	Span	Offset	Max Iterations	Tolerance	Combiner Out RF In
Power	5.000 000 000 GHz		3	0.10 dB	LAN 🗲 🔶 LAN
Z EVM	5.000 000 000 GHz		3	-50.00 dB	Calibration will turn on output
ACP			3	-50.00 dB	power.
	5.000 000 000 GHz				Start 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.

≡ ₩ ₽- ©) 🕞 🎧 > Gro	up 1: Channel Bonding Signal S	etup 🗲 Channel Bondir	ng Setup	RF Out (All)	Trigger ? ~ 📼 ~
Receiver	Calibrations		Advanced		M9484C	Receiver
Receiver Receiver Optimization Attenuation 78	Source IQ DC Alignment Source Correction Failsafe Max Power No 20.00 dBm C IQ Headroom 80.00 %	minal Cable Gain 10 0.00 dB Equi	tion aging Start aging Max aging Max alization Aperture 0.0 %	Memory Model Nonlinear Order 5 Memory Order 1 Negative Order 1	RF1 & RF2 Out	RF In IOMH2 Ref In LAN urn on output power. alibration

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.

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

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.

Mode / Measurement / View Selector	Screen Name Spectrum A
CSequencer	Mode
Sequerong Do	Spectrum Analyzer
When Sequencing is On and there are multiple Screens, all Screens update in sequence. When Sequencing is Off, only the selected Screen updates.	IQ Analyzer (Basic) Vector Modulation Analyzer 5G NR
	Power Amplifier
	LTE FDD & NB/eMTC & V2X
	LTE TDD & LTE-A TDD
	Phase Noise
	W-CDMA with HSPA+
	Analog Demod
	Bluetooth
To launch 89600 VSA press the button below.	EMI Receiver
Launch VSA	Remote Language Compatibility
2022	SCPI Language Compatibility

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.

Bng 501 1872 mV					- Fot 1070			_
1.5	Constellati	on Ed	ditor					
	Name		DvbS2x 32APSk	(7/9				
	Symmetry		90 deg					
ΗQ	Magnitude RM	AS				Normalize	RMS	
· · · · · · · · · · · · · · · · · · ·	Sumbol Mann	ina	User-defined S	mhols				
300	Sin Concernation	mg	eser activication	,				
/div	Constellation	State	5		-			
	Add Inse	ert	DVB-S2 APS	к 🖡	Preset To Stan	dard Constellation		
-1.5	8APSK (2+4+2)		DVB S2X AP	SK ▶		Magnitude	Phase	Symbol
	16APSK (4+12)		Square QAN	•	8186397173626	0.22971334499037113	45.0	0000
-2.424657534	16APSK (4+12) Short		PSK		13186397173631	0.22971334499037113	-45.0	0002
	16APSK (8+8)	•	243186397173626	0.1624	13186397173628	0.22971334499037113	135.0	0004
: Ch1 Spectrum	32APSK (4+12+16rb)		243186397173631	-0.162	4318639717362	0.2297133449903711	-135.0	0006
Rng 4 dBm	32APSK (4+12+16rb) Short		9631624952115	1.2616	5770178809729	1.2863947319460782	78.8	0001
32APSK 32/45	32APSK (4+8+4+16)		9631624952115	-1.261	6770178809729	1.2863947319460782	-78.8	0003
32ADSK 11/15	54ADSK (16, 16, 16, 16)		0963162495211	1.2616	5770178809729	1.2863947319460782	101.3	0005
224000 7/0	CAAPSK (10+10+10+10)		096316249521189	-1.261	6770178809729	1.2863947319460785	-101.3	0007
SZAPSK 7/9	04APSK (8+10+20+20)		128094719445992	0.1664	7172807359853	0.643197365973039	15.0	0008
NAN MA	64APSK (4+12+20+28)	*	128094719445992	-0.168	47172807359847	0.643197365973039	-15.0	000A
	128APSK (16+16+16+32+40)		128094719446	0.1664	17172807359872	0.64319736597303911	165.0	000C
dB	256APSK (32 states/ring)		128094719446025	-0.166	47172807359792	0.64319736597303911	-165.0	000E
/div	12	1.26	16770178809729	0.2509	6316249521139	1.2863947319460782	11.3	0009
	13	1.26	16770178809726	-0.250	96316249521206	1.2863947319460782	-11.3	000B

c. Select \mathbf{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.

Format Fi	lter Advanced	
Save As Quick	Setup	Quick Setups
Constellation Symbol Rate Result Length	DVB-S2X 4+8+4+16APSK 1 500 MHz 2000 Symbols	40-180 Edit Recall
Search Length	5 ms h Enable	2500000 Symbols
Pattern Sea	rch Enable	
Offset 0	Symbols	

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**.

≡ ₩ 8	⊕ ⊕ G	> Configure Channels			RF Out (All)	Trigger G	?~ 📷~
Use the dropdown to co Group Configuration Independent	nfigure the available RF Chann Add	els into Groups. Any remaining i Remaining RF Channels: 4	Channels will be set to	Independent.			
1 CHANNEL	2 CHANNELS	4 CHANNELS					
Independent	2 Tx Coherent	4 Tx Coherent					
	2 Channel Bonded (Beta)	Nx4 MIMO (Beta)					
	Nx2 MIMO (Beta)						
					Apply	C	ancel

- 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.

= #	₽~ €	90	🞧 🕻 App	s
Apps	5G NR × Cu	istom Modula	tion (Beta) ×	
🖒 Generate			Carrier	Wave
n Preset	Quick Setups	[+ Export 8	9600 VSA Setup	
Custom IQ	DVB-S2	>	QPSK	
Custom AS	DVB-S2X	>	8PSK	
Filter	APC025		16APSK >	
	TETRA		32APSK >	
	NXDN			

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

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

9. Select Filter > Alpha to 0.2.

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

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

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

る Apps 5G NR ×	Custom Modulation (Beta) \times	
🖒 Generate	Carrier	Waveform
Basic	Custom Modulation	Custom IQ 😽
Marker	User Defined Sample Rate	
Crest Factor Reduction	Sample Rate	5.12 GSa/s

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

🐣 Generate	Carrier Waveform	[+ Import Signal Setup [+ Expo	rt Signal Setup
Basic Marker Crest Factor Reduction Multi Carrier Correction Routing	Custom Modulation User Defined Sample Rate Sample Rate Number of Frames Total Sample Points Waveform Length Mirror Spectrum	Castor 10 5.12 GSa/s 1 3413 007 ms	
IQ Spectrum -20 -40 -60 (math -80 -100 -120		bl, auge fell stage, an flight felder an flight an stage strategies in a stage strategies and best set and best 215 CH	spectrum

- **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:

Spectrum Analyzer Swept SA	1, +						Frequenc	y 🕇 💥
	Input: RF Inpu Coupling: DC Com Align: Off Free NFE	t Ζ: 50 Ω · CCorr RCal I Ref: Ext (S) :: Adaptive	Atten: 6 dB Prc: Int off, LNA off µW Path: Standard	PNO: Fast Gate: Off IF Gain: Low Sig Track: Off	Avg Type: Log-Power Trig: Free Run	1 2 3 4 5 6 W \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	Center Frequency 11.991328814 GHz	Scttings
1 Spectrum Scale/Div 10 dB	T		Ref Level -6.00 dB	m	Mkr1	11.991 GHz -24.42 dBm	Span 8.76656801 GHz Swept Span	
-16.0							Zero Span Full Span	
-26.0			1				Start Freq 7.608044811 GHz	
-36.0		- Juli Marki	AND AN IN				Stop Freq 16.374612817 GHz	
-46.0			de traker	and dear			AUTO TUNE CF Step	
-56.0							876.656801 MHz Auto Man	
-66.0	<mark>i prados do televista de dele</mark>	<mark>∦</mark> ┨┤┤╹┤	<u> </u>			the states and a state of the s	Freq Offset 0 Hz	
-86.0							X Axis Scale Log Lin	
					Arthology of the south of	an a	Signal Track (Span Zoom) On Off	
Center 11.991 GHz Res BW 3.0 MHz			Video BW 3.0 MH	-	Sweep ~1	Span 8.767 GHz 6.1 ms (1001 pts)		Limited

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

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



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.

Constell	lation Edi	itor					? X
Name	E	QPSK					Constellation Graph
Symmetry		90 deg					
Magnitude	RMS			Normalize RI	MS		0.8
Symbol Ma	pping	State Indexes +					0.6
Constellati	on States	5					0.4
Add	nsert [Delete Copy	Preset To Standard (Constellation			0.2
🖌 Index			Q	Magnitude	Phase	Symbol	0
0	1	The second first	0	1	0.0	0000	
1	6.123	0317691118863E-17	1	1	90.0	0001	-0.2
2			1.2246063538223773E-16	1	180.0	0002	-0.4
3	-1.83	69095307335659E-16		1	-90.0	0003	06
							-0.0
							-0.8
							-1
							-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

- d. Turn off Pulse Search Enable (checkbox cleared).
- e. Set the Symbol Rate to 3 GHz.

Save As Quick S	Setup	Quick Set	ups
Constellation	QPSK	Edit	Recall
Symbol Rate	3 GHz		
Result Length	200 Symbols		
Search Length	5 ms	15000000 5	
Pulse Search	h Enable		
Pattern Sea	rch Enable		
Pattern			
Different D.C.	Vershalls		

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.

Format Filter		Advanced			
Measurement Filt	er	Root Raised Cosine			
Reference Filter		Raised Cosine -			
Alpha/BT		0.2			
Equalizer					
Equalizer Type	М	inimize Error Vector 👘			
Filter Length	33				
Convergence	18	-06			
Convergence 1E-06 Adaptive Operations Equalizer Mode Run Hold					

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.



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 A SYNC AN 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.

Bandwidth	FR2 400MHz	Ý
Numerology	μ = 3: 120 kHz	Y
Duplex Type	FDD	
Duplex Type	FDD	Ŷ
Modulation	QPSK	~

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.

Bandwidth	FR2 400MHz	÷	Radiated transmit power
Numerology	µ = 3: 120 kHz	*	BS output power Transmit ON/OFF power TAE
Duplex Type	מטד		Unwanted emissions Occupied bandwidth ACLR Occupient bandwidth
Test Model	NR-FR2-TM1.1	~	 Operating band unwanted emissions Transmitter spurious
Number of Layers	1		Receiver spurious emissions
Phase Compensation	Off	~	
DCI/DLSCH Payload Data	PN23	*	

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.

			RF Out (All)	Trigger ? ~ Preset ~
Apps 5G NR	 Custom Modulation (Beta) 			
🖒 Generate	Carrier Wavefor	n		2 -
Export 89600 VSA Set	tup			
Basic	Total Number of Antennas			
Marker	Required License Version Date			
Crest Factor Reduction	Waveform Comment		801 100221-06) MSa/s 1000000000000000000000000000000000000	
AWGN	3GPP Version			
AWGN	User-Defined Sample Rate			
Routing	Sample Rate			
	Time Scale Factor	10		
	Number of Radio Frames	2		
	Subframe Offset	đ		
IQ Spectrum	CCDF			
0		and a state in our state and a state of the state of the	need to be a set of the	
-20				spectrum
-40	Na a sé sa ter din siti ran a tinna a tinn a siti na sa tinn a din sa ting ting ta ta ting ta sa ta sa ta ting	an ar ar an that the citizent is ministed an ar	NING THE STATE OF STATES	
-80	the still be as he the providence of	Il the second second free		
-100				
-120				491.52 MHz

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.

≡ Ⅲ 臼~				RF Out (All)	Tripper	?~ •••••
🖒 Generate		Carrier Waveform				₽~
+ Export 89600 VSA Setup						
Basic	Total Number of Antennas		1			

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 > 0K.
- 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.





In this example, the EVM is $\sim 2\%$

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.

Enabled	Signal Mode	Frequency Offset	Attenuation	Status	
	File: No file selected				>
	None				>
	None				>
	Nane				>
	None				>
	None				>
	None				>
	None				>

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	Group 1: Signal Summary	> Signal 1: Setup	RF Out (All)	Trigger	?~	PRESET
General		Mode	Signal Attenuation				
Waveform File		Waveform File 🗸 🗸 🗸	0 dB				
Trigger	Mute	Frequency Offset	Power				
Markers		0 Hz	0 dB				
		Sample Rate 3.000 000 000 000 000 GHz					
		Reset Phase Accumulator					

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

	Group 1: Signal Summary	 > Signal 1: Setup
General En	able Mode Analog Modulation ~	Signal Attenuation 0 dB
Trigger Mute	Frequency Offset 0 Hz	Power 0 dB
	Sample Rate 1.280 000 000 000 MHz	
	Reset Phase Accumulator	

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.

Enabled	Signal Mode	Frequency Offset	Attenuation	Status	
	File: 01_GSM_Framed_slots 1 3 5 off_EDGE Framed_slots	-1.2000000000000 GHz	0.00 dB	> Playing	• >
	None				>
	None				>
	None				>
	None				>
	None				>
	None				>
	None				>

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

Advanced Measurements Setting Up 8 Virtual Signal Generators

– 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

Advanced Measurements Setting Up 8 Virtual Signal Generators

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

≡ ₩ 8]•	G	> Apps			RF Out (All) Tr	iper ? ~ Peser ~
් Apps 5G	NR ×						
🖒 Generate			Carrier Wavefo	m.			۲ <u>.</u>
IIII Full-filled Confi	g 🁎 DL Test Model	DL FR	C Config 🔶 Auto Frequency Offsel	t [+ Export 89600 VSA Setu	ip		
+	General	Carrier Typ		Downlink 🗸			
Carrier 0 (DL)	Spectrum Control	Cell ID	Fullfilled Preset Config		X		
	Cell-Specific Power Definition Downlink	Bandwidth Numerolog Numerolog Max RB k0 Intra-Cell G	Bandwidth Numerology Y Duplex Type Duplex Type	FR1 100MHz µ = 1: 30 kHz FUD FDD	~		
Channel /	llocation Summar	Y	Modulation	64QAM	*	Fra	me0 ∽ µ=1 ♀
CR8 µ = 1 273 - 250 - 200 -							DL-SCH0
150-				ок	Cancel		
100-							
50 -							
0	2	4	6 8	10 12	14 16	18 2) Slot

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.

🖒 Generate		Carrier	Waveform	
[+ Export 89600 VSA Set	nb		a company	
Basic	Subframe Offset		0	
Marker	Number of Subframes		10	
Crest Factor Reduction	Slot Offset in Subframe		N/A	
AWGN	Number of Slots in Subframe		N/A	
Routing	Total Sample Points		1228800	
	Waveform Length		10 ms	
	Mirror Spectrum			
	Phase Compensation		Off 🗸	

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

猶 Apps 5G NR ×	¢		
🖒 Generate		Carrier Waveform	
[+ Export 89600 VSA Set	up		
Basic	Group		1
Marker	Signal		5
Crest Factor Reduction			
AWGN			
Routing			

- **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

Enabled	Signal Mode	Frequency Offset	Attenuation	Status		
	File: 01_GSM_Framed_slots 1 3 5 off_EDGE Framed_slots	-1.2000000000000 GHz	0.00 dB	Playing		>
	File: 02_W-CDMA_TM1_1 DPCH.wfm	-1.00000000000000 GHz	0.00 dB	Playing		>
	File: 03_LTE full filled_16QAM.wfm	-900.0000000000 MHz	0.00 dB	Playing		>
	File: 04_802.11ac_160 MHz0.wfm	1.00000000000000 GHz	0.00 dB	Playing		>
	File: NR5G_G1S5.wfm	-700.0000000000 MHz	0.00 dB	Playing		>
	File: NR5G_G1S6.wfm	-300.0000000000 MHz	0.00 dB	Playing		>
	File: NR5G_G1S7.wfm	300.0000000000 MHz	0.00 dB	Playing		>
	None					>

Advanced Measurements Setting Up 8 Virtual Signal Generators

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.

III 🗠 🛛	Θ Θ					
Group 1: Signals						
01_GSM_Framed_sl_	-1.2000 GHz 0.00 di		Adjustments	Output Mod On	RF Output On	
02_W-CDMA_TM1_1.	-1.0000 GHz 0.00 di		1/0 Off	1/0 00	Phase 0.000 den	2.000000000000 GHz
M 802 11ac 160 M	100000 GHz 0.00 di		AWGN Off	1/4. 011	Corr Off	
R5G G1S5 wfm	-700.00 MHz 0.00 d		Swap 1&Q Off		PwrLim Off	Transaction 1
R5G_G1S6.wfm	300.00. MHz 0.00 di		Delay 0.000 s			-5.00 dBm
R5G_G1S7.wfm	300.000 MHz 0.00 dl	3 🔊				ALC OFF
	-200.00 MHz 0.00 dl	1 💽 🗌				

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

- Keysight Signal Studio for Digital Video RF Output \times File Control System Tools Format Help 🗅 🚅 日 🔯 🧎 DVB-T/H Quick Setups DVB-T2 DVB-C, J.83 A/C Instrument B-Waveform Setup DVB-S Frequency Offset Power 52X 0.00 Hz 0.00 dB DVB-S2/S2X ISDB-T > ISDB-Tmm 🗌 Hint ATSC ٠ ATSC-M/H DTV J.83 B, DOCSIS DS 12514032 DOCSIS 3.1 Downstream Off DOCSIS 3.1 Upstream Off DTMB (CTTB) 2 СММВ Reference C Acquire Ref Gaussia --- dB - dB 1% 0.1% --- dB 0.01% --- dB 0.001% --- dB 0.00 dB 20.00 dB dB
- 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.

Keysight Signal Studio for	Digital Video - RF Output*	- 🗆	\times
File Control System Tools	Format Help		
D 🖻 🖬 👪 1			
Quick Setups	Generator		
Instrument	Update to Instru Update from In	nstru Local Prese DC Ca	Power Se
Carrier 0			Hint
Carriero	✓ 1. Configuration		
	Instrument Model Number	N5162/N5172/N5182 EXG/MXG	
	V 2 Resid		
	Frequency	4.500 000 000 000 GHz	
	Amplitude	-10.00 dBm	
	RF Output	On	
	* 3. I/Q	Off	
	LOffset	0.000 %	
	O Offset	0.000 %	
	I/Q Gain Balance	0.000 dB	
	Quadrature Angle Adjustment	0.00 deg	
	I/Q Timing Skew Path	RF	
	I/Q Correction Optimized Path	RF Output	
	I/Q Skew	0 ps	
	I/Q Delav	0 ps	
	Internal Channel Correction	Off	
	✓ 4. ALC	-	
	ALC	On	
	ALC Bandwidth	Auto	
	Power Search Reference	Fixed	
	RF Durina Power Search	Nomal	-

- **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.

Keysight Signal Studio for Digital Video - RF Output*								\times	
File Control System Tools	Format Help								
D 🖻 🖬 🔯 1									
Quick Setups	Carrier								
⊡…Hardware	+. X 🐚								
⊡ Waveform Setup	Carrier	State	Format		Frequency Offset	Power			
Carrier 0	Carrier 0	On	DVB-S2/S2X		0.00 Hz	0.00 dB			
	Carrier							Hint	
	✓ 1. Basic							A	
	State			On					
	Format			DVB-S2	/S2X				
	Frequency Offset	t		0.000000	Hz				
	Initial Phase			0.00 deg					
	Power			0.00 dB		_			
	2. DVB-S2/S2X	Settinas	3						
	Filter Type			Root Nyq	uist				
	Roll-off Factor			0.25					
	Svmbol Rate			20.0000	000 MHz				
	Support DVB-S22	X		True					
	VL-SNR Header			False					
	FEC Frame			Normal					
	Modulation Type			256 APS	SK				
	Code Rate			32/45					
	Insert Pilot			False					
	CRC-8 Encoder			True					
	Number of LDPC	Blocks		188					
	Multi-oath Channel OFF								

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.

🐖 Keysight Signal Studio	for Digital Video - RF	Output*		— 🗆	\times
File Control System To	ools Format Help				
D 🛩 🖬 👪 1					Harry
Quick Setups	Waveform Setur	p			
⊡Hardware Instrument	+. X 🐚				
	Camer	State	Format	Frequency Offset	Power
Carrier 0	Carrier 0	On	DVB-S2/S2X	0.00 Hz	0.00 dB
	<				>
	Waveform Setur	p			Hint
	Waveform L	enath	3147120		
	Fast Downlo	ad	UIT		
	Y 2. Spectrum	n Control			
	Mirror Spoot		Off		
	Oversamplin	ia Ratio	2		_
	3. Impairme	Apple Adjust	orm nont 0.000 deg		
	I/Q Gain Bal	Anule Autust	0.000 dB		-
	CCDF Waveform]			
	IN Gaussian IN	Reference 🏠	Acquire Ref		
		Neleience M	Acquire ner.		
	10%	dB 🔺	Gaussia	an	
	1%	dB	108%		
	0.1%	dB			اصعه
	0.001%	dB	o\$881%⊨		
	0.0001%	dB 👻	0.00 dE		20.00 dB

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

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

Autorange



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

Meas01 - Flex Frame Properties					?	×
Carrier Aggregation Frame Definit	ion Measurement	Control Time	Filter Custom N	Nodulation		
Preset Measurement Quick Se	tups 🕨 Save A	As Quick Setup				
Selected CC for Trace Display: CC0						
Component Carriers						
Reference Frequency: 0 Hz						
Enabled Name Absolute Center	Offset	Symbol Rate	Assigned Channels			
CC0 4.5 GHz	4.5 GHz	1 GHz	Ch1	Copy CC0 to 🕨 🛅 🗙		
+ Add CC						
				CC0		
195.3125 kHz					5.85	GHz
•				4.3 GHZ		
Acquisition Configuration						
Channel Status Frequency Center Fi	requency Span A	ssigned Carriers				
Ch1 👽 390.625 kHz	390.625 kHz None					
😵 Overall Status: Error: unassigned	component carriers: [(CC0]				
					Edit	

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**.

Carrier Aggregation	Frame Definition	n Measurement Co	ontrol Time	Filter	Custom Mo	dulation		
Preset Measurement	Quick Set	ps 🕨 Save As	Quick Setup					
Selected CC for Trace D	isplay: CC0	•						
Component Carriers								
Reference Frequency	20 GHz							
Enabled Name At	osolute Center	Offset	Symbol Rate	Assigned	t Channels		1	
✓ cc0 4	.5 GHz	-15.5 GHz	20 MHz	Gh1		Copy CC0 to	· DX	
	Acq	uisition Configuration				? ×		
+ Add CC	Frequ	ency Span: 40 MHz el Status Frequency	Center Freque	ency Span	Assigned	Carriers		
4.475 GHz	Ch1	4.5 GHz erall Status: No Error	40 M	Hz CCO	ссо к	Cancel		4 525 GHz
Cross-Correlated EVN Enabled	1 Configure							
Acquisition Configura Channel Status Free Ch1 & 4.5	ution quency Center Fre 6 GHz 4(quency Span Ass) MHz CCO	igned Carriers					
🥑 Overall Status: 🔥	No Error							Edit

- 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.

Carrier Aggregation	Frame Definition	Measurement Control	Time	Filter Custon	n Modulation
Component Carrier:	ссо –				
All					20
195.3125 kHz					4.527 GHz
					7.3 C
CC0			Allo	:0	
Component Carrier C	Configuration	Allo	ation Sumn	nary	
Frame Configuration	on Modulation	Inde	ex Enabled	Frame Pa	rt Allocati
Frame Type: Per	riodic 🔹 💽	0	•	FramePart0	Alloc0
Symbol Rate: 20	MHz				
Length: 307	79440 Symbols				
Frame Parts					
 FramePart0 					
Alloc0					

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.

Component Carrier Configuration	
Frame Configuration Modulation	
Preferred Bit To Symbol Mapping: Default	
Scrambler: 0 + X	
Scrambler Configuration	
Sequence Type: DVB-S2/S2X PLFRAME -	
Sequence Index: 0	
Reset Symbol Index: 0	

Configure the Preamble (PLHEADER)

Modulation: 2/PI BPSK	Modulation (Q	Modulation (QPSK to APSK)			Unmodulated		
PLHEADER	Payload: Slot #1		Payload: Slot #16	Pilot block	Payload: Slot #S	PLHEADER	
			For modes requiring pilots				
E PLSCODE	E						

- SOF (Start of Frame): 26 symbols (y1y2...y26): 01 1000 1101 0010 1110 1000 0010
 - **9.** Select the **Frame Configuration** tab and configure the Start of Frame Index (SOF), 26 symbols long:
 - In the Frame Parts area, select Alloc0.
 - In the Configuration area, set
 - Name to SOF
 - Type to Preamble
 - Sequence to Custom
 - Modulation to **DVB-S2/S2X 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

PLHEADER (90 symbols) includes:
Advanced Measurements Using the VSA Flex Frame to Create a DVB-S2X Signal

- Start Symbol to 0
- Total Length to 26

Note that Scrambling is not applied to Preamble.

Frame Parts		
▲ FramePart0	Configuration	Location
Alloc0	Enabled: 🗸	Start Symbol: 0
	Name: Alloc0	Last Symbol
	Type: Preamble -	Symbol Index: 25
	Power Poost: 0 dp	- or -
	Payload	Total Length: 26 Symbols
	Sequence:	End of Frame
	Custom	Repeat Pattern
	Custom Sequence Type: Bit Sequence 👻	Repetition Parameters
	Modulation: DVB-S2/S2X π/2 BPSK -	Active Symbols: 0
	Include in BER Calculations	Repeat every 1 Symbols
	Autodetect Bit Sequence Offset	
	01100011010010111010000010	
	Scrambling	
Add Frame Part Remove Frame Part		
Add Allocation Remove Allocation	Scrambler ID: 0	

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

✓ FramePart0	Configuration	Location
SOF	Enabled:	Start Symbol: 26
PLSCODE	Name: PLSCODE	Last Symbol
	Type: Preamble -	Symbol Index: 89 - or -
	Power Boost: 0 dB	Total Length: 64 Symbols
	Payload Sequence: Hataasur	End of Frame
	Modulation: DVR.52/52V - /2 PDSK	Repeat Pattern
	DVB-32/32A II/2 DP3K	Repetition Parameters
	Scrambling	Active Symbols: 0
	Scrambler ID: 0	Repeat every 1 Symbols
Add Frame Part Remove Fran		
Add Allocation Remove Allo	cation	

Configure the Payload

Modulation: 2/PI BPSK	Modulation (QF	SK to	APSK)	Unmodulated	015	
PLHEADER	Payload: Slot #1		Payload: Slot #16	Pilot block	Payload: Slot #S	PLHEADER
				For modes requiring pilots		

 Pilots are grouped in blocks of 36 symbols and inserted every 16 payload slots

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

14. In the Configuration area:

- Name to Data
- Type to Data
- Sequence to Unknown
- Modulation to DVB-S2/S2X APSK

Notice that Scrambling is not applied to Preamble.

- MODCOD to 256APSK Normal 128/180
- Scrambling to Enabled

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

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.

Frame Parts		
▲ FramePart0	Configuration	Location
Alloc0	Enabled: 🗸	Start Symbol: 90
PLSCODE	Name: Data	Last Symbol
Alloc2	Type: Data v	
FramePart1		
Data	Power Boost: 0 dB	
	- Payload	✓ End of Frame
	Sequence: Unknown 👻	Reneat Pattern
	Modulation: DVB-S2/S2X APSK -	- Depetition Decomptors
	MODCOD: 256ABSK Normal 128/180	Active Surphala of too
		Active Symbols: 0:1439
	Scrambling	Repeat every 1476 Symbols
	✓ Enabled	
Add Frame Part Remove Frame Part	Scrambler ID: 0 -	
Add Allocation Remove Allocation		

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

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

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.

Frame Parts		
 FramePart0 	Configuration	Location
Alloc0	Enabled: 🗸	Start Symbol: 90
PLSCODE	Name: Pilot	Last Symbol
Pilot	Type: Dilot -	
FramePart1	Phot -	
Data	Power Boost: 0 dB	
	Payload	✓ End of Frame
	Sequence: Unknown 🗸	
	Modulation: QPSK -	
		Repetition Parameters
	Scrambling	Active Symbols: 1440:1475
	Enabled	Repeat every 1476 Symbols
	Scrambler ID: 0 -	
Add Frame Part Remove Frame Part		
Add Allocation Remove Allocation		

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.

Carrier Aggregation Frame Defin	ition Measurement Control	Time Filter	Custom Modulation
Component Carrier: CC0	•		
All			
195.3125 kHz			4.527 GHz 4.5 0
Overall Allocation Control			\odot
Frequency Estimation & Equ	ualization & Synchronizatio	on	
Synchronization Source:	Auto	• Þ	
Frequency Estimation Mode:	Normal	•	
Equalization Mode:	Zero-forcing	•	
Channel Estimation Source:	Preamble and Pilots	-	
Normalized Channel Delay Spread:	10 Symbols		
EQ Tracking:	Off - Reset		
Tracking Convergence:			

Configure the Analysis Region

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

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

Carrier Aggregation	Frame Definition	Measurement Control	Time	Filter	Custom Modulation
Component Carrier:	CC0 -				
All					
195.3125 kHz					4.527 GHz 4.5 C
Result Length: 8000 S	Symbols				

Configure the RRC filter

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

Carrier Aggregation	Frame Definition	Measureme	ent Control	Time	Filter	Custom Modulation	
Component Carrier:	cco –						
All							C
195.3125 kHz						4.525	GHz 4.5
Measurement Filter:	Root-raised Cosine	Length:	30 Symbol	s			
Reference Filter:	Raised Cosine	•					
Alpha/BT:	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.

Carrier Aggregation Frame Definition	n Measurement	Control Time	Filter	Custom Modulation			
Preset Measurement Quick Set	ıps ▶ Save A	As Quick Setup					
Selected CC for Trace Display: CC0			🌁 Save Q	Quick Setup ?	×		
Component Carriers			Name	DVB-S2X setup			
Reference Frequency: 0 Hz			🗌 Share v	with all users			
Enabled Name Absolute Center	Offset	Symbol Rate		ОК С	ancel		
CC0 4.5 GHz	4.5 GHz	20 MHz	Ch1	Сору СС	0 to 🕨	$\square \times$	

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.

F: (CCO) FlexFrame Su mary Num. of Symbols Moduleti Tolumn Visibilit × 7 52 09 10.99 8000 All Expand All 53 10 10.88 26 SO 64 11.03 Collapse All Label 10.99 V Metrics EQ FVM (dB) ✓ Power (dBm V Num, of Symbols Modulation Format Bit Errors J RED Bit Errors (bit) Bit Count (bit) Cancel

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.

C: (CC0) Flex	xFrame Syr	ns/Errs *								- ×			
EVM Mag Err Phose Err Freq Err System Cloc Channel Poy Active Chan Result Leng IO Offset IO Gran Imb	etion = k Error = wer = nel Power = th = elança =	-55.947 132.57 107.98 942.74 0.99996 212.74 -14.992 -10.995 8 -10.995 8 -59.135 0.002	dB m%cms mdeg uHz usec mppn dBr dBr ksym dB dBr ksym	-24,766 s 608,37 738,58	dB pk m% pk mdeg pk	al sym 731 at sym 731 at sym 496	व न 16	Marti Perlena Gener Aggregate Ad75 Gbiz Component Came Overal Alacate Frame Perl A Tramehento	re COB a COB a COB a Contral incator Tr 201 Pres	elinture Messoor pe press	Control Tim	n Film Synchrotezation J	1 X 433 Gir Dun familiae
BER Bit Errors Bit Count	Frame Sum		maeg					FrankPart0 (FrankPart0) FrankPart0 (Equalization & Sy Synchronization	t.SCOOF Pres Nata Dist Nat Pilo natironization Source	ontole of a second seco			*
FramePart FramePart	Hame Sum SOF PLSCODE Data Pilot	mary EVM (dB) -54.86 -55.55 -56.12 -54.84 -55.57	Power (dBm) -10.99 -10.88 -11.03 -10.99 -11.05	Num. of Symbo 800 2 6 773 18	NS Modulat 10 16 16 16 10	ion Format B Mixed n/2 BPSK n/2 BPSK APSK APSK QPSK	ER 	Equilization Ma Charmel Estenan Narmalismed Cha Dophay If Show SVM i Pointes per Synd Compensation Compensation Compensation Compensation Compensation	de: need Delay Spee need Delay Spee net yendaal Cloud: In Q Other Q Other Q Gen brobalan iar Filter	Zerei foncarg Prosentalité and P ante 10 Synebols 2 2 0 0 0 0 0			
													65

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.

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.



NOTE

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.

= #	èr ⊛		<u>م</u> >	Apps							Frigger ? ~	PRESET
Apps (Custom Modulation											
🐣 Generate			Carrie	er	Waveform				[+ In	nport Signal Setup	[+ Export Signa	al Setup
n Preset	Quick Setups [+ E	xport 896	00 VSA Set	tup								
Custom IQ	DVB-S2	> ustom	1Q Type				ASK & PSK & C	am ~				
Custom AS	DVB-S2X	>	8APSK									
Filter	APCO25		16APSK									
	TETRA		32APSK									
	NXDN		64APSK									
	dPMR		128APSK									
	DECT		256APSK	>	256APSK 116/180							
1.000	DMR	-			256APSK 124/180							
+ Add Seç	ARIB	>	Move u	-	256APSK 128/180		O		ak a	Pho Bar Barbal	Differential	all of
DataSec	ZigBee	> 1	mbols		256APSK 135/180	N9	16QAM	Phase Rotation	Shift	4	Differential	Unset
	Wi-SUN(802.15.4g)	>			256APSK 20/30							
	ITU-T G.9959	>			256APSK 22/30	DataSe	ag					
		-									1000 S	ym

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

🖒 Generate	Carrier	Waveform		
卷 Preset 🗍 Quick Setups [+ E	kport 89600 VSA Setup			
Custom IQ Selection	Symbol Rate		20 Msps	
Custom ASK & PSK & QAM Settings				
Filter				

7. Select Filter > Alpha to 0.25.

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

🖒 Generate	Carrier	Waveform
衟 Preset 🔲 Quick Setups [+ E	xport 89600 VSA Setup	
Custom IQ Selection	Filter	Root Nyquist 🗸
Custom ASK & PSK & QAM Settings	Alpha	0.25
Filter	Length(symbol)	32

Configure the PLHEADER (Preamble)

In Part 1, the PLHEADER using $\pi/2$ -BPSK modulation is split into two: SOF (Start of Frame) of 26 symbols and PLS (PHY Layer Signaling) of 64 symbols for a total of 90 symbols. The N7608C by default uses a single segment for PLHEADER with 90 symbols using QPSK modulation and provides a payload of 180 symbols. For the purpose of this example, we will merge the two. You can split the PLHEADER into two by adding a segment and provide a payload of 52 symbols for the SOF. Since N7608C doesn't support $\pi/2$ -BPSK modulation, it uses QPSK so it would require a payload of 52 symbols for the SOF, instead of the 26-symbols used in Part 1.

NOTE

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

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

📙 🛛 🛃 🗖 🚽 🛛 FlexFrame	2			>
File Home Share	View			\sim
← → · ↑ 🔒 « He	elp > Signals > FlexFrame	✓ 🖒 Search Flex	rame	عر
^	Name ^	Date modified	Туре	Size
📌 Quick access	DVB_RCS2_Reference_Waveform_ID2_f	10/15/2021 1:48 PM	SETX File	189 KB
📃 Desktop 🛛 🖈	Hw_generated_DVB_S2X_64_APSK_8_1	10/15/2021 1:48 PM	HTML Document	3 KB
🕹 Downloads 🖈	Hw_generated_DVB_S2X_64_APSK_8_1	12/8/2021 1:41 PM	SDF File	65,541 KB
🛱 Documents 🖈	Hw_generated_DVB_S2X_64_APSK_8_1	11/11/2021 12:35	SETX File	125 KB
Dictures 🖌	Ideal_DVB_S2X_16_APSK_4_12_rate_26	10/15/2021 1:48 PM	HTML Document	3 KB
	Ideal_DVB_S2X_16_APSK_4_12_rate_26	12/8/2021 1:41 PM	SDF File	36,869 KB
<u> </u>	Ideal_DVB_S2X_16_APSK_4_12_rate_26	10/15/2021 1:48 PM	SETX File	132 KB
<u> </u>	Ideal_DVB_S2X_32_APSK_4_12_16_rate	10/15/2021 1:48 PM	HTML Document	3 KB
M9484C Demo v	Ideal_DVB_S2X_32_APSK_4_12_16_rate	12/8/2021 1:41 PM	SDF File	10,006 KB
Users	Ideal_DVB_S2X_32_APSK_4_12_16_rate	11/11/2021 12:35	SETX File	112 KB
This DC	🞒 MixedModulation	10/15/2021 1:48 PM	HTML Document	3 KB
	MixedModulation.sdf	12/8/2021 1:41 PM	SDF File	5,002 KB
🔰 3D Objects	MixedModulation.setx	10/15/2021 1:48 PM	SETX File	108 KB
E Desktop	PSK8_DVBRCS2	10/15/2021 1:48 PM	Text Document	1 KB
Documents	PSK8_DVBS2	10/15/2021 1:48 PM	Text Document	1 KB
🕹 Downloads	PSK8_WLAN11ad	10/15/2021 1:48 PM	Text Document	1 KB
Music	QAM16_DVBRCS2	10/15/2021 1:48 PM	Text Document	1 KB
Dictures	QAM16_WLAN11ad	10/15/2021 1:48 PM	Text Document	1 KB
		10/15/2021 1:48 PM	Text Document	2 KB
VIGEOS	QPSK_Default	12/6/2021 1:44 PM	Text Document	1 KB
SystemDrive (C:)	UPSK_DVBRC52	10/15/2021 1:48 PM	Text Document	1 KB
🕳 UserData (D:) 🗸	QPSK_DVBS2	10/15/2021 1:48 PM	Text Document	1 KB

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.

Name	Туре	Number of Symbols	Ramp Samples	Payload	Constellation	Phase Rotation	Shift	Bits Per Symbol	Differential	Offset
LHEADER	Data	90		180 bits binary data [0001]	QPSK	0				
ataSeg	Data	2000	0	PN15	DVB-S2X 256APSK 128/180	0		8		

9. In the Constellation Edit dialog, select Recall.

Quick	Setups	Insert	Delete Rec	call Sav	e Normaliz	Nam	e QP	SK_Defaul	t 🗌	Show F	totation	Show S	Symbo
ndex		Q	Magnitude	Phase	Symbol	-	-	÷ - 1	-			1 -	-1
0	0.707	0.707	1	45	0000	0.8							
1	-0.707	0.707	1	135	0001	0.6						•	
:	0.707	-0.707	1	-45	0002	0.4							
3	-0.707	-0.707	1	-135	0003	0.2							
						-0.2 -0.4 -0.6							
						-0.8				********	*****		

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.

		R Load from File	I Save to File	Clear		
2001111000101101000	1001011101101111011	1000100010111000100	001111000101110100	101110001000100001111	0111011100	0
010010110100100010	1110111000100001111	0110100011101000100	10000100011101001	0		1
						\otimes
rent: 0 Total: 180(Max:	128K bits)					
rent: 0 Total: 180(Max:	128K bits)					
rrent: Q Total: 180(Max:	128K bits)					

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

Name	Type I	Number of Symbols	Ramp Samples	Payload	Constellation	Phase Rotation	Shift B	its Per Symbo	Differentia	al Offset
PLHEADER	Data	90	0	180 bits binary data [0001]	QPSK_Default_for FlexFrame Example	0				
DataSeg	Data	1440	0	PN15	DVB-S2X 256APSK 128/180	0	E			
PLHEA	DER				DataSeg					
0	90								1530 Syr	m

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).

 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.

Quick	Setups	Insert	Delete Rec	call Sav	e Normali	ze Na	ne DVB	S2X 256/		Show	Rotation	🗌 s	how Sym
Index	1	Q	Magnitude	Phase	Symbol		-		_				
0	0.284	0.028	0.285	5.625	0000	15							
1	0.284	-0.028	0.285	-5.625	0010	1.5					•		
2	-0.284	0.028	0.285	174.37	8000	1.0							
3	-0.284	-0.028	0.285	-174.3	0018	0.5							į
4	0.273	0.083	0.285	16.875	0001	0.0			11				
5	0.273	-0.083	0.285	-16.87	0011		•		1	1		111	
6	-0.273	0.083	0.285	163.12	0009	-0.5	•		(here ends	• •			
7	-0.273	-0.083	0.285	-163.1	0019	-1.0							
8	0.22	0.181	0.285	39.375	0002	-1.5				•			
9	0.22	-0.181	0.285	-39.37	0012								
10	0.00	0.101	0.005	140.00	0004		-1.5	-1.0	-0.5	0.0	0.5	1.0	1.5

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

	ⓒ (→) (→) Apps		Trigger ? ~ PRESET ~
Apps Custom M	odulation (Beta) ×		
🖑 Generate	Carrier Waveform		[← Import Signal Setup [+ Export Signal Setup
Basic	Custom Modulation		
Marker	User Defined Sample Rate		
Crest Factor Reduction	Oversampling Ratio	4	
Multi Carrier	Number of Frames	1	
Our start	Total Sample Points		
Correction	Waveform Length	104.5 us	
Routing	Mirror Spectrum		
IQ Spectrum	CCDF		
0		was control till monetar and a data data data	
-20		aller of the second	spectrum
-40		de to del no de la	
-60		WAAAAAAAA	Teaching the battle sector and excited as
-100			
-120	nonnainnan deirail deile	Theorem	B000 MHz

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.

File Edit	Control Source Input MeasSetu Frequency	7 Tra	ce Markers Window Util	ities Hel					?
A: (CC0) I	ResBW Time Average	ne Sy	rms/Errs D: (CC0) FlexFrame	Summary	E: (CC0) FlexFrame Err Vect Time	F: (CC0) FlexFrame Phase Err	G: (CC0) FlexFrame Mag Error	H: Ch1 CCDF	* ×
1.5 	Frequency vs. Time Time vs. Time New Measurement Duplicate Measurement Measurements							SYNC	NOT FOUND
m /div -1.5	Measurement Type: Flex Frame Flex Frame Properties Analog Demod		Vector Power Spectrum Analysis General Purpose: Flex Frame	L					
-8.2 B: Ch1 Specto	2397260: Custom IQ Custom OFDM rum Channel Quality		Wireless Connectivity Radar Analysis Other standard formats					8.	2397260274 + ×
30 dBm	Channel Sounding								

- 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

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





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

Carrier Aggregation Frame Definition N	easurement Control Time Filter Custom Modulation	
Preset Measurement Quick Setups	Save As Quick Setup	
Selected CC for Trace Display: CC0		
Component Carriers		
Reference Frequency: 20 GHz		
Enabled Name Absolute Center O	ffset Symbol Rate Assigned Channels	
✓ CC0 4.5 GHz -15.5	GHz 1 GHz Ch1 Copy CC0 to 🕨 🗋 🎽	
+ Add CC		
	000	
3.15 GHz	all a	5.85 GHz
	4.5 UTZ	
Cross-Correlated EVM		
Enabled Configure		
Acquisition Configuration		
Channel Status Frequency Center Frequency	Span Assigned Carriers	
Ch1 4.5 GHz 40 MHz	CCO	
Solution 2018 Status: Error: CC0 bandwidth (Syrr	bol Rate) not entirely captured within Ch1 bandwidth.	
		dit

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

Carrier Aggregation Fran	ne Definition Measurement Control Time Filter	Custom Modulation
Preset Measurement	Quick Setups 🕨 Save As Quick Setup	
Selected CC for Trace Display	- cco -	
Component Carriers		
Reference Frequency: 20	GHz	
Enabled Name Absolute	Center Offset Symbol Rate Assigned	Channels
CC0 4.5 GHz	-15.5 GHz 20 MHz Ch1	Copy CC0 to 🕨 🛅 📉
	Acquisition Configuration	? X
+ Add CC	Frequency Span: 40 MHz Channel Status Frequency Center Frequency Span	Assigned Carriers
4 475 GHz	Ch1 2 4.5 GHz 40 MHz Ch2 40 MHz CC0	CC0 4 525 GHz
Cross-Correlated EVM Enabled Co	nfigure	
Acquisition Configuration		
Channel Status Frequency	Center Frequency Span Assigned Carriers	
Ch1 🥩 4.5 GHz	40 MHz CC0	
🥏 Overall Status: No Erro	ar -	
		Edit

- 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.

Carrier Aggregation	Frame Definition	Measurement Control	Time	Filter Custom Mo	dulation			
Component Carrier:	cco -							
All		CC0						
4.475 GHz		4.5 GHz			4.525 GHz			
cco 199	_			Data				
							9 8	œ
Component Carrier C	onfiguration	Allo	cation Summ	ary				
Frame Configuration	Modulation	Ind	ex Enabled	Frame Part	Allocation	Allocated Symbol Indexes	Total	
and and the		0		FramePart0	PLHEADER	0:89	90	
Frame Type: Per	iodic 🔹 💌	1	J	FramePart0	Data	90:1529	1440	4
Symbol Rate: 20 I	MHz							
Length: 153	0 Symbols							

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

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

Frame Parts		
FramePart0	Configuration Fnabled: Name: PLHEADER Type: Preamble Power Boost: 0 dB Pavload	Location Start Symbol: 0 Last Symbol Symbol Index: 89 - or - Total Length: 90 Symbols
	Sequence: Custom - Custom Sequence Type: Bit Sequence - Modulation: QPSK - Include in BER Calculations Autoretect Bit Sequence Offset	End of Frame Repeat Pattern Repetition Parameters Active Symbols D Repaint-overv 1 Symbole
Add Frame Part	0001111000101101000100101110110111 1011100010001011100010000111100010 11010010	
Add Allocation Remove Allocation	Scrambler (D) 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

Frame Configuration Madulation Index Enabled Frame Part Allocation A	omponent Carrier Configuration	Alloca	ation Summary					
Frame Type: Periodic 0 FramePart0 PLHEADER 0.89 90 Symbol Rate: 20 MHz 1 FramePart0 Data 90:1529 1440 4 Length: 1530 Symbols 1 FramePart0 Data 90:1529 1440 4 rame Parts Configuration Enabled: 1 Image: Data Image: Data 10:0 Image: Data Symbol Start Symbol: Start Symbol: Start Symbol: Start Symbol: Symbol: Data 90:1 Image: Data Image: Data 10:0 Image: Data Symbol: Data 90:1 Image: Data Symbol: Data 90:1 Image: Data Symbol: Data Symbol: Data Symbol: Data 90:1 Image: Data Symbol: Data Symbo	Frame Configuration Modulation	Inde	Enabled Frame Part		Allocation	Allocated Symbol Indexes	Total	
Symbol Rate: 20 MHz Length: 1530 Symbols ame Parts FramePart0 PLHEADER Data Data Power Boost: 0 dB Payload Sequence: PN15 Modulation: DVB-52/S2X APSK MODCOD. 256APSK Normal 128/180 I Include in BER Calculations Autodetect Bit Sequence Offset Scrambling	Frame Type: Automatic	Q	✓ FramePart0	PL	HEADER	0:89	90	
Symbol Rate: 20 MHz Length: 1530 Symbols ame Parts FramePart0 PHEADER Data PHEADER Data Power Boost: 0 dB Payload Sequence: PM15 Modulation: DVB-52/52X APSK Modulation: DVB-52/52X APSK Modulation: DVB-52/52X APSK Modulation: VB-52/52X APSK Modulation: Sequence Offset Scrambling	Periodic		FramePart0	Da	ità	90:1529	1440	Ŷ
Length: 1530 Symbols ame Parts FramePart0 PHEADER Data Type: Data Type: Power Boost: 0 dB Payload Sequence: PN15 Modulation: DVB-S2/S2X APSK MODICOD: 2 b6APSK Normal 128/180 Autodetect Bit Sequence Offset Serambling	Symbol Rate: 20 MHz							Ą
name Parts FrameParts PLHEADER Data	Length: 1530 Symbols							
FramePart0 PLHEADER Data Name: Data Type: Data Type: Data Power Boost: 0 dB Payload Sequence: PN15 Modulation: DVB-S2/S2X APSK Papetition: Parametors Active Symbols: Include in BER Calculations Include to BER Calculations Include to BER Calculations Include to BER Calculations Carambling	ame Parts							
PLHEADER Data Name: Data Type: Data Type: Data Power Boost: 0 dB Payload Sequence: PN15 Modulation: DVB-S2/S2X APSK MODCOD: 256APSK Normal 128/180 Include in BER Calculations Include to BER Calculations	FramePart0	Configuration		_	Location			
Data Name: Type: Data Type: Power Boost: 0 dB Payload Sequence: PN15 Modulation: DVB-S2/S2X APSK Modulation: DVB-S2/S2X APSK Modulation: DVB-S2/S2X APSK Modulation: DVB-S2/S2X APSK Repeat Pattern Payload Include in BER Calculations Payload Properties Payload	PLHEADER	Enabled: 🗹			Start Symbol	90		
Type: Data Power Boost: 0 dB Payload Sequence: PN15 Modulation: DVB-S2/S2X APSK MoDCOD: 256APSK Normal 128/180 Include in BER Calculations Include to BER Calculations Scrambling	Data	Name: Data	i la		Last Symbo			
Power Boost: 0 dB Payload Sequence: PN15 Modulation: DVB-S2/S2X APSK MODCOD: 256APSK Normal 128/180 ✓ Include in BER Calculations ✓ Autodetect Bit Sequence Offset Scrambling		Type: Dat	-		Symbol In	dex: 90		
Power Boost: 0 dB Payload Sequence: PN15 Modulation: DVB-S2/S2X APSK MODCOD: 256APSK Normal 128/180 ✓ Include in BER Calculations ✓ Autodetect Bit Sequence Offset Scrambling		Burning and the second			=/AT =			
Payload Sequence: PN15 Modulation: DVB-S2/S2X APSK MODCOD: 256APSK Normal 128/180 Include in BER Calculations Active Symbols: Include the BER Calculations Represt every Scrambling Scrambling		Power Boost: 0 dE			Total Leng	lh i Symbols		
Sequence: PN15 * Modulation: DVB-S2/S2X APSK * MODCOD: 256APSK Normal 128/160 * Include in BER Calculations Active Symbols: 0 Include in BER Calculations Repeat every 1 Symbols Image: Autodetect Bit Sequence Offset Scrambling *		Payload			✓ End of F	rame		
Modulation: DVB-S2/S2X APSK + MODCOD: 256APSK Normal 128/180 * Active Symbols: ☑ Include in BER Calculations Repeat every 1 Symbols: ☑ Autodetect Bit Sequence Offset Scrambling		Sequence:	PN15		Repeat Pat	tern		
MODCOD: 256APSK Normal 128/180 * Active Symbols: Q Include in BER Calculations Regreat: every 1 Symbols I Autodetect Bit Sequence Offset Scrambling		Modulation:	DVB-S2/S2X APSK		Expansion			
✓ Include in BER Calculations Regreat every 1 Symbols ✓ Autodetect Bit Sequence Offset Scrambling		MODCOD:	256APSK Normal 128/	180		ibolic B		
Autodetect Bit Sequence Offset		✓ Include in BFR	Calculations					
Scrambling		Z Autodatect Bit	Conviorse Offerst			ay 1 Symbols		
Scrambling		Autodetect bit	sequence onser					
		Scrambling						

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.

Component Carrier: CC0				
All		CCI		
4,473 GHz	4	 1.5 GHz		4.527 GH
Overall Allocation Control				۲
Frame Part Allocation Type	Include in EVM	Calculate BER	Synchronization	Chan Estimation
FramePart0 PLHEADER Pream	ble 🔽			
FramePart0 Data Data				
Frequency Estimation & Eq	uplication & Sunch			-
	ualization & synci	ronization		۲
Synchronization Source:	Auto	ironization	•	۰
Synchronization Source: Frequency Estimation Mode:	Auto Normal	ironization	•	۲
Synchronization Source: Frequency Estimation Mode: Equalization Mode:	Auto Normal Zero-forcing	ironization	• •	
Synchronization Source: Frequency Estimation Mode: Equalization Mode: Channel Estimation Source:	Auto Normal Zero-forcing Preamble Only 7	TONIZATION	zation	0
Synchronization Source: Frequency Estimation Mode: Equalization Mode: Channel Estimation Source: Normalized Channel Delay Spread:	Auto Normal Zero-forcing Preamble Only 7	nonization	zation	0
Synchronization Source: Frequency Estimation Mode: Equalization Mode: Channel Estimation Source: Normalized Channel Delay Spread: EQ Tracking:	Auto Normal Zero-forcing Preamble Only 7 10 Symbols Off 7	I Initial Equali	zation	0

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.

	Frame Defini	ion Measurement Control	Time Filter	Custom Modulation
omponent Carrier:	cco			
All		CCD		
4.473 GHz		4.5 GHz		4.527 GHz

Configure the RRC filter

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

Carrier Aggregation	Frame Definition	Measurement Control	Time Filter	Custom Modulation
Component Carrier:	CC0 -			
All		CC0		
4.475 GHz		4.5 GHz		4.525 GHz
Measurement Filter:	Root-raised Cosine	ength: 32 Symbols		
Reference Filter:	Raised Cosine			
Alpha/BT:	0.25			

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.

Carrier Aggregation Frame Definit	tion Measurement	Control Time	Filter	Custom Modulation	ı	
Preset Measurement Quick Se	etups 🕨 🦳 Save A	s Quick Setup				
Selected CC for Trace Display: CC0			Save 🤇	Quick Setup ?	×	
Component Carriers			Name	DVB-S2X setup		
Reference Frequency: 0 Hz			🗌 Share	with all users		
Enabled Name Absolute Center	Offset	Symbol Rate		ОК С	ancel	
CC0 4.5 GHz	4.5 GHz	20 MHz	Ch1	Сору С	0 to 🕨	$\square \times$





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.

C: (CC0) FlexFrame Syms/	Errs				- ×		_
						Mapp01 - Files Frame Properties ?	×
EVM =	-49.361	dB	-39.752 dB	nk at sym 388		Carrier Aggregation Frame Definition Measurement Control Time Filter	
Mag Err =	233.33	m%rms	1.0242 %	pk at sym 388		ALL COD	
Phase Err =	233.80	mdeg	-1.3871 deg	pk at sym 169		1475 CU:	Chin
Freq Err =	-1.0487	Hz				4.473 GHz 4.323	anz
Sync Correlation =	0.99997						
Sustem Clock Error =	42 452	usec				Component Carrier: CC0 *	
Channel Power =	-11.112	dBm					
Active Channel Power =	-11.105	dBm				Overall Allocation Control	
Result Length =	1.53	ksym				Frame Part Allocation Type Include in EVM Calculate BER Synchronization Chan Estimatio	
IQ Offset =	-67.616	dB				FramePart0 PLHEADER Preamble	
IQ Gain Imbalance =	-0.007	dB				FramePart0 Data 🛛 🗹 🔽	
IQ QuadSkew =	-45.191	mdeg					
BER =	0.0000					and a second	
Bit Errors =	0.0000	bit				Equalization & Synchronization	
Bit Count =	11.520	kbit			EQ	Synchronization Source:	
D: (CC0) ElexFrame Summ	arv				- ×	Equalization Mode: Zero-forcing *	
er (eee) mean runne summ						Channel Estimation Source	
FramePart Allocation	EVM (dB)	Power N	lum, of Symbols Mo	dulation Format B	ER	Preamble Only =	
FramePart0	-49 74	-11 11	1530	Mixed	0	Normalized Channel Delay Spread: 10 Symbols	
PLHEADER	-49.81	-11.11	90	OPSK	***		
Data	-49.74	-11.11	1440	APSK	0	Display	
						Show EVM in dB	
						Reference and all	
						Points per symbol: 2	
						Compensation	
						Compensate Symbol Clock Frror	
						Comparente IO Officet	
						Compensate (0) Gain Imbalance	
					-	C Use Multi-carrier Filter	
					EQ		E

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.

C: (CC0) Fle:	xFrame Syn	ns/Errs •	1						+	×			
EVM Mag Err Phase Err Freq Err Sync Corres Time Offset System Olor Channel Po Active Char Result Leng	= = = = = = = = = = = = = = = = = = =	-55.947 132.57 107.98 942.74 0.99996 212.74 -14.992 -10.995 8	dB m%irm mdeg uHz usec mppn dBn dBn ksym	-24.766 8 608.37 738.58	dB pl m% pl mideg pl	(at sym 73). ∢at sym 731- ∢at sym 4964	e	Anne Appropriation	n Franse Definitu	ny Weattorese	et Conmol Tam CCO 45 CH2	e tite	-1 - X -1525 CHr
IQ Offset IO Glan Imb IO QuadSke BER Bit Errors Bit Count	elança = aw = =	-59 135 0 002 -11 108	dB dB mdeg					Create Advance Comp Frame Part Allocation FramePart0 SOT FramePart0 PLSC0 FramePart0 PlSc0 FramePart0 Plot	Data Piezontale Data Piezontale Data	Indude in DVM 3 - - - - - - - - - - - - -	Column III	fyrduntsirjen 2	Coan Estimation V V
D: (CC0) Flex	Frame Sum	mary						Equilibrium & Synchron Synchronization Source	=	Kan-			
FramePart FramePart0	Allocation SOF PLSCODE Data Pilot	EVM (dB) -54.86 -55.55 -56.12 -54.84 -55.57	Power (dBm) -10.99 -10.88 -11.03 -10.99 -11.05	Num. of Symbo 800 2 6 773 18	45 Module 16 16 14 10	tion Format Bi Mixed n/2 BPSK n/2 BPSK APSK QPSK	ER 	Equitation Mode Channel Editoriation Go Nairrealited Channel D Doplay 25 Stoie EVM in all Innits per Synthetic Compensation 2 Congensation 2 Congensation 2 Congensation 2 Congensation 42 Calif	uron Hay Speak I Clock Error H Hadalance	Zenes-Koncang Prosentalise and Polads 10 Symbolis 2			
													19.4

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	Required Options
RF bandwidth of 160 MHz or aboveTwo-channel configuration	 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	Recommended Software
 M9484C Firmware version A.11.01 or higher 7631APPC PathWave Signal Generation for 5G NR 	 N9042B UXA Firmware version 2023 (XA34) or higher
5	 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**.

Ξ:	: 0~	© 0 A	> Configure Channels				RF Out (All)	Trigger	?~ 📼
Use the di	ropdown to con	figure the available RF Chann	els into Groups. Any remaining	Channels will be set to	Independent.				
Group Cr Indepe	onfiguration	Add	Remaining RF Channels: 4						
1 Cł	HANNEL	2 CHANNELS	4 CHANNELS						
Ind	ependent	2 Tx Coherent	4 Tx Coherent						
		2 Channel Bonded (Beta)	Nx4 MIMO (Beta)						
	_	Nx2 MIMO (Beta)							
						-			
							Apply	(Cancel

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

	Adjustments	Output Mod On	RF Output Off	
Group 1: Signals	I/Q Off AWGN Off	I/Q Off Pulse Off	Phase 0 deg Corr Off	20.000 000 000 000 000 00 GHz
lo file selected	Swap I&Q Off Delay 0 s	AM Off	PwrLim Off	0 dBm
	 1/1/00	Dut		ALC ON
	Adjustments	Output Mod Dn	RF Output Off	
	I/Q Off AWGN Off	I/Q Off Pulse Off	Phase 0 deg Corr Off	20.000 000 000 000 00 00 GHZ
	Swap 1&O Off	AM Off	PwrLim Off	1.1.1.1

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

≡ 📰 🗗 🛛 🛛	Apps			RF Out (Ali)	Trigger	?~ 🚥~
Keysight PathWave Sig	gnal Generation					
5G NR	Custom Modulation (Beta)	NR-V2X	LTE FDD (Beta)		Beta)	

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

			RF Out (All) Trigger ? ~ 🛲 ~
🖒 Generate	Carrier Waveform		∆ ~
Export 89600 VSA Setu	ip.		
Basic	Total Number of Antennas	2	
Marker	Required License Version Date	2021.0801	
Crest Factor Reduction	Waveform Comment		
Colorest Colorest Colorest	3GPP Version	V17.4,0 (2022-12)	
AWGN	User-Defined Sample Rate		

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

沿 Apps 5G	NR × Custom Mod	ulation (Beta) ×			
🐣 Generate			Carrier	Waveform	
HIII-filled Confi	g 🏾 👎 DL Test Model	d the DL FRC Config	🐟 Auto Freque	ncy Offset	[+ Export 89600 VSA Setup
+ …	General	Carrier Type			Downlink 🗸
Carrier 0 (DL)	Spectrum Control	Cell ID			0
	Cell-Specific	Bandwidth		FR2 100MHz 🗸	
	Downlink	Numerology Mode		Single Numerology $ \sim $	
		Numerology		μ = 3: 120 kHz 🗸	
		Max RB		66	
		k0		0	
		Configured Bandwidth	0	95.04 MHz	

 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.

h Apps 5G	NR × Custom Ma	dulation (Beta) 🛛 🗙					
🖒 Generate			Carrier	Waveform			
HIII Full-filled Confi	g 🌱 DL Test Mode	I gt⁺ DL FRC Config	Auto Freque	ncy Offset	[-+ Export 89600 VSA Setup		
+	General	BWP		Shared Sp	ectrum Channel Access		
Carrier 0 (DL)	Spectrum Control Cell-Specific Downlink	SS/PBCH DCI DL-SCH CSI-RS LTE-Coexistence PRS	NR-PBCH Active Ind MIB Power Boo RB Offset kSSB by s	Active Indices Power Boosting of each SS Block RB Offset by 60 kHz SCS		0:3	
						0,	
						0	
				ubcarrierSpacingCommon	0		
				Delta Frequency to Carrier Center Half Frame Index		-33.12 MHz	
						0	
				PSS Power Boosting	r Boosting	0 dB	1

 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).

්ර් Apps 5G උ Generate	NR × Custom Mo	odulation (Beta) ×	Carri	er Waveform			
IIII Full-filled Conf	ig T+ DL Test Mode	l d ⁺ DL FRC Config	🔹 Auto Fr	equency Offset 🛛 🕞 Exp	ort 89600 VSA Setup		
	General	BWP		General Settings	Antenna Port(s) Generated	p0, p1	>
Carrier 0 (DL)	Spectrum Control	SS/PBCH		Transmission Settings	DMRS port(s)	0,1	
	Cell-Specific			Resource Allocation	Number of Layers		
					Number of Antenna ports		
	DOWNINK	ULSUN		modulation and county	Number of DMRS CDM groups without data	2	
		CSI-RS		DMRS Settings	Number of Codewords	1	
		LTE-Coexistence		PTRS Settings			
		PRS		HARQ Settings			

- 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).

🖒 Generate			Carrier	Waveform		[← Import Signal Setup
IIII Full-filled Co	nfig 👎 DL Test Mo	idel -o- Au	to Frequency C	iffset [+ Export 8960	0 VSA Setup	
+	General	BWP	+ •••		Enabled	
Carrier 0 (DL)	Spectrum Control	SS/PBCH	DL-SCH 0	Transmission Settings	Power Boosting	0.00 dB
	Cell-Specific	DCI		Resource Allocation	Scrambling	
		DL-SCH		Modulation and Coding	n_ID	Cell ID
		CSHRS		DMRS Settings	RNTI	
				PTRS Settings		

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.

ති Apps 5 ලී Generate	G NR × Custom Mo	odulation (Beta) ×	Carrie	r Waveform			2
Full-filled Cor	nfig Y→ DL Test Mode	I g ⁺⁻ DL FRC Config	🔶 Auto Fre	quency Offset [+ Exp	ort 89600 VSA Setup		
+ …	General	BWP		General Settings	Channel Coding		
Carrier 0 (DL)	Spectrum Control	SS/PBCH	DL-SCH 0	Transmission Settings	MCS	20	
	Cell-Specific	DCI	DL-SCH1	Resource Allocation	MCS Table	Table 5.1.3.1-1 (64QAM) 🗸	
	Downlink	DL-SCH		Modulation and Coding	TB Scaling Factor	1.0 ~	
		CSLDS		DMDS Settings	Coding Rate	0.5537109375	
		Corito		Divino Scalinga	Modulation	nigam 🗸	
		LIE-Coexistence		PTRS Settings	Transport Block Size		
		PRS		HARQ Settings	BaseGraph		
✓ Channel	Allocation Summa	ry				Frame 0 🗸 \mu = 3 💉	🖌 🔽 Display Detail
CR8 µ = 3 66 50 40 20 10 0					DL-SCH0 DL-SCH1 SS/PBCH0	SubCarrier DL-SCH1	0 12 14

17. Select the Waveform tab > Select Generate.

View the waveform by selecting Spectrum on the bottom display.

Antenna 0 🗸 IQ	Spectrum CCDF	
0 -20 40 60 -80 -100 -120 61.44 MHz		Spectrum

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.

		Adjustments	Output Mod On	RF Output On	
roup 1: Signals		I/Q Off AWGN Off	I/Q On Pulse Off	Phase 0 deg	20.000 000 000 000 00 GHz
15G_Ant0.wfm 0 Hz 0 dB 🕨		Swap I&Q Off Delay 0 s	AM Off	PwrLim Off	0 dBm
	Fader	I/Q Out			ALC OFF
		Adjustments I/Q Off	Output Mod On	RF Output On Phase 0 deg	20.000 000 000 000 00 GHz
		AWGN Off Swap I&Q Off	AM Off	PwrLim Off	0 dBm

21. Select the Signal block to open.

Group 1: Signals	
File None selected	

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.

En	abled	Signal Mode	Frequency Offset	Attenuation	Status	
		File: No file selected				>
		None				>
		None				>
ài t		Nane				>
5		None				>
		None				>
		None				>
в		None				>

23. Select the Trigger tab and set Trigger Source to Global Trigger.

= # 8	• © © 6	Group	1: Signal Sumi	mary 💙 Signal 1: Setup		
General	Trigger Mode	Trigger Sou	rce	Global Trigger		
Waveform File	Continuous 🗸 🗸	Global Trig	gger 🗸	Global Trigger Source Immediate		
Trigger Markers	Continuous Mode Trigger & Run 🛛 🗸			Synchronization State On	i	
	Trigger Delay			Edit Global Trigger	>	
				Enable Playback	Synchronization ()	
Group 1: Signals			Adjustmen	ts	Output Mod On	RF Output Off
No file selected		- Fader –	I/Q AWGN Swap I&Q Delay	Off Off Os	I/Q Off Pulse Off AM Off	Phase 0 deg Corr Off PwrLim Off
	Vector Modul	ation		I/Q Out		

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



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 > 0K.

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.



 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.



 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.

ssible Logical Instruments	Configuration
Analyzer	Keysight/Agilent X-Series Signal Analyzer
Keysight/Agilent X-Series Signal Analy CXA, EXA, MXA, MXE, PXA, UXA, CXA-m, UXM Series. Frequency range depends upon model and options. Baseband or RF inputs depending upon options.	Zer Keysight/Agilent X-Series Signal Analyzer Hints: Hints: The primary instrument that has trigger out wired to trigger in on the other instruments must be placed first in the configuration.
elect the instrument(s) to use for each logica	l instrument in the configuration.

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.

2	Vector - Keysight PathWave Vector Signal Analysis (89600 VSA)								
File	Edit	Control	Source	In	put	MeasSetup	Trace	Markers	W
নি	Recall			►		Recall Setup			
	Preset	eset 🕨				Recall Recor	ding	_	
						Recall Trace.			
	Save					Recall Last P	ower-do	wn Setup	
	Export					Recall Signal	Studio S	Setup	
	Copy Tra	ace				D			
						Recall Layou	t		
一一			C			Recall Display Preferences			
<u>'</u> D'	Print		Ctri+P	P Recall User		Recall User C	olor Ma	p	
	Exit		Alt+F4			Recall Demo			

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

Advanced Measurements

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

nalog	Digital Trigger	Playbac	k Trigger Exten	nal Mixer Exter
nput Trigg	ger Channel: 🔋			
Style:			Level:	
xternal			114	
Slope:			Delay:	-
ositive			03	
Holdoff S	tyle:		Holdoff:	
Time Crit	eria:		Time1:	Time2:
Frequenc Criteria:	y Mask Trigger		Mask(s) to apply:	
Enter			Upper	
Window	Туре:		RBW: 🗹 Auto	
Flat Top	(ampl acc)		586 6536 i Hz	
Masks	Frequency Offset	A	implitude Offset	
Upper	0 Hz	0 dB		
Lower	0 Hz	0 dB		
				Edit
Trigger C	luți			
Desired:			Actual:	
Triager (Dut 1		Tringer Out 1	

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.

Configuration Input & Anten	na Time Decode	Advanced		
✓ 3GPP Conformance Test				
Tracking:	Equalizer Trainin	ng		
	Signal Source:			
✓ Phase	Time Pacis:			
Tracking Source: 3Gpp	▼ Freq Moving	g Avg. Filter 19 RS		
EVM Window and Symbol Timing		Transient I	Period	
EVM Window Length Mode:				
EVM Window Length in Samples:		Length:		
Symbol Time Adjustment Mode:		End 🔻		
% of FFT Duration:	-3.125 %	Power Cl	hange Threshold: 10 dB	
IQ Impairments				
IQ Imb. Estimation Mode: Off		IQ Imb.		
Compensate IQ Offset	DC Punctured	t		
UL Spectrum Flatness				
Spectrum Flatness Enabled				
Test Environment Condition: No	rmal 🔹 Test Tolerance	e: 1.4 dB		
Error Vector Unit				
Time Domain: Per Symbol 🔻	Freq Domain: Per Subcarri	ier 🔻		

- **12.** Close the 5G NR Properties dialog.
- 13. From the toolbar, select the Auto-Range dropdown and select EVM-Table or Algorithm Based.
 - EVM Table or Algorithm Based performs EVM optimization based on prescribed table/algorithm instead of using EVM in the feedback loop. This method of EVM auto-range is normally faster than Meas Based Iteration, but may not achieve the most optimal setup for minimized EVM).
 - EVM Meas Based Iteration has a feedback loop around the entire measurement, uses the measured EVM in the feedback loop, and tries to adjust hardware parameters to minimize the EVM. It is the slowest EVM auto-range method, but it should achieve the most optimal setup for good EVM.

File	Edit	Control Source Input	MeasSetup	Trace Markers Window	Utilities Help	
B	11	O VE EVM	•	📩 📫 🛛 🖽 -	R - ♦ H - २ .	📐 50% 0% Color Normal

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



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

Equipment Setup

M9484C front panel Channel 1 Event 2 to UXR rear panel Aux Trig In



- 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 A SYNCAN 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.

≡ 📰 🗠	0 0 G) > Apps			RF Out (All)	Trigger	?~	PRESET
Keysight PathWa	ive Signal Genera	ation						
5G NR	<u>@</u>	Custom Modulation (Beta)	NR-V2X	LTE FDD (Beta)	LTE TDD (B	eta)		

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.

Bandwidth	FR1 100MHz	~	NR-FR1-TM3.1
Numerology	μ = 1:30 kHz	~	 Output power dynamics Total power dynamic range (upper OFDM symbol power limit at
Duplex Type			max power with all 64QAM PRBs allocated
Test Model	NR-FR1-TM3.1	Ý	 Transmitted signal quality Frequency error EVM for 64QAM modulation (at max
Phase Compensation	Auto	¥	power)
DCI/DLSCH Payload Data	PN23	~	

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.

	ⓒ ⊙ ∩ > Apps: 5G NR		RF Out (All) Trigger ? ~ PRESET ~
💍 Generate	Carrier Waveform		Ľ×.
Export 89600 VSA Setu	ib.		
Basic	Capability	Waveform Playback 🗸	
Marker	Total Number of Antennas	4	
Crest Factor Reduction	Required License Version Date	2021.0801	
	Waveform Comment		
AWGN	3GPP Version	V17.4.0 (2022-12)	
Routing	User-Defined Sample Rate		
	Sample Rate	122.88 MSa/s	
	Time Scale Factor	1	
	Number of Radio Frames	2	
Antenna 0 🗸 IQ	Spectrum CCDF		
0			
-20			Spectrum
-40	والمحاصفة ومنتقاه فالمناط فلنقل وتحارفه والزامي المتقاصية فتقده وأمالهم والمراجع	ne a di si in si si se di si	
-80			
-100			
-120 -61.44 MHz			61.44 MHz

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

	Apps : 5G NR	
💍 Generate		Carrier Waveform
[→ Export 89600 VSA	Setup	
Basic	Capability	Waveform Playback 🗸
Marker	Total Number of Antennas	4
Ordet Faster Deductio	Required License Version Date	2021.0801

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.

Original de Oligensels						
Group 1: Signais	51.40	_	Adjustments	Output Mod Con	RF Output On	5,000,000,000,000,00 GHz
NR5G_Ant0.wfm 0 Hz	0 dB	- Fader -	I/Q Off AWGN Off Swap I&Q Off Delay 0 s	I/Q On Pulse Off	Phase 0 deg Corr Off PwrLim Off	-10.00 dBm
	Vector N	Nodulation				ALC OFF
Group 2: Signals			Adjustments	Output Mod On	RF Output On	
VR5G_Ant1.wfm 0 Hz	0 dB	Fader -	AWGN Off	I/Q On Pulse Off	Phase 0 deg Corr Off	5.000 000 000 000 00 GHz
			Delay 0 s		PwrLim Off	-10.00 dBm
	Vector N	Adulation				ALC UFF
Group 3: Signals			Adjustments	Output Mod On	RF Output On	Colores Management and the
NR5G_Ant2.wfm 0 Hz	0 dB	Fader -	AWGN Off	I/Q On Pulse Off	Phase 0 deg Corr Off	5.000 000 000 000 00 GHz
			Delay 0 s		PWILIM OT	-10.00 dBm
	Vector N	Adulation	· · · · · · · · · · · · · · · · · · ·			ALC OFF
				Output Mod On	BE Output	Engeneration
Group 4: Signals			Adjustments			
Group 4: Signals NR5G_Ant3.wfm 0 Hz	0 dB	Fader -	I/Q Off AWGN Off	I/Q On Pulse Off	Phase 0 deg Corr Off	5.000 000 000 000 00 GHz

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.

Tardware Argentia Arg					7	×
Configurations Discovered Instruments						
Current Analyzer Configuration: Analyzer3 - (Chann	els:	Baseband: 2 Channel +			
+0 ×	A	۲		Analyzer3		
Hardware Configurations Discovered Instruments arrent Analyzer Configuration: Analyzer3 Cha Analyzer Configurations Analyzer1 Keysight/Agilent X-Series Signal Analyzer N9040B (TCPIP0::localhost::hislip0::INSTR) Analyzer2 Keysight VSA Stream Keysight VSA Stream	Nam	Name:	Analyzer3			
Analyzer1 Keysight/Agilent X-Series Signal Analyzer Jig N9040B (TCPIP0::localhost:hislip0::INS	STR)		Configuration Type: Simulated	Analyzer		
 ▲ Analyzer2 ▲ Keysight VSA Stream ➡ Stream (USR::Stream) 						

6. Scroll down the Possible Logical Instruments and select Keysight/Agilent Infinium Series Oscilloscope, and then select the right arrow to move it under Configuration.

New Hardware Configuration			?	×
 Select the logical instrument(s) to use. Sources and An Simulate Hardware 	alyzers cann	ot be combined within t	he same configi	uration
Possible Logical Instruments	Confi	iguration		
Analyzer Keysight VSA Stream	Keys	ight/Agilent Infiniium Se	ries Oscilloscop	e
Keysight/Agilent Infiniium Series Oscilloscope Frequency/bandwidth from DC to 31.25 GHz depending upon model. 4 Inputs.				
ADC Keysight/Agilent Technologies Infiniium Series Sc	cope	TCPIP0::loca	lhost::inst0::INS	TR -
3. Name the configuration				
Analyzer2				

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

2. Select the instrument(s) to use for each logical instrument in the cor	nfiguration.
ADC Keysight/Agilent Technologies Infiniium Series Scope	TCPIP0::localhost::inst0::INSTR +

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.

Inpu	t MeasSetup	Trace	Marke	rs Window	Utilities	Help			
	Channels		×	✓ Basebar	nd: 4 Chann	nel 🕨		1 Channel	
	Analog			I+jQ		۱.		2 Channel	
	Digital			Custom				3 Channel	
	Captura							4 Channel	
							OV	5	
	Irigger							70	
	Playback Trigg	ger						Lineb de er	
	External Mixer	r						Liniviag	
	Extensions							500	
								500 m%	
	User Correctio	on						/div	
	Playback User	Correction							
	Data Fram							0	
	Data FIOIII							96	
	Recording				T :	4.38	311		Start -
					l Im	iecen i :	sym		Hes R

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.

Γ	MeasSetup Ti	race M	arkers Wi	ndow	Utilities	Help
0	🏊 Meas01 - M	easSetup			?	\times
	Frequency	ResBW	Time	Ave	rage	
	Measurement	Channel:	All 1	2	3 4	
	Center:		Span	:		٦
	5 GHz		100 N	1Hz		
	Show Cent	er/Span		Full	Span	
	Frequency St					
	25 kHz					
	🗸 Auto Frequ	iency Step)			
		k Ch	annel 1	•		
						_
	Time Data:		✓ Zoo			

- 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:
 - Level to 1 V Analog Digital Trigger Playback Trigger External Mixer Extensions Input Trigger Channel: 1 Level: External Defay: Slope: Positive Holdoff Style: Holdoff: Time Criteria: Time1: Time2: Frequency Mask Trigger Criteria: Mask(s) to apply: RBW: 🖌 Auto Window Type: Flat Top (amplacc) Masks Frequency Offset Amplitude Offset 0 dB Lower 0 Hz 0 dB Trigger Out Actual Desired: Trigger Out 1 Trigger Out 1
- Style to External

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

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.

📥 Meas01 - 5G NR De	mod Properties			
Configuration	Input & Antenna T	ime	Test Model	? >
Save As Quick Setup	Quick Setups	0 : CD0	Settings changed bu	it not applied.
		unlink	3GPP Version:	Latest (2022-03) 🔻
Carriers	Link Direction: • Do	wniink	Carrier Indexes:	0
Bandwidth	Configure + A	dd Carrie		504 400 1411
BWP			Bandwidth:	FR1 100 MHz 🔻
 Channel 	Reference: CC0 🔻	Displa	Duplex Type:	TDD -
SS/PBCH		C-111D	Numerology:	µ = 1:30 kHz ⊸
РДССН				7110.4
	✓ CC0	0	lest Model:	ТМЗ.1 -
PDSCH			Modulation Format:	TM1.1
CSI-RS	Open lest Model			TM2.0
Results & Filters	Cross-Correlated EVM	Confid	Map PDSCH in PD	TM2.0a
		Coniiç		TM2.0b
Manually apply sett	inas		Close	TM3.1
				TM3.1a
				TM3.2

NOTE

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.

Configuration	Input & Antenna Time	Decode Adv	vanced						
Save As Quick Setup	Quick Setups CC0 : C	CD0 -							
Carriers Bandwidth	Add PDSCH Remove P	PDSCH Clear All	Ena	able Channels					
BWP Channel SS/PBCH PDCCH PDSCH CSI-RS Results & Filters	Modulation: Transport Block Size: Transport Block 2 n _{ID} Source n _{ID} CORESET ID: Custom ModFormat:	QAM64 835976 Cell ID ~ 1 -1 ~ Off ~		Resulting Format: RB Ref CORESET ID: RB Offset: RA Configuration: Allocated RBGs: VRB-To-PRB Mapping: Rate Match Patterns:	D D D D D D D D D -1 * 3 RB Config1 * Non-Interleaved * None	D D D D D RA Type: RB Number: RBG Size [P]: VRB-To-PRB Interleaver: Edit BWP Max RB: 273 seed RBs 136.5 204.7 seed RBs Allocated RE	Type1 270 RB 16 n2	•	•
	Antenna Port Ref. Antenna Port:	1000 - Idex X3 Wideband -	Ant. De Codew DMRS User D	et. Threshold: rord Number: CDM group(s) without dat efined PRB Bundle Size:	-36 dB 1 -36 dB 1 -36 dB 1 -36 dB 1 -36 dB -36 dB				

- 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.

Configuration	Input & Anten	na	Т	ime	Deco	de	Advanced
Analysis Region –							
Result Length:	5 Subframes		0 SI	ots		at µ	3 5 ms
Meas Offset:	2 Subframes		0 S	/mbols		at µ	3
Meas Interval:	3 Subframes		0 S	/mbols		at µ	3
Time Scale Factor	: 1						
Analysis Start Bou	ndary			Acqu	uisition N	/ ode	;
Frame				0	Normal		
				0	Reduced	acqu	uisition length
					rame tri	gger	is present
				09	Slot trigg	jer is	present
⊖ Slot							
First Slot Index:		at µ	3				
Timing Diagram -							
⊬ −	Result Leng	th 5	Subf	. —	>		
					,	Mea	s. Interval 3:0
Frame Bo	undary	_	_		_	wea:	s. Onset 2:0

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



File Edit Control Source Input MeasSetup Trace Markers Window Utilities Help				and the				?
📘 📔 📥 🐧 All 🔻 Range To Peak Power (Default) 🐁 🛑 🤖 🛤 🛛 🗛 🚟 💵	R L O	11 1	1. 🤾	Ш 🙏				
A: OFDM Meas: All Layers * + X	E OFDM Detecte	d Allocati	ions Time: A	All Layers				+ ×
Rng-0.5 dBm*	Rng 290	3.5 mV*						
20000	Kcamers							
Control	Bart							
Collst	Hear							
-1.5	328							
-6 906 6 9062	carriers /div							
Res BW 30 kHz TimeLen 224 Sym								
B: Chil Spectrum + X	-1.64 kcarriers							
Rng - 0.5 dBm	Start 0	sym			Dalast	Dari		Stop 55 sym
-0.501	ing on				Delay u	540		DIG EACH A
	P: Frame Summar	У						~ X
LogMag hearth and a second and differential and the second and different and the Madhiber Second and a bar	Name	(%ms)	(dBm)	RE Modulation	RBs	RNTI	BWP ID	
-100.501 glu de anarreste fon alle constitution alle i dat de Able man de Autori (illes) dens as condes Enterviet ber	PDSCH0	0 370	-40	16 QAM64	4320	(bcO		-
dBm Center 5 GHz Span 100 MHz	PDSCH0_Layer0	0.406		*** QAM64	1080			
Res BW 1.90968 kHz TimeLen 2 mSec	PDSCH0_Layer1	0.330		*** QAM64	1080			
C: Summary + X	PDSCH0_Layer2 PDSCH0_Layer3	0.355		*** QAM64	1080			
·	PDSCH1			*** QAM64		0x0		
Analyzed Subframe (ISID sym0) in (St1 sym07)	PDSCH1_DMRS			*** OPSK		0x0		
Channel Flower -11.09 dBm	PDSCH1_Layer1			*** QAMIN				
OFONByin Tix Power -11.02 dBm	PDSGH1_Layor2			CAM64				-
EVNV 0.37053 96mmi EVN/Ex 1.4756 96mi	PDSCH1_Cayers	_		CQAMID4				×.
Mag En 8 265 96ms	G: DMRS MIMO I	nfo						+ X
Allingen Pri I (115) Hep- Enninge Err (110)42 / deg	Name	Meas Channel	Antenna I Port	Despread EVM %rms)	Power (dBm)	TAE (sec)	Frequency Offse	(Phase Offset (deg)
The OFFILI Facility of Facility and All Instance	PDSCH0_DMRS	Ch1	Point0	0 238	43.62	134.41	p 40.7243	-0.36
D. OFDM EIT VECT Spectrum: All Layers - X	PDSCH0_DMRS	Chi	Port1		-125.46			
Rng -0.5 dBm*	PDSCH0_DMRS	Ch1	Port3		130.41			
96	PDSCH0_DMRS		Port0					
	PDSCH0_DMRS	Ch2 Ch2	Port1 Port2	0.172	-43 25	255.018	-40 7361	-104-45
Literag	PDSCH0_DMRS	Ch2	Port3		-139.39			
a hande intelligender hat her eine fineten in find fich er hande her	PDSCH0_DMRS	Ch3	Port0	849	-128.57			
% Stort 1 538 keamer	PDSCH0_DMRS	Ch3	Port2	0 194	-42.70	288 487	-40 6782	-150.64
Res BW 30 kHz TimeLen 224 Sym	PDSCH0_DMRS	Ch3	Port3	***	-121.90			

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.

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

4 Other X-Series Signal Analyzer Measurements

- "Setting Up a Group Delay Measurement" on page 212
- "Setting Up Millimeter-Wave Measurements" on page 222
 - "Setting up a 5G NR Millimeter-Wave Measurement" on page 222
 - "Setting-up a Millimeter-Wave DVB-S2X 64APSK Measurement" on page 231
 - "Setting-up a Millimeter-Wave 5G NR, 2 GHz BW FR2 Measurement" on page 253
- "Using the X-Series Analyzer's SCPI Recorder Function" on page 277
- "Using the X-Series Analyzer's Preload/Unload Function" on page 290



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.

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.

NOTE

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

A Group Del	ay +				Meas Set	, dr
		Connection Management		Close	Connection Management	Set
					Frequency 10.270000000 GHz Auto Man	Ton Sig Ger
- Singal Generator List	e (Optional)	Hostname/IP Address	Connect		Amplitude	Adv
1	t	oxer15.srs.is.keysight.com	~ Information		-10.00 dBm	Glo
2	k	-m9384b-30137			RF Output On Off Advanced	
					Apply Settings to Signal Generator	
New Signal Generator						
Hostname/IP	k-m9384b-30137	Add To Generat	or			
Address	and the second second second					

- **7.** Select **Apply Settings to Signal Generator** to send these settings directly to the VXG, then **Close** the Connection Management window.
- 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.

🏠 Meas Setup 🔻 🕌	
Number of Tones 501	Settings
Tone Spacing 1.00000000 MHz	Tone
Ref Tone Adjustment	Signal Generator
Off	Advanced
Configure Tone Table	Global
Measurement Threshold Level -60.00 dB	
On Off	
Measurement Range 495.99 MHz	
Auto Man	
Apply Tones to Signal Generator	

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.

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.



NOTE

- 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 $^\circ.$



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



Setting Up Millimeter-Wave Measurements

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

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

We will connect the output of the 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.

=	III	Apps : 5G NR		RF Out (All)	Trioger	?~ 📼	e r •
谐	E+ Export 89600 VSA S	Setup					
~	Waveform	Number of Slots in Subframe	N/A				
æ.		Total Sample Points	1228800				
		Waveform Length	10,ms				
		Mirror Spectrum					
		Phase Compensation	Auto ~				
*		Radio Frequency	o dina				

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.

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

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.

Dow	nlink Test Model (Base Station T	x Test based on 38.141 v17.	5.0)	×
	Bandwidth	FR2 400MHz	~	NR-FR2-TM3.1a
	Numerology	μ = 3: 120 kHz	~	 output power dynamics ortal power dynamic range (upper OFDM symbol power limit at
>	Duplex Type	TDD		max power with all 256QAM PRBs allocated)
	Test Model	NR-FR2-TM3.1a	~	Transmitted signal quality Frequency error EVM for 2560AM
	Phase Compensation	Auto	~	modulation (at max power)
	DCI/DLSCH Payload Data	PN23	~	

- 8. Select OK to exit the Downlink Test Model setup.
- **9.** Select **Generate** to generate the Waveform, and then select **Home** to exit the setup panel.

≡ ₩ 2-	🕒 🕘 🎧 > Apps		RF Out (All) Trigger ? ~ Peart ~
る Apps 5G NR > で Generate		Carrier Waveform	5-
+ Export 89600 VSA Set	up		
Basic	Capability	Waveform Playback 🗸	
Marker	Total Number of Antennas	1	
Crest Factor Reduction	Required License Version Date		
AWGN	Waveform Comment		
Anger .	3GPP Version		
Routing	User-Defined Sample Rate		
	Sample Rate		
	Time Scale Factor	1	
IQ Spectrum	CCDF		
0			the second se
-20			spectrum
-40 -60		den men bis de publiel dit und Allem Briter al sur senat, est à dési pares, et à la dura poi destaband les adaptements	iniz de Maline a la Maline
-80	Concerting to the second	at row to be dead to short a share to see	
-100			
-120			491.52 MHz

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**.

\equiv		₽~	€	6	ଜ	> Configure Analyzer		RF Dut (All)		? •	Parat ~
The M9 the des	484C s ired sig	ystern work nal from the	s with Key source.	rsight X-Si	aries Sigr	al Analyzers. Once a remo	se signal analyzer is connected, use the [Auto Configure Ana Auto Configure Analyzer	alyzer] button to automatically set u	o the analy	zer to m	reasure
		Click to ac	M9484C) ce Interfaci	8		Output Channel Output 1 🗸	Cilck to change co	nnection		
								TCPIP:hislip0:	INSTR		

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.

≡ Ⅲ ⊡ · ⊙ ⊡ ∩	> Configure Analyzer > Remote Instrument	RF Out (Alf) Trigger
Connection Type	Hostname or IP Address	
	141.121.149.32	Test Connection
	Protocol Type Address HiSLIP V histip0	

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.

≡ ₩	₽- ©	١Đ	Apps	4				Trigger	? ~ PR	554T -
15 Apps	Custom Modulation (Beta)	×							
🐣 Generate			Carrier	Waveform		[+ Impor	t Signal Setup	[+ Ex	port Signal S	etup
n Preset] Quick Setups [+	Export 8	39600 VSA Setup							
Custom IQ	DVB-S2		tom IQ Type		ASK & PSK & QAM 🗸					
Custom AS	DVB-S2X		8APSK >							
Filter	APC025		16APSK >							
	TETRA		32APSK >							
	NXDN	*	64APSK 🔿	16+16+16+16APSK 128/180						
	dPMR		128APSK >	8+16+20+20APSK 7/9						
	DECT		256APSK >	8+16+20+20APSK 4/5						
$+ \operatorname{Add}\operatorname{Sec}$	DMR	t.	📥 Move Up	8+16+20+20APSK 5/6						
Name	ARIB	> s	Ramp Samples	4+12+20+28APSK 132/180	Constellation	Phase Rotation	Shift Bits Pe	r Symbol	Differential	Offset
PLHEADER			0	Last with strend space from suit	QPSK	0				0
DataSeg	ZigBee		0	PN15	DVB-S2X 4+12+20+28APSK 132/180	0		6		
	Wi-SUN(802.15.4g)) >								
LHE	ITU-T G.9959	*			DataSeg					
0	90								2090 Sym	8

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

	Apps				Trigger ? ~ PRESET ~
Apps Custom Modulation (Beta)					
🖑 Generate	Carrier	Waveform		[🕂 Import Signal Setup	[- Export Signal Setup
卷 Preset 🔲 Quick Setups [+ Export	89600 VSA Setup				
Custom IQ Selection Sy	mbol Rate		400 Msps		
Custom ASK & PSK & QAM Settings					
Filter					

8. Select Filter > Alpha to 0.1.

We will match these settings in the UXA setup.

ී Generate			c	arrier	Waveform	j j		[+ Impor	t Signal Setup	[+ Exp	port Signal S	etup
Preset] Quick S	etups [+ E	kport 89600 VSA	Setup								
Custom IQ Sel	ection	-	Filter			Root Ny	quist 🗸					
Custom ASK &	PSK & Q/	AM Settings	Alpha			0.1						
Filter			Length(symbo	ol)		32						
+ Add Segme	ent —	Remove Segn	nent 🛨 Mov		🛓 Move Down							
Name	Туре М	Number of Sym	bols Ramp Sa	amples	Payload	C	onstellation	Phase Rotation	Shift Bits Per	r Symbol	Differential	Offset
PLHEADER	Data	90	0		180 bits binary data [0001]		QPSK	0				1.
DataSeg	Data	2000	0		PN15	DVB-S2X 4+13	2+20+28APSK 132/180	0		6		1
LHEAD	ER					DataSeg						
0	90										2090 Sym	

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

≡ ₩ 2~	E D Apps		Tripper ? ~ Pesset ~
Apps Custom M Generate	odulation (Beta) × Carrier Waveform	n	[+ Import Signal Setup [+ Export Signal Setup
Basic	Custom Modulation		
Marker	User Defined Sample Rate		
Crest Factor Reduction	Oversampling Ratio	4	
Multi Carrier	Number of Frames	1	
Correction	Total Sample Points		
Conection	Waveform Length		
Routing	Mirror Spectrum		
IQ Spectrum	CCDF		
-20			
-40		The stand in the second second second	
-60	en ste net attente aven i så bedradt att til fikk	NT MAAAAAAaaaaaaa	thile lines is a second a strate of
-80			a shakara na shakara shekara sh
-120			
			1.60 GHz

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.
- im Analyzer 1 + **O** Marker KEYSIGHT Input: Ext RF 17 50 0 Atten: 0 dB Avg Type: Power (RMS) Trig: Free Run 1 2 3 4 5 Select Marker Pre: Int off, LNA off to Off Align: Auto W W W W W Marker 1 Marker Frequency Settings Mkr1 81.000 0 GHz 1 Spectrum 81.000000000 GHz Band Power -12.72 dBm Scale/Div 10 dB Ref Level -12.00 dBm Peak Band Function od Search Band Power Pk Search Config Band Span 400 000000 MHz Propertie Band Left 80.80000000 GHz Band Right Marker→ 81.200000000 GHz N dB Points Counter -3.01 dB On Off **[**"]1 Measure at Marker Measure at Marker Confid Meas at Mkr Windo On Off Center 81.0000 GHz Span 500.0 MHz Sweep (SW Pre) ~2.39 ms (1001 pts) Video BW 300 kHz*
- 4. Set Band Span to 400 MHz.

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

NOTE

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

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

	Screen Name Spectrum A	inalyzer 1	120ee
Sequencer	Mode	Measurement	View
To launch 89600 VSA press the button below. Launch VSA 89600 Software Version	EMI Receiver Channel Quality / Group Delay GSM/EDGE /EDGE Evo LTE FDD & NB/eMTC & V2X LTE TDD & LTE-A TDD Noise Figure 5G NR & V2X Power Amplifier Pulse Remote Language Compatibility SCP1 Language Compatibility Vector Modulation Anatyzer W-CDMA with HSPA+ WLAN	Digital Demod Custom OFDM Monitor Spectrum IQ Waveform Channel Power Occupied BW Power Stat CCDF ACP SEM Spurious Emissions PAvT	Normal Demod Traces Demod Error Results Summary Eye Diagram Dual Segment Frame Summary User View Autosaved

6. Select Frequency and set to 81 GHz.



 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.

Spectrum Analyzer 1 VMA 2 Swept SA Digital	Demod +			Kea:	s Setup 🔰 👯
	R	adio Standard Presets	Close		
Category	Standard	Profiles		Radio Std: None	Settings
Cellular	ATSC	8-APSK Code Rate 100/180 (5/9)		Preset To S	d Meas
Wireless Networking	DVB-C	8-APSK Code Rate 104/180 (26/45)			Frame
Digital Video	DVB-S2	16-APSK Code Rate 3/5			Meas Time
Radio	DVB-S2X	16-APSK Code Rate 13/18			Demod
Others		16-APSK Code Rate 18/30 (3/5-L)			Advanced
		16-APSK Code Rate 20/30 (2/3-L)			BER
		16-APSK Code Rate 23/36			Limits
		16-APSK Code Rate 25/36			Global
		16-APSK Code Rate 26/45			
		16-APSK Code Rate 28/45			
		16-APSK Code Rate 90/180 (1/2)	Press OK to execute the selected preset and exit this dialog		
		16-APSK Code Rate 96/180 (8/15)			
		16-APSK Code Rate 100/180 (5/9)	OK Cancel		Prototype

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



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



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.

Meas Setu	p 7 👬
Selected Segment Segment 2	
Segment Type: Data Meas Interval	Settings
2000 symbols Meas Offset	Meas Standard
90.00 symbols Meas Offset Reference	Frame Meas Time
Rel To Sync Pattern V	Demod

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.

ectrum /	Analyzer 1	VMA 2 Digital Demod	• +						Meas Set	up v
				Segment Config [Diagram			Close		
	Seg Name	Modulation Format	Symbol Rate	Meas Offset	Meas Interval	Meas Offset Ref	Equalizer	Sync Sez	Search Length 3,36 ms	Settings
1	Seg1	Custom IQ	400.0000000 MHz	000 97585	90 symbols	14446			Segment Number	Meas Standard
2	Seg2	Custom IQ	400.0000000 MHz	90.00 symbols	2000 symbols	Rel To Sync Pattern			2 Segment Config	Frame
									Burst/Sync Search	Meas Time
S	nc Pattern S	tart		Frame Leng	th 5.225 μs	-		+	Burst Search On Off	Demod
									Burst Search Threshold	Advanced
									-15.00 dB	BER
*	Seg1 225,00								Sync Search On Off	Limits
	+		Seg2 5.00	<u>10 µs</u>	-				Sync Offset	Global
									Sync Pattern	1

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.

Spectrum Analyze Swept SA	r 1 VMA 1 Digital Demod	+					
	Input: Ext 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: FByp, On Info BW: 440 MHz	Format: Custo Sym Rate: 400 Meas Intvl: 90 Equalizer: On	m IQ / Custom IQ MHz / 400 MHz / 2000 symbols / On	CF: 81.0000000 Trig: Free Run	00 GHz
1 Spectrum			2 Raw M	ain Time 🔹			
Scale/Div 10.00 d	B Ref Value	0.00 dBm	Scale/D	iv 10.00 dB	Ref Value 10.	00 dBm	
-10.0 -20.0 -30.0 -40.0 -50.0 -70.0 -80.0 -80.0 -90.0	na) ann da ann a' bhanna bhlig fach de	hing the contract of the track of the proceeding of the	0.00 -10,0 -20,0 -30,0 -30,0 -50,0 -50,0 -60,0 -70,0	estaurationse estaute	and an and a state of the state	analangan ang ang ang ang ang ang ang ang an	ang
Ctr: 81.00000000) GHz	W	/idth: 440 MHz -80.0				
Res BW: 1.122 kH	z Actual Info E	3W: 440 MHz	Start: -1	43.64 ns			Stop: 3.36 ms
3 Seg1_IQ Meas Tir (Const)	ne 🔻		4 Seg2_I (Const)	Q Meas Time			
1.00 750 m 500 m 250 m			1_00 750 m 500 m 250 m				
-250 m -500 m -750 m -1.00			-250 m -500 m -750 m -1.00				
-3.718			3.718 -3.718				3.718
5 Seg1_Metrics	TX Power	-11.62 dBm	6 Seg2_1	Metrics 1	TX Power	-11.62 dBm	
EVM Mag Error	1.17 %rms 0.88 %rms	2.58 %pk -2.35 %pk	EVM Mag Er	TOF	0.80 %rms 0.52 %rms	2.42 %pk 2.31 %pk	
Frag Error	0.44 %pk	-1.41 pk	Phase	Error	0.72 %pk	-5.26 °PK	
Clock Error		-47 93 mHz	Clock F	Fror		-229.14 Hz	
I/Q Offset		-38.52 dB	I/Q Off	set		-71.15 dB	
SNR (MER)		38.63 dB	SNR (M	AER)		39.60 dB	
Quad Error		0.06 °	Quad E	Error		-0.02 °	
Gain Imb.		-0.02 dB	Gain In	nb.		0.00 dB	



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.

1.20 k 900			
600 300 So	ale/Div		
300 30	00.00		
-600			

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%.

Spectrum Analyzer 1 Swept SA	VMA 1 Digital Demod	• +							\$	Meas Setu	p 🔻	器
	Input: Ext RF Coupling: DC Align: Auto	Input Z: 50 Ω Corr CCorr RCal Freq Ref. Ext (S)	Atten: 10 dB Pre: Int off, LN μW Path: FBy Info BW: 440	IA off p, On MHz	Format: Cust Sym Rate: 40 Meas Intvl: 90 Equalizer: Or	om IQ / Custom IQ 00 MHz / 400 MHz 0 / 2000 symbols 1 / On	CF: 81.000000000 Trig: Free Run	GHz				
1 Spectrum	*		2	Raw Main	Time				Avg Ho	ld Number	Setti	ngs
Scale/Div 10.00 dB	Ref Value 0	.00 dBm	S	cale/Div	10.00 dB	Ref Value 10	.00 dBm		Averagi Or	ing 1	Meas Stan	s dard
-30.0 -40.0 -50.0 -60.0 -70.0	olanaidhean bile iolatea	<mark>i nanimali phini nataké pravila</mark> t	det territe belgebre	20.0 30.0 40.0 50.0 a alla	an dan at da	and a bailt manifes	at faller start and the small	ata atilia ang katana	Of Average	f e Mode	Fram	ie
-80 0 -90 0				60.0	o al chila adax	this year is hattake	a ni fi sha dhe dha an da	realistic stille	Expon	ential V	Meas	s Time
Ctr: 81.000000000 G Res BW: 1.122 kHz	Hz Actual Info B\	W V: 440 MHz	idth: 440 MHz S	80.0 tart: -143.	64 ns			Stop: 3.36 ms	Op	timize EVM	Dem	od
3 Seg1_IQ Meas Time (Const)	T.		4	Seg2_IQ I Const)	leas Time	•			EVM O Method	ptimization	Adva	anced
1.00 750 m 500 m 250 m				1.20 900 m 600 m 300 m					Iterative Iterative Optimiz	e v EVM ation Target	BER	
-250 m -500 m -750 m -1.00				300 m 600 m 900 m -1.20					Segme For be "Allow	ent 2 v st EVM, set Full Bypass	Limit	s al
-3.718			3.718 -4	4.461				4.461	in Auto	" to On(in		
5 Seg1_Metrics	TX Power	-11.58 dBm	6	Seg2_Met	rics	TX Power	-11.58 dBm		uie An	ipilitude mend)		
EVM	1.16 %rms	2.19 %pk	1	EVM		0.74 %rms	2.08 %pk		AL	ito Couple		
Phase Error	0.45 %pk	-2.04 %pk		Phase Err	or	0.68 %pk	-4.88 °pk		Me	eas Preset		
Clock Error		-26.32 mHz		Clock Erro	or		-17.12 Hz					
I/Q Offset SNR (MER)		-38.20 dB 38.75 dB	0	I/Q Offset SNR (ME	R)		-70.82 dB 40.29 dB					
Quad Error Gain Imb.		-0.01 dB		Quad Erro Gain Imb.	or		-0.02 ° 0.00 dB					

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**

: (CC0) FlexFram	Analog	Digital	Capture	Trigger	Playback Trigge	er External Mixer	Extension	
15	Logical In	strument:				P	reset All	
1.5						Sł	now All	
Const		LO Dith	er		Off			
		Microwa	ave Path Cont	trol	Full Bypass			
300		Mixer Mode Phase Noise Optimization RCal Correction			Normal			
/div					Best Wide Off	set		
					Off			
-1.5		Widebar	nd IF Output		Off			
-2 4246		Paramet	ers Influence	ed by the M	easurement Type			
2.72.10		Control	Method	_	Attenuation			
: Ch1 Spectrum		IF Gain			-8			
		Mechan	ical Attenuat	ion	10			
100		Preamp	lifier / LNA	-	Off			
	1	lechanica	Attenuation	i.				

- 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.

Mixer Selection:					
V3050A Signal Analyzer Fi	requency Extend	der			
Harmonic Table:					
Harmonic LO Doubler	Min Freq	Max F	req		
Input Attenuation:					
10 dB					
Cable IF Loss:			Bias		
0.26 dB					
Mixer Paths:			Aux IF Freque	ency:	
Normal					
USB Mixer					
USB Mixer detected					

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

E Flex Frame	- Keysight 89600 VSA Software - Press 1	the Mc	ode key to switch applications						o x
File Edit	Control Source Input MeasSetu Frequency		ace Markers Window Utili	ties Hel 8- .:::		8 M A I			
A: (CC0) I	Time Average	ne S	Syms/Errs D: (CC0) FlexFrame S	Summary	E: (CC0) FlexFrame Err Vect Time	F: (CC0) FlexFrame Phase Err	G: (CC0) FlexFrame Mag Error	H: Ch1 CCDF	
1.5	Frequency vs. Time Time vs. Time							SYNC	NOT FOUND
1-0 + 300	I-0 + New Measurement I Duplicate Measurement I 300 Measurements								
/div	Measurement Type: Flex Frame Flex Frame Properties		Vector Power Spectrum Analysis	,					
-1.5	Analog Demod		General Purpose: Flex Frame						
-8.2 B: Ch1 Spect	-9.23972602 Custom IQ Custom OFDM Channel Quality		Cellular Wireless Connectivity Radar Analysis Other standard formats					8	2397260274
30	Channel Sounding								
dBm	✓ Flex Frame								
Looking -									

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

File Edit Control Source Input MeasSetup Trace M	Aarkers Window Utilities Help
🗁 📗 📩 EVM- Meas Based Relation 🖛 💷 🥮	i 📩 🛤 😐 🔠 💶 🕞 🗔 🔿 *1
A: (CC0) FlexFrame Meas Time G: (CC0) FlexFrame Mag Error	Previous Layout ame Syms/Errs
1.5	Stack 2
	Stack 3
	Stack 4
ΗQ	Stack 6
	Grid 2x2
300	Grid 2x3
m Idiv	Grid 3x2
	Custom
15	Tile Visible
-1.5	
-2.42465753 2.42	4657534

- 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 CCO.
---	---------------	------------------	------------------

CC0) FlexFrame Syrr	Carrier Aggregation Frame Preset Measurement Selected CC for Trace Display: Component Carriers Reference Frequency: 81 GI	Custom Modulation						
	Enabled Name Absolute C	enter Offset Symbol Rate Assign 0 Hz 400 MHz CK1	Copy CC0 to >					
	+ Add CC 80 GHz	Acquisition Configuration Frequency Span: 2 GHz Channel Status Frequency Center Frequency Span Ch1 Ø 81 GHz 2 GHz Overall Status: Error: unassigned compo	? × Assigned Carriers None 82 GHz OK Cancel					
	Cross-Correlated EVM Enabled Configure Acquisition Configuration Channel Status Frequency Center Frequency Span Assigned Carriers Ch1 & 81 GHz 2 GHz None Ø Overall Status: Error: unassigned component carriers: [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**.

A Meas01 - Flex Frame Properties						
Carrier Aggregation Frame Definition Measurement Co Component Carrier: CC0	ntrol Time	Filter	Custom Modulation	¢		
Alt 80 GHz 81 G	CO GHz	-	1.8	12 GHz		
cco	_	AllocD	_		-	
						o I
Component Carrier Configuration	Allocat	ion Sumn	hary			
Frame Configuration Modulation	Index	Enabled	Frame Part	Allocation	Allocated Symbol Indexes	T
Preferred Bit To Symbol Mapping: Default.	0		FramePart0	Alloc0	0:999	10
Scrambler: 0 + X DVB-52X DVB-RCS2						
Scrambler Configuration 802.11ad/ay						
Sequence Type: DVB-S2/S2X PLFRAME =						
Sequence Index: 0						

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.

Carrier Aggregation	rame Definition	Measurement Control	Time Filter	Custom Modulation	i .			
Component Carrier: CC	0 7							
All		CC0						
80.46 GHz		 81 GHz		81.54	4 GHz			
cc0			Alloci					
Component Carrier Conf	figuration		Allocation Sur	nmary				
Frame Configuration	Modulation		Index Enable	ed Frame Part	Allocation	Allocated Symbol Indexes	Total	
Frame Type:	Burst –	0	0	FramePart0	Alloc0	0:2089	2090 4	Ą
Symbol Rate: 4	100 MHz						ł	ł
Length: 2	2090 Symbols	Auto						

- **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.

む Apps ⑦ Generate	Custom M	odulation	× Carrier	Waveform			[≁ Import Signal S	etup [+ Export Signal Setu
n Preset	Quick Se	tups [+ Expor	89600 VSA Setup			Segment Payload Edit		×
Custom IQ Sel Custom ASK & Filter	ECTION	Ci M Settings	ustom IQ Type			Pattern ~ Constraint of the lease of the le	Save to File 00101110110111000100 01010100101110001000100010001000100010	Clear 0 0 0 1 0 0
+ Add Segm	ent —	Remove Segment		🛓 Move Down				
Name	Type N	umber of Symbols	Ramp Samples	Payload				
PLHEADER	Data	90	0	180 bits binary data (000	n]	Current: 180 Total: 180	(Max: 128K bits)	
	Data R 90	2000	0	PN15	DVB-S DetaSeg		Updates are availa Required updates	ible need to be downloaded. View updates

- 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



arrier Aggregation Frame Definition	Measurement Control Time Filter	Custom Modulation
omponent Carrier Configuration	Allocation Summary	
Frame Configuration Modulation	Index Enabled	Frame Part Allocation Allocated Symbol Indexes Total
Frame Type: Burst		
Symbol Rate: 400 MHz		
Length: 2090 Symbols	Auto 🔛	
ame Parts		
FramePart0 + Add Allocation	Configuration	Location
PLHeader	Enabled:	Start Symbol: 0
	Name: PLHeader	Last Symbol
	Type: Pilot -	Symbol Index: 89
	Power Boost: 0 dB	- or -
	Pavload	Total Length: 90 Symbols
	Sequence: Custom	End of Frame
		Repeat Pattern
	Custom Sequence Type: Bit Sequ	Repetition Parameters
	Modulation: QPSK	Active Symbols: 0
	✓ Include in BER Calculations	Repeat every 1 Symbols
	Autodetect Bit Sequence Offset	
	00011110001011010001001011110110 100010001011100010000111100010 11100010001000001111011100110000 010010	01111011 11010010 01001011 11010001
	1101000100100001000111010010	

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.

Carrier Aggregation Frame Definition M	easurement Control T	ime Filter Custom Mod	ulation		5 a
Component Carrier Configuration Frame Configuration Modulation Frame Type: Burst • • Symbol Rate: 400 MHz • Length: 2090 Symbols •	Allocatio Index 1 0 1	n Summary :nabled Frame Part I FramePart0 I FramePart0	Allocat PLHeader Data	ion Allocated Symbol Inde 0:89 90:2089	xes Total 90 2000
Frame Parts FramePart0 + Add Allocation PLHeader Data	Configuration Enabled: Name: Data Type: Data Power Boost: 0 dB Payload			Location Start Symbol: 90 Last Symbol Symbol Index: 90 - or- Total Length: 1. Symbols	
	Sequence: Modulation: MODCOD: ✓ Include in BER Cal	PN15 DVB-S2/S2X APSK 4+ 12+ 20+ 28APSK Norma culations	+ + 1 132/180 -	Repeat Pattern Repetition Parameters Active Symbols: 0 Repeat every 1 Symbols:	
Add Frame Part Remove Frame Part Add Allocation Remove Allocation	Autodetect Bit See Scrambling Enabled Scrambler ID: 0	guence Offset			

- 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

Carrier Aggregation Frame Defin	ition	Measurement	t Control Tin	ne Filter C	ustom Modulation	
All			CC0			
80.46 GHz			 81 GHz		81.54	G
Overall Allocation Control						6
Frame Part Allocation Type	e Ir	clude in EVM	Calculate BER	Synchronizatio	on Chan Estimatic	m
FramePart0 PLHEADER Pilot				4	1	
FramePart0 Data Data					J	
Synchronization Source: Frequency Estimation Mode: Equalization Mode:	Auto Norm Zero-f	al			•	
Channel Estimation Source:	Alloca	tions with Kno	wn Sequences	🔽 🗹 Initial Eq	ualization 🕨	
Normalized Channel Delay Spread:	20 Sym	ibols				
EQ Iracking:	Off					
Tracking Convergence:	1E-06				Ø	
Display						•
Show EVM in dB						
Points per Symbol:	2					

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

Carrier Aggregation	Frame De	efinition	Measurement Control	Time	Filter	Custom Modulation
Component Carrier:	CC0					
All			CC0			
80.5 GHz			 81 GHz			81.5 GHz
Search Length: 10.4	5 µs	4180	Symbols			
Result Length: 209) Symbols	0				

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.

NTHWAVE 🖻 File -> 🗟 System ->	省区) B					
G Home 5G NR ×							
🖒 Generate 🛓 Generate & Download	Carrier	Waveform	Hardware				
[→ Export 89600 VSA Setup							
Number of Radio Frames		1					
Subframe Offset		0					
Number of Subframes		10					
Slot Offset in Subframe	N/A						
Number of Slots in Subframe	Number of Slots in Subframe						
Total Sample Points	1228800						
Waveform Length	10 ms						
Mirror Spectrum							
Phase Compensation		Off 🗸 🔗					
V Marker							
Marker 1 Source	Waveform Start 🗸						
Marker 2 Source	Frame Start 🗸						
Marker 3 Source		RF Blanking (Control 😒				
Marker 4 Source		RF.ALC Contr					
✓ Crest Factor Reduction							
		-					

- 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
| | 🗏 System ~ 街 🗗 🗗 | 1 | | |
|--------------------------------|-------------------------------|-----------------------|-----------|--|
| $$ Home 5G NR \times | Fullfilled Preset Config | \rightarrow | | |
| 🐣 Generate 🛓 Generate & Do | Bandwidth | Bandwidth FR2 2000MHz | | |
| 🗰 Full-filled Config 🍯 DL Test | Numerology | µ = 6: 960 kHz | ~ | |
| + - ₽
✓ Carrier 0 (DL) | ✓ Duplex Type | TDD | | |
| BWP Setup | Duplex Type | TDD | ~ | |
| Channel Setup | Transmission Periodicity | 1.25 ms | ~ | |
| | Number of Downlink Slots | 59 | | |
| | Number of Downlink
Symbols | 6 | | |
| | Number of Uplink Slots | 18 | | |
| | Number of Uplink Symbols | 4 | | |
| Channel Allocation Si | Number of Special Slots | | | |
| CRB μ = 1
250 - | TDD Slot Allocation | DDDDDDDDDDDDD | | |
| 200 - | Modulation | 2560AM | ~ | |
| 100 - | | | OK Cancel | |

- Select **OK** to close the window.

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

		S	05 Ballinink Sides	UL Slot
1.25 ms	6 sym.	+		6 sym.

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

🖒 Generate 🛓 Generate & Downloa	d Carrier	Waveform Hardware	
🗰 Full-filled Config 🍯 DL Test Mode	el g ^{te} DL FRC Config	 Auto Frequency Offset 	[→ Export 89600 VSA Setup
+ - ₪ ✓ Carrier 0 (DL) BWP Setup Channel Setup	 General Enabled Frequency Offset Timing Offset Power Boosting Initial Phase Spectrum Control DC Punctured Window Beta Windowing Method Baseband Filter Cell-Specific 		 ✓ O Hz O s O dB O deg O deg O.01 Centered at Symbol Boundary ∨ ✓
	Cell ID		201

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

+ - 3	SS/PBCH DCI DL-SCH CSI-RS PRS I	RIM-RS LTE-Coexistence
✓ Carrier 0 (DL)	✓ SS/PBCH Block	
BWP Setup	Name	SS/PBCH0
	Enabled	
Channel Setup	Antenna Port Weight	
	Numerology	μ = 6: 960 kHz 🗸
	SS Block Pattern	
	Periodicity	10 ms 🗸
	Half Frame Index	0
	Lmax	64 🗸
	Shared Spectrum Channel Access	
	Active Indices	0:63
	Power Boosting of each SS Block	0,
	RB Offset by 60 kHz SCS	1024
	PSS Power Boosting	0 dB
Channel Allocation Sun	ımary	Frame 0 🗸 \mu = 6 🗸
CRB µ = 6		Di-SCHO D
140		DI-SCH0 S
120-2		SS/PBCH0
90		
60		
30 -		
0		
0 64 1	28 192 256 320 384	448 512 576 640 Slot

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.

🖒 Generate 🔺 Generate & Downl	oad	Carrier	Waveform Hardware						白
🗰 Full-filled Config 🏾 🔭 DL Test Mo	del 🚽 DLFR	C Config	Auto Frequency Offset	[→ Exp	ort 89600	VSA Set	qu		
+ - 0	SS/PBCH	DCI	DL-SCH CSI-RS PRS	RIM-RS	LTE-Co	existenc	e + -	۵	
✓ Carrier 0 (DL)	Name	Enabled	Slot		Symbol	BWP	PRB Allocation	RNTI	Coding
BWP Setup	DL-SCH0_D	2	0:58,80:138,160:218,240:298,3	20:378,4	0:13	BWP1	RAType1, 0:147	1	On
Channel Setup	DL-SCH0_S		59,139,219,299,379,459,5	39,619	0:5	BWP1	RAType1, 0:147	1	On

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

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

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

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

- Set Time Density to 4.

Noma	Enchlad	all sent	- O	lat	Killer		mbal	DIAID		DALT
Name	Enabled				00.030	Ъy	mbor	BWP	PRB Allocation	RNI
DL-SCH0_D	× .	0:58,80:1	38,160:218,	,240:298,3	20:378,4	- ():13	BWP1	RAType1, 0:147	1
DL-SCH0_S		59,1	39,219,299,	379,459,5	39,619	9	0:5	BWP1	RAType1, 0:147	1
✓ Modula	tion and (Coding			-		_	-	-	٦.
Channel	Coding					2				
MCS Tal	ble					Table !	5.1.3.1	1-2 (2560	(MA	
MCS					1	20				
TB Scali	ng Factor					1.0 ~				
xOverhe	ad					0 ~				
Coding I	Rate					0.666	50890			
Modulat	ion									
Transpo	rt Block Si	ze				12297				
BaseGra	ph									
Payload	Data					RNG			>	
V DMRS S	Settings									
DMRS-D	ownlink-r1	6				3				
n_SCID						0				
N_ID_0						Cell ID	F . 1			
N_ID_1					[Cell ID	ļ.]
DMRS P	owerBoos	ting				0 dB]
DMRS C	onfiguratio	on				Type 1	4			
DMRS D	uration					Single	Symb	\sim 10		
DMRS-a	dd-pos					1	1			
PDSCH	Mapping					Type A	~			
DMRS-ty	peA-pos					2 🗸				
DMRS N	apping Re	ference				CRBO	\sim			
Y PTRS S	ettings					_				
PTRS Er	nabled				1	2.2				
PTRS Pc	owerBoost	ing				0 dB				
PTRS po	ort(s)									
Frequen	cy Density	(K_PTRS)				2~				
Time De	nsity (L_P	TRS)				$4 \sim$				
PTRS RE	Offset					$00 \sim$				

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

SS/PBCH	DCI	DL-SCH	CSI-RS	PRS	RIM-RS	LTE-Co	pexistend	xē + -	6
Name	Enabled	l.	s	lot		Symbol	BWP	PRB Allocation	RNT
DL-SCH0_D		0:58,80:1	38,160:218,	240:298,3	320:378,4	0:13	BWP1	RAType1, 0:147	1
DL-SCH0_S	×	59,1	39,219,299,;	379,459,5	39,619	0:5	BWP1	RAType1, 0:147	1
TB Scali	ing Factor		_		1	.0 🗸			
xOverhe	ad				C	1 v			
Coding	Rate					166650390	626		
Modulat	tion					BenAM -			
Transpo	rt Block S	ize				2224			10
BaseGra	aph								1
Payload	Data							>	
V DMRS S	Settings								
DMRS-D	ownlink-r	16			0				
n_SCID)			٦
N_ID_0						Cell ID			1
N_ID_1						Cell ID			1
DMRS P	owerBoos	sting) dB			
DMRS C	onfigurati	on			1	iype 1 🗸			
DMRS D	uration				s	ingle Symb	ol ~		
DMRS-a	dd-pos)			Ť.
PDSCH	Mapping				1	iype A 🗸			
DMRS-ty	ypeA-pos				2	l v			
DMRS N	Apping R	eference			c	RB0 🗸			
Y PTRS S	ettings								
PTRS Er	nabled				V				
PTRS P	owerBoos	ting) dB			
PTRS po	ort(s))			
Frequen	cy Density	(K_PTRS)			2	×			
Time De	ensity (LLP	TRS)			4	× 🖉			
PTRS R	E Offset				Ċ	0 🗸			

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

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.

G Home 5G NR ×			
🕑 Generate 🛓	Carrier	Waveform	A
Export 89600 VSA Setup			
✓ Basic			
Total Number of Antennas		1	
Playback License Mode		PC License V	
Required License Version Date			
Waveform Comment			
3GPP Version		V16.6.0 (2021.06)	
User-Defined Sample Rate			
Sample Rate		2.21184 GShis	
Time Scale Factor			
Number of Radio Frames		1	
Subframe Offset		0	
Number of Subframes		10	
Slot Offset in Subframe			
Number of Slots in Subframe			
Total Sample Points		22116400	
Waveform Length			
Mirror Spectrum			
Phase Compensation		Off ~	
IQ Spectrum CCDF			
0			
20	a testa de deserva esta de la	s descent the second second second Million second administration of the second second second second second second	
-20			Spectrum
-40			
-60	and the second sec	med based of a studies of an an an all bases over the domestic based on the	
80			
-100	II.		
-1.11 GHz			1.11 GHz

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.

Analog Digital Captu	re Trigger	Playback Trigger	External Mixer	Extensio
Input Trigger Channel: 1	T			
Entry Channel: All 1				
Style		Delay:		
External	ę	0 s		1
Slope:		Level:		
Positive		500 mV		
Holdoff Style:		Holdoff:		
Conventional		0 s		
Time Criteria:		Time1:	Time2:	
Trigger Out				
Desired:		Actual:		
Trigger Out 1		Trigger Out 1		

- 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

		Show All
4 Misc		4
Adc Dither	Off	
Capture Bit Packing	Auto	-
Ext Reference Lock Bandwidth	15 Hz	-
External Trigger Location	Trigger 1 In	*
IF Path	2 GHz	
IF Path Auto	Manual /	luto
Instrument User Corrections	Off	
LO Dither	Off	
Microwave Path Control	Full Bypass	
Mixer Mode	Normal	
Phase Noise Optimization	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.

File Edit Control Source Input MeasSetup Trace Markers	Mindow Utilities Help	(Linearity)
		TYCHING
A cit specificit		
	Measû'î - Analyzer ? X Analog Digital Capture Trigger Playback Trigger External Mixer Extensions Measurement/Logical Channel:	
dB ////////////////////////////////////	Mixer Selection: V3050A Signal Analyzer Frequency Extender Harmonic Table: Harmonic Lo Doubler Min Freq Max Freq	Span 2 GHz TimeLen 382 0313 nSec
B: Ch1 Main Time 🔹	Input Attenuation:	• ×
	20 dB Cable IF Loss 0.26 dB D.A Mixer Paths: Aux IF Frequency: Normal USB Mixer USB Mixer detected Model: V3050A Serial Number: US62160117'	n, what yeed wat when the week when the stand of the second stand
авирк Start 0 Sec Trig Ch 1		Stop 381.64 nSec Trig Lvl 500 mV

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.

Meas01 - 5G NR De	mod Properties						?	X
Configuration Save As Quick Setup	Input & Antenna Quick Setups	Time Deco	de Advanced					
Carriers Bandwidth BWP Channel	Link Direction: Configure	Downlink + Add Carrier - Display: C	Uplink Allow Multiple	Mixed Carrier Definitions				
SS/PBCH PDCCH	¥ 000	Cell ID	Bandwidth FR2 2000 MHz	Carrier Center	Frequency for Phase Compensation Disabled	Tx DC Freq.		
CSI-RS RIM-RS Results & Filters	Open Test Model Cross-Correlated F Enabled	VM Configure	1					

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.

Configuration	Input & Antenna	Time Dec	code A	dvanced			1
- Save As Quick Setup	Quick Setups	¢C0;CD0 •					
Carriers			ID	Numerology	RB Offset	RB Number	
Bandwidth		Initial-DL-BW	1	μ = 6 : 960 kHz =	0 RB	273 RB	-
BWP	L.	DL-BWP	2	u = 6 : 960 kHz	0 RB	273 RB	
Channel		DL-BWP		μ = 6:960 kHz =	0 RB	273 RB	
SS/PBCH			-	Numerology	PP Offert	DD Number	
PDCCH		✓ Initial-UL-BW	2 0	μ = 6 : 960 kHz -	0 RB	148 RB	
CSI-RS RIM-RS Results & Filters	CORESETs Add CORESET	Remove CO	RESET				•
CSI-RS RIM-RS Results & Filters	CORESETS Add CORESET CORESET: CORESET ID:	Remove COP	RESET	BWP1 +			
CSI-RS RIM-RS Results & Filters	CORESETs Add CORESET CORESET: CORESET ID: Symbol Numb	Remove CO 0 1 2 2 2	RESET	BWP1 + • DMRS Scramb	əling ID:	-1	
CSI-RS RIM-RS Results & Filters	CORESETs Add CORESET CORESET: CORESET ID: Symbol Numb	Remove CO 1 1 1 1 1 1 1 1 1 1 1 1 1	BWP ID:	BWP1 - DMRS Scramb CCE To REG M	oling ID: Happing Type:	-1 Non-interleaved	
CSI-RS RIM-RS Results & Filters	CORESETs Add CORESET CORESET: CORESET ID: Symbol Numb RB Offset-RI6: Allocated PB (Remove COI	BWP ID:	BWP1 + DMRS Scramb CCE To REG M	olíng ID: Napping Type:	-1 Non-interleaved	-

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



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

A: Summary *	
Analyzed Subfrance	7040 ments to 1040 men0003
Channel Primer	[arc/s/m] 10 [arc/s/mas]
Channel Power (Active)	13.07 dBm
OFOMSym Ty Power	13.04 (Rev)
EVM	2 7805 Skrins
EVMPK	11 243 %ok
Mag Err	1.944 %ms
Mag Err Pk	-9 808 3 m
Phase Err	0.0343 deg
Phase Err Pk	-0.777 dea
Frequency Error	38148 Hz
Frequency Error Worst	6.4285 Hz
Symbol Clock Error	0.0044 ppm
IQ Offset	56124 dB
IQ Gain Imbalance	***
IQ Quad Error	***
IQ Timing Skew	**
Time Offset	-36.859 ns
Sync Correlation	99.527 %
Sync Source	P55, 555
Cell ID	201
Ordented CODIE	

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

Save As Quick Setup	Quick Setups	CC0 : CD0 👻		
Carriers	SS/PBCH			
Bandwidth	Lmax		SSB Transmitted:	
BWP	✔ Auto Detect Act	ive Block	Det Power Threshold:	
Channel SS/PRCH	RB Offset(60kHz):	1024 RB	Numerology:	
PDCCH			SCS Common:	
PDSCH	Periodicity:		Half Frame Index:	
CSI-RS	230.4 MHz bandwid			
RIM-RS Results & Filters	Power Boosting PSS power boosti	ng 0 dB	PBCH power boosti	ng 0 dB
	3GPP Version: P.			

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.

Source Ar Outer Seture								
Save As Quick Setup	Quick Setups							
Carriers	Add PDSCH Remove P		Enable Channels					
Bandwidth	PDSCH:							
BWP								
A Channel	☑ Enabled BWP II	D BWP1 - RNTI:	1 3GPP V	ersion: R17 Late	est (2022-09) 🔫			
SS/PBCH	Modulation and C	ading Time (Frag	Allecation				-	
PDCCH	Modulation and C	-	Time/Free Allocation					
PDSCH	RV Index:	0	Frame Period:	1 Frames				
CSI-RS	MCS Table:	Table 256QAM -	Allocated Slots:	0:58,80:138,160	:218,240:298,320:378,400:458,48	0:538,560:618		
RIM-RS	MCS:	20	Slot Format:	0: D,D,D,D,D,D,	D,D,D,D,D,D,D,D		-	
B IL B CH	TB Scaling Factor S:	1 *	DEX Symbols:					
Results & Filters	xOverhead:	0 -	Mapping Type	ТуреА	- TypeA Pos:	Pos2		
	Target Code Rate:	0.66650390625	First Symbol:	0	Last Symbol:	13		
	Modulation:	QAM256	Resulting Format:	DDDDDDDDDDDD				
	Transport Block Size:	122976	RB Ref CORESET ID:		- RA Type:	Type1		
	Transport Block 2	۲	RB Offset:	0 RB	RB Number:	148 RB		
	no Source	Cell ID	RA Configuration:		▼ RBG Size [P]:			
	Dip	201	Allocated RBGs:					
	CORESET ID:	-1 +	VRB-To-PRB Mapping:	Non-Interleave	d 👻 VRB-To-PRB Interleaver:			
	Custom ModFormat:	Off -	Rate Match Patterns:	None	Edit			
				← BWP Max RB: 148 → →				
					Unused RBs Allocated RE	3s		

👭 PATHWAVE 🖻 File 🗸 🗮	System ~	省日	2 8					~ {Ç}	? ~
$\widehat{}$ Home 5G NR $^{ imes}$									
🖒 Generate 🔺 Generate & Downlo	ad	Carrier	Waveform						
₩₩ Full-filled Config 🎽 DL Test Mod	el 🛱 DL FR	C Config	🚸 Auto Frequency	/ Offset	[≁ Exp	ort 89600	VSA Set	цр	
+ ~ t a	SS/PBCH	DCI	OL-SCH CSI-RS	PRS	RIM-RS	LTE-Co	existenc	e -	
✓ Carrier 0 (DL)	Name	Enabled	Slo	ot		Symbol	BWP	PRB Allo	ocation
BWP Setup	DL-SCH0_D	S	0:58,80:138,160:218,2	40:298,320	:378,4	0:13	BWP1	RAType	1, 0:147
Channel Setup	DL-SCH0_S		59,139,219,299,3	79,459,539,	,619	0:5	BWP1	RAType	1, 0:147
	Scrambli RNTI n_ID V Transmi DMRS pc PRB Bun User Def Number Number Antenna Number Vumber V Resourc	ssion Sett ort(s) dle Size ined Precor of Layers of Antenna Port(s) Ger of DMRS C of Codewo ee Allocatio	ings ding ports nerated DM <mark>I</mark> groups without dat rds on		✓ 1 Ce Wi 1 1 1 1 1 1	all ID deband \	*		

18. Scroll Down to RS Sequence and set:

- DMRS AddPos to Pos1
- Select Enable PTRS

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

- LPTRS to 4

Configuration Save As Quick Setup	Input & Antenna Time Quick Setups CC0 ;	Decode Adva	anced				
Carriers Bandwidth BWP Channel SS/PBCH PDCCH PDSCH CSI-RS RIM-RS Results & Eithers	Add PDSCH Remove P PDSCH: 0 Transport Block Size: Transport Block 2 np Source np CORESET ID: Custom ModFormat:	09CH Clear All - 122976 Cell ID - 201 -1 - Off -	Enable Channels RB Ket CORESETID: RB Offset: RA Configuration: Allocated RBGs: VRB-To-PRB Mapping: Rate Match Patterns:	-1 0 RB Config1 Non-Interleaved None	KA lype: RB Number: RBG Size [P]: VRB-To-PRB Interleaver Edit BWP Max RB: 148 – BWP Max RB: 148 – 111 Allocated R	Type1 148 RB 16 16 85	
	Antenna Port						۲
	RS Sequence DMRS Config DMRS Max Length	Type1 -	DMRS-Downlink-r16		Enable PTRS KPTRS 2		•
	DMRS Length	Single-Symbol -	Nscid: 0		LPTRS 4		
	DMRS AddPos	Pos1 -	N _D ⁰ 0		PTRS RE Offset 0	0	
	DMRS Map Ref DMRS Init Option:	CRB0 •	N _{ID} ¹ 0 DMRS Init: 0		AdditionalDMRS-DL-A	Alt	

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

Configuration I	nput & Antenna 👘 Time	Decode	Advanc	ted					
Save As Quick Setup	Quick Setups	CD0 ·							
Carriers Bandwidth BWP	Add PDSCH Remove P PDSCH: 0	DSCH Clear	All	Enable Channels					
▲ Channel SS/PRCH	Modulation and C	oding Tim	e/Freq A	Allocation					\odot
55/P0CH	Modulation and Codin	g		Time/Freq Allocation					
PDCCH	RV Index:	0		Frame Period:	1 Frames				
PDSCH	MCS Table:	Table 256QA	м –	Allocated Slots:	59:80:619				
CSI-RS	MCS:	20		Slot Format:	0: D,D,D,D,D),D,D,D,D	,D,D,D,D,D		
RIM-RS	TB Scaling Factor S:	1	*	DL X Symbols:					
Results & Filters	xOverhead:	0	Ŧ	Mapping Type	ТуреА		TypeA Pos:	Pos2	
	Target Code Rate:	0.6665039062	Ś	First Symbol:	1		Last Symbol:	5	
	Modulation:	QAM256		Resulting Format:	DDDDDDDDDDD				
	Transport Block Size:	43032		RB Ref CORESET ID:	-1		RA Type:	Type1	
	Transport Block 2		۲	RB Offset:	0 RB		RB Number:	148 RB	
	n _{ID} Source	Cell ID		RA Configuration:					
	no			Allocated RBGs					
	CORESET ID:	-1		VRB-To-PRB Mapping:	Non-Interle	aved -	VRB-To-PRB Interleaver:		
	Curtan MadEormati	Off		Rate Match Patterns:	None		Edit		
	Custom wour onnat.	OII		BWP Max RB: 148					
						Unu	37 74 111 Ised RBs ■Allocated RB	5	

20. Scroll Down to RS Sequence and set:

- DMRS AddPos to Pos1
- Select Enable PTRS

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

- LPTRS to 4

Configuration	nput & Antenna Time	Decode A	dvanced			
Carriers Bandwidth BWP Channel SS/PBCH	Add PDSCH Remove P PDSCH: 0 Transport Block Size: Transport Block 2 pp Source	DSCH Clear All 43032	Enable Channels RB Ret CURE RB Offset: RA Configura	sel ID: -1 0 RB ttion: Config1	 KA lype: RB Number: RBG Size [P]: 	iype1 - 148 RB 16
PDCCH PDSCH CSI-RS RIM-RS Results & Filters	n _{ID} CORESET ID: Custom ModFormat:	201 -1 Off	Allocated RBI VRB-To-PRB Rate Match P	BB Mapping: Non-Inter atterns: None	leaved ✓ VRB-To-PRB Inte Edit ← BWP Max RB: 37 Unused RBs ⁷⁴ Alloc	rleaver: n2 → 148
	Antenna Port RS Sequence DMRS Config	Туре1	DMRS-Downli	nk-r16	Enable PTRS	6
	DMRS Max Length DMRS Length	1 - Single-Symbol -	N _{ID} ^{DMRS} Source Nscid:	Cell ID	- KPTRS LPTRS	2 -
	DMRS AddPos	Post -	NID ⁰		PTRS RE Offset	00 +
	DMRS Init Option:	NR Standard -	N _{ID} DMRS Init:			S-DL-Alt

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.

Meas01 - 5G NR D	Demod Properties			?	×
Configuration	Input & Antenna	Time	Decode	Advance	d
Analysis Region					
Result Length:	4 Subframes	0 Slots	at µ	6 4 ms	
Meas Offset:	0 Subframes	0 Symbols	at µ	6	
Meas Interval:	1 Subframes	0 Symbols	at µ	6	
Time Scale Facto	1				
Analysis Start Bou	undary	Acquis	ition Mode		
Frame		O No	rmal		
Half-frame		O Rec	luced acqu	isition leng	yth
O Subframe		© Fra	me trigger	is present	
O Slot		Slo	t trigger is	present	
First Slot Index:	0 at j	μ6 ι	Jse Periodio	Trigger	
Time/Spectrum/G All Enabled Char EVM includer	CCDF Data Source				
Timing Diagram					
	Result Length 4	Subt.	->		
			-		
	-		→ Meas	. Interval 1	:0
				. Offset 0:0)
Frame Bo	bundary				

- 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.

Tracking:	Equalizer Training		
Amplitude	Signal Source: RS+Dat	ta 🕂	
Phase Timing	Time Basis: Per Frame	-	
Tracking Source: RS+Data -	🔲 Freq Moving Avg. Fil	ter 19 RS	
EVM Window and Symbol Timing		Transient Period	
EVM Window Length Mode: 3GPP		Excluded	
EVM Window Length in Samples: 72 sa	mples	Length:	
Symbol Time Adjustment Mode: Max	of EVM Window Start/End =		
% of FFT Duration: -3.12	5 %	Power Change Threshold:	10 dB
Signal Repetition Pattern			
Repetition Pattern: Standard - F	irst Slot: 0		
IQ Impairments			
IQ Imb. Estimation Mode: Off	Compensate IQ limb.		
Compensate IQ Offset	DC Punctured		
UL Spectrum Flatness			
Spectrum Flatness Enabled			
Test Environment Conditions 11	- Test Tolerance: 1.4 dl	В	

- **23.** Close the 5G NR Demod Properties window and select Control > Restart to restart the measurement.
- 24. View the results of the measurement. Try to improve EVM by adjusting the Mechanical Attenuation setting until the OV1 indicator goes away in the IF Gain and Mechanical Attenuation settings in the Input > Extensions and the Input > External Mixer windows.

For this example, the optimum settings were Input Attenuation set to 8 dB and IF gain set to -12 dB.



Other X-Series Signal Analyzer Measurements Using the X-Series Analyzer's SCPI Recorder Function

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.



Other X-Series Signal Analyzer Measurements Using the X-Series Analyzer's SCPI Recorder Function

 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.

= *** E	- ●	ps : 5G NR		Trigs T	
🐣 Generate		Carrier Waveform			
🚥 Full-filled Config	T* DL Test Model 🕼 DL FRC Config				
-t ete. Conter 0 (DL)	Bandwidth	FR1 100MHz	~	NR-FR1-TM3.1b Output power dynamics	
	Numerology	μ = 1: 30 kHz	×	 Total power dynamic range (upper OFDM symbol power limit at max power with all 1024004M PRBs 	
	> Duplex Type			allocated) • Transmitted signal quality • Frequency error	
	Test Model	NR-FR1-TM3.1b	~	 EVM for 1024QAM modulation (at max power) 	
	Phase Compensation	Auto	~		
💛 Channel A	DCI/DLSCH Payload Data	PN23	*		
CRB µ = 1 273 - 250 -					
200					DL-SCH1
150					
50 -				OK Cancel	

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

G Home	5G NR ×			
🕑 Generate	±	Carrier	Waveform	5
Export 89	600 VSA Setup			
✓ Basic				
Total Num	ber of Antennas		1	
Playback I	License Mode		PC License 🗸	
Required I	License Version Date		2023,0201	
Waveform	Comment			
3GPP Vers	sion		V16.6.0 (2021-06)	
User-Defin	ied Sample Rate			
Sample Ra	ate		2.21184 GSn/s	
Time Scal	e Factor		1	
Number of	f Radio Frames		1	
Subframe	Offset		0	
Number of	f Subframes		10	
Slot Offse	t in Subframe			
Number of	f Slots in Subframe			
Total Sam	ple Points		22116480	
Waveform	Length			
Mirror Spe	ectrum			
Phase Cor	mpensation		off ~	
IQ SI	ccDF			
	- Second Street	and the first sector deduces in sector of	streets and the second second second with the second second second second second second second second second se	No.
-20				Spectrum
-40	Garan da <mark>ri</mark>			
- 60	n	and the second s	and a share a state of the second	
-80		Harter plant of them		
		Le de la Ma	the first of the state of	
-100				
120	1704			111.642
-0.	in Shiz			1.11 Sh2

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 > 0K.
- 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.

	\$
350000000	
Сору	
	€ 350000000 Copy

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 R	eference Frequency	
The paramete offset frequen	r sets the reference frequency of all the carriers. The center frequencies of carriers a cy from this value.	are defined as
Remote Command	<pre>[:SENSe]:CCARrier:REFerence <freq> [:SENSe]:CCARrier:REFerence?</freq></pre>	
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.

System Settings		SCPI Recorder	ょ	C ? X
System	Function Label	SCPI	1	Continuous SCPI Recording
I/O Config				
Preload / Unload Modes				250
User Interface				Piay
Power On				<u>D</u> onv
Restore Defaults				insert*0201
Alignmente				150yeDp
Aighments				Maye Down
Licensing				Dimete R/W
Security				Dittelt with
Diagnostics				
Service				
SCPI Recorder				

- From the context sensitive menu of the function key.

5G NR & V2X 1 Modulation Analysis	+						Meas S	etup 🔻 👯
	Input: Ext RF Coupling: DC Align: Off	Input Ζ: 50 Ω Corr CCorr RCal Freq Ref: Int (S)	Atten: 10 dB Pre: Int off, LNA off µW Path: Bypass	Trig: Free Run #IF Gain: Low	Carrier Ref Freq: 3.9 CC Info: DL, 1 CC, 9	50000000 GHz SISO		
1 CC0-BWP1 IQ Meas Time	*		#PNO: Best Wide 2 CC0-B Detected Scale/D	WP1 Allocations iv 328 subcarriers			Configure Preset Bandwidth 100 MHz	Settings
1.20 800 m 400 m			2.95 k 2.62 k 2.29 k 1.97 k			NO DATA	Frequency Range FR1	Radio Meas
-400 m -800 m -1.20			1.64 k 1.31 k 983 655				Duplex Mode TDD	Component Carriers
-5.948 3 CC0 Spectrum	¥	da k	328 5.948 Start: 0. 4 CC0 Raw Mai	00 symbols in Time		Stop: 1.00 symbols	SCS µ = 1: 30 kHz Auto	Meas Time
Scale/Div 10.00 dB -10.0 -20.0 -30.0 -40.0	Ref Value	0.00 dBm	Scale/D 0.00 -10.0 -20.0	iv 10.00 dB Ref	Value 10.00 dBm		Man RB Alloc Preset Fulfilled QPSK	Advanced
-50.0 -60.0 -70.0 -80.0 -90.0			-30.0 -40.0 -50.0 -60.0 -70.0				Remove from User	Menu
Ctr: 3.500000000 G Res BW: 100 Hz	Hz Info BW: 9	Wid 8.30 MHz	th: 110.6 MHz - ^{80.0} Start: 0.	00 ns		Stop: 22.00 ms	Help on this setting	
5 CC0 Frame Summa	ry ▼		6 Error S	Summary 🔻		_	Show SCPI Comm	and
EVM P	ower per RE Nu	m.RB	Channe EVM (F	el Power (Active / Total) RMS / Peak)	CC0		Add to SCPI Recor	der
			Freque Symbo IQ Offs Time C Sync C Sync S	ncy Error (RMS / Worst I Clock Error et (SISO) iffset orrelation ource)/		Start SCPI Record	er

- 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.

System Settings		SCPI Recorder	าc ? X
System	Function Label SCPI		Continuous SCPI Recording
I/O Config			Off
Preload / Unioad Modes			250
User Interface			Flavi
Power On			Donv
Restore Defaults			insent DRG.
Alianments			- Nove Dp
Algrimenta	e e e e e e e e e e e e e e e e e e e		Maye Down
Licensing			Driets Roy
Security			Deep wi
Diagnostics			
Service			
SCPI Recorder			

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.

5G NR & V2X Modulation Ana	1 alysis	+		a second and	Meas Setu	p 🕇 🔆
	Input: RF Coupling: AC Align: Off	Input Z: 50 Ω Atte Corr CCorr RCal Prea Freq Ref: Ext (S) μW #PN	n: 14 dB (e4) Trig: Free Run amp: Off #IF Gain: Low Path: Standard IO: Best Wide	Carrier Ref Freq: 3.500000000 GHz CC Info: DL, 1 CC, SISO	Configure Preset	
1 CC0-BWP1 IQ Meas Time I-Q			2 CC0 Raw Main Time Scale/Div 10.00 dB		Bandwidth 100 MHz	Settings Radio
1.20 800 m			Group	Configuration	Frequency Range FR1 •	Meas Standard
0 -400 m			Fulfilled	DL NR-TM3.1 (64 QAM)	Duplex Mode TDD •	Componen Carriers
-800 m -1.20 -1.60			DL NR-TM1.1	DL NR-TM3.1 (16 QAM)	SCS μ = 1: 30 kHz	Meas Time
-3.624		4	3.624 DL NR-TM1.2	DL NR-TM3.1 (QPSK)	Auto Man	Channel Profile
3 CC0 Spectrum Scale/Div 10.0	v 0 dB Ref Value	0.00 dBm	DL NR-TM2	DL NR-TM3.1a (256 QAM)	RB Alloc Preset Fulfilled QPSK	Advanced
-10.0			DL NR-TM3.1	DL NR-TM3.1b (1024 QAM)	Advanced Preset Parameters	Decode
-30.0 -40.0 -50.0 -60.0 -70.0 -80.0 -80.0		Alexalization press, parametric and straining	DL NR-TM3.2 DL NR-TM3.3		CP-OFDM Apply Preset (to All CCs)	Power Meas
Ctr: 3.5000000 Res BW: 100 F	000 GHz Hz	Width: 110.6	MH	OK Cancel		

6. Select Apply Preset (to All CCs).

5G NR & V2X Modulation Ana	1 alysis	+					\$	Meas Setu	p 🔻 💥
	Input: RF Coupling: AC Align: Off	Input Z: 50 Ω A Corr CCorr RCal F Freq Ref: Ext (S) μ #	atten: 14 dB (e4) Preamp: Off W Path: Standard PNO: Best Wide	Trig: Free Run #IF Gain: Low I	Carrier I CC Info	Ref Freq: 3.500000000 GHz DL, 1 CC, SISO	Configur	e Preset	
1 CC0-BWP1 IQ Meas Time I-Q			2 CC0 Raw Ma Scale/	ain Time Div 10.00 dB			Bandwic 100 MH	ith z v	Settings
1.20 800 m			0.00 -10.0 -20.0		, blieffield, er en be	an a Malikan Sani Sani ya Sani ya Kani ya Kanan Ya	Frequen FR1	cy Range ▼	Meas Standard
0 -400 m -800 m			-30.0 -40.0 m -50.0	dheatadh ha an		<mark>a parti a parti a dal da parti da parti</mark>	Duplex I TDD	Mode •	Component Carriers
-1.20 -1.60			-80.0 -70.0 -80.0				μ = 1: 3 μ = Δut	0 kHz 🔹	Meas Time Channel
-3.024 3 CC0 Spectrum Scale/Div 10.0	v 00 dB Ref Value	0.00 dBm	4 Error	Summary V		Stop: 22.00 ms	Mai RB Alloc Fulfilled	n Preset QPSK v	Profile Advanced
-10.0			EVM Erecu	nel Power (Active / (RMS / Peak) Jency Error (RMS /	Total) ·	-10.29 dBm / -10.29 dBm /	K Advar Pa	nced Preset rameters	Decode
-40.0 -50.0 -60.0 -70.0		stats and the other estimation between the second	IQ Off Time	ol Clock Error iset (SISO) Offset			CP-OFD App (to	M bly Preset All CCs)	Power Meas
-80.0 -90.0 Ctr: 3.5000000	000 GHz	Width: 11	0.6 MHz Sync	Correlation Source itude Error					
Res BW: 100 H	z		Filast						



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".

System Settings		SCPI Recorder	ち	C ? X
System	Function Label	SCPI		Continuous SCPI Recording
I/O Config	Active Mode & Measurement	:INST:CONF:NR5G:EVM		On Off
Preload / Unload	Query Operation Complete	*OPC?		Recording Limit 250
User Interface	Measurement Switch	:CONF:EVM:NDEF		Play
Power On	Query Operation Complete	*OPC?		Сору
Restore Defaults	Carrier Reference Frequency	:SENSe:CCARrier:REFerence 350000000		meen 19P07
Alizzanta	RB Alloc Preset	:SENSe:RADio:STANdard:PRESet:RBALloc DLTM3DOT1B		Move Up
Alignments	Apply Preset (to All CCs)	:SENSe:RADio:STANdard:PRESet:IMMediate		Move Down
Licensing	Optimize EVM	:SENSe:EVM:OPTimize		Delete Row
Security	Sween / Messure			Delete All
Diagnostics				
Service	Restart	:INITiate:RESTart		
SCPI Recorder				

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.

System Settings		SCPI Recorder	ょ	C ? X
System	Function Label	SCPI		Continuous SCPI Recording
I/O Config	Active Mode & Measurement	:INST:CONF:NR5G:EVM		On Off
Preload / Unioad Modes	Query Operation Complete	*OPC?		Recording Limit 250
User Interface	EVM Optimization Method	:SENSe:EVM:OPTMethod ITERative		Play
Power On				Сору
Restore Defaults				Inser CPC
Alignments				Move Down
Licensing				Delete Row
Security				Delete All
Diagnostics				
Service				
SCPI Recorder				

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.

Ctr: 3.500000000 GHz	Width: 110.6 MHz	Magnitude Error	0.24 %	
Res BW: 100 Hz		Phase Error	0.00 rad	
	? Mar 22, 2023 11:26:20 AM			



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.

Recall	SCPI Recorder	Recall from File		ちつ?	X
State	Computer D: U	Jsers Instrument Documents ScpiRecording		Mode 5G NR & V2X	V
Screen Config + State	Name	△ Date	Size Content		
Correction	5GNR 100 MHz way	veform .tx 3/22/2023 11:41 AM	60 B Txt file		
Complex Correction					
Recording					
SCPI Recorder					
Recording + State					
Demod Info					

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**.

System Settings				F	Preload / Unioad Mode	s	5	? ۲	×	
System	To redu startup.	To reduce the analyzer startup time, check only the Modes you want to preload. Selected (checked) Modes will be preload at the next startup.								
I/O Config	If you e	ncounter	out of m	emory error, unload unused Mo	odes. It helps you keep	o using the analyzer prog	ram withou	it having to	estart it.	
Preload / Unload	Power On Mode			Spectrum Analyzer v						
Modes	Preload	Loaded	Unload	Mode	:INST:SEL	Preload: Select All				
User Interface	1	0		Spectrum Analyzer	SA	Preload: Deselect All				
Power On				Real-Time SA	RTSA	Move Up				
Restore Defaults				EMI Receiver	ЕМІ	Move Down				
Alignments		e		IQ Analyzer	BASIC	Unload				
Licensing		0		WCDMA	WCDMA					
Security				GSM/EDGE	EDGEGSM					
Diagnostics				Phase Noise	PNOISE					
Service				Noise Figure	NFIG					
SCPI Recorder		0		Analog Demod	ADEMOD					
				Bluetooth	ВТ					

- 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" on page 292
 - "Setting Up Triggers on the Signal Analyzer using 5G NR Mode" on page 292
 - "Setting Up a 1 CC 28 GHz EVM Measurement" on page 294
 - "Setting up an 8 CC 28 GHz EVM Measurement" on page 301
 - "Setting Up a 1 CC 3.5 GHz ACP Measurement" on page 311
 - "Using PathWave N7631APPC to Create a Waveform File then Automatically Configure the Analyzer to View the Results" on page 316



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

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.

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.



NOTE

NOTE

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.

	Enabled	Signal Mode	Frequency Offset	Attenuation	Status	
1		File: No file selected				>
		None				>
		None				>
		None				>
		None				>
		None				>
		None				>
		None				>
Fading					Remaining Sample Rate:	3.000000000000000 GHz

- 5. In the Vector Modulation Signal Setup:
- 2- Θ G > Group 1: Signal Summary > Signal 1: Setup General Mode Signal Attenuation Waveform File 0 dB Waveform File Mute Frequency Offset Power Trigger 0 Hz 0 dB Markers Sample Rate 3.000 000 000 000 000 GHz **Reset Phase Accumulator**

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.

Group 1: Signal 1: Select Waveform File for Playback	A C: > Users > jacquipa > Documents > Keysight > PathWave > Sig	gnalGenerator > Examples	×
Recent	Name A	Date Modified	
Waveforms	4000_SampleIQPulseOnOff_50%_wfm.csv	May 8, 2020, 10:55:50 AM	Delete
This Computer	5G_100MHz_1CC_FR1.wfm	Aug 22, 2021, 11:43:56 PM	🗋 Rename
	5G_100MHz_8CC_FR2.wfm	Aug 22, 2021, 11:44:04 PM	Clear Arb Memory
	5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC Punctured.wfm	Jul 10, 2019, 6:47:40 PM	manory
	5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DC Punctured_28GHz.wfm	Jul 14, 2019, 7:07:46 PM	
	5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_1.wfm	Nov 20, 2022, 11:17:24 PM	All Formats 🗸
	5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_28GHz.wfm	Jul 14, 2019, 7:05:20 PM	Select

d. Select the General tab > Enable.

	Group 1: Signal Summary	> Signal 1: Setup
General Waveform File Trigger Markers	Mode Waveform File Frequency Offset O Hz Sample Rate 122.880 000 000 MHz Reset Phase Accumulator	Signal Attenuation O dB Power O dB

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.

	⊕ ⊝ ⋒	> Output 1: Adjustments
General	I/Q Common Delay	Optimizations
I/Q Adjustments	0 s	👽 Optimize Dynamic Range with OBW
AWGN	Swap I & Q	Enable System RF Flatness Correction

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:

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.

 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

NOTE

Recall	C Demod Info	Recall from File		50?>	<
State	Computer D: Users Instrument Documents	ight angleNR5G $ ight angle$ data $ ight angle$ Example setup	demo files Mo	de 5G NR	V
Screen Config + State	Name		∆ Date	Size Content	
Correction	4-carrier_APSK.scp		1/30/2020 10:56 AM	402 KB Scp file	
Complex Correction	4-carrier_APSK.setx		1/30/2020 10:56 AM	594 KB Setx file	
Recording	5G_100MHz_8CC_FR2.scp		3/3/2021 10:51 PM	431 KB Scp file	
Recording + State	5G_MIMO.setx		1/30/2020 10:56 AM	133 KB Setx file	
Demod Info	5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC	Punctured.scp	9/21/2018 3:53 PM	274 KB Scp file	
	5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC	Punctured.setx	8/30/2018 4:57 PM	90 KB Setx file	
	5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_D	C Punctured_28GHz.scp	2/21/2019 1:58 PM	455 KB Scp file	
	5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_D	C Punctured_28GHz.setx	2/21/2019 2:01 PM	131 KB Setx file	
	5GNR_2x2_MIMO_VXG_Scope_Updated.scp		5/15/2019 12:14 PM	74 KB Scp file	
	5GNR_2x2_MIMO_VXG_Scope_Updated.setx		5/15/2019 12:14 PM	135 KB Setx file	
	5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_C	orrected_28GHz.scp	2/21/2019 1:48 PM	455 KB Scp file	
	5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_D	C Punctured_28GHz.setx	2/21/2019 1:05 PM	131 KB Setx file	
	Jacquie.setx		8/23/2021 10:24 AM	131 KB Setx file	
	File name: Jacquie setx	File type: All S	Supported Files (* scp;* sgen;* nrcc;*	.pwsg,*.setx) Recall	D

- 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"

SIGNall ON

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

RF1:OUTPut ON

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

RFAL1:OUTPut ON

On the X-Series Signal Analyzer:

NOTE

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

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

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

MMEMory:LOAD:EVM:SETup CC0, "D:\Users\Instrument\Documents\NR5G\data\NR5GEvm\CarrierSetu p\5GNR_1CC_FR2_120kHz SCS_100MHz_256QAM_DCpunctured_28GHz.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.

	Enabled	Signal Mode	Frequency Offset	Attenuation	Status	
		File: No file selected				>
		None				>
		None				>
		Nane				>
		None				>
		None				>
7		None				>
		None				>

5. In the Vector Modulation Signal Setup:

General	Enable	Mode	Signal Attenuation
Waveform File		Waveform File 🗸 🗸 🗸	0 dB
Trigger	Mute	Frequency Offset	Power
Markers		0 Hz	0 dB
		Sample Rate 3.000 000 000 000 000 GHz	
		Reset Phase Accumulator	

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.

	Group 1: Signal Summary	> Signal 1: Setup
General Enable	Mode	Signal Attenuation
Waveform File	Waveform File 🗸 🗸	0 dB
Trigger Mute	Frequency Offset	Power
Markers	0 Hz	0 dB
	Sample Rate 122.880 000 000 000 MHz	
	Reset Phase Accumulator	

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.

 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.

Recall	C Demod Info	Recall from File			ッへ	? X
State	Computer D: Users Instrument Documents	NR5G data NR5GEvm CamerSetup	\rangle		Mode 5G NR	V
Screen Config + State	Name 🛆	Date	Size C	Content		
Correction	1CC_FR1_30kHz SCS_100MHz_256QAM_DC Punctured	1/7/2020 4:38 PM	90 KB S	Setx file		
Complex Correction	1CC_FR1_30kHz SCS_100MHz_256QAM_DC Punctured	1/7/2020 4:38 PM	6 MB V	Vfm file		
Recording	1CC_FR2_120kHz SCS_100MHz_256QAM_DC Puncture	1/7/2020 4:38 PM	131 KB S	Setx file		
Recording + State	1CC_FR2_120kHz SCS_100MHz_256QAM_DC Punctur	1/7/2020 4:38 PM	455 KB S	Scp file		
Demod Infa	1CC_FR2_120kHz SCS_100MHz_256QAM_DC Punctur	1/7/2020 4:38 PM	6 MB V	Vfm file		
	5G_100MHz_8CC_FR2.scp	3/3/2021 10:51 PM	431 KB S	Scp file		
	BCC_FR2_120kHz SCS_100MHz_256QAM_Corrected_28	1/7/2020 4:38 PM	131 KB S	Setx file		
	8CC_FR2_120kHz SCS_100MHz_256QAM_Corrected_;	1/7/2020 4:38 PM	455 KB S	Scp file		
	8CC_FR2_120kHz SCS_100MHz_256QAM_Corrected_2	1/7/2020 4:38 PM	49 MB V	Vfm file		
	A1_3.nrcc	6/18/2020 3:06 PM	58 KB N	Vrcc file		
	8CC_FR2_120kHz SCS_100MHz_256QAM_Corrected_8	1/7/2020 4:38 PM	153 KB S	Setx file		
	Signal_Studio_5G_100MHz_1CC_FR1.scp	2/12/2021 1:46 PM	67 KB S	Scp file		
	VXG_A1_3_Config.sgen	6/16/2020 10:53 AM	904 KB S	Sgen file		
	File name: 8CC_FR2_120kHz SCS_100MHz_256QAM_Con	rrected_28GHz scp		File type:	All Files (*.*)	Recall

- 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.

Component Carrier	CC0		
Sync Mode	CP Auto Correlation		
Multi-Carner Filter	iûn -	-	
Extended Frequency Lock Range	On Off		
DC Punctured	On Off		
DC Offset from CC Center	0 Hz	AUTO	
RF for Phase Compensation	0 Hz	AUTO	
Channel Power Threshold	-30.00 dB		
Report EVM in DB	On Off		
Time Scale Factor	1.0000		

5. Select 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.



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 "

SIGNall ON

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

IQO:CORR:CHANNel:FLATness ON

RF1:OUTPut ON

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

RFAL1:OUTPut ON

On the X-Series Signal Analyzer:

NOTE

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

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

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

Navigate to the desired waveform file.

MMEMory:LOAD:EVM:SETup CC0, "D:\Users\Instrument\Documents\NR5G\data\NR5GEvm\CarrierSetu p\8CC FR2 120kHz SCS 100MHz 256QAM Corrected 28GHz 34.scp"

EVM:CCARrier0:TIME:LENGth:SEARch 10ms

EVM:CCARrier0:TIME:LENGth:RESult 2

EVM:CCARrier0:FRAMe:TRIGger ON

EVM:CCARrier0:MCFilter ON

EVM:CCARrier0:DC:PUNCture ON

EVM:CCARrier0:PHASe:COMPensation:AUTO OFF

EVM:CCARrier0:PHASe:COMPensation:FREQuency 0 Hz

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.

=	III 🖻	• © 🤄	<u>ن</u>	Group 1: Signal Sur	unary				RF Out (All)	Tragent ? - Mean
	Enabled	Signal Mode			Frequency Offsi	et.	Attenuation	Status		
1		File: No file selected								>
		None								>
		None								>
		Nane								>
		None								>
		None								>
		None								>
		None								>
Fading	Enable							Re	maining Sample Rate:	3.000000000000000 GHz

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

	€	Group 1: Signal Summary	> Signal 1: Setup
General	Enable	Mode	Signal Attenuation
Waveform File		Waveform File 🛛 🗸 🗸	0 dB
Trigger	Mute	Frequency Offset	Power
Markers		0 Hz	0 dB
		Sample Rate 3.000 000 000 000 000 GHz	
		Reset Phase Accumulator	

- **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.

≡ ₩ ₽~ © @	Group 1: Signal Summary	> Signal 1: Setup
General Enable	Mode	Signal Attenuation
Waveform File	Waveform File 🗸 🗸 🗸	0 dB
Trigger Mute	Frequency Offset	Power
Markers	0 Hz	0 dB
	Sample Rate 122.880 000 000 000 MHz	
	Reset Phase Accumulator	

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
```

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.

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.



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"

SIGNall ON

DM:OPTimization:CHANnel ACP

RF1:OUTPut ON

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

RFAL1:OUTPut ON

On the X-Series Signal Analyzer:

SYSTem:PRESet

INSTrument:CONFigure: NR5G:ACP

CCARrier:REFerence 3.5GHZ

ACPower:CORRection:NOISe ON

Using PathWave N7631APPC to Create a Waveform File then Automatically Configure the Analyzer to View the Results

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

This example shows you how to create and analyze a 5G NR signal using the embedded PathWave software and then automatically configure the analyzer to make the measurement.

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

On the VXG:

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



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



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



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.

≡ Ⅲ ⊡~			
🖒 Generate	Carrier Way	veform	ū~
Export 89600 VSA Setu	qu		
Rented			The second se
basic	Subframe Offset	0	
Marker	Number of Subframes	10	
Crest Factor Reduction	Slot Offset in Subframe	N/A	
AWGN	Number of Slots in Subframe	N/A	
	Total Sample Points	1228800	
Routing	Waveform Length	10 ms	
	Mirror Spectrum		
	Phase Compensation	Auto 🐱	
	Radio Frequency	28 GHz	

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.

Bandwidth	FR2 100MHz	~
Numerology	µ = 3: 120 kHz	~
✓ Duplex Type		
Duplex Type	FDD	Ý
Modulation	256QAM	~

- 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.

🖒 Generate			Carrier Waveform		[+
🗰 Full-filled Config	g 🍸 → DL Test Model	dather DL FRC Config	🔹 Auto Frequency Offset	[→ Export 89600 VSA Setup	
+ •••	General	DC Punctured			
Carrier 0 (DL)	Spectrum Control	Window Beta		0.01	
	Cell-Specific	Windowing Method		Centered at Symbol Boundary $ \checkmark $	
	Downlink	Baseband Filter		•	

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.

🖒 Generate			Carrier W	/aveform		2∼
IIII Full-filled Confi	g 🏾 🕈 DL Test Model	DL FRC Config	🗢 Auto Frequency	Offset + Export 89600 VSA Setup		
+ ··· Carrier O (DL)	General Spectrum Control Cell-Specific	BWP SS/PBCH	SS/PBCH Block NR-PBCH MIB	Numerology SS Block Pattern Periodicity Lmax	μ = 3: 120 kHz ↔ Case D ↔ 10 ms ~ 64 ~	
	Downlink	DL-SCH CSI-RS LTE-Coexistence PRS		Shared Spectrum Channel Access Active Indices Power Boosting of each SS Block RB Offset by 60 kHz SCS	0.7 0.0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0	

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.

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**.

≣		₽]~	€		ŵ	> Configur	e Analyzer								RF OUT (All)	Trager	? •	Passal ~
The Mi the des)484C s ired sig	ystem works nal from the	with Key: source.	sight X-Sei	ries Sigr	nal Analyzers.	Once a remo	te signal ar	Auto Config Analy:	onnected, L	use the (Au	uto Configu	ire Analyzer] I	outton to aut	omatically set u	p the anal	yzer to n	neasure
		Click to acc	M9484C) e Interface				ß	Output Cl	hannel				c	Hick to change co	mnection		
															TCPIPhislip0	INSTR		

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 Key-

sight 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.

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.

TIP

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:SIGNall ON

RF1:OUTPut ON

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

RFAL1:OUTPut ON

6 5G NR Measurements Using the VSA Software

This section includes the following topics:

- "5G Waveform and EVM Analysis Using VSA Software" on page 326
 - "Setting Up a 1 CC 28 GHz EVM Measurement" on page 326
 - "Setting Up an 8 CC 28 GHz EVM Measurement" on page 339
 - "Creating a Basic 5G NR Signal Using PathWave N7631APPC Embedded Software" on page 349
 - "Creating a DL MIMO Signal Using PathWave N7631APPC Signal Generation" on page 369



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

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

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.
Ξ		► © €	Group 1: Sig	gnal Summary			RF Out (All)	Trigger	?- 🔤
	Enabled	Signal Mode		Frequency Offset	Attenuation	Status			
1		File: No file selected							>
		None							>
		None							>
		None							>
		None							>
		None							>
		None							>
		None							>
Fading	Enable					Remainir	ig Sample Rate:	3.0000000	100000000 GHz

5. In the Vector Modulation Signal Setup:

	Θ	Group 1: Signal Summary	> Signal 1: Setup
General	Enable	Mode	Signal Attenuation
Waveform File		Waveform File 🗸 🗸 🗸	0 dB
Trigger	Mute	Frequency Offset	Power
Markers		0 Hz	0 dB
		Sample Rate 3.000 000 000 000 000 GHz	
		Reset Phase Accumulator	

- **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.

Recent	🐥 🏴 🛅 C: > Users > jacquipa > Documents > Keysight > PathWave > SignalG	enerator > Examples	
Waveforms	Name ^	Date Modified	
This Computer	4000_SampleIQPulseOnOff_50%_wfm.csv	May 8, 2020, 10:55:50 AM	Delete
	5G_100MHz_1CC_FR1.wfm	Aug 22, 2021, 11:43:56 PM	🗋 Rename
	5G_100MHz_8CC_FR2.wfm	Aug 22, 2021, 11:44:03 PM	
	5GNR_1CC_FR1_30kHz_SCS_100MHz_256QAM_DC Punctured.wfm	Jul 10, 2019, 6:47:40 PM	
	SGNR_1CC_FR2_120kHz_SCS_100MHz_2560AM_DC Punctured_28GHz.wfm	Jul 14, 2019, 7:07:46 PM	
	SGNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_1.wfm	Nov 20, 2022, 11:17:24 PM	
	5GNR_8CC_FR2_120kHz_SCS_100MHz_256QAM_Corrected_28GHz,wfm	Jul 14, 2019, 7:05:20 PM	
	5GNR_UXR_Recording_28_GHz.csv	May 20, 2019, 3:29:44 PM	
	GSM_1C_BURST_SECUREWAVE.wfm	Jul 18, 2013, 11:49:36 AM	
Clear Arb Memory	File Properties Name SGNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DC Punctured_28GHz w Sample Rate: 122880000.0 Hz Scale: 85.0 Occupied Bandwidth. N/A Required License(s):	dm	

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

	Group 1: Signal Summary	> Signal 1: Setup
General Enable	Mode	Signal Attenuation
Waveform File	Waveform File 🗸 🗸 🗸	0 dB
Trigger Mute	Frequency Offset	Power
Markers	0 Hz	0 dB
	Sample Rate 122.880 000 000 000 MHz	
	Reset Phase Accumulator	

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

≡ ₩ ₽~ ©	Group 1: Signal Summary > Signal 1: Setup
----------	---

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.

	⊕ ⊖ ∩ >	Output 1: Adjustments
General	I/Q Common Delay	Optimizations
I/Q Adjustments	0 s	👽 Optimize Dynamic Range with OBW
AWGN	Swap I & Q	Enable System RF Flatness Correction

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.

 Select Recall (If accessing the signal analyzer remotely, select the Folder icon at the bottom of the display) Demod Info > Set Data Type to CC Setup > Recall From >

5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DC punctured_ 28GHz_34.scp > Recall

Recall	C Demod Inf	io	Recall from File	9	ッつ	? X
State	Corr	nputer $ angle$ D: $ angle$ Users $ angle$ Instrument $ angle$ Documents $ angle$ NR	5G data Example	setup demo files 〉	Mode 5G NR	▼
Screen Config + State	Name			△ Date	Size	Content
Correction	4-carrie	er_APSK.scp		1/30/2020 10:56 AM	402 KB	Scp file
Complex Correction	4-carrie	er_APSK.setx		1/30/2020 10:56 AM	594 KB	Setx file
Recording	5 G_10	0MHz_8CC_FR2.scp		3/3/2021 10:51 PM	431 KB	Scp file
Recording + State	5G_MI	MO.setx		1/30/2020 10:56 AM	133 KB	Setx file
Demod Info	5GNR_	1CC_FR1_30kHz_SCS_100MHz_256QAM_DC Punc	ured.scp	9/21/2018 3:53 PM	274 KB	Scp file
	5GNR_	1CC_FR1_30kHz_SCS_100MHz_256QAM_DC Punct	ured.setx	8/30/2018 4:57 PM	90 KB	Setx file
		1CC_FR2_120kHz_SCS_100MHz_256QAM_DC Pun	ctured_28GHz.scp	2/21/2019 1:58 PM	455 KB	Scp file
	5GNR_	1CC_FR2_120kHz_SCS_100MHz_256QAM_DC Pun	ctured_28GHz.setx	2/21/2019 2:01 PM	131 KB	Setx file
	5GNR_	2x2_MIMO_VXG_Scope_Updated.scp		5/15/2019 12:14 PM	74 KB	Scp file
	5GNR_	2x2_MIMO_VXG_Scope_Updated.setx		5/15/2019 12:14 PM	135 KB	Setx file
	5GNR_	8CC_FR2_120kHz_SCS_100MHz_256QAM_Correcte	ed_28GHz.scp	2/21/2019 1:48 PM	455 KB	Scp file
	5GNR_	8CC_FR2_120kHz_SCS_100MHz_256QAM_DC Pun	ctured_28GHz.setx	2/21/2019 1:05 PM	131 KB	Setx file
	Jacquie	e.setx		8/23/2021 10:24 AM	131 KB	Setx file
	File name:	Jacquie setx	File type:	All Supported Files (* scp;* sgen;*	.nrcc;*.pwsg;*.setx)	Recall

- 2. Select Meas Setup > Meas Time and set:
 - Search Length to 10 ms
 - Result Length to 2 Sub Frame
 - Frame Trigger to On
- **3.** Ensure that RF for Phase Compensation Auto is *not* selected and the value is **0 Hz**. **Close** the Advanced Settings table.
- 4. Select the Settings tab > Optimize EVM.

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

EVM should be less than 1%.



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:

NOTE

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

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.

 \ge II

- 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.

Ge Lu		_	1 mint	-
otyre: Estasoni			Level:	
external		те.,	T.A.	
Slope:			Delay:	
Positive			02	
Holdoff S	tyle:		Holdoff:	
Abovela				
Time Crit	eria:		Time1:	Time2:
		2	0×	0 s.
Criteria: Enter	,	*	Mask(s) to apply: Upper	
Window	Type:		RBW: Auto	
Macrop	(ampi acc)		BAU DODU KIMZ.	
IVIGANA	Frequency Offset	A	mplitude Offset	
Upper	0 Hz	0 dB		
Lower	0 Hz	0 d8		
				Edit
Trigger C	lut		-	
Desired:			Actual:	
Trigger	Dut 1		Tringer Out 1	

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.

and a signal capture migger	- ayout any get external		
ogical Instrument:		eset All	
		Sh	ow All
A Misc			*
Adc Dither	Off		
Capture Bit Packing	Auto		
Ext Reference Lock Bandwidth	15 Hz		
External Trigger Location	Trigger 1 In		
IF Path	1 GHz		
IF Path Auto	Manual Au	ito	
Instrument User Corrections	Off		
LO Dither	Off		
Microwave Path Control	Preselector Bypass		
Mixer Mode	Normal		
Phase Noise Optimization	Best Close In		-
Phase Noise Optimization	Best Close In		
Optimizes the phase noise distribution	Best Wide Offset		
situations. The frequency offset of the	Fast Tuning		
analyzer model	Balanced		
	Spur Avoidance		

- 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.
---	--------	-------	---------	----	----------

	Configuration	Input & Anten	na T	ïme	Decod	de	Advanced
	- Analysis Region -						
	Result Length:	5 Subframes	0 S	lots		at µ3	3 5 ms
	Meas Offset:	2 Subframes	0 S	ymbols		at µ3	3
Ì	Meas Interval:	3 Subframes	0 S	ymbols		at µ3	3
	Time Scale Factor	r. 1					
	Analysis Start Bou	indary		- Acau	isition N	/lode	
	~ -				lormal	7	
	Frame			OR	educed	 acqu	isition length
	 Half-frame 			• Fi	rame tri	aaer	is present
	Subframe			0.5	lot triac	ier is i	present
	⊖ Slot				iot ingg	,	
	First Slot Index:		at µ3				
	Timing Diagram						
				<i>.</i>			
			tn 5 Sub	ſ			
						Maac	Interval 2.0
					^	Meas	
	Frame Bo	oundary				wicas.	-Onset-2.0

- 7. From the toolbar, select the Auto-Range dropdown and select EVM-Table or Algorithm Based.
 - EVM Table or Algorithm Based performs EVM optimization based on prescribed table/algorithm instead of using EVM in the feedback loop. This method of EVM auto-range is normally faster than Meas Based Iteration, but may not achieve the most optimal setup for minimized EVM).
 - EVM Meas Based Iteration has a feedback loop around the entire measurement, uses the measured EVM in the feedback loop, and tries to adjust hardware parameters to minimize the EVM. It is the slowest EVM auto-range method, but it should achieve the most optimal setup for good EVM.



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



Using the equivalent SCPI commands

On the VXG:

SYSTem:PRESet

RF1:FREQuency:CW 28GHZ

RF1:POWer:AMPLitude 5dBm

SIGNal1:MODE WAVeform

SIGNal1:WAVeform "D:\Users\Instrument\Documents\MCS demo waveforms

5GNR_1CC_FR2_120kHz_SCS_100MHz_256QAM_DCPunctured_28GHz.wfm"

SIGNall 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.

=		• © 🤅 🏠	> Group 1: Signal Summi	ary		RF Out (All)	***** ? - ****
	Enabled	Signal Mode		Frequency Offset	Attenuation	Status	
1		File: No file selected					>
		None					>
		None					>
		None					>
		None					>
		None					>
		None					>
		None					>
Fading						Remaining Sample Rate:	3.00000000000000 GHz

5. In the Vector Modulation Signal Setup:

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

General	Enable	Mode	Signal Attenuation
Waveform File		Waveform File 🗸 🗸 🗸	0 dB
Trigger	Mute	Frequency Offset	Power
Markers		0 Hz	0 dB
		Sample Rate 3.000 000 000 000 000 GHz	
		Reset Phase Accumulator	

- **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.

	Group 1: Signal Summary	> Signal 1: Setup
General Enable	Mode	Signal Attenuation
Waveform File	Waveform File 🗸 🗸 🗸 🗸 🗸 🗸	0 dB
Trigger	Frequency Offset	Power
Markers	0 Hz	0 dB
	Sample Rate 122.880 000 000 000 MHz	
	Reset Phase Accumulator	

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

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**.

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.

Analog	Digital	Capture	Trigger	Play	yback Trigger	External Mix	er Extensions
Input Trig	ger Channe	el: 1					
Entry Ch	annel:	1					
Style					Delay:		
Free Run			•				
Slope:					Level:		
					2 V		
Holdoff	Style:				Holdoff:		
Time Crit	teria:				Time1:	Time	2:
Trigger (Dut						
Desired				4	Actual:		
Trigger	Out 1			• T	rigger Out 1		
✓ Display	/ Trigger Re	ference Line	on Active Tra	ace			

 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.)

al Instrument:		Preset Al
		Show All
A Misc		*
Adc Dither	Off	
Capture Bit Packing	Auto	
Ext Reference Lock Bandwidth	15 Hz	T = 1
External Trigger Location	Trigger 1 In	*
IF Path	1 GHz	*
IF Path Auto	Manual Auto	
Instrument User Corrections	Off	+
LO Dither	Off	
Microwave Path Control	Preselector Bypass	*
Mixer Mode	Normal	
Phase Noise Optimization	Best Close In	-
Phase Noise Ontimization	Best Close In	
Optimizes the phase noise distributio	Best Wide Offset	
situations. The frequency offset of th	e (Fast Tuning	
analyzer model	Balanced	

- 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.

Configuration Input & Anten	na Time Decode	Advanced			
Tracking Source: 3GPP	Freq Mov	ing Avg. Filter	19 RS		
EVM Window and Symbol Timing			Transient Period		
EVM Window Length Mode:					
EVM Window Length in Samples:	36 samples		Lenath:		
Symbol Time Adjustment Mode:			20.194.1		
% of FFT Duration:	-3.125 %		Power Change Thresh	hold: 10 dB	
IQ Impairments					
IQ Imb. Estimation Mode: Off		ate IQ Imb.			
Compensate IQ Offset	✓ DC Punctu	red			
UL Spectrum Flatness					
Spectrum Flatness Enabled					
Test Environment Condition: No	rmal 🔹 Test Tolerar	nce: 1.4 dB			
Error Vector Unit					
Time Domain: Per Symbol 🔻	Freq Domain: Per Subca	arrier 🔻			
MIMO Condition Number					
Control: Off RB C	iranularity: 1				
Auto Set Span		Report E	VM in dB		
Independent SSB/BWP Measurem	nent	Extend Fr	equency Lock Range	480 kHz	
Multicarrier Filter On		Compens	ate Symbol Clock Offs	et	
Per Slot Channel Frequency Respo	onse				

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 Autorange 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.



D. CC Sur								~
Di ce sui	ninary ·							~ ~
TAE Min	-58.208 p	os betwe	en CC4 a	nd CC0				
TAE Max	291.04 p	s betwe	en CC1 a	nd CC0				
cc	Channel Power (dBm)	Rel. Power (dB)	EVM (%rms)	TAE (sec)		Center Freq. (Hz)	Freq. Error (Hz)	Clo Err (pp
CC0(Ref.)	-5.86	0.00	0.739		0	11.65 G	-115.575 m	-0.0
CC1	-5.72	0.14	0.732	291.038	p	11.75 G	19.3616 m	0.(
CC2	-5.79	0.07	0.743	58.2077	p	11.85 G	45.8891 m	0.0
CC3	-5.87	-0.01	0.773	116.415	p	11.95 G	43.2913 m	0.1
CC4	-5.81	0.05	0.792	-58.2077	p	12.05 G	-891.232 µ	-0.(
CC5	-5.89	-0.03	0.806	-58.2077	p	12.15 G	44.2917 m	0.0
CC6	-5.90	-0.04	0.807		0	12.25 G	74.1079 m	-0.1
CC7	-5.87	-0.01	0.798	116.415	p	12.35 G	109.725 m	-0.1
	4			001				

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 "

SIGNall ON

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

IQO:CORR:CHAN:FLAT ON

RF1:OUTPut ON

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

RFAL1:OUTPut ON

On the X-Series Signal Analyzer

INSTrument:SELect VSA89601

MMEMory:LOAD:DEMO

"D:\Users\Instrument\Documents\NR5G\data\NR5GEvm\CarrierSetu p\1CC_FR2_120kHz_SCS_100MHz_256QAM_DC_Punctured_28GHz.setx"

INITiate: PAUSe

INPut:TRIGger:STYLe "External"

INPut:TRIGger:LEVel:EXTernal 1V

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

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

NR5G:RLENgth 10

NR5G:SUBFrame:INTerval 2

NR5G:FRAMe:TRIGger:ENABled 1

NR5G:CAGGregation:CONFigure "Contiguous8CC"

NR5G:DC:PUNCtured 1

NR5G:MCFilter:ENABled 1

FREQuency:CENTer 28 GHz

NOTE

INPut:ANALog:CRITeria:RANGe:AUTO "EVM", -1

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.

			RF Out (All)	Trigger ? ~ PRESET ~
🖒 Generate	Carrier Wave	form		₽~
Export 89600 VSA Setu	ip:			
Basic	Subframe Offset	0		
Marker	Number of Subframes	10		
Crest Factor Reduction	Slot Offset in Subframe	N/A		
AWGN	Number of Slots in Subframe	N/A		
Porting	Total Sample Points	1228800		
Routing	Waveform Length	10 ms		
	Mirror Spectrum	<u> </u>		
	Phase Compensation	Auto 🗸		
	Radio Frequency	28 GHz		

TIP

Phase Compensation is applied by default at baseband for RF up-conversion. This means the waveform generation is per the carrier frequency, unlike conventional Signal Studio waveforms, which are independent from carrier frequency. Phase Compensation is set to Auto by default. The frequency is coupled with the VXG frequency setting under the Instrument node. You can select Manual to specify a different frequency, or turn it off.

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

- 6. Select the Carriers tab.
- 7. Select the Full-Filled Config tab and set Bandwidth to FR2 100 MHz, Numerology to $\mu = 3:120$ kHz, 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.

Bandwidth	FR2 100MHz	~
Numerology	μ = 3: 120 kHz	~
 Duplex Type 		
Duplex Type	FDD	~
Modulation	256QAM	~

- 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.

🖒 Generate			Carrier W	/aveform		₽~
IIII Full-filled Confi	g 🛛 🕇 DL Test Model	DL FRC Config	🗢 Auto Frequency	Offset - Export 89600 VSA Setup		
+ ···· Carrier 0 (DL)	General Spectrum Control Cell-Specific	BWP SS/PBCH DCI	SS/PBCH Block NR-PBCH MIB	Numerology SS Block Pattern Periodicity Lmax	μ = 3: 120 kHz ~ Case D ~ 10 ms ~ 64 ~	
	Downlink	DL-SCH		Shared Spectrum Channel Access	0.7	
		LTE-Coexistence		Power Boosting of each SS Block	0,	
		PRS		RB Offset by 60 kHz SCS	46	

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.

🖒 Generate			Carri	er Waveform		[← Import Signal Setup [+ Export Signal Setup
HIII Full-filled Con	fig 🍸 DL Test Mode	I 🖬 DL FRC Config	🗢 Auto Fr	equency Offset [+ Expo	rt 89600 VSA Setup	
	General	BWP	+	General Settings	Channel Coding	
Carner 0 (DL)	Spectrum Control	SS/PBCH		Transmission Settings	MCS	20
	Cell-Specific	DCI		Resource Allocation	MCS Table	Table 5.1.3.1-2 (256QAM). ~
		DL-SCH		Modulation and Coding	TB Scaling Factor	1.0 🗸
					Coding Rate	
		CSHKS		DMRS Settings	Modulation	
		LTE-Coexistence		PTRS Settings	Transport Block Size	
		PRS		HARO Settinos	RaseGranh	

11. Select Generate to generate the Waveform.

💍 Generate			Carrie	r Waveform		[← Import Signal Setup
HIII Full-filled Confi	g 🅈 DL Test Model	g" DL FRC Config	+ Auto Fre	quency Offset [+ Expor	t 89600 VSA Setup	
+ ••• Carrier 0 (DL)	General Spectrum Control Cell-Specific Downlink	BWP SS/PBCH DCI DLSCH CSI-RS	+ ••• DL-8CH D	Ceneral Settings Transmission Settings Resource Allocation Modulation and Coding DMRS Settings	Channel Coding MCS MCS Table TB Scaling Factor Coding Rate Modulation	20 Table 5.1.3.1.2 (258QAM) ~ 1.0 ~ 0 666502906225 2580 MAR ~
CRB μ = 3 66 60 50	Nocation Summar	LTE-Coexistence PRS y		PTRS Settings	Transport Block Size ReserCranh DL-Schin SubCa SS/RICH 12- 10-	rier DL-SCH0
40- 30- 20- 10- 0	16 24	32 40	48	56 64 72 I	8- 6- 4- 2- 0- 30 Slot	2 4 0 8 10 12 14 Symbol

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



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.

-			A 1997	-	
Style:			Level:		
External			1.1		
Slope:			Defay:		
Positive			03		
Holdoff S	tyle:		Holdoff:		
Abouts		8			
Time Crit	eria:		Time1:	Time2:	
			ūs-	-0 s	
Criteria: Enter Window Flat.Top	(Type: (amplacc)	+	Mask(s) to apply: Upper RBW: I Auto 580.6536 kHz		
IVIASKS -	Frequency Offset	A	mplitude Offset		
Upper	0 Hz	0 dB			
Lower	0 Hz	0 dB			
				Edit	
Trigger C	lut				
Desired:			Actual:		
Triager	Dut 1		Transer Out 1		

 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.

ical Instrument:		Preset
1	2	Show All
Misc	100	
Adc Dither	Auta	
Capture Bit Packing	Auto	
Ext Reference Lock Bandwidth	15 Hz	
External Trigger Location	Trigger 3 In	
Instrument User Corrections	0()	Ť
LO Dither	Off	
Microwave Path Control	Preselector Bypass	4
Mixer Mode	Normal	*
Phose Noire Oppinization	Best Wide Offset	
RF Input Port	RF Input	7
Signal Path	Auto	
ase Noise Optimization		
ase Noise Optimization	Auto	

- 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.

Configuration	Input & Antenna	Time Decode	e Advanced				
Save As Quick Setup	. Quick Setups	CC0 : CD0 🔻					
Carriers	Link Direction: 💿 D	ownlink O	Uplink O	Mixed			
Bandwidth	Configure +	Add Carrier	Allow Multiple Ca	rrier Definitions			
BWP							
 Channel 	Reference: CC0 🔻	Display: CCC) 🔻				
SS/PBCH		Cell ID	Bandwidth	Carrier Center	Frequency for Phase Compensation	Tx DC Freq.	
PDCCH	✓ CC0	V 0	FR2 100 MHz 🛛 👻	20 GHz	20 GHz 👻	✔ 20 GHz	\times
PDSCH							
CSI-RS	Open Test Model						
Results & Filters	Cross-Correlated EV	M Configure					

- Set Cell ID to 0

When the checkbox is selected, Cell ID auto-detection is enabled for the carrier.

NOTE

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

- Set Bandwidth to FR2 100 MHz
- 9. Select the Bandwidth panel and set Numerology to $\mu = 3:120 \text{ kHz}$

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.

Configuration	Input & Antenna	Time Deco	de Advanced	
Save As Quick Setup	Quick Setups	CC0: CD0		
Carriers Bandwidth	Bandwidth: FR2	100 MHz +		
BWP	Resource Grid			
Channel	Numerology	Grid Start	Grid Size	Grid Enabled
SS/PBCH	µ = 2 : 60kHz	0 RB	132 RB	
PDCCH	μ = 3 : 120kHz	0 RB	66 RB	1
PDSCH	μ = 4 : 240kHz:	0 RB	34 RB	
CSI-RS	Ref. Point A: -4	7.52 MHz at -47.5	2 MHz from center	
Results & Filters	Num. st Meas. Co.			Channels Chil -

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.

Save As Quick Setup	Quick Setups CC0 : CD0						
Carriers		D	Numerology		RB Offset	RB Number	
Bandwidth	Initial-DL-BWP (D	µ = 3 : 120 kH	łz –	0 RB	273 RB	
BIAD	DL-BWP 1	i	µ = 3 : 120 kH	łz +	0 RB	66 RB	
DW/P	DL-BWP 2	2	µ = 3 : 120 kH	łz +	0 RB	273 RB	
SS/PBCH	DL-BWP :	3	µ = 3 : 120 kH	łz –	0 RB	273 RB	
PDCCH		d	Numerology		RB Offset	RB Number	
PDSCH	✓ Initial-UL-BWP (0	$\mu=3:120\text{ kH}$	łz +	0 RB	66 RB	
CSI-RS Results & Filters	CORESETS Add CORESET Remove	CORESET					
	CORESET: 0 CORESET ID:	1	в	WP ID		BWP1 -	
	Symbol Number:		- D	MRS	Scrambling ID:	-1.	
	CORESETO RB Offset:		c	CE To	REG Mapping Type	Non-interleaved	
	CORESETO RB Number:						
	Allocated RB Groups (6RBs):	0:44					

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

TIP

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.

save As Quick Setup	Quick Setups	CCO: CDO			
Carriers	SS/PBCH				
Bandwidth	Lmax:	L64 +	SSB Transmitted:	þ :7	
BWP	🔽 Auto Detect Act	tive Block	Det Power Threshold:	-30	
Channel SS/PBCH	RB Offset(60kHz):	46 RB	Numerology:	μ = 3 : 120 kHz	
PDCCH	kSSB(60kHz):	0	SCS Common:	60kHz	
PDSCH CSI-RS	Periodicity: Power Boosting	10 ms 🔶 🔫	28.8 MHz bandwidth 0	MHz from center	
Results & Filters	PSS power boost	ing 0 dB	PBCH power boos	sting 0 dB	
	3GPP Version: L	atest (2019-06) =			

These following settings use the default values.

- RB Offset(60kHz) = 46 RB
- kSSB(60kHz) = 0
- Periodicity = 10 ms
- Numerology = μ = 3 = 120 kHz

Configuration	Input & Antenna	Time Decode	Advanced	
Save As Quick Setup	Quick Setups	CC0:CD0		
Carriers	SS/PBCH			
Bandwidth	Lmax:	L64 ·	SSB Transmitted:	0:7
BWP	Auto Detect Ac	tive Block	Det Power Threshold:	-30
Channel	PR Officer(60kHa)	46 RB	Numerolame	u - 3 - 120 kHz - +
SS/PBCH	the offset(overlap.		Numerorogy.	JI = 3. ILO KIL
PDCCH	-kSSB(60kHz):	0	SCS Common:	60kHz
PDSCH	Periodicity:	10 ms –	28.8 MHz bandwidth 0	MHz from center
CSI-RS	Power Boosting			
Results & Filters	PSS power boost	ting 0 dB	PBCH power boos	ting 0 dB
	3GPP Version:	atest (2019-06) 👘		

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.

Meas01 - 5G NR Demo	od Properties						?
Configuration	Time Decode A	dvanced					
Save As Quick Setup	Quick Setups						
Signal Carrier		move PDSCH Clear P	DSCHs				
BWP							
Channel	Enabled RNTI:	13G	PP Version: Latest (2018	-09/12) 🔻			
РДССН	Modulation and	Coding Time/Freq A	llocation				•
PDSCH	- Modulation and Codi	ng	Time/Freq Allocatio	n			
CSI-RS	MCS Table:	Table 256QAM 🚽	Slot Format:	0: D,D,D,D,D,D,D,D,D,D,D,D,D,D			
	MCS:	20	DL X Symbols:				
	TB Scaling Factor S:	1 -	Mapping Type	ТуреА –	TypeA Pos:	Pos2	
	Coding Rate:	0.66650390625	First Symbol:	0	Last Symbol:	13	
	Modulation:	QAM256	Resulting Format:	DDDDDDDDD	DDDDD		
	Transport Block Size:	55304	RA Type:	Туре1 –			
	n _{ID} Source	Cell ID 🚽	RB Offset:	0 RB	RB Number:	66 RB	
	n _{ID}		RA Configuration:		RBG Size [P]: 4		
	CORESET ID:		Allocated RBGs:				
				←─── BWP RB Ba	ndwidth: 66 —	_	
				16.5 Unused RBs	Allocated RBs		
	RS Sequence						•
	Power Boosting						<u> </u>

3GPP has different Tables for PDSCH MCS.

TIP

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

📥 Meas01 - 5G NR Der	mod Properties							?	
Configuration	Time Decode A	Advanced							
Save As Quick Setup.	Quick Setups								
Signal Carrier BWP	Add PDSCH Rei	move PDSCH CI							
▲ Channel	Modulation and	Coding Time/Fr	eq Allo	cation				•	
SS/PBCH	- Modulation and Codi	ng		Time/Freq Allocatio	n —				
PDCCH	RV Index:	0		Allocated Slots:	0:79				
PDSCH	MCS Table:	Table 256QAM		Slot Format:	0: D,D,D,D,D,D,D,I),D,D,D,D,D,D,D		-	
CSI-RS	MCS:	20		DL X Symbols:					
	TB Scaling Factor S:			Mapping Type	TypeA –	TypeA Pos:	Pos2	•	
	Coding Rate:	0.66650390625		First Symbol:	0	Last Symbol:	13		
	Modulation:	QAM256		Resulting Format:	DDDDDDDDD	DDDDD			
	Transport Block Size:	55304		RA Type:	Type1 –				
	n _{ID} Source	Cell ID		RB Offset:	0 RB	RB Number:	66 RB		
	n _{ID}			RA Configuration:	Config1 👻	RBG Size [P]:	4		
	CORESET ID:								
					← BWP RB Ba	ndwidth: 66 –	>		
					16.5 Unused RBs	Allocated RBs	;		
	RS Sequence							•	
	Power Boosting							•	
	Antenna Port							•	

M9484C VXG and X-Series SA Measurement Guide

361

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.

Configuration	Input & Antenna	a Ti	ime	Decod	de de	Advanced
- Analysis Region						
Result Length:	5 Subframes	0 SI	ots		at µ3	
Meas Offset:	2 Subframes	0 S	/mbols		at µ3	
Meas Interval:	3 Subframes	0 S	/mbols		at µ3	
Time Scale Factor:	1					
Analysis Start Bour	ndary		- Acqu	uisition N Normal	Node -	
• Frame			OF	Reduced	_ acquis	ition length
⊖ Half-frame			• F	rame tri	gger is	present
 Subframe Slot 			0 5	lot trigg	ger is pi	resent
First Slot Index:) a	t µ3				
Timing Diagram –						
k	Result Length	15 Subf	. —	_		
		L		>	Meas. I	nterval 3:0
From - Dev	undan:			\longrightarrow	Meas. (Offset 2:0
Frame Bol	indary					

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.

Configuration I	nput & Antenn	a Time	Decode	Advanced			
Tracking Source	2000			ing Ave Filter			
	30PP			ing Avg. Filter	19 RS		
EVM Window and Syn	nbol Timing —				Transient Period		
EVM Window Length	h Mode:						
EVM Window Length	h in Samples:				Length:		
Symbol Time Adjust	ment Mode:						
% of FFT Duration:		-3.125 %			Power Change Thresh	old: 10 dB	
⊂ IQ Impairments							
IQ Imb. Estimation M	ode: Off			ate IQ Imb.			
Compensate IQ C	Offset	1	J DC Punctu	ıred			
UL Spectrum Flatness							
Spectrum Flatnes	s Enabled						
Test Environment Cor	ndition: Norr	mal 🔻	Test Tolera	nce: 1.4 dB			
Error Vector Unit							
Time Domain: Per S	Symbol 🔻	Freq Domai	n: Per Subo	arrier 🔻			
MIMO Condition Num	ıber						
Control: Off	- RB Gr	anularity: 1					
Auto Set Span			1	Report E	VM in dB		
Independent SSB/BV	WP Measureme	ent		Extend Fr	requency Lock Range	480 kHz	
Multicarrier Filter On	ı			Compens	sate Symbol Clock Offse	t	
Per Slot Channel Free	quency Respor	ise					-

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.

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.

Trace	? ×
Format Coupling Y Scale	X Scale Average Digital Demod
Trace D 🔹 🕂 🔀 Visible	
Symbol Table Format:	Ideal State
Hex	Shape:
Symbol Table Bit Order:	Circle 👻
Auto	, Size:
Symbol Shape:	5 %
Bars	
Eye Length:	Code Order:
2	Bit Reverse 👻
Time Unit:	
sym	🗌 Show 2D Avg Line
Frequency Unit:	
carrier 🔹	
Filtered SubSegments:	Filtered Channel Types:
Select All Clear All	Select All Clear All
SSBlock0	I PSS ▲
Laver0	I SSS ■
	✓ – – – – – – – – – – – – – – – – –
	PBCH DMRS
	✓ PDSCH0

- 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:SIGNall 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 front panel Channel 1 Event 2 to UXR rear panel Aux Trig 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 A SYNCAN in the bottom left corner, tap or click the warning message and choose **Perform Alignment** before proceeding.



 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.

☰ ⅲ 臼∗	e ⊚ G	Configure Channels			RF Out (All)	Trigger G	? ~ Preset ~
Use the dropdown to co	onfigure the available RF Cha	annels into Groups. Any remain	ing Channels will be set	t to Independent.			
Group Configuration							
Independent	Add	Remaining RF Channels:	4				
1 CHANNEL	2 CHANNELS	4 CHANNELS					
Independent	2 Tx Coherent	4 Tx Coherent					
	Nx2 MIMO (Beta)	Nx4 MIMO (Beta)					
					Apply	(Cancel

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.



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

沿 Apps 5G	NR × Custom Mod	ulation (Beta) ×		-	
🖒 Generate			Carrier	Waveform	
HH Full-filled Confi	g 🛛 👎 DL Test Model	d the DL FRC Config	🐟 Auto Freque	ncy Offset	[→ Export 89600 VSA Setup
+ …	General	Carrier Type			Downlink \checkmark
Carrier 0 (DL)	Spectrum Control	Cell ID			0
	Cell-Specific	Bandwidth			FR2 100MHz 🗸
	Downlink	Numerology Mode			Single Numerology 🗸
		Numerology			μ = 3: 120 kHz 🗸
		Max RB			66
		kO			0
		Configured Bandwidth			

 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.

h Apps 5G	NR × Custom Mo	dulation (Beta) 🛛 🗙	-				
🖒 Generate			Carrier	Waveform			
HIII Full-filled Config	g 👎 DL Test Model	ਊ ⁺ DL FRC Config	🐟 Auto Freque	ncy Offset	[→ Export 89600 VSA Setu	,	
+	General	BWP		Shared Sp	ectrum Channel Access		
Carrier 0 (DL)	Spectrum Control	SS/PBCH	NR-PBCH	Active Ind	ices	0:3	
	Cell-Specific	DCI	МІВ	Power Boo	osting of each SS Block	0,	0,0,0,0,0,0,0,0,0
	Dowelink	DI-SCH		RB Offset	by 60 kHz SCS	0	
	Dewinner	DE SON		kSSB by s	ubcarrierSpacingCommon	0	
		CSI-RS		Delta Freq	uency to Carrier Center	-33.12 MHz	
		LTE-Coexistence		Half Fram	e Index	0	
		PRS		PSS Powe	r Boosting	0 dB	

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).

h Apps 5G	NR × Custom Mo	odulation (Beta) ×					
🖒 Generate			Carri	er Waveform			
HIII Full-filled Conf	ig 🌱 DL Test Mode	el 💣 DL FRC Config	👄 Auto Fr	equency Offset [+ Exp	port 89600 VSA Setup		
+	General	BWP		General Settings	Antenna Port(s) Generated	p0, p1	>
Carrier 0 (DL)	Spectrum Control	SS/PBCH		Transmission Settings	DMRS port(s)	0,1	
	Cell-Specific	DCI		Resource Allocation	Number of Layers		
	Downlink	01-80H		Modulation and Coding	Number of Antenna ports		
	Commune	DEGUN		modulation and coding	Number of DMRS CDM groups without data	2	
		CSI-RS		DMRS Settings	Number of Codewords	1	
		LTE-Coexistence		PTRS Settings			
		PRS		HARQ Settings			

- 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).

🖒 Generate			Carrier	Waveform		[+ Import Signal Setup
IIII Full-filled Co	nfig 👎 DL Test Mo	idel 😽 Au	to Frequency C	iffset [+ Export 8960	0 VSA Setup	
+	General	BWP	+ ***		Enabled	
Carrier D (DL)	Spectrum Control	SS/PBCH	DL-SCH 0	Transmission Settings	Power Boosting	0.00 dB
	Cell-Specific	DCI		Resource Allocation	Scrambling	
	Downlink	DL-SCH		Modulation and Coding	n_ID	Cell ID
		CSI-RS		DMRS Settings	RNTI	
				PTRS Settings		

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.

🐣 Generate			Carrie	r Waveform			2
HIII Full-filled Con	fig 🌱 DL Test Mode	I 💣 DL FRC Config	🝝 Auto Fre	equency Offset [+ Exp	ort 89600 VSA Setup		
	General	BWP		General Settings	Channel Coding		
	Spectrum Control	SS/PBCH	DL-SCH 0	Transmission Settings	MCS	20	
	Cell-Specific	DCI	DL-SCH 1	Resource Allocation	MCS Table	Table 5.1.3.1-1 (64QAM) 🗸	
	Downlink	DI-SCH		Modulation and Coding	TB Scaling Factor	1.0 🗸	
	Continue	DE SOIT		Modelocon and county	Coding Rate	0.5537109375	
		CSI-RS		DMRS Settings	Modulation	wagaw 😔	
		LTE-Coexistence		PTRS Settings	Transport Block Size	18432	
		PRS		HARQ Settings	BaseGraph		
✓ Channel	Allocation Summa	ry				Frame 0 ∽ µ = 3	💛 🔽 Display Detai
CRB μ = 3 66 50 40 30 20 					DL-SCHB DL-SCHT DL-SCHT SS/PBCHD	SubCarrier DL-SCH1	

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

h Apps 5G NR ×	Custom Modulation (Beta) ×		
🖒 Generate		Carrier Waveform	
[→ Export 89600 VSA Setu	Þ		
Basic	Marker 1 Source		Waveform Start \checkmark
Marker	Marker 2 Source		Frame Start 🗸
Crest Factor Reduction	Marker 3 Source		RF-Blanking Control
AWGN	Marker 4 Source		
Routing			

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

You should see a spectrum like the one below.

🖒 Generate	Carrier	Waveform	₽~
Export 89600 VSA Set	μ ρ		
Basic	Marker 1 Source	Waveform Start 🗸	
Marker	Marker 2 Source	Frame Start \sim	
Crest Factor Reduction	Marker 3 Source		
AWGN	Marker 4 Source		
Routing			
Antenna 0 💛 🛛 IQ	Spectrum CCDF		
-20	terrorisenten, billetinikinikinekinekinekinek		
		and the second state of th	
-40	Market and a second strength of the second st		
-40 -60	All All and the second second second	alitesed and a family of the second	
-40 -60 -80 -100	- And a product of the state of	alan and a second a second a second a second a	

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 Infinitum 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.

Taluware		ſ	~
Configurations	Discovered Instruments		
		1	Ċ
TCPIP0			
Keysight N	042B Signal Analyzer (TCPIP	0::141.121.151.206::inst0::INSTI	R)
Keysight/Ag	gilent PXA Signal Analyzer (T	CPIP0::K-N9030B-42898::inst0:	:INSTR)
Keysight/Ag	gilent UXA Signal Analyzer (T	CPIP0::k-n9040b-12206::inst0::	INSTR)
Keysight NS	042B Signal Analyzer (TCPIP	D::uxa-us90420108::inst0::INST	R)
Keysight/Ag	gilent PXA RF Tuner (TCPIP0::H	<-N9030B-42898::inst0::INSTR))
Keysight/Ag	gilent UXA RF Tuner (TCPIP0::I	k-n9040b-12206::inst0::INSTR)	
▷ SIM			
N LICP			

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



6. Scroll down the Possible Logical Instruments and select Keysight/Agilent Infinium Series Oscilloscope, and then select the right arrow to move it under Configuration.

	ł	~
 Select the logical instrument(s) to use. Sources and Analyz Simulate Hardware 	ers cannot be combined within the same config	uration
Possible Logical Instruments	Configuration	
Analyzer Keysight/Agilent Infinitum Series Oscilloscope Frequency/bandwidth from DC to 31.25 GHz depending upon model. 4 Inputs. 2. Select the instrument(s) to use for each logical instrument	Keysight/Agilent Infiniium Series Oscilloscop Hints: in the configuration.	e V
ADC Keysight/Agilent Technologies Infiniium Series Scop	: TCPIP0::localhost::inst0::INS	STR -
ADC Keysight/Agilent Technologies Infiniium Series Scop 3. Name the configuration. Analyzer2	TCPIP0::localhost::inst0::IN	TR -

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

10 P			0.000	-107
style:			Level:	
External		е.,	17	
Slope:			Delay:	
Positive			05	
Holdoff S	tyle:		Holdoff:	
Time Crit	eria:		Time1:	Time2:
Frequenc	y Mask Trigger			
Criteria:			Mask(s) to apply:	
Enter			Upper	
Window	Type:		RBW: 🗹 Auto	
Flat Top	(ampl acc)		58/ 658/ LHz	
Masks				
	Frequency Offset	A	mplitude Offset	
Upper	0 Hz	0 dB		
Lower	0 Hz	0 dB		
				Edit
Trigger C	lut			
Desired			Actual:	
Tringer	Dut 1		Transit Out 1	

- 13. From the menu bar, select MeasSetup > Measurement Type > Cellular > 5G NR > 5G NR Modulation Analysis.
- 14. Change the trace layout to Grid 2x3.



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.

Meas01 - 5G NR Demod Prope	erties						2
Configuration	Input & Antenna	Time De	ode Advanced				
Save As Quick Setup	Quick Setups	CC0 : CD0 -					
Carriers	Link Direction:	Downlink	O Uplink	Mixed			
Bandwidth BWP	Configure	+ Add Carrier	Allow Multiple C	arrier Definitions			
Channel	Reference: CC0	- Display:	CC0 -				
SS/PBCH		Cell (D	Bandwidth	Carrier Center	Frequency for Phase Compensation	Tx DC Freq.	
PDCCH	y nau	v 0	FR2 100 MHz =	28 GHz	28 GHz -	28 GHz	X
CSI-RS	Open Test Model						
RIM-RS	Cross-Correlated	evm					
Results & Filters	Enabled	Configure					
Manually apply se	ttings						

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.

Configuration	Input & Antenna Time	e Decode	Advanced	
Save As Quick Setup	Quick Setups CC0 :	CD0 👻		
Carriers Bandwidth	Bandwidth: FR2 100 M	IHz 🔻		
BWP Channel	Numerology μ = 2 : 60kHz:	Grid Start 0 RB	Grid Size	Grid Enabled
SS/PBCH PDCCH	μ = 3 : 120kHz:	0 RB	66 RB	
PDSCH CSI-RS	μ = 4 : 240kHz: Ref. Point A: -47.52 Mi	0 RB Hz at -47.52 MHz	34 RB	
Results & Filters	LTE-CRS Rate Match			۲
Manually apply sett	ings			

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.

🚰 Meas01 - 5G NR De	mod Properties						?	×
Configuration	Input & Antenna	Time Deco	ode Ao	dvanced				
Save As Quick Setup	Quick Setups	CC0 : CD0 🔻						
Carriers			ID	Numerology	RB Offset	RB Number		
Bandwidth		Initial-DL-BWP	0	µ = 3:120 kHz ▼	0 RB	273 RB		
RW/D		☑ DL-BWP	1	µ = 3 : 120 kHz 🔻	0 RB	66 RB		
		DL-BWP	2	µ = 3 : 120 kHz ▼	0 RB	273 RB		
Channel		DL-BWP		µ = 3 : 120 kHz 🔻	0 RB	273 RB		
SS/PBCH								
PDCCH		Jusitial III DWD	ld	Numerology	RB Offset	RB Number		
PDSCH			•	μ = 5.120 kHz ·	UND			
CSI-RS	CORESETs							
Results & Filters	Add CORESE	Remove CORE						
	CORESET:	•						
	CORESET ID:	1	BWP ID:	BWP1 -				
	Symbol Num	ber: 1		 DMRS Scramb 	ling ID: -1			
	RB Offset	r16 Configured		CCE To REG M	apping Type: Nor	n-interleaved 🔹		
	RB Offset-R16	5: 0						
	Allocated RB	Groups (6RBs): 0:1	0					
				Precoder Gran	ularity: San	ne as REG bundle 🔻		

- 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.

Configuration	Input & Antenna Ti	me Decode /	Advanced	
Save As Quick Setup.	Quick Setups	0:CD0 🔻		
Carriers	SS/PBCH			
Bandwidth	Lmax:	L64 ·	SSB Transmitted:	0:3
BWP	Auto Detect Active	e Block	Det Power Threshold:	-30
Channel	RB Offset(60kHz):	0 RB	Numerology:	µ = 3 : 120 kHz 🔻
PDCCH	kSSB(60kHz):	0	SCS Common:	60kHz 🔻
PDSCH	Periodicity:	10 ms 👻	Half Frame Index:	0
CSI-RS	28.8 MHz bandwidth -	-33.12 MHz from cente	r	
Results & Filters	Power Boosting PSS power boosting	g 0 dB	PBCH power boosting	0 dB
	3GPP Version: R16	Latest (2021-12) 🔻		

- 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

Carriers	Add PDSCH Remove P	DSCH Clear All 🝦 🕴	Enable Channels				
Bandwidth BWP Channel	PDSCH:	D BWP1 - RNTI:	1 3GPP V	ersion: R16 Latest (2021-12) 🔻		
SS/PBCH PDCCH PDSCH	Modulation and Codin RV Index:	Coding Time/Freq A g 0	Vilocation Time/Freq Allocation Frame Period:	1 Frames			•
CSI-RS	MCS Table:	Table 64QAM ▼	Allocated Slots:	2:79			
Results & Filters	MCS: TB Scaling Factor S:	20 1 -	DL X Symbols:	0: 0,0,0,0,0,0,0,0	ט,ט,ט,ט,ט,ט		
	xOverhead: Target Code Rate:	0 • 0.5537109375	Mapping Type First Symbol:	TypeA - O	TypeA Pos: Last Symbol:	Pos2 13	
	Modulation: Transport Block Size:	QAM64 10248	Resulting Format: RB Ref CORESET ID:		D D D D D D RA Type:	Туре1	•
	Transport Block 2	Cell ID 🔹	RB Offset: RA Configuration: Allocated RBGs:	20 RB	RB Number: RBG Size [P]:	20 RB	
	n _{ID} CORESET ID: Custom ModFormat:	0 -1 • Off •	VRB-To-PRB Mapping: Rate Match Patterns:	Non-Interleaved	VRB-To-PRB Interleaver:		
				← Ur	BWP Max RB: 66 16.5 33 49.5 nused RBs Allocated RB	s	

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.

	Carriers	Add PDSCH Remove	PDSCH Clear All	↓ i e	Enable Channels					
	Bandwidth									
	BWP						<u> </u>			
4	Channel						Ùn	16.5 33 4	49.5 1 RBs	-
	SS/PBCH	L								
	PDCCH	Antenna Port								
	PDSCH	Ref. Antenna Port:	1000 -	Ant.	Det. Threshold:		-36 dB			
	CSI-RS	🗌 Use Antenna Ports I	Index							
	Results & Filters	Antenna Ports Index:	0	Code	eword Number:		1 .	-		
		Antenna Ports Used:	0:1	DMR	S CDM group(s) witho	ut data:	2 .	-		
		PRB Bundle Size:	Wideband -		Defined PRB Bundle S					
		RS Sequence								
		DMRS Config	Туре1		DMRS-Downlink-r1	6		Enable PTRS		
		DMRS Max Length		· I	N _{ID} Source	Cell ID		KPTRS		
		DMRS Length	Single-Symbol	- 1	Nscid:	0		LPTRS		
		DMRS AddPos	Pos0	- 1	N _{ID}			PTRS RE Offset		
		DMRS Map Ref		- 1	N _{ID} ¹			AdditionalDMRS-D	L-Alt	
		DMRS Init Option:	NR Standard	-	DMRS Init:					
		Power Boosting	1							
		rower boosting	_							
		Power Boosting: 0 dB		DMF	RS Power Boosting: 3	dB	Р	TRS Power Boosting:		

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

24. Select PDSCH1 and set:

- MCS Table to Table 64 QAM
- MCS to 20
- Allocated Slots to 2:79
- RB Offset to 45 RB

- RB Number to 18 RB

Save As Quick Setup	Quick Setups CC0 : C	CD0 -							
Carriers	Add PDSCH Remove P	DSCH Clear All	En	able Channels					
Bandwidth									
BWP									
 Channel 	Enabled BWP I	D BWP1 - RN	TI: 1	3GPP V	ersion: R16 Latest (2021-12) 🔻			
SS/PBCH	Modulation and (odina Time/Fr	n All	location					
PDCCH	Modulation and Coding Time/Freq Allocation Modulation and Coding Time/Freq Allocation RV Index: 0 MCS Table: Table 64QAM ▼ N(CS) 20								
PDSCH	RV Index:	0		Frame Period:	1 Frames				
CSI-RS	MCS Table:	Table 64QAM 🔻		Allocated Slots:	2:79				
Results & Filters	MCS:	20		Slot Format:	n 1 Frames 2:79 0: D,D,D,D,D,D,D,D,D,D,D,D,D,D,D,D,D,D,D,				
	Iters BWP ID BWP ID BWP1 RNTI: 1 3GPP Version: R16 Latest (2021-12) Modulation and Coding Time/Freq Allocation Ime/Freq Allocation Ime/Freq Allocation MCS Table: Table 64QAM Frame Period: 1 Frames MCS: 20 Slot Format: 0: D,D,D,D,D,D,D,D,D,D,D,D,D,D,D,D,D,D,D,								
	xOverhead:	Modulation and Coding Time/Freq Allocation Modulation and Coding Number of the second seco							
	Target Code Rate:	0.5537109375		First Symbol:	0	Last Symbol:	13		
	Modulation:	QAM64		Resulting Format:	DDDDDDDD	DDDDD			
	Transport Block Size:	9224		RB Ref CORESET ID:	-1 -	RA Type:	Туре1	•	
	TB Scaling Factor S: 1 Image: Constraint of the second secon								
	n _{ID} Source	Cell ID 🔹		RA Configuration:					

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**.

Carries Add PDSCH Remove PDSCH Clear All Enable Channels. Bandwidth BWP Channel SS/PBCH PDSCH Channel SS/PBCH PDSCH Ref. Antenna Port NBC Channel Antenna Port 1000 Ant. Det. Threshold: -36 dB Codeword Number: 1 Antenna Ports Index Antenna Ports Index Antenna Ports Index Antenna Ports Index Antenna Ports Index Antenna Ports Index Codeword Number: 1 PRB Bundle Size: Wideband User Defined PRB Bundle Size: 1 RS Sequence DMRS Config Type1 OMRS-Downlink-116 RS Sequence DMRS Config Type1 OMRS-Downlink-116 DMRS Max Length 1 DMRS AddPos Pos0 N ₁₀ ⁰ DMRS Init: 0 DMRS In	Save As Quick Setup	Quick Setups	: CD0 🔻					
Bandwidth PDSCH: 0	Carriers	Add PDSCH Remove	PDSCH Clear All	Enable Channels				
BWP Channel SS/PBCH PDCCH PDSCH Ref. Antenna Port CSLRS Antenna Ports Index Antenna Ports Used: Via S Filters Image: Size Wideband User Defined PRB Bundle Size: Image: Size Image: Size PRB Bundle Size: Image: Size Image: Size <t< td=""><td>Bandwidth</td><td>PDSCH: 0</td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	Bandwidth	PDSCH: 0						
Channel SS/PBCH PDCCH PDCCH PDSCH CSI-RS Results & Filters Results & Filters RESUlts & Filters RS Sequence DMRS Config Type1 OMRS CDM group(s) without data: 2 RS Sequence RS Sequence DMRS Config Type1 OMRS-Downlink-r16 DMRS-Downlink-r16 DMRS-Downlink-r16 DMRS-Downlink-r16 DMRS-Downlink-r16 DMRS AddRos Pos0 V N 0 0 PTRS RE Offset 00 V Codeword N 0 Codewo	BMb				÷	BWP Max RB: 66		
SS/PBCH PDCCH PDCCH Ref. Antenna Port 1000 Ant. Det. Threshold: -36 dB CSI-RS Antenna Ports Index Antenna Ports Index Antenna Ports Index Antenna Ports Used: 01 DMRS COM group(s) without data: 2 PRB Bundle Size: Wideband User Defined PRB Bundle Size: 1 RS Sequence DMRS Config Type1 DMRS-Downlink-r16 Enable PTRS DMRS Max Length 1 N ₀₀ DMRS Source Cell ID KPTRS 2 DMRS Max Length Single-Symbol Nscid: 0 LPTRS 1 DMRS AddPos Pos0 N ₀₀ DMRS Init: 0 Power Boosting Power Boosting	 Channel 					Unused RBs Allocate	d RBs	
PDCCH Antenna Port PDSCH Ref. Antenna Port CSI-RS Use Antenna Ports Index Antenna Ports Index: 0 Codeword Number: 1 Antenna Ports Used: 0:1 DMRS CDM group(s) without data: 2 PRB Bundle Size: Wideband User Defined PRB Bundle Size: 1 DMRS Config Type1 DMRS Config Type1 DMRS Source Cell ID Cell ID KPTRS DMRS Length Single-Symbol Nip0 0 DMRS AddPos Pos0 Nip0 0 DMRS Init Option: NR Standard DMRS Init Option: NR Standard	SS/PBCH							
PDSCH CSI-RS Results & Filters Antenna Ports Index Antenna Ports Index: Antenna Ports Index: O Codeword Number: 1 Antenna Ports Index: O Codeword Number: 1 Antenna Ports Index: O Codeword Number: 1 Antenna Ports Used: 0:1 DMRS CDM group(s) without data: 2 PRB Bundle Size: Wideband User Defined PRB Bundle Size: 1 RS Sequence DMRS Config Type1 DMRS-Downlink-r16 Enable PTRS DMRS Max Length 1 Nip0 DMRS Length Single-Symbol Nip0 O DMRS AddPos Pos0 Nip0 O DMRS Map Ref CRB0 Nip1 O DMRS Init Option: NR Standard DMRS Init: O	PDCCH	Antenna Port						
CSI-RS Results & Filters Antenna Ports Index: Antenna Ports Index: Antenna Ports Index: Antenna Ports Index: Codeword Number: 1 Antenna Ports Used: 0:1 DMRS CDM group(s) without data: 2 PRB Bundle Size: Wideband User Defined PRB Bundle Size: 1 RS Sequence DMRS Config Type1 DMRS-Downlink-r16 Enable PTRS DMRS Max Length 1 Nip DMRS Length Single-Symbol * Nip<0	PDSCH	Ref. Antenna Port:	1000 -	Ant. Det. Threshold:	-36 dB			
Results & Filters Antenna Ports Index: 0 Codeword Number: 1 1 Image: Codeword Number: 1 Antenna Ports Used: 0.1 DMRS CDM group(s) without data: 2 Image: Codeword Number: 1 Image: Codeword Number: 1 Image: Codeword Number: 1 PRB Bundle Size: Wideband User Defined PRB Bundle Size: 1 Image: Codeword Number: 1 Image: Co	CSI-RS	🗌 Use Antenna Ports	Index					
Antenna Ports Used: 0:1 DMRS CDM group(s) without data: 2 PRB Bundle Size: Wideband User Defined PRB Bundle Size: 1 RS Sequence DMRS Config Type1 DMRS-Downlink-r16 Enable PTRS DMRS Max Length 1 Nip DMRS Source Cell ID KPTRS 2 DMRS AddPos Pos0 Nip 0 DMRS Map Ref CRB0 Nip<1	Results & Filters	Antenna Ports Index:	0	Codeword Number:	1	-		
PRB Bundle Size: Wideband User Defined PRB Bundle Size: 1 RS Sequence DMRS Config Type1 DMRS-Downlink-r16 Enable PTRS DMRS Max Length 1 Nip DMRS Source Cell ID KFTRS 2 DMRS Length Single-Symbol Nip 0 LPTRS 1 Wideband Vinp MRS Max Length 1 Nip 0 URS AddPos Pos0 Nip 0 DMRS Map Ref CR80 Nip OMRS Init Option: NR Standard DMRS Init: 0		Antenna Ports Used:	0:1	DMRS CDM group(s) witho	out data: 2	-		
RS Sequence DMRS Config Type1 DMRS-Downlink-r16 Enable PTRS DMRS Max Length 1 Np PMRS Source Cell ID KPTRS 2 DMRS Length Single-Symbol ▼ Nscid: 0 LPTRS 1 ▼ DMRS AddPos Pos0 Np0 0 PTRS RE Offset 00 ▼ DMRS Map Ref CR80 Np0 ¹ 0 AdditionalDMRS-DL-Alt DMRS Init Option: NR Standard DMRS Init: 0 ▼		PRB Bundle Size:	Wideband 🔹	User Defined PRB Bundle S				
DMRS Config Type1 DMRS-Downlink-r16 Enable PTRS DMRS Max Length 1 Nip MRS Source Cell ID KPTRS 2 DMRS Length Single-Symbol * Nscid: 0 LPTRS 1 DMRS AddPos Pos0 Nip 0 PTRS RE Offset 00 DMRS Map Ref CRB0 Nip 0 AdditionalDMRS-DL-Alt Power Boosting		RS Sequence						
DMRS Max Length 1 Image: Night Source Cell ID KPTRS 2 Image: Night Source Cell ID KPTRS 2 Image: Night Source Image: Nigh Source		DMRS Config	Туре1 -	DMRS-Downlink-r		Enable PTRS		
DMRS Length Single-Symbol * Nscid: 0 LPTRS 1 • DMRS AddPos Pos0 * Nip ⁰ 0 PTRS RE Offset 00 • DMRS Map Ref CR80 * Nip ¹ 0 AdditionalDMRS-DL-Alt DMRS Init Option: NR Standard * DMRS Init: 0 •		DMRS Max Length		N _{ID} Source	Cell ID 🚽	KPTRS		
DMRS AddPos Pos0 NID ⁰ 0 PTRS RE Offset 00 Image: CRB0 NID ¹ 0 Additional DMRS-DL-Ait DMRS Init Option: NR Standard DMRS Init: 0 Image: CRB0 Image: C		DMRS Length	Single-Symbol 🔻	Nscid:	0	LPTRS		
DMRS Map Ref CRB0 V N _{ID} ¹ 0 AdditionalDMRS-DL-Ait DMRS Init Option: NR Standard DMRS Init: 0		DMRS AddPos	Pos0 -	N _{ID} ⁰		PTRS RE Offset		
DMRS Init Option: NR Standard DMRS Init: 0 Power Boosting		DMRS Map Ref		N _{ID} ¹		AdditionalDMRS-E	DL-Alt	
Power Boosting		DMRS Init Option:	NR Standard 🔻	DMRS Init:				
Power Boosting			-					
		Power Boosting						
Power Boosting: 0 dB DMRS Power Boosting: 3 dB PTRS Power Boosting: 0 dB		Power Boosting: 0 d	B	DMRS Power Boosting: 3	dB	PTRS Power Boosting:		

Now you should see the demodulated signal and EVM results per layer in the Frame Summary for PDSCHO 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.

Configuration	Input & Anten	na	Ti	ime	Deco	de	Advanced
- Analysis Region							
Result Length:	5 Subframes		0 SI	ots		at µ	3 5 ms
Meas Offset:	2 Subframes		0 Sy	ymbols		at µ	3
Meas Interval:	3 Subframes]	0 S	ymbols		at µ	3
Time Scale Factor:	1						
- Analysis Start Bour	ndary			Acqu	isition I	Mode	;
• Frame				\bigcirc N	lormal		
○ Half-frame					educed	acqu	uisition length
Subframe				• F	rame tri	igger	is present
				0 s	lot trigg	ger is	present
First Slot Index:		at u	3				
Timing Diagram –							
k		th 5 9	Subf	. —	→		
				<u> </u>			
			Т				
			L		\longrightarrow	Mea	s. Interval 3:0
						Mea	s. Offset 2:0
Frame Bou	indary						

To improve setup speed

Live measurement:

- Use external frame trigger and enable Frame trigger is present. The real frame boundary must be within $\pm 50~\mu s$ of the external trigger.
- If external frame trigger is not available, use Reduced acquisition length. The reduced acquisition length may fail to synchronize in scenarios where > 1 frame SSB periodicity are defined, unless hardware triggering is used.
- Change Analysis Start Boundary to Subframe.
- Reduce Result Length and Measurement Interval.

Playback mode

- Reduce the Result Length and Measurement Interval.
- Set Analysis Start Boundary to Subframe.
- Reduce the number of active traces.

TIP

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)

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).

L Decode Settings	Antenna Time	Ľ	Decode Advanc	red	
PBCH Decode:	Decoded TB	*	PDCCH Decode:	Off (Scrambled Bits)	
PDSCH Decode:	Decoded TB	+			
PDSCH Decoder Algorithm:	Offset Min Sum	*			
E Decode Settings PUSCH Decode: PUSCH Decoder Algorithm:	Off (No Bits) Offset Min Sum		PUCCH Decode:		
E Decode Settings PUSCH Decode: PUSCH Decoder Algorithm: Puscede Advanced Settings	Off (No Bits) Offset Min Sum		PUCCH Decode:		

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.

Configuration	Input & Antenr	na Time	Decode	Advanced					
✓ 3GPP Conforman	ce Test								
Tracking:		Equalizer Train							
			Signal Source:						
✓ Phase			Time Basis						
Tracking Source:			Freq Movin		19 RS				
EVM Window and S	Symbol Timing -		Transient Period						
EVM Window Length Mode:									
EVM Window Len	EVM Window Length in Samples:				Length:				
Symbol Time Adj	Symbol Time Adjustment Mode:				Longun				
% of FFT Duration:		-3.125 %			Power Change Threshold: 10 dB				
- IQ Impairments	Q Impairments								
IQ Imb. Estimation	Mode: Off			e IQ Imb.					
Compensate IC	Compensate IQ Offset			ed					
UL Spectrum Flatne	ss								
✓ Spectrum Flatr	ess Enabled								
Test Environment Condition: Normal Test Tolerance: 1.4 dB									
Error Vector Unit									
Time Domain: Per Symbol • Freq Domain: Per Subcarrier •									

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.

File Edit Control Source	Input MeasSetup Trace Markers Window Utilitie	s Help											
	efault 🕜 🥚 📴 🛤 📧 🖽 井	₽□, ◊		а 💦 📶 з	🛓 50% U				New Radio Speedu	p 🛄 saveForma	ttedTrace		
A: OFDM Meas		C: MIMO Info							E: RE Power 3D				
Rng 6 dBm 1.5		Name	Meas. Chan- nel	An- tenna Despre Port (%rms)	ad EVMPo (dE	wer TAI Im) (se	E F ¢) (-requenc Hz)					
Const	*******	PDSCH0_DMRS PDSCH0_DMRS PDSCH0_DMRS PDSCH0_DMRS	Ch1 Ch1 Ch2 Ch2	Port0 Port1 Port0 Port1	0.934 -3	3.31 6.81 3.37 3.24 91	0 15.33 p	-1 -1	-16.2				
300	*******	PDSCH1_DMRS PDSCH1_DMRS PDSCH1_DMRS PDSCH1_DMRS	Ch1 Ch1 Ch2 Ch2	Port0 Port1 Port0 Port1	1.003 -3 	3.43 5.17 4.30 3.25 655	0 5.051 p	16. (h	dBm	ine or		2	
/dw -1.5 -2.201 Res BW 30 kHz	2.2607 TimeLen 56 Sym		4						1 135	4.3 bym	63.30	100	
B: Summary		D: Frame Summary							F: Decoded Info				* X
		Name	EVM (%ms)	Power per RE (dBm)	Modulation	um. of RBs	NTI BV	VP.			and the second		
Analyzed Subfrane Charnel Power OFUDSym Tx. Power Errorenergy Error Symbol Clock Error Tig Offsot Sync Corrolation Sync Source Cell ID	[SB0,ymb] to [SB0,ymb] -2,408 dBm -2,408 dBm -2,605 dBm -2,605 dBm -4,503 ppm -4,574,98 Wints -0,053 ppm -4,5743 0B -346,34 us -99,987 % PSS, SSS 0	PSS SSS PBCH_DMRS PDSCH0_DMRS PDSCH0_DMRS PDSCH0_Layer0 PDSCH1_DMRS PDSCH1_Layer0 PDSCH1_Layer1	0.022 0.026 0.692 0.057 1.542 1.375 1.495 1.588 1.544 1.391 1.593 1.493	34 35 34 35 34 35 34 35 31 35 31 35 31 35 31 35	BPSK QPSK QPSK QAM256 QAM256 QAM256 QAM256 QAM256 QAM64 QPSK QAM64 QAM64	24 24 40 320 320 160 160 400 200 200	0x1 0x1 0x1 0x1		PECH Descent SSEConfigueex Periodindes Periodindes Periodindes Periodindes Periodindes Stathdex Stathdex Stathdex Stathdex Stathdex Stathdex Stathdex Stathdex	 Consentindex=0, Blackindex=00, Blackindex=00, Blackindex=00, Blackindex=00, Blackindex=00, Charaetridex=0, Charaetr	Hamenologi-Stabio Symbolicides (104, Symbolicides (Un Decode:3Exet0.01000 Decode:3Exet0.01000 Decode:3Exet0.001000 Decode:3Exet0.01000 Decode:3Exet0.01000 Decode:3Exet0.01000	FDS Sub 00, C 00, C 00, C 00, C

 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:



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

	File Edit Control Source	Input MeasSetup Trace Markers Window Utilities Help Rauge To Due Obward Obtacillo * 🛑 🖹 ঝ 🗛 🎛 - 🏬		? 0 si Color Normati 🛛 民 Macro05
	A: OFDM Meas: All Layers *	E Slat Summary	C: OFDM Err Vect Spectrum G: OFDM Detected Allocatio	ons Time: All Layers 🔹 👻 🗙
Format Coupling Y Scale Trace A = + V Scale Symbol Table Format Hex - Symbol Table Bit Order:	Ring & dBm 1.3 X Scale Average Digital Demod Ideal State Shape: Circle •		Rng 6 dBm 9 Linklag 900 m th 7dv 0	
Auto -	5%	3.0383	% Start -1.584 kcarrier	Stop 1.583 kcarrier
Bars -		TimeLen 233 Sym	Res BW 120 kHz	TimeLen 233 Sym
Lye Length:	Code Order:	0 + X	D: OFDM Err Vect Time: H: OFDM Frr Vect Time: All Layer	• • ×
2	ilit Reverse 💎			
Time Unit: sym Frequency Unit: cartier	☑ Shaw 2D Avg Line		Liñes	tideal and a state of a data
Filtered SubSegments:	Filtered Channel Types:		helles	and the absolute leading the second
Select All Clear All	Select All Clear All	A A A A A A A A A A A A A A A A A A A	800	ATT CARL BUILDED A
SSBlock0 SWP1 Layer0 BWP1 Layer1	IZ PSS IZ SSS IZ PBCH IZ PBCH DMRS IZ PDSCH0	Right 29 18 GHz TimeLan I mBec		ланана 1913 година 1913 година
1		ab #11 Di 2x2 MIMO off		Rata Features in Lise: 1 INT REF CAL! None

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 Infinium 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.

Analog	Digital	Trigger	Playback	Trigger	External Mix	er Exte	ensions
<u>L</u> ogical Ir	nstrument:					Preset	
1						Show Al	11
▲ Misc	:						ľ
Cus	tomTrigCon	nmand					
Cus	tomTrigTyp	e		Of	f.	On	
Har	dware DDC	Sample Rate	N	aN			
Res	ampleLocati	on	D	river			*
Sam	npleMode		F	ullRateDo	dc		-
Use	rSampleRate		11	+09			
Use	rSCPIPreset						

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.

Configuration	Input & Antenna Time	e Decode A	dvanced				
Save As Quick Setup	Quick Setups CC0 :	CD0 🔻					
Carriers Bandwidth	Bandwidth: FR2 100 M	IHz 🔻					
BWP	Resource Grid						
	Numerology	Grid Start	Grid Size	Grid Enabled			
 Channel SS/PBCH 	μ = 2 : 60kHz:	0 RB	132 RB				
PDCCH	μ = 3 : 120kHz:	0 RB	66 RB				
PDSCH	μ = 4 : 240kHz:	0 RB	34 RB				
CSI-RS	Ref. Point A: -47.52 M	Hz at -47.52 MHz fro	m center				
Results & Filters	LTE-CRS Rate Match			۲			
Manually apply sett	Manually apply settings						

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.

Meas01 - 5G NR De	mod Properties						?	×
Configuration	Input & Antenna	Time Decc	ode Ad	dvanced				
Save As Quick Setup	Quick Setups	CC0 : CD0 🔻						
Carriers			ID	Numerology	RB Offset	RB Number		
Bandwidth		Initial-DL-BWP	0	µ = 3 : 120 kHz 🔻	0 RB	273 RB		
RWD		✓ DL-BWP	1	µ = 3 : 120 kHz ▼	0 RB	66 RB		
		DL-BWP	2	µ = 3 : 120 kHz 🔻	0 RB	273 RB		
Channel		DL-BWP		µ = 3 : 120 kHz 🔻	0 RB	273 RB		
SS/PBCH								
PDCCH		Junitial III DWD	Id	Numerology	RB Offset	KB Number		
PDSCH			U	μ = 5 : 120 kHz +	UKD	00 KB		
CSI-RS	CORESETs							
Results & Filters Add CORESET CORESET CORESET								
	CORESET ID:	1	BWP ID:	BWP1 -				
	Symbol Numl	ber: 1		DMRS Scramb	ling ID: -1			
	RB Offset-	r16 Configured		CCE To REG M	apping Type: No	n-interleaved 🚽		
	RB Offset-R16	j: 0						
	Allocated RB	Groups (6RBs): 0:1	0					
				Precoder Gran	ularity: San	ne as REG bundle 👻		

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.

Configuration	Input & Antenna Ti	me Decode A	dvanced	
Save As Quick Setup	Quick Setups	0:CD0 🔻		
Carriers	SS/PBCH			
Bandwidth	Lmax:	L64 -	SSB Transmitted:	0:3
BWP	Auto Detect Active	e Block	Det Power Threshold:	-30
 Channel 	RB Offset(60kHz):	0 RB	Numerology:	µ = 3 : 120 kHz 🔻
PDCCH	kSSB(60kHz):	0	SCS Common:	60kHz -
PDSCH	Periodicity:	10 ms 👻	Half Frame Index:	0
CSI-RS	28.8 MHz bandwidth -	-33.12 MHz from center		
Results & Filters	Power Boosting PSS power boosting	g O dB	PBCH power boosting	0 dB
	3GPP Version: R16	Latest (2021-12) 🔻		

- 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

Carriers	Add PDSCH Remove P	DSCH Clear All 🝦 🗄 🖬	nable Channels					
Bandwidth	PDSCH:							
▲ Channel	✓ Enabled BWP II	D BWP1 - RNTI: 1	3GPP V	ersion: R16 Latest (2021-12) 🔻			
SS/PBCH	Modulation and Coding Time/Freq Allocation							
PDCCH	- Modulation and Coding]	┌ Time/Freq Allocation -	Time/Freq Allocation				
PDSCH	RV Index:	0	Frame Period:	1 Frames				
CSI-RS	MCS Table: Table 64QAM 👻		Allocated Slots:	2:79				
Results & Filters	MCS:	20	Slot Format:	0: D,D,D,D,D,D,D,D	,D,D,D,D,D,D,D,D,D,D			
	TB Scaling Factor S:	1 🔹	DL X Symbols:					
	xOverhead:		Mapping Type	ТуреА –	TypeA Pos:	Pos2	- =	
	Target Code Rate:	0.5537109375	First Symbol:	0	Last Symbol:	13		
	Modulation:	QAM64	Resulting Format: DDDDDDDDDDDDDDDD					
	Transport Block Size:	10248	RB Ref CORESET ID:	-1 🔹	RA Туре:	Туре1	-	
	Transport Block 2		RB Offset:	20 RB	RB Number:	20 RB		
	n _{ID} Source	Cell ID 🛛	RA Configuration:					
	nio							
	שויי		VRB-To-PRB Mapping:	Non-Interleaved	VRB-To-PRB Interleaver:			
	CORESET ID:	-1 •	Dete Metels Detterment	None	5 .0			
	Custom ModFormat:	Off 👻	Rate Match Patterns:	None	Edit			
				← – – Ur	BWP Max RB: 66 16.5 33 49.5 nused RBs Allocated RB	s		

- 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.

(Carriers	Add PDSCH Remove		Enable Channels					
l	Bandwidth								
l	BWP					<u> </u>		>	
4	Channel					Un	16.5 33 used RBs Allocated	49.5 1 RBs	-
	SS/PBCH	L							
	PDCCH	Antenna Port							
	PDSCH	Ref. Antenna Port:	1000 -	Ant. Det. Threshold:		-36 dB			
	CSI-RS	Use Antenna Ports	Index						
	Results & Filters	Antenna Ports Index:	0	Codeword Number:		1	-		
		Antenna Ports Used:	0:1	DMRS CDM group(s) witho	out data:	2	-		
		PRB Bundle Size:	Wideband 🛛 👻	User Defined PRB Bundle S					
		RS Sequence							
		DMRS Config	Type1 👻	DMRS-Downlink-r1	16		Enable PTRS		
		DMRS Max Length		N _{ID} Source	Cell ID		KPTRS		
		DMRS Length	Single-Symbol 🔻	Nscid:	0		LPTRS		
		DMRS AddPos	Pos0 -	N _{ID} ⁰			PTRS RE Offset		
		DMRS Map Ref		N _{ID} ¹			AdditionalDMRS-D	L-Alt	
		DMRS Init Option:	NR Standard	DMRS Init:					
		1							
		Power Boosting							
		Power Boosting: 0 dE	3	DMRS Power Boosting: 3	dB	F	PTRS Power Boosting:	0 dB	

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

25. Select PDSCH1 and set:

- MCS Table to Table 64 QAM
- MCS to 20
- Allocated Slots to 2:79
- RB Offset to 45 RB

- RB Number to 18 RB

Save As Quick Setup	Quick Setups CC0 : C	CD0 🔻							
Carriers	Add PDSCH Remove P	DSCH Clear All	Enable Channels						
Bandwidth									
DWD	PDSCH:								
DWF	Finabled BW/DI		3GPD 1	Version: P16 Latest	(2021-12) =				
Channel Channel Channel Channel									
SS/PBCH	Modulation and 0	Coding Time/Freq A	llocation						
PDCCH	Modulation and Codin	q	Time/Freg Allocation						
PDSCH	PDSCH RV Index: 0		Frame Period:	Frame Period: 1 Frames					
CSI-RS	MCS Table:	Table 64QAM 🔻	Allocated Slots:	2:79					
Results & Filters	MCS:	20	Slot Format:	0: D,D,D,D,D,D,D,D,	,D,D,D,D,D,D,D,D,D,D,D,D				
	TB Scaling Factor S:	1 -	DL X Symbols:						
	xOverhead:		Mapping Type	ТуреА -	TypeA Pos:	Pos2	•		
	Target Code Rate:	0.5537109375	First Symbol:	0	Last Symbol:	13			
	Modulation:	QAM64	Resulting Format:	DDDDDDD	DDDDD				
	Transport Block Size:	9224	RB Ref CORESET ID:	-1 🔻	RA Type:	Type1	•		
	Transport Block 2	$\mathbf{\overline{v}}$	RB Offset:	45 RB	RB Number:	18 RB			
	n _{ID} Source	Cell ID 🛛	RA Configuration:						

26. Scroll down and open the Antenna Port dropdown and set:

- Antenna Ports Used to 0:1
- DMRS CDM group(s) without data to **2**.

27. Select the Power Boosting dropdown and verify that DMRS Power Boosting is set to 3 dB.

Save As Quick Setup	Quick Setups	:CD0 🔻							
Carriers	Add PDSCH Remove PDSCH Clear All Enable Channels								
Bandwidth BWP	PDSCH: 0				← BWP Max BB' fi	i6			
 Channel 				_	16.5 35 Unused RBs Alloca	49.5 Ited RBs			
SS/PBCH									
PDCCH	Antenna Port						•		
PDSCH	Ref. Antenna Port:	1000 -	Ant. Det. Threshold:	-36 dB					
CSI-RS	Use Antenna Ports	Index							
Results & Filters	Antenna Ports Index:	0	Codeword Number:	1	-				
	Antenna Ports Used:	0:1	DMRS CDM group(s) wi	thout data: 2	–				
	PRB Bundle Size:	Wideband 🛛 👻	User Defined PRB Bundl	le Size: 1					
	RS Sequence						•		
	DMRS Config	Type1 -	DMRS-Downline	k-r16	Enable PTRS				
	DMRS Max Length		N _{ID} Source	Cell ID 👻	KPTRS				
	DMRS Length	Single-Symbol 🔻	Nscid:	0	LPTRS				
	DMRS AddPos	Pos0 -	NID		PTRS RE Offset				
	DMRS Map Ref		N _{ID} ¹		AdditionalDMRS	S-DL-Alt			
	DMRS Init Option:	NR Standard	DMRS Init:						
	Power Boosting						•		
	Power Boosting: 0 d	IB	DMRS Power Boosting:	3 dB	PTRS Power Boosting				

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.

Configuration	Input & Antenn	a T	ime	Deco	de Advanced	ł	
- Analysis Region -							
Result Length:	5 Subframes	0 SI	ots		at µ3 5 ms		
Meas Offset:	2 Subframes	0 S	mbols		at µ3		
Meas Interval:	3 Subframes	0 S	/mbols		at µ3		
Time Scale Factor	1						
Analysis Start Bou	ndary		Acqui	sition I ormal	Mode		
Frame			○ Re	duced	acquisition leng	th	
Half-frame			💿 Fra	ame tri	igger is present		
○ Subtrame				ot trigg	ger is present		
First Slot Index:	0 a	at µ3					
- Timing Diagram							
k Result Length 5 Subf. →							
					Meas. Interval 3:	0	
Frame Bo	undary			,	Meas. Offset 2:0		

TIP

To improve setup speed

Live measurement:

- Use external frame trigger and enable Frame trigger is present. The real frame boundary must be within $\pm 50 \ \mu s$ of the external trigger.
- If external frame trigger is not available, use Reduced acquisition length. The reduced acquisition length may fail to synchronize in scenarios where > 1 frame SSB periodicity are defined, unless hardware triggering is used.
- Change Analysis Start Boundary to Subframe.
- Reduce Result Length and Measurement Interval.

Playback mode

- Reduce the Result Length and Measurement Interval.
- Set Analysis Start Boundary to Subframe.

- Reduce the number of active traces.
- **29.** To configure the PBCH and PDSCH decoding, select the **Decode** tab and set.
 - PBCH Decode to **Decoded TB**
 - PDSCH Decode to Decoded TB
 - PDSCH Decoder Algorithm to Offset Min Sum (default)

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).

L Decode Settings	Antenna Time	-	Jecode Advanc	ed
PBCH Decode:	Decoded TB	*	PDCCH Decode:	Off (Scrambled Bits)
PDSCH Decode:	Decoded TB	+		
PDSCH Decoder Algorithm:	Offset Min Sum	*		
L Decode Settings PUSCH Decode:	Off (No Bits)		PUCCH Decode:	Off (Scrambled Bits)
PUSCH Decoder Algorithm:				
PUSCH Decoder Algorithm: Recode Advanced Settings				

30. Select the Advanced tab and select the DC Punctured check box.

NOTE

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.

Configuration Input & Antenr	a Time Decode	Advanced					
✓ 3GPP Conformance Test							
Tracking:	Equalizer Tra	ining					
	Signal Sourc	e: RS					
✓ Phase	Time Basis						
	Time Dasis.						
Tracking Source: 3GPP	▼ Freq Mov		RS				
EVM Window and Symbol Timing		Trar	nsient Period				
EVM Window Length Mode:							
EVM Window Length in Samples:		Le	ngth:				
Symbol Time Adjustment Mode:							
% of FFT Duration:	-3.125 %	Pc	ower Change Threshold:				
IQ Impairments							
IQ Imb. Estimation Mode: Off		ate IQ Imb.					
Compensate IQ Offset	DC Punctu	ired					
UL Spectrum Flatness							
Spectrum Flatness Enabled							
Test Environment Condition: Nor	mal Test Tolera	nce: 1.4 dB					
Error Vector Unit							
Time Domain: Per Symbol 🔻	Freq Domain: Per Subc	arrier 🔻					



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

- Trace A: Composite constellation diagram showing different modulation formats for the different channels/signals present in the transmitted signal. See Trace F (Frame Summary) for the list of channels and modulation formats.
- Trace C: Summary trace showing composite error metrics.
- Trace D: Error Vector Spectrum showing EVM versus subcarrier and symbol.
- Trace E: Detected Allocations Time showing the detected allocations of all channels/signals within the measurement interval.
- Trace F: Frame Summary. EVM, per Layer EVM, Power per RE, Mod Format, Number of RB, RNTI, and BWP ID of the individual channels/signals.

One of the most powerful tools in the 89600 VSA is the coupling of markers across different measurements, traces, and domains. Coupled markers allow you to understand the identity and characteristics of a symbol simultaneously in time, frequency, and error.

Place a marker on Traces A, D, and E and couple the markers (Markers > Couple Markers), and then show the results in a markers window (Window > Markers).

Right click on Trace D and select **Peak**. The exact symbol associated with this peak EVM can now be understood in terms of time domain symbol index, frequency domain subcarrier number, channel type, modulation format, IQ magnitude, and phase values. Other parameters are shown in the Marker window.

Change the traces so you can see the Constellation diagram, MIMO Info table, Frame Summary Table (or Slot Summary Table), Summary table, 3D Power, Decoded Info plus any additional traces.

File Edit Control Source	Input MeasSetup Trace Markers Window Utilitie	s Help									
	efault 🔹 🥚 📑 🛤 🗉 🕮 📲	R . O	1	🛛 🏌 🏭	1 50 % 0				New Radio Speedup	saveFormattedTrace	
A: OFDM Meas	- ×	C: MIMO Info						+ ×	E: RE Power 3D		- ×
Rng 6 dBm 1.5		Name	Meas. Chan-	An- tenna Desp Port (%rm	read EVM Pov 5) (dB	ver TAE m) (see	E Free c) (Hz)	quenc)			
Const	*****	PDSCH0_DMRS PDSCH0_DMRS PDSCH0_DMRS PDSCH0_DMRS	Ch1 Ch1 Ch2 Ch2	Port0 Port1 Port0 Port1	0.934 -3	3.31 6.81 3.37 3.24 91	0 	4	-18.2		
300	****	PDSCH1_DMRS PDSCH1_DMRS PDSCH1_DMRS PDSCH1_DMRS	Ch1 Ch1 Ch2 Ch2	Port0 Port1 Port0 Port1	1 003 -3 -10 -10 0 938 -3	3 43 5 17 4 30 3 25 655	0	5	mgp		
-1.5	***************************************								-151.1 44		
-2.261 Res BW 30 kHz	2.2607 TimeLen 56 Sym		9					- 4		4ym 63.3ggs1	
B: Summary		D: Frame Summary	1						F: Decoded Info		**
	and a second second	Namo	EVM (%rms	Power per Ri (dBm)	Modulation	ium. I RBs RI	NTI BWP			Marine and a second	
Analyzed Subframe	[Sf0,sym0] to [Sf0,sym111]	PSS	0 022	-04.3	OPSK	-24		**	FBOH Decoder = On	PDCCH Decode≓-Off	PDS
Channel Power	-3.678 dBm	555			BPSK				SSPContinues at Car	attratestal Mathematicaus 201.44* Demonts 20 tatt Frances	CUN
EVM	1.5264 %rms	PBCH	0.692	-34.3	QPSK	40			Fenodinder =0, Elbo	kindex=30, Symbolindex=304, DecodedE#s=0x310000	IB, C
Frequency Error	-524.98 Hz	PBCH_DMRS	0.057	34.35	QPSK	40			Feriodindes =0, Bloc		10. C
Symbol Clock Error	-0.053 ppm	PDSCH0	1.542	-34.35	QAM256	320	0x1	1	Periodindes =0, Bloc	kinstex=02, Symbolindex=016, DecodedBits=8:010000	
IQ Offset	-48.783 dB	PDSCH0_DMRS	1.375	-31.3	QPSK	320	Our 1		Periodode - Pus	Hindex-do, Symbolindex-uzu, Decodedears-dua rabbo	10 T
Syne Correlation	346.34 US 99.997 W	PDSCH0_Layer0	1.495		QAM256	160			PDSCH Index =0, Can		
Sync Source	PSS. SSS	POSCHO Layer	1,000	20170	COMM250	100			Slothidex 402 CR	C+Pest.	
Cell ID	0	POSCHI DMRS	1 301	31.35	OPSK	400	Ox1		Sicilinge× =u3, CH	C=FB(s	
		PDSCH1 Laver0	1.593		QAM64				PERSONAL ST. LINE		
		PDSCH1_Laym1	1.493		QAM64			1	Skilvides02, CP Skilvides03, CP	ChFasi ChFasi	
									1.000		

 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

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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:



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



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