



TECHNICAL OVERVIEW

N9055EM0E Power Amplifier Measurement Application

Key Features

- Characterize PA (Power Amplifier) with Pre-distortion applied in RF and millimeter wave, with simple and integrated multi-touch user interface
- Provide smart link for automated signal generator closed loop control with power servo to auto-adjust PA output power
- Extracts DPD model and apply Pre-distortion to linearize PA output with supported DPD model as Look-up table (LUT), Volterra Series, Memory Polynomial
- Show both Pre-DPD and Post-DPD measurement results in one screen, for ease of comparison. Easily switch between Pre-DPD and Post-DPD results
- Support PA measurements with AM/AM, AM/PM, ACP, Delta EVM, Demod EVM (5G NR and 802.11ac/ax/be), Power vs Demod EVM
- Supports multi-carrier measurements to show EVM results in single screen
- Support Keysight Signal Studio waveforms or user-defined waveforms
- Use embedded DPD (Look-Up-Table or Memory Polynomial) function of the M9384B VXG, so it can avoid downloading Pre-distorted waveform for each DPD iteration, which can improve measurement speed
- Support frequency up to 44 GHz with 2 GHz bandwidth with N9042B UXA and M9384B VXG

Power Amplifier Measurement Application

Modern mobile communications, such as 5G NR and WLAN place new demands on linearity, bandwidth and power consumption in wireless components, mobile terminals or base stations. One of the most non-linear components is the PA (Power Amplifier). The design of the power amplifier must allow it to:

- Increase spectral efficiency
- Reduce distortion and non-linearity

N9055EM0E Power Amplifier measurement application is an integrated PA testing system mainly targeting 5G NR, WLAN, or other wideband PA test scenarios. N9055EM0E is running inside Keysight X-series Signal Analyzers which can connect Keysight Signal Generators for signal generation to make both Pre-DPD and Post-DPD PA measurements as the typical measurements shown in the right table.

Digital Pre-Distortion Technology

Power amplifiers with high PAPR (Peak to Average Power Ratio) signals can create non-linearity problems. When a high power signal is applied to the PA input, the PA can't linearly amplify the signal, possibly resulting gain saturation and distortion, and ultimately leading to signal quality degradation, such as worse ACP and EVM. DPD technology can be used to compensate for the non-linear behavior of the PA. DPD applies "inverse" distortion to the PA input signal to cancel the distortion generated by the PA. There are several types of DPD methods, including memoryless and memory, which convey the memory effect on a PA. N9055EM0E supports the following four methods:

- Look-up table
- Volterra series
- Memory polynomial

Apply Your Signals in Real World Testing

To use N9055EM0E Power Amplifier measurement application, you must have some properly configured instruments, as described here.

Signal Generator	Signal Analyzer
VXG M9384B	X-Series Signal Analyzer – UXA N9042B
X-Series Signal Generator – MXG ¹	X-Series Signal Analyzer – UXA N9041B ¹
	X-Series Signal Analyzer – UXA N9040B ¹
	X-Series Signal Analyzer – PXA N9032B ²
	X-Series Signal Analyzer – PXA N9030B ¹

1. Those instruments will be support with the XA2021 release (March 2021).

2. This Instrument will be support with the XA2022 release (July 2021).



Typical Measurements!

Distortion measurement

- AM/AM
- AM-PM

Spectrum measurement

- Channel Power
- ACP

Modulation Quality

- Delta EVM
- Demod EVM (5G or WLAN)
- Power vs. Demod EVM

Power Amplifier Connection

To use N9055EM0E Power Amplifier measurement application, a connection diagram is shown below. SA (Signal Analyzer) and SG (Signal Generator) are connected through LAN connection.

- Connect SA and SG Trigger and 10 MHz Reference together (usually from SG to SA)
- Connect PA (DUT) between SA and SG RF or mmWave port.

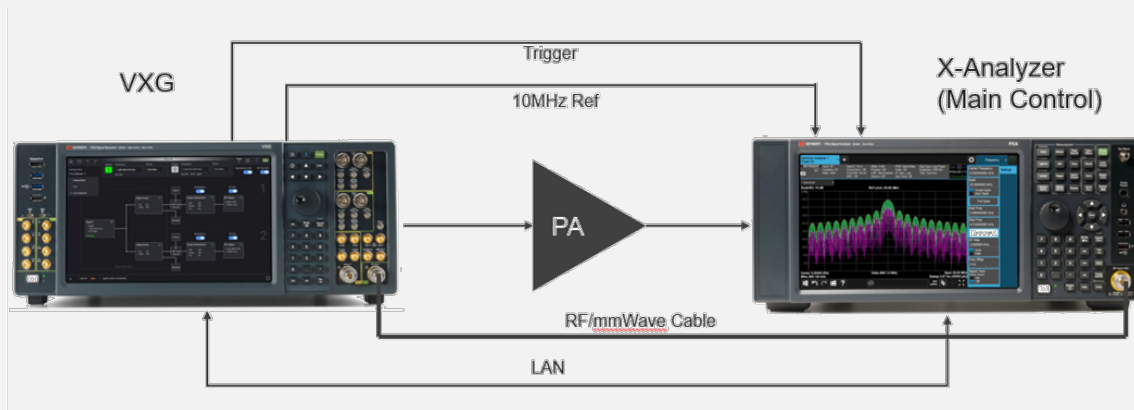


Figure 1. N9055EM0E Power Amplifier Test connection diagram

Connect to Remote Signal Generator via LAN Connection

If it is the first time to use a new generator, you'll need to input the IP address or Host name, associated with a Name as optional for logging. Then you can add the configuration to the Signal Generator List, which will be stored even after instrument reboot.

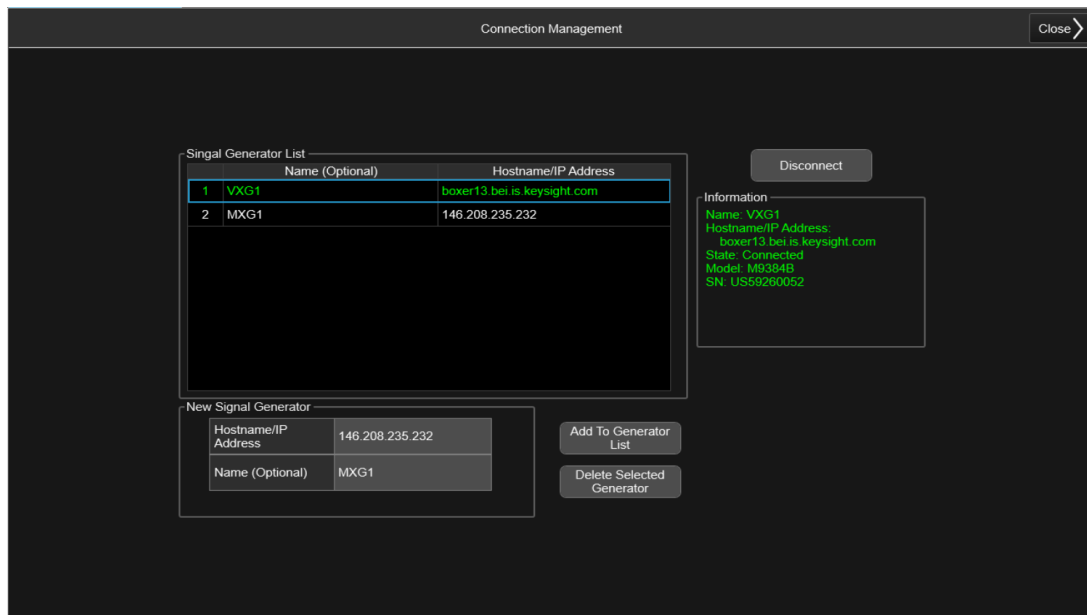


Figure 2. Signal Generation Management in the N9055EM0E Power Amplifier Test

After connection is established between SA and SG, the SG Information is shown automatically in the information box and the button will be changed to "Disconnect". You can add more Signal Generators in the list, only the "Connected" SG is highlighted in green color.

Pre-DPD Measurements

Pre-DPD measurements are done by measuring reference signal played in SG. You can see the pre-DPD measurement results as shown in yellow color in all trace windows of PA Test.

You can restart the measurement to see new result or use "Continuous" mode to check Pre-DPD results continuously.



Figure 3. Pre-DPD Measurements

PA Test reference waveform is downloaded from SA to SG via LAN connection. The waveform name is configured as "RefWaveform" when it completes downloading to SG.

This is a screenshot for VXG, after reference waveform is downloaded from SA to VXG. You can see the "RefWaveform" file is shown with the status as playing.

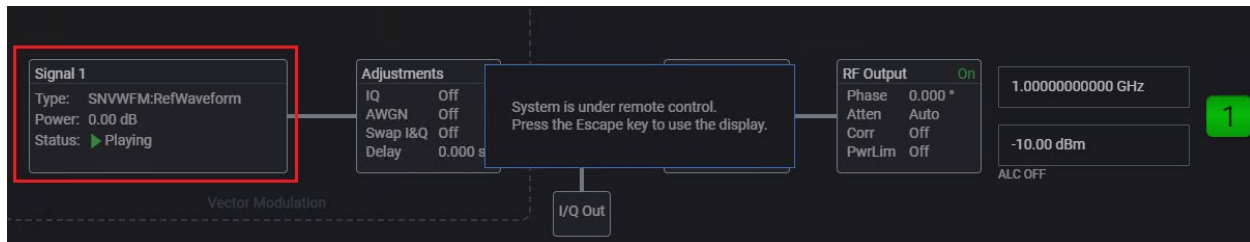


Figure 4. VXG screen display after reference waveform is downloaded from SA to SG

Digital Pre-distortion and Post-DPD Measurements

As you may know, PA is required to have higher linearity to amplify high PAPR signals. However, due to the limitations of cost, power consumption, and physical space, it is not easy to find higher linearity components that meet all of a particular system's requirements especially for wideband system like 5G, WLAN or Satellite Communication. DPD, one of the most cost-effective linearization techniques, adds an expanding non-linearity in the baseband that complements the compressing characteristic of the RF power amplifier (Figure 5). Ideally, the cascade of the pre-distorter and the power amplifier becomes linear and the original input is amplified by a constant gain. With the pre-distorter, the power amplifier can be utilized up to its saturation point while still maintaining good linearity, thereby significantly increasing its efficiency (Figure 6).

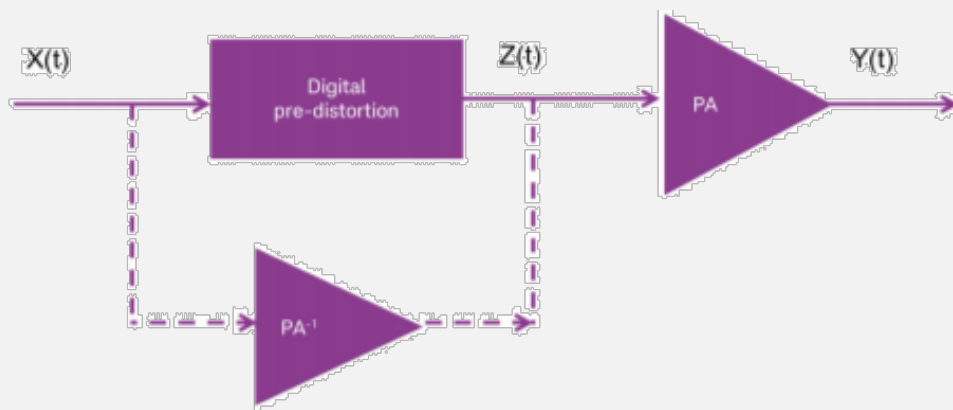


Figure 5. DPD for a PA cascade

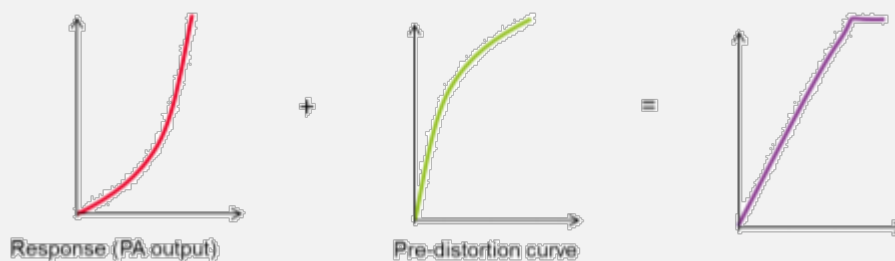


Figure 6. PA response with DPD

As shown in Figure 7, the DPD can be seen as an “inverse” of the PA. The DPD algorithm needs to model the PA behavior accurately and efficiently for successful DPD deployment.

Two DPD modes are supported with N9055EM0E:

- **Extract and Apply:** When DPD Mode is set to "Extract and Apply" (default), Power Amplifier measurements are done by measuring the post-distorted waveform played in SG. Once DPD process is completed, the pre-distorted waveform is generated inside SA, and then downloaded into SG again.
 - Three PA model types are supported: Memory polynomial, Volterra series and LUT (Look-Up Table)
 - Users can specify the number of iterations
 - For memory polynomial and Volterra series memory model types, users can specify the memory order and non-linear order
 - The DPD model can be exported for further verification
 - Customer's proprietary DPD algorithm written in MATLAB (coming later)
- **Apply Only:** The waveform is directly pre-distorted according to the specified DPD mode
 - If the PA Model Type is LUT (Look-up Table), the waveform is pre-distorted with the user input DPD model file of PA input versus PA output in terms of amplitude and phase;
 - If the PA Model Type is Memory Polynomial or Volterra Series, the waveform is pre-distorted with the Memory Polynomial or Volterra Series Coefficient File.
 - Waveform is directly pre-distorted with the user input LUT or coefficient file, loaded using Recall function of Signal Analyzer.

The required measurement bandwidth for acquiring signals will be determined by the bandwidth to be optimized. For example, to cover the channel adjacent to a 400 MHz 5G NR signal or 320 MHz 802.11be signal, 1200 MHz or 960 MHz bandwidth must be available for capture. The X-Series signal analyzers UXA N9042B together with M9384B VXG can support a maximum bandwidth up to 2 GHz, which can provide bandwidth for analyzing DPD-applied waveforms with 400 MHz 5G NR FR2 signals or 320 MHz WLAN 802.11be signals.

Toggle between Pre-DPD and Post-DPD measurements

You can toggle measurement results between Pre-DPD (measuring Reference Waveform) or Post-DPD (measuring DPD Waveform), by turning DPD state.

In addition to explicitly setting DPD state to off, if a parameter is changed that needs to re-calculate DPD LUT or coefficients, the DPD State will be changed to off.

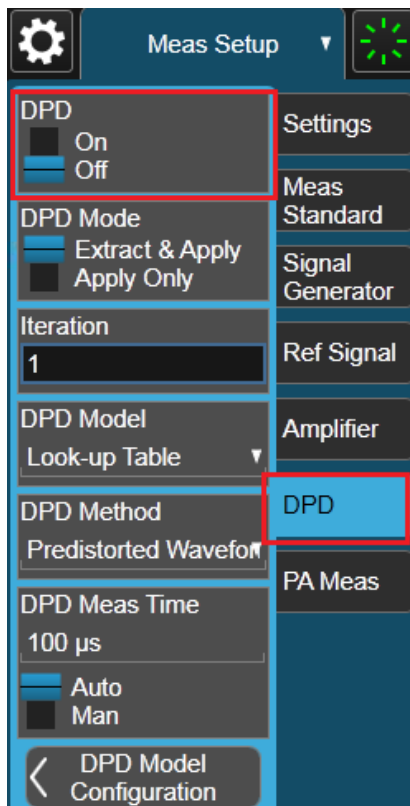


Figure 7. Toggle the DPD On/Off to switch between Pre-DPD and Post-DPD measurements

Enable Demod EVM in Power Amplifier Measurement Application

N9055EM0E Power Amplifier measurement application doesn't provide complicated EVM configuration. All the demodulation EVM parameters are synchronized from the measurement mode such as N9085EM0E for 5G NR and N9077EM1E/N9077EM2E for WLAN. So please make sure you have the 5G NR or WLAN license installed and the signal can be correctly demodulated in 5G NR or WLAN measurement application. You can either switch measurement Mode from Power Amplifier to 5G NR or open a new window for 5G NR mode as the example of Figure 8. When the EVM State is turned on in the Power Amplifier, demodulation EVM parameters will be synchronized from 5G NR mode automatically.

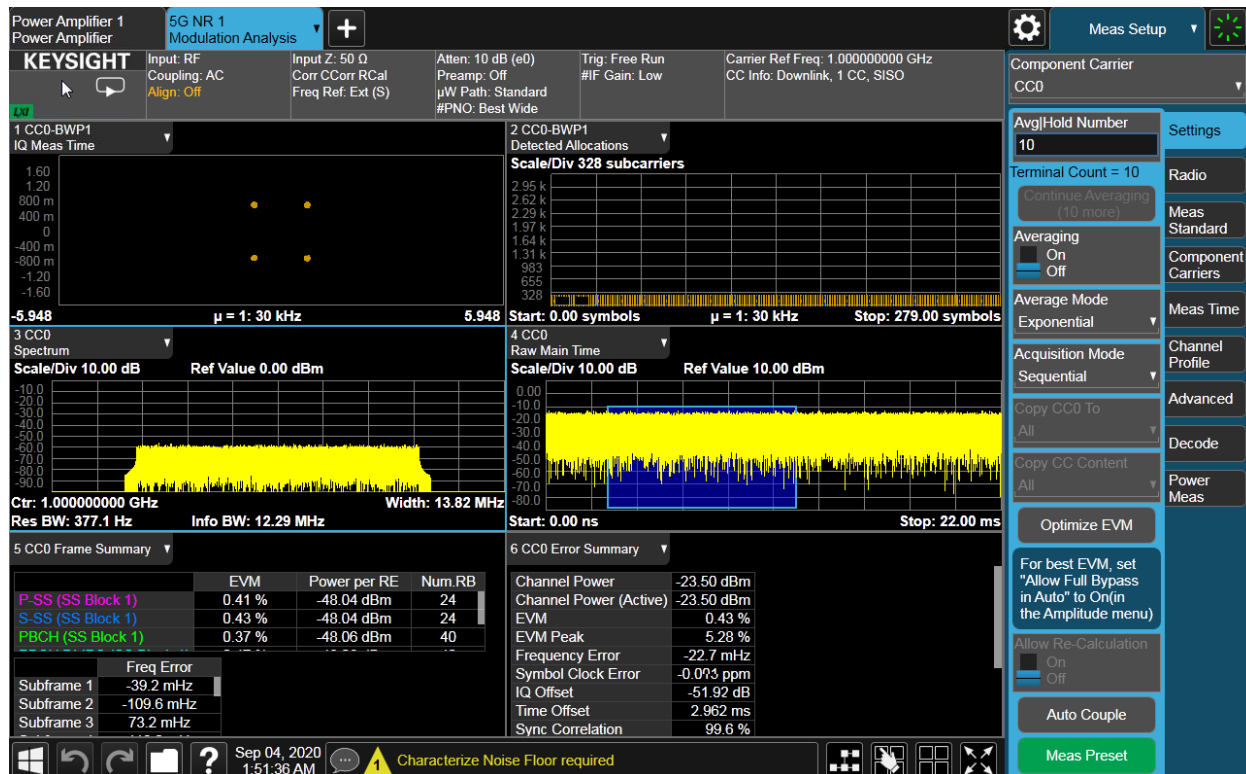


Figure 8. Switch from PA Test mode to 5G NR mode to check the correct demodulation settings

Enable "Optimize EVM"

You can turn on **"Optimize EVM"** in EVM configuration dialog, to get the optimized EVM result, Optimize EVM is designed as an "On/Off" state because there are multiple sub-measurements in one PA measurement loop such as ACP or EVM. As ACP and EVM use different hardware configurations, especially Mechanical Attenuator, then you'll hear a click noise when Mechanical Attenuator is adjusted. You can use "Single Mode" to avoid the continuous adjusting of the attenuator.

It is recommended to turn on "Optimize EVM" only in EVM vs. Power measurement, when Meas Type = Power Sweep; or use single mode when Meas Type = Single Power.

EVM vs. Power Measurement

The default measurement type is “Single Power” which means it will only make EVM measurement at the specified power. If you want to make the Power vs. EVM measurement, you can toggle the Meas Type from Single Power to Power Sweep, and then specify the Start Power, Stop Power, and Power Step. Min Power with DPD can also be specified, so only the power above the specified level will apply the DPD. You can toggle Extract DPD Once as On for only one time of DPD model extraction or it can extra the DPD model for each power level.

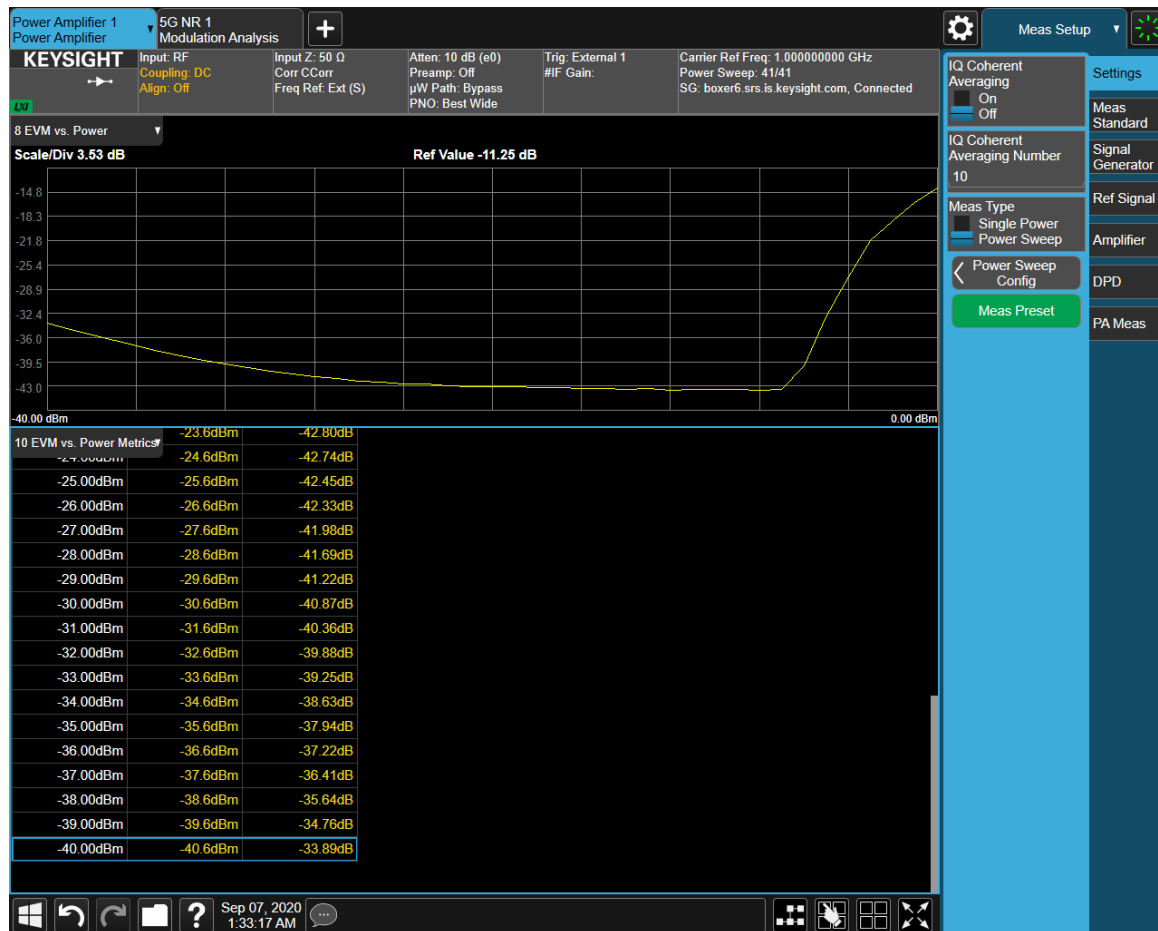


Figure 9. Power vs. EVM result for 5G NR signal with DPD

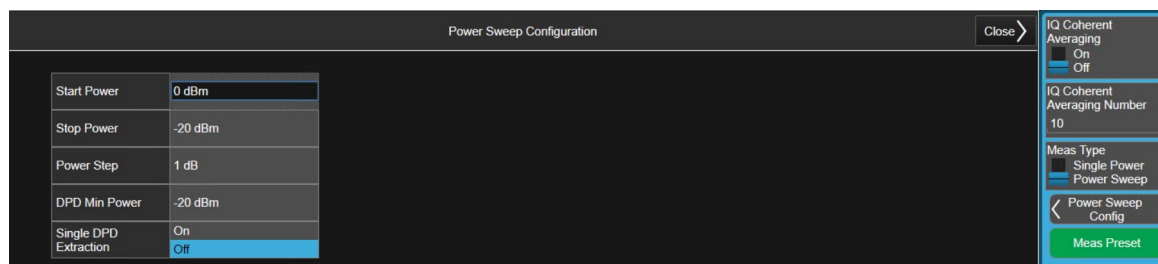


Figure 10. Switch Meas Type from Single Power to Power Sweep and show the Power Sweep parameter settings

Apply DPD directly to M9384B VXG

M9384B VXG supports DPD LUT (Look-Up Table) and Memory Polynomial models with FW version A.06.xx or later. Then N9055EM0E Power Amplifier measurement application doesn't need to download the Pre-distorted waveform into M9384B VXG. N9055EM0E Power Amplifier measurement application just sends the DPD LUT or Memory Polynomial coefficients directly to M9384B VXG, via SCPI command. This can significantly improve the overall PA test speed. You can see the flag “D” is shown on M9384B VXG GUI. This means the DPD model is now enabled in M9384B VXG. When the connected SG is connected and detected with this feature, it will automatically switch the DPD Method from “Pre-distorted Waveform” to “Generator”.

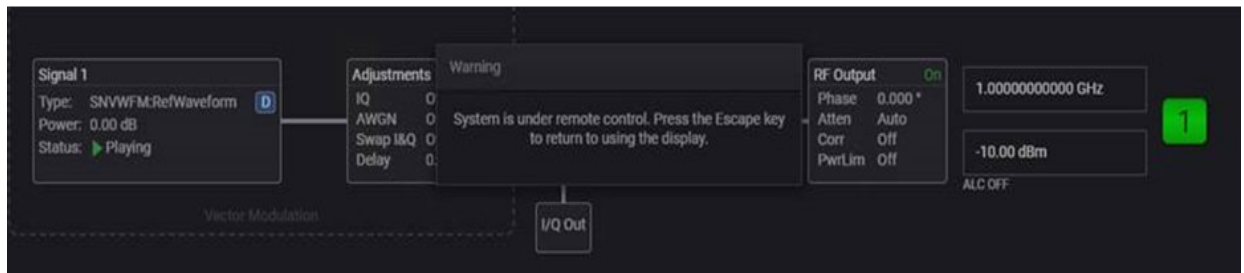


Figure 11. VXG front-panel display with DPD LUT enabled

Feature Summary

Feature	Parameter Setting
General Settings	Average On/Off
	Meas Type: Single Sweep or Power Sweep
	Power Sweep Config: Start Power, Stop Power, Power Step, DPD Min Power, Single DPD Extraction On/Off
Signal Generator	Frequency
	RF Output: On/Off
	DC Calibration: On/Off
	ALC: On/Off
	Run-time Scaling: 70% (default)
	VXG: Channel 1 or Channel 2
	Apply settings to Signal Generator
	Connection Management
Measurement Standard	Radio Standard Presets
	5G NR (BTS 10 MHz to 400 MHz and MS 5 to 400 MHz)
	WLAN: 802.11ac/ax 20/40/80/160 MHz
	802.11be 20/40/80/160/320 MHz
	5G NR settings
	FR1 or FR2
	SCS: 15/30/60/120 kHz
	Preset from 5G NR EVM
Reference Signals	Signal Studio or user-defined
	Signal Studio waveforms
	- User defined types: - CSV/TEXT files¹ - Big Endian 16 bits - VSA Files (*.sdf)
	Waveform Sample Rate
	Waveform Processing (Predefined Resampling Ratio with 1 as default)
	Export to Signal Generator
	Max Input Power
	Loss In
Amplifier Settings	Gain
	Power Control Mode: PA Input or PA Output
	Input Power
Digital Pre-Distortion (DPD)	DPD Mode: On/Off
	DPD Mode
	Extract and apply
	Apply Only

1. This feature requires the M9384B VXG with FW version A.06 or above.

Digital Pre-Distortion (DPD)	DPD Iteration
	DPD Model
	• Look-up table
	• Memory polynomial
	• Volterra series
	DPD Mode: Generator or Pre-distorted Waveform
	• Generator supports the LUT and Memory Polynomial ¹ DPD models
	DPD Meas Time: Auto or Manual
	LUT: Normalized or Absolute, LUT Size, AM/AM and AM/PM Polynomial order
	Memory Polynomial: LES using QR or SVD, Memory Order, Non-linear Order and Odd Orders Only On/Off
	Volterra Series: LES using QR or SVD, Memory Order, Non-linear Order Cross Term Order, and Odd Orders Only On/Off
PA Measurement	AM/AM: polynomial order
	AM/PM: polynomial order
	ACP: RWB, Measurement Type, Power Ref Type, Carrier settings, Offset settings
	Radio Format: 5G NR or WLAN
	EVM: On/Off
	Report EVM in dB: On/Off
	EVM Meas Time
	Optimize EVM: On/Off
	Preset from 5G NR EVM or WLAN EVM
Measurement (Common)	AM-AM trace (Pre-DPD and Post-DPD)
	AM-PM trace (Pre-DPD and Post-DPD)
	Number Results with Pre-DPD and Post-DPD (Delta EVM, Input Power, Output Power, Gain, Crest Factor In, Crest Factor Out)
	EVM Error Summary with Pre-DPD and Post-DPD (Channel Power, Channel Power/Active, EVM, Peak EVM, Frequency Error, Symbol Clock Error, I/Q Offset, Sync Correlation, Sync Source, Magnitude Error, Phase Error, I/Q Gain Imbalance, I/Q Quad Error, I/Q Time Skew, Cell ID)
Measurement (ACP)	ACP graph with Pre-DPD and Post-DPD with marker
	ACP Metrics with Pre-DPD and Post-DPD
	• Total Carrier Power, Total PSD
	• Offset frequency, Integration BW, Filter, ACP value (dBc and dBm)
Measurement (EVM)	EVM vs. Power trace with marker
	EVM vs. Power Metrics (Total Power, Carrier Power, EVM)
	EVM Metrics (Channel Power, Composite EVM, Peak EVM, Frequency Error, Sync Error, I/Q Offset)

1. This feature requires the M9384B VXX with FW version A.06 or above.

Ordering Information

Flexible Software Licensing and Configuration

- **Node-locked:** Allows you to use the license on one specified instrument/computer.
- **Transportable:** Allows you to use the license on one instrument/computer at a time. This license may be transferred to another instrument/computer using Keysight's online tool.
- **Floating:** Allows you to access the license on networked instruments/computers from a server, one at a time. For concurrent access, multiple licenses may be purchased. Floating support single site, single region and worldwide three different types.
- **USB portable:** Allows you to move the license from one instrument/computer to another by end-user only with certified USB dongle, purchased separately.
- **Subscription (time-based):** License is time limited to a defined period, such as 12-months



Try Before You Buy!

Evaluate a full-featured version of our X-Series measurement application with our FREE trial. Redeem one 30-day trial license of each measurement application online at www.keysight.com/find/X-Series_apps_trial

Power Amplifier Measurement Application, Multi-touch (N9055EM0E)		
Software License Type	Software License	KeysightCare Subscription
Node-locked perpetual	R-Y5C-001-A	R-Y6C-001-y ²
Node-locked time-based	R-Y4C-001-z ¹	Included
Transportable perpetual	R-Y5C-004-D	R-Y6C-004-y ²
Transportable time-based	R-Y4C-004-z ¹	Included
Floating perpetual (single site)	R-Y5C-002-B	R-Y6C-002-y ²
Floating time-based (single site)	R-Y4C-002-z ¹	Included
USB portable perpetual	R-Y5C-005-E	R-Y6C-005-y ²
USB portable time-based	R-Y4C-005-z ¹	Included
One-month KeysightCare Support and Subscription		
Software License Type		
R-Y6B-501	1-month extension for node-locked perpetual license	
R-Y6B-504	1-month extension for transportable perpetual license	
R-Y6B-502	1-month extension for floating (single site) perpetual license	
R-Y6B-505	1-month extension for USB portable perpetual license	

1. z means different time-based license duration. F for 6 months, L for 12 months, X for 24 months, and Y for 36 months. All time-based licenses have included the support subscription same as the time-base duration.
y means different support subscription duration. L for 12 months (as default), X for 24 months, Y for 36 months, and Z for 60-months. Support subscription must be purchased for all perpetual licenses with 12-months as the default. All software upgrades and KeysightCare support are provided for software licenses with valid support subscription.
2. Support subscription for all perpetual licenses can be extended with monthly extensions.

Hardware and Software Configuration

Model	Description	Additional Information
Software		
N9055EM0E	Power Amplifier Measurement Application	Required
N9085EM0E	5G NR Measurement Application	5G NR EVM
N9077EM1E	WLAN 802.11ac/ax Measurement Application	802.11ac/ax EVM
N9077EM2E	WLAN 802.11be Measurement Application	802.11be EVM
N7631EMBC	Signal Studio for 5G NR, Waveform playback	5G NR waveforms
N7617EMBC	Signal Studio for WLAN, Waveform playback	WLAN waveforms
N9041B/N9040B UXA and N9030B PXA Signal Analyzers		
526/532/544/550	Frequency range, up to 26.5, 32, 44 or 50 GHz	One required
B1X/B2X/B5X/H1G	Analysis bandwidth, 160 ¹ , 255, 512 MHz or 1 GHz ²	One required
P26/P32/P44/P50	Preamplifier, 26.5, 44, 50 GHz or 50 GHz basic	Optional
N9032B PXA Extended Signal Analyzer		
508/513/526	Frequency range, up to 8.4, 13.6 or 26.5 GHz	One required
R10/R15/R20	Analysis bandwidth, 1, 1.5, or 2 GHz	One required
P08/P13/26	Preamplifier, 8.4, 13.6, or 26.5 GHz	Optional
N9042B UXA Extended Signal Analyzer		
526/544/550	Frequency range, up to 26.5, 44 or 50 GHz	One required
R10/R15/R20/R40	Analysis bandwidth, 1, 1.5, 2, or 4 or GHz	One required
P26/P44/P50/P5L	Preamplifier, 26.5, 44, 50 GHz or 50 GHz basic	Optional
M9384B VXG Microwave Signal Generator		
M9384B-001	Add channel 1	One required
F14/F20/F32/F44	Frequency range, 1 MHz to 14, 20, 31.8 or 44 GHz	One required
D05/D06	RF bandwidth 500 MHz with 256 MSa	One required
D10/D11	RF bandwidth 1 GHz with 256 MSa	
D20/D21	RF bandwidth 2 GHz with 256 MSa	
D2E	RF bandwidth 2 GHz with 256 MSa for F33/F44 limited	
M05/M10	Baseband generator memory up to 512 MSa/1 GSa	Optional
ST5	Low phase noise	Optional
ST6	Enhanced low phase noise	Optional
1EB	High output power from 20 GHz to 44 GHz	Optional
1EE	High output power from 20 GHz to 43.5 GHz, limited above 43.5 GHz	Optional

1. B1X option for 160 MHz analysis bandwidth is only qualified with N9030B PXA.

2. N9041B UXA only qualifies with H1G option for 1GHz analysis bandwidth.

Additional Information

Websites

- X-Series measurement applications: www.keysight.com/find/X-Series_apps
- Download X-Series measurement application: www.keysight.com/find/X-Series_apps_software
- Learn about compatible instruments: www.keysight.com/find/X-Series_apps_platforms
- Learn more about models and options: www.keysight.com/find/X-Series_apps_model
- 30-day trial license for X-Series measurement application: www.keysight.com/find/X-Series_apps_trial
- X-Series Signal Analyzers: www.keysight.com/find/X-Series
- M9384B VXG Microwave Signal Generator: www.keysight.com/find/VXG
- N7614C Signal Studio for Power Amplifier: www.keysight.com/find/N7614C
- N9055EM0E Power Amplifier measurement application: www.keysight.com/find/N9055EM0E

Literatures

- X-Series Measurement Application, Brochure, [5989-8019EN](#)
- 5G NR Measurement Application Technical Overview, [5992-2916EN](#)
- WLAN Measurement Application, Technical Overview, [5992-2840EN](#)
- Signal Studio for 5G NR, Technical Overview, [5992-2762EN](#)
- Signal Studio for WLAN, Technical Overview, [5992-2742EN](#)
- N7614C Signal Studio for Power Amplifier, Technical Overview, [5992-2741EN](#)

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