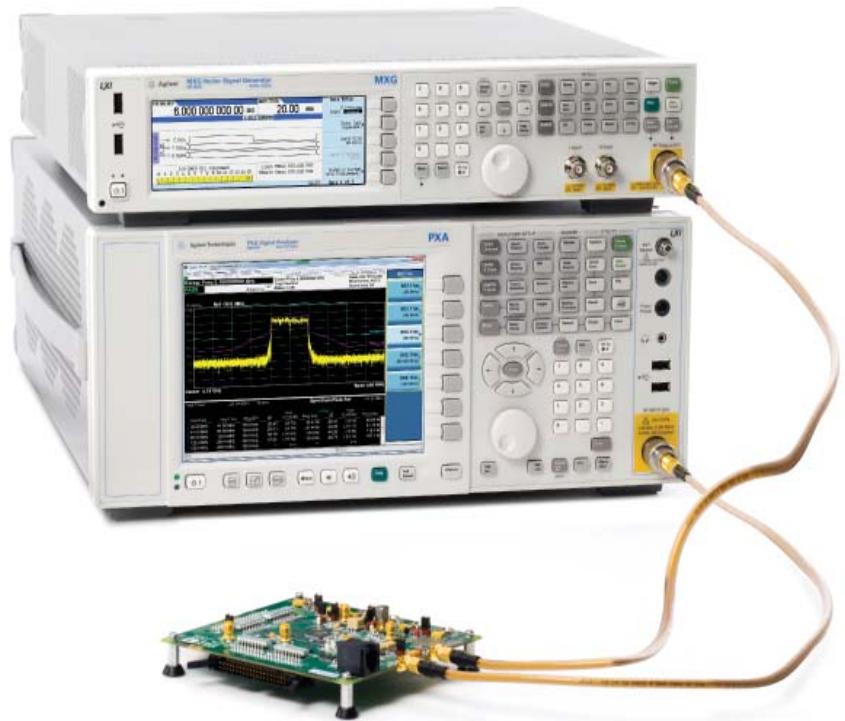


# Creating and Optimizing 802.11ac Signals and Measurements

## Application Note



# Introduction

The new IEEE 802.11ac wireless LAN standard, currently under development, aims to provide higher data throughput rates of over 1 gigabit per second to improve the user experience and to enable new applications such as transmission of multiple streams of high-definition multimedia data. To achieve these data rates, the Very High Throughput (VHT) physical layer specification has introduced new features, including wider bandwidth channels up to 160 MHz and 256QAM modulation. 802.11ac devices will need to meet more stringent specifications for RF performance, especially for error vector magnitude (EVM) over wider bandwidths, so it is important to have test tools that provide the best reference signals and EVM measurements, particularly for R&D and design validation.

This application note details how to create and optimize 802.11ac signals using the N7617B Signal Studio for WLAN 802.11a/b/g/n/ac software with Agilent's RF signal generators to get the highest quality signals from the instruments. The application note also includes the analysis of 802.11ac signals using the N9030A PXA signal analyzer, with either the 89600 VSA software or the N9077A X-Series WLAN application, and provides hints for achieving the best EVM measurements with this solution.

# Generation of 802.11ac Signals

## Choosing a signal generator

The N7617B Signal Studio for WLAN 802.11a/b/g/n/ac software allows users to configure parameters to create waveform files which can then be downloaded to various RF signal generators for playback. The choice of which signal generator to use depends on the requirements for channel bandwidth, performance characteristics, and price. 802.11ac requires the support of 20, 40, and 80 MHz channel bandwidths, with optional support for 160 MHz and 80+80 MHz (consisting of two 80 MHz channels that are not adjacent in frequency). The table below provides a comparison between some of Agilent's RF signal generators. Note that the EVM performance of the E4438C ESG is not as good as the first-generation MXG or the EXG/MXG X-Series signal generators, since it is operating at its maximum RF modulation bandwidth limit when generating an 80 MHz 802.11ac signal. The ESG also lacks the internal channel correction that is available in the EXG/MXG, which will be described later in this application note. Phase noise performance is provided for a 300 kHz offset, which is close to the subcarrier spacing of 312.5 kHz that is used for WLAN OFDM signals. Performance is fairly similar between the different instruments, and it is not the main factor affecting the EVM.

Table 1. Comparison of RF signal generators

	N5182B MXG	N5172B EXG	N5182A MXG	E4438C ESG
Maximum RF modulation bandwidth	160 MHz	120 MHz	100 MHz	80 MHz
Maximum output power 5-6 GHz	16 dBm 18 dBm (Option 1EA)	16 dBm 18 dBm (Option 1EA)	11 dBm 16 dBm (Option 1EA)	10 dBm
Phase noise for CW at ~300 kHz offset	-118 dBc/Hz std or with Option UNX, -126 dBc/Hz with Option UNY (at 6 GHz)	-125 dBc/Hz (at 6 GHz)	-122 dBc/Hz (at 5.8 GHz)	-124 dBc/Hz (at 5.7 GHz)
Max baseband generator waveform memory	1 Gsamples	512 Msamples	64 Msamples	64 Msamples
Typical EVM for 80 MHz BW signal at 5.775 GHz, -5 dBm power level <sup>1</sup>		-47 to -49 dB (0.35% to 0.45%)		-40 to -42 dB (0.8% to 1%)

1. Equalizer training using preamble only.

## Optimizing signal generator hardware performance

The EXG/MXG and ESG signal generators offer several features that can improve the channel flatness and EVM performance of the instrument, including I/Q calibrations, internal channel corrections, and I/Q adjustments. An overview of these features is provided in the following section. Some calibration procedures require the use of a spectrum analyzer or power meter. Additional information on compatible instruments and how to configure the connections may be found in the appendix of this application note. For more details on the features or how to use them, please refer to the User's Guide for each instrument, which can be downloaded from the respective product web pages at [www.agilent.com](http://www.agilent.com).

### I/Q calibrations

I/Q calibrations are available for the EXG, MXG, and ESG signal generators. When the internal baseband generator is used to create I/Q signals, the I/Q calibrations provide corrections for I/Q offset, gain balance, and quadrature error, superseding the factory-supplied calibration data. The calibration can improve performance that may have degraded over time or changed due to temperature changes, and a new I/Q calibration is recommended if the ambient temperature has changed by more than 5 degrees Celsius since the last calibration was performed.

The 3 types of I/Q calibrations can be accessed by pressing the **I/Q** key on the instrument's front panel, selecting **I/Q Calibration** and then the calibration type, and executing the calibration. Each calibration improves the DC offset, gain and quadrature error for the I/Q modulator, but they apply to different frequency ranges.

1. DC calibration: Optimizes the I/Q performance for the current instrument settings at one frequency. This is a quick calibration that usually completes in a few seconds. However, changing any instrument settings after performing the calibration will cause the instrument to revert to the factory calibration data. The I/Q modulation should be turned on, with the **Optimized Path** set to **RF Output**, and the **I/Q Source** set to **Internal**, prior to the calibration. The DC calibration data is cleared if the instrument is preset or the power is turned off.
2. User calibration: Provides a faster calibration that is limited to a user-defined frequency span when a calibration over the instrument's full frequency span is not needed. Factory data is used for the rest of the frequency range. The calibration data is retained through a preset or power cycle (except in older N5182A MXG instruments with firmware revision A.01.50 or below). Use the softkeys in the I/Q Calibration menu to enter the start and stop frequencies for the calibration.
3. Full calibration: Calibrates over the full frequency span of the instrument. The procedure may take one minute or longer to complete. The calibration data is retained through a preset or power cycle (except for N5182A MXG with firmware revision A.01.50 or below).

## Internal channel corrections

Internal channel correction is available in the EXG and MXG signal generators, and corrects for magnitude and phase flatness over the supported modulation bandwidth for arbitrary center frequencies. The feature is turned off by default, because the switching speed is impacted when this feature is on, but for the wideband signals used for 802.11ac, the channel correction is useful to improve the flatness and EVM, especially for 160 MHz bandwidth signals. Figure 1 shows an example of the EVM and flatness before and after this correction is turned on.

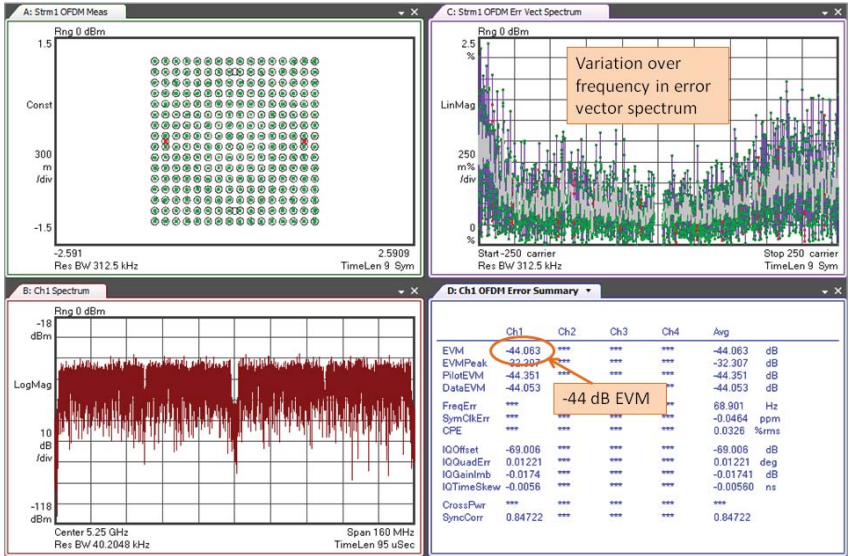


Figure 1(a): EVM and channel flatness without internal channel correction.

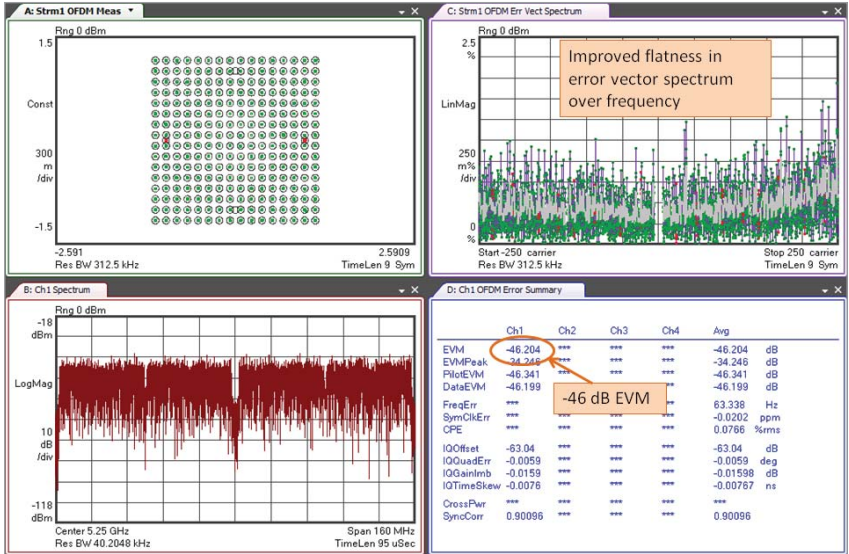


Figure 1(b): EVM and channel flatness with internal channel correction turned on.

To turn on the channel correction, press these keys on the front panel: **I/Q > More > Int Channel Correction > Int Channel Correction On**. Note that if you are using the N7617B Signal Studio software with your instrument, you should turn on the channel correction AFTER the waveform has been downloaded, because Signal Studio may preset the instrument during the download process, which turns off the channel correction. N7617B Signal Studio version 1.8.7.0 or later provides a setting in the IQ section on the Instrument page that allows you to turn on the internal channel correction as part of the download process.

The internal channel correction feature was first introduced in the N5182A MXG and the functionality has improved with later revisions, so the feature is slightly different for various model instruments and firmware revisions. Please refer to the section that applies to your instrument for more details.

### **N5182A MXG signal generator**

The internal channel correction was first introduced in firmware version A.01.60 for the N5182A MXG, along with an I/Q modulator skew calibration that corrects for timing skew errors in the I/Q modulator for the RF output path and improves out-of-channel image rejection. The I/Q modulator skew calibration can provide significant improvement in EVM performance (more than the internal channel correction), and it only needs to be performed once for each set of hardware. Instruments that shipped with firmware version A.01.60 and above had the calibration performed at the factory, and the calibration does not need to be performed again unless the hardware in the instrument is repaired or replaced. Once the I/Q modulator skew calibration has been performed, it is always applied when the optimized path is RF output.

A new internal channel correction can be performed without any external equipment, and it is recommended when the ambient temperature has changed by more than 5 degrees Celsius since the previous calibration. To do a new calibration, first run a full I/Q calibration by pressing these keys: **I/Q > > I/Q Calibration > Calibration Type: Full > Execute Cal**. Next, go to the Internal Channel Correction menu to perform the calibration: press **I/Q > More > Int Channel Correction > Execute Int Chan Corr Cal**, then set **Int Channel Correction On**.

For N5182A instruments that shipped with an earlier firmware version, upgrading is highly recommended to get the benefits of these new calibrations, especially the I/Q modulator skew calibration. The new features can be added by installing the latest firmware (available at [www.agilent.com/find/upgradeassistant](http://www.agilent.com/find/upgradeassistant)) and obtaining the necessary license key by ordering N5182AK-R2C. After installation of the license file, the license will be displayed in the MXG's menus as Option U01 or higher with a description of "Core FW enhancement." Once the firmware and license key have been installed, the I/Q modulator skew calibration and internal channel correction will need to be performed.

The I/Q modulator skew calibration requires the RF output of the signal generator to be connected to the RF input of a spectrum analyzer, and the instruments to be connected via LAN, GPIB, or a LAN-to-GPIB gateway. To perform the I/Q modulator skew calibration, first press these keys: **I/Q > More > Int Channel Correction > Configure Spectrum Analyzer** and use the softkeys to configure the connection type and IP address or device name for the spectrum analyzer and to test the connection (see Appendix A for details). Then return to this menu and press **Execute I/Q Mod Skew Cal** to initiate the calibration.

### **N5172B EXG and N5182B MXG X-series signal generators**

In the X-series models, the I/Q modulator skew calibration has been included in the factory calibrations and is no longer available as a user calibration. Instruments with firmware version B.01.01 do not have an Int Channel Correction menu to allow the user to perform a new channel correction; there is only a softkey that toggles the correction on or off.

New calibrations are available in instruments with firmware version B.01.10 or higher, providing improved performance. While previous calibrations only corrected for symmetric I/Q mismatch errors, the new Enhanced Factory Calibration can correct for some asymmetric errors as well. For I/Q channel flatness, previous calibrations only calibrated at a single attenuator step of 5 dB, which also worked for higher levels of attenuation since the match at the RF connector remains relatively constant for those attenuator steps. The new routine calibrates at multiple attenuator settings to better account for changes in the match for other settings. A spectrum analyzer and power meter are required for the calibration.

Instruments shipped with firmware version B.01.10 or higher have the Enhanced Factory Calibration performed at the factory, and there is no firmware feature to allow a user to perform this calibration. A feature will be added to enable users to perform this calibration in firmware version B.01.20 which is planned for release in Q4 2012.

To perform the Enhanced Factory Calibration with firmware version B.01.20 or later, press these keys: **Utility > More > Service > I/Q Int Channel Correction Calibrations > Enhanced Factory Calibration**. Go to the **Configure Spectrum Analyzer** and **Configure Power Meter** menus to configure the instruments (see Appendices A and B for more information), then press **Execute Enhanced Int Channel Correction Cal** to initiate the calibration.

In addition to the factory calibration, which corrects to the RF connector of the instrument, firmware version B.01.20 will also introduce a new User Channel Correction that provides correction to the point where the device under test (DUT) is connected to compensate for cables, switches, or other components between the signal generator's RF port and the DUT. The User Channel Correction requires a power meter and can be performed over a user-specified frequency span.

To perform the User Channel Correction, press these keys: **I/Q > More > Int Channel Correction > Correction Type: User > User Calibration > Configure Power Meter** and use the menus to configure the connection to the power meter and zero and calibrate the sensor (see Appendix B or the instrument User's Guide for details). Press **Return** and enter the desired start frequency and stop frequency, then press **Execute User Channel Correction Cal** to perform the calibration. To enable the calibration, press **Return > Int Channel Correction On**.

EXG/MXG instruments with B.01.01 firmware can be upgraded to add the new capabilities simply by downloading and installing the new firmware. The Factory Calibration, Enhanced Factory Calibration, and User Channel Correction will need to be performed before they can be used.

## I/Q adjustments

The ESG, EXG, and MXG signal generators provide an I/Q Adjustment menu (press these keys: **I/Q > I/Q Adjustments**) that can be used to compensate for (or deliberately add) impairments to the I/Q signal. These adjustments allow you to correct for errors that have not been compensated for by the other available corrections in the instrument. Adjustments can be applied to the internal baseband, external I/Q outputs, or external I/Q inputs. The following adjustments are available. For more information on any item, you can consult the User's Guide, or press the Help key on the instrument's front panel and then press the desired key to see an explanation of that key's function. Figure 2 shows the map for the I/Q Adjustments menu for the EXG and MXG. The ESG's I/Q adjustment menus have a different arrangement but the same settings are available; see Figure 3 for the menu map.

- Internal baseband: I and Q offset, I/Q gain balance, quadrature angle, I/Q phase, I/Q skew, I/Q delay
- External I/Q outputs: I/Q attenuator, common mode I/Q offset range, common mode I/Q offset, differential mode I and Q offsets
- External I/Q inputs: I and Q offsets, quadrature angle adjustment

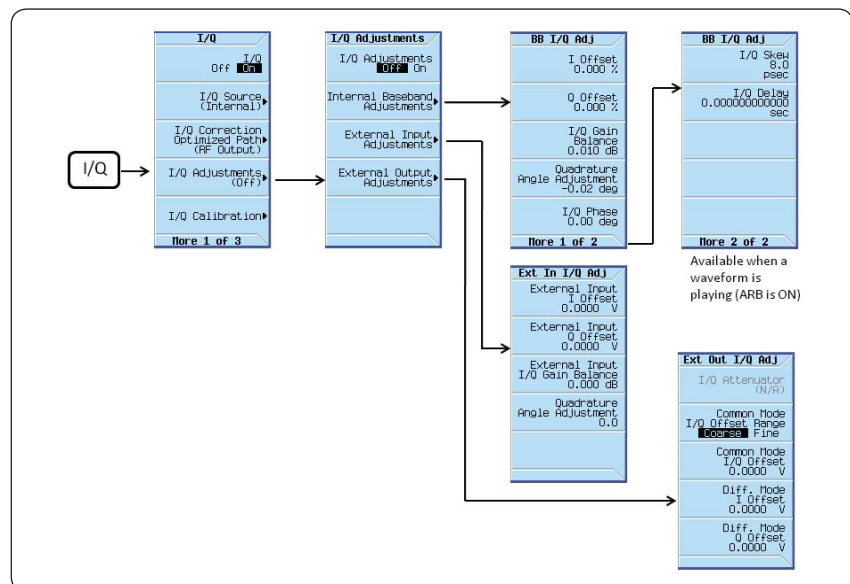


Figure 2. Menu map for I/Q adjustments in the EXG and MXG signal generators.



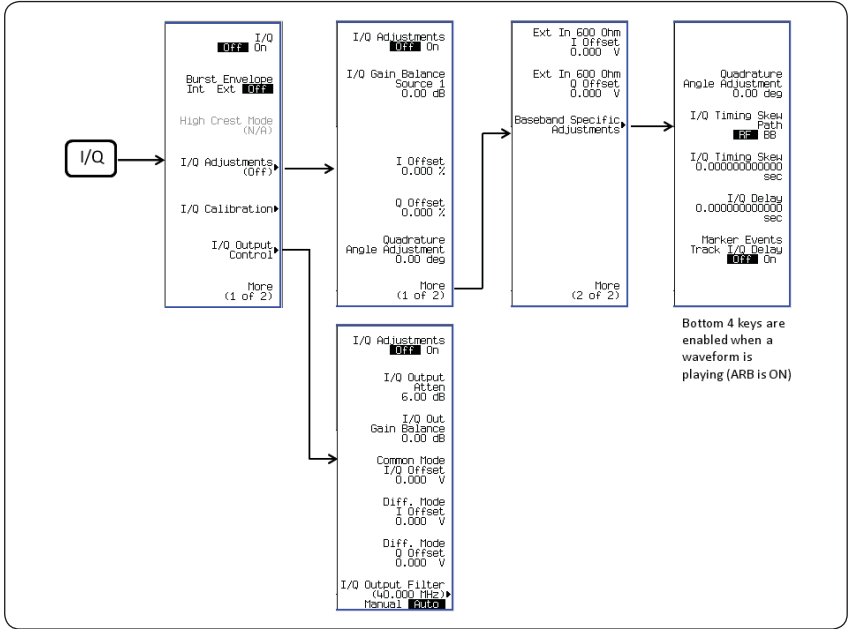


Figure 3. Menu map for I/Q adjustments in the ESG signal generator.

You can analyze the 802.11ac signal from the signal generator using the 89600 VSA software or the N9077A X-series WLAN application to determine what the IQ errors are in the signal and how to compensate for them. For example, the OFDM Error Summary display in the 89600 VSA software shown in Figure 4 lists the I/Q offset, quadrature error, gain imbalance, and timing skew for this signal. Performing one of the calcs found in the I/Q Calibration menu usually provides a good correction for the I/Q offset. The other errors may be compensated for by entering the opposite values in the I/Q Adjustment's Internal Baseband Adjustment menu. There may be some interaction between the parameters, so some experimentation may be needed.

	Ch1	Ch2	Ch3	Ch4	Avg	
EVM	-44.902	***	***	***	-44.902	dB
EVMPeak	-35.082	***	***	***	-35.082	dB
PilotEVM	-46.153	***	***	***	-46.153	dB
DataEVM	-44.865	***	***	***	-44.865	dB
FreqErr	***	***	***	***	-3.2039	Hz
SymClkErr	***	***	***	***	-0.2197	ppm
CPE	***	***	***	***	0.1676	%rms
<b>IQOffset</b>	<b>-52.045</b>	<b>***</b>	<b>***</b>	<b>***</b>	<b>-52.045</b>	<b>dB</b>
<b>IQQuadErr</b>	<b>0.24374</b>	<b>***</b>	<b>***</b>	<b>***</b>	<b>0.24374</b>	<b>deg</b>
<b>IQGainImb</b>	<b>-0.0260</b>	<b>***</b>	<b>***</b>	<b>***</b>	<b>-0.02606</b>	<b>dB</b>
<b>IQTimeSkew</b>	<b>0.01107</b>	<b>***</b>	<b>***</b>	<b>***</b>	<b>0.01107</b>	<b>ns</b>
CrossPwr	***	***	***	***	***	
SyncCorr	0.83110	***	***	***	0.83110	

Figure 4. IQ errors highlighted in the OFDM Error Summary display from the 89600 VSA software.

Similar information is displayed in the N9077A embedded application's Numeric Results display for the modulation analysis measurement, as shown in Figure 5.

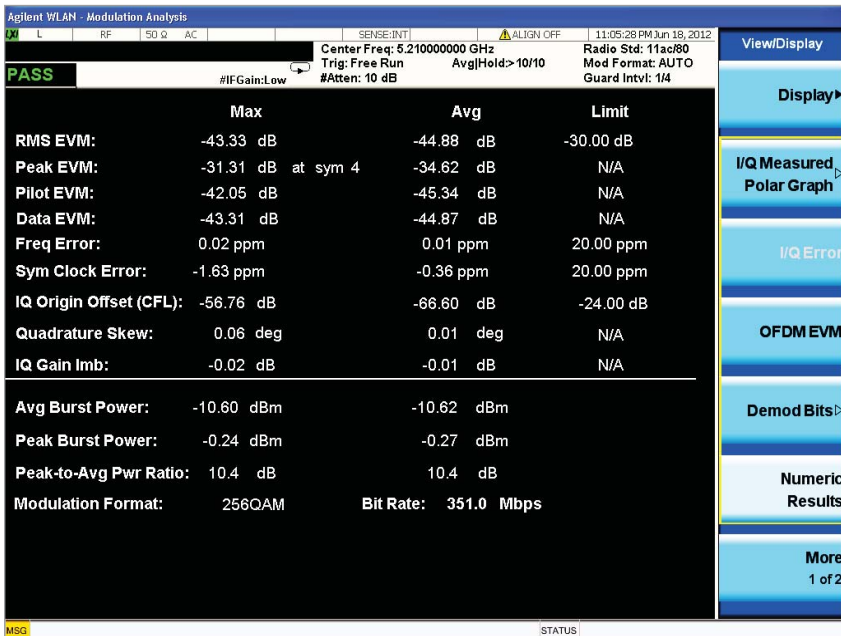


Figure 5. IQ Errors in the N9077A X-Series WLAN application.

# N7617B Signal Studio Software Settings

## Instrument settings

N7617B Signal Studio for WLAN 802.11a/b/g/n/ac software provides an “Instrument” settings page that allows you to automatically enable certain settings each time a waveform is downloaded to the signal generator, or send commands to change instrument parameters from the software’s user interface. Many of the adjustments described in the previous section are accessible from the “Instrument” settings page, as shown in Figure 6. For example, you can click the “DC Cal” button to execute a DC I/Q calibration, or set “Perform DC I/Q Calibration” to “On” to automatically perform the cal each time that a waveform is downloaded. For EXG/MXG instruments that offer the internal channel correction, you can turn that on automatically from the IQ settings. You can also turn on I/Q adjustments and enter the appropriate values for various parameters.

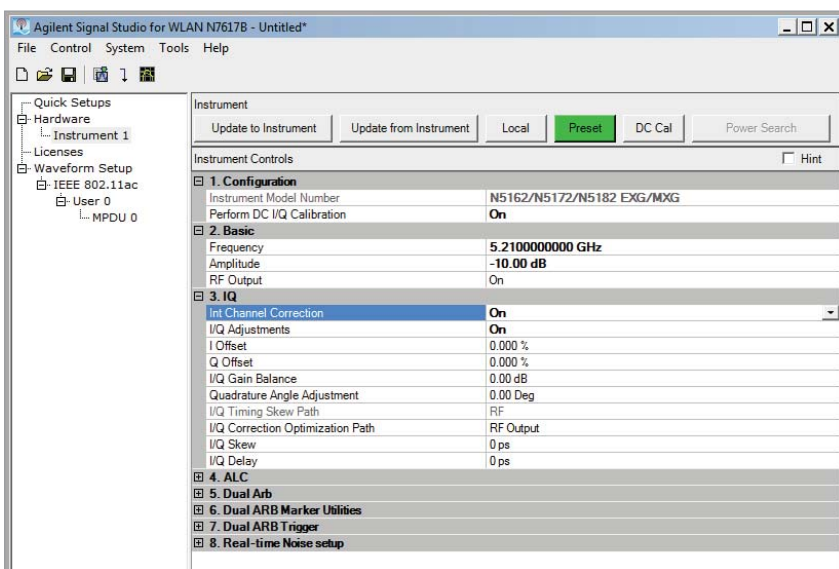


Figure 6. Instruments Settings screen in the N7617B Signal Studio software.

## Spectrum control settings

Signal Studio software provides settings that allow you to modify the spectral characteristics of the output signal. By default, a raised cosine window is applied to the OFDM signal with no additional filtering. This window reduces spectral regrowth by smoothing out the transition from one symbol to the next in the time domain signal, over the number of samples specified by the “Windowing Length” parameter. The maximum value for the windowing length is 16 samples when a short guard interval (400 ns) is used, or 32 samples when a long guard interval (800 ns) is used. For more explanation of this OFDM window, please refer to the “OFDM Raised Cosine Windowing” article in the Concepts section of the online help file.

You can also apply a baseband filter to reduce the transmitted bandwidth. The software offers five menu options for baseband filtering: None, Gaussian, Root Raised Cosine, Ideal Low Pass, or User Defined. These filters allow you to improve the spectral efficiency of the signal, at the expense of inter-symbol interference, channel flatness, or EVM performance, depending on the type of filter that is used. For example, the ideal low pass filter can be used to optimize the adjacent channel power (ACP) performance of the signal. This applies a low-pass rectangular filter with very steep cut-off. Since the filter is a finite impulse response (FIR) filter with a finite number of coefficients and is not truly “ideal,” the resulting ripple in the cut-off band is minimized with a Hamming window.

The 89600 VSA displays in Figures 7, 8, and 9 compare the results of some different spectrum control settings. Figure 7 shows the results with the default OFDM windowing length setting of 2, with no baseband filtering. I/Q adjustments were used to improve the EVM results, and the same adjustment values were used for the measurements in Figures 8 and 9. Figure 8 shows the case of OFDM windowing length of 16 with no baseband filtering, and Figure 9 shows the default OFDM windowing but with the addition of an ideal low pass baseband filter with a length of 32 symbols. Note that changing the OFDM windowing length sharpens the cut-off at the band edges with minimal change in the EVM or the channel flatness shown in Trace C, channel frequency response. Using the ideal low pass filter provides an even sharper cut-off for better ACP, but it degrades the EVM by about 1 dB, and the channel flatness has worsened from about 0.6 dB to 1.7 dB peak-to-peak.

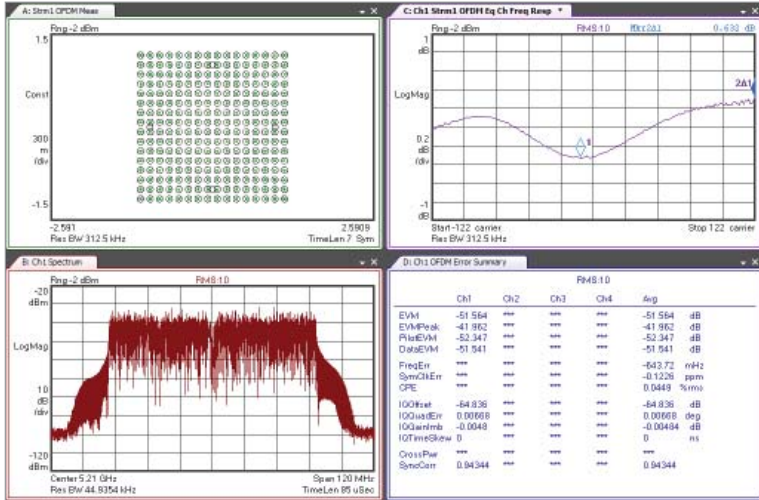


Figure 7. OFDM windowing length = 2 (default), no baseband filtering.

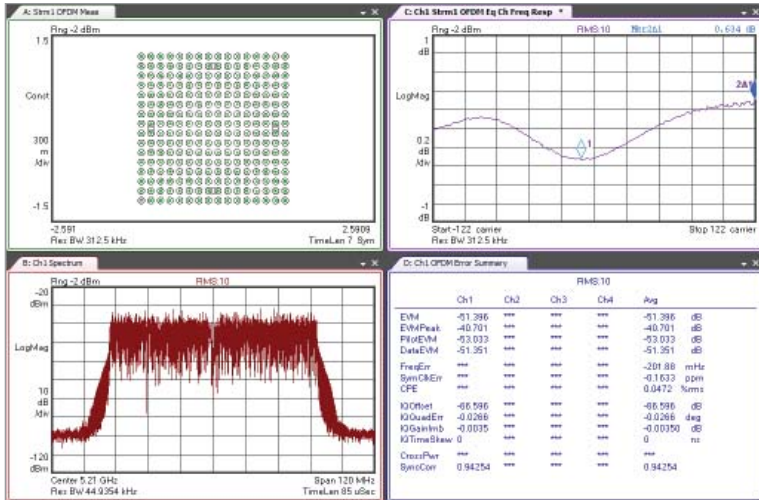


Figure 8. OFDM windowing length = 16, no baseband filtering.

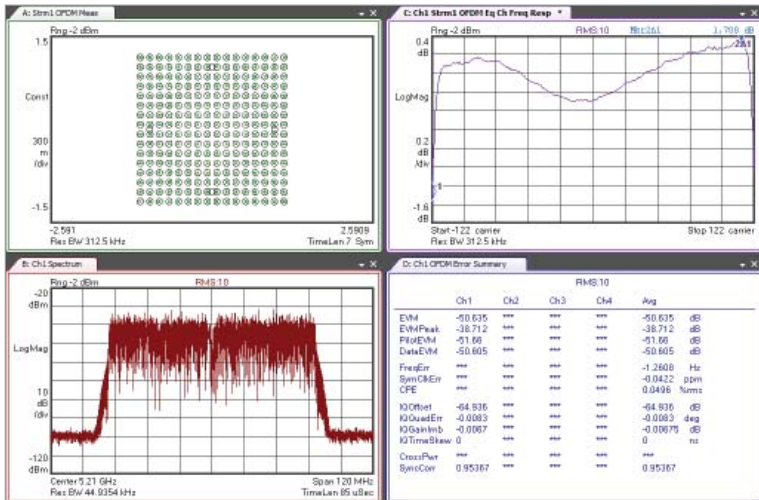


Figure 9. OFDM windowing length = 2 (default), ideal low pass filter with length = 32 symbols.

# Analyzing 802.11ac Signals with the N9030A PXA Signal Analyzer

## Optimizing EVM measurements using 89600 VSA software

The 89600 VSA software offers comprehensive modulation analysis for single-channel and multi-channel signals using a variety of different instruments for signal capture. 89601B Option BHJ supports analysis of 802.11ac WLAN signals, along with required Option B7Z for 802.11n WLAN analysis.

### PXA hardware settings in the 89600 VSA software

When the 89600 VSA software is used with the PXA, the software chooses general settings for the PXA hardware that are not necessarily optimal for 802.11ac modulation analysis, so it is necessary to change some of the settings. Once this has been done, you can save the settings in a file for later recall and reuse. To modify the PXA settings in the 89600 VSA software, go to the menu bar and select **Input > Extensions**. For phase noise optimization, the default value is “BestCloseIn” which is appropriate when the measurement analysis region is within 140 kHz of the input signal. Since WLAN is a wider bandwidth signal, the correct value to choose is “BestWideOffset”.

Next, click on the “Analog” tab to adjust the range and mixer Level settings. If you use the Auto-range function, the PXA will generally end up at a range setting that is higher than the optimal value for good EVM measurements for WLAN. This is partly due to the high crest factor of an OFDM signal, and partly due to the VSA choosing a setting that is a compromise between good EVM measurements and lower distortion for ACP or other out-of-band measurements. You can observe that if you use auto-range and then lower the range by 1 or 2 steps using the up/down arrow keys, the EVM will often improve. At some point you will get an overload error; the step at which that occurs will typically give the best EVM result for an 802.11ac signal.

For EVM measurements, you can get better measurements if you increase the mixer level to maximize the signal-to-noise ratio (SNR) in the receiver, even though this also increases the distortion. The default value of 0 dB was chosen to provide the best balance between SNR and distortion. Try setting the range, then increasing the mixer level to the highest possible level to see the effect on the EVM. For example, for an 802.11ac signal with –10 dBm input into the PXA, a typical range value would be about –2 dBm without an overload error at the default mixer level of 0 dB. Changing the mixer level setting to 8 dB will improve the EVM by about 2-3 dB. As the PXA input level changes, the range and mixer level settings will need to be adjusted to keep the signal to the ADC as close to full scale as possible in order to get the best signal-to-noise ratio. The VSA software will automatically adjust the attenuation, IF gain, and preamplifier in the PXA based on the range and mixer level settings.

For further explanation about the impact of input power level and range settings on EVM measurements in the PXA when using the 89600 VSA software, please see Appendix C.

## VSA Demodulation Properties

The 802.11ac Demodulation Properties Settings screen provides another opportunity to improve the EVM results. The “Advanced” tab is shown in Figure 10. Note that Equalizer Training is set to the default value of “Preamble Only.” The 802.11ac standard indicates that this is the appropriate method for the equalizer training when testing the EVM of a transmitter. However, for other applications such as testing of power amplifiers or other components, you may want to set the Equalizer Training to use “Preamble, Pilots & Data.” This will allow the software to average out noise over a greater number of symbols, resulting in 1-3 dB better EVM results. Since you are generally interested in comparing the EVM at the input and output of a component, using the same equalizer training settings for both EVM measurements allows you to make a valid comparison to determine the impact of the component under test on the EVM results.

Due to the difference in EVM results based on the Equalizer Training settings, it is important to know which setting was used for an EVM measurement in order to compare results fairly.

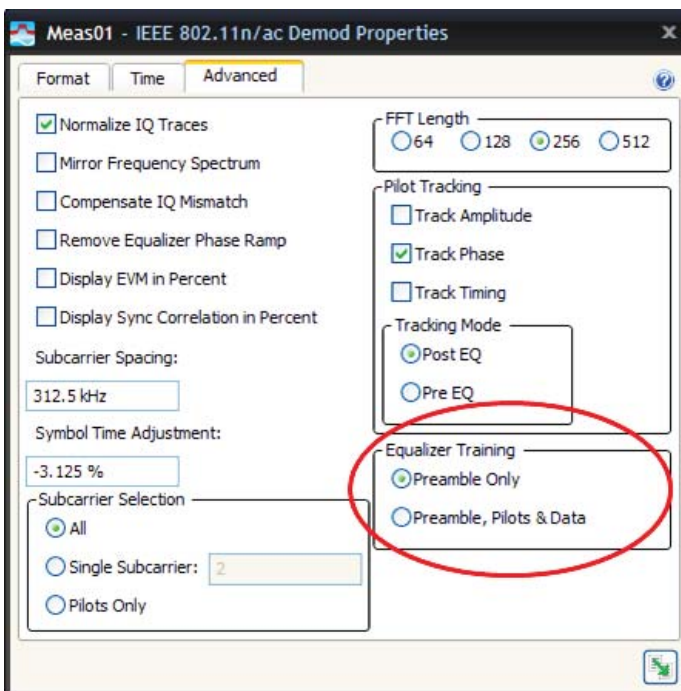


Figure 10. 802.11ac Demod Properties “Advanced” tab.

## Optimizing EVM measurements using the N9077A WLAN application

The N9077A X-series WLAN measurement application supports 802.11a/b/g (option 2FP), 802.11n (Option 3FP), and 802.11ac (Option 4FP). Its simplified one-button measurements provide both swept measurements such as channel power and spectrum emission mask, as well as IQ measurements such as EVM and spectrum flatness.

### Hardware settings with N9077A

The modulation analysis measurement provides results for EVM and IQ errors, as shown in Figure 5. As explained in the earlier section on PXA hardware settings, the mixer level setting is important for optimizing the EVM measurement. However, the N9077A does not provide direct settings for the range and mixer level like the VSA software. Since the application provides both out-of-band measurements such as spectrum emission mask, as well as EVM, a mixer level of 0 dB was chosen to provide the best balance between distortion and signal-to-noise ratio. This setting cannot be changed by the user.

To optimize the signal level to the ADC, the user has control of 3 parameters: attenuation (mechanical and electronic attenuator, if present), IF gain, and the preamplifier. For signals with power level around  $-10$  dBm or higher, the attenuator can be adjusted quickly by pressing these keys: **AMPTD > Attenuation > Adjust Atten for Min Clip**. This will set the attenuator automatically for minimal clipping, although firmware limits the mechanical attenuator from going below 6 dB to protect the input from overloading. You may be able to manually adjust the attenuator to a lower level to improve the EVM by pressing **Mech Atten** and entering the attenuation value. The instrument will display a warning message of "Input overload; ADC Over Range" in the lower right corner of the display if the attenuation value is too low.

As the input level decreases to around  $-20$  dBm, you will need to reduce the mechanical attenuator manually down to 0 dB. For input levels around  $-30$  dBm, it may be necessary to turn on the IF gain by setting the IF Gain to "High Gain." This adds 10 dB of gain to the signal. Figure 11 provides a menu map showing how to access the IF gain control while performing a modulation analysis measurement. The **Mech Atten** setting can be used to adjust the input level if needed.



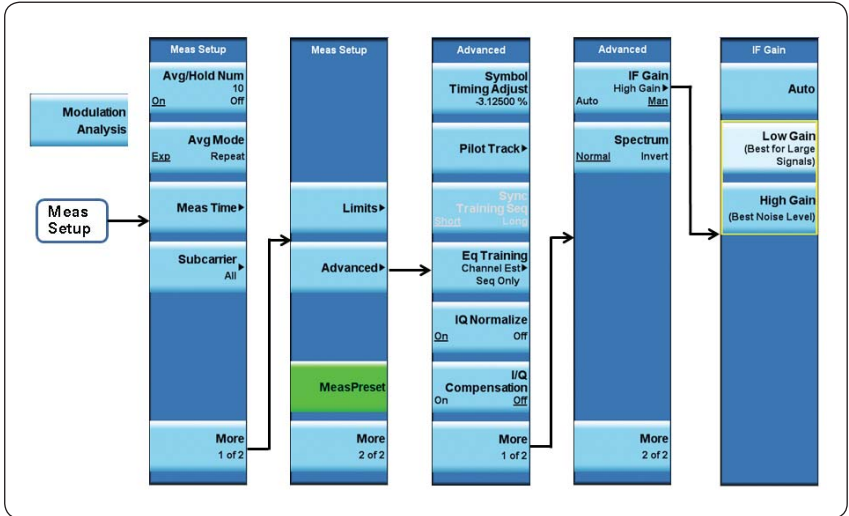


Figure 11. N9077A menu keys for accessing the IF gain settings for modulation analysis measurements.

For input power levels around  $-40$  dBm, the IF gain alone may not be enough, so you can try switching the IF gain back down to “Low Gain” and turning on the preamplifier (press **AMPTD > More > Internal Preamp > Full Range**). Again, the attenuation settings can be used to lower the power if the preamplified signal causes an input overload.

For input power levels around  $-50$  dBm or less, you can try switching the IF gain to “High Gain”, in addition to turning the preamplifier on to get the maximum input to the ADC.

Note that the IF gain has an “Auto” setting. In this mode, the IF gain will be set to high initially, and data will be acquired. If there is an input overload, the IF gain will be set to low and data will be acquired again. This process takes some time, so you can achieve faster measurements by manually setting the IF gain.

## Equalizer training setting in N9077A

As explained earlier for the VSA, some improvement in EVM measurements can be obtained by changing the equalizer training from using only the preamble to using the preamble, pilots, and data. In the N9077A, this setting can be accessed through the keys shown in the menu map in Figure 12. Setting **Channel Est Seq Only** indicates that the equalizer is trained only using the channel estimation sequence portion (long training field) of the preamble. The standard indicates that this is the proper method for testing the EVM of a WLAN transmitter. Setting **Channel Est Seq & Data** specifies that the equalizer is trained using both the channel estimation sequence and the data symbols in the burst. This usually allows a more accurate estimate and typically improves the EVM by 1 to 3 dB.

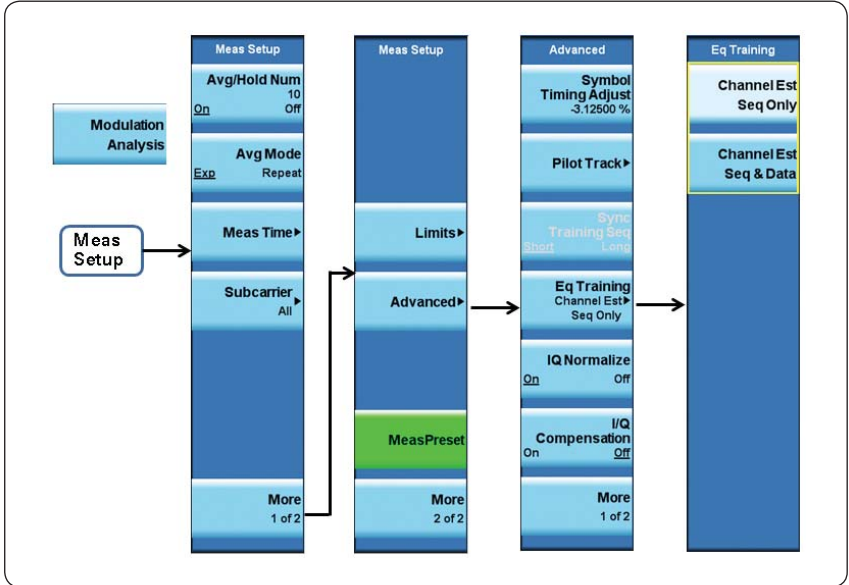


Figure 12. Menu map for equalizer training settings for EVM measurements.

# Summary

Designing components, transmitters, and receivers to meet the demanding requirements for 802.11ac WLAN devices requires test equipment that can provide the best reference test signals and measurements. Features such as internal channel corrections, I/Q calibrations, and I/Q adjustments can be used to optimize the hardware performance of Agilent's RF signal generators. N7617B Signal Studio for WLAN 802.11a/b/g/n/ac provides a convenient way to enable some of those corrections and adjustments when downloading waveform files into the signal generators, and also provides some filter options for controlling the spectrum of the signal. This application note explained how to optimize the input level to the ADC in the PXA signal analyzer using either the 89600 VSA software or the N9077A WLAN measurement application to provide the best EVM results for signal analysis. The equalizer training settings can yield additional improvement in EVM results for testing components or modules.

## Appendix A: Configuring a Spectrum Analyzer for EXG/MXG Calibrations

Certain calibrations require the use of a spectrum analyzer, which must be connected to the EXG or MXG via LAN or a LAN-to-GPIB gateway. Compatible spectrum analyzer models are Agilent E4440A, E4443A, E4445A, E4446A, E4448A, N9020A MXA, and N9030A PXA. Note that if a LAN connection is used, it should be a networked LAN connection and not a direct connection or a local hub.

The spectrum analyzer configuration menu displays these softkeys:

- **Connection Type:** Select **Sockets** if you are using a LAN connection, or **VXI-11** if you are using a LAN-to-GPIB gateway.
- **Spectrum Analyzer IP Address:** Enter the IP address of the instrument
- **Spectrum Analyzer IP Port:** This is displayed when the connection type is "Sockets." Use the value of **5025** for standard (default) or **5023** for telnet programming.
- **SA VXI-11 Device Name inst0:** This is displayed when the connection type is "VXI-11" and it goes to a menu where you can enter the device name. The default value is **inst0**.
- **Test Connection:** Press this key to test the connection to the spectrum analyzer. If the configuration is correct, you should see "Connection Status: Passed" along with the identification information from the spectrum analyzer.

# Appendix B: Configuring a Power Meter for EXG/MXG Calibrations

Certain corrections require the use of a power meter, which must be connected to the EXG or MXG via LAN or a LAN-to-GPIB gateway. Compatible power meters include the E4419A/B and N1911A/12A. The U2000A/01A/02A/04A USB power sensors may also be used. The softkey menus for configuring the power meter or sensor are shown in Figure 13.

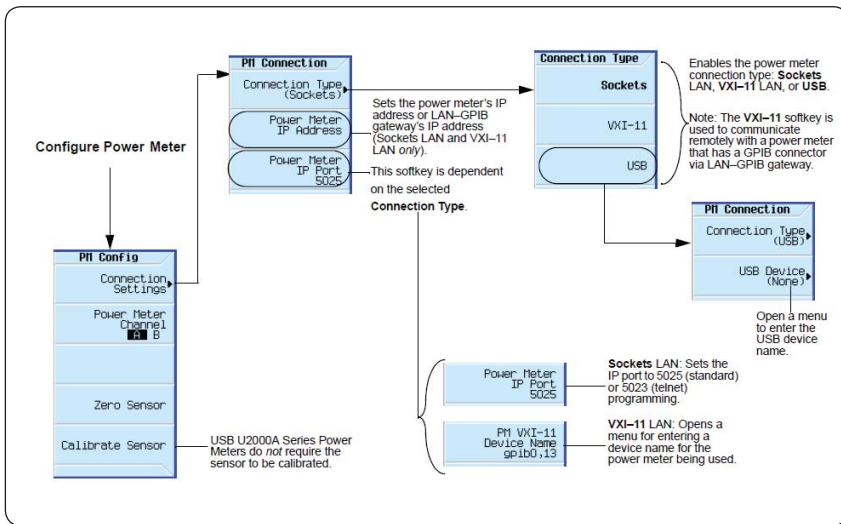


Figure 13. Power meter configuration menu map for EXG/MXG.

## Appendix C: Impact of PXA Input Power on EVM

The noise density of the PXA affects the noise floor for an EVM measurement as a function of the input power level. The graph in Figure 14 shows the noise density vs. input range setting in the 89600 VSA software, with noise density given in dB/Hz relative to the full scale signal to the ADC in the PXA. It assumes that you are decreasing the range setting as you decrease the input power to keep the signal close to the ADC's full scale.

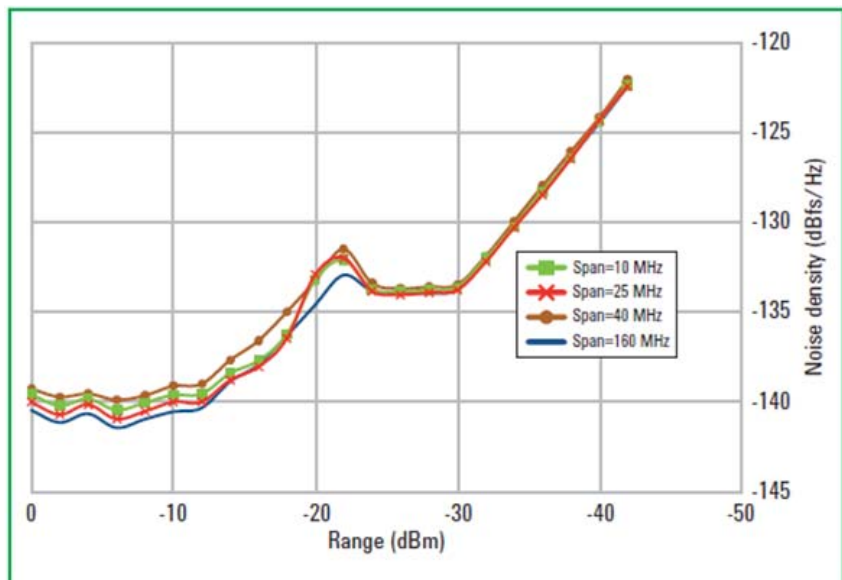


Figure 14: PXA noise density as a function of input range in the 89600 VSA software settings (nominal at 1.8 GHz).

The flat region between 0 and about -12 dBm range has a constant noise density relative to full scale. The result is a constant EVM floor over the region for signals near full scale. In this region, only the input attenuator is changing, so no additional noise is being introduced.

In the sloped region from about -12 to -22 dBm, the attenuation has reached 0 dB, and IF gain is now being added to ensure that the signal remains near the top of the ADC's range. As this happens, the noise density increases by 7 dB, from -140 dBfs to -133 dBfs, which results in a corresponding increase in the EVM floor.

Thus, for a 160 MHz bandwidth signal at a range setting of -12 dBm, the AWGN component of the EVM floor would be  $(-140 + 82) \text{ dB} = -58 \text{ dB}$  (The noise density is expressed in dBm/Hz. To calculate noise power for the entire 160 MHz bandwidth, add  $10 \cdot \log(160 \text{ MHz})$ , or 82 dB. For the same signal at a range of -22 dBm, it would be  $(-133 + 82) = -51 \text{ dB}$ ). The actual EVM floor is slightly higher, because there are other contributors in addition to AWGN. Nevertheless, the EVM floor will generally start to degrade as the range drops into the -20 dBm region.

Following this region, there is a dip down and then another flat section on the curve, which reflects the point at which the PXA's preamplifier is turned on, with the IF gain temporarily set back to zero and RF attenuators again being used to keep the signal close to full-scale.

For range settings below -30 dBm, the IF gain is turned on, in addition to the preamplifier, so you again see an almost dB-for-dB increase in the noise floor as the range decreases.

This sample noise density curve reflects a ranging algorithm that is designed to maintain a specific level to the input mixer. While the default level provides a reasonable balance between distortion and sensitivity, it can be modified by the user, effectively moving the curve slightly to the right or left. The mixer level setting is found on the VSA's **Input > Analog** settings menu. A higher mixer level will provide better sensitivity, while a lower mixer level will provide less distortion.

## Related Literature

*N7617B Signal Studio for WLAN 802.11a/b/g/n/ac  
Technical Overview, 5990-9008EN*

*89601B/BN-B7R, 89601B/BN-B7R, 89601B/BN-B7Z WLAN  
Modulation Analysis VSA Software Technical Overview, 5990-6389EN*

*N9077A & W9077A WLAN X-series Measurement Application  
Technical Overview, 5990-9642EN*

*Testing New-generation Wireless LAN Application Note, 5990-8856EN*

*Testing Very High Throughput 802.11ac Signals Application Note, 5990-9987EN*

## Web

*X-series Signal Generators*  
**[www.agilent.com/find/X-Series\\_SG](http://www.agilent.com/find/X-Series_SG)**

*N9030A PXA Signal Analyzer*  
**[www.agilent.com/find/pxa](http://www.agilent.com/find/pxa)**

*802.11ac WLAN technology information*  
**[www.agilent.com/find/802.11ac](http://www.agilent.com/find/802.11ac)**

## Recorded Webcasts

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