TECHNICAL OVERVIEW

Signal Optimizer Software K3101A

- Perform versatile, task-based calibration for 5G and wideband test systems
- Measure true characteristics of a device-under-test (DUT) by establishing independent calibration reference planes at the input and the output of the DUT
- Create and apply transmitter corrections to waveform files from Keysight Signal Studio and other software tools
- Run a calibration to obtain correction file for receiver hardware and apply to any Keysight 89600 VSA software measurements
- Navigate block diagram-based user menu to configure the signals, source hardware, analyzer hardware and measurements easily and quickly

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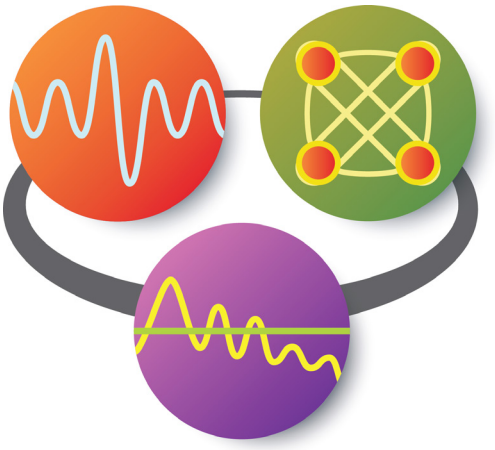
Build Confidence into your Wideband System

Developing a reliable test system with optimum performance is essential — but calibrating wideband channel at RF, centimeter wave (cmWave) and millimeter wave (mmWave) is often a challenge.

Keysight's Signal Optimizer is a versatile calibration software for 5G and wideband test system. It integrates measurement science and system calibration into an all-in-one task-based interface to confidently validate wide bandwidth high frequency designs used in 5G, automotive radar, satellite, aerospace and defense applications. Use Signal Optimizer and build confidence into your wideband system today.



Simple, integrated task-based user interface

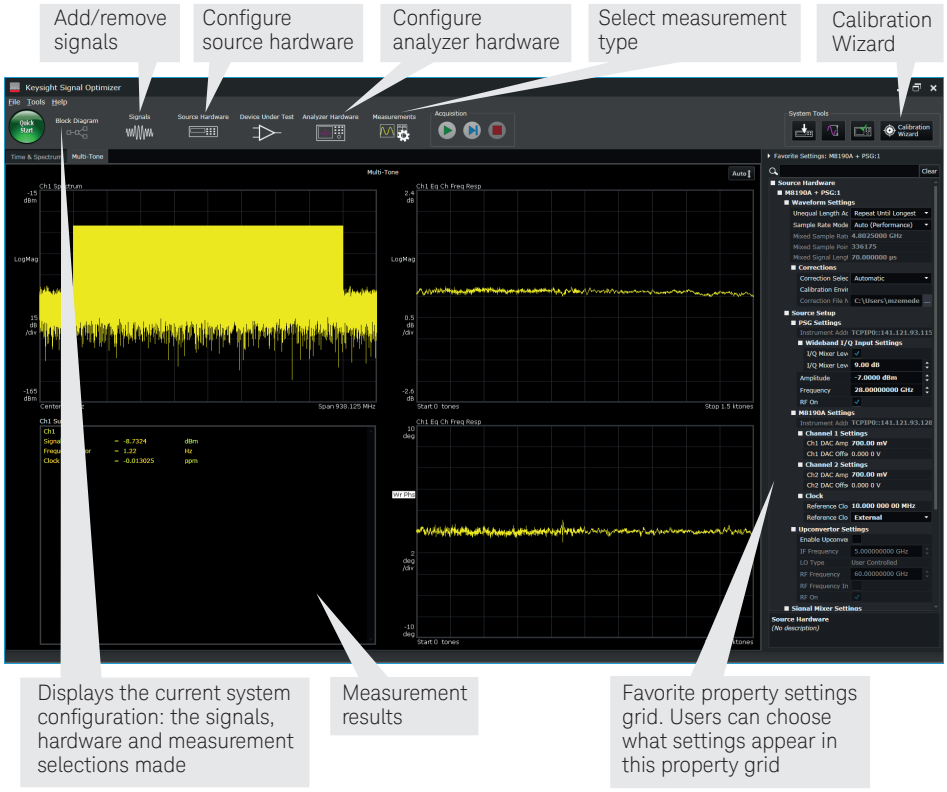


Figure 1. User interface of Signal Optimizer.

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Wideband Calibration (K3101A)

Signals at cmWave and mmWave frequencies often have bandwidths up to 2 GHz and beyond. Performing amplitude and phase flatness calibrations at these frequencies and bandwidths can be quite challenging due to low signal-to-noise (SNR), distortion or IQ modulator errors.

Calibration to the device under test (DUT) plane

In any test system, the ability to achieve instrument-port accuracy at the DUT plane will enhance measurement accuracy and repeatability. Most measurement setups do not allow connecting a DUT directly to test instrument front panel test ports. Instead, devices are connected to instruments via test fixtures, adapters, or cables. The non-ideal nature of these test fixtures and cables degrade measurement accuracy and this is particularly true as we go high in frequency to cmWave and mmWave bands where signal losses are greater through transmission lines such as coaxial cable and waveguide. For the highest measurement accuracy, measurements must be calibrated and most importantly have the reference plane at the place where the DUT is connected. Keysight's Signal Optimizer software enables vector calibration to the DUT input plane and DUT output plane separately allowing measurement of the true characteristics of the DUT.

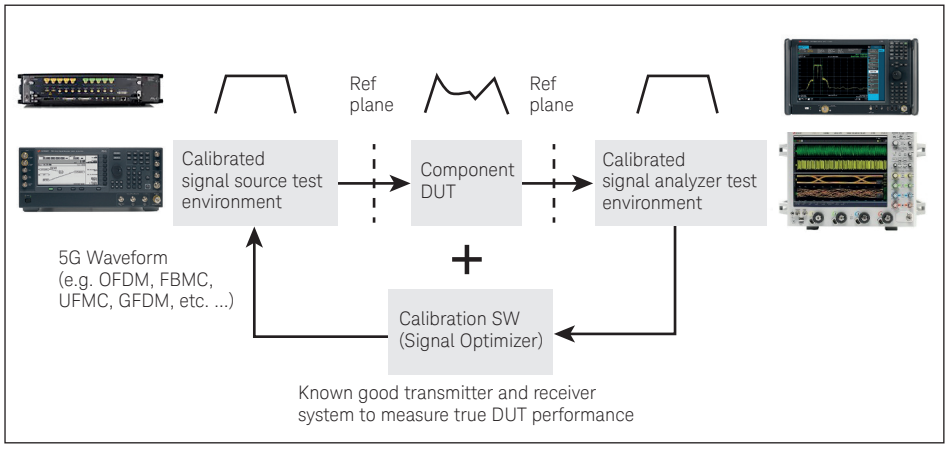

Figure 2. Calibrated Tx and Rx measurement system to measure true DUT performance.

Source and analyzer calibration setup

The Signal Optimizer's integrated Calibration Wizard helps make the complicated task of performing system calibration easier and simpler with step-by-step guided calibration of receiver and transmitter test environments so you can measure your devices with ease and confidence.

The calibration supports both single-point calibration as well as multi-point or batch calibration. The batch calibration allows users to build a list of frequency, bandwidth and amplitude points manually or by loading a set of points from a user-created or previously saved .csv file. The Calibration Wizard will cycle through the points as it performs the batch calibration and generates a set of correction files. Once the correction files are generated, the software automatically selects the right correction file based on the operating conditions.

Millimeter-waves expanding the wireless future

Millimeter-wave technology has been in use for decades, primarily in aerospace, defense and backhaul applications where the benefits have justified the high costs of development, manufacturing and support. In recent years, advancements in the fabrication of millimeter-wave devices have been pushing down the cost of extremely high frequency devices, making them more viable in commercial applications. Looking ahead, development of 5G wireless communication is underway. The ability to meet the 5G vision of "everything everywhere always connected" will depend on successful utilization of wider bandwidths in cmWave and mmWave frequencies. Other communications applications include millimeter-wave line-of-sight backhaul systems and satellite-to-satellite links.

Engineers working at the leading edge count on Keysight to give them easier access to accurate, repeatable measurements at ever-higher frequencies and wider bandwidths.

Signal Optimizer software is a versatile, task-based calibration software for 5G and wideband test system at RF, microwave and millimeter-wave frequencies.

Wideband Calibration (K3101A) (Continued)

Analyzer calibration

For analyzer vector calibration, a Keysight U9391 comb generator is used. The comb generator is a universal receiver system calibrator which is easily injected at the desired calibration plane. CW tones of known amplitude and phase are generated and the CW tones are measured in the receiver and compared to the known amplitudes and phases. Using this information, a filter is designed and applied to the measured signal to compensate for the differences measured.

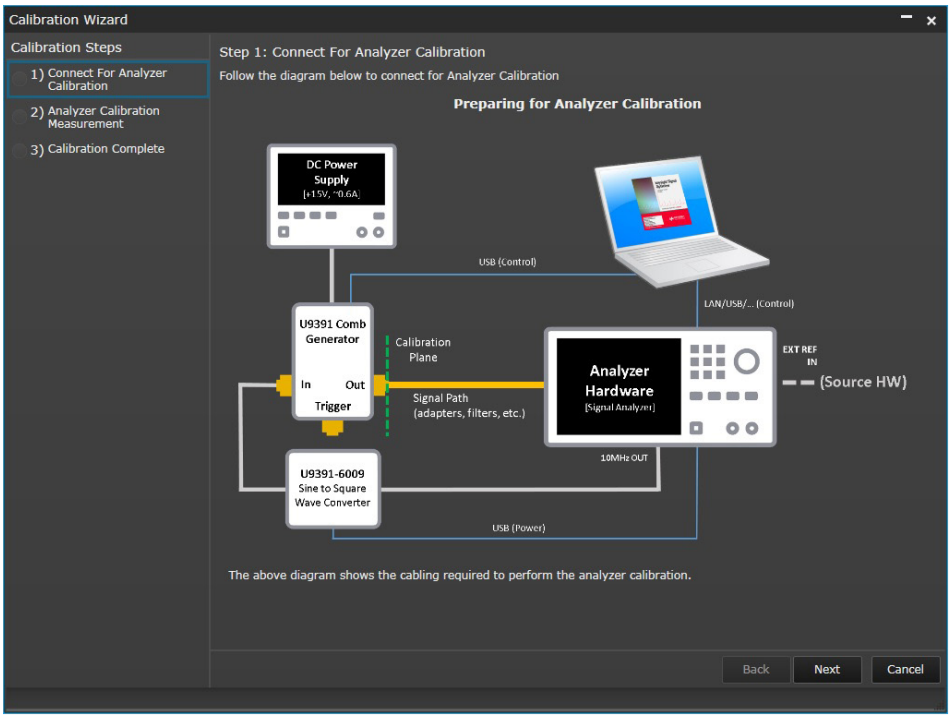

Figure 3. Connection diagram for analyzer (receiver) calibration.

Wideband Calibration (K3101A) (Continued)

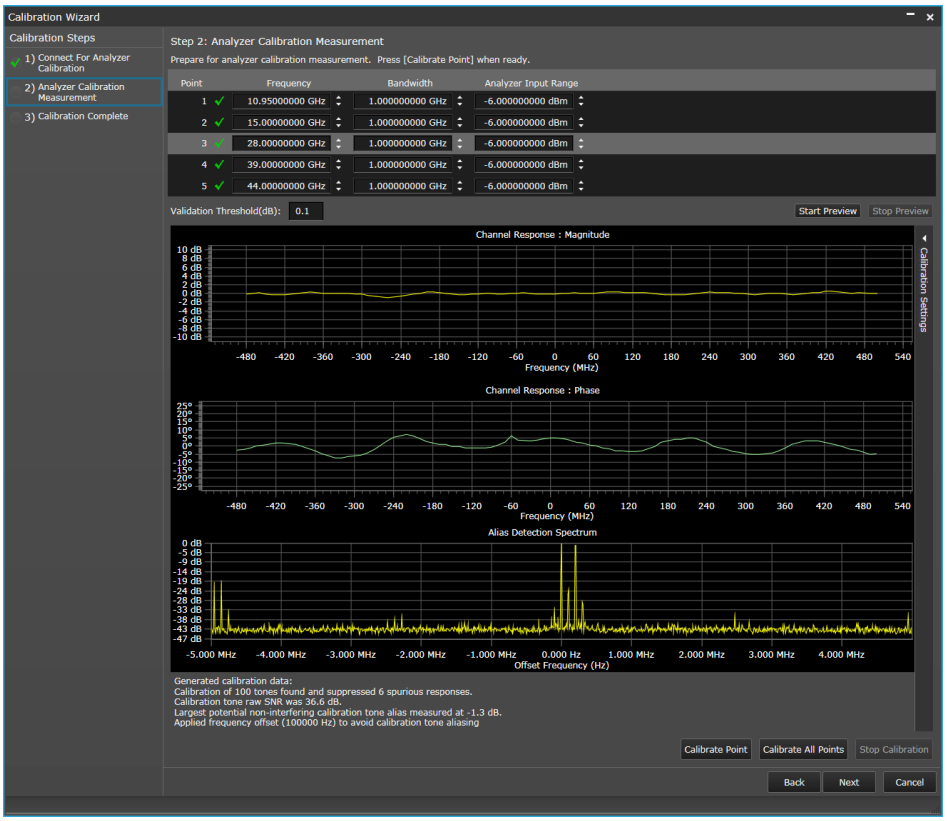

Figure 4. Analyzer calibration measurement results graphs.

The display in Figure 4 shows the frequency, bandwidth and input range for the batch calibration and three graphs: channel response magnitude, channel response phase, and alias detection spectrum. To avoid the calibration signal aliasing, the calibration detects and reconfigures the calibration measurement and the result is shown in the Alias Detection Spectrum graph. The software also provides other performance checks to ensure high quality calibration, including a user-settable validation threshold for IF magnitude ripple, SNR check of calibration signal and a status indicator for successful calibration of each point. A correction file is then created and saved for each successful calibration point. These files can be easily applied to measurements to correct for the impairments in the signal acquisition setup under those operating conditions. Calibration data are also stored and easily recalled to be used at later times.

Wideband Calibration (K3101A) (Continued)

Source calibration

For source (transmitter) calibration, a Keysight proprietary calibration waveform with known amplitude and phase characteristics is used. The output signal is measured using a golden receiver, such as the calibrated analyzer mentioned earlier. The measured signal is compared with the signal of the known amplitude and phase. Using this information, a filter is designed and applied to the baseband data to pre-correct the waveform.

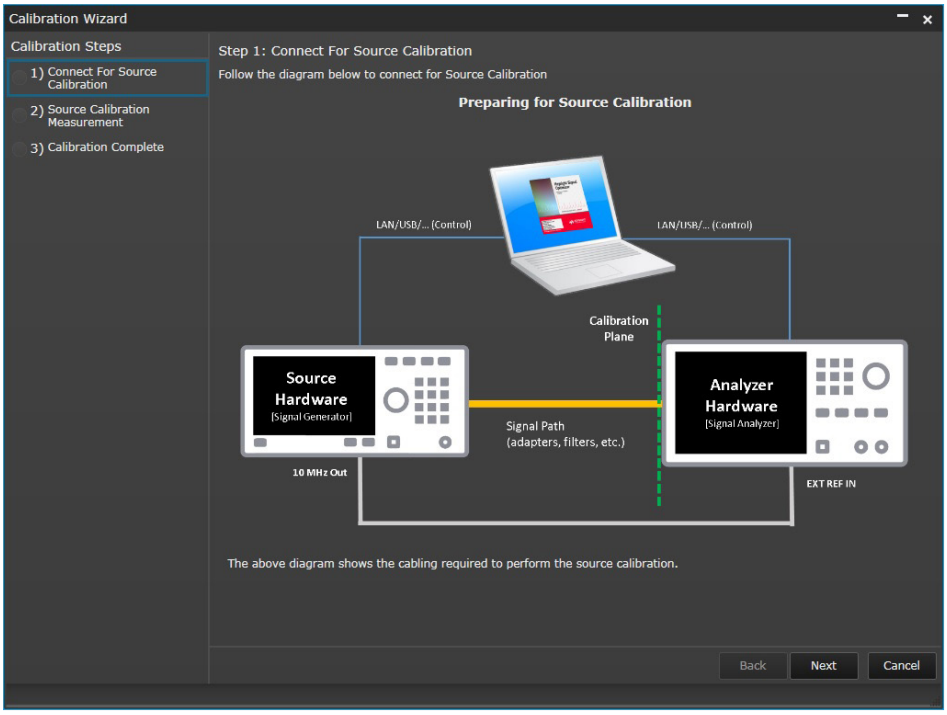

Figure 5. Connection diagram for source (transmitter) calibration.

In addition to flattening the frequency response of the source, the source calibration also eliminates the differential frequency response of the analog I and Q channels and the residual quadrature error of the IQ modulator as shown in Table 1. This is key because IQ gain imbalance versus frequency can become a dominant source of EVM error, especially as the modulation bandwidth increases.

Table 1. List of impairments eliminated by Signal Optimizer software compared to equalization filter used in most receivers.

Impairment	Signal Optimizer source calibration	Signal Optimizer analyzer calibration	Equalization filter
IQ amplitude imbalance	Yes	NA	No
Phase related issues	Yes	NA	No
– IQ phase imbalance	Yes		
– IQ quadrature error	Yes		
– IQ time skew	Yes		
Channel amplitude flatness	Yes	Yes	Yes
Channel phase linearity	Yes	Yes	Yes

Wideband Calibration (K3101A) (Continued)

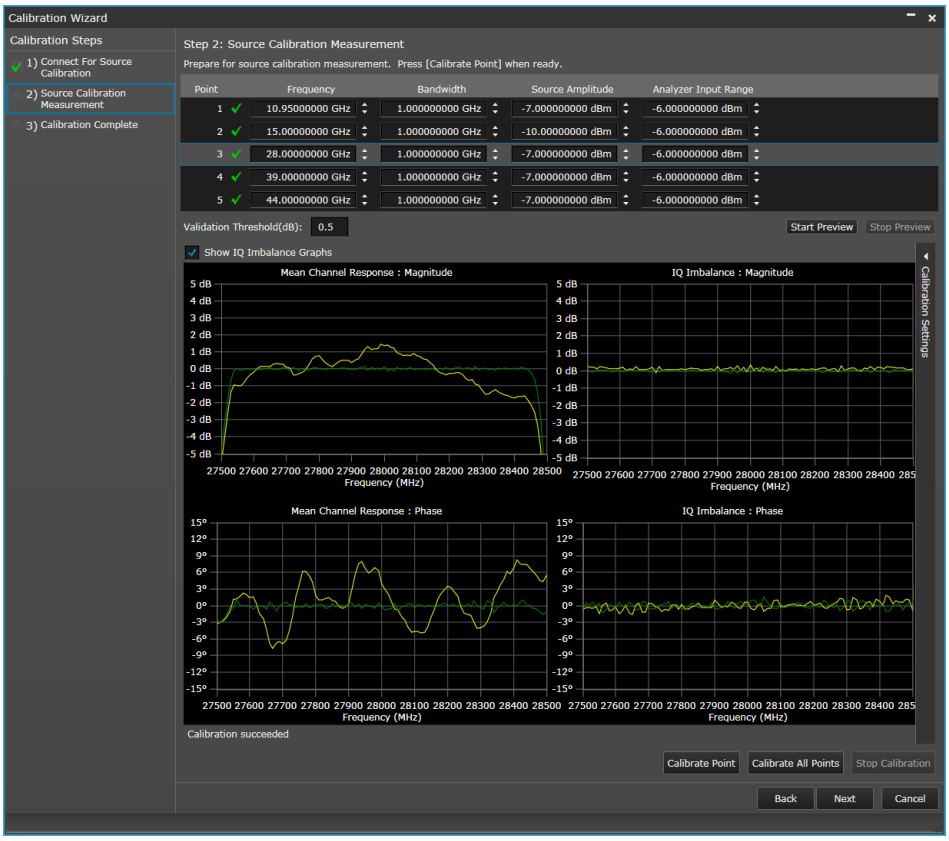

Figure 6. Source calibration measurement results graphs.

The display in Figure 6 shows the frequency, bandwidth and input range for the batch calibration and four graphs: the left two graphs show the overall channel response in amplitude and phase and the right two graphs show the amplitude and phase difference between I and Q as a function of frequency. Usually there are controls available at baseband or at the IQ modulator to modify gain between I and Q and also the quadrature. What is different with Signal Optimizer is these settings apply over the whole BW of the signal of interest and the gain and phase imbalances vary as a function of frequency.

The yellow trace in each graph represents the raw performance of the source, while the green trace shows the result with pre-corrections applied. The ideal response is shown in gray, but may be difficult to see behind the optimized green trace.

The software also provides other performance checks to ensure high quality calibration, including a user-settable validation threshold for channel response flatness, SNR check of the signal and a status to indicate success of each calibration point. A correction file is then created and saved for each successful calibration point. These files can be easily applied to signals to pre-correct for the impairments in the signal generation setup under those operating conditions. Calibration data are also stored and easily recalled to be used at later times.

Wideband Calibration (K3101A) (Continued)

Calibration results

After deriving and applying corrections, improved performance can be seen, as in the example shown in Figures 7 and 8 below. Figure 7 shows ~6% measured EVM performance before corrections are applied for a single carrier, 1 GHz wide, 64-QAM signal at 40 GHz center frequency. After corrections are applied to both source and analyzer, the measured EVM value drops to approximately 0.9% as shown in Figure 8. Both these are without applying adaptive equalization filter and with EVM normalization reference set to constellation maximum.

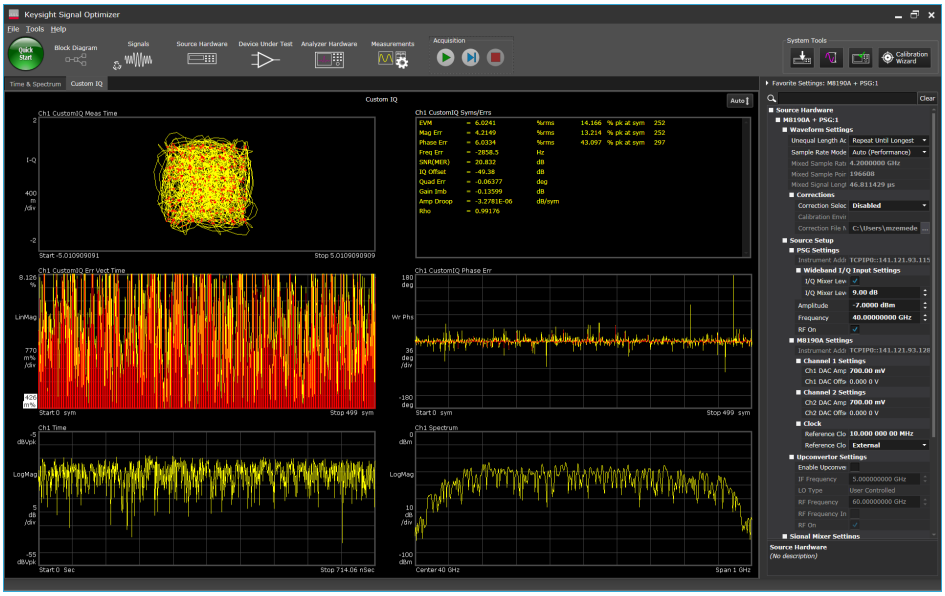

Figure 7. 6% EVM of a single carrier, 1 GHz wide, 64-QAM signal at 40 GHz center frequency before correction.

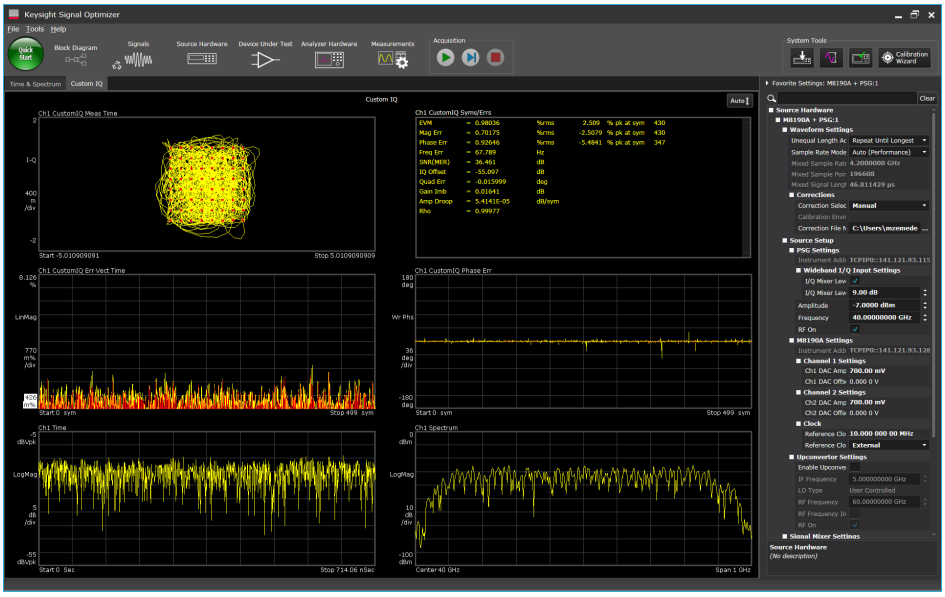

Figure 8. 0.9% EVM of a single carrier, 1 GHz wide, 64-QAM signal at 40 GHz center frequency after correction (no equalization filter).

Signal Creation and Analysis

In addition to calibration, Keysight's Signal Optimizer software provides a simple to use stimulus-response capability with built-in multi-tone and imported waveform files.

Multi-tone

The base configuration of Signal Optimizer software (K3101A) comes standard with multi-tone signal creation and measurement capability as well as importing externally created files. Multi-tone provides a quick way to verify the overall calibration quality by looking at the amplitude flatness and phase linearity over the frequency bandwidth of interest. The following signal generation and measurement capabilities are available:

- Edits signal generation and measurement configuration in basic multi-tone editors
- Automatically couples the common signal and measurement parameters to save time and complexity
- Provides spectrum, frequency response, and summary measurement data

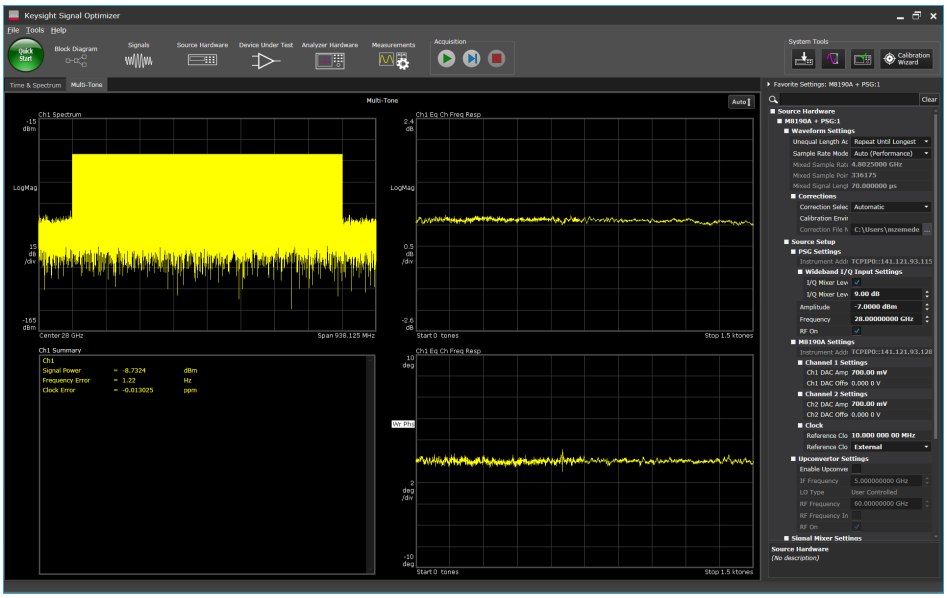

Figure 9. Multi-tone measurement showing a flat amplitude and linear phase after calibration across a 700 MHz wide bandwidth.

File import

Imports externally created waveform from the following formats and sources and apply source correction:

- CSV file
- LabVIEW CSV file
- MATLAB HDF file
- N5110A (Baseband Studio) waveform file
- M8190A DUC IQBIN file
- WFM (Signal Studio) file [1]

1. A valid Signal Studio license must be installed on the signal generator to play back imported waveforms.

Software Features

Wideband calibration (K3101A). This is the base configuration for Signal Optimizer software

Features	Source	Analyzer
Calibration Wizard	•	•
Multi-point (batch) calibration (available when calibration type is set to “Source Only” and “Analyzer Only”)	•	•
Single point calibration	•	•
Channel response calibration (phase and magnitude)	•	•
I/Q imbalance calibration	•	
Alias avoidance – to avoid calibration signal aliasing		•
Save calibration points to .csv file (batch calibration mode only)	•	•
Load calibration points from .csv file (batch calibration mode only)	•	•
Multi-tone signal	•	•
File import: – Source: CSV, LabVIEW CSV file, MATLAB HDF, N5110A (Baseband Studio) waveform file, M8190A DUC IQBIN file, WFM (Signal Studio) file	•	•
Sample rate multiplier on imported file	•	
.NET API for remote control	•	•
Export corrected waveforms from Signal Optimizer	•	
Rename calibration file with customized name	•	•
S-parameter embedding	•	•

Ordering Information

Software licensing and configuration

Signal Optimizer offers flexible licensing options, including:

- Node-locked (fixed)
  - Most economical. License rights assigned to one specified computer or instrument

- Transportable
  - Highly flexible. License rights may be moved from one computer/instrument to another by the end-user

- Floating (network)
  - Maximum flexibility. Server-based pool of licenses can be used by a set number of concurrent users

For detailed licensing information and pricing, please refer to the Signal Optimizer web page at **www.keysight.com/find/SignalOptimizer**

K3101A Signal Optimizer, base calibration (Required)

Model-Option	Description
K3101A-1FP	Signal Optimizer, base calibration - node-locked perpetual license
K3101A-1FY	Signal Optimizer, base calibration - node-locked 1-year time-based license
K3101A-1TP	Signal Optimizer, base calibration - transportable perpetual license
K3101A-1TY	Signal Optimizer, base calibration - transportable 1-year time-based license
K3101A-1NP	Signal Optimizer, base calibration - floating perpetual license
K3101A-1NY	Signal Optimizer, base calibration - floating 1-year time-based license

Ordering Information (Continued)

Hardware configuration

This is a minimum configuration. For a complete list of currently supported hardware and required configurations, please visit: www.keysight.com/find/SignalOptimizer_hardware

Source hardware

Description	Models supported	Minimum required option	Maximum modulation bandwidth [1]	Maximum frequency range (without external upconverter) [1,2]
MXG	N5182B	656 or 657	160 MHz	6 GHz
EXG	N5172B	653 or 655	120 MHz	6 GHz
MXG	N5182A (Discontinued)	651, 652 or 654	100 MHz	6 GHz
Arbitrary Waveform Generator (AWG)	M8190A (DUC x3, x12, x24, x48)	001, 002 or LPN; 14B	5 GHz analog bandwidth (direct DAC out)	Variable sample rate from 125 MSa/s to 8/12 GSa/s
PSG+AWG	E8267D + M8190A	PSG: 016 AWG: 001, 002 or LPN; 14B	2 GHz	44 GHz

1. Depending on model/option.
2. Up to 44 GHz supported by Signal Optimizer software.

Analyzer hardware

Description	Models supported	Minimum required option	Maximum integrated analysis bandwidth [3]	Maximum frequency range (without external downconverter) [3,4]
X-Series signal analyzers	N9041B UXA	Standard (50 GHz)	1 GHz	110 GHz
	N9040B UXA	508, 513, 526, 544, or 550	1 GHz	50 GHz
	N9030A/B PXA	503, 508, 513, 526, 543, 544, or 550	512 MHz	50 GHz
	N9020A/B MXA	503, 508, 513, 526, 532, 544, or 550	160 MHz	50 GHz
Infiniium Oscilloscopes	S-Series		8 GHz	8 GHz
	V-Series		33 GHz	33 GHz
	Z-Series		63 GHz	63 GHz
PXIe performance vector signal analyzer	M9393A	F08, F14, F18, F27 (optional FRZ, FRX)	160 MHz	27 GHz (optional 50 GHz)
	M9393A + M9203A combined	F08, F14, F18, F27 (optional FRZ, FRX)	1 GHz	27 GHz (optional 50 GHz)
Wideband signal analysis solution	Z9070B-001 (consists N9030A PXA signal analyzer, DSOS804A oscilloscope and 89600 VSA software)	PXA: MPB, CR3 89600 VSA: 200	8 GHz	50 GHz

3. Depending on model/option.
4. Up to the frequency range of U9391 Comb generator, maximum 67 GHz.

Ordering Information (Continued)

Calibration hardware

Description	Models supported	Requirement	Frequency range[1]
Comb generators Sine to Square Wave Converter (U9391-6009) is included	U9391C	A DC power supply that is able to output 300 mA (nominal)[2] at 15 ± 10% Vdc	10 MHz to 26.5 GHz
	U9391F	A DC power supply that is able to output 300 mA (nominal)[2] at 15 ± 10% Vdc	10 MHz to 50 GHz
	U9391G	A DC power supply that is able to output 850 mA (nominal)[2] at 15 ± 10% Vdc	10 MHz to 67 GHz

1. Up to 44 GHz supported by Signal Optimizer software.
2. Current drawn by the device under normal operating conditions. Higher current is required during device start up. See the U9391 Technical Overview (5989-7616EN) for more information. For recommended power supplies, refer the FAQ page at http://www.keysight.com/main/editorial.jspx?cc=MY&lc=eng&ckey=2898212&nid=-32692.762062&id=2898212

System requirements

Option	Description
Operating system	Microsoft Windows 7 Professional, Enterprise or Ultimate (64 bit)
	Microsoft Windows 10 Professional, Enterprise or Education (64 bit)
CPU	2 GHz (> 3 GHz recommended)
RAM	8 GB (16 GB recommended)
HDD/SSD	20 GB available before installation, 10 GB available after installation
Additional drives	License transfer requires network access or a USB memory device
Interface support	LAN and USB
Browser	Internet Explorer Version 10 or higher required for full context-sensitive help functionality
Dependencies	The Signal Optimizer software must be installed on a standalone PC or AXIe/PXIe embedded controllers (not on X-Series signal analyzers)
	89600 VSA software version 22.20 or later must be installed on the same PC with the Signal Optimizer software. 89600 VSA license is not required
	Keysight IO Libraries Suite version 15.5 or later

Additional Information

Websites

www.keysight.com/find/SignalOptimizer

Access the online documentation, which includes the complete software HELP

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