E5055/6/7/8A 8/26.5/44/54 GHz SSA-X Signal Source Analyzer

Comprehensive signal source and component characterization

- Absolute and residual phase noise measurements
- Low phase noise RF source for 2-port residual noise measurement up to 54 GHz
- Millimeter-wave frequency extension with external downconverter
- 2-port network analyzer
- Clock jitter analysis

KEYSIGHT

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SSA-X Signal Source Analyzer

All in One

The E5055A/6A/7A/8A 8 GHz/26.5 GHz/44 GHz/54 GHz SSA-X Signal Source Analyzers are a comprehensive signal source analysis solution for various applications including VCO, DRO, OCXO, reference clock signal, frequency converter embedded-LO, radar, high-speed digital communication, and 5G/6G communications. The SSA-X achieves high phase noise measurement sensitivity using low phase noise internal LO sources and dual channel receiver architecture with cross correlations to improve the measurement sensitivity. The SSA-X is equipped with low noise DC sources including one tuning voltage and two power supplies to drive VCO devices.

The SSA-X is also the optimal solution for residual phase noise measurements of active devices. The 2-port configuration for the SSA-X provides two channels and a low phase noise signal source up to 54 GHz to enable residual noise measurements with very high measurement sensitivity. The two ports can also be used to measure the absolute phase noise of two signal sources at different frequencies. An optional 2-port VNA can be added to the SSA-X to enable S-parameter measurement of 1 or 2-port devices.

The SSA-X all-in-one architecture simplifies complex test setups while enabling comprehensive signal source and device characterization.

Key features and performance [1]

- Carrier frequency range 1 MHz to 8 GHz/26.5 GHz/44 GHz/54 GHz.
- mmWave phase noise/AM noise measurement can be done with external downconverter, E-band, D-band and more waveguide bands
- Phase noise offset frequency range 1 mHz to 1 GHz, the maximum offset frequency can be extended to 3 GHz for 150 MHz ≤ carrier < 54 GHz with the offset extension mode
- AM noise offset frequency range 1 mHz to 30 MHz
- High sensitivity -98 dBc/Hz at 10 Hz offset, -170 dBc/Hz at 1 MHz offset (1 GHz carrier, +10 dBm)
- Fast measurement 110 msec (100 Hz to 10 MHz offset, RBW=10%)
- Two channels for residual noise measurement up to 30 MHz offset or 2-channel absolute noise measurement.
- Extremely low phase noise 54 GHz internal signal source for residual noise measurement
- Best in class residual noise measurement sensitivity

1. Refer to E505xA SSA-X signal source analyzer data sheet, 3122-1508.EN for more information about the specifications and the measurement performance.

- Built-in floating low-noise DC sources for VCO characterization
  - DC tuning voltage source -35 V to +35 V, 1 nVrms/SQRT(Hz) at 10 kHz offset
  - Two DC power supplies: DC supply 1: 0 to 16V, DC supply 2: -16 V to 0V, 3 nVrms/SQRT(Hz) at 10 kHz offset
  - Pulsed phase noise and AM noise measurement
- Spectrum Analysis up to 54 GHz
- 2-port VNA measurement up to 54 GHz
- Frequency/Power/Phase transient measurement with 7 GHz bandwidth for signal setting time and frequency hopping evaluation
- Clock jitter analysis with high sensitivity, 2 femtoseconds at 10 GHz
- Allan variance measurement up to 100 nsec to 1000 sec.

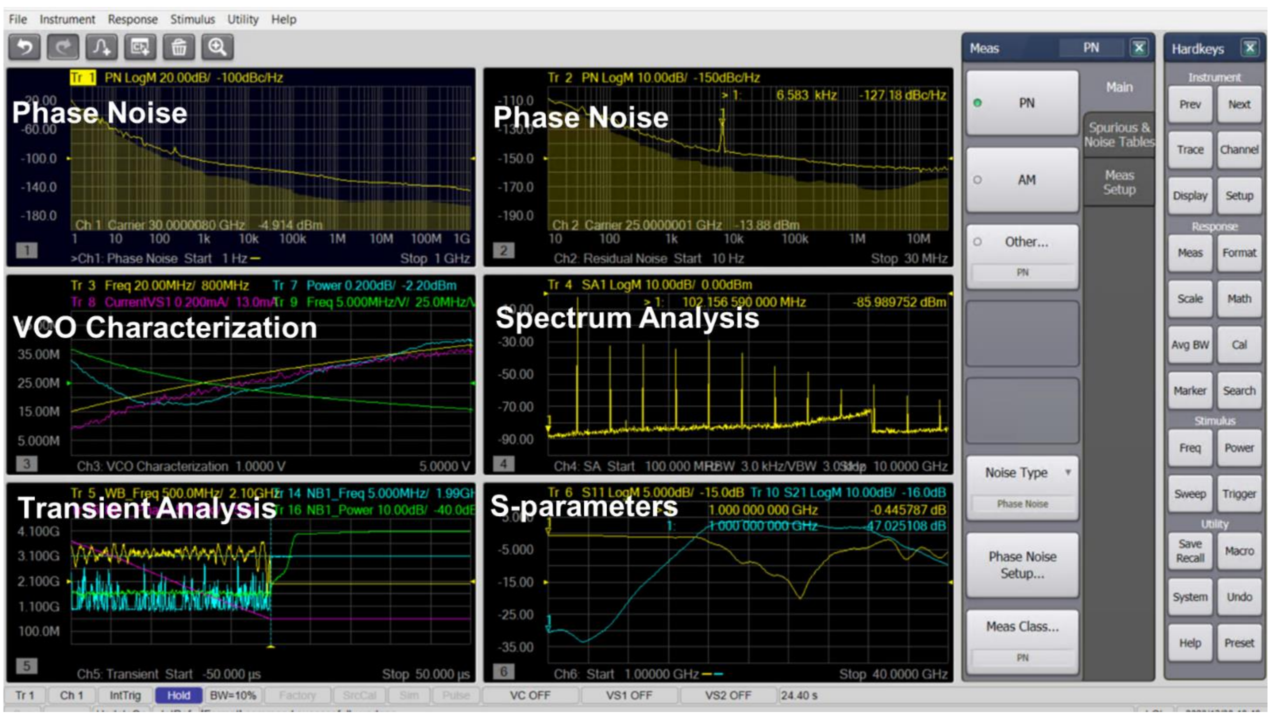

Figure 1. Comprehensive signal source/component characterization with SSA-X

Absolute Phase Noise/AM Noise Measurements

Extremely high measurement sensitivity

The SSA-X has two uncorrelated internal LO sources with low phase noise, and it has two input ports, each port has two uncorrelated receivers. Cross correlation (XCORR) is used to improve phase noise measurement sensitivity and to enable phase noise measurement of signal sources with lower phase noise than the SSA-X's phase noise measurement sensitivity. The internal LO has extremely low phase noise even at microwave frequencies, the SSA-X achieves -69 dBc/Hz at 10 Hz offset for 26.5 GHz.

Table 1. SSB phase noise sensitivity (dBc/Hz) (E5056A/57A/58A Opt.2xx), Cross correlation factor = 1, signal level = +10 dBm (< 44 GHz), +5 dBm (≥ 44 GHz), Auto range OFF, Max. input level = signal level + 3 dB for specification, Auto range ON for typical, start offset = 1 Hz [1]

RF input frequency		Offset frequency [Hz] from the carrier									
		1	10	100	1 k	10 k	100 k	1 M	10 M	30 M	100 M
1 MHz	specification	-124	-146	-154	-158	-164	-169	–	–	–	–
	typical	-138	-153	-162	-168	-172	-177	–	–	–	–
10 MHz	specification	-113	-138	-152	-158	-164	-169	-171	–	–	–
	typical	-119	-145	-158	-168	-173	-177	-179	–	–	–
100 MHz	specification	-93	-118	-140	-153	-159	-164	-166	-166	-166	–
	typical	-100	-130	-147	-160	-166	-171	-173	-173	-172	–
1 GHz	specification	-73	-98	-121	-148	-161	-166	-167	-167	-167	-165
	typical	-80	-111	-130	-156	-166	-173	-175	-175	-174	-173
3 GHz	specification	-63	-88	-111	-140	-157	-163	-165	-165	-165	-163
	typical	-70	-101	-120	-147	-164	-171	-175	-175	-174	-173
8 GHz	specification	-55	-80	-103	-132	-151	-158	-162	-162	-162	-160
	typical	-62	-93	-112	-139	-158	-165	-172	-172	-172	-171
10 GHz	specification	-53	-78	-101	-130	-149	-158	-165	-165	-162	-160
	typical	-60	-91	-110	-137	-157	-164	-173	-173	-170	-171
16 GHz	specification	-48	-73	-96	-125	-144	-152	-162	-161	-158	-156
	typical	-56	-87	-105	-132	-153	-160	-171	-171	-168	-169
26.5 GHz	specification	-44	-69	-92	-121	-140	-148	-156	-155	-153	-151
	typical	-52	-83	-101	-128	-148	-156	-165	-165	-163	-164
44 GHz	specification	-39	-64	-87	-116	-135	-143	-152	-151	-149	-147
	typical	-47	-78	-96	-123	-144	-151	-162	-162	-159	-158
50 GHz	specification	-38	-63	-86	-115	-134	-142	-151	-150	-149	-147
	typical	-46	-77	-95	-122	-143	-150	-159	-160	-157	-159
54 GHz	specification	-37	-62	-85	-112	-127	-131	-133	-133	-128	-129
	typical	-46	-77	-95	-122	-138	-143	-146	-146	-142	-146

1. Decomposition model (PM = AM model) for offset >30 MHz

Cross correlation and gain indicator

The users can increase the cross correlation factor to improve the sensitivity. The sensitivity is improved by 5 x LOG (N) (dB) where N is the number of cross correlations. For example, when XCORR factor of 100 is applied, the sensitivity improves by 5 x LOG (100) = 10 dB.

The S96301xB SSA-X signal source analyzer advanced feature application enables the cross correlation 100000 times at most, and it allows the sensitivity improvement by 25 dB at maximum [1].

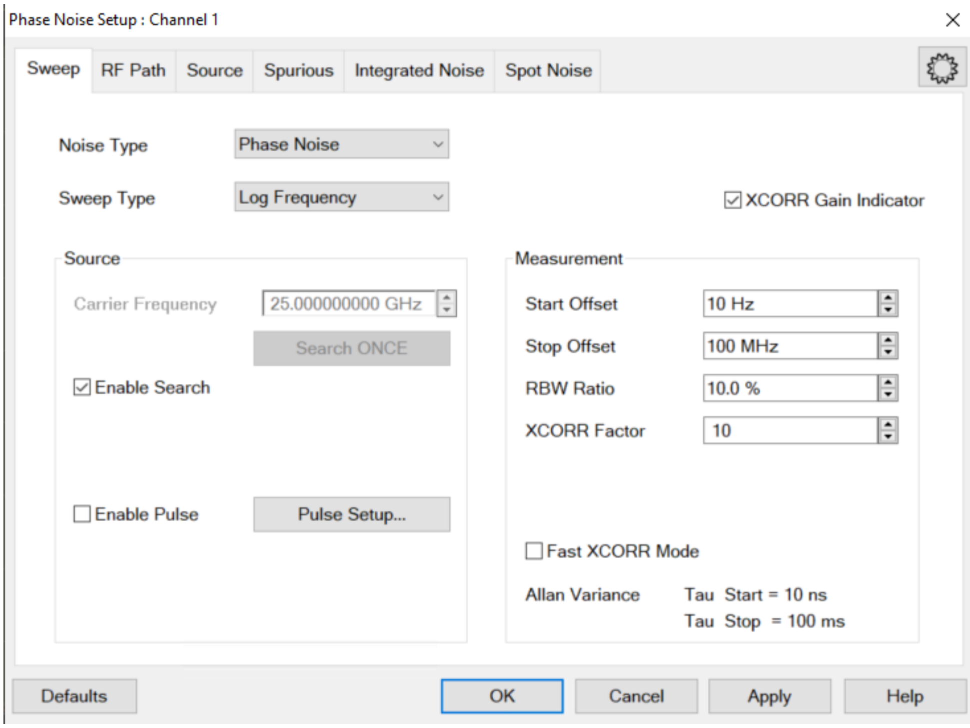

Figure 2. Cross-correlation setup dialog box

1. If the phase noise of the signal source under test has more than 25 dB better sensitivity than the SSA-X measurement sensitivity at 1 Hz offset, then Keysight N5511A phase noise test system, which provides the highest phase noise measurement performance is required.

The SSA-X shows a cross correlation gain indicator (shaded area) to show achievable measurement sensitivity with the cross-correlation factor specified by the user. Initially, the SSA-X measures the DUT phase noise, and the gain indicator projects the sensitivity improvement based on the measurement data and given cross correlation factor. The cross correlation gain indicator is updated at every sweep.

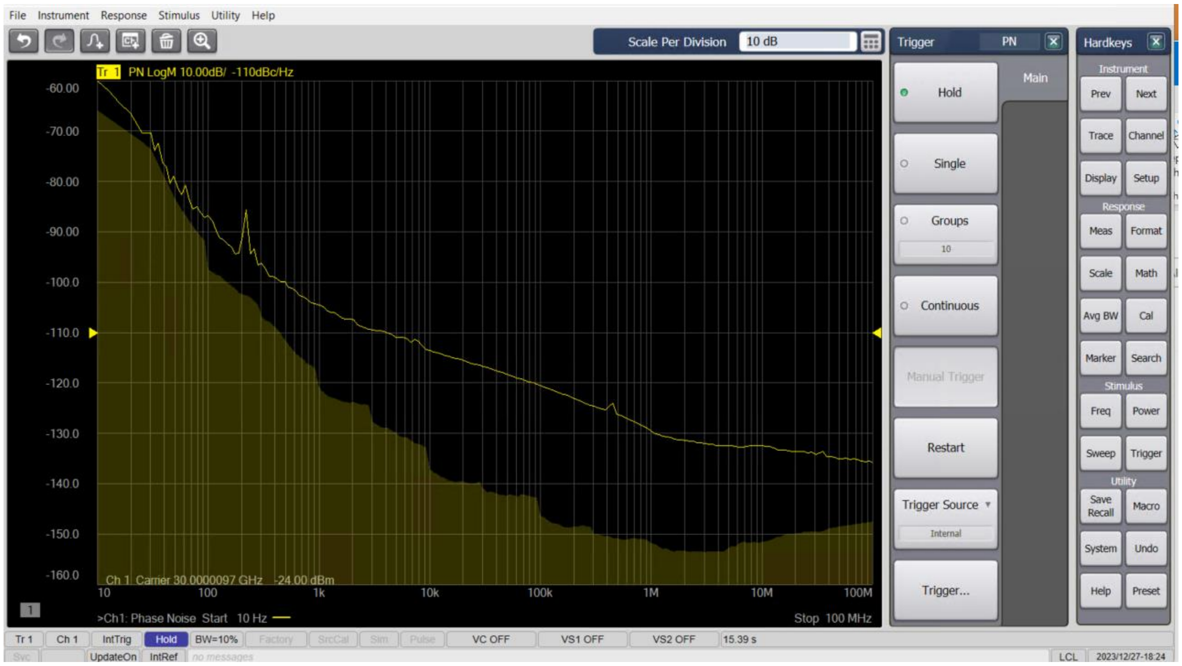

Figure 3. Cross-correlation gain indicator

The SSA-X has an auto carrier search function to automatically measure the carrier frequency, power, phase noise and show the spurs. The users can easily measure the phase noise of the signal source under test.

Figure 4. Phase noise and spurs

High speed measurement

Standard sweep mode and fast cross-correlation mode

The high sensitivity of the SSA-X enables to speed up the measurements. The measurement time from 1 Hz to 100 Hz offset is < 10 seconds in the standard log sweep mode, (RBW=10%, XCORR =1). The SSA-X also has fast cross correlation mode used for higher test efficiency. The fast XCORR mode takes a fewer number of cross correlations in some offset frequency ranges compared with the standard mode to speed up the measurements with only a small degradation of the measurement sensitivity.

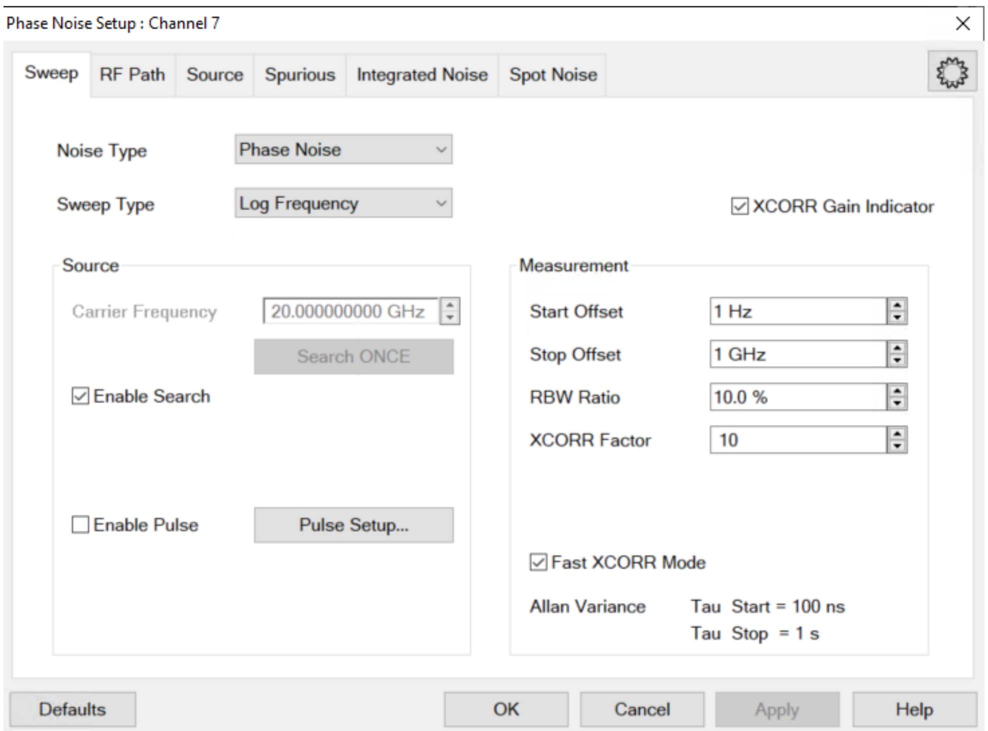

Figure 5. Fast XCORR mode

Speed optimization with segment sweep

In addition to the log sweep mode, the SSA-X also has segment sweep mode. The user can manually change the number of cross correlations in the segment sweep mode to optimize the measurement speed, depending on the measurement sensitivity and the absolute phase or residual noise of the signal source under test.

When the offset frequency range and the number of cross correlations are set in the log sweep mode, the default number of cross correlations for each offset frequency segment is automatically populated. (This setting is not viewable in the log sweep mode.) The user can easily populate the number of the cross correlations for each segment used in the log sweep in the segment mode and adjust the number of cross correlations in particular segments for the speed optimization.

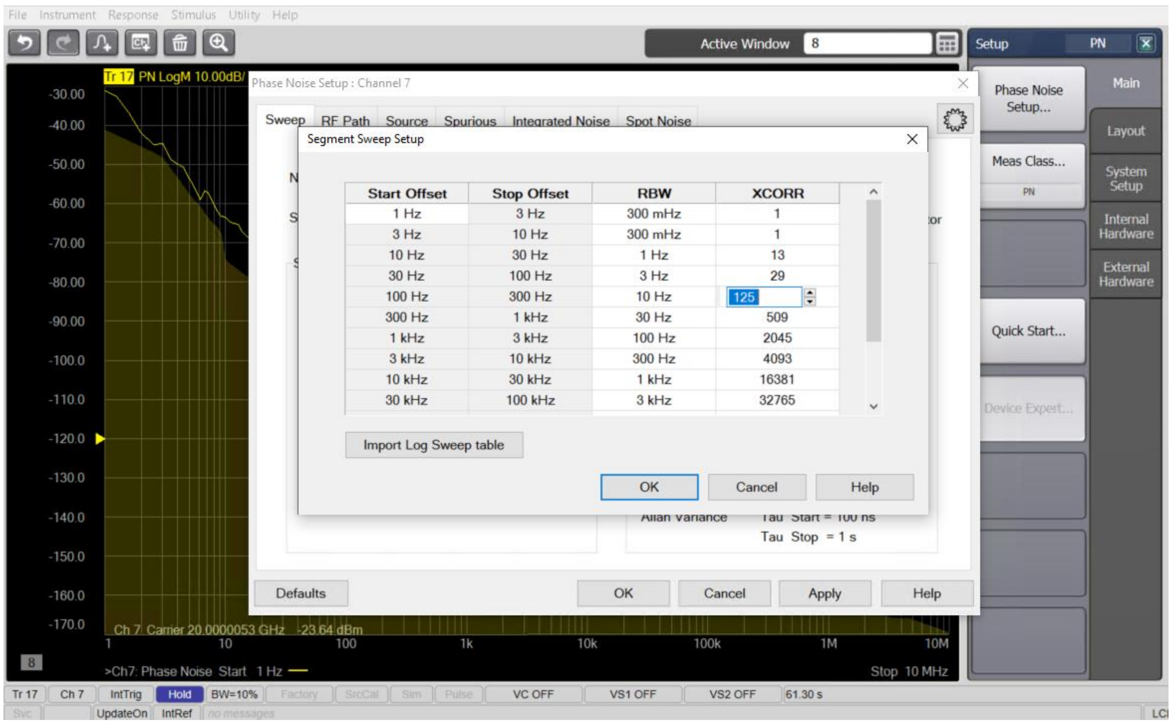

Figure 6. Segment sweep

AM noise measurement

The SSA-X can measure phase noise and AM noise [1] simultaneously.

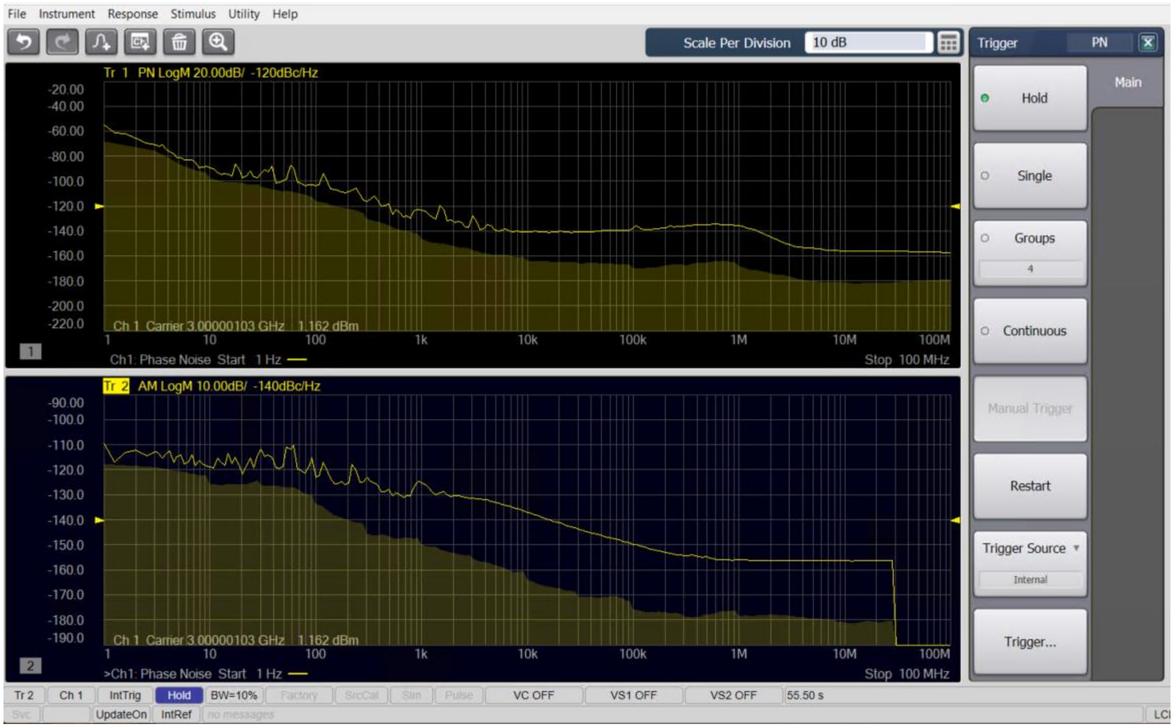

Figure 7. Phase noise and AM noise measurements

1. AM noise measurements can be done up to 30 MHz offset.

Pulsed measurement

The SSA-X can measure the phase noise of pulsed signals. This measurement is valuable in radar applications. If the phase noise of the transmitter source is higher than the power of the reflected signal from the object, which is slightly frequency-shifted due to the doppler effect, the signal can't be observed.

The user can set the pulse repetition intervals between 50 nsec and 10 msec. For 1 MHz ≤ carrier ≤ 3 GHz at +10 dBm, the nominal phase noise sensitivity at 300 kHz offset is -177 dBc/Hz – $20\log_{10}$ (duty cycle).

Figure 8. Pulsed phase noise measurement

Millimeter-wave frequency extension

The SSA-X option 40x enables to extend the frequency range of the phase noise measurement to millimeter-wave waveguide bands. The option 40x provides two independent LO outputs and two IF signal inputs. The users can connect a pair of millimeter-wave waveguide downconverters to the SSA-X. The two independent low phase noise LO signals enable high sensitivity sub-THz absolute phase noise measurements using cross correlations. Keysight's E5051AWxx Millimeter-wave phase noise measurement downconverter/phase detector includes a pair of downconverters with two LO inputs and two IF outputs. The E5051AWxx can be used as the downconverter of the E5056/57/58A SSA-X and also the external phase detector of the N5511A phase noise test system.

Figure 9. Keysight's E5051AWxx Millimeter-wave phase noise measurement downconverter/phase detector

Residual Phase Noise/AM Noise Measurements

The SSA-X with 2-port option adds a second channel with two receivers to enable residual phase noise and AM noise measurements of 2-port active devices. The SSA-X has a very low phase noise signal source up to 54 GHz and supplies the RF signal to the reference channel and the input of the DUT, and the SSA-X can perform the cross correlation on both reference channel and test channels, achieving a measurement sensitivity of -157 dBc/Hz at 26.5 GHz carrier and 10 kHz offset. The SSA-X can perform residual noise measurements up to 30 MHz offset.

Table 2. Residual phase noise sensitivity (dBc/Hz) (E5055A/56/57/58A), Cross correlation factor = 10, Fast XCORR mode OFF, Source Out signal used, Signal level setting = +10 dBm (< 44 GHz), +5 dBm (44 GHz), 0 dBm (50 GHz), -5 dBm (54 GHz), Auto range OFF, Max. input level = Signal level +3 dB for specification, Auto range ON for typical, Path delay compensation 0 second.

RF input frequency		Offset frequency [Hz] from the carrier								
		1	10	100	1 k	10 k	100 k	1 M	10 M	30 M
10 MHz	specification	-122	-138	-150	-158	-163	-167	-169	–	–
	typical	-136	-149	-159	-167	-172	-178	-178	–	–
100 MHz	specification	-120	-134	-147	-155	-160	-164	-166	-166	-166
	typical	-130	-144	-155	-163	-169	-172	-173	-175	-174
1 GHz	specification	-117	-133	-146	-154	-160	-165	-166	-166	-166
	typical	-128	-142	-155	-162	-168	-172	-174	-175	-174
3 GHz	specification	-115	-128	-143	-152	-159	-165	-166	-166	-166
	typical	-123	-138	-151	-161	-167	-172	-173	-174	-174
8 GHz	specification	-105	-121	-136	-148	-156	-161	-163	-163	-163
	typical	-113	-131	-144	-157	-164	-168	-170	-172	-171
10 GHz	specification	-107	-124	-140	-152	-160	-166	-167	-165	-162
	typical	-123	-137	-149	-160	-168	-173	-174	-175	-172
16 GHz	specification	-107	-122	-136	-149	-159	-165	-168	-164	-160
	typical	-121	-134	-147	-158	-166	-173	-176	-174	-169
26.5 GHz	specification	-105	-119	-133	-146	-157	-163	-167	-159	-150
	typical	-117	-132	-143	-154	-165	-172	-175	-172	-166
44 GHz	specification	-96	-113	-127	-139	-149	-157	-162	-156	-147
	typical	-110	-125	-136	-149	-160	-167	-170	-168	-161
50 GHz	specification	-95	-111	-125	-139	-149	-158	-161	-154	-146
	typical	-111	-124	-135	-148	-160	-167	-171	-168	-164
54 GHz	specification	-93	-103	-111	-116	-121	-126	-126	-124	-121
	typical	-105	-116	-123	-129	-134	-139	-140	-140	-139

For amplifier measurements, the SSA-X provides a source signal through a built-in power splitter. Figure 10 shows an example setup. The RF1 output signal of the SSA-X provides the RF Input 1 of the SSA-X as the reference signal. The RF2 output signal of the SSA-X provides the DUT input. The output of the DUT is connected to the RF Input 2 of the SSA-X. Any noise from the RF input source is cancelled and only the phase noise contribution of the DUT is measured. With the SSA-X, the users can measure the low residual noise of amplifiers with a simple measurement setup. Other instruments such as a high-performance signal generator, splitters, and phase shifters are not required.

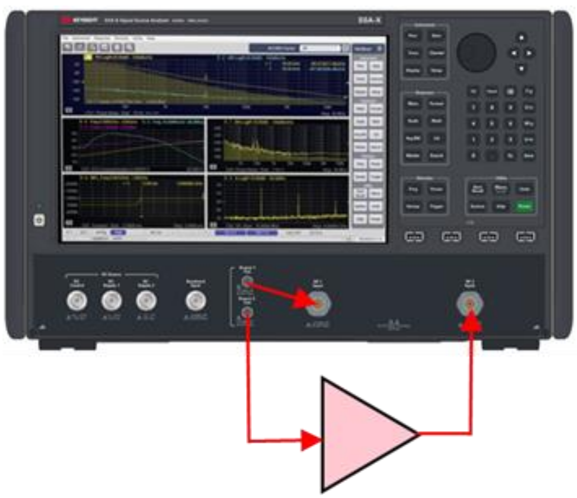

Figure 10. Amplifier residual noise measurement setup

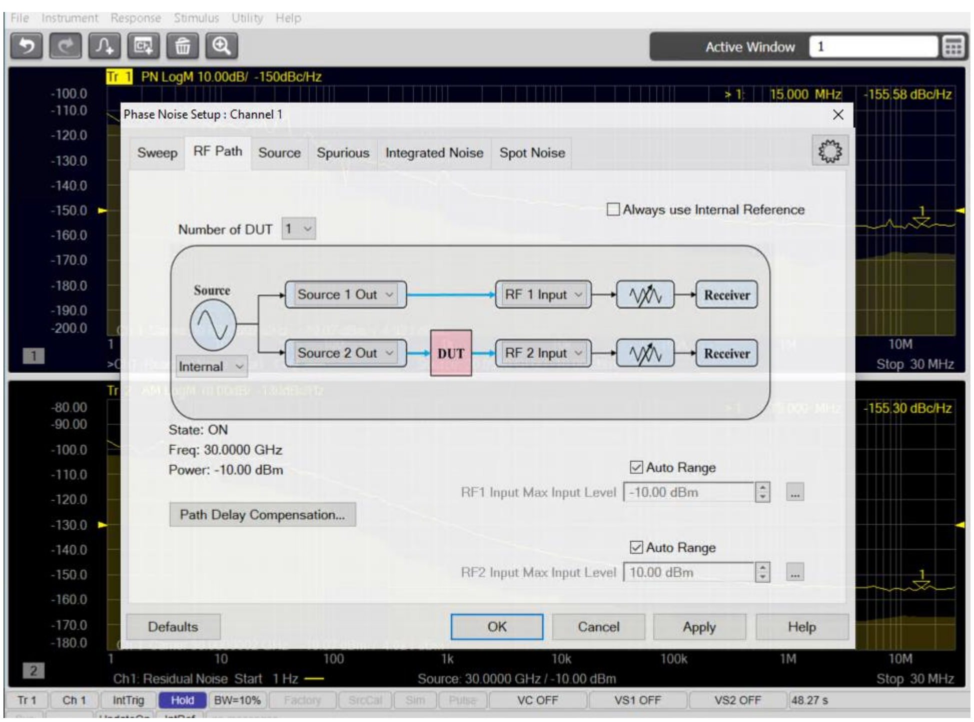

Figure 11. Residual noise measurement setup

Figure 12. Amplifier residual noise measurement

The residual noise of frequency converters with embedded LOs is determined by the phase noise of the embedded-LO, and typically the phase noise performance is not as great as a typical high-performance signal generator. Based on the assumption, the users can measure the residual noise of the frequency downconverter embedded LO as the absolute phase noise on a single channel by supplying the DUT input signal from an external signal generator as given in the Figure 13. The 2-port option configuration is not required for this measurement.

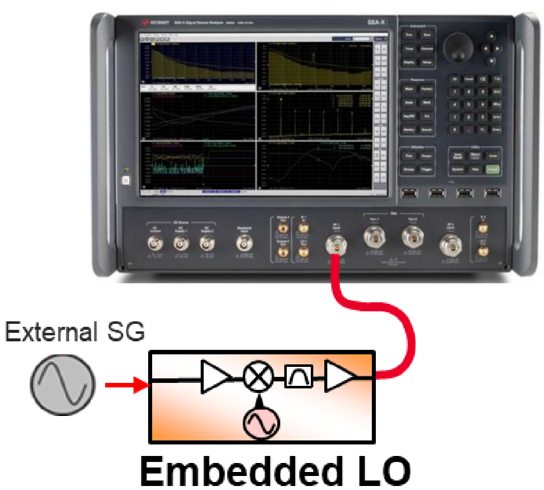

Figure 13. Frequency converter embedded-LO residual noise measurement setup

The residual noise of mixers can also be measured with the SSA-X 2-port option as seen in Figure 14. The mixer residual noise measurement requires two identical mixers, an external signal generator and a power splitter.

The SSA-X output signals are provided as RF signal for the two mixers, and the output of the external signal generator is supplied as the LO of the two mixers through the power splitter. The SSA-X measures the IF signal of the mixers on the two channels. The RF signal from the SSA-X and the LO signal from the external signal generator are common and cancelled out. The residual noise of the two mixers is uncorrelated and the sum of the residual noise is measured. The residual noise is obtained by subtracting 3 dB from the measurement value. The SSA-X can achieve very low residual noise measurements of these devices by using the internal clean sources and the high-performance external signal generator and also by taking the cross correlations.

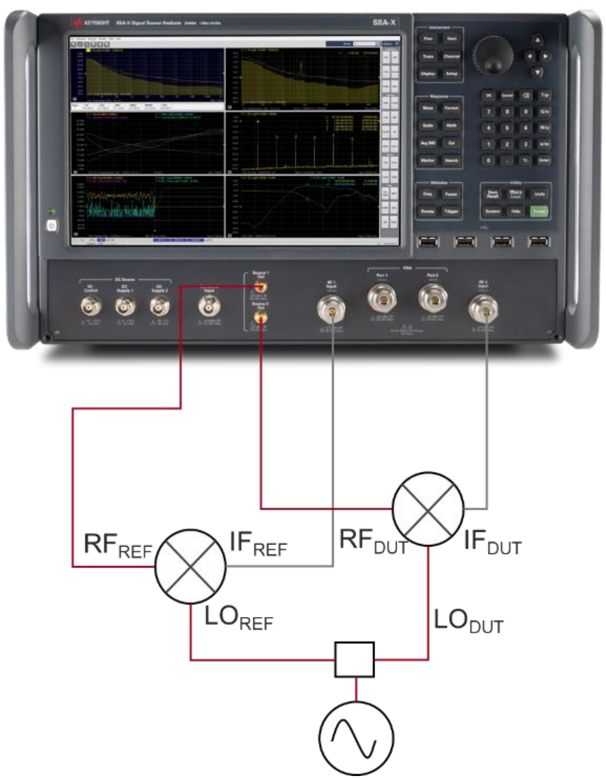

Figure 14. Mixer residual noise measurement setup

VCO (Voltage-Controlled Oscillator) Characterization with Extremely Low Noise Internal DC source

The SSA-X has extremely low noise level internal DC sources: one DC control voltage source and two DC power supplies for VCO evaluation with a simple setup. When larger current is required for driving a VCO, the users can use DC power supply parallel mode to double the current of DC power supply [1].

Table 3. DC source performance

DC source	Voltage	Maximum current	Noise level (typical)
DC control voltage source	-35 V to 35 V	20 mA typical	< 1 nVrms / √Hz at 10 kHz offset
DC power supply 1	0 V to 8 V	1 A (2 A) [1]	< 3 nVrms / √Hz at 10 kHz offset
	8 V to 16 V	0.3 A (0.6 A) [1]	< 3 nVrms / √Hz at 10 kHz offset
DC power supply 2	-8 V to 0 V	1 A	< 3 nVrms / √Hz at 10 kHz offset
	-16 V to -8 V	0.3 A	< 3 nVrms / √Hz at 10 kHz offset

1. The maximum current in the parallel mode. The port of DC power supply 2 must be unconnected in the parallel mode.

The users can sweep either DC tuning (control) voltage or DC power supply voltage to measure these parameters: output frequency, tuning sensitivity, RF output power, and DC consumption current on DC control voltage source and DC power supplies.

The SSA-X carrier search function automatically searches for the VCO output signal and measures the phase noise of VCO.

The harmonics of a VCO can also be measured with the SSA-X's FFT-based spectrum measurement function for comprehensive VCO characterization.

Figure 15. VCO characterization

Signal Transient Measurements

The SSA-X measures frequency, RF power and phase transients over time for signal source switching characteristics such as frequency hopping and PLL setting time. It has two modes: wideband and narrowband. The wideband mode enables frequency transient measurements up to 7 GHz bandwidth, and the narrowband mode enables frequency and phase transient measurements up to 320 MHz and RF power transient measurement up to 30 MHz for more detailed analysis.

In addition to an external trigger and manual trigger, it has a video trigger feature to trigger the measurement with either frequency or power transient of the signal source.

The SSA-X also has a hysteresis feature to ensure proper measurement triggering for noisy signals or signals with some small ringing. The users can specify a frequency or power deviation range to avoid unwanted measurement triggering. When the signal deviation is within the specified range, the measurement is not triggered even when the signal crosses the target frequency or power.

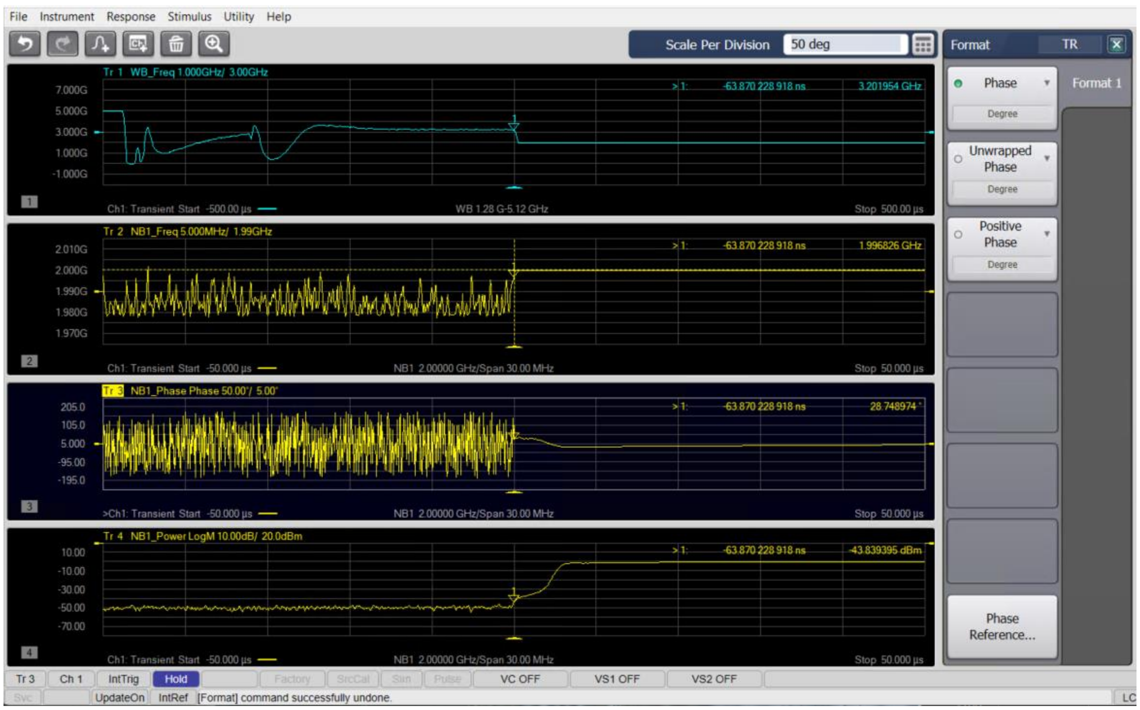

Figure 16. Transient measurement

Clock Jitter Analysis

The jitter of reference clock signals used in high-speed digital applications such as PCI Express® 6.0 can cause bit errors. The SSA-X with the S96302B Precision Clock Jitter Analysis application software allows the users to analyze data-independent jitters: random jitter (RJ) and periodical jitter (PJ) of the clock signals in the time and frequency domain by utilizing the SSA-X's phase noise measurement and transient measurement. It can measure the random jitter as low as 2 fsec for a 10 GHz signal.

The S96302B provides the clock frequency and the random jitter within an integrated (offset frequency) band specified by the user.

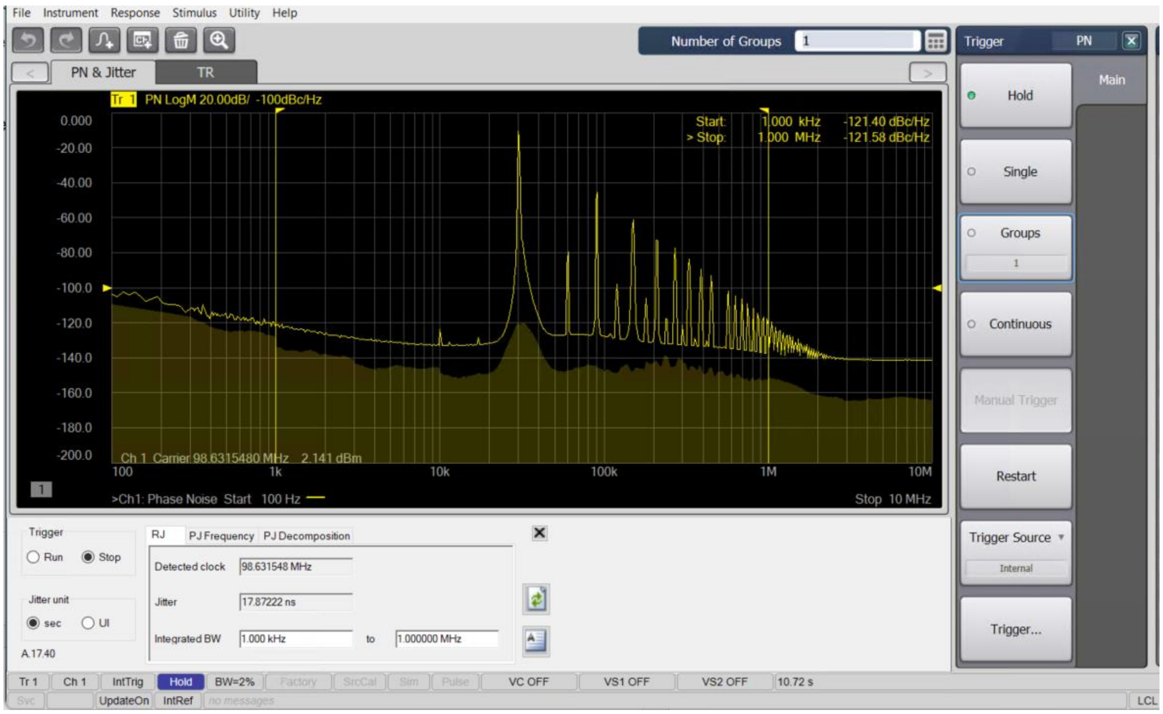

Figure 17. Random jitter measurement

The S96302B quickly identifies the periodical jitters and the offset frequencies through the phase noise measurement. The periodic jitter frequencies help the user to understand clock signal quality and contamination sources of signal integrity.

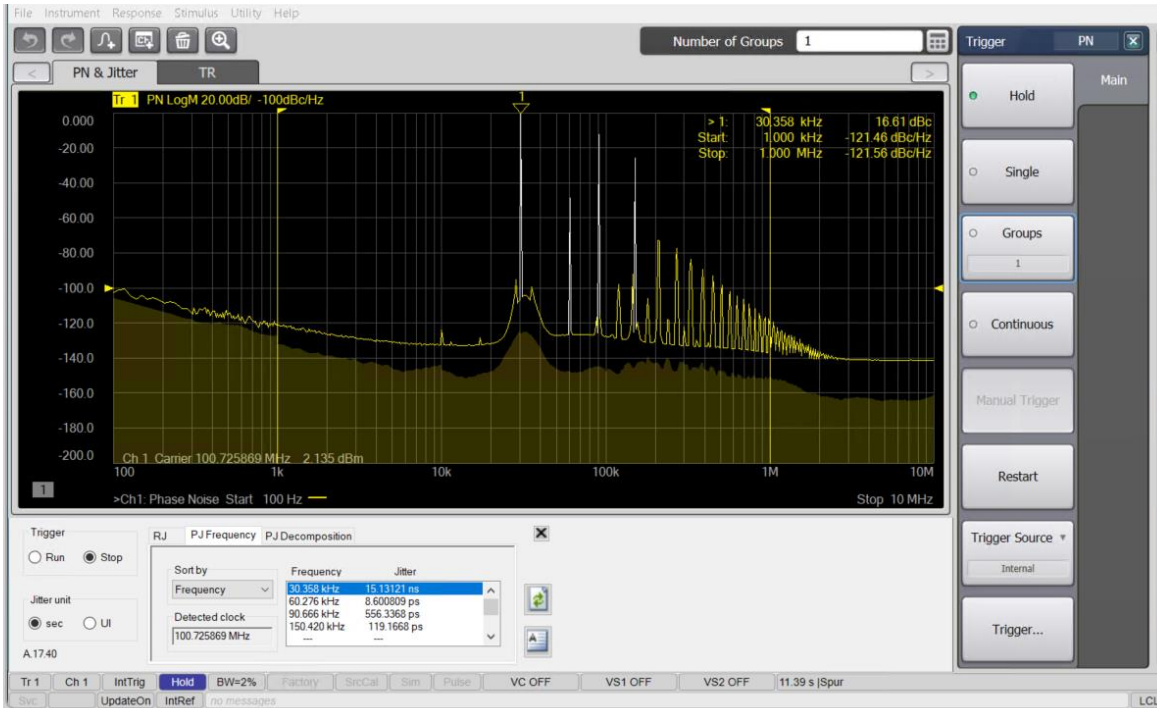

Figure 18. Periodic jitter measurement

The user can select one of the spurs and evaluate the jitter characteristics of the clock signal in the time domain. The S96302B provides jitter trend, jitter histogram, RJrms, PJrms, TJp-p, PJp-p, PJd-d in the dual-Dirac model for the users to be able to estimate the system's data-independent bit-error-rate (BER) during a specific period of time, and the uncorrected jitter information that is useful for evaluation of the transmitter, the receiver and the clock and data recovery (CDR) retimer circuits.

Figure 19. Jitter trend

Figure 20. Periodic jitter separation histogram

The S96302B can also measure a reference clock with Spread Spectrum Clocking (SSC), which is used in PCIe Refclk. An example of this measurement is shown using a 100 MHz clock signal modulated with a 30kHz triangle wave with 0.5% center-spread.

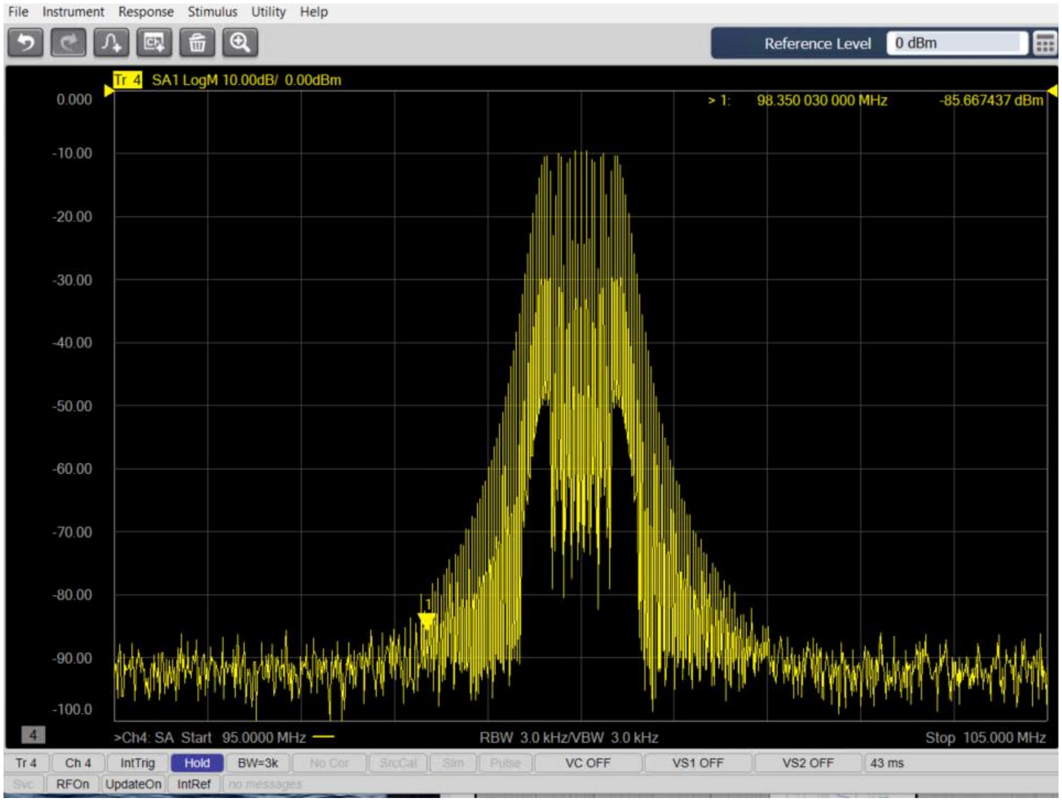

Figure 21. Spread spectrum example

Vector Network Analysis

The SSA-X with option 26x enables 2-port vector network measurements up to 54 GHz. It supports the VNA calibration accessories like ECal modules and power sensors and allows the user to accurately make basic vector network measurements like S-parameter measurements for active and passive components. The measurement performance is comparable with Keysight's midrange VNAs like the E5080B vector network analyzer.

Figure 22. Amplifier gain (S-parameter) measurement

E505xA SSA-X Configuration

Summary of E505xA configuration

The table below shows all available and selectable options in the E505xA SSA-X Signal Source Analyzer.

Product / Option number	Description	Additional Information
E5055A	SSA-X Signal Source Analyzer, 1 MHz to 8 GHz	
E5056A	SSA-X Signal Source Analyzer, 1 MHz to 26.5 GHz	
E5057A	SSA-X Signal Source Analyzer, 1 MHz to 44 GHz	
E5058A	SSA-X Signal Source Analyzer, 1 MHz to 54 GHz	
Port configuration options (mandatory)		
1-port configuration		One of the port configuration options must be selected.
E505xA-100	Standard phase noise	
E505xA-200	Enhanced low phase noise	
2-port configuration		
E505xA-150	2-port standard phase noise, standard noise source	
E505xA-151	2-port standard phase noise, low-noise source (Export-controlled)	
E505xA-160	2-port standard phase noise, standard noise source, network analyzer	
E505xA-161	2-port standard phase noise, low-noise source, network analyzer (Export-controlled)	
E505xA-250	2-port enhanced low phase noise, standard noise source	
E505xA-251	2-port enhanced low phase noise, low-noise source (Export-controlled)	
E505xA-260	2-port enhanced low phase noise, standard noise source, network analyzer	
E505xA-261	2-port enhanced low phase noise, low-noise source, network analyzer (Export-controlled)	
mmWave measurement configuration option		
E505xA-400	LO output (standard noise) / IF in	Available on E5056A/57A/58A.
E505xA-401	LO output (low-noise) / IF in (Export-controlled)	
Calibration options		
E505xA-1A7 [1]	Calibration + Uncertainties + Guardbanding	
E505xA-A6J [1]	ANSI Z540-1-1994 Calibration	
Other hardware options		
E505xA-181	Add keyboard	
E505xA-182	Add mouse	
E505xA-1CM	Rackmount kit for installation without handles	
E505xA-1CP	Rackmount kit for installation with handles	

1. Available from May 2024.

Application software

Option number	Description	Additional information
Advanced Features software		
S963015B	SSA-X Signal Source Analyzer advanced features for E5055A	
S963016B	SSA-X Signal Source Analyzer advanced features for E5056A	
S963017B	SSA-X Signal Source Analyzer advanced features for E5057A	
S963018B	SSA-X Signal Source Analyzer advanced features for E5058A	
Spectrum Analysis software		
S963905B	Spectrum analysis for E5055A	
S963906B	Spectrum analysis for E5056A	
S963907B	Spectrum analysis for E5057A	
S963908B	Spectrum analysis for E5058A	
Other application software		
S96325B	Pulsed-RF measurements for SSA-X Signal Source Analyzer	
S96302B	Precision clock jitter analysis for SSA-X Signal Source Analyzer	Requires S96301xB Advanced features software.

Summary

The E505xA Signal Source Analyzers enables comprehensive signal source analysis and 2-port device residual noise measurements for the emerging 5G, 6G, aerospace and defense, and high-speed digital applications.

Web sources

Visit our Signal Source Analyzer Web site for additional product information and literature:
www.keysight.com/find/E5058A

Phase noise measurements: www.keysight.com/find/phasenoise

RF and microwave accessories: www.keysight.com/find/mta

Related literature

Literature	Publication number
E505xA SSA-X Signal Source Analyzer – Data Sheet	3122-1508.EN
E505xA SSA-X Signal Source Analyzer – Configuration Guide	3122-1545.EN