PN3 Signal Source Analyzer

Model E5045A, E5046A, E5047A

5 MHz to 7, 26, 40 GHz

Definitions

The specifications in the following pages describe the warranted performance of the instrument for 23 ±5 °C after a 30-minute warm-up period (unless otherwise stated).

Min / Max: Parameter range that is guaranteed by product design, and / or production tested. Warranted performance specifications include guard-bands to account for the expected statistical performance distribution, measurement uncertainties, and changes in performance due to environmental conditions.

Typical: Expected mean values, not warranted performance.

Introduction

Fully integrated cross-correlation signal source analyzer for 5 MHz to 7, 26, 40 GHz

The PN3 Signal Source Analyzer is an integrated solution that offers an indispensable set of measurement functions for evaluating signal sources ranging from VHF to microwave frequencies, such as crystal oscillators, PLL synthesizers, clocks, phase-locked or free-running VCOs, DROs, SAW or YIG oscillators, and others.

The flexible instrument comprises a two-channel cross-correlation system with two internal tunable reference sources and allows measurements with externally fed references.

KEYSIGHT

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The PN3 Signal Source Analyzer supports many other functions including:

- Absolute and residual phase noise measurements.
- Amplitude noise measurements.
- Pulsed absolute and residual phase noise measurements.
- Two-channel 100 MHz FFT analysis.
- Transient measurements (frequency, phase, amplitude vs. time).
- Spectrum analysis.
- Frequency counter function / power meter.

Additionally, the unit offers:

- Two programmable low noise DC supplies up to 15 V and 500 mA current capability.
- Three low noise tuning voltages for -5 to +20 V voltage range.

It is a compact and powerful instrument available with LAN (VXI-11), USBTMC, or with GPIB (optionally) interfaces. Platform independent intuitive graphical user interface (GUI), API library, and powerful SCPI command language set is available.

Operated with an external 24 V DC supply, it consumes less than 70 W.

Facts, Figures, and Specifications

Phase noise measurement performance

Measurement parameters:

SSB phase noise [dBc/Hz], spurious noise [dBc], integrated RMS phase noise deviation [deg, rad], time jitter [s], residual FM/PM [Hz RMS]

Parameter	Min	Typical	Max	Note
RF frequency range	*FMIN* 5 MHz 5 MHz 5 MHz		*FMAX* 7 GHz 26 GHz 40 GHz	Using internal references E5045A E5046A E5047A
RF frequency range	5 MHz 5 MHz		7 GHz 18 GHz	Using external references E5045A E5046A / E5047A
Input power range < 18 GHz 18 GHz to 30 GHz > 30 GHz	 -15 dBm -10 dBm -5 dBm		 +20 dBm +23 dBm +23 dBm	Damage level +26 dBm
Input impedance VSWR		50 Ω 2		AC coupled, 10 V DC max
Offset analysis range	0.01 Hz 0.01 Hz		100 MHz > 25% of f_C	f_C > 150 MHz f_C < 150 MHz
Resolution (PPD)	200	200	1600	RBW adjustable (x1 / x2 / x4 / x8), PPD (points per decade) can be lower for lowest decade of measurement
Measurement accuracy		±4 dB ±3 dB ±2 dB		Offset < 10 Hz Offset 10 Hz to 1 kHz Offset 1 kHz to 100 MHz
Spurious levels Internal References External References		 -90 dBc -85 dBc		
Trigger				Single, continuous, manual, bus
Frequency counter Measurement parameters: Frequency [Hz]				
RF frequency range	*FMIN*		*FMAX*	
Absolute accuracy		300 ppb		
Sensitivity				See plot “Typical RF sensitivity”
Power detector Measurement parameters: RF Power Level [dBm]				
RF frequency range	*FMIN*		*FMAX*	E5045A, E5046A, E5047A
Absolute accuracy		±1 dB		
Power range	-10 dBm		+13 dBm	

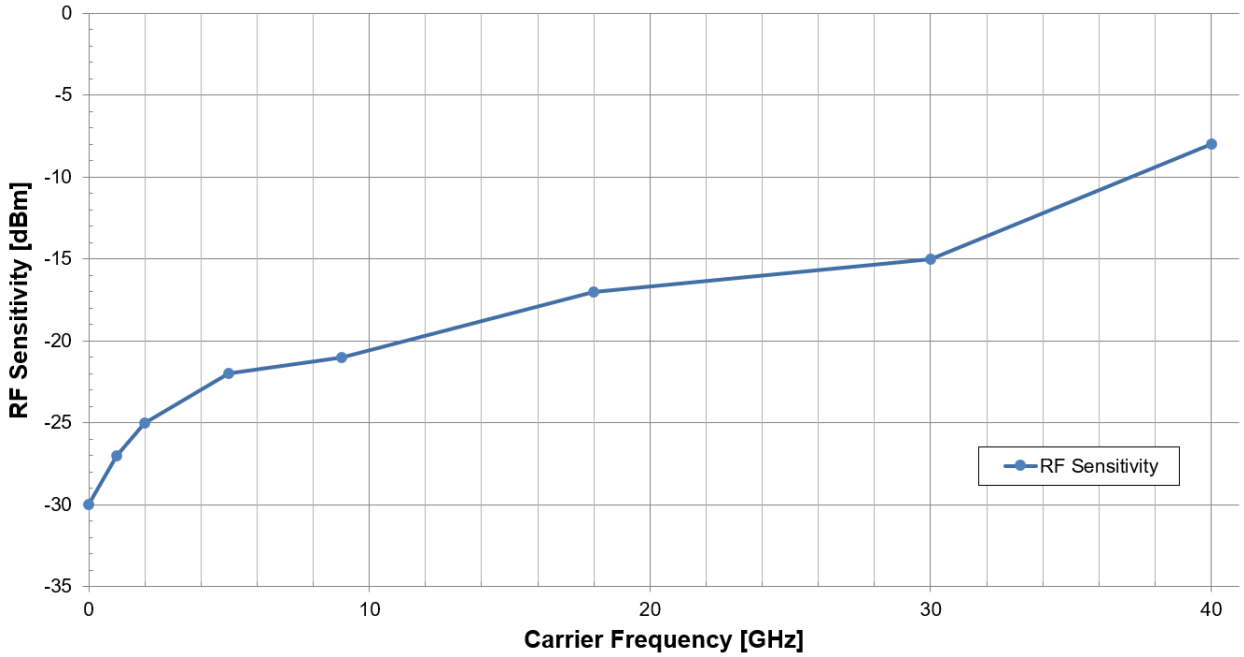


Figure 1. Typical RF sensitivity 5 MHz to 40 GHz

Phase noise measurement time

Total measurement time consists of setup time, data transfer time, and the correlation time multiplied by the number of correlations. The measurement times below are normalized to one correlation with the following conditions:
Nominal RBW settings, correlation factor ≥ 10, measurement time (without setup time) ≥ 2 seconds.

Offset range	Time (s) per correlations	No. of points (settable)
0.1 Hz to 100 MHz	52	200 per decade
1 Hz to 100 MHz	6.2	200 per decade
10 Hz to 100 MHz	0.8	200 per decade
100 Hz to 100 MHz	0.06	200 per decade
1 kHz to 100 MHz	0.01	200 per decade
10 kHz to 100 MHz	< 0.004	200 per decade

Note: Selecting the Noise floor configuration *"Imaginary Part of Cross Correlation"* instead of the default *"Gain Indicator"* decreases total measurement time by one correlation cycle.

Absolute phase noise measurements with internal references

Parameter	Min	Typical	Max	Note
Internal references				Cross-correlation
Frequency range	5 MHz		FMAX	
RF tracking range		±1 ppm ±10 ppm ±1000 ppm		Option 200 Standard High drift mode

Absolute phase noise sensitivity — internal references (standard)

Abs. PN with internal references	Offset 1 Hz	10 Hz	100 Hz	1 kHz	10 kHz	100 kHz	1 MHz	10 MHz	100 MHz
10 MHz	-90	-125	-150	-163	-170	-175	-175		
100 MHz	-70	-105	-135	-160	-172	-178	-180	-182	
1 GHz	-50	-85	-115	-140	-155	-160	-163	-172	-175
3 GHz	-40	-75	-105	-133	-145	-152	-155	-162	-165
10 GHz	-30	-65	-95	-123	-137	-143	-147	-155	-167
25 GHz	-22	-55	-85	-114	-130	-138	-140	-146	-155
40 GHz	-18	-53	-85	-113	-123	-131	-132	-145	-152
Remarks	Specified values in dBc/Hz. Typical values are 5 to 8 dB lower. Test conditions: carrier power ≥ 10 dBm; measurement starting from 1 Hz offset; one correlation. More correlations improve the sensitivity by 5 dB × $\log_{10}$(No. of correlations).								

Absolute phase noise sensitivity — internal references (Option 200)

Abs. PN with internal references (Option 200)	Offset 1 Hz	10 Hz	100 Hz	1 kHz	10 kHz	100 kHz	1 MHz	10 MHz	100 MHz
10 MHz	-115	-140	-150	-163	-170	-175	-175		
100 MHz	-95	-120	-135	-160	-172	-178	-180	-182	
1 GHz	-75	-100	-115	-140	-155	-160	-163	-172	-175
3 GHz	-65	-90	-105	-133	-145	-152	-155	-162	-165
10 GHz	-55	-80	-95	-123	-137	-143	-147	-155	-167
25 GHz	-45	-70	-85	-114	-130	-138	-140	-146	-155
40 GHz	-44	-68	-85	-113	-123	-131	-132	-145	-152
Remarks	Specified values in dBc/Hz. Typical values are 5 to 8 dB lower. Test conditions: carrier power ≥ 10 dBm; measurement starting from 1 Hz offset; one correlation. More correlations improve the sensitivity by 5 dB × $\log_{10}$(No. of correlations).								

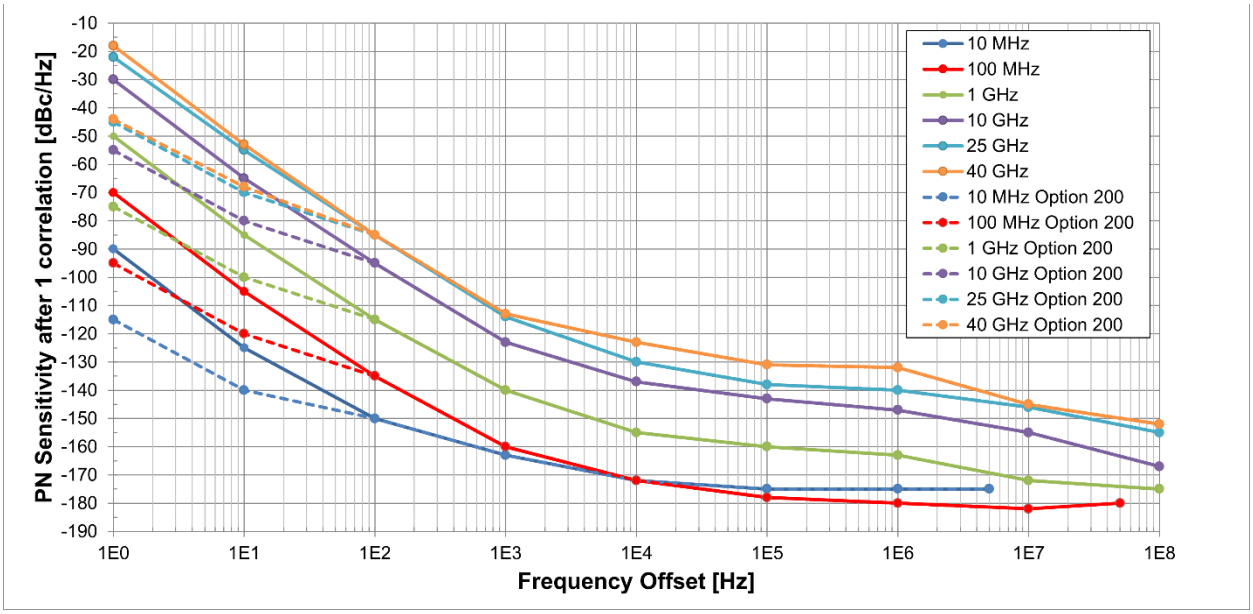


Figure 2. After 1 correlation

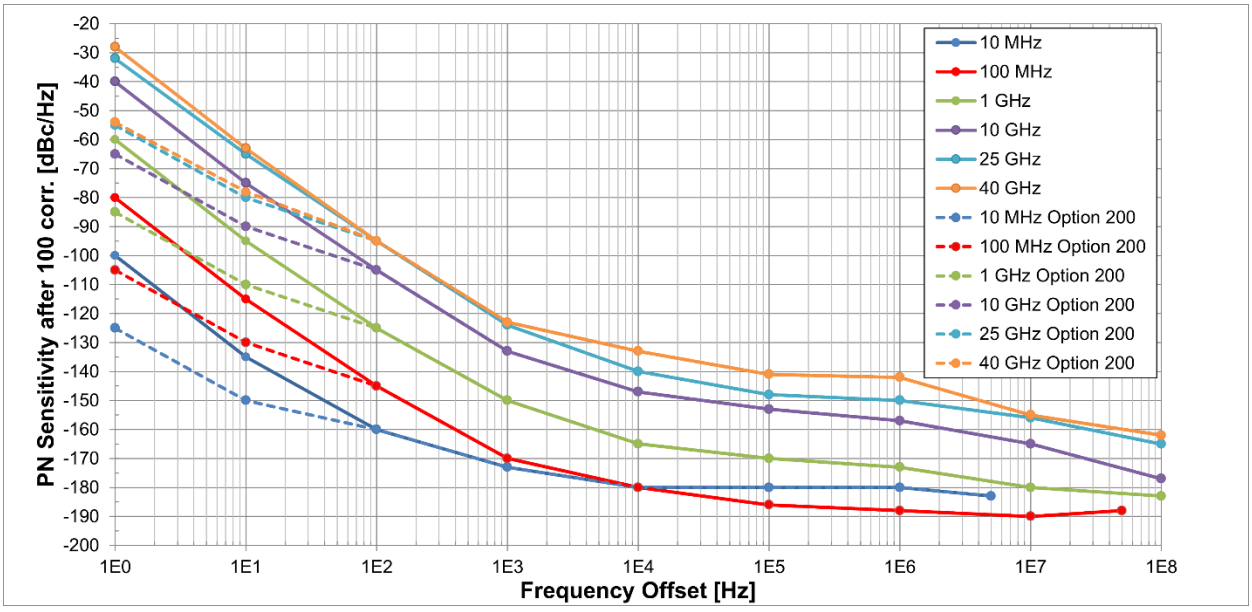


Figure 3. After 100 correlations

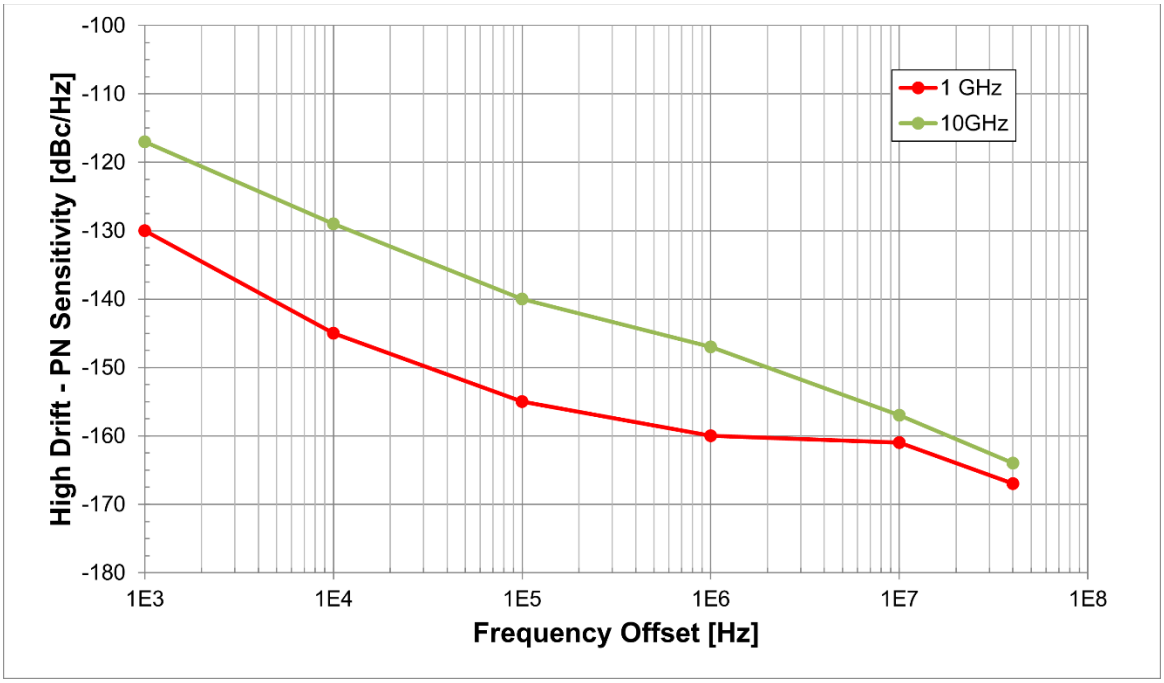


Figure 4. Phase noise sensitivity in High Drift measurement mode

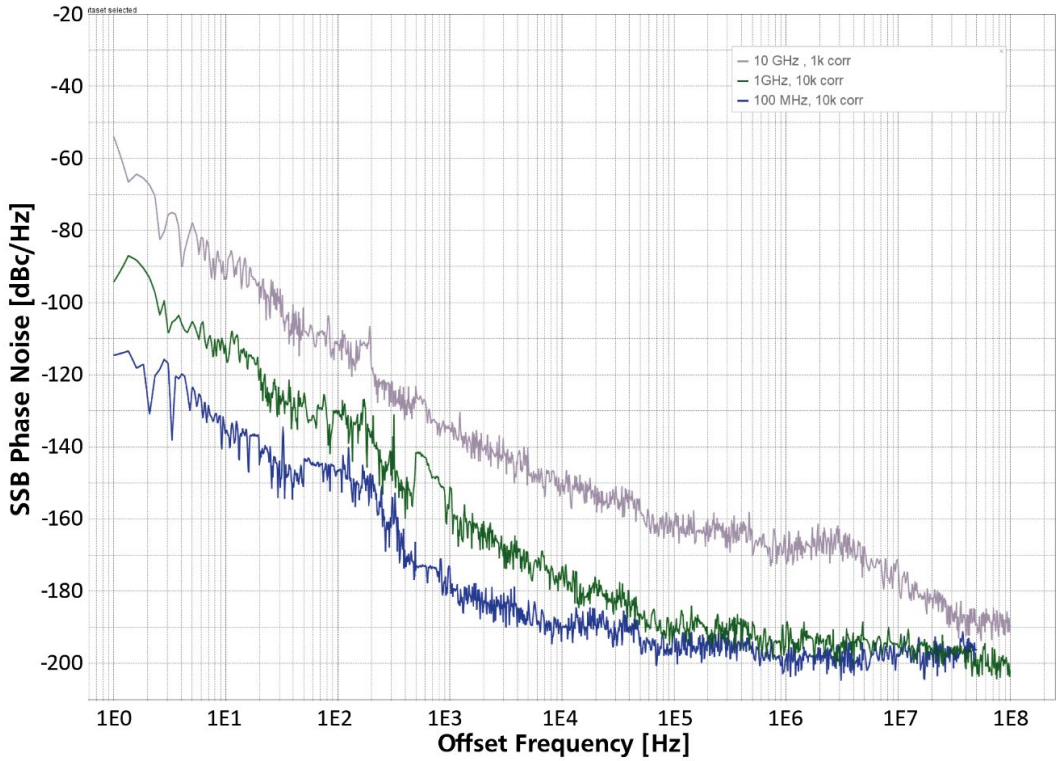


Figure 5. Typical noise floor examples

Absolute phase noise measurements with external references

Parameter	Min	Typical	Max	Note
External references				single channel / cross-corr.
Frequency range	5 MHz 5 MHz		7 GHz 18 GHz	E5045A E5046A / E5047A
RF input power range	0 dBm		+23 dBm	Damage level +26 dBm
Reference input level range ≤ 2 GHz > 2 GHz	 +10 dBm +13 dBm	 +15 dBm +15 dBm	 +21 dBm +21 dBm	 Low frequency input ports High frequency input ports
Tuning voltage range	-5 V		+20 V	User adjustable
Tuning output current		20 mA		

Absolute phase noise sensitivity — external references

Abs. PN with external references	Offset 1 Hz	10 Hz	100 Hz	1 kHz	10 kHz	100 kHz	1 MHz
10 MHz	-135	-150	-155	-170	-175	-175	-175
100 MHz	-120	-130	-140	-170	-178	-178	-178
1 GHz	-100	-110	-125	-155	-170	-170	-170
3 GHz	-95	-110	-125	-155	-170	-170	-170
10 GHz	-90	-110	-120	-145	-155	-155	-155
18 GHz	-85	-105	-115	-130	-140	-145	-145
Remarks	Test conditions: carrier power ≥ 5 dBm; after one correlation						

Absolute phase noise measurement — pulsed (Option 006 / 007)

Parameter	Min	Typical	Max	Note
RF frequency range	30 MHz 30 MHz		7 GHz 26 GHz 40 GHz	E5045A E5046A E5047A
RF input power range	+10 dBm		+20 dBm	No power measurement
Input parameters Pulse rate (PRF) Pulse width Duty cycle	 500 Hz 1 µs 50 ns 2% 0.2%		 1 MHz 1 ms 1 ms 60% 60%	 Option 006 Option 007 Option 006 Option 007
Offset analysis range	0.01 Hz		PRF	
Measurement accuracy		±4 dB ±3 dB ±2 dB		Offset < 10 Hz Offset 10 Hz to 1 kHz Offset 1 kHz to 100 MHz
Measurement time				See table “Meas. time”

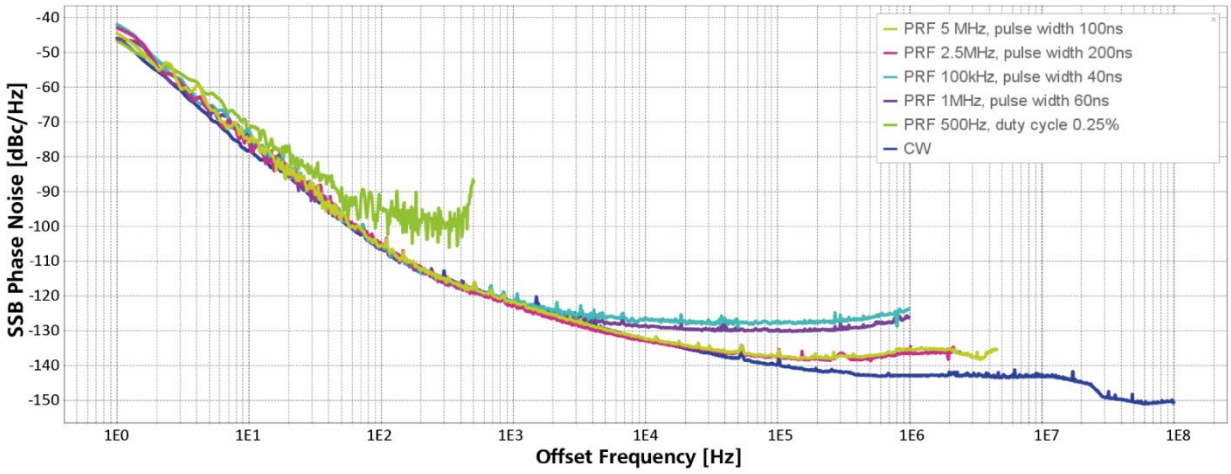


Figure 6. 8 GHz pulsed signals, with pulse widths ≥40 ns and PRF ≤5 MHz (Option 007)

Residual (additive) phase noise measurement — CW (Option 020) and pulsed (Option 020 + 006)

Measurement parameters:

SSB phase noise [dBc/Hz], spurious noise [dBc], integrated RMS phase noise deviation [deg, rad], time jitter [s], residual FM/PM [Hz RMS]

Parameter	Min	Typical	Max	Note
RF frequency range	10 MHz 10 MHz		7 GHz 18 GHz	E5045A E5046A / R5047A
RF input power range RF port REF ports	 +3 dBm +13 dBm		 +23 dBm +20 dBm	
LO output power range	+14 dBm		+25 dBm	Option 300
Offset analysis range	0.01 Hz		100 MHz	
Measurement accuracy		±3 dB ±2 dB		Offset < 1 kHz Offset > 1 kHz

Additive phase noise sensitivity — single channel

Abs. PN with external references	Offset 1 Hz	10 Hz	100 Hz	1 kHz	10 kHz	100 kHz	1 MHz
10 MHz ≤ f ≤ 1 GHz	-130	-140	-150	-160	-170	-170	-170
1 GHz ≤ f ≤ 4 GHz	-130	-140	-150	-160	-170	-170	-170
4 GHz ≤ f ≤ 16 GHz	-115	-125	-135	-145	-150	-155	-160
Remarks	Test conditions: RF carrier power ≥ 10 dBm; REF ≥ 13 dBm Two channel cross-correlation can improve noise floor by 5 dB per 10x correlations.						

LO output (Option 300)

Parameter	Min	Typical	Max	Note
Use: Additive phase noise				
Frequency range	1 MHz		18 GHz	< 1.5 GHz: LO Low, >= 1.5 GHz: LO High
Frequency resolution		1 Hz		
Power level	14 dBm	20 dBm	25 dBm	
Use: LO for downconversion				
Frequency range	2 GHz		20 GHz	LO High ports
Frequency resolution		0.5 GHz		
Power level	13.5 dBm	18 dBm	21 dBm	

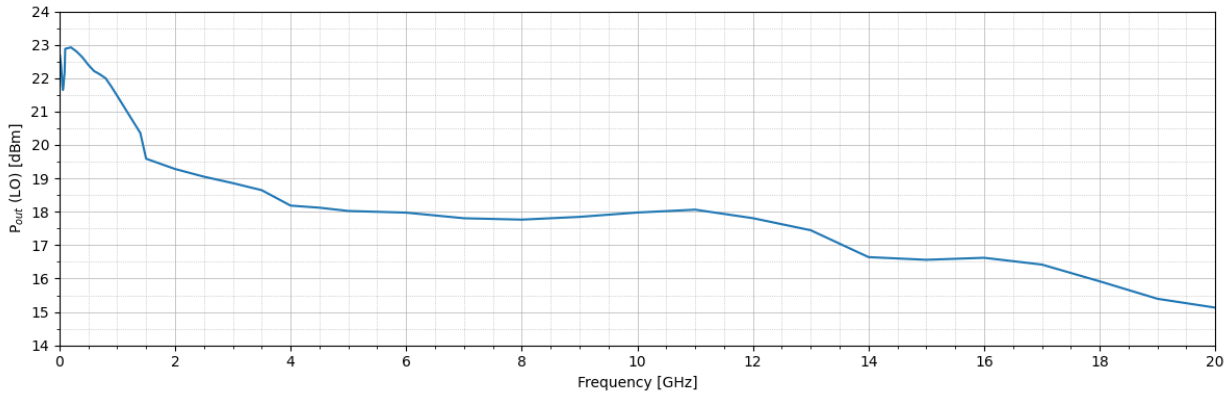


Figure 7. Option 300 – power output (typical)

Absolute amplitude noise measurement (Option 001)

Measurement parameters:

SSB amplitude noise [dBc/Hz]

Parameter	Min	Typical	Max	Note
RF frequency range	5 MHz		7 GHz 26 GHz 40 GHz	E5045A E5046A E5047A
RF input power range	-10 dBm		+20 dBm	5 MHz to 40 GHz
Offset analysis range	0.1 Hz		40 MHz	
Measurement uncertainty		±2 dB		
AM noise sensitivity (1 corr.) 1 Hz 10 Hz 100 Hz 1 kHz 10 kHz > 100 kHz		 -100 dBc/Hz -115 dBc/Hz -135 dBc/Hz -145 dBc/Hz -155 dBc/Hz -160 dBc/Hz		1 GHz, Pin = -10 dBm to +20 dBm

Transient analysis (Option 002)

Measurement parameters:

Wideband mode (WB): frequency [Hz], narrowband mode (NB): frequency [Hz], RF power [dB], phase [deg]

Parameter	Min	Typical	Max	Note
RF frequency bands (WB)	5 MHz 20 MHz 80 MHz 320 MHz 0.5 GHz 14 GHz 17 GHz 27 GHz		100 MHz 400 MHz 1.8 GHz 3 GHz 15 GHz or FMAX 21 GHz 29 GHz or FMAX 40GHz	Band 1 Band 2 Band 3 Band 4 Band 5 Band 6, only E5046A / E5047A Band 7, only E5046A / E5047A Band 8, only E5047A
Measurement spans Wideband Mode (WB) Narrowband Mode (NB)	 200 kHz		 80 MHz	 Bands 1-8 200 kHz, 1.25 MHz, 80 MHz
Frequency resolution				See tables below
Time span	10 µs		1 min	Limited to <2 million samples
Time resolution	16 ns		50 ms	Limited to <2 million samples
Trigger mode				Single, continuous, internal (WB video or NB video), external

Transient analysis — wideband: frequency resolution vs. time resolution (residual FM, 5% video bandwidth, typical)

Frequency measurement uncertainty is ± (resolution + time-based uncertainty). Tabulated resolutions are measured with the PN3 Signal Source Analyzer and DUT locked to the same 10 MHz reference. Input level 0 dBm.

Time resolution	16 ns	128 ns	500 ns	1 µs	≥10 µs
Frequency band	**Frequency resolution [Hz]**				
5 MHz to 100 MHz	3 k	100	30	15	10
20 MHz to 400 MHz	5 k	700	200	100	20
80 MHz to 1.6 GHz	10 k	1 k	200	100	50
320 MHz to 3 GHz	30 k	1.5 k	300	150	150
0.5 GHz to 15 GHz	80 k	4 k	1 k	1 k	1 k
14 GHz to 21 GHz	200 k	10 k	2 k	2 k	2 k
17 GHz to 29 GHz	200 k	10 k	2 k	2 k	2 k
27 GHz to 40 GHz	200 M	40 M	30 M	20 M	10 M

Transient analysis — narrowband: frequency resolution vs. time resolution (residual FM, 80 MHz span, 5% video bandwidth, typical)

Frequency measurement uncertainty is ± (resolution + time-based uncertainty). Tabulated resolutions are measured with the PN3 Signal Source Analyzer and DUT locked to the same 10 MHz reference. Input level 0 dBm.

Time resolution	16 ns	128 ns	500 ns	1 µs	10 µs
Frequency range	**Frequency resolution [Hz]**				
< 200 MHz	1.5 k	50	10	4	4
< 800 MHz	2.5 k	150	15	10	4
< 2 GHz	2.5 k	500	20	10	4
< 20 GHz	30 k	4 k	150	70	20
> 20 GHz	50 k	4 k	400	150	50

Transient analysis — narrowband: frequency resolution vs. time resolution (residual FM, 1.25 MHz span, no video bandwidth, typical)

Frequency measurement uncertainty is ± (resolution + time-based uncertainty). Tabulated resolutions are measured with the PN3 Signal Source Analyzer and DUT locked to the same 10 MHz reference. Input level 0 dBm.

Time resolution	256 ns	500 ns	1 µs	10 µs	≥ 20 µs
Frequency range	**Frequency resolution [Hz]**				
< 200 MHz	60	30	15	1.5	0.5
< 800 MHz	70	30	15	1.5	1.5
< 2 GHz	100	40	15	3	1.5
< 20 GHz	1 k	300	150	30	15
> 20 GHz	3 k	1 k	400	60	30

Transient analysis — narrowband: frequency resolution vs. time resolution (residual FM, 200 kHz span, no video bandwidth, typical)

Frequency measurement uncertainty is ± (resolution + time-based uncertainty). Tabulated resolutions are measured with the PN3 Signal Source Analyzer and DUT locked to the same 10 MHz reference. Input level 0 dBm.

Time resolution	1 µs	10 µs	≥ 20 µs
Frequency range	**Frequency resolution [Hz]**		
< 200 MHz	1	0.5	0.3
< 800 MHz	1.5	0.5	0.3
< 2 GHz	3	1	0.4
< 20 GHz	20	10	3
> 20 GHz	50	20	10

Time stability measurement (Option 004)

Measurement parameters:

ADEV (no dead time)

Parameter	Min	Typical	Max	Note
Measurement time	1 s		10 days	
Resolution bandwidth (RBW)		100 Hz		
ADEV sensitivity τ = 1 s τ = 100 s		 5e-12 1e-12		With RBW 100 Hz

Baseband noise analysis

Input connectors:

2 BNC female (rear panel), AC coupled

Measurement parameters:

Noise spectrum [dBV/Hz, dBm/Hz, nV/√Hz]

Parameter	Min	Typical	Max	Note
Frequency input range	1 Hz		100 MHz	
DC voltage input range Input Impedance	-12 V	 1 kΩ	+12 V	 DC
AC voltage range			+10 dBm	
Input noise density (1 correlation) 10 kHz		 <10 nV/√Hz		
Trigger				Single, continuous, manual, bus

Spectrum monitoring (Option 005)

Measurement parameters:

Spectral noise density [dBm, dBm/Hz, dBV/Hz]

Parameter	Min	Typical	Max	Note
RF frequency range	5 MHz 5 MHz 5 MHz		7 GHz 26 GHz 40 GHz	E5045A E5046A E5047A
RBW	5.8 Hz		58 kHz	
Measurement uncertainty Absolute Relative		 ±3 dB ±1 dB		
Noise floor 10 MHz to 4 GHz 4 GHz to 18 GHz 18 GHz to 40 GHz		 -95 dBm/Hz -90 dBm/Hz -80 dBm/Hz		
Spurious (SFDR) 10 MHz to 4 GHz 4 GHz to 18 GHz 18 GHz to 40 GHz		 -70 dBc -60 dBc -55 dBc		Spurious free dynamic range
Trigger				Continuous

VCO characterization (Option 003)

Measurement parameters:

Frequency [Hz], KVCO (tuning sensitivity) (Δf / ΔVc) [Hz/V], frequency pushing [Hz/V], RF power level [dBm], DC supply current [mA], SSB phase noise [dBc/Hz]

Parameter	Min	Typical	Max	Note
Sweep parameters DC Supply Voltage DC Supply Current Tuning Voltage Tuning Current	 0 V -5 V 	 500 mA 20 mA	 15 V 20 V 	 Adjustable Adjustable
RF frequency range Uncertainty	*FMIN*	 0.5 ppm	*FMAX*	
RF input power range Uncertainty	-5 dBm	 0.5 dB	+20 dBm	
DC supply current Uncertainty	0 mA	 1%	500 mA	
Output settling time		20 ms		
Measurement speed		70 ms/point		Frequency, K_{VCO}, pushing, supply current, and power

Tuning voltage and dual power supply

Parameter	Min	Typical	Max	Note
DUT tuning				BNC front panel output
DC voltage range	-5 V		+22 V	
Setting resolution		1 mV		
Setting uncertainty		±10 mV		
Noise level		< 5 $nV_{rms}/\sqrt{Hz}$		> 2 kHz
DC current max		20 mA		
DC power supplies				BNC rear panel output (Channel 1 and 2)
DC voltage range	0 V		15 V	
Setting resolution		10 mV		
Setting accuracy		±20 mV		
Noise level		< 10 $nV_{rms}/\sqrt{Hz}$		> 20 kHz
Output resistance		< 0.5 Ω		
DC current measurement range	0 mA		500 mA	Per channel
Resolution		100 µA		

Data processing capabilities

Graphical user interface: The analyzer employs a graphical user interface based on the Windows operating system.

Display functions	Phase Noise, Time Domain, Data Table, Residual, Statistics
Trace functions	
Noise floor	Two display modes to discern if the measurement is limited by the system noise floor: Gain Indicator: Shows the theoretical improvement in phase noise sensitivity by applied correlations compared to one correlation. Default. Imaginary Part of Cross Correlation: Shows the residual imaginary part from the cross correlation. It can be selected for faster measurements.
Data traces	Display current measurement and / or multiple memory data (up to 16 traces)
Title	Add customized title to each measurement window
Auto-scale	Automatically selects scale resolution and reference value to vertically center the trace
Marker functions	16 independent markers

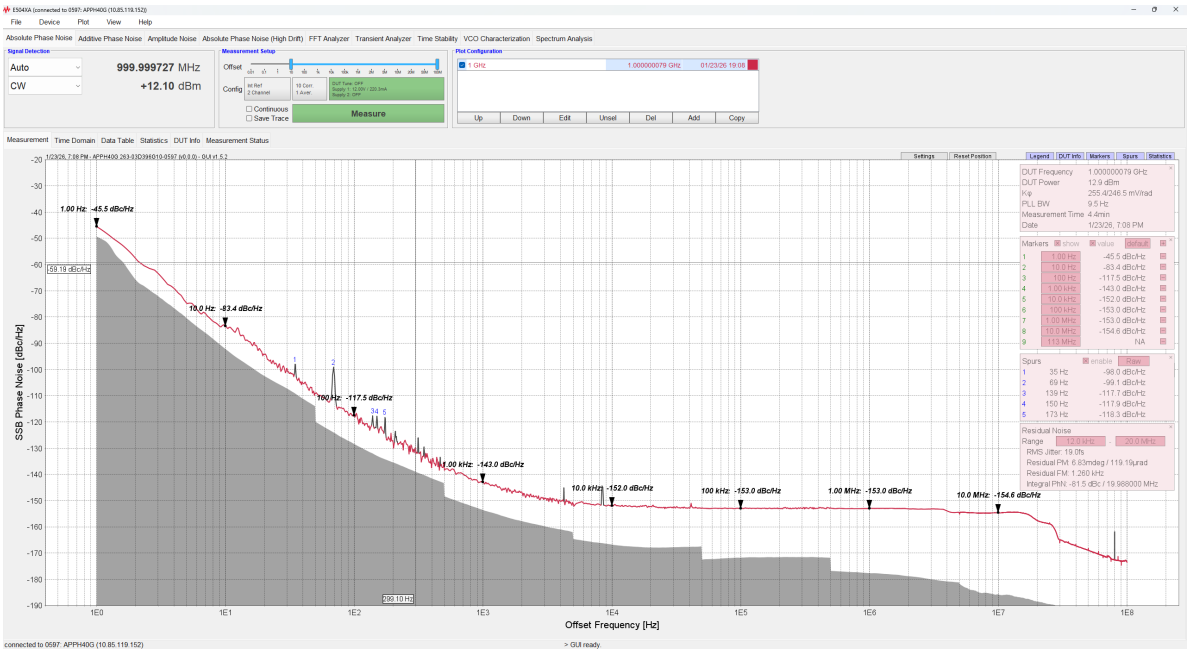


Figure 8. GUI interface (absolute phase noise)

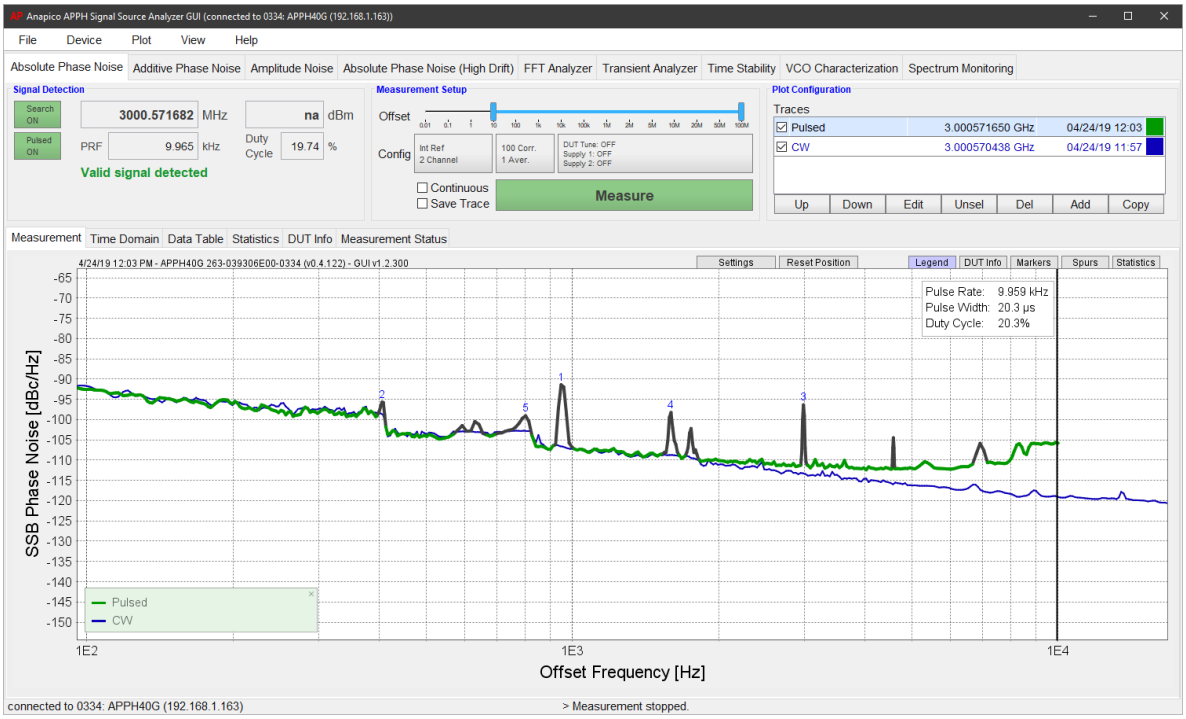


Figure 9. GUI interface (PULSED RF absolute phase noise)

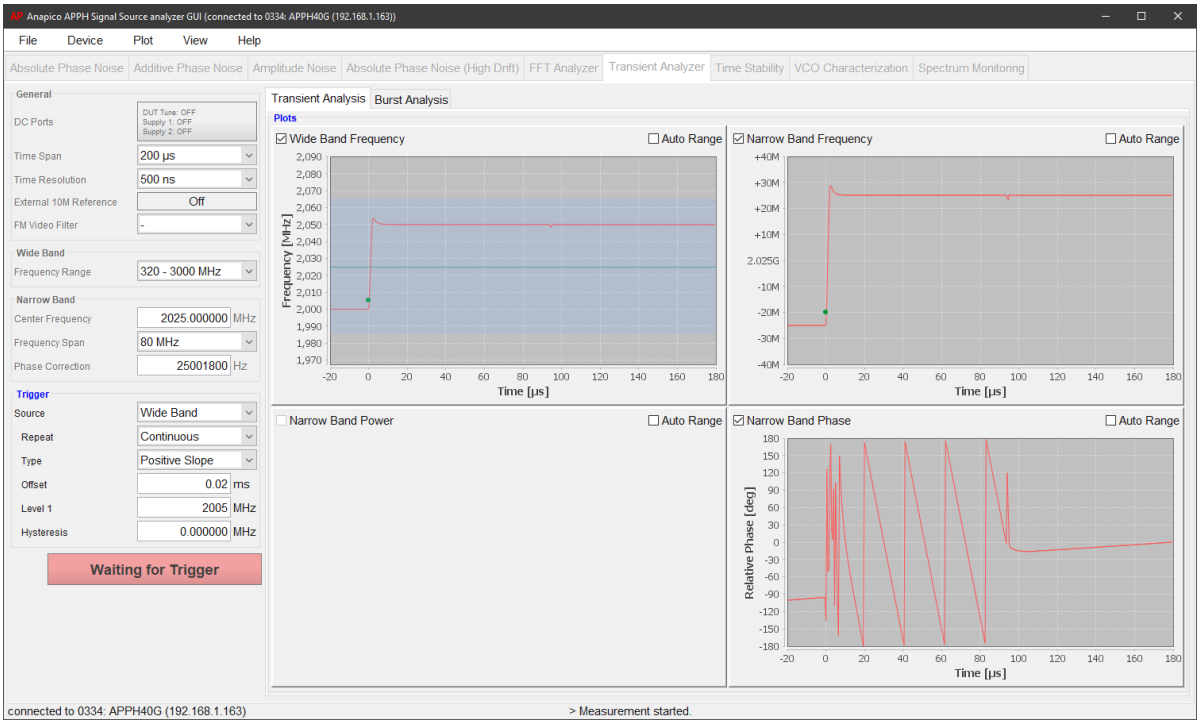


Figure 10. GUI interface (transient analyzer)

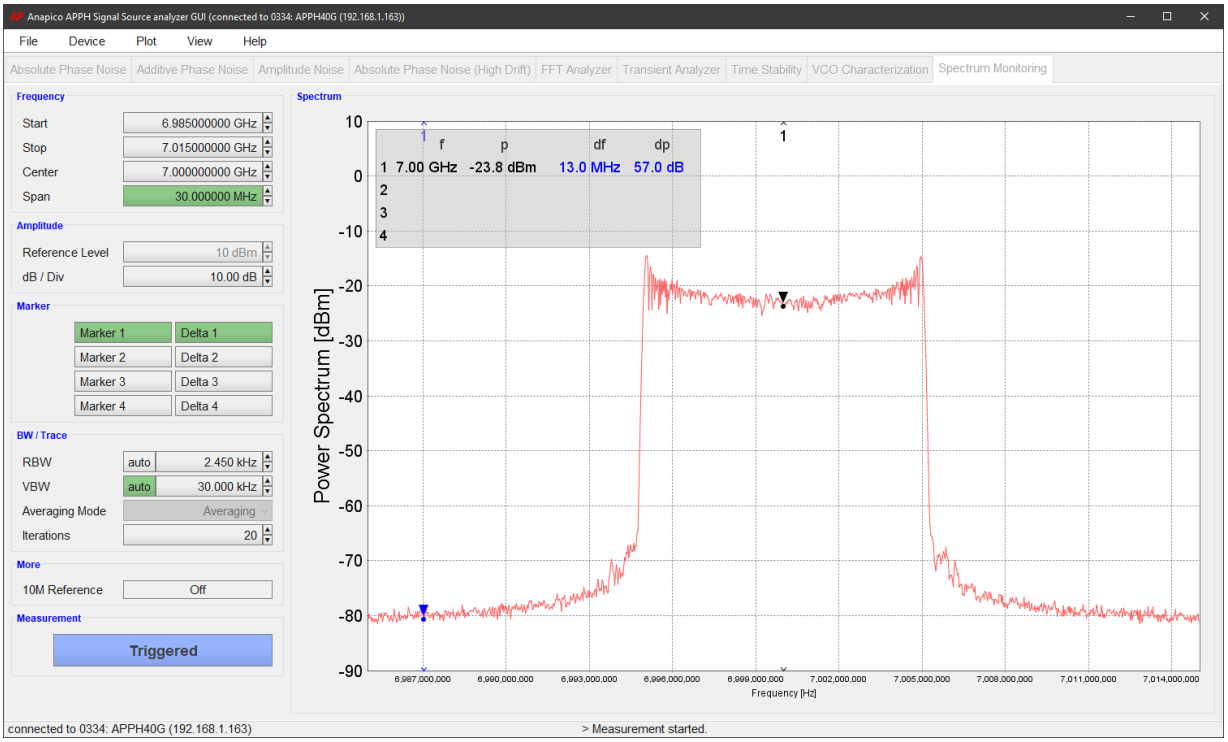


Figure 11. GUI interface (spectrum monitoring)

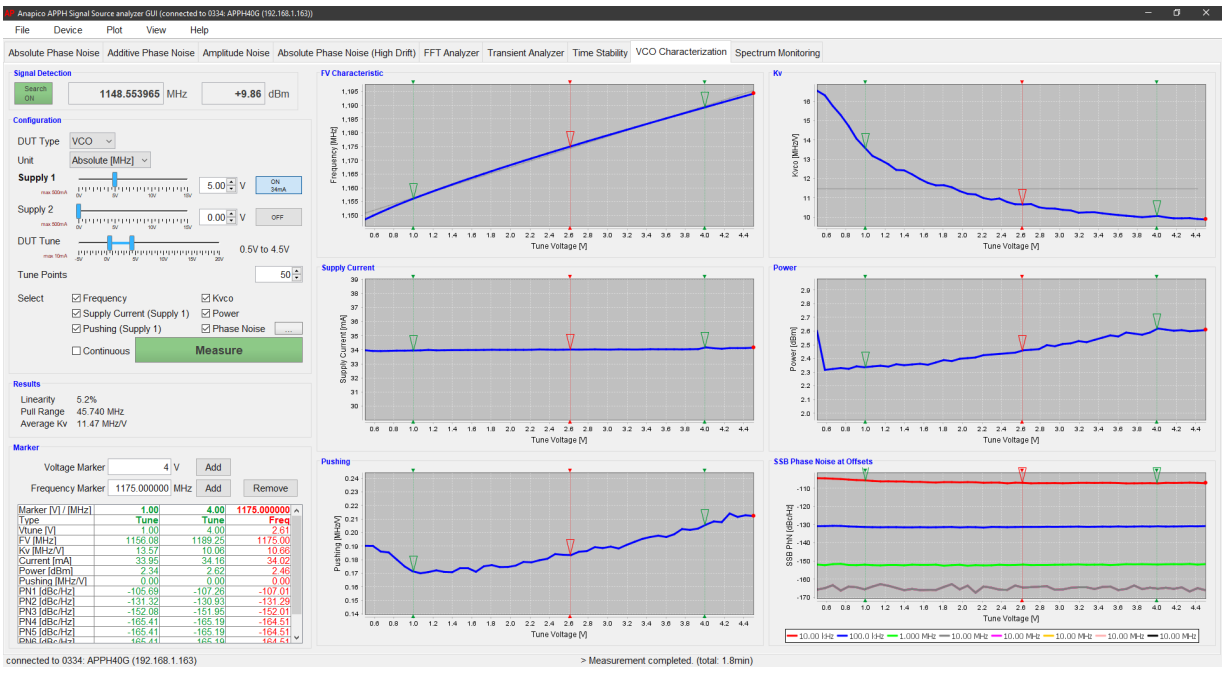
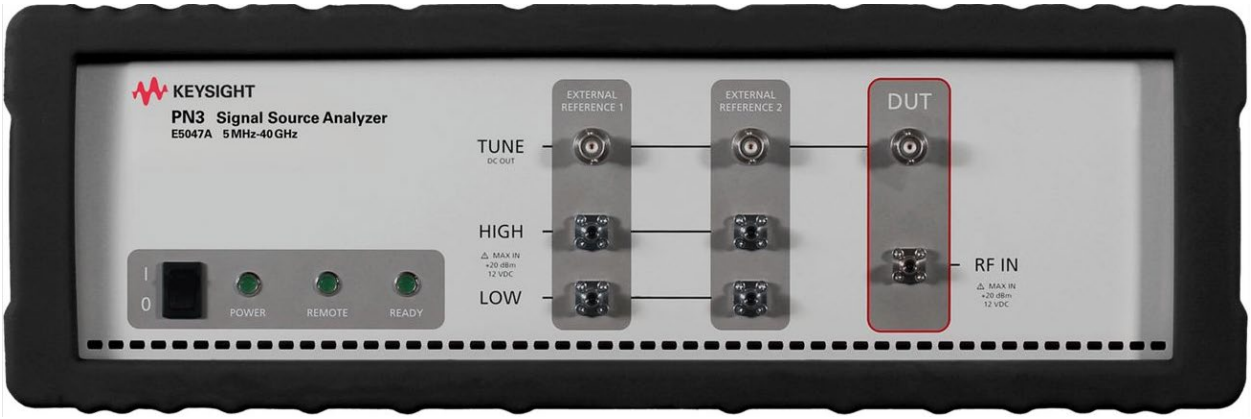


Figure 12. GUI interface (VCO testing)

Connectors

Front



RF inputs

RF IN: SMA female (for E5045A / E5046A); K female (for E5047A)

REF1 IN HIGH / LOW, REF2 IN HIGH / LOW: SMA female

DC outputs

REF1 TUNE, REF2 TUNE: BNC female

Operation

Switch I / 0: DC Power Switch

POWER, READY, REMOTE: Status LED

Rear

HF / VHF / AUX inputs

BASEBAND CH1, BASEBAND CH2: BNC female

REF IN 10 MHz: BNC female

EXT TRIG: BNC female

DC outputs

DC SUPPLY CH1, DC SUPPLY CH2: BNC female

Operation

LAN: RJ-45

USB B: USB 2.0 device

DC 24V: DC Power Plug (24V, 2A)

GPIB (Option GPIB): IEEE-488 GPIB Connector

Front — Option 300

Additional RF inputs

LO1 IN HIGH / LOW, LO2 IN HIGH / LOW: SMA female

RF1 IN, RF2 IN: SMA female

Additional RF outputs

LO1 OUT HIGH / LOW, LO2 OUT HIGH / LOW: SMA female

RF1 OUT, RF2 OUT: SMA female

Order Information

Product / Option	Description
E5045A	Base Model: 7 GHz Signal Source Analyzer
E5046A	Base Model: 26 GHz Signal Source Analyzer
E5047A	Base Model: 40 GHz Signal Source Analyzer
Option 001	Amplitude noise measurement
Option 002	Transient analysis
Option 003	VCO characterization
Option 004	Time stability analysis
Option 005	Spectrum monitoring
Option 006	Pulsed signal measurement (option 006 and 007 are mutually exclusive)
Option 007	Pulsed signal measurement for narrow pulses and low duty cycles (option 006 and 007 are mutually exclusive)
Option 008	Burst mode phase noise measurement
Option 020	Additive phase noise measurement
Option 200	Ultra-low noise internal sources
Option 300	Access to internal reference (if use for residual phase noise measurement, order Option 020, too)
Option 800	GPIB interface

General Characteristics

Remote programming interfaces:

Ethernet 100BaseT LAN interface
USB 2.0 device
GPIB (IEEE-488.2,1987) with listen and talk (Option 800)
Control language SCPI Version 1999.0

Power requirements: 24V ± 3.0 VDC; 70 W maximum

Mains adapter supplied: 100-240 VAC, 50-60 Hz in / 24 V, 6.67 A DC out

Environmental, Safety and Regulatory Information:
(Levels similar to MIL-PRF-28800F Class 3/4)

Intended use: Only use the product indoors. The product case is not waterproof (IP22).
Operating temperature: +5 °C to +50 °C
Altitude: ≤ 4600 m above sea level (approximately 15100 ft)
Relative Humidity: 5% to 75±5% (in temperature range of 30 °C to 40 °C) and 5% to 45±5% (temperature > 40 °C)
Overvoltage category: II
Pollution degree: suitable for pollution degree 2 environments where nonconductive contamination can occur.

CE Safety / EMC complies with applicable Safety and EMC regulations and directives.
Emission limits for class A equipment.

Weight: ≤ 12.0 kg (27 lbs) net

Dimensions:

incl. rubber: 154 mm H x 467.5 mm W x 342 mm L (6.1 in H x 18.4 in W x 13.5 in L)
with handle: 154 mm H x 520 mm W x 342 mm L (6.1 in H x 20.5 in W x 13.5 in L)
handle: radius 230mm (9 in); can be turned 360° in 30° steps