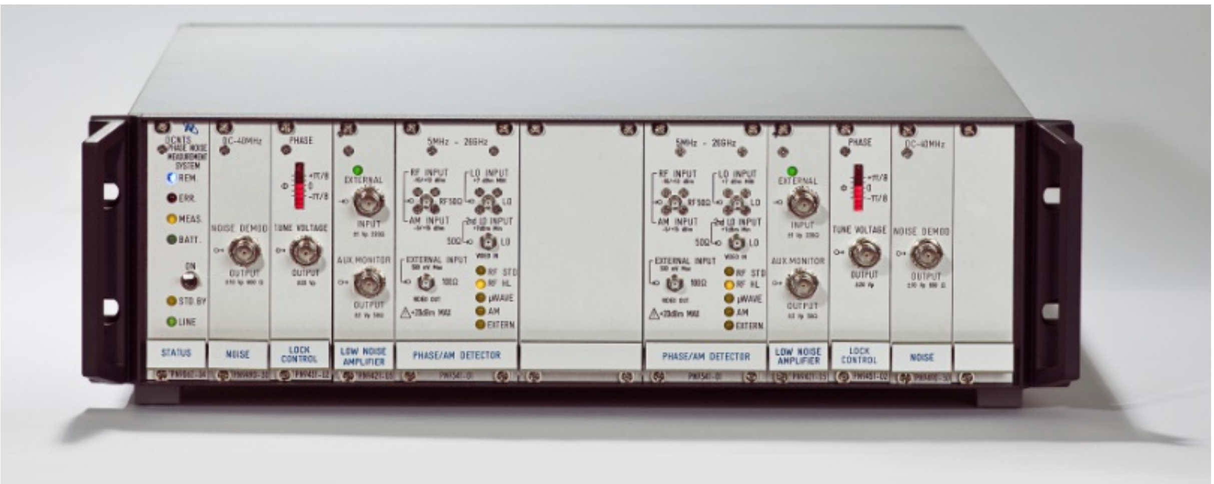
DCNTS Phase Noise Analyzer

2 MHz to 1.8 / 26 / 50 / 140 GHz

Datasheet



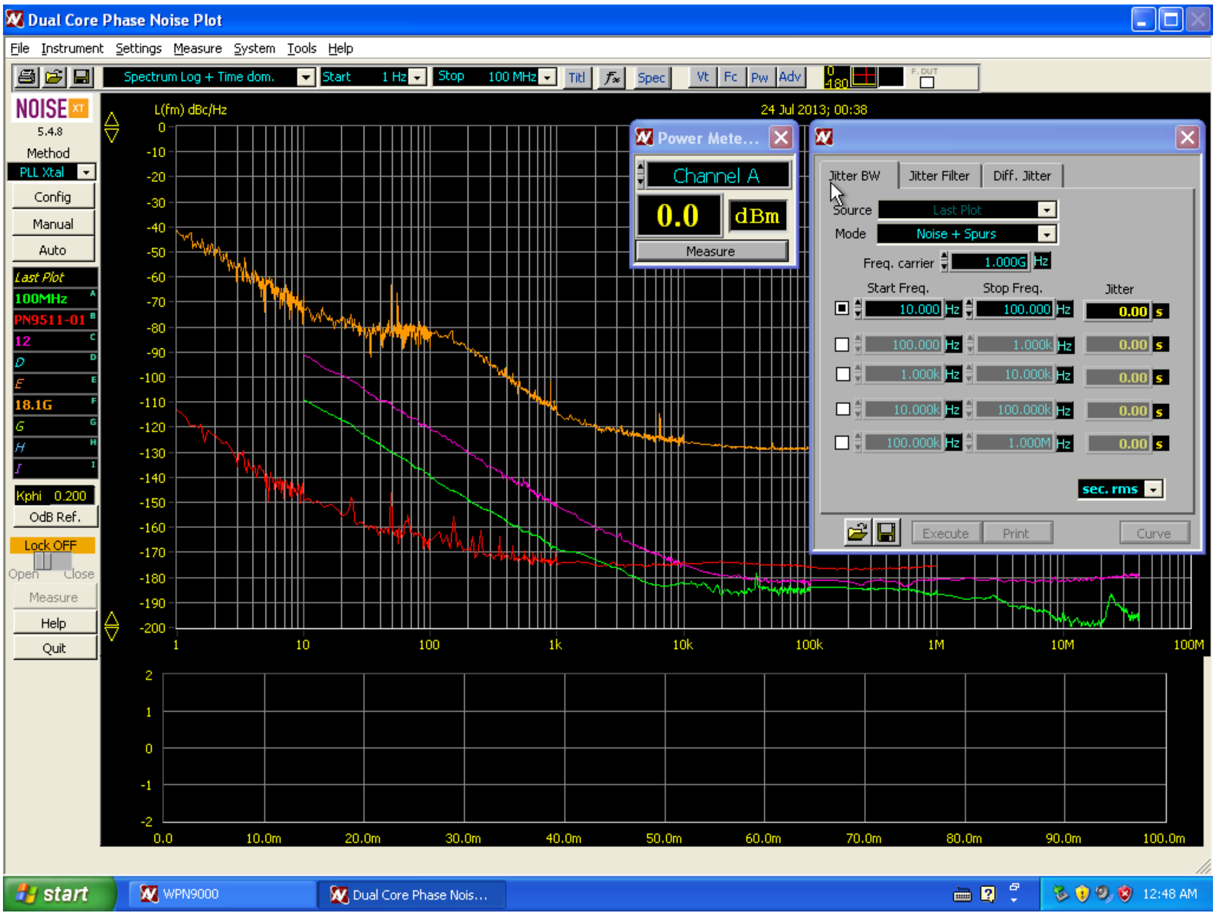
The DCNTS is the highest performance Phase Noise Analyzer with unique flexible capabilities as summarized below:

	Phase Noise	Amplitude Noise	Absolute Noise	Allan Variance	Jitter	Low Spurious
Absolute for 1 port DUT	Yes	Yes	Yes	Yes	Yes	Yes
Residual for 2 ports DUT	Yes	Yes(1)	No	Yes	Yes	Yes
Continuous Wave	Yes	Yes	n.a.	Yes	Yes	Yes
Pulsed Carrier	Yes	Yes	n.a.	Yes	Yes	Yes
INT/EXT Reference Source	Yes	Yes(1)	n.a.	Yes	Yes	Yes
INT/EXT Detectors	Yes	Yes	n.a.	Yes	Yes	Yes

(1) in-phase residual noise technique for 2 ports DUTs measures absolute AM noise.

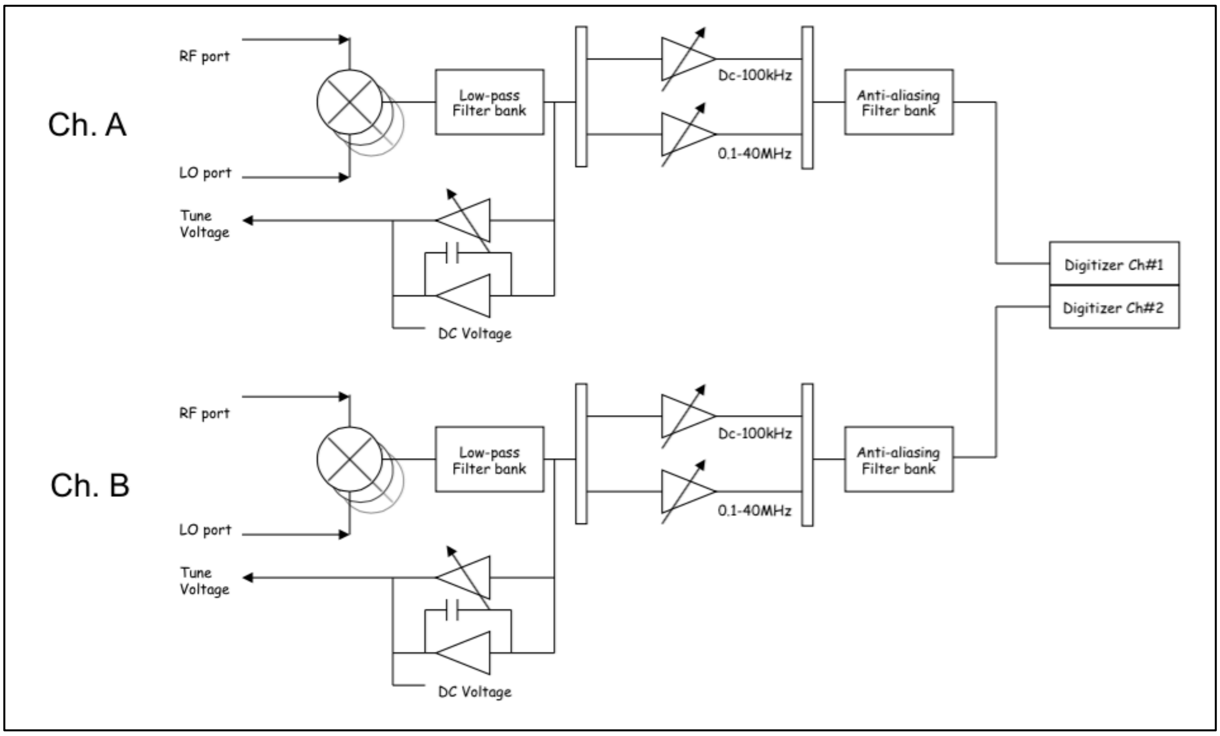
The DCNTS measures phase or amplitude noise on continuous or pulsed signals (gated CW) with the help of external low-pass video filters; the user can select to work on CW signals or pulsed. This selection is available for all modes excepted for Analog Baseband (absolute noise voltage) measurements.

The DCNTS options base is huge due to its complete compatibility with the PN9000 product line that counts over 300 various options and plug-ins developed though our 23 years of continuous innovation. Any PN9000 option is compatible with this state of the Art instrument.



The DCNTS is an extremely flexible base that provides access to all points in the Analyzer chain: phase detector, base band amplifier, phase lock loop, anti-aliasing filtering, digitizer, frequency counter etc…

It can either use its optional internal synthesizers or use external reference oscillators or synthesizers in order to improve dynamic range and measurement time. The DCNTS can also use external phase detector to extend its frequency coverage to any requirement, only limited by the customer supplied phase detectors or reference sources frequency coverage.



DCNTS engine diagram

Beyond this common architecture, the DCNTS can house optional modules and software plug-ins, over a hundred of such options have been designed through the years.

Reference crystal oscillators, frequency synthesizers, up or down-converters, frequency multipliers or dividers, phase shifters, amplifiers, power splitters are available. And when an ideal option is not available, we do offer custom modules or software plug-ins development.

Due to its highly flexible design, most of the signals present at various locations in the analyzers are accessible through SMA or BNC connectors allowing the researcher to find solutions for unusual use of the instrument.

About Cross-correlation

Most of the systems on the market only guarantee their performance only 1 cross-correlation and there are absolutely no guaranteed specifications for more than one cross-correlation. Those datasheet say that you can get « up to 5LogN » dB when using the cross-correlation but does not guarantee that the improvement will be as computed at all offsets.

The reason is that the cross correlation does not always work perfectly at all offsets. To understand why, I need to refresh a bit the math behind it.

The cross correlation is a simple vector averaging. If a vector is random in phase, it will average to zero. Here, in our dual channel system, the vector is the result of the multiplication of the complex FFT of channel A by the conjugate complex FFT of channel B. When you do that, you obtain what is called a cross-spectrum where each point in the spectrum is a vector (complex value, not just magnitude). We will average the spectrums and if the channel A and B are completely different, their phase relation will be random, their phase relation is the phase of the obtained vector. Averaging those cross-spectrum will tend towards zero (so - infinite dBc/Hz). If the signals are the same between A and B, the phase relation will be the same in all averaged vectors across time (for a single spectrum point) and this vector will not change if you increase the number of averages, it is stable and gives you a « normal » value, the noise that you are measuring.

Now, in the real world, the situation is never « A and B » are completely different or « A and B » are exactly the same but something in between. Here we are looking at A and B, they may look different but a small part of it is the same, this is the common noise. You need to see each channel as the sum of multiple noises.

Each channel sampled by the digitizer is the sum of the DUT noise, the LO noise, the mixer noise, the LNA noise, the digitizer circuits noise etc … Traditionally, we assume that only the DUT and LO noises are the dominant ones but it is not a perfect assumption in the case of cross correlation. Yes, the LO noise from channel A and the LO noise of channel B will be different and their contribution will have no phase relation so their noise will average to zero when doing more and more cross-correlations. But the noise due to the LNA, digitizer will be a little bit the same even if coming from different LNA or digitizing channels. The reason is that there is only one power supply feeding both channels and the power supply noise may leak into the channels, this cross-talk leakage it will not cancel in the cross-correlation and constitute the noise floor of the instrument.

You can find many little sources of noise that you wouldn't see in a single channel system because they are 10 or 20 dB lower than the single channel measurement and that may become a problem in your new analysis.

In cross-correlation systems, the isolation between the 2 RF ports of the mixers is one of the two keys for performance; they are separated by a power splitter and its isolation impacts the potential maximum improvement and may limit it to 10, 15, 20dB at various offsets, depending on the isolation of the channels at various stages.

It is therefore very difficult to predict this limit and sometimes risky to guarantee and most have decided to not guarantee the improvement, maybe because this improvement varies from unit to unit or maybe even across time. Noise XT guarantees the performance and plots hereafter will illustrate our State of the Art dynamic range

Noise XT has extensively tested the DCNTS since 2007 and we have very good confidence of the performance that we can guarantee. We have tested our isolation and it is about 30dB at minimum, some offsets can get more than 30dB. This is why our software allows up to 1,000,000 averages.

All specifications in this document are typical values unless specified otherwise.

RF Input Port

Description	Specification
RF IN connector	Type-N F or 2.4mm (for 50GHz), 50 ohms nominal
RF IN frequency range	2 MHz to 1.8 / 26 / 40 / 50 GHz (1)
RF IN measurement level	-30 dBm to +20 dBm (2MHz to 1 GHz) -20 dBm to +20 dBm (<1.8 GHz) -5 dBm to +15dBm (>1.8 GHz) other power ranges depending on options
RF Input Gain	-10 / 0 / +10 / +20 dB (2MHz to 1.8 GHz only)
Input damage level	AC > +23dBm, 0V DC max (on High Level detectors); AC > +16dBm, 0V DC max otherwise

(1) Maximum frequency depends also on options

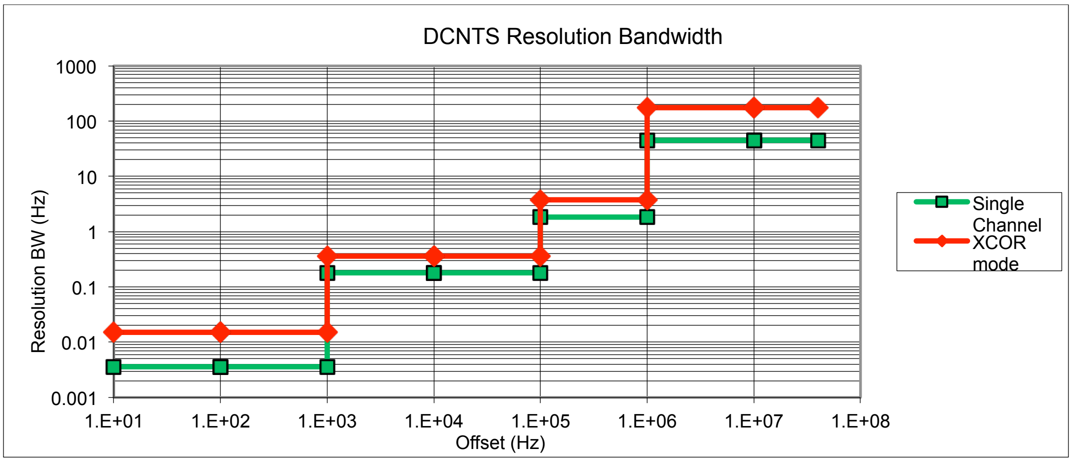
Phase Noise Analyzer performance

Description	Specification
RF IN frequency range	2 MHz to 1.8 / 26 / 40 / 50 GHz (1)
Measurement frequency bands	2-1800 MHz, 1.8 to 26.5 GHz, other bands depending on options
Measurement parameters	SSB noise (dBc/Hz), Spurious (dBc), Integrated phase deviation (dBc, deg, rad), Jitter (s, UI), Residual FM (Hz)
Number of traces	10 data traces in 10 memories with access to all math tools
Number of markers	10 tracking independently any trace
Measurement trigger	Manual through GUI, Remote through Ethernet or GPIB with option
Offset frequency range	0.01 Hz to 1 MHz (Fc <80 MHz) 0.01 Hz to 40 MHz (Fc>80 MHz) (option)
Phase Noise accuracy	+/- 2 dB for offsets up to 1 MHz +/- 3 dB for 1 MHz to 40 MHz
SSB noise sensitivity	See Table for complete values
IF gain setting	0 to +90 dB in 10 dB step (automated) +20 to +40 dB in Pulsed PM for Kphi meas
Enhanced sensitivity	Cross-correlation method available in all modes 1 to 1,000,000 averages Independent setting per offset decade
Reference Local Oscillator	Internal or External Sources
Residual spurious response level (measurement engine), excluding AC power related spurs	-50 dBc at 1 Hz offset -70 dBc at 10 Hz offset -90 dBc at 100 Hz offset <-110 dBc above 1kHz offset <-140 dBc above 1kHz (option) for internal sources, see the specific specs
Spurious detection Algorithm	Normal Enhanced for High Resolution mode 2D mode for faster noise floor improvement (2)
Measurement time	See time table
Resolution Bandwidth	Variable settings in each independent decade Lowest offsets: 500 uHz min

	1MHz offset: 2 Hz min High offsets: 45 Hz min, See RBW graph below
Internal Sources output power	+13 dBm +/- 3 dB

(1) Maximum frequency depends on model type
(2) Patent pending

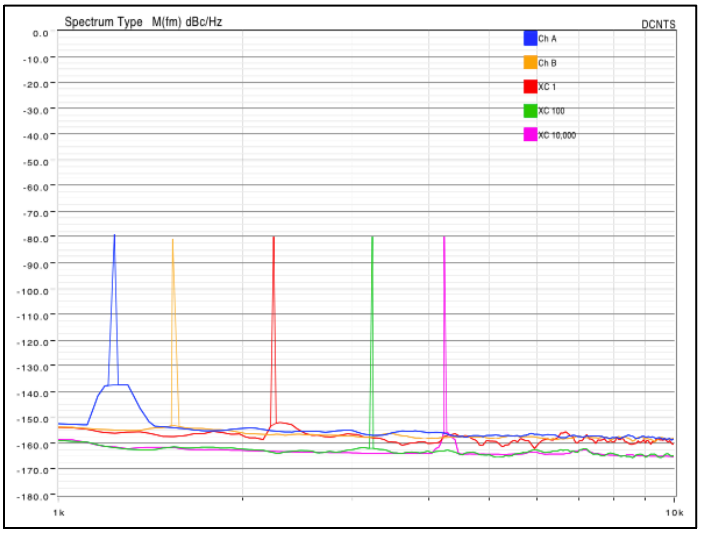
DCNTS Instantaneous Resolution Bandwidth



1- to allow perfect detection with a RefSpur of 10dB, the resolution bandwidth has to be lower than 10 Hz
2- RBW lower than 1 Hz are not useful to detect spurious as it corresponds to the same level as the phase noise plot. However the user should pay attention at the RBW at high offsets.

The accuracy of the instrument to report correct phase noise points at various offsets is calibrated using a swept spurious that generates a flatness response calibration table. This is done per decade and for various IF gains values.

A simple verification can be done using a commercial Signal Generator with built-in Sine modulation (AM or PM). Below is the result of the test with the modulation at various offsets and for various cross-correlation settings. The spur level should not change and stay the same for all test configurations.



Accuracy check at 1GHz with AM modulation on signal generator

Amplitude Noise Sensitivity

AM Offset Span: 100 Hz to 40 MHz
Detector Input Frequency: 10 MHz to 26.5 GHz
RF Input Power: 0 to +20 dBm
Nominal Conditions : Ka= 0.300 V/V (+15dBm Input Power at 1 GHz)

dBc/Hz vs offset (Hz)	100	1k	10k	100k	1M	10M
100 cross-correlations	-145	-155	-165	-170	-170	-170
1,000 cross-correlations	-150	-160	-170	-175	-175	-175
10,00 cross-correlations		-165	-175	-180	-180	-180

Please add +5dB for guaranteed performance

Phase Noise Sensitivity

PM Offset Span: 0.01 Hz to 40 MHz

<u>Standard RF Detector</u>:
Input Frequency: 2 MHz to 1.8 GHz
RF Input Level: 0 to +13 dBm
LO Input Level: +7 to +13 dBm
Nominal Conditions: Kphi=0.300 V/rd (+13dBm Input Power at 100 MHz)

dBc/Hz vs Offset (Hz)	1	10	100	1k	10k	100k	1M	10M
100 cross correlation	-140	-150	-160	-170	-178	-178	-178	-178
1.000 cross correlation			-175	-175	-183	-183	-183	-183
10.000 cross correlation				-180	-188	-188	-188	-188

Please add +5dB for guaranteed performance

<u>High Level RF Detector</u>:
Input Frequency: 2 MHz to 1.6 GHz
RF Input Level: 0 to +23 dBm
LO Input Level: +15 to +20 dBm
Nominal Conditions: Kphi=0.600 V/rd (+15dBm Input Power at 100 MHz)

dBc/Hz vs Offset (Hz)	1	10	100	1k	10k	100k	1M	10M
100 cross correlation	-140	-160	-178	-183	-185	-185	-185	-185
1.000 cross correlation			-180	-185	-190	-190	-190	-190
10.000 cross correlation				-190	-195	-195	-195	-195

Please add +5dB for guaranteed performance

<u>Standard Microwave Detector</u>:
Input Frequency: 1.8 GHz to 26.5 GHz
RF Input Level: 0 to +15 dBm
LO Input Level: +7 to +15 dBm
Nominal Conditions: Kphi=0.300 V/rd (+13dBm Input Power at 4 GHz)

dBc/Hz vs Offset (Hz)	1	10	100	1k	10k	100k	1M	10M
100 cross correlation	-130	-140	-150	-160	-170	-178	-178	-178
1.000 cross correlation			-155	-165	-175	-183	-183	-183
10.000 cross correlation				-170	-180	-188	-188	-188

Please add +5dB for guaranteed performance

High Level Microwave Detector:

Input Frequency:	1.8 GHz to 26.5 GHz
RF Input Level:	0 to +23 dBm
LO Input Level:	+15 to +20 dBm
Nominal Conditions:	Kphi=0.600 V/rd (+15dBm Input Power at 4 GHz)

dBc/Hz vs Offset (Hz)	1	10	100	1k	10k	100k	1M	10M
100 cross correlation	-138	-148	-158	-168	-178	-184	-184	-184
1.000 cross correlation			-163	-173	-183	-189	-189	-189
10.000 cross correlation				-178	-188	-194	-194	-194

Please add +5dB for guaranteed performance

Cross-correlation recommended settings for optimized high performance

Default resolution bandwidth and 2D spurious detection algorithm

offset (Hz)	1	10	100	1k	10k	100k	1M	10M	40M
Averages (# cross-correlations)	10	10	100	100	1k	1k	10k	10k	10k

The DCNTS shares the same spurious detection algorithms with the PN9000 option PN9692-HR. This is the best algorithm on the market for spurious detection. Accurate detection allows spurious detection as low as -175 dBc and a so small noise proximity that spurious at dBc levels even lower than the dBc/Hz noise can be detected at close to the carrier offsets.

This unusual dynamic range is due to a ultra flexible FFT configuration with averages and instantaneous resolution bandwidth settings that can be adjusted in each decade, independently.

Measurement timetable

Default FFT settings used

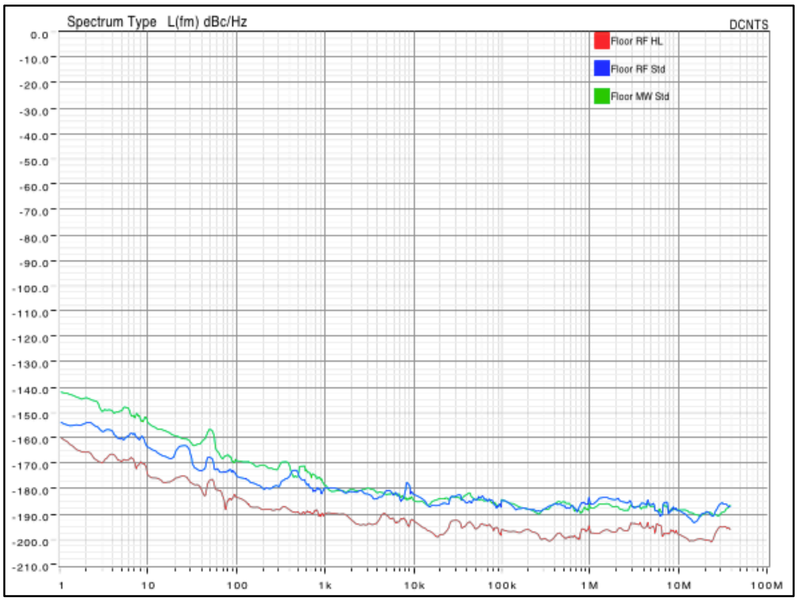
Decade up to	Averages	Resolution BW (Hz)	Meas. Time (s)
0.1 Hz	2	4m	839
1 Hz	5	4m	2100
10 Hz	5	57m	131
100 Hz	7	915m	12
1 kHz	7	915m	12
10 kHz	20	45	1.7
100 kHz	20	45	1.7
1 MHz	20	477	1.1
10 MHz	20	11k	1
40 MHz	20	11k	1

Example: for a measurement with default setting from 100 Hz to 1 MHz, time= 20s
External programs installed on the DCNTS by the customer may affect measurement speed.

Internal Main Detectors Noise floor plots of the DCNTS

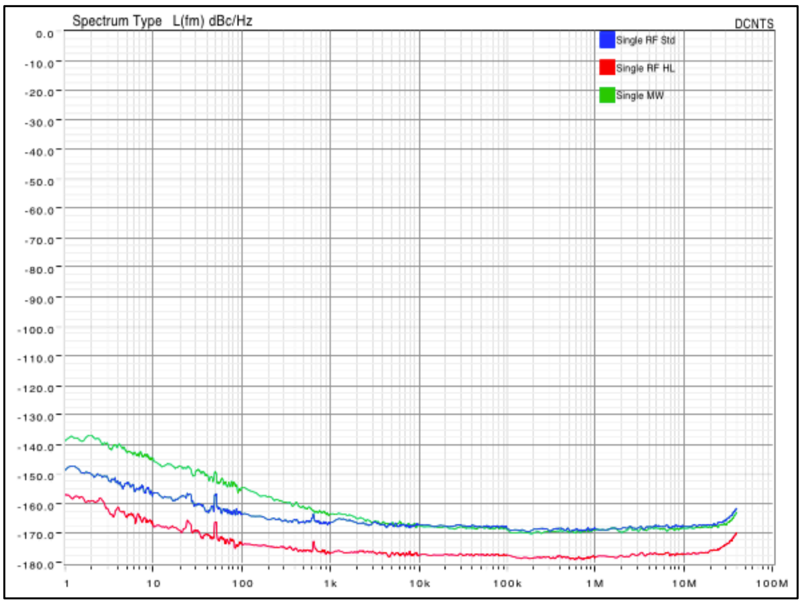
The DCNTS main AM/PM detector contains multiple phase detectors to operate over the very wide frequency coverage. The user can also connect external phase detector to accommodate any frequency range even with the most basic configuration of the DCNTS. All system functions are preserved even when using external detectors, sources etc …

State of the Art performance is obtained using the cross-correlation function like shown below:



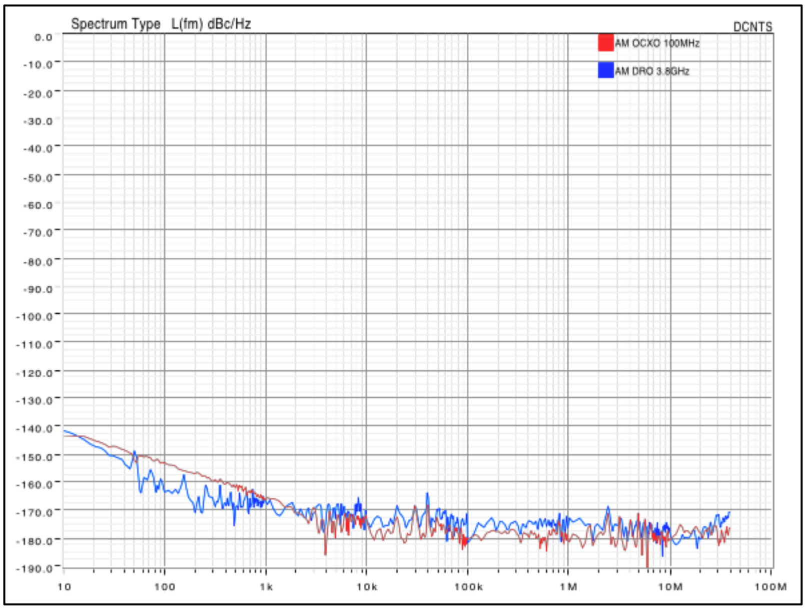
Cross-correlation Phase Noise floor on 3 built-in phase detectors

If two reference sources or phase shifters are not available, the DCNTS can work in single channel mode (like a PN9000) and still offers very good dynamic range. The user can choose to work on channel A or B; both channels are fully symmetrical.



Single Channel Phase Noise floor on 3 built-in phase detectors

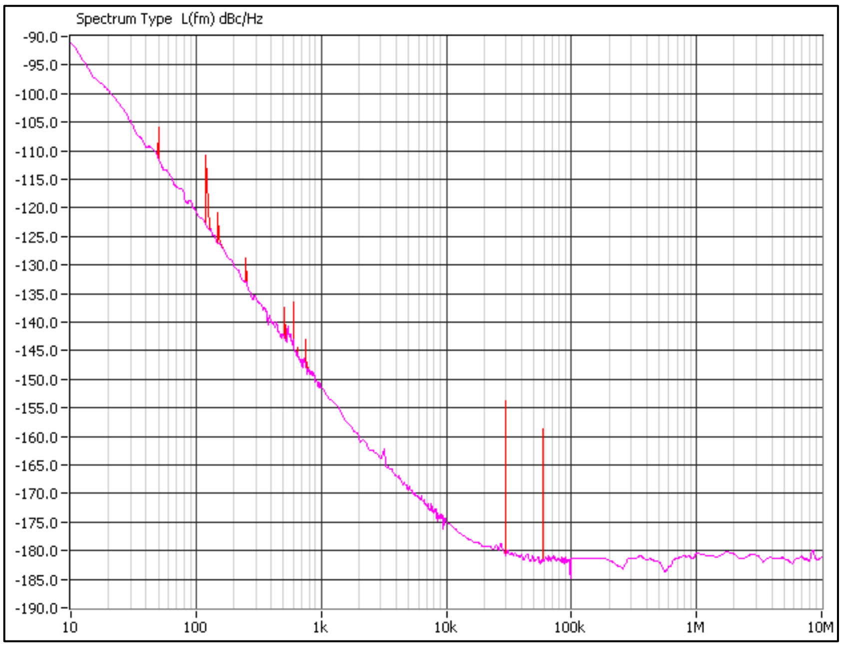
The PN9341 option provides built-in optional AM crystal detectors allowing very low amplitude noise measurements without the need for any reference source.



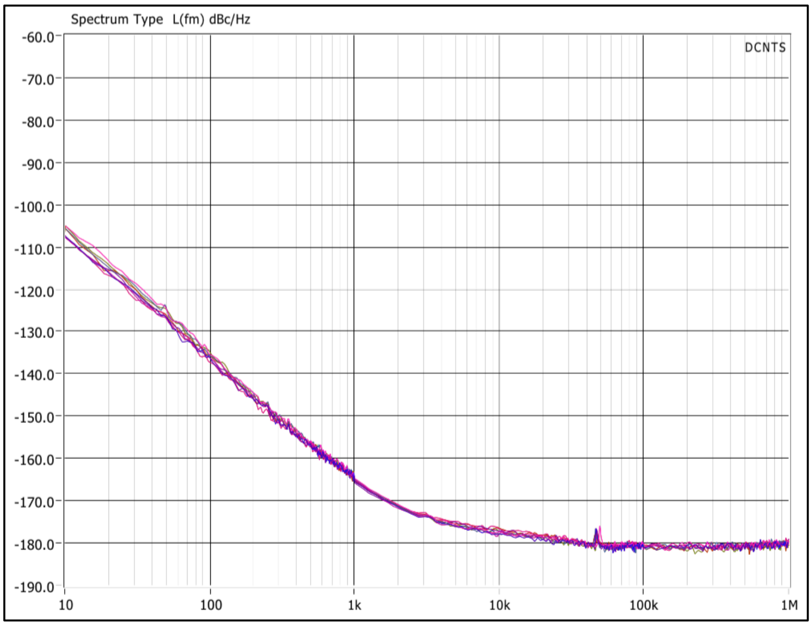
Amplitude Noise measurements at 100 MHz and 3.8 GHz

Simple testing in Absolute Phase Noise mode (PLL Synth or PLL Xtal)

The DCNTS can use any external frequency oscillator or synthesizer to measure phase noise in single or cross-correlation mode. This allows the user to either save some cost by re-using his own laboratory sources or optimize a complete rack and stack Test Station. This way, many customers have upgraded from the HP 3048 or E5500 to this new core but preserving their past investment on reference sources.



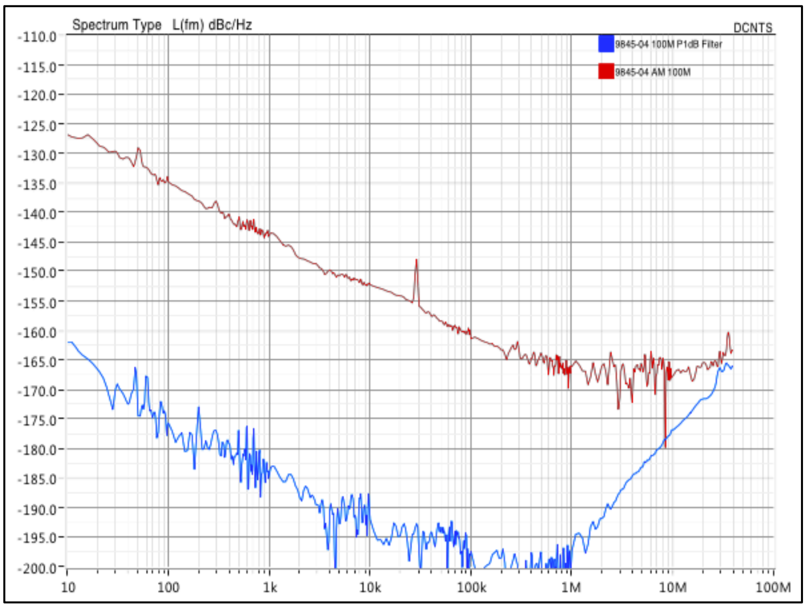
SAW Oscillator at 320 MHz (external sources mode)



Crystal Oscillators batch at 100 MHz (internal PN9531 reference sources)

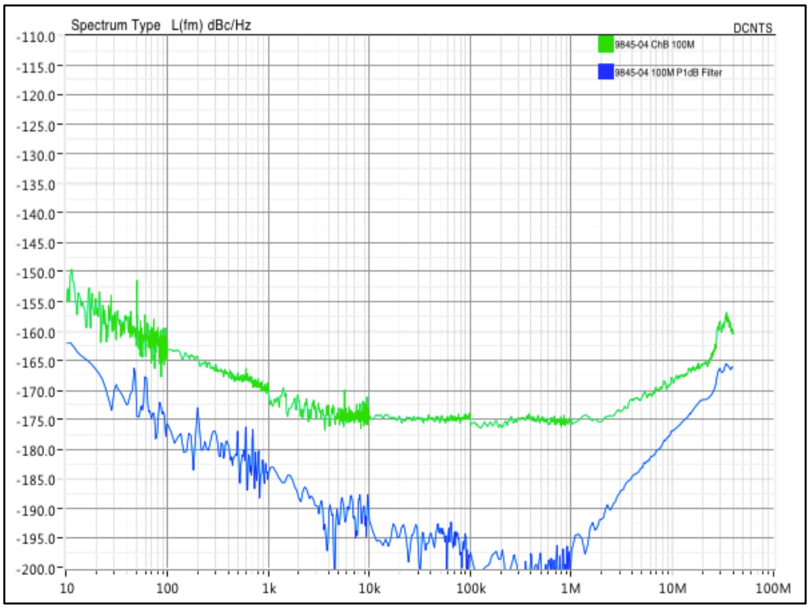
Residual Phase Noise Testing

While Absolute phase noise is widely used and the main testing method for signal generators, additive (or residual) phase noise is extremely useful to measure the added phase noise of 2 ports devices like amplifiers, frequency multipliers or dividers.
With the help of external phase shifters (line stretchers, variable delay lines or trombones), the NXA can fully automate the very low noise measurements, making this test easy to implement in production, even by non-experts.
The Cross-correlation helps a lot to improve the dynamic range compared to single channel systems, in particular when high power (over +20dBm) is not available.

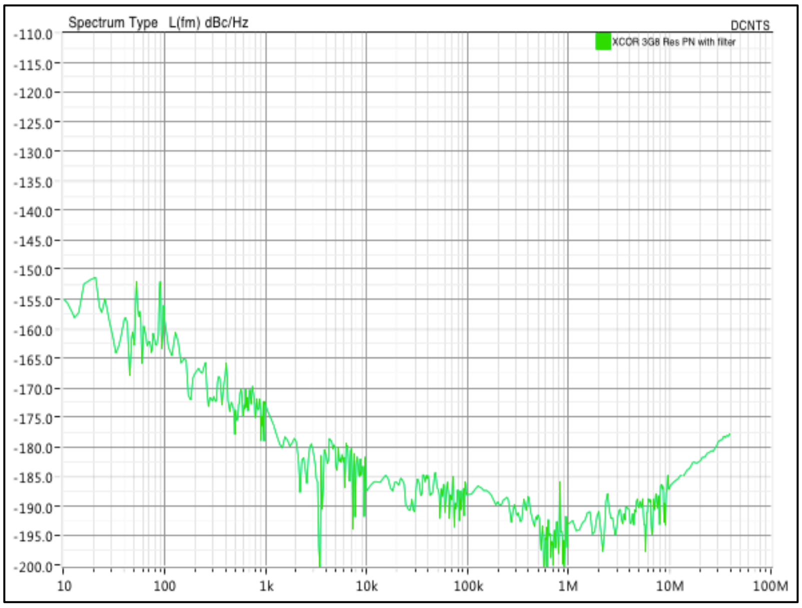


100 MHz Residual Phase noise (Xcor mode and AM noise showing 40dB rejection)

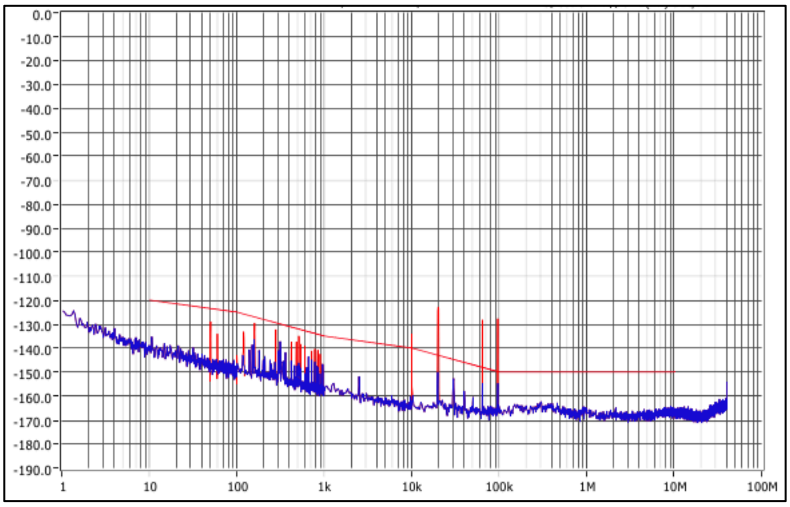
Specialized residual phase noise modules are available to accommodate various frequencies, the power amplifier, power splitter and phase shifters are built-in options from 10 MHz to 40 GHz.



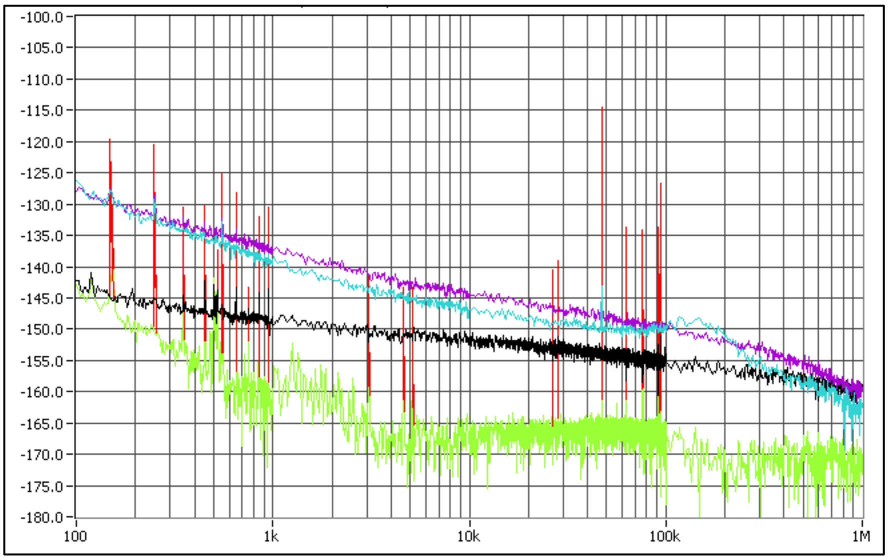
100 MHz Residual Phase noise with PN9845 module (Single channel vs Xcor using different averaging in decades)



4 GHz Residual Phase noise Floor in Xcor mode tested with PN9841 module



35 GHz Residual Phase noise Floor in Single Channel mode with PN9870 module

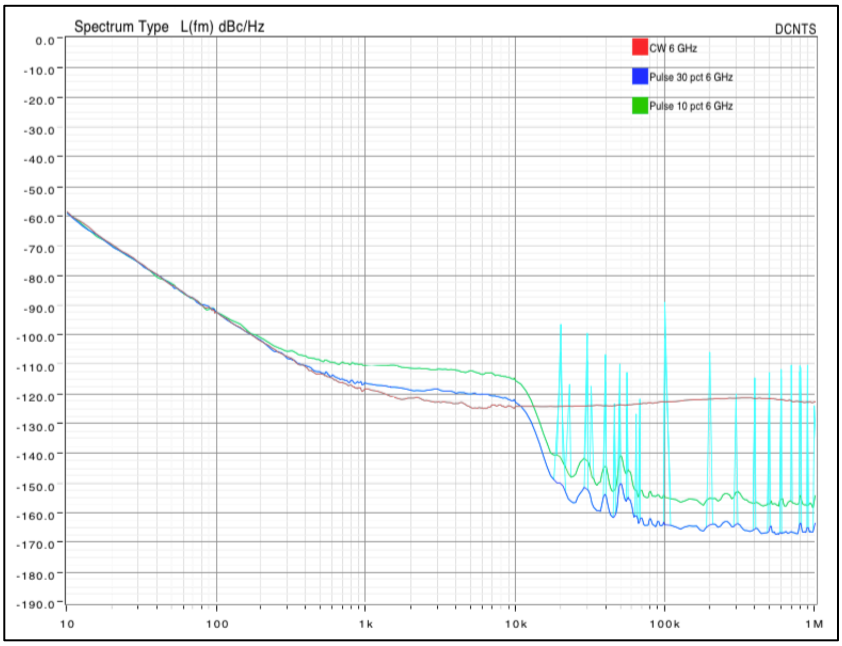


4 different microwave amplifiers tested for residual phase noise showing parallel amplification (green) as the best phase noise by far.

Measuring Pulsed signals

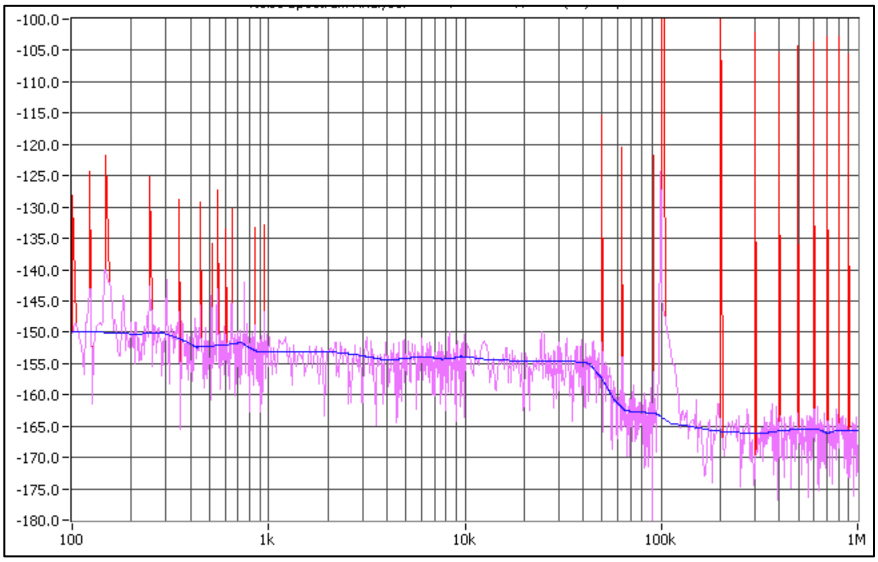
In modern radars, signals are pulsed and it is very important to verify the quality of the transmitted signal. The gated CW signal can have a duty cycle as low as 5% and most of the phase noise analyzers cannot handle non CW tones.

The DCNTS has special features to allow phase and amplitude noise measurements on pulsed signals. Both absolute and residual noise measurement are possible, making the instrument ideal to test power transmitters as well as complete emitters.

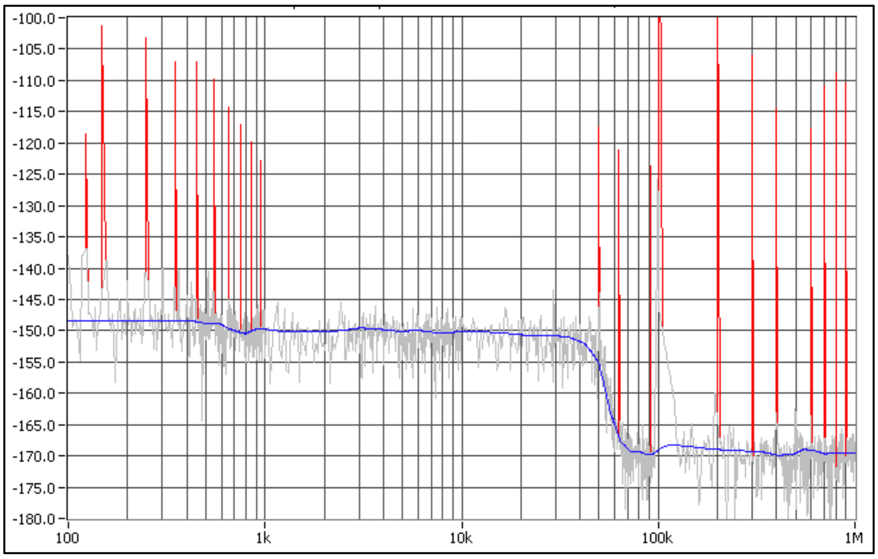


6 GHz CW, 10% and 30% duty cycle with 10kHz LPF Absolute Phase noise (PRF 100kHz)

With the help of a specialized module or an external phase shifter, Residual (Additive) pulsed phase noise provides very good dynamic range from a few MHz to 50 GHz.



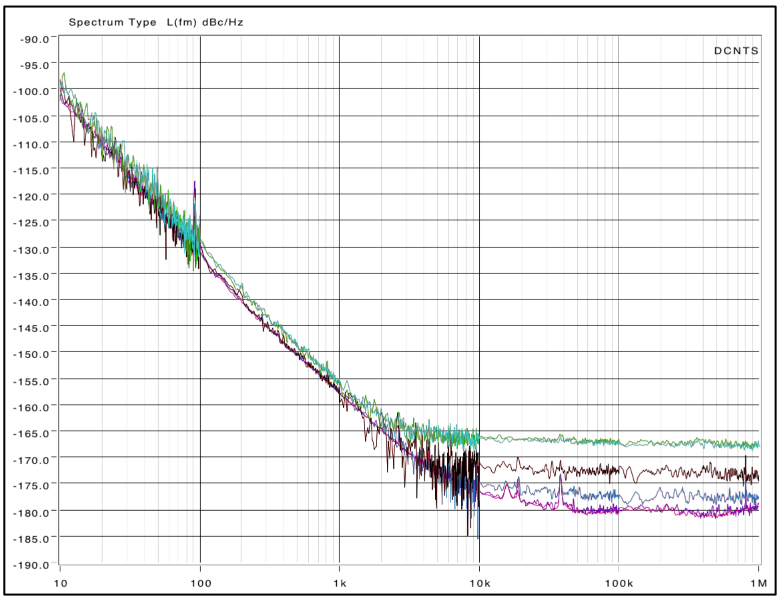
4 GHz Residual pulsed Phase noise (10% duty cycle, PRF 100kHz)



4 GHz pulsed Amplitude noise (20% duty cycle, 1000 xcor, PRF 100kHz)

Varying the Number of Cross-correlations

In addition to traditional FFT settings to control the resolution bandwidth, number of displayed points and spurious extraction, the user can optimize the dynamic range of the instrument in each decade by adjusting the number of cross-correlation averages.



Single channel and 10 to 10,000 cross-correlations showing improvement and convergence on this 100 MHz OCXO test

Frequency Stability Measurements

The DCNTS has an option to measure frequency stability and display Allan Variance plots from 0.1 to 10,000 seconds. This is the PN3100 option.

This measurement can be done ant any frequency where the regular phase noise plots can be done. It uses its internal frequency counter to measure the beat note frequency in between a DUT and a reference clock. An internal or external 10 MHz clock drives the 32 bits counter and built-in pre-scalers are used to generate counting gates.

This option is similar to the PN3100 option part of the PN9000 offer but can be configured in a dual counter configuration in order to perform differential reciprocal counting, very useful when no (or too small) beat note can be generated.

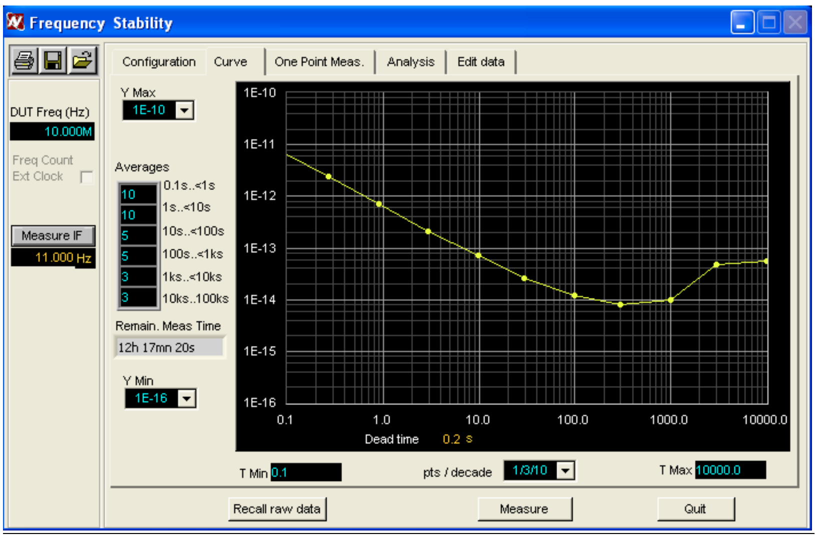
All frequency measurement data is available as text files for external post processing through any statistical analysis software.

Residual test performed with a SLC Clock synthesizer

IF Beat = 1Hz	***Resolution***	***SLC @ 10MHz***
Time = 1s	10^{-14}	< 10^{-12}
Time = 10s	10^{-15}	< 10^{-13}
Time = 100s	10^{-16}	< 2 10^{-14}
Time = 1000s	10^{-17}	< 2 10^{-15}

Residual test performed with a SLC Clock synthesizer

IF Beat = 10Hz	***Resolution***	***SLC @ 10MHz***
Time = 0.1s	10^{-12}	< 2 10^{-11}
Time = 1s	10^{-13}	< 2 10^{-12}
Time = 10s	10^{-14}	< 2 10^{-13}
Time = 100s	10^{-15}	< 4 10^{-14}
Time = 1000s	10^{-16}	< 4.10^{-15}



Residual Allan Variance test using a SLC as the DUT versus its internal 10MHz time base. Please note that the performance at 1000 seconds and longer would improve when using the external frequency counter clock (not used here in this plot)

General Information

Front panel information

Description	Supplemental information
RF Input	SMA, 2.92, 2.4 mm depending on frequency (female), 50 ohms
Baseband IN	2 x SMA + 2 BNC (female), 110 ohms, DC coupled
DC control	2 x BNC (female)
Local Oscillator IN / OUT	SMA, 2.92, 2.4 mm depending on frequency (female), 50 ohms
Extension Auxiliary ports	2 x SMA (female) (PN9341 option for pulse)
Display	Status LEDs
Slots	14 plug-in slots (9 used by DCNTS base)

Rear panel information

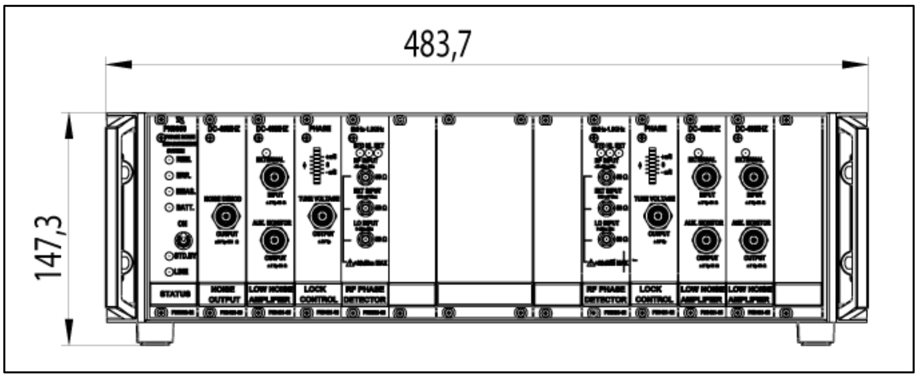
Description	Supplemental information
USB	USB 2.0 Digitizer link
RS-232	Digital Chassis communication
AC	100-240 VAC 50/60Hz 4A max
FAN	Exhaust

Analyzer environment and dimensions

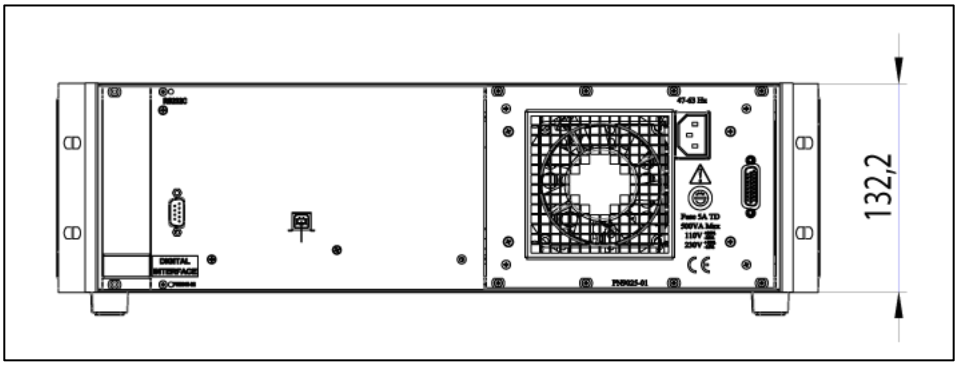
Description	Supplemental information
Operating environment	
Temperature	+10 degC to +40 degC
Humidity	RH 20% to 80% at wet bulb temp.<29 degC (non-condensing)
Altitude	0 to +2 000 m
Non-operating storage environment	
Temperature	-10 degC to +60 degC
Humidity	RH 20% to 90% at wet bulb temp.<40 degC (non-condensing)
Altitude	-427 to +4 810 m
Vibration	0.5 G maximum, 5 Hz to 500 Hz
Instrument dimensions	See figure below
Weight (NET)	Depends on options

Dimensions information

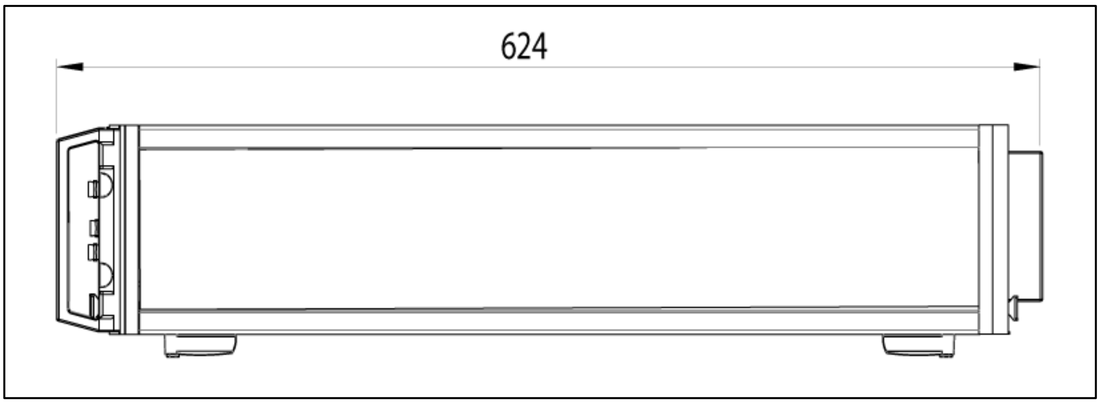
Dimensions are in millimeters (mm)



Front view



Rear view



Side view

Display functions

Description	Supplemental information
Measurement windows	Up to 2 windows (time and frequency)
Spectrum Window	10 traces or specification lines trace color, thickness adjustable by trace and by type (noise in dBc/Hz and spurious in dBc) Math tools: Addition, subtraction, multiplication or division of trace data Combination of traces (concatenate tool) X-axis adjustable by decade Y-axis min/max values set by user
Time domain window	Baseband / Phase detector voltage display versus time
Marker functions	10 independent markers Marker color matches trace color
Jitter and Variance	Plots can be obtained from the phase noise plots to display the frequency stability or jitter density
Special Processing	A Radar computation function is included in the math tools as well as smoothing functions with variable parameters Additional specialty functions can be added in the software, please contact Noise XT for details.

Data Processing Capabilities

Description	Supplemental information
Graphical user interface	The analyzer uses a graphical user interface based on Windows® 7 OS The user can use keyboard, the mouse or any combination of the two.
Limit-line test	Test limits can be defined and stored on trace memories like regular measurements Test limits are defined by a list of 7 X-Y coordinates
Internal Data Storage	Internal Removable SSD drive (option) that contains Operating System, DCNTS Operating Software and calibration tables This HDD/SSD drive may be used to store measurements and configuration files
External Data Storage	USB thumb drives may be connected to any USB port of the PC
File Management	The DCNTS uses proprietary format to store plots (*.plot) that can only read by Noise XT's products. However, there are multiple export formats either as text files that can be open in any spreadsheet software (tab separated)
Printing	Any Windows® OS compatible printer may be used, a default pdf printer is installed by default Printing can also be done to BMP, JPG and PNG picture files.
Automation	Remote control of the DCNTS can be done over the TCP/IP layer (even when no Ethernet cable is connected). National Instruments LabView® examples and Microsoft VBA® examples are available for scripting purposes
GPIB	The DCNTS can also be remotely controlled over GPIB with the help of an optional National Instruments GPIB adapter (not included).