Manual
WPN9000

AEROFLEX
A passion for performance.

PN9000
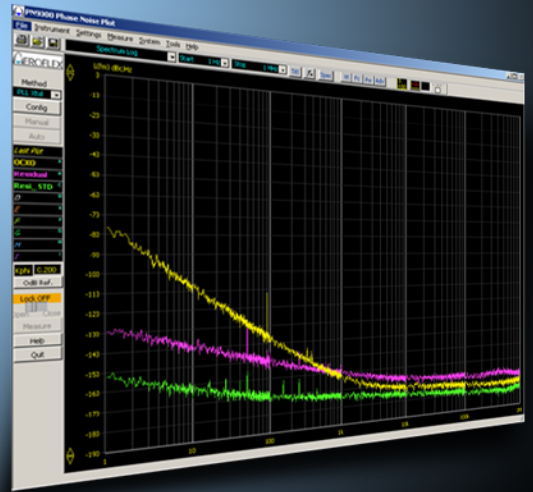
General Presentation

Phase Noise Measurement Principle

Device Type Menu

Top Bar Menu

TABLE OF CONTENTS

1

GENERAL PRESENTATION

1 – Warning Initial Visual Inspection

After unpacking the instrument, inspect the shipping container and its cushioning material for signs of stress or damage. If damage is identified, retain the packing material for examination by the carrier in the event that a claim is made. Examine the instrument for signs of damage; do not connect the instrument to a supply when damage is present, internal electrical damage could result in shock if the instrument is turned on.

2 – Mounting Arrangements

Excessive temperatures may affect the performance of the instrument. Avoid standing the instrument on or close to other equipment which is hot.

3 – Caution Installation Requirements

Ventilation

This instrument is forced air cooled by a fan mounted on the rear panel. Air must be allowed to circulate freely through the ventilator grills located on the underside of the instrument. Before switching on the instrument, ensure that the air outlet on the rear panel is not restricted (i.e. clearance of at least 75 mm at the rear, 25 mm at each side, 15 mm on the underside). Failure to provide adequate clearances will increase internal temperatures and reduce the instrument reliability, so its performance may not meet specifications.

Power cords

🟡 General :

When the equipment has to be plugged into a Class II (ungrounded) 2-terminal socket outlet, the cable should either be fitted with a 3-pin Class 1 plug and used in conjunction with an adapter incorporating a ground wire, or be fitted with a Class II plug with an integral ground wire. The ground wire must be securely fastened to ground. Grounding one terminal on a 2-terminal socket will Dot provide adequate protection.

In the event that a moulded plug has to be removed from a lead, it must be disposed of immediately. A plug with bare flexible cords is hazardous if engaged in a live socket outlet.

Power cords with the following terminations are available from EUROPTEST. Please check with your local sales office for availability.

🟡 Wire ended :

This equipment is provided with a 3-wire (grounded) cordset which includes a molded IEC 320 connector for connection to the equipment. The cable must be fitted with an approved plug which, when plugged into an appropriate 3-terrninal socket outlet, grounds the case of the equipment. Failure to ground the equipment may expose the operator to hazardous voltage levels. Depending upon the destination country, the color coding of the wires will differ:

Harmonised Wire Ended

	North America	Harmonised
Line (Live)	Black	Brown
Neutral	White	Blue
Ground (Earth)	Green	Green/yellow
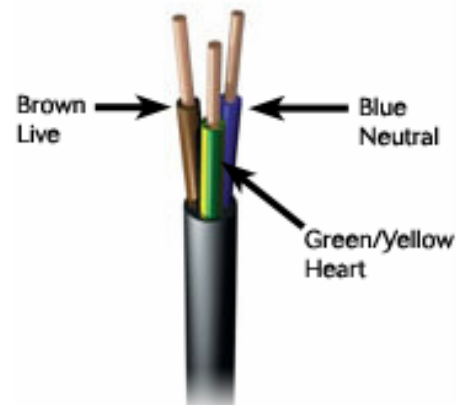
4 - Installation

British

The UK lead is fitted with an ASTA approved molded plug to BS 1363.
A replaceable fuse to BS 1362 is contained within the plug. This fuse is only designed to protect the lead assembly.
The fuse(s) or circuit breaker to protect the equipment is fitted at the back of the equipment.

North American

The North American lead is fitted with a NEMA 5-15P (Canadian CS22.2 No 42) plug and carries approvals from UL and CSA for use in the USA and Canada.

Continental Europe

The Continental European lead is fitted with a right angle IEC83 standard C4 plug (CEE 7/7) which allows it to be used in sockets with either a male earth pin (standard C 3b) or side earth clips (standard C 2b) the latter is commonly called the German 'Schuko' plug. In common with ailier Schuko style plugs, the plug is not polarised when fitted into a Schuko socket. The lead carries approvals for use in Austria, Belgium, Finland, France, Germany, Holland, Italy, Norway and Sweden. Note that this plug will not fit Italian standard CEI 23-16 outlets. The lead should not be used in Denmark given that the earth connection will not be made.

Français

Le câble d'alimentation d'Europe Continentale est muni d'un connecteur mâle à angle droit type CEI83, standard C4 (CEE 7/7), qui peut être utilisé dans une prise femelle à ergot de terre (standard C 3b) ou à clips latéraux (standard C 2b), cette dernière étant communément .appelée prise "Schuko" allemande. De la même façon que les autres connecteurs de type Schuko, celui-ci n'est pas polarisé lorsqu'il s'adapte à une prise femelle Schuko. Ce câble d'alimentation est homologué en Allemagne, Autriche, Belgique, Finlande, France, Hollande, Italie, Norvège et Suède. A noter que ce connecteur n'est pas compatible avec les prises de courant italiennes au standard CEI 23-16. Ce câble ne doit pas être utilisé au Danemark à cause du défaut de connexion de masse.

Deutsch

Das kontinentaleuropaische Netzkabel ist mit einem rechtwinkeligen Stecker nach IEC83 C4 (CEE? /7) Standard versehen, welcher sowohl in Steckdosen mit Erde-Stift (Standard C 3b) oder seitlichen Erdeklemmen, im allgemeinen "Schukosteckdose" genannt, paBt. Üblicherweise ist der Schukostecker bei Verwendung in Schukosteckdosen nicht gepolt. Dieses Netzkabel besitzt Zulassung für Osterreich, Belgien, Finnland, Frankreich, Deutschland, Holland, Italien, Norwegen und Schweden.
Hinweis: Dieser Schukostecker paBt nicht in die italienischen Standardsteckdosen nach CEI 23-16 Norm. Dieses Netzkabel sollte nicht in Dänemark verwendet werden, da hier keine Erdeverbindung hergestellt wird.

Español

El cable de alimentacion tipo Europeo Continental dispone de Una clavija C4 normalizada IEC83 (CEE 7/7) que permite su utilizacion tanto en bases de enchufe con toma de tierra macho (tipo C 3b) o con toma de tierra mediante contactos laterales (tipo C 2b) que, en este ùltimo caso, suele denorninarse "Schuko". Al igual que cualquier otra clavija tipo Schuko, las conexiones a red no estàn polarizadas cuando se conectan a una base tipo Schuko. El cable lleva autorizaciòn para su usa en Austria, Bélgica, Finlandia, Francia, Alemania, Holanda, Italia, Noruega y Suecia. Observe que este cable no se adapta a la norma italiana CEI 23-16. El cable no debe utilizarse en Dinamarca en el caso de no efectuarse conexiòn a tierra.

Italiano

I cavi d'alimentazione per l'Europa continentale vengono fomiti terminati con una spina ad angolo retto del tipo C4 secondo lo standard IEC83 (CEE 7/7) che può essere usato in prese in cui la terra può essere fomita o tramite connettore maschio (C 3b) o tramite clips laterali (C 2b), quest'ultima comunemente detta di tipo tedesca "Schuko". Questa spina, quando collegata ad una presa Schuko, non è polarizzata.

Il cavo può essere usato in Austria, Belgio, Finlandia, Francia, Germania, Glanda, Norvegia, Svezia ed Italia.

E' da notare che per l'Italia questo non risponde allo standard CEI 23-16.

Questa spina non dovrebbe invece essere usata in Danimarca in quanta non realizza il collegamento di terra.

5 – Connecting To Supply

The power supply is automatically switched to work in two voltage ranges :

- 110V ± 20%

- 230V + 10%,-20%

- Frequency: 47-63 Hz

- Power: 500 VA max

Fuses

- One fuse of 5A TD is used for the two voltage ranges

Fuse is cartridge type measuring 5 mm X 20 mm.

The following electrical tests and inspection information is provided for guidance purposes and involves the use of voltages and currents that can cause injury. It is important that these tests are only performed by competent personnel.

Prior to carrying out any inspection and tests, the instruments must be disconnected from the main supplies and all external signal connections removed. All tests should include the instrument's own supply lead, all covers must be fitted and the equipment supply switch must be in the 'ON' position.

The recommended inspection and tests fall into three categories and should be carried out in the following sequence:

- 1. Visual inspection

- 2. Earth bonding tests

- 3. insulation resistance test

Operational conditions

This product must be used in a II environment class at 2000 m altitude. The operational temperature must be between 0°C and 50°C.

Visual inspection

A visual inspection should be carried out on a periodic basis. This interval depends on the operating environment, maintenance and use, and should be assessed in accordance with guidelines issued by the Health and Safety Executive (HSE). As a guide, this instrument when used indoors in a relatively clean environment would be classified as 'low risk' equipment and hense should be subject to safety inspections on an annual basis. If the use of the equipment is contrary to the conditions specified, you should review the safety re-test interval.

As a guide, the visual inspection should include the following where appropriate:

Check that the equipment has been installed in accordance with the instructions provided (e.g. that ventilation is adequate, supply isolators are accessible, supply wiring is adequate and properly routed).

The condition of the mains supply leads and supply connector(s).

Check that the mains supply switch isolates the instrument from the supply.
The correct rating and type of supply fuses. Security and condition of covers and handles.
Check the supply indicator functions (if fitted).
Check the presence and condition of all warning labels and markings and supplied safety information.
Check the wiring in re-wireable plugs and appliance connectors.
If any defect is noted this should be rectified before proceeding with the following electrical tests.

Earth bonding tests

Earth bonding tests should be carried out using a 25 A (12 V maximum open circuit voltage) DC source. Tests should be limited to a maximum duration of 5 seconds and have a pass limit of 0.1W after allowing for the resistance of the supply lead. Exceeding the test duration can cause damage to the equipment. The tests should be carried out between the supply earth and exposed case metalwork; no attempt should be made to perform the tests on functional earths (e.g. signal carrying connector shells or screen connections) as this will result in damage to the equipment.

Insulation resistance test

A 500 V DC test should be applied between the protective earth connections and combined live and neutral supply connections with the equipment supply switch in the 'ON' position. It is advisable to make the live/neutral link on the appliance tester or its connector to avoid the possibility of returning the instrument to the user with the live and neutral poles linked with an ad-hoc strap. The test voltage should be applied for 5 seconds before taking the measurement. Marconi Instruments products employ reinforced insulation in their construction and hence a minimum pass limit of 7 MW should be achieved during this test.
Where a DC power adapter is provided with the instrument, the adapter must pass the 7 MW test limit.
We do not recommend dielectric flash testing during routine safety tests. Most portable appliance testers use AC for the dielectric strength test which can cause damage to the supply input filter capacitors.

Rectification

It is recommended that the results of the above tests are recorded and checked during each repeat test. Significant differences between the previous readings and the measured values should be investigated.
If any failure is detected during the above visual inspection or tests, the instrument should be disabled and the fault should be rectified by an experienced Service Engineer who is familiar with the hazards involved in carrying out such repairs.
Safety critical components should only be replaced with equivalent parts, using techniques and procedures recommended by EUROPTEST SAS
The above information is provided for guidance only. EUROPTEST products are designed and constructed in accordance with International Safety Standards such that in normal use they represent no hazard to the operator. EUROPTEST SAS reserve the right to amend the above information in the course of continuing its commitment to product safety.

6 - Cleaning

Before cleaning the device, switch off the instrument and disconnect it from the supply. The exterior surface of the case may be cleaned using a soft cloth moistened in water. Do not use aerosol or liquid sol vent cleaners.

7 – Putting Into Storage

If the instrument is to be put into storage, ensure that the following conditions are maintained:
      Temperature range: -40 to 70°C
      Humidity: Less than 93% at 40°C

8 - Precautions

WARNINGS, CAUTIONS and NOTES
These terms have specific meanings in this manual:
WARNINGS contain information to prevent personal injury.
CAUTIONS contain information to prevent damage to the equipment.
Notes contain important general information.

HAZARD SYMBOLS
The meaning of hazard symbols appearing on the equipment is as follows:

Symbol	Nature of hazard

General hazard

Dangerous voltage

9 - Safety

This product has been designed and tested in accordance with BS4743 'Specification for safety requirements for electronic measuring apparatus' and IEC Publication 348 'Safety requirements for electronic measuring apparatus'.

10 – Warning Electrical Hazard

AC supply voltage. This equipment conforms with IEC Safety Class 1, meaning that it is provided with a protective grounding lead. To maintain this protection the supply lead must a1ways be connected to the source of supply via a socket with a grounded contact.
Be aware that the supply filter contains capacitors that may remain charged after the equipment is disconnected from the supply. Although the stored energy is within the approved safety requirements, a slight shock may be felt if the plug pins are, touched immediately after removal.
Removals of covers. Disconnect the supply before removing the covers so as to avoid the risk of exposing high voltage parts. If any internal adjustment or servicing has to be carried out with the supply on, it must only be performed by a skilled person who is aware of the hazard involved.
It is banned to use this product in the II, III, IV classification.
If this material is used in others conditions other than these specified by the manufacturer, the operator's protection is compromised.

11 – Warning Heavy Instrument

The weight of this instrument exceeds the 18 kg (40 lb) guideline for manual handling by a 'single person. To avoid the risk of injury, an assessment should be carried out prior to handling which takes account of the load, workplace environment and individual capability, in accordance with European Directive 90/269ŒEC and associated National Regulations.

12 – Warning Tilt Facility

When the instrument is in the tilt position, it is advisable, for stability reasons, not to stack other instruments on top of it.

13 – Caution Pulse Input

Before switching on the instrument, ensure that no signal voltage is present on the PULSE INPUT socket.

14 – Caution Static sensitive Components

This equipment contains static sensitive components which may be damaged by handling -refer to the Maintenance part of the Service Manual for handling precautions.

15 - Calibration

EUROPTEST, manufacturer of PN9000 Phase Noise Measurement Systems, advises that calibration should be performed once a year (*the PN9000 chassis & the central processing unit are needed*).
Over this time the manufacturer will not approve the accuracy of measurements made by the user.
The calibration of the system is performed when the latter is in good working order. The equipment will be checked before calibration. Should defective parts be found out, EUROPTEST will issue a quote shortly for the repair of the device.

2

PHASE NOISE MEASUREMENT PRINCIPLE

Basic Methods of Measurement

Phase/AM Noise Measurement on RF carrier signal is the main purpose of the system. There are two sorts of Phase/AM Noise which can be measured on a carrier, the absolute noise and the additive noise: Absolute noise takes into account the total noise of the carrier such as for a source (Phase or AM). The additive noise takes into account only the noise added to the input carrier by a component or a circuit, such as an amplifier; the noise of the input carrier should be removed from the measurement.

There are two basic methods for absolute phase noise measurement

First method: the phase noise is demodulated by means of a reference synthesizer locked on the DUT to maintain the quadrature on the front end RF phase detector. This method is adapted to stable sources allowing an easy lock of the reference. This method offers the lowest residual noise close to the carrier.

➡ See Application Note PLL.

Second method: The phase noise is demodulated by means of a delay line acting as a frequency demodulation which is insensitive to the carrier frequency instability. The conversion of the frequency demodulation to the phase noise display is performed by signal processing. This method is perfectly adapted to unstable sources such as free running VCO's.
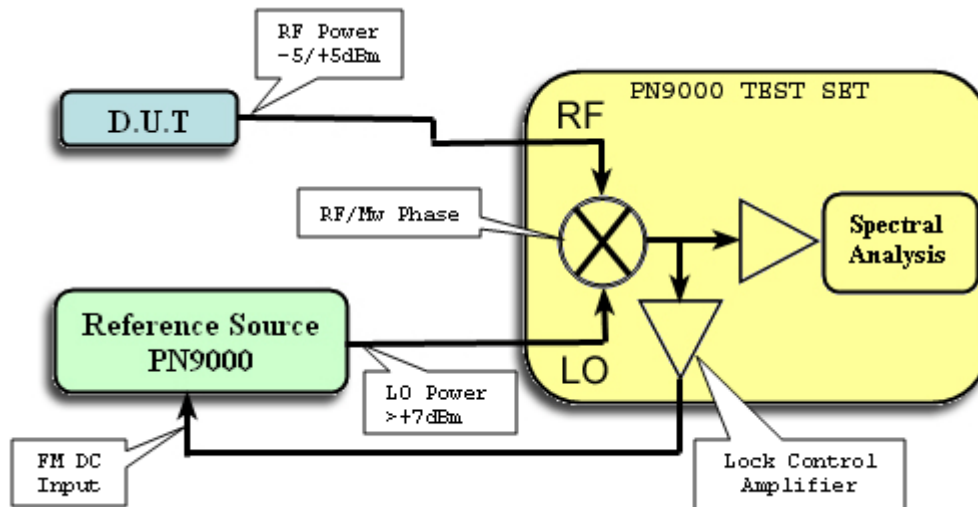
➡ See Application Note VCO.

For the microwave range a down-converter is needed.

➡ See Application Note Down-converter VCO.

Only one source is split into two channels. The first one loads the DUT and the second one load the reference input of the phase detector.

➡ See Application Note Added noise.

This measurement is based on two sources phase detector methods. Two signals with the same frequency are input into a RF double-balanced mixer. Both signals are maintained at phase quadrature by the phase lock loop, one of the sources must be electronically tunable with a DC FM input.

The PN9000 provides a Standard and High Level RF mixer (5MHz to 1.8GHz) and a microwave mixer (1.5GHz to 18/26 GHz).

The residual of this method comes from the reference source, the noise floor of the system itself is −170dBc/Hz (extend to −176dBc/Hz with the High Level mixer).

The internal PN9100 option is a RF synthesizer (2MHz to 4,5GHz) which provides the lowest phase noise available for a wideband synthesizer. Doublers can extend this range up to 18GHz.

Internal "Macro" programs allow automatic measurement process with one Key: "measure". The process includes three steps:

- Demodulator factor measurement (units: Volts per radian, provides the 0dBc/Hz reference).

- The phase lock loop of the reference (to maintain the quadrature).

- Phase noise spectrum measurement.

A wide range of offset frequencies can be measured from 0.01Hz to 40MHz. The system corrects the effect of the phase lock loop automatically. The total accuracy is ±2dB. With the RF/Mw standard mixers, the DUT power range is ±5dBm. For lower or higher power, use the internal RF/Mw Amplifiers or Attenuators.

Application Note VCO
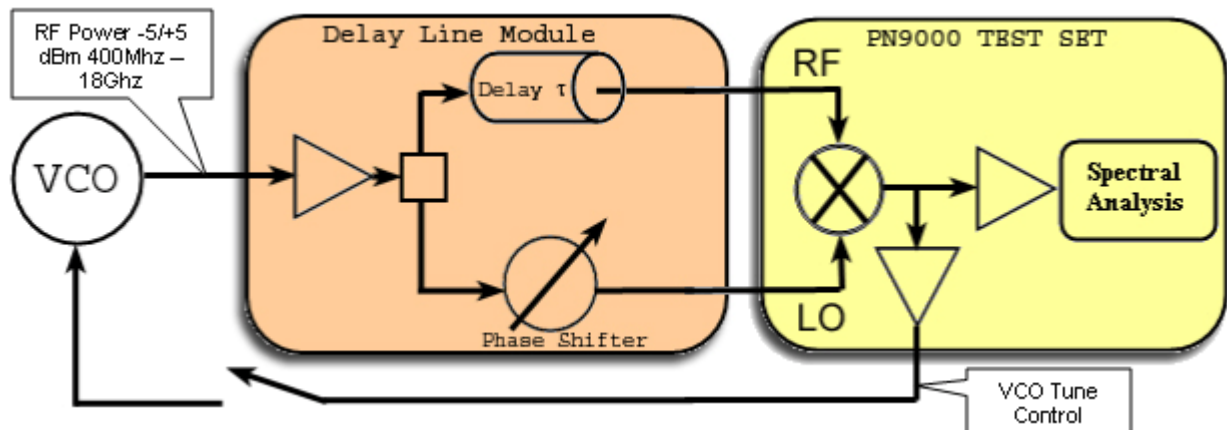
VCO Measurement

The Delay line method acts as a frequency discriminator: since a delay is a linear phase shift with frequency, the frequency fluctuations of the VCO are converted into a noise voltage at the output of the phase detector. After the spectral analysis has been performed, the system transforms the frequency spectrum into the equivalent phase spectrum and displays the curve in the same format as the one with the phase demodulation method. The conversion is inversely proportional to the square offset frequency: $1/f^2$. Due to this conversion, the residual white noise of the test set is transformed into a $1/f^2$ noise. The sensitivity of this demodulation decreases by 20dB per decade as the offset frequency of measurement decreases (Have a look at the curve).

This method is very useful to measure sources that have a high amount of frequency drifts, such as a free running VCO. A 100nsec Delay Line allows a 250KHz frequency drift without affecting the accuracy of the measurement. It also enables the measurement of a source without a lower noise reference source. But it is not an adequate method for synthesized sources which present lower close in phase noise if the residual noise shape of the delay line method is adapted to a VCO phase noise spectrum.

The demodulation is proportional to the length of the Delay Line (t):

Noise Voltage (fm) = KF 2πt Df (fm) [sin(2πt fm) / (2πt fm)]
KF = phase detector demodulation factor
Df (fm) = frequency fluctuations of the VCO, function of the offset
The PN9000 software corrects the [sin(2πt fm) / (2πt fm)] transfer function up to fm = 1/t
Noise Voltage (fm) = KF 2πt Df (fm) up to fm = 1/t

The compromise of this method is between the sensitivity (that is proportional to t) and the maximum offset frequency of the measurement that is inversely proportional to t. The PN9000 system proposes different values for the delay line:

- 🟡 100 ns : Sensitivity −140dBc/Hz at 100KHz offset, Foffset max = 5MHz, VCO drift 250KHz.

- 🟡 20 ns : Sensitivity −125dBc/Hz at 100KHz offset, Foffset max = 25MHz, VCO drift 1.25MHz.

- 🟡 20 ns : Sensitivity −165dBc/Hz at 20MHz offset.

Measurement Process

The VCO is loaded to the Delay Line module input, the optimum power range is −5dBm to +5dBm. This signal is amplified to +20dBm with a limiting power amplifier.
The phase detector, constantly expressed in Volt per radian, has to be measured to refer the spectral density of the phase noise to 0dBc/Hz, which represents the carrier power or 1radian rms.
In case of a two sources configuration, a beat note frequency is set between the two RF and LO paths.

Then the system measures the phase slope at 0Volt crossing, which corresponds to the quadrature condition. For the Delay Line configuration with only one source, one of the easiest solutions is to adjust both paths in quadrature and move the phase between these RF and LO paths by a calibrated amount DF, and measure the DC voltage DV at the output of the phase detector :

Demodulation factor $KF = DV / DF = DV / 2\Pi F_o Dt$
With F_o the VCO carrier frequency.
F_o is measured with the internal RF frequency counter.

The electronical phase shifter operates this quadrature adjustment and performs calibration automatically. The losses of the Delay Line are proportional to the carrier frequency; above 1GHz the sensitivity decreases by 20 log (1GHz / Fo GHz).
In case of large frequency drifts, the VCO can be locked by the Voltage Control, which enables to maintain the quadrature condition without affecting the spectrum above a 100Hz offset.
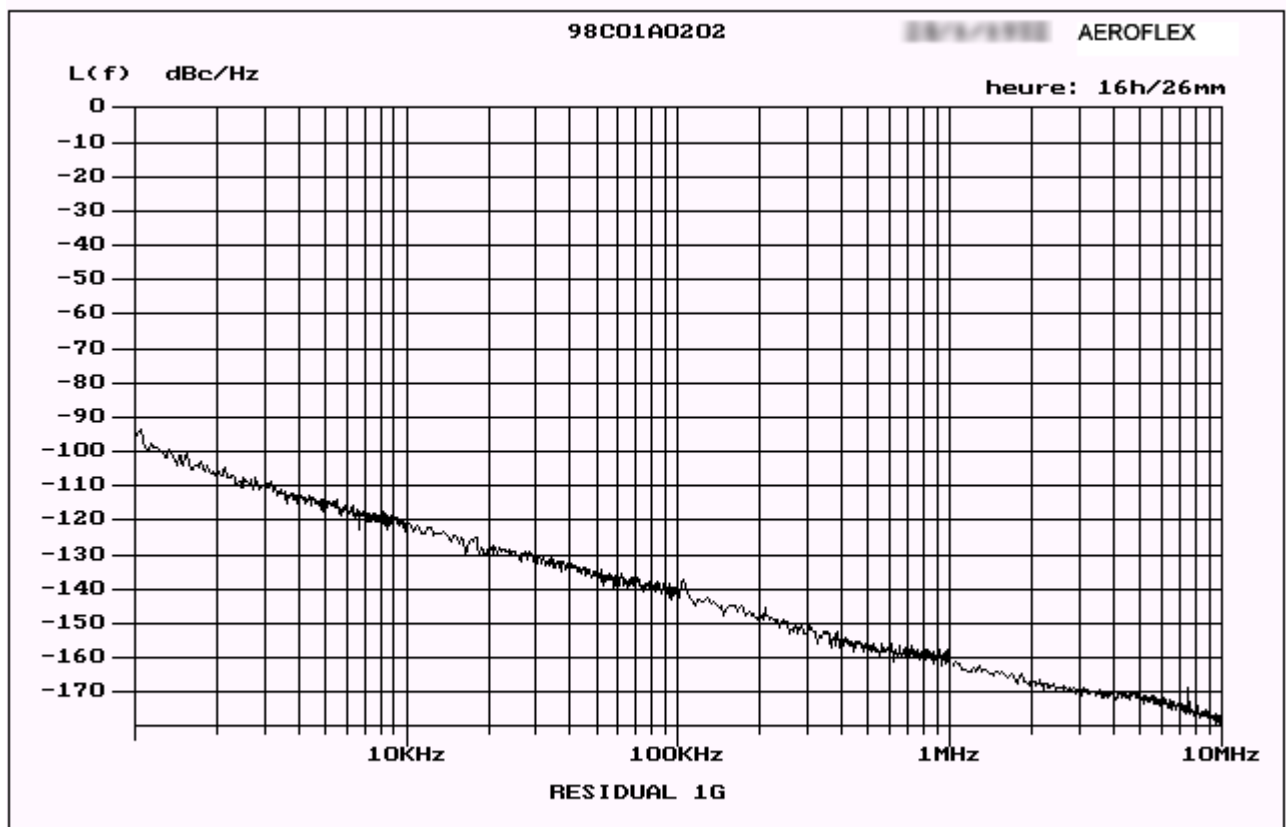
The standard input frequency range of the Delay Line module is from 250MHz to 2GHz.

See application note n°1x.

The microwave range has to be downconverted to this base band. In the PN9000 test set, three types of reference sources are available:
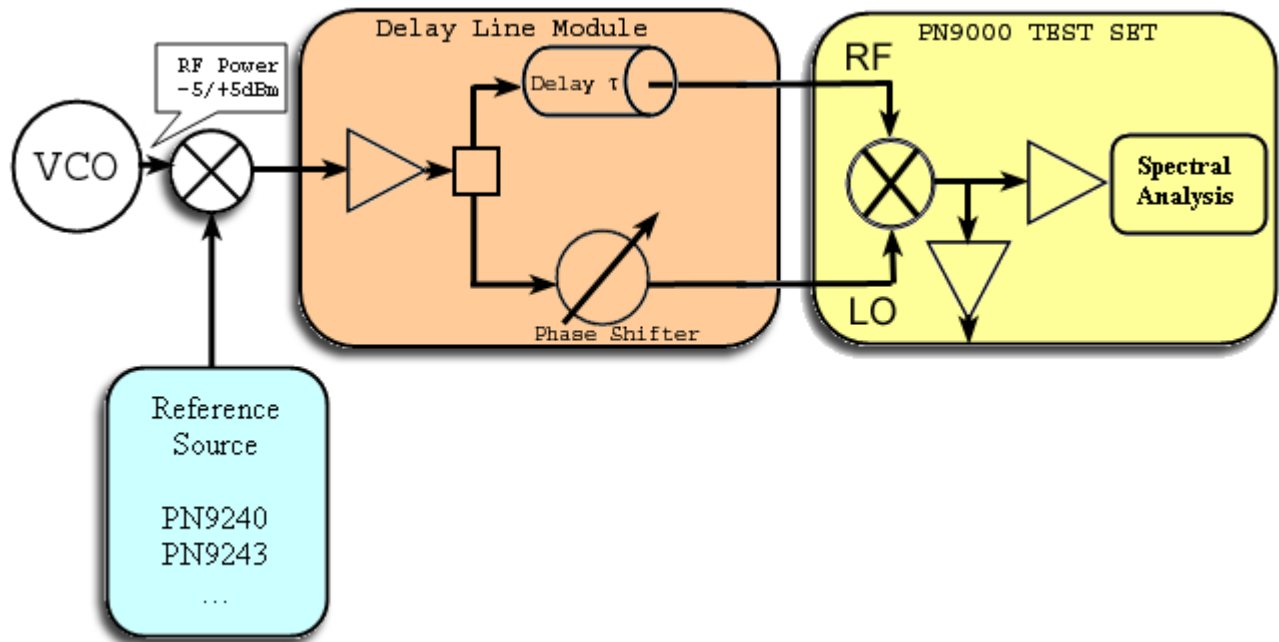
- The PN9100 synthesizer.

- The PN925x PLL microwave down converters family (PN9253, PN9254).

- The PN924x VCO microwave down converters family (PN9242, PN9243, PN9245).

The PN9100 synthesizer, with the doublers option, provides a continuous frequency range up to 18GHz. The "PN925x" PLL microwave Down Converter and the "PN924x" VCO microwave Down Converter provide a frequency range from 2GHz to 18GHz with fixed reference frequencies.

Phase noise spectrum considerations:

The phase noise spectrum has to be compatible with the VCO specifications. It is important to consider the standard shape of the phase noise spectrum: a free running VCO presents mainly two slopes: 30dB (close to the carrier) and 20dB per decade. For a 4GHz VCO the typical specifications are:

−100dBc/Hz at 10KHz.
−120dBc/Hz at 100KHz and a noise floor.
＜-160dBc/Hz at 10MHz from the carrier.

One of the best low noise free running sources is DRO-type with no frequency tunable command (option Down Converter "PN924x"). Typical performance for 4GHz is:

−125dBc/Hz at 10KHz.
−145dBc/Hz 100KHz and a noise floor.
＜-165dBc/Hz at 10MHz from the carrier.

The global phase noise spectrums of the "PN924x" reference sources are perfectly adapted to VCO specifications. A synthesized source presents lower noise close to the carrier (<10KHz), but higher phase noise far from the carrier (▷ 100KHz). This spectrum is not perfectly adapted to VCO specifications; generally a large pedestal noise floor due to the synthesis provides a phase noise rise at a range of 100KHz from the carrier.

The PN9100 phase noise spectrum at 4GHz is:

-120dBc/Hz at 1KHz
-124dBc/Hz at 10KHz
-124dBc/Hz at 100KHz
-145dBc/Hz at 1MHz and a noise floor
-162dBc/Hz at 10MHz from the carrier

The PN925x phase noise spectrum at 4GHz is:

-120dBc/Hz at 1KHz
-130dBc/Hz at 10KHz
-130dBc/Hz at 100KHz
-145dBc/Hz at 1MHz and a noise floor
-162dBc/Hz at 10MHz from the carrier

 The PN924x phase noise spectrum at 4GHz is:

-125dBc/Hz at 10KHz
-145dBc/Hz at 100KHz
-160dBc/Hz at 1MHz and a noise floor
-168dBc/Hz at 10MHz from the carrier

Conclusion: Regarding the phase noise spectrum adapted to a free running VCO, the PN924x provides the lowest phase noise far from the carrier. The PN9100 or the PN92xx can be used taking; their phase noise specifications in the offset range of 100KHz to 10MHz from the carrier must be taken into account.

Intermodulation considerations:
The input mixer generates intermodulation, mainly because it is a wide band mixing. Intermodulation spuriouses may occur between the VCO and the reference source, but also with all the harmonics. A standard solution to reduce these spuriouses is to operate with very low input signals in order to optimize the mixer intermodulation. But this condition conflicts with low noise floor measurements. Another solution is to move slightly one of the frequencies (VCO or reference source) in order to reject the spuriouses out of the measurement span. Advantages/drawbacks to VCO measurements:

PN9100: Continuous frequency range up to 18GHz. In case of intermodulation, the PN9100 frequency can be moved to reject the intermodulation out of the span, good spectrum close to the carrier, phase noise limited to −124dBc/Hz at 100KHz from the carrier at 4GHz. The source is compatible with very low noise synthesized sources measured with the phase demodulation method.

PN925x: frequency range up to 18GHz, or 26GHz available as an optional extra, good spectrum close to the carrier. Source compatible with very low noise synthesized microwave sources measured with the phase demodulation method. Phase noise limited to −130dBc/Hz at 100KHz from the carrier at 4GHz. Fixed value not tunable in case of intermodulation.

PN924x: frequency range up to 18GHz, good spectrum adapted to the shape of VCO. Fixed values are not tunable intermodulation occurs.
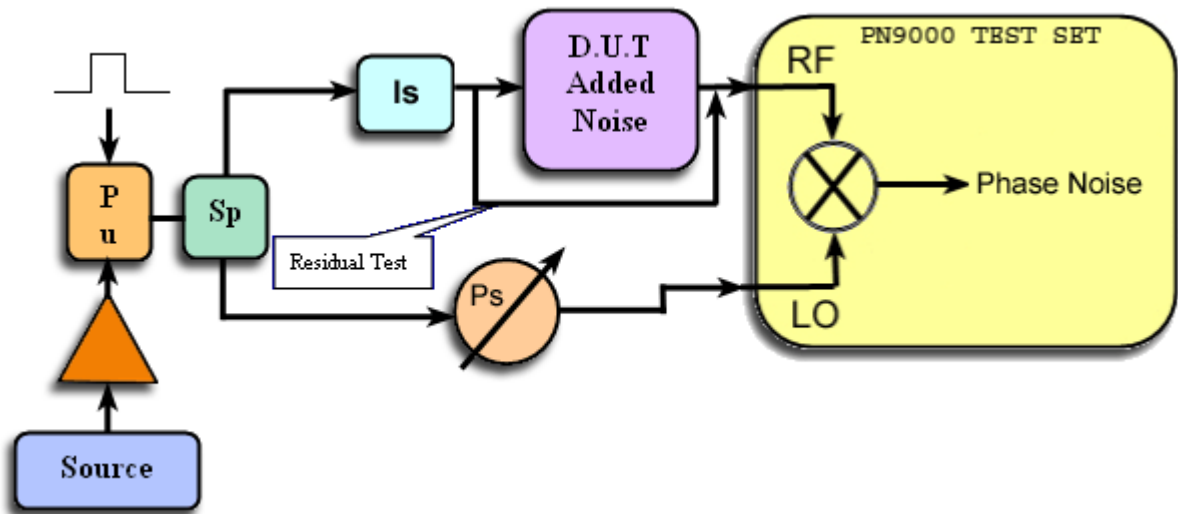
This method quantifies the amount of noise added to a signal as it passes through a DUT device. The technique of measurement is the same as for the Residual Test of the phase detector method, which determines the noise floor of a system.

A Residual Test (DUT bypassed) is determined by dividing a signal with a power splitter "Sp" and phase shifting one path "Ps" by 90°, both signal paths (RF and LO) enter the mixer in quadrature with correlated phase fluctuations. The measured noise is only generated by the test set itself as long as the delay difference of the signal paths is minimized to reject the source noise.

In case of Added Noise measurements, the DUT is inserted in the RF path, so that the measured noise is the sum of the residual noise (DUT bypassed) and the added noise of the DUT. This measurement can be performed under CW or Pulsed conditions.

The different parts of the set up are:

Source (microwave synthesizer):
The Source is at the test frequency, its absolute phase noise is reduced by the correlation factor given by $20 \log (2 p t Fm)$.
With t = delay difference between the two paths, Fm = offset of measurement
Example: Absolute phase noise of the Source = -50dBc/Hz at 100Hz from the carrier
t = 10ns and Fm = 100Hz , correlation factor = -104dB, the noise floor only due to the Source is -50dBc/Hz -104dB = -154dBc/Hz at 100Hz from the carrier.
Another caution is the AM noise of the Source; the phase detector has only about 30dB AM rejection. AM contribution can be estimated by setting the two paths in phase, in this condition the mixer demodulates the AM noise, from this noise only 30dB reduction can be achieved when the two paths are in quadrature.
Power Amplifier "A" (+20dBm):
The PN9000 system needs a High Level phase detector to achieve a good dynamic.
LO power ＞+15dBm and RF power ＞+10dBm, which approximately corresponds to +20dBm before the power splitter, a power amplifier is needed because the most of microwave sources don't provide +20dBm output power.
Pulser "Pu":
If the DUT is operating under pulsed conditions, it is better to provide pulsed signals on the two paths.
This way, the DC offset and the internal phase noise of the phase detector are minimized.
An isolator "Is" can be inserted in the RF path to prevent from bad SWR at the input of the DUT.
The phase shifter "Ps" can be mechanical or electrical tunable. This phase shifter is used for two purposes: to adjust the phase to measure the demodulation factor and to adjust the phase to set the quadrature. An

electrical phase shifter has two limits: its internal added noise can be too large and the maximum input power can be too low to be compatible with the high level phase detector.

Measurement Process

Set the Source at the test frequency. Adjust the signal power:

+7dBm $<$ LO $<$ +13dBm , RF $<$ +5dBm for the standard mixer.
+15dBm $<$ LO $<$ +22dBm , RF $<$ +15dBm for the high level mixer.

The phase detector, always expressed in Volt per radian, has to be measured to refer the spectral density of the added noise to 0dBc/Hz, which represents the carrier power or 1 radian rms. In the case of a two-sources configuration, a beatnote frequency is set between both RF and LO paths; then the system measures the phase slope at 0Volt crossing, which corresponds to the quadrature condition. For the ADD NOISE configuration with only one source as Source, one of the easiest solutions is to move the phase between the two RF and LO paths and measure the DC voltage at the output of the phase detector. If the signal powers are respected for RF and LO, the maximum Vpeak+ or minimum Vpeak- voltage obtained, when the two paths are in phase or out of phase, corresponds to the phase slope at the quadrature condition (the amplitude of a sinusoidal signal is equal to the slope at 0 Volt crossing). To operate in this mode with the PN9000, run the "Beat Free run" calibration mode and adjust the phase shifter to a maximum or a minimum DC Voltage. By pressing the "return" key"when one of these conditions is obtained, the system registers the value as the constant phase detector demodulation.

⚠️Caution: If a too large RF signal is used, the relation between the peak voltage and the 0Volt crossing phase slope is not valid, an error from 1dB to 3dB can occur. After this calibration process, adjust both paths in quadrature and run a spectral density measurement (in accordance with no phase lock loop in this process set the parameter "Loop compensation" = off, in the menu "STATUS/GAIN").

Measurement Process, Pulse

The PN9000 provides three main advantages when testing Added Noise under pulse conditions:

PRF video filters can be inserted between the phase detector and the low noise amplifiers. The low noise amplifiers support a large voltage swing.
The High Level mixer provides a high demodulation factor. These features allow to get the best dynamic under pulse conditions (see curve, Residual test at 10GHz with 10% Duty Cycle and a PRF=10KHz).
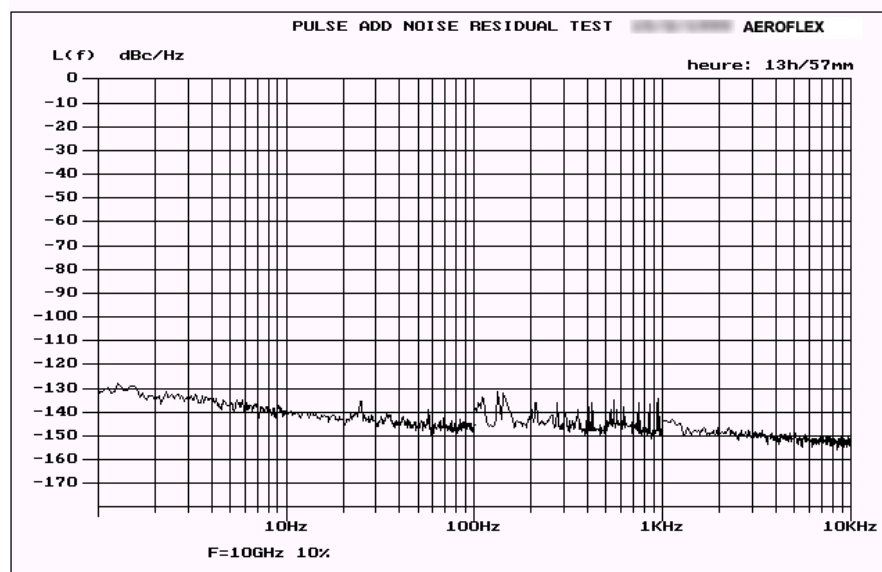
The measurement process is the same as CW, but the video filter has to be selected in the calibration process. The system takes into account the loss of sensitivity due to the Duty Cycle; the spectrum is normalized.

PN9000 Hardware Configuration :

- The PN9000 family offers an "Added Noise" as an optional extra, including: a Power Amplifier, a Pulser, a Power Splitter, a Phase Shifter, a Pulse generator with low jitter and video filters.

- Frequency range: 2GHz to 18GHz.

- Input power (from the Source): +10dBm.

- Output power: RF +13dBm (to the DUT), LO +17dBm.

- Pulse generator: pulse width from 100ns to 1ms, PRF: 100Hz to 1MHz, Duty Cycle 1% to 50%.

The pulse generator includes an external trigger and an auxiliary output to drive the DUT with a programmable delay from 20ns to 1ms between the microwave pulse and the DUT pulse.

The PN9100 Low Noise Synthesizer is the adequate Source to provide the lowest phase and AM noise:

- Frequency range: from 2MHz to 4.5GHz, and up to 18GHz with doublers.

- Output power: > +10dBm.

The PN9000 Phase Noise test set, the Added Noise module and the PN9100 module are housed into a standard 3U mainframe, which offers a compact system that includes all the hardware configuration in order to run an Added Noise measurement.

3

DEVICE TYPE MENU

Measurement Wizards

The user can select one of the wizards that correspond to a given kind of DUT or method. The software menu has different configurations according to each type of device in order to simplify the user interface. In the menu the software shows only the commands required by the selected method. To run a measurement, the wizard has to be selected before any other command.
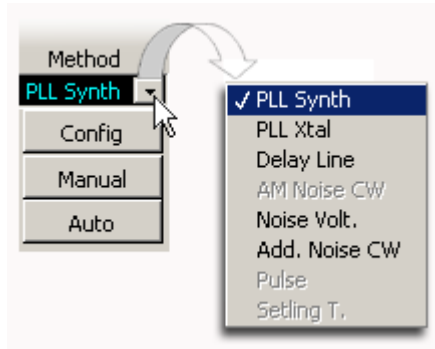
According to the DUT, the user can choose from among the following elements:

- PLL synthesizer (for stable DUT, with a remote programmable reference source).
- PLL Crystal (for crystal sources, with no remote programmable reference source).
- VCO (for free running unstable sources with the delay line measurement method).
- AM Noise (AM measurement for any type of source).
- Noise Voltage (Spectrum analysis of external noise source).
- Added Noise (additive noise from DUT).
- Pulse (for source or two ports device under pulse condition).
- Setling Time
- Frequency Stability measurement.

Principle:
Running a Phase Noise measurement is not an easy task, mainly because of the wide range of different sorts of sources to be tested. The purpose of the PN9000 wizards is to simply the approach of each different type of measurement methods.

Menu Config

- PLL method :
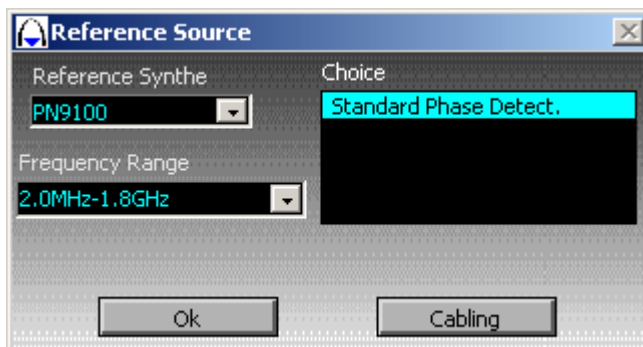
Select the reference source (this source could be internal such as the PN9100 or external with remote control , see menu "Settings / Ext LO Driver Ext LO driver). Select the frequency range. Select the demodulation configuration: Standard RF, High Level RF, microwave, and microwave transposition, microwave H3. These selections depend on the installed options: internal PN9100 synthesizer, PN9151 & PN9152 frequency doublers, microwave phase detector. The basic configuration is the RF phase detector working up to 1.8GHz.

Cabling: Shows the cabling according to the selected measurement process.

⬤ CRYSTAL method :
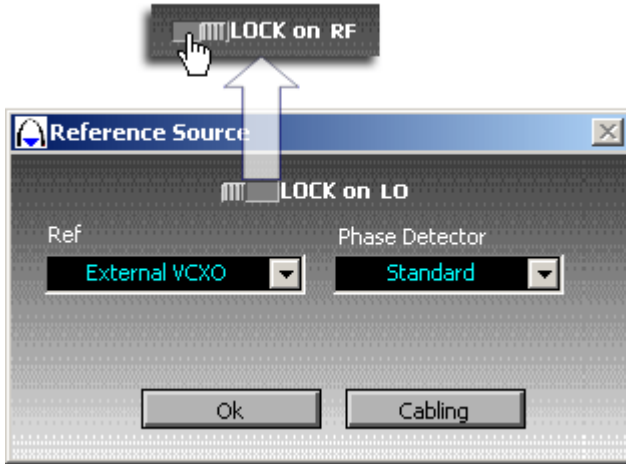
For the general setting the reference source is lock on LO port and should be locked on the DUT. For specific application the lock can be set on the RF source.

Select internal or external reference (internal Low noise Crystal sources can be installed in the PN9000 mainframe). Select standard or High Level phase detector (if the option has been installed). The standard phase detector works with +7 to +10 dBm on the LO port and has +3dBm 1dB compression point on the RF port. The High Level phase detector works with +15 to +20 dBm on the LO port and has +15dBm 1dB compression point on the RF port. The High Level phase detector provides 10dB improvment of dynamic range.

Cabling: Shows the cabling according to the selected measurement process.

⬤ VCO method :
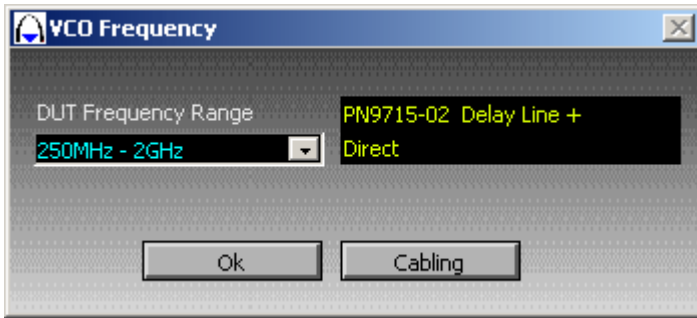
Select the frequency range, the basic RF range called "Direct" for the PN9715, 18, family is 250MHz to 2GHz (previously the frequency range was limited to 400MHz for the PN9711/12/13, extended to 250MHz with the PN9715/18). From 1.5GHz to 2GHz it is advised to have the "Microwave phase detector" option with the PN9715. For the PN9718, the phase detector is included in the delay line module.

Cabling: Shows the cabling according the selected measurement process. For more details.

⬤ AM NOISE method :
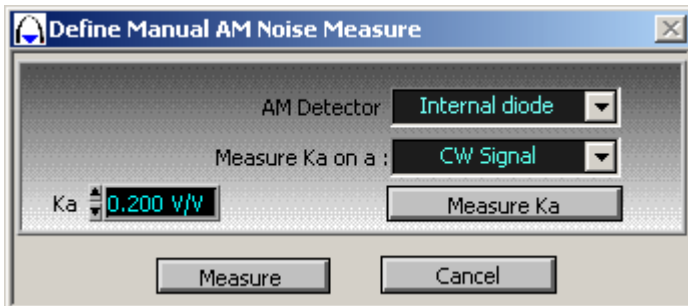
If you want to test a source with no AM modulation ability, by means of the internal AM detector, act as follows:

1. Connect the source to the RF port of the phase detector module. The frequency range is from 10MHz to 18GHz.

2. Select "internal diode" and "CW Signal".

3. Press the "Measure Ka" key: the system measures the demodulation factor and reports the value in the parameter box ("Ka"), expressed in Volt/Volt.

4. Press the "Measure" key to run the spectral analysis. The low frequency range is limited to 10Hz.

ADDED NOISE method:
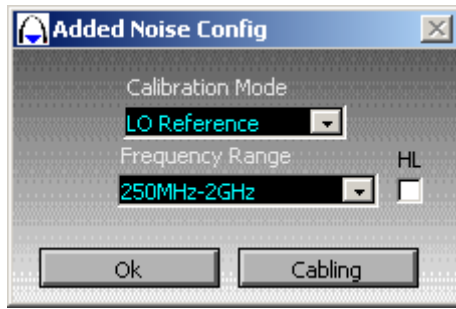
Two methods of calibration are proposed:

Phase adjustment or LO reference 2nd source substitution to perform the calibration with a beat frequency. The second source should have the same power as the LO port.

By selecting the frequency range, the system switches the right phase detector (RF or microwave).

HL: RF High Level mixer can be selected.

Cabling: Shows the cabling according to the selected measurement process.

> After the user has configured the system and set the required parameters, the wizard proposes two methods:
> The Manual mode or the Automatic mode. Only just after the first selection of a Wizard, the operator must select the "Config Menu" with the cabling display.

Setling Time method:
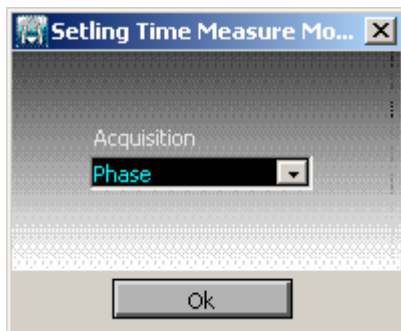
Actually only one method of measurement is available (Phase Method).

The Auto Mode

When "auto" is selected, the second window shows the different steps to perform the measurement. For PLL method (see HELP/OPERATING MODE PLL for Details) the steps are :

- The analysis of the DUT stability,
- The calibration of the phase detector,
- The automatic RF input gain,
- The automatic Loop parameters definition,

It can be customized. The user can skip some parts of the process (not yet available on current software version).
When this process is done, the spectral analysis is started and the result window is opened with the "Measure" box switched on (red color , this measurement process can be stopped at any moment). This wizard can take two minutes to perform its analysis and choose the optimum configuration.

The Manual Mode

After configuring the first window like the automatic way, the user can prepare the measurement by choosing all the parameters manually: RF gain, Loop parameters, low noise gain...

SEE HELP/OPERATING MODE PLL VCO CRYSTAL for details:

Operating mode: PLL RF
Operating mode: PLL mW
Operating mode: Crystal
Operating mode: VCO
Operating mode: Added Noise
Operating mode: Setling Time
Operating mode: Frequency Stability

PLL RF Method

This method is dedicated to stable sources, meaning RF signal locked on a crystal time-base. For the principle of this method see: Application Note PLL

There are two methods to run a measurement:

-The Manual mode, for which the user has to select all parameters to define the measurement.
-The Auto mode, for which the system selects automatically these parameters.

A) PLL RF Method, MANUAL Mode WINDOW
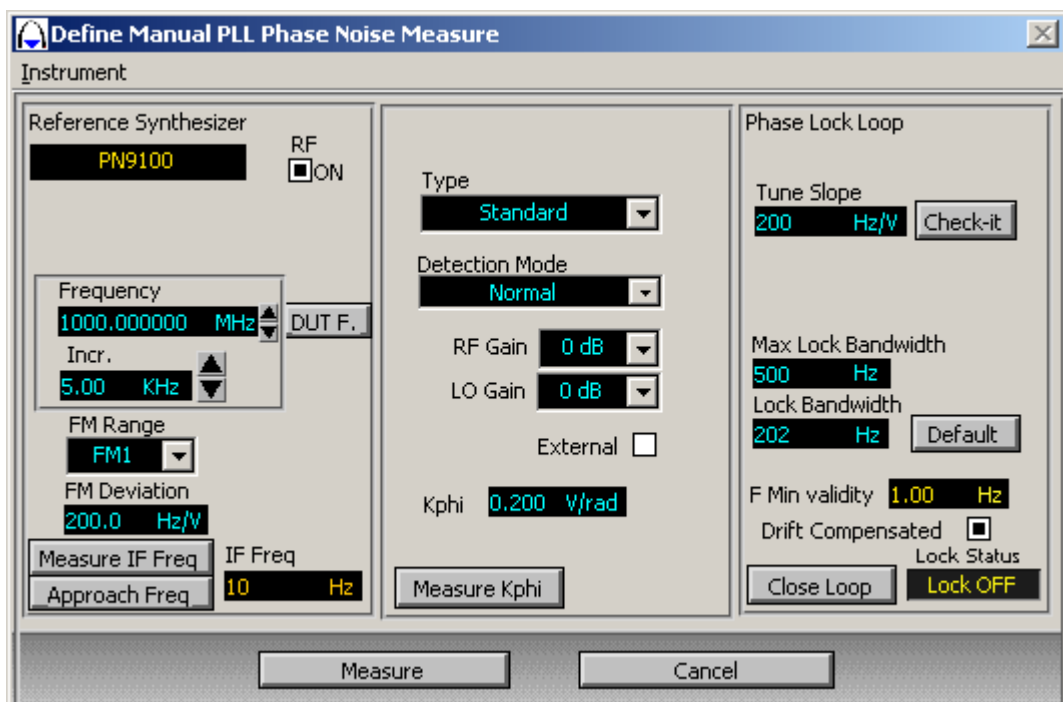
Reference Synthesizer Menu
Reference Synthesizer: Visualization of the reference source driver. See menu: "Wizard PLL Method/Config".

RF ON: Switch on/off the reference source power.

Frequency: Enter the carrier frequency (Up/Down 1 Hz increment) under test (or use the automatic entry: DUT F.).

DUT F.: Command measuring the DUT frequency and programming the reference source at the measured value (Frequency value limited by F. Counter accuracy).

Inc.: Frequency increment used for the calibration. The calibration is performed on a beat frequency, at a range from 1Hz to 10KHz. If there is no limit concerning the reference source, use a standard value of 5KHz (middle of the range).

FM Range / FM Deviation: All the synthesizers offer different FM ranges that correspond to the optimization of FM deviation and FM noise. The larger the FM deviation is, the larger the FM noise will be. Always start with the minimum FM range and a low FM deviation to insure lower residual phase noise. If the maximum Loop Bandwidth is not wide enough to insure stable lock, then increase the FM deviation to increase the maximum Loop bandwidth available. The FM deviation of the PN9100 depends on the carrier frequency and the FM range.

Measure IF Freq: Command measuring the offset frequency between the DUT and the reference source.

Approach Freq: Command measuring the offset frequency between the DUT and the reference source, and programs the reference source frequency to a near value of the DUT.

Type:

Phase Detector Type: RF standard, 2MHz/1.8GHz, +7/+10dBm LO power, +3dBm 1dB compression on RF port. Microwave, 1.8GHz to 18GHz , +7/+15dBm LO power, +3dBm 1dB compression on RF port.

External AC/DC : The system can bypass the front end phase detector and load directly the low noise amplifier to measure as example a noise source .The coupling can be AC or DC.

DETECTION Mode Normal/H3 :

Normal: The reference source is programmed at the exact DUT frequency.

H3 mode: The reference source is programmed at 1/3 of the DUT frequency. In this case, the third Harmonic of the reference source corresponds to the DUT frequency; this mode allows the system to measure three times as high as in frequency. For example: the PN9100 max frequency = 4.5GHz, the H3 mode allows measurement up to 3 x 4.5G = 13.5GHz. This mode requires a DUT Power > 0dBm and provides a loss of 10dB for the noise floor. The software automatically takes into account the H3 calibration of the parameters (Demodulation factor and Tuneslope of the reference).

Transposition: The system use a double transposition, the first reference source transpose to an IF frequency (Ex: 10 MHz or 100 MHz). The second reference source demodulate the phase noise of the IF frequency. The lock control can be set to one or the other reference source.

Transposition H3: Some as transposition, except the first reference source can be set 1/3 of its nominal value.

RF/LO GAIN: The PN9000 input front end includes amplifiers to adjust the RF/LO levels to the standard operating value:

RF gain = 0 , +10dB , +20dB , -10dB
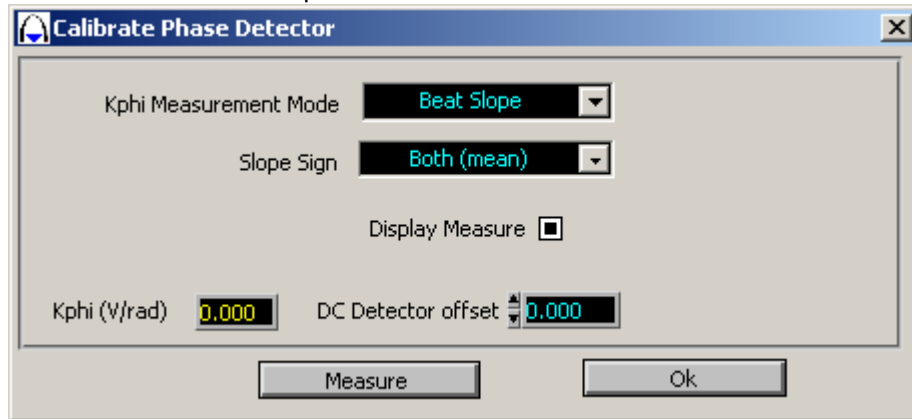LO gain = 0 , +10dB

These values are not calibrated and move according to the frequency. The maximum output levels of these amplifiers are +13dBm. They can be used only for the standard RF phase detector (from 2MHz to 1.8GHz).
There is no need for RF/LO levels to be precise, they just have to be sufficient to generate a calibration factor Kphi > 0.05 (obtain for RF > -6 dBm).

EXTERNAL: Selection of the External input of the LNA module (green LED).

Kphi: Displays the current calibration factor.

Measure Kphi: Runs the measurement process for the calibration.

Kphi Measurement Mode: For standard measurements, select the "Beat Slope" mode. This mode automatically sets an offset frequency between the DUT and the reference source (defined in the reference source driver) and measures the zero crossing slope of this beat frequency. This value exactly corresponds to the demodulation factor of the phase detector.

Slope Sign: If the beat frequency is distorted, the positive zero crossing is different from the negative zero crossing. The standard selection is "Both (mean)"; it corresponds to the average of the two zero crossing minimizing the error. If the user wants to improve the calibration accuracy, he can select the positive or negative slope.

How to select the right slope :

- If the FM DC command of the reference source is positive (+1 Volt on the tune voltage increases the carrier frequency), select the positive slope.

- If the FM DC command of the reference source is negative (+1 Volt on the tune voltage decreases the carrier frequency), select the negative slope.

Measure: Run the calibration process. This measurement can be displayed or not ("Display Measure" on/off). The result is expressed in term of Kphi (V/rad). The minimum valid limit is Kphi > 0.05 , if Khi < 0.05 the input RF level is too low.

OK : Exit the window.

PHASE LOCK LOOP Menu :

Tune Slope: Enter the "Tuneslope" reference source (expressed in Hz per Volt), or measure it with the "Check it" command. With the PN9100 as reference, the system automatically reports the nominal FM deviation, according to the carrier frequency and the FM range. For an optimum accuracy, this value can be measured with the "CHECK IT" command.

Lock Bandwidth: Define the bandwidth of the reference source phase lock loop. Application Note Phase lock Loop. The standard value for the PN9100 is 500Hz for the FM1 range and 5KHz for the FM2 and above ranges, these values are automatically reported for the PN9100. With the PN9100 as reference source, and if low noise is required, use the FM1 range but be sure that the stability of the source to be

measured is good enough to be locked with 500Hz. Otherwise use the FM2 range. If another Lock Bandwidth value is required by the operator, a default value can be entered in the menu: "Advanced" and used later on by pressing the key "Default".

How the system computes the Lock Bandwidth:

Bandwidth = Kphi x Loop Gain x Tuneslope
The calibration process measures the demodulation factor Kphi, the Tuneslope is defined by the reference source (FM DC sensitivity, expressed in Hertz per Volt).
By entering a bandwidth value the system computes the corresponding Loop Gain. If this value is not compatible with the Loop gain range (max gain =20), the system selects the maximum value.

Drift Compensated: On/Off. Application Note Phase lock Loop.

Generally use "drift compensated on". Select "drift compensated off" for Tuneslope < 5Hz and span analysis < 1Hz.

Close Loop: command to close the loop after entering the loop parameters, the status of this command is displayed in "status loop".

After entering all the parameters, the user can run a measurement "Measure" or quit this window "Cancel".

B) PLL RF Method, Automatic Mode Window
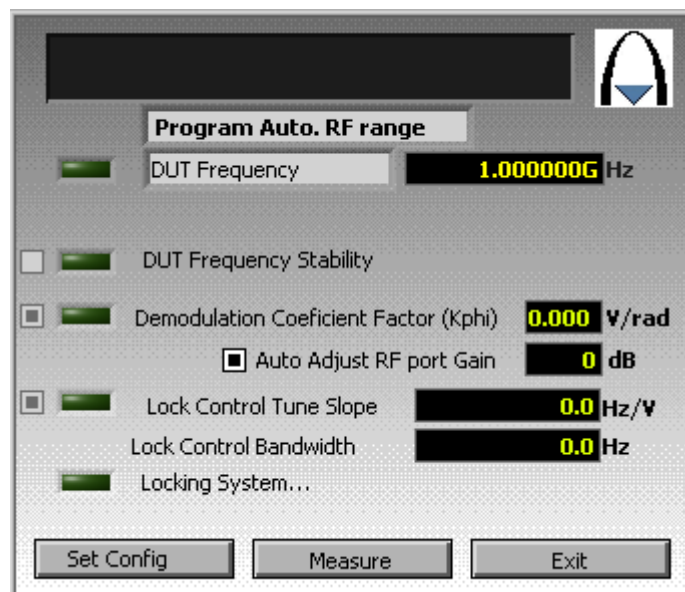
Some parameters can be selected before running a measurement: RF or Microwave, the demodulator, the name of the curve before each measurement. The RF/LO gains are selected automatically by the process.

The system follows a standard measurement process whose steps are :
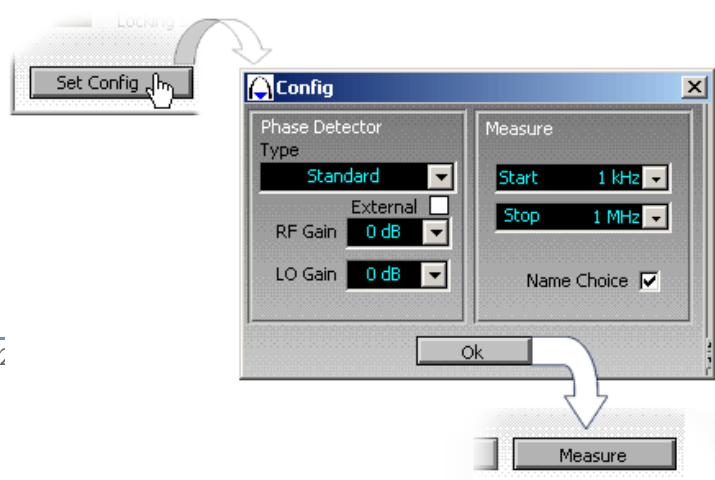
- Measure the DUT frequency.
- Measure the calibration factor.
- Adjust the input RF level to get a demodulation > 0.1 V/rd.
- Compute the Lock Bandwidth.
- Lock the reference source.
- Run the measurement.

Step 1: DUT frequency measurement:

The frequency counter is connected to the RF channel (just after the RF amplifier gain), the sensitivity is -10dBm. The frequency range is from 2MHz to 1.8GHz (operating up to 2GHz). After measuring the frequency, the value is reported in the window and the reference source is programmed at this value. The Bar Graph of the PN9000 mainframe should light from the top to the bottom, which means that a low frequency beat signal is detected between the two sources.

Step 2: DUT stability check (not yet operating):

The user can select or not this command. The system will perform several frequency measurements and check the frequency differences. These differences should stay within a limit if the DUT is stable enough.

Step 3: Calibration:

See the manual mode for details. The system uses the beat slope mode with an offset frequency defined in the reference source driver. Input level adjustment: if the calibration factor "Kphi" is too low, the system adjusts the RF input gain to increase Kphi (only with the RF phase detector).

Step 4: Locking Process:

The system checks the Tune slope reference source and computes the parameters of the phase lock loop. The resulting bandwidth is displayed. After closing the Loop the green led is on if the Lock Voltage is OK.

⚠️In the actual software version, no step can be skipped.

Demodulation Factor (Kphi measurement)

This function allows setting the 0 dBc reference of the spectrum. Proceed as follows.

PLL MW Method

This method is dedicated to stable sources, meaning RF signal locked on a crystal time-base. For the principle of this method see: Application Note PLL

There are two methods to run a measurement:

-The Manual mode, for which the user has to select all parameters to define the measurement.
-The Auto mode, for which the system selects these parameters automatically. In the "CONFIG" menu, first select the frequency range from 1.8GHz to 18GHz or 26GHz.
There are different methods to measure PLL mW, according to the different options that have been installed.
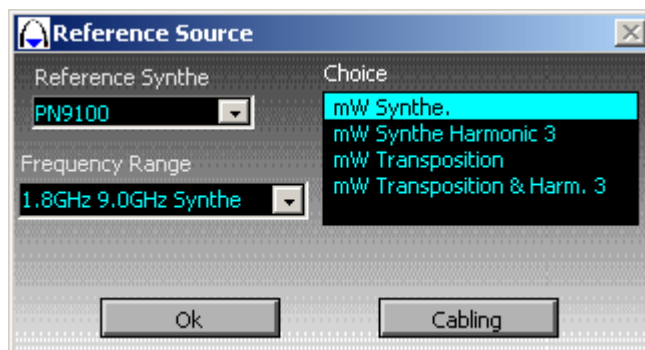
1) Direct measurement "mW Synthe.": with a microwave synthesizer generating the exact DUT frequency, options PN9100+PN9251+PN9252 for a 18GHz range.
2) Down converter transposition measurement "mW Down Converter" with PN9253 or PN9254 options and a RF synthesizer as second LO, PN9100.
3) Harmonic 3 measurement "mW Synthe Harmonic 3": the microwave synthesizer output is only 1/3 of the DUT frequency, same cabling as direct measurement. The input phase detector is able to demodulate on the fundamental frequency of its LO port or on its third Harmonic but with a loss of sensitivity = 10 dB.
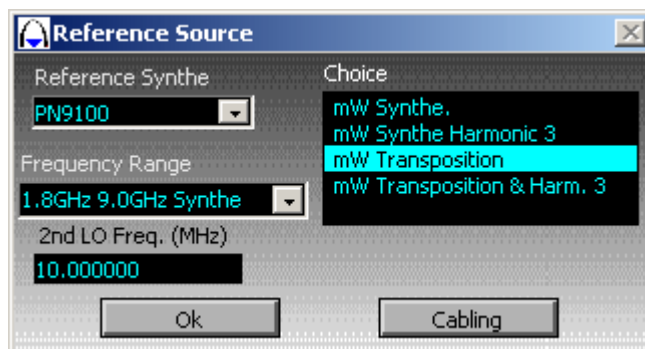
4) Transposition on an IF frequency: the microwave synthesizer is offset by an IF frequency. Then a second RF reference is needed on the second LO port of the phase detector module. This allows to use a microwave synthesizer with no FM DC capability or to set the PN9100 on CW mode, providing a lower phase noise very close to the carrier (1Hz to 100Hz). Then the second LO is locked on the IF frequency. This method has other an advantage in the sense that it sets a frequency offset between the two sources which are present at the front end mixer. This prevents from wrong interactions between both sources.
5) Transposition on an IF frequency with a first LO microwave used on its third Harmonic: the microwave synthesizer is offset by an IF frequency, such as in "4/", and set at 1/3 of this value; then a second RF reference is needed on the second LO port of the phase detector module, at the exact IF frequency.

A) PLL MW Direct method, Manual Mode Window
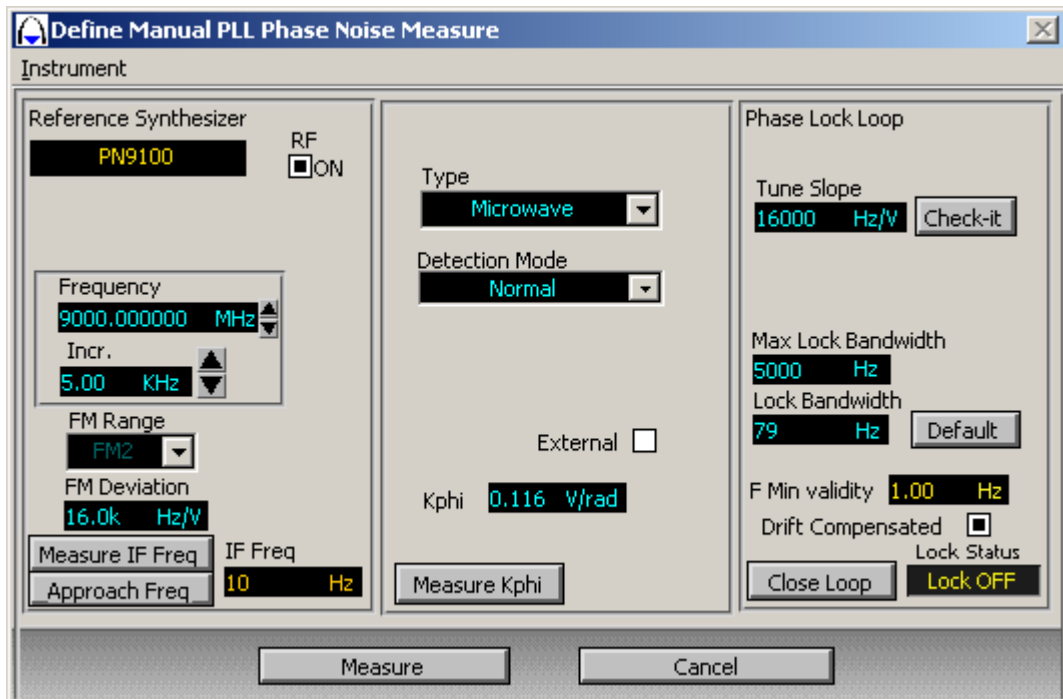
Reference Synthesizer Menu
Reference Synthesizer: Select the reference source driver. See menu: (see menu "Wizard PLL method/Config").

RF ON: Switch on/off the reference source power.

Frequency: Enter the carrier frequency under test , expressed in MHz.

Incr.: Frequency increment used for the calibration. The calibration is performed on a beat frequency, with a range from 1Hz to 10KHz (use a standard value of 5KHz, the middle of the range).

FM Range / FM Deviation: All the synthesizers offer different FM ranges that correspond to the optimization of FM deviation and FM noise. The larger the FM deviation is, the larger the FM noise will be. The user will always start with the minimum FM range and a low FM deviation to insure lower residual phase noise. If the maximum Loop Bandwidth is not wide enough to insure stable lock, then the user will increase the FM deviation in order to increase the maximum Loop bandwidth available.

Measure IF Freq: Command measuring the offset frequency between the DUT and the reference source.

Approach Freq: Command measuring the offset frequency between the DUT and the reference source, and that programs the reference source frequency at a value close to the DUT value.

Type :

Phase Detector Type: Microwave, 1.8GHz to 18GHz, +7/+15dBm LO power and RF port 0dBm/+7dBm. When operating in microwave mode, there are no input amplifiers to adjust the level on the front end phase detector. The levels should be compatible with the standard ranges.
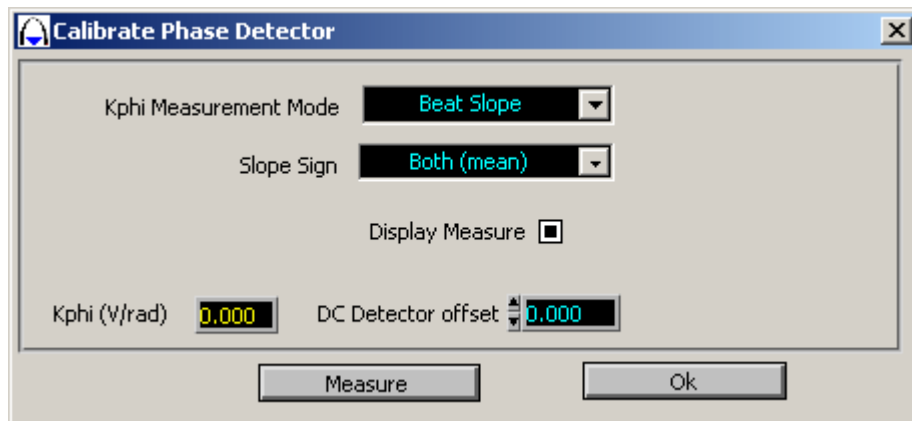
DETECTION Mode Normal/H3:

Normal: The reference source is programmed at the exact DUT frequency.

H3 mode: The reference source is programmed at 1/3 of the DUT frequency. In this case, the third Harmonic of the reference source corresponds to the DUT frequency; this mode allows the system to measure three times as high as in frequency. For example: the PN9100 max frequency = 4.5GHz, the H3 mode allows measurement up to 3 x 4.5G = 13.5GHz. This mode requires a DUT Power > 0dBm and provides a loss of 10dB for the noise floor. The software automatically takes into account the H3 calibration of the parameters (Demodulation factor and Tuneslope of the reference).

EXTERNAL: Selection of the External input of the LNA module (green led) in case of external microwave phase detector.

Kphi: Displays the current calibration factor.

Measure Kphi: Runs the measurement process for the calibration.

Kphi Measurement Mode: For standard measurements, select the "Beat Slope" mode. This mode automatically sets an offset frequency between the DUT and the reference source (defined in the reference source driver) and measures the zero crossing slope of this beat frequency. This value exactly corresponds to the demodulation factor of the phase detector.

Slope Sign: If the beat frequency is distorted, the positive zero crossing is different from the negative zero crossing. The standard selection is "Both (mean)"; it corresponds to the average of the two zero crossing minimizing the error. If the user wants to improve the calibration accuracy, he can select the positive or negative slope.

How to select the right slope:

- If the FM DC command of the reference source is positive (+1 Volt on the tune voltage increases the carrier frequency), select the positive slope.
- If the FM DC command of the reference source is negative (+1 Volt on the tune voltage decreases the carrier frequency), select the negative slope.

Measure: Run the calibration process. This measurement can be displayed or not ("Display Measure" on/off). The result is expressed in term of Kphi (V/rad). The minimum valid limit is Kphi > 0.05 , if Khi < 0.05 the input RF level is too low.

OK: Go out the window

PHASE LOCK LOOP Menu:

Tune Slope: Enter the "Tuneslope" reference source (expressed in Hz per Volt), or measure it with the "Check it" command. With the PN9100 as reference, the system automatically reports the nominal FM deviation, according to the carrier frequency and the FM range. For an optimum accuracy, this value can be measured with the "CHECK IT" command.

Lock Bandwidth: Define the bandwidth of the reference source phase lock loop. Application Note Phase lock Loop. The standard value for the PN9100 is 500Hz for the FM1 range and 5KHz for the FM2 and above ranges, these values are automatically reported for the PN9100. With the PN9100 as reference source, and if low noise is required, use the FM1 range but be sure that the stability of the source to be measured is good enough to be locked with 500Hz. Otherwise use the FM2 range. If another Lock Bandwidth value is required by the operator, a default value can be entered in the menu: "Advanced" and used later on by pressing the key "Default".

How the system computes the Lock Bandwidth :

Bandwidth = Kphi x Loop Gain x Tuneslope

The calibration process measures the demodulation factor Kphi, the Tuneslope is defined by the reference source (FM DC sensitivity, expressed in Hertz per Volt).
By entering a bandwidth value the system computes the corresponding Loop Gain. If this value is not compatible with the Loop gain range (max gain =20), the system selects the maximum value.

Drift Compensated: On/Off. Application Note Phase lock Loop. For the general case use "drift compensated on".

Close Loop: command to close the loop after entering the loop parameters, the status of this command is dispayed in "status loop".

After entering all the parameters, the user can run a measurement "Measure" or quit this window "Cancel".

B) PLL MW method, Automatic Mode Window
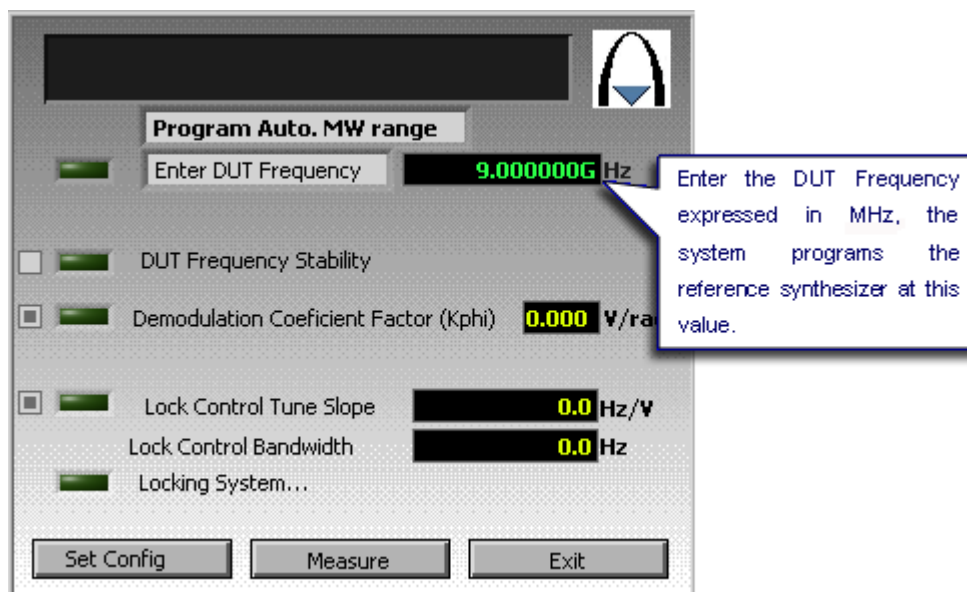
Some parameters can be selected before running a measurement (for the present version, use only the microwave phase internal detector, later others modes will be available. Select, or not, the choice of the curve name before each measurement).

*launch the measurement by pressing the "Measure" key.*

The system follows a standard measurement process whose steps are:

- Measure the beat frequency between the DUT and the reference synthesizer and approach the reference by programming the offset frequency. (Test the DUT stability, not yet operating).

- Measure the calibration factor. There is no microwave input amplifier, if the DUT port is too low (< 0 dBm) the system stops the process.

- Lock the reference source (with the PN9100 as reference and with the FM1 mode, the Loop Bandwidth is set to 500Hz, and set to 5KHz with the FM2 mode, the FM1 shows a better close-in noise, see Data Sheet in the Help menu). If the stability of the DUT frequency is not compatible with 500Hz Loop Bandwidth, then the locking process will fail.

- Run the measurement.
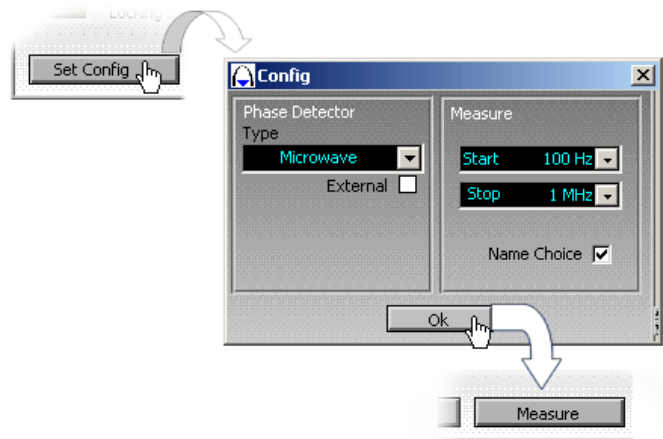
1.A) MW Downconverter method, Manual mode window :
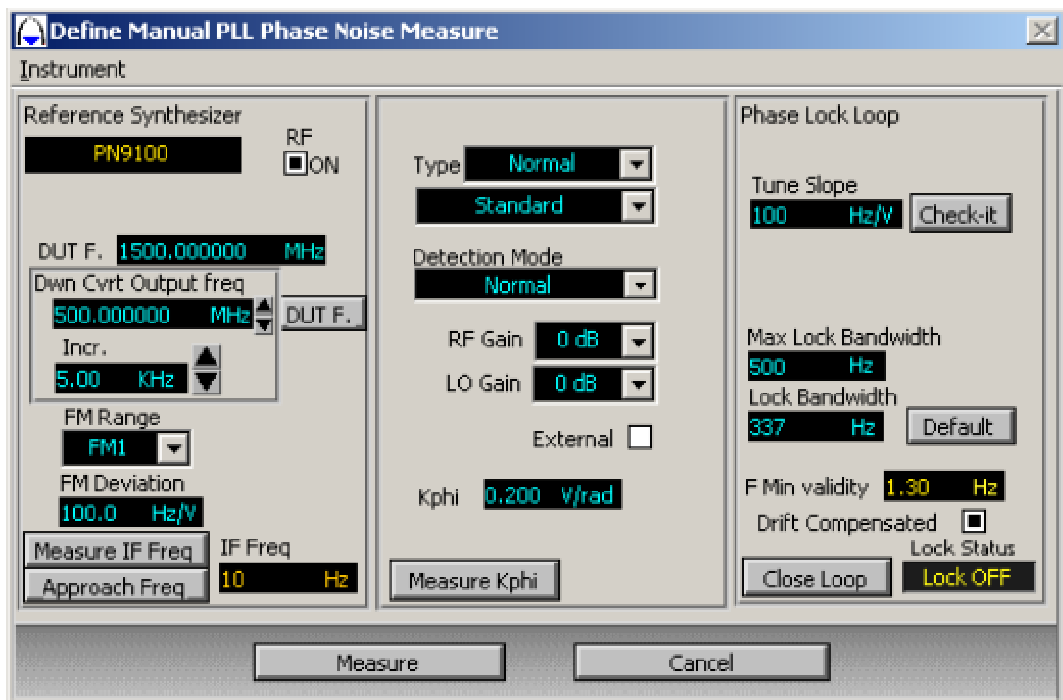
Reference Synthesizer Menu

Reference Synthesizer: Select the reference source driver. See menu: (see menu "Wizard PLL method/Config").

RF ON: Switch on/off the reference source power.

DUT F.: Enter the frequency of the carrier which is under test (expressed in MHz). The system computes the reference source of the Down converter and programs the RF synthesizer at the IF frequency. For

example: with a PN9253 Down Converter: DUT = 10GHz, Selected reference = 11,4GHz , IF = 1,4GHz, the PN9100 reference is programmed at 1,4GHz. This value can be measured with the "CHECK IT" command, reported to the PN9100.

DUT F. (In "Dwn Cvrt Output freq" frame): Check the IF Frequency and program the synthesizer at this value.

Increment: Frequency increment used for the calibration. The calibration is performed on a beat frequency, with a range from 1Hz to 10KHz (use a standard value of 5KHz, the middle of the range).

FM Range / FM Deviation : All the synthesizers offer different FM ranges that correspond to the optimization of FM deviation and FM noise. The larger the FM deviation is, the larger the FM noise will be. The user will always start with the minimum FM range and a low FM deviation to insure lower residual phase noise. If the maximum Loop Bandwidth is not wide enough to insure stable lock, then the user will increase the FM deviation in order to increase the maximum Loop bandwidth available.

Measure IF Freq : Command measuring the offset frequency between the DUT and the reference source.

Approach Frequency : Command that measures the offset frequency between the DUT and the reference source, and that programs the reference source frequency at a value close to the DUT value.
-The "DUT F." command measures the DUT frequency and reports it to the reference.
-The "Approach Frequency" command measures the Beat Frequency between the DUT and the reference, and reports this offset frequency to the reference.

PHASE DETECTOR Menu:
Phase Detector Type: The Microwave transposition is set by the Down Converter module (PN9253). The phase detector is only loaded by an IF frequency < 1.8 GHz; the system selects the RF standard phase detector. The microwave Down Converter includes an IF amplifier which compensates the microwave mixing losses, 0dBm input Level at 10GHz provides 0dBm IF output. IF the microwave input level is low, RF amplifier can be used (RF channel).

RF/LO Gain: Adjust the input level on the RF phase detector (generally use the RF channel only).

External: Selection of the External input of the LNA module (green led) in case of external microwave phase detector.

Kphi: Displays the current calibration factor.

Measure Kphi: Runs the measurement process for the calibration.

Kphi Measurement Mode: For standard measurements, select the "Beat Slope" mode. This mode automatically sets an offset frequency between the DUT and the reference source (defined in the reference source driver) and measures the zero crossing slope of this beat frequency. This value exactly corresponds to the demodulation factor of the phase detector.

Slope Sign: If the beat frequency is distorted, the positive zero crossing is different from the negative zero crossing. The standard selection is "Both (mean)"; it corresponds to the average of the two zero crossing minimizing the error. If the user wants to improve the calibration accuracy, he can select the positive or negative slope.

How to select the right slope:

- If the FM DC command of the reference source is positive (+1 Volt on the tune voltage increases the carrier frequency), select the positive slope.
- If the FM DC command of the reference source is negative (+1 Volt on the tune voltage decreases the carrier frequency), select the negative slope.

Measure : Run the calibration process. This measurement can be displayed or not ("Display Measure" on/off). The result is expressed in term of Kphi (V/rad). The minimum valid limit is Kphi > 0.05 , if Khi < 0.05 the input RF level is too low.

OK: Go out the window

PHASE LOCK LOOP Menu :
Tune Slope: Enter the "Tuneslope" reference source (expressed in Hz per Volt), or measure it with the "Check it" command. With the PN9100 as reference, the system automatically reports the nominal FM deviation, according to the carrier frequency and the FM range. For an optimum accuracy, this value can be measured with the "CHECK IT" command.

Lock Bandwidth: Define the bandwith of the reference source phase lock loop. Application Note Phase lock Loop. The standard value for the PN9100 is 500Hz for the FM1 range and 5KHz for the FM2 and above ranges, these values are automatically reported for the PN9100. With the PN9100 as reference source, and if low noise is required, use the FM1 range but be sure that the stability of the source to be measured is good enough to be locked with 500Hz. Otherwise use the FM2 range. If another Lock Bandwidth value is required by the operator, a default value can be entered in the menu: "Advanced" and used later on by pressing the key "Default".

How the system computes the Lock Bandwidth:

Bandwidth = Kphi x Loop Gain x Tuneslope

The calibration process measures the demodulation factor Kphi, the Tuneslope is defined by the reference source (FM DC sensitivity, expressed in Hertz per Volt).
By entering a bandwidth value the system computes the corresponding Loop Gain. If this value is not compatible with the Loop gain range (max gain =20), the system selects the maximum value.

Drift Compensated: On/Off. Application Note Phase lock Loop. For the general case use "drift compensated on".

Close Loop: command to close the loop after entering the loop parameters, the status of this command is displayed in "status loop".

After entering all the parameters, the user can run a measurement "Measure" or quit this window "Cancel".

2.A) MW Downconverter method, Automatic mode window

Some parameters can be selected before running a measurement (for the present version, use only the microwave phase internal detector, later others modes will be available. Select, or not, the choice of the curve name before each measurement).
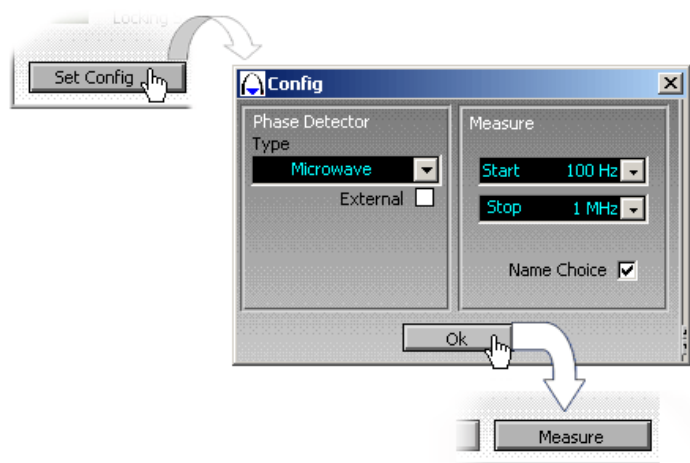
The system follows a standard measurement process whose steps are:

- Measure the beat frequency between the DUT and the reference synthesizer and approach the reference by programming the offset frequency. (Test the DUT stability, not yet operating).

- Measure the calibration factor. There is no microwave input amplifier, if the DUT port is too low (< 0 dBm) the system stops the process.

- Lock the reference source (with the PN9100 as reference and with the FM1 mode, the Loop Bandwidth is set to 500Hz,

Launch the measurement by pressing the "Measure" key.

and set to 5KHz with the FM2 mode, the FM1 shows a better close-in noise, see Data Sheet in the Help menu). If the stability of the DUT frequency is not compatible with 500Hz Loop Bandwidth, then the locking process will fail.

- Run the measurement.

CANCEL: To stop the process.

3.A) MW Harmonic 3 method, manual mode window

DETECTION MODE: Harmonic 3, the reference source is programmed at 1/3 of the DUT frequency. In this case, the third Harmonic of the reference source corresponds to the DUT frequency. This mode allows the system to measure three times as high in frequency.

For example: The PN9100 max frequency = 4.5GHz, the H3 mode allows measurements up to 3 x 4.5G = 13.5GHz. This mode requires a DUT Power > 0dBm and provides a loss of 10dB for the noise floor. The software takes into account the H3 calibration of the parameters automatically (demodulation factor and the tuneslope of the reference).
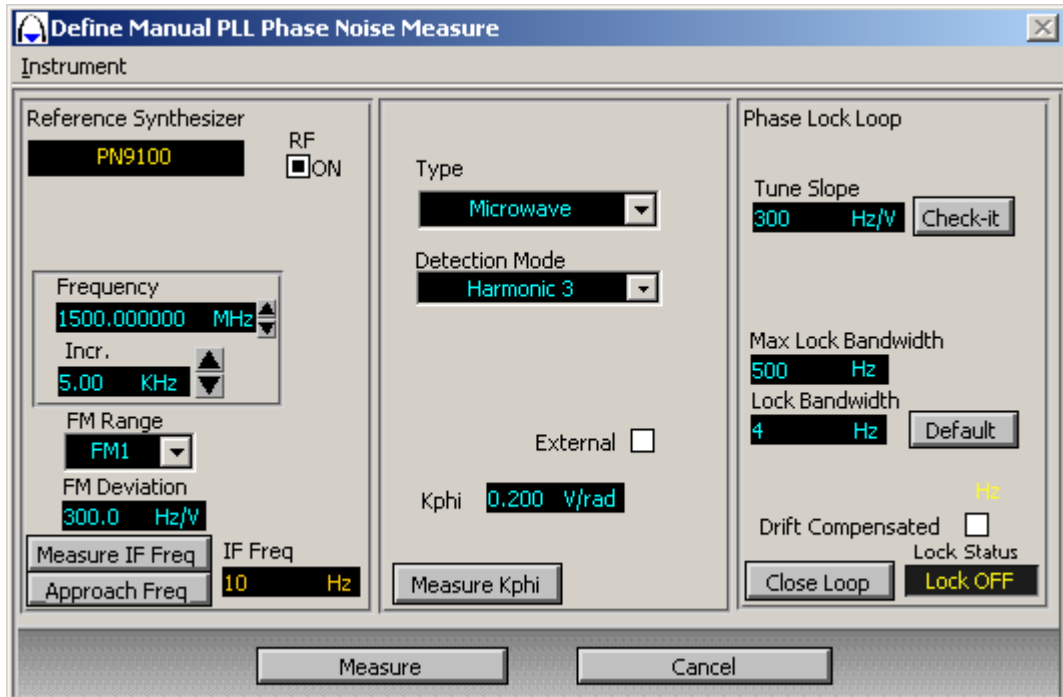
This windows is the same as for "Direct measurement", the software selects only the detection mode = Harmonic 3.

4.A) MW Transposition method on IF frequency, manual mode window
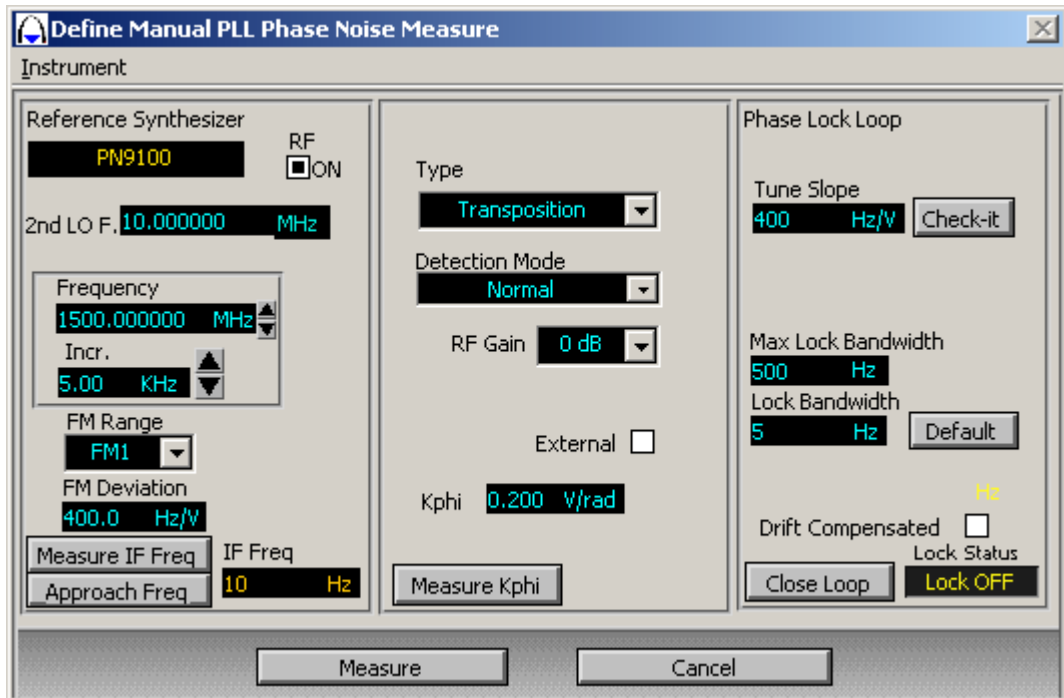
This window is the same as for "Direct measurement". The additional display is the selection for the offset frequency "2nd LO freq " and Type = Transposition. The user will always have to measure the Tuneslope for this configuration. Otherwise the system can make a mistake concerning the Tuneslope between the two reference sources (the lock control can be plugged in with one of the two reference sources).

4.B) MW Transposition method on IF frequency, Automatic mode window
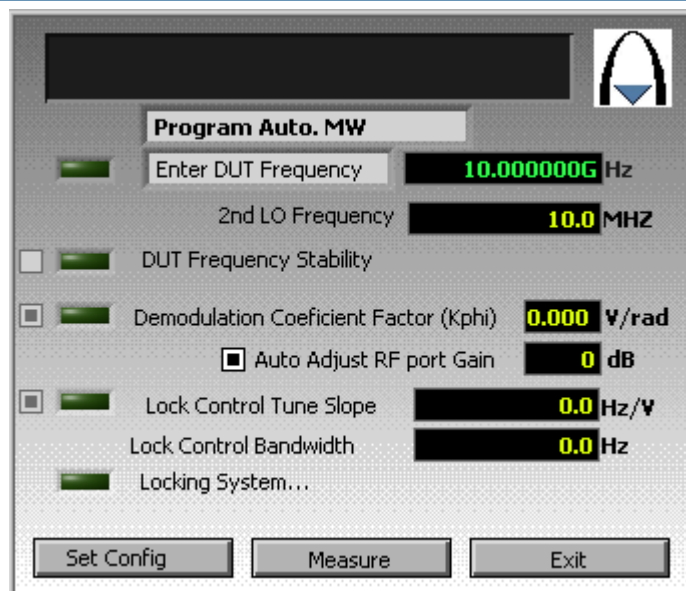
This window is the same as for "Direct measurement". The additional display is only the offset frequency "2nd LO freq " defined in the manual mode.
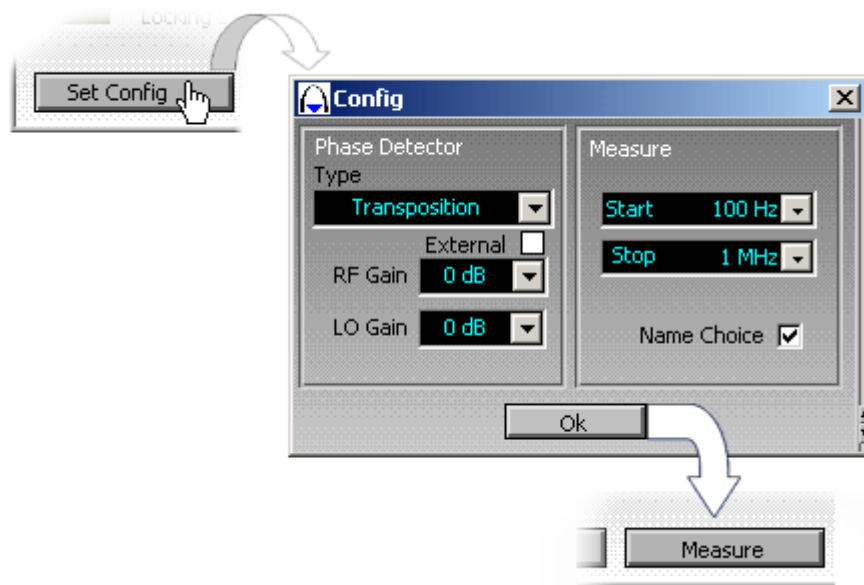
5.A) MW transposition method, with first LO used on its 3th harmonic, manual mode window
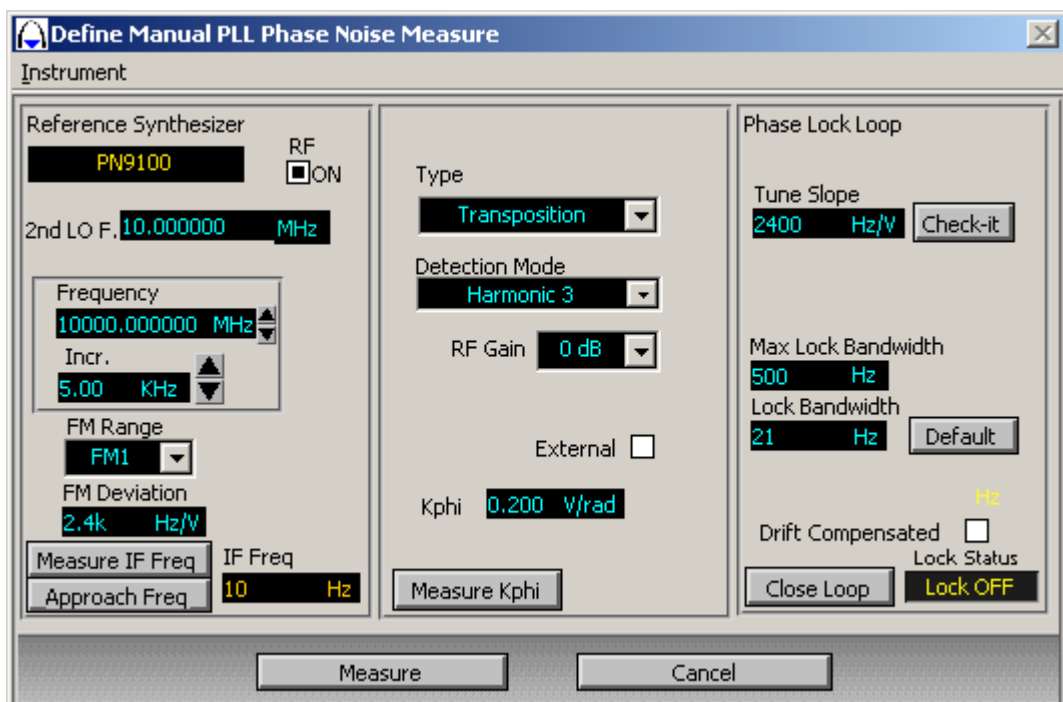
This window is the same as for "Direct measurement". The additional display is the selection of the offset frequency "2nd LO freq", Type = Transposition and Detection mode = Harmonic 3. For this configuration the user will always measure the Tune slope. Otherwise the system can make a mistake concerning the tune slope between the two reference sources.

PLL XTAL: Crystal Measurement Menu

This method is dedicated to low noise VCXO sources, when the residual phase noise to be measured is not compatible with a kind of synthesizer as reference source. Remember that the PLL method, with a PN9100 as reference, is adapted fot standard VCXO sources.

The principle of this method is the same as the PLL method, except that the reference source is another VCXO and so it is not remote programmable. The frequency of this reference cannot be moved by GPIB command, but only with the DC Tune Voltage.

There are two modes to run a measurement:
- The Manual mode, for which the user has to select all parameters to define the measurement.
- The Auto mode, for which the system selects these parameters automatically.

1.A) Crystal Method, Manual Mode Window
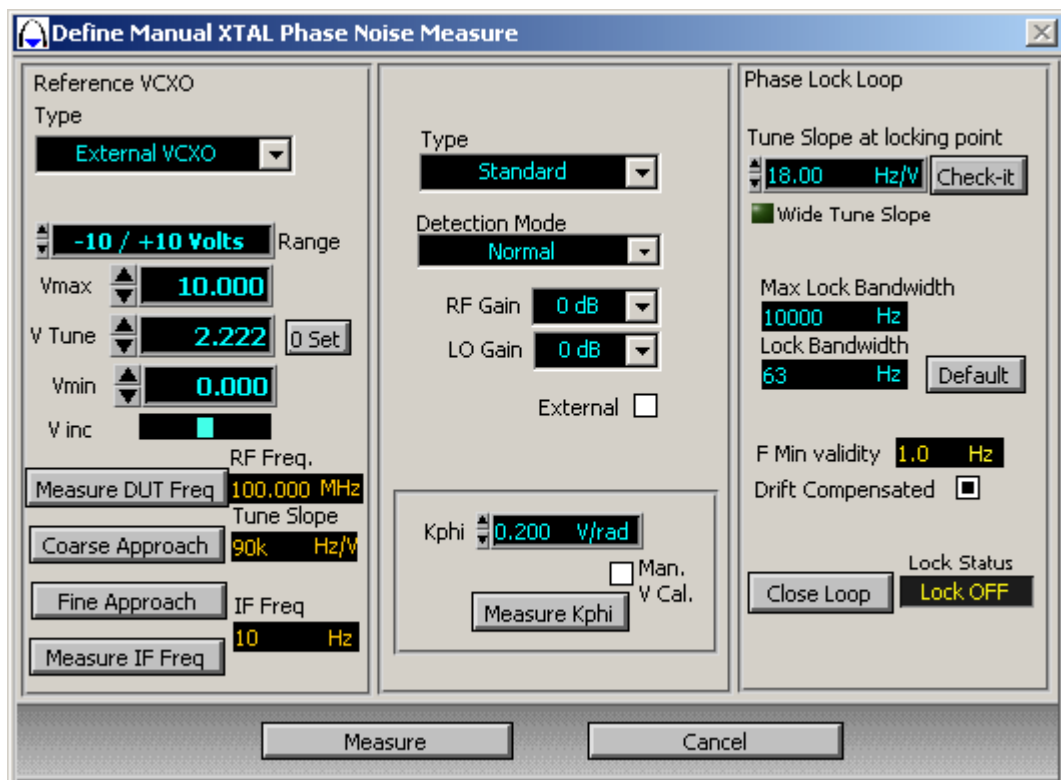
Type: Select the reference source either internal VCXO or external.

PART NUMBER: Selection of the internal VCXO, PN9510, PN9530.

Range: Select the corresponding Vtune range.

Vmax, Vmin: Limits of the tune voltage within the range.

V Tune: Voltage controlling the frequency reference source.(can be set to 0 by "0 Set")

V inc: Move the little blue box to define the selected digit for Vmax,Vtune,Vmin.

Measure DUT Freq: Command that measures the carrier frequency of the DUT.

Coarse Approach : Approach the reference source with the RF frequency counter. This mode should be absolutly used for reference source having a large Tuneslope (>50 KHz/V). The system set automatically a specific hardware configuration for large Tuneslope reference: .

Fine Approach: This mode should be used to improve the coarse approach, or can be used directly for reference source having a low Tuneslope.

Measure IF Freq: Command that measures the carrier frequency of the DUT and the reference source.

Phase Detector Menu:

PHASE DETECTOR TYPE: RF standard, 2MHz/1.8GHz, +7/+10dBm LO power, +3dBm 1dB compression on RF port.
High Level, 2MHz to 1.8GHz, +15/+20dBm LO power, +13dBm 1dB compression on RF port.

External AC/DC: The system can bypass the front end phase detector and load directly the low noise amplifier to measure as example a noise source. The coupling can be AC or DC.

DETECTION MODE: Normal, harmonic 3.
In the normal mode the reference source is set at the DUT frequency.
IF DUT = 10MHz, the reference = 10MHz.
In the Harmonic 3 mode, the reference is set at 1/3 of the DUT frequency.
IF DUT = 30MHz, the reference = 10MHz.

RF/LO GAIN: The PN9000 input front end includes amplifiers to adjust the RF/LO levels to the standard operating value. RF gain = 0, +10dB, +20dB, -10dB.
LO gain = 0, +10dB.
These values are not calibrated and vary according to the frequency. The maximum output levels of these amplifiers are +13dBm. They can be used only for the standard RF phase detector (from 2MHz to 1.8GHz). There is no need for RF/LO levels to be precise; they must be sufficient to generate a calibration factor Kphi > 0.05 (result for RF > -6 dBm)

EXTERNAL: selection of the External input of the LNA module (green led).

Kphi: Displays the current calibration factor.

Measure Kphi: Runs the measurement process for the calibration.

Kphi Measurement Mode: For standard measurements, select the "Beat Slope" mode. This mode automatically sets an offset frequency between the DUT and the reference source (defined in the

reference source driver) and measures the zero crossing slope of this beat frequency. This value exactly corresponds to the demodulation factor of the phase detector.

Slope Sign: If the beat frequency is distorted, the positive zero crossing is different from the negative zero crossing. The standard selection is "Both (mean)"; it corresponds to the average of the two zero crossing minimizing the error. If the user wants to improve the calibration accuracy, he can select the positive or negative slope.

How to select the right slope:

- If the FM DC command of the reference source is positive (+1 Volt on the tune voltage increases the carrier frequency), select the positive slope.
- If the FM DC command of the reference source is negative (+1 Volt on the tune voltage decreases the carrier frequency), select the negative slope.

Measure: Run the calibration process. This measurement can be displayed or not ("Display Measure" on/off). The result is expressed in term of Kphi (V/rad). The minimum valid limit is Kphi > 0.05 , if Khi < 0.05 the input RF level is too low.

OK: Exit the window.

Phase Lock Loop Menu:

TUNESLOPE at locking point: Enter the Tuneslope reference source (expressed in Hz per Volt) or measure it with the "Check it" command.

Warning: For crystal sources the Tune Slope significantly changes with the Tune Voltage. As example from +2Volts to +8Volts, the tuneslope can change with a ratio of 2.

BANDWIDTH: defines the bandwidth of the reference source phase lock loop. See Application Note Phase lock Loop.

A standard value is reported by selecting "Default".

Bandwidth = Kphi x Loop Gain x Tuneslope.

The calibration measures the demodulation Kphi, the Tuneslope is defined by the sensitivity of the DC FM reference source. By entering a bandwidth value the system computes the corresponding Loop Gain. If this value is not compatible with the Loop gain range (max gain =20), the system selects the maximum value.

Notice: The bandwidth of the FM DC port for a crystal is much lower than a synthesizer.

-For a 10MHz source, the typical value is 50Hz
-For a 100MHz source, the typical value is 500Hz

This bandwidth can be limited by internal filtering. By changing the bandwidth in the menu, the results should be the same inside the loop bandwidth. If not it means that the bandwidth is too large.

Example: first measurement with 200Hz bandwidth, second measurement with 20Hz.

The appearance of differences between the two curves inside the Loop Bandwidth means that the 200Hz bandwidth was too large.

DRIFT COMPENSATED: On/Off. See Application Note Phase lock Loop. In the general case use "drift compensated on". Select "drift compensated off" for Tuneslope < 5Hz and span analysis <1Hz.

CLOSE LOOP: Command to close the loop after entering the loop parameters. The status of this command is dispayed in "status loop". After entering all the parameters, the user can run a measurement "Measure" or quit this window "Cancel".

1B) Crystal method, Automatic mode window
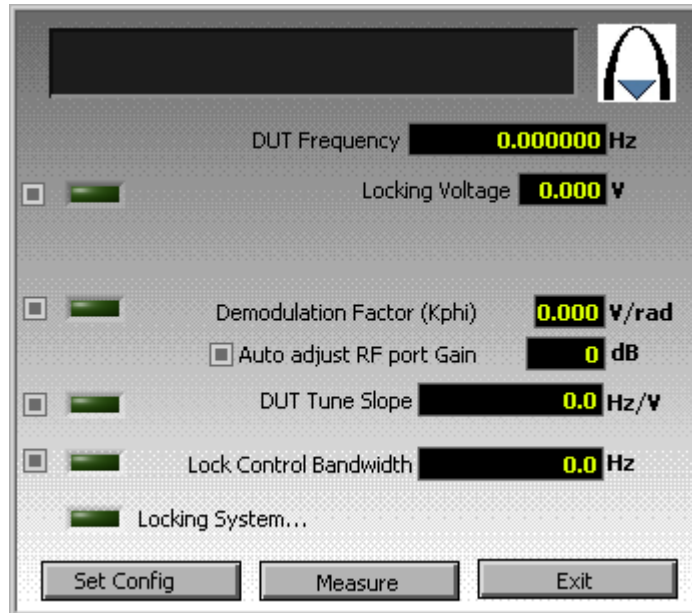
Some parameters can be selected before running a measurement (the Tunning voltage range, the RF demodulator, high Level and the RF/LO gain).
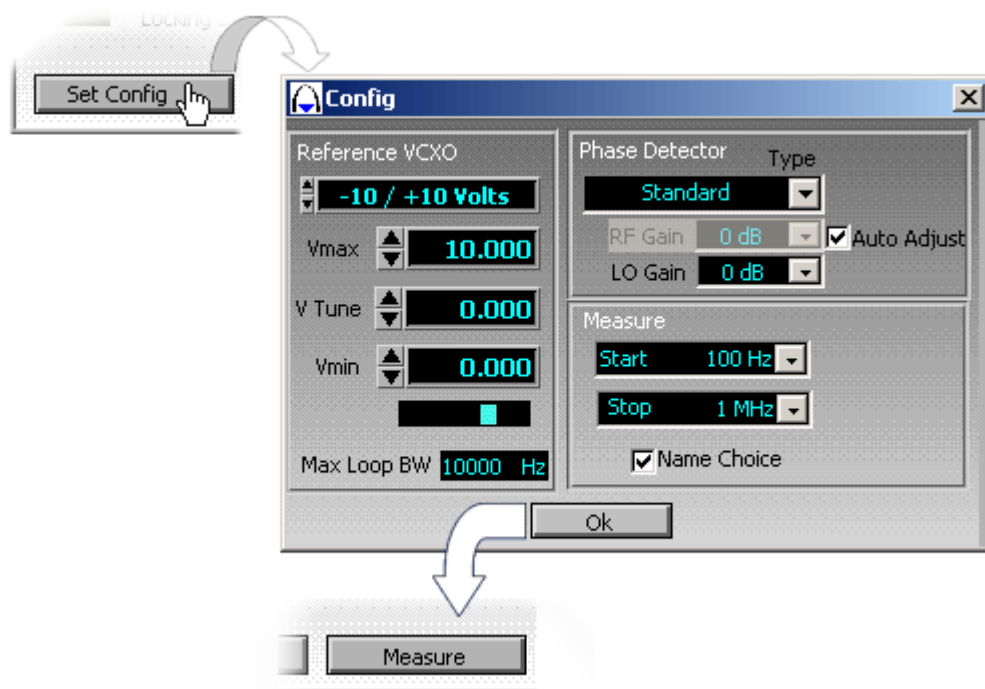
The system follows a standard measurement process whose the steps are:

- Measure the DUT frequency.
- Search the Locking Voltage.
- Adjust the input RF level.
- Measure the calibration factor.
- Compute the Loop Bandwidth.
- Lock the reference source.
- Run the measurement.

Step 1: DUT frequency measurement.
-The frequency counter is connected to the RF channel (just after the RF amplifier gain)
-The sensitivity is -10dBm. The frequency range is from 2MHz to 2GHz
-After measuring the frequency, the value is reported in the window

Step 2: Search for the Locking Voltage.
-The system moves the TuneVoltage to approach the two sources.
-The Bar Graph of the PN9000 chassis should light up and down, which means that a low frequency beat signal between is detected the two sources.

Step 3: DUT stability check (not yet operating).
-The user can select or not this command. The system will perform several frequency measurements and check the frequency differences. If the DUT is stable enough, these differences should stay within a limit.

Step 4: Calibration.
-See the manual mode for details. The system uses the beat slope mode with an offset frequency obtained from moving the TuneVoltage (+1Volt).

Step 5: Lock process.
-The system checks the Tuneslope reference source and computes the parameters of the phase lock loop. The resulting Bandwidth is displayed.
-After closing the Loop, the green led is lighted on if the Lock Voltage is OK.

In the actual software version, no step can be skipped.

VCO Measurement Menu

This method is mainly dedicated to unstable sources, such as free running VCO. The user can also prefer to use this method for noisy PLL sources, because there is no phase lock loop in the measurement process (stable phase lock loop of the reference source with the PLL method is difficult to achieve with noisy source).

There are two modes to run a measurement:

- 🟡 The Manual mode, for which the user has to select all the parameters to define the measurement.
- 🟡 The Auto mode, for which the system selects these parameters automatically.

1) VCO Methode, Manual Mode Window
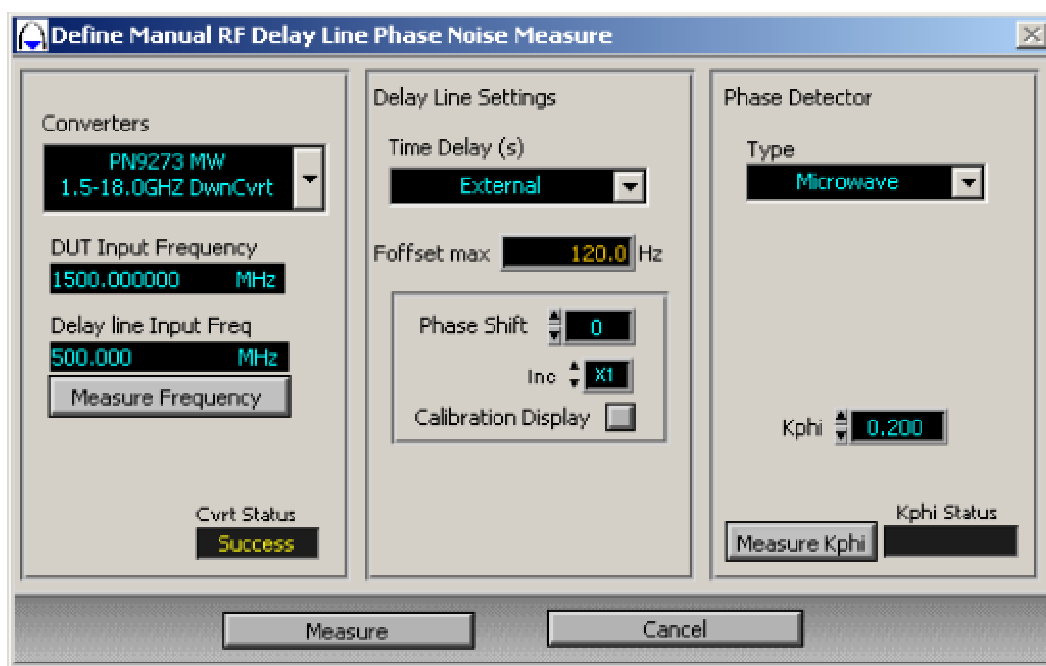
CONVERTERS: According to the DUT frequency, select the appropriate up or down converter reference source driver.

DUT FREQUENCY: Enter the carrier frequency under test, the system selects the right reference source for the Down converter automatically.

DELAY LINE OPERATING FREQUENCY: Beat frequency obtained from the Down converter output. This beat frequency should be compatible with the basic range of the delay line (250MHz to 2GHz).

MEASURE FREQUENCY: Run a measurement of the frequency loading the delay line.

TIME DELAY: Selection of the delay line length, 100nsec or 20nsec for the standard module.

F Offset max: The delay line method limits the measurement offset, depending on the delay line length. This parameter displays this maximum offset. See Application Note VCO.

PHASE SHIFT: Manual control of the phase shifter. "Calibration display": visualization of the phase detector output according to the phase shifter position. The phase detector output is a DC voltage that corresponds to the phase difference between the RF and LO channels.

TYPE: Selection of the phase detector.

RF/LO GAIN : The PN9000 input front end includes amplifiers to adjust the RF/LO levels to the standard operating value.

RF gain = 0 , +10dB , +20dB , -10dB.
LO gain = 0 , +10dB.

These values are not calibrated and vary according to the frequency. The maxima output levels of these amplifiers are +13dBm. They can be used only for the standard RF phase detector (from 2MHz to 1.8GHz). There is no need for RF/LO levels to be precise, they just have to be sufficient to generate a calibration factor: Kphi > 0.05 (obtained for RF > -6 dBm). These amplifiers should not be used in normal operating conditions; they introduce added noise and increase the noise floor.

Kphi: Displays the current calibration factor.

MEASURE Kphi: Runs the measurement process for the calibration.
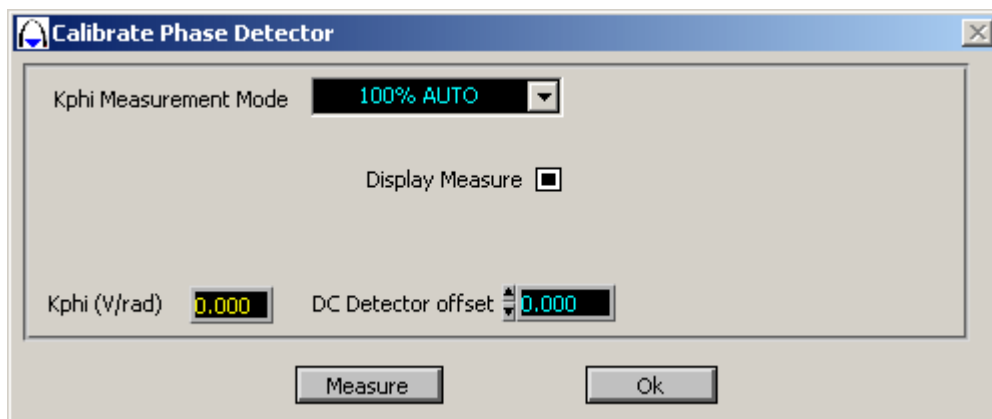
Kphi measurement mode: The standard mode is "100% Auto"; the system controls the phase shifter to adjust the quadrature on the front end phase detector. Then the system selects a calibrated phase shift to measure the demodulation factor "Kphi".

-DC offset:
-Beat DC/Vdc:

MEASURE : Run the calibration process. This measurement can be displayed or not ("Display Measure" on/off). The result is expressed in term of Kphi (V/rad). The minimum valid limit is: Kphi > 0.05. If Khi < 0.05, the RF input level is too low. In normal operating conditions these amplifiers should not be used, they introduce added noise and increase the noise floor. The output level of the Delay Line module is compatible with good calibration factor range.

OK : Go out the window.

After entering all the parameters, the user can run a measurement "Measure" or quit this window "Cancel".

2) VCO Method, Automatic Mode Window
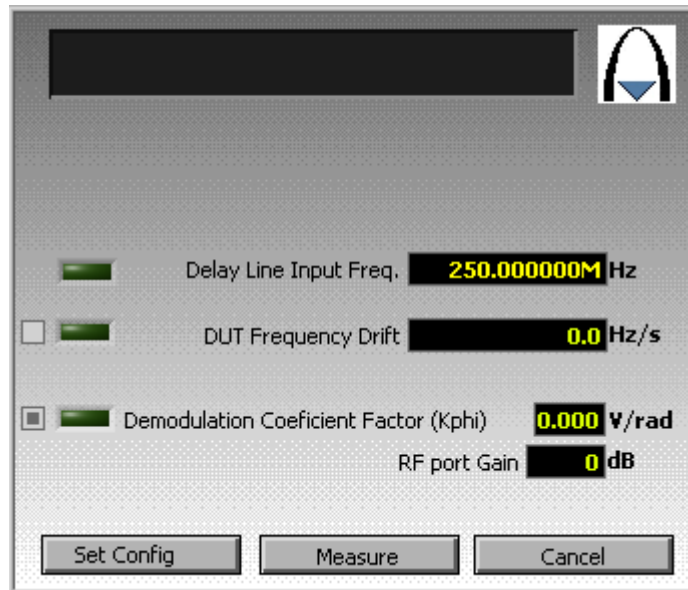
Before running a measurement some parameters can be selected (the delay line length):
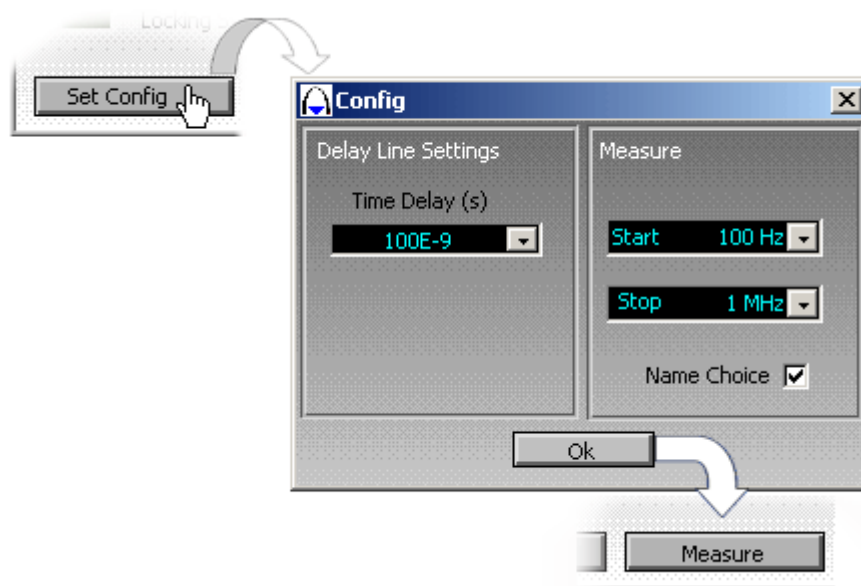
The system follows a standard measurement process whose steps are:

- 🟠 Measure the DUT frequency.
- 🟠 Adjust the quadrature.
- 🟠 Measure the calibration factor.
- 🟠 Run the measurement.

Step 1: DUT frequency measurement.
-The frequency counter is connected to the RF channel (just after the RF amplifier gain), the sensitivity is -10dBm. The frequency has a range from 2MHz to 2GHz.
-After measuring the frequency, the value is reported in the window.

Step 2: DUT stability check (not yet operating).

Step 3: Calibration. See the manual mode for details.
The system uses a calibrated phase shift. Input level adjustment: if the calibration factor "Kphi" is too low, the system adjusts the RF input gain to increase "Kphi".

CANCEL: To stop the process.

AM Noise Measurement Menu

The simplest noise measurement

> ✏️ The principle:
>
> AM measurements are done using a low noise crystal detector. The analysis can be done from 1kHz to 40 MHz offset from the carrier.

The Complete Automatic Measurement.
The wizard shows the exact cable setting with a drawing where the user can interact with. This first screen is mainly related with the hardware configuration. The analysis bandwidth is set in this window moving the square cursors. After the user has configured the system and set the required parameters the wizard proposes two methods: the manual one and the automatic one.
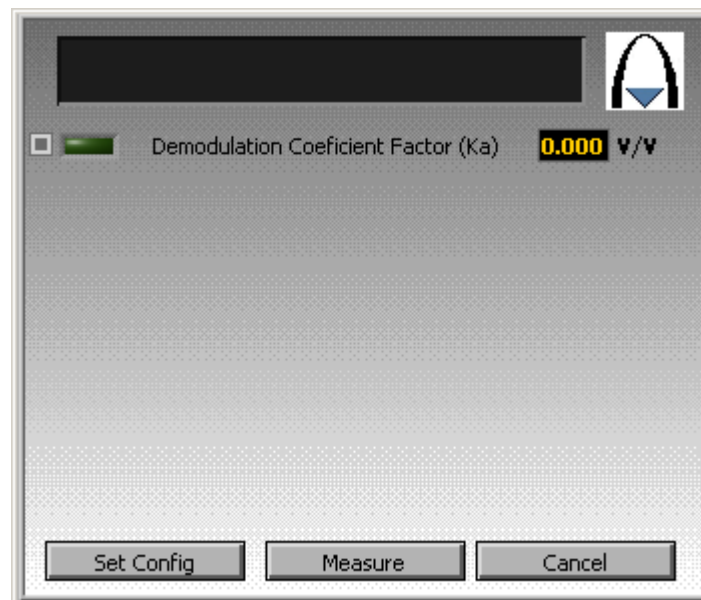
When "auto" is selected, the second window shows the different steps to perform the measurement. It can be customized. The user can skip the calibration process.
When the process is done, the measurement is started and the result window is opened with the "Measure Control" box (if not already opened).

The Manual Way.
After configuring the first window like the automatic way, the user can prepare the measurement by manually choosing the calibration parameters according to his knowledge, measuring the demodulation factor.

A manual process to prepare an AM noise measurement is usually 3 steps:

- 🟠 Choose the calibration method,
- 🟠 Press the "Measure Ka",
- 🟠 Then press the measure button.

When the measure is done, the user can store and recall any plot in memory or on disk.
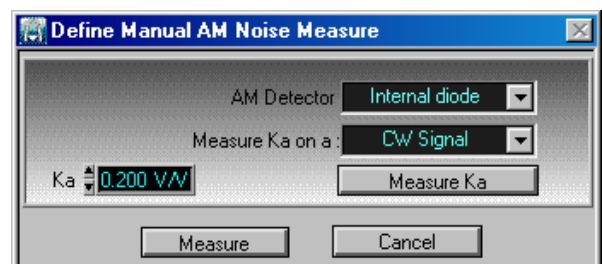
Noise Voltage Measurement Menu
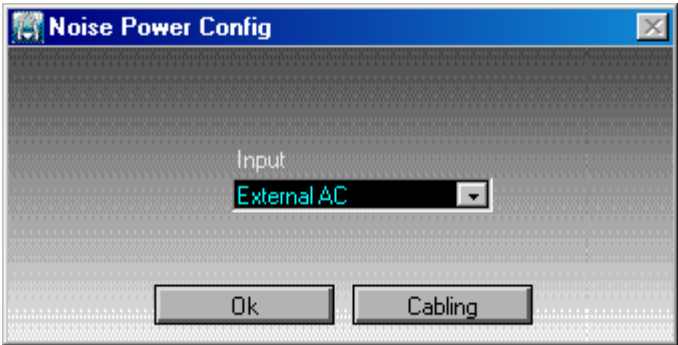
Choose the input External AC, External DC or External LNA. You can display the cabling method to get more information.

This measurement method is available in manual mode only.

Added Noise Measurement Menu

Select the frequency range, RF or Microwave.
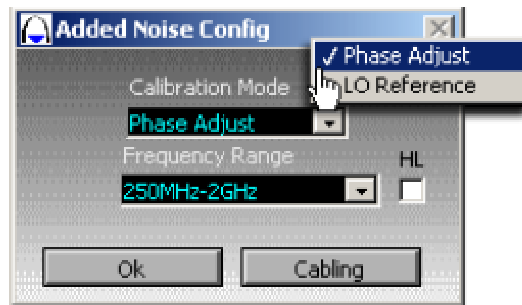
Calibration Mode: There are two modes "Phase Adjust" and "LO Reference":

- ● Phase Adjust: The calibration will be performed by moving an internal phase shifter.
- ● LO Reference: The calibration will be performed by remplacing the LO signal by an external source in order to set a beat frequency between RF an LO ports.

HL: Enable High Level Mode.

Measurement Phase Adjuste process:

There are two steps to run a measurement (See: Application Note Added noise):

1) Calibrate the demodulation factor and adjust the phase.
2) Run the spectral analysis (measurement).

On Line Help

---
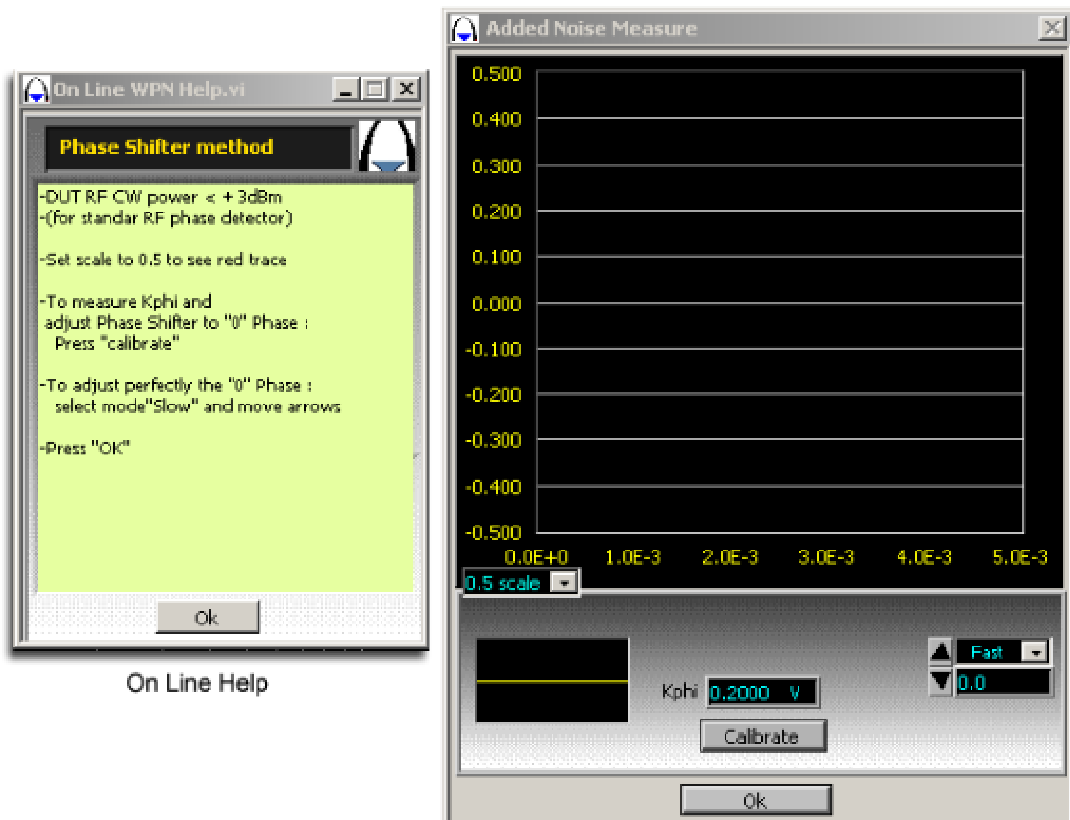
1) Calibration:

When opening this window, the system is set on calibration mode: free running, DC coupling. The system stays on free running mode to perform the calibration, there are two cases: "Manual phase shifter" or "Automate phase shifter".

Manual phase shifter: The operator adjusts the quadrature, or zero DC value. The operator has to move the mechanical phase shifter until he gets the maximum or the minimum DC value. Press the "Kphi Set" key to register this value. After pressing this key, the operator has to move the demodulation voltage to "zero", which is represented by the green line.

Automate phase shifter: The system automatically controls the phase shifter. In microwave range the automate phase shifter is called "Colby"; (Option 9841-10).

In RF range: The phase shifter is always automatic.

During the phase shifter move, the bottom black box shows the demodulation voltage making easier the setting at the maximum or minimum. From this display, the system shows the current Kphi measured at the maximum or the minimum value. For a standard input power.

Clear: Reset the Kphi value.

2) Measurement:

After the zero DC value is obtained, press the "Measure" key.

Measurement LO Reference process:

On Line Help
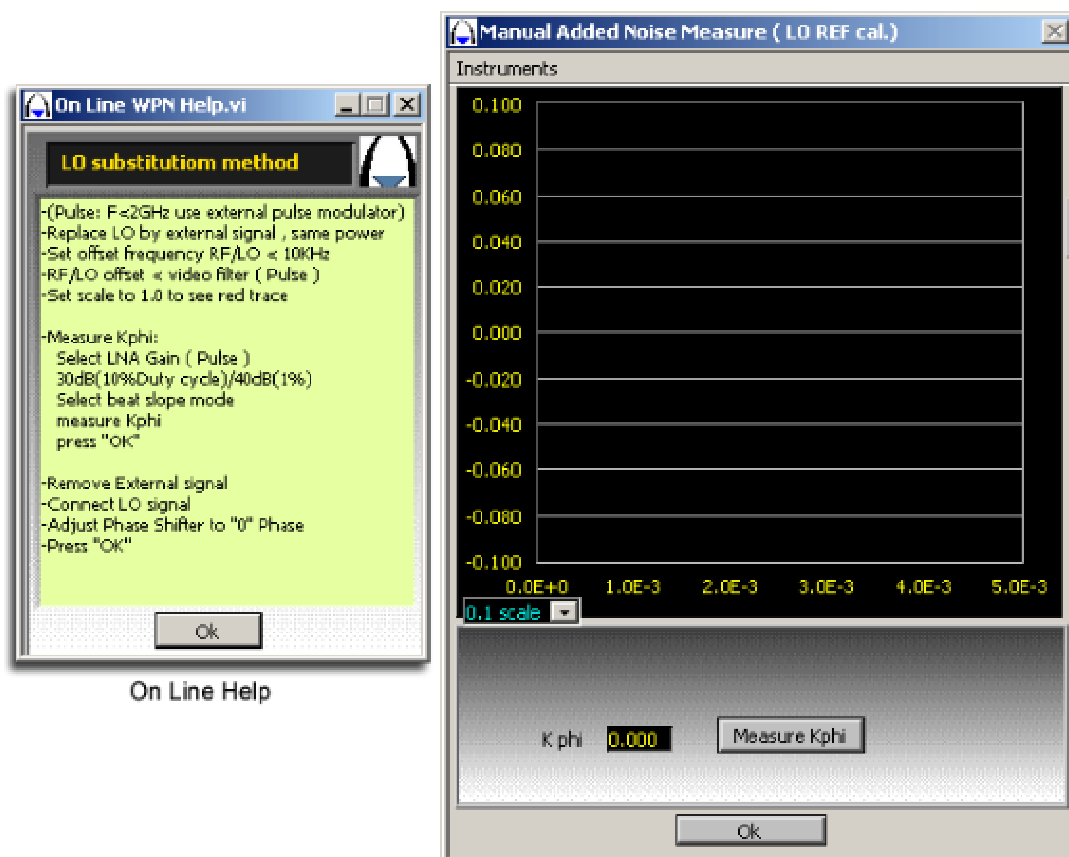
1） Calibration:

The LO Channel is remplaced by an external source with the source power. The frequency offset should be … than 10 KHz to perform the calibration with the "Beat Slope" method as for the PLL meyhod.

1） See on sinus if the beat signal is correct.
2） Press "Measure Kphi".
3） Remove the second source and connect the added noise LO channel.

2） Measurement:

After the zero DC value is obtained, press the "Measure" key.

Notice: if it has been installed, the "Phase Shift" function corresponds to the RF phase shifter only (included in the PN9715 module). The microwave phase shifter has to be moved manually.

Pulse Measurement Menu

⚠️ This measurement method is available in manual mode only.

Manual Mode Window (Screenshots)

Units :

"N" for nanosecond.
"U" for microsecond.
"M" for millisecond.

Introduction

In order to measure a pulse modulated signal, the PN9000 system will have to cope with the following problems:

1) Loss of power:

The average or "rms" power, decreases in accordance with the duty cycle of the pulse signal. The exact loss of power is given by the formula 20 log (duty cycle). Thus, for 10 % duty cycle the rms power of the modulated signal is 20 dB lower than in CW, and for 1% duty cycle it is 40 dB lower (100 times as low!). As a result, the detected phase noise will also be lower at the same ratio. To display the real noise of the modulated signal and to control the measurement process (such as the lock control) the software will have to compensate it by computing an offset which corresponds to the duty cycle. That is the reason why the software menu needs the value of the duty cycle.

As a consequence, the residual noise of the system will increase in the same proportions. Generally it is not a problem because pulsed sources are mostly in the MW range and have a higher phase noise than RF sources. However one must pay attention to it. The system has also to compensate the loss of the phase lock loop sensitivity due to the duty cycle.

With a lower input power, it could be tricky to calibrate the phase detector. So the PN9000 software includes a gain adjustment to prevent from this (used for calibration only).

2) Bessel response for spurs:

The power of a pulsed signal is split around the carrier on the fundamental and harmonics of the pulse signal. It can easily be seen thanks to a spectrum analyzer. These "spurs" are very powerful and can saturate the LNA used to bring the phase noise, which is low by nature, to the operating input level of the A/D converter. A filter (called video or PRF filter), will be connected between the phase detector output and the LNA input. The optimized cut value for this filter is half the PRF because this is the useful frequency range of a pulsed signal without aliasing problem.

3) DC offset of the detected phase noise signal:

When the reference source is in CW mode and the DUT is in pulse mode, the DC offset voltage at the output of the phase detector can be larger than the useful beat signal. Sometimes this beat signal never crosses the zero voltage needed to calibrate and to lock the reference. The PN9000 software includes a special function to solve this problem (DC offset compensation).

It is very useful to use a reference source when operating in CW mode because it makes the operating mode easier. Then there is no need to pulse and trigger the reference.

Advice for measurements

In addition to the above phenomena, the jitter (or phase noise) of the pulse generator can contribute to increase the noise of the pulse modulated signal, although this is difficult to quantify.

The PN9815 option is a single slot module that has been designed to prevent from this problem. It includes two functions: a pulse generator and a microwave pulser.

The pulse generator is driven from of a crystal oscillator and digital circuits to adjust PRF and duty cycle from the PN9000 software. The use of the PN9815 is strongly advised to generate a low noise pulse waveform.

The microwave pulser, driven by the pulse generator, can be used for two purposes:

- To generate a pulsed signal from a CW signal.
- To generate a pulse window allowing measurement at a specific place in the initial DUT pulse.

For example: If the noise contribution of the rising and falling edge has to be removed, the PN9815 can be programmed with a smaller pulse width in order to remove this part of the initial pulse.

The PN9813 option is a single slot module which provides 5 video filter values. They are selected from the software. These values must be specified by the customer when the purchase order is placed. Additional values can be provided in a second module, upon request. There is no time limit.

The PN9341 phase detector option must be used because it includes the SMA connectors to connect the video filter. They are located on the front panel.

One must take care of the increase of the residual noise due to power reduction.

For example: If the MW phase detector is used, the residual noise of the base system will be −165 dBc/Hz at 10 kHz offset with +6 dBm CW RF and LO inputs. With a 10 % duty cycle pulsed signal, the residual noise of the base system will increase by 20 dB, i.e.−145 dBc/Hz, which still allows to measure very clean radar sources. With 1 % duty cycle it will be reduced to −125 dBc/Hz.

Measurement Methods

1) RF or MW DUT with Direct Phase Noise detection:

➡ See the appendix of the WPN9000 manual to get a picture of the diagram.

- Up to 1.8 GHz with the standard RF phase detector.
- Up to 4.5; 9 & 18 GHz with the MW phase detector.

This depends on the PN9100 options implemented in the system.

The only drawback of this method is that the built-in counter will not measure MW RF and LO inputs of the phase detector between 1.8 to 2.0 GHz. It will measure the IF beat only with a maximum value of 400 KHz. If the beat value is higher than 400 KHz, an external counter or a spectrum analyzer will have to be used.

2) MW signal down converted to the RF Frequency range:

➡ See the appendix of the WPN9000 manual to get a picture of the diagram.

This method requires the use of a MW down converter (PN952/55, PN9253/54 or PN9273/74), to down convert the MW DUT signal to the RF frequency range of the PN9000 base system. This configuration, used for low noise MW source phase noise measurements, provides two advantages:

- Lower residual noise (noise floor), see the PN9253/54 and PN9273/74 datasheets for the specifications.
- The built-in counter will measure RF & LO inputs and IF beat output of the standard RF phase detector. This makes the LO tuning to the RF input frequency much easier.

Note: IF the DUT is already a pulsed signal, the PN9815 can be removed. The pulse generator waveform of the PN9815 can still be used to drive the DUT pulse.

Measurement Process

Whatever the method is (direct or down conversion), the measurement process will be the same as for an RF or CW signal with some additional settings due to the pulse modulation. The process will include:

- 🟠 Signal connections
- 🟠 Parameter settings.
- 🟠 Tune LO to the DUT frequency signal, directly or through the MW down converter.
- 🟠 DC offset compensation.
- 🟠 Phase detector calibration.
- 🟠 Phase locking LO on RF signal.
- 🟠 Measurement.

1) <u>Connections & Input Levels</u>:

> 📝 To make easy measurements, a good level of the DUT signal is 0 to +10 dBm for duty cycle > 5 % and + 5 to + 10 dBm min. for duty cycle < 5 %.
>
> (When the DUT is a CW source, connect the DUT signal to the "CW RF input" of the PN9815 to generate a pulsed signal).

- When the direct phase noise detection is used, connect the "Pulsed DUT output" to the "RF input" of the PN9341 phase detector.

- When a down converter is used, connect the "Pulsed DUT output" to "DUT input" of the MW down converter, and "IF output" to the "RF input" of the PN9341 phase detector.

- Connect the PN9100 output to the PN9341 LO input. The output level of the PN9100 is +10 dBm.

- Connect "Tune voltage" of noise output module to "FC Tune" of PN9100 module.

- Connect "External input" of the PN9341 phase detector to the "Video Input" of the PN9813 video filter and the output to the "2nd LO input" of the PN9341 phase detector.

2) <u>Configuration Settings</u>:

Use the following menus to set up the measurement configuration:

- Select the Wizard "Pulse".

- Select "Source".

- Select the frequency range: RF or Microwave.

- Select the "Manual" menu.

3) <u>Pulse Configuration</u>:

This selection has two purposes:

- Program the PN9815 and the PN9813 modules.

- Define the pulse configuration for the pulse compensation software.

Select in the top box : "Pulse config" / "Pulse" , to open the pulse setting menu.
Select the pulse width and the repetition rate (units: N for nanosecond, U for microsecond, M for millisecond).
The system computes the corresponding duty cycle and PRF.
Select the video filter (≤ 1/2 PRF).
PRESS: "SEND TRIG" and press "OK" to quit the menu.

4) Carrier frequency:

In the "Manual" menu, select:

- The carrier frequency.

- The frequency increment (used during the calibration process, this increment should be lower than the video filter (select a value between ½ PRF and 1/10 PRF).

- The FM range:
   FM1 for duty cycle > 10%
   FM2 < 10%

Measure the IF frequency between the two sources, and approach the reference if needed (the residual beat signal should 10 times as low as the Loop Bandwidth used to lock the reference).

5) Open the "Scope":
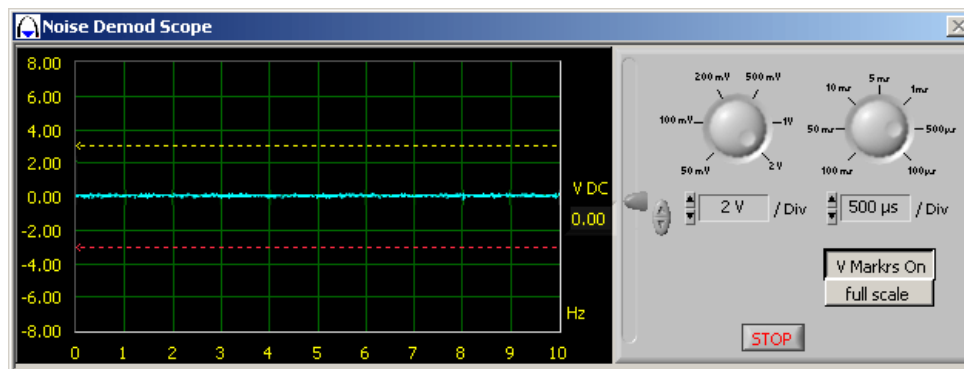
In the "Instrument" menu, select "Scope" and place it on the bottom right of the display, just along the "Manual" menu, in order not to hide the "Manual" menu and not to hide the calibration display. Select the full range scale: +/- 5 Volts, and Time=1msec (click on the Scope button).

6) Calibration:

Select the menu "Manual" : calibration.

Select the modes "Beat slope" and "both (mean)".

Select gain (20dB , 30dB , 40dB) according the pulse power , increase the gain up to 40dB for low duty cycle (= low pulse power).

Select: "measure". The system set an frequency increment (defined in the "Manual" menu) and run the calibration. If the power is too low, increase the gain up to 40dB, or increase the DUT output power up to +10dBm.
On the calibration signal check if the two slopes, negative and positive (in green and in red) are detected, if not: run a new measurement. In any case run several measurements to be sure the detected slope is

stable. In case of problems change the beat frequency from ½ PRF down to 1/10 PRF. During this process, the "Scope" also displays this beat signal.

The software detects the DC offset of the beat signal and compensates it automatically. The display shows only the AC part and report the DC value in the menu. At this point the system knows the DC offset at the output of the phase detector, and will able to compensate its effect on the measurement process.

    7) <u>Lock process</u>:

        a) Set the Loop Bandwidth and the beat frequency

        Press the "Default" button, the initial default value is displayed, then the system computes the maximum value taking into account the pulse parameters (calibration factor, duty cycle…).

        If the final value is too low (< 100Hz), then change the FM range of the reference (for the PN9100 select FM2 instead of FM1).

        Remove: "drift compensation" (off = clear the box).

        b) "Scope" setting

        The "Scope" will be used to check if the locking process is well operating (generally the Bar graph is not sensitive enough under pulse conditions).

        Select the y scale in order to have a nice representation of the beat signal, change the scale with the increment keys . Change the time scale (10msec, 50msec, 100msec) to get several periods of the beat signal in order to display correctly the maximum and the minimum voltage (if the beat is too low: move the reference RF frequency with the increment keys to get a beat), then press "Vmark" to set the reference lines used to check the locking process (then remove the beat with the same increment keys , the residual beat should be 10 times lower than the Loop Bandwidth).

        The reference frequency can also be moved with "Vcontrol" (use a small increment).

> Note: A good locking process is obtained when the final lock voltage is closed to the average value between the maximum and minimum, represented by a red line.

        c) Close the Loop

        Press "Lock on ". The system applies a DC Voltage offset in order to compensate the effect of the phase detector DC offset and : locks the reference, waits few seconds and tests the lock condition (the test can be removed in case of problems, in this case the operator can manually, with Vcontrol and with the scope, perform the Lock).

        The DC offset compensation can be seen by opening the Vcontrol menu.

        The good operating lock process can be checked on the "Scope", there are three possibilities:

- 🟡 The "Scope" still displays a beat signal , the system is unlocked, the lock process failed.
- 🟡 the "Scope" displays a DC voltage, but far from the average value (red line), the system is locked but far from the quadrature, the lock process failed.
- 🟡 The "Scope" displays a DC voltage closed to the average line (red line), the system is locked and is in quadrature, the lock process is ok.

        If the lock process is still defective, either:

- The two sources are too far so approach the reference.
- The loop bandwidth is too small so increase the bandwidth if possible.
-

Move the reference with Vcontrol to perform the lock (remove the lock process test).

Note: If the lock process failed and if the lock test is "on", the measurement will not start.

8) Measurement:

Run the spectral analysis.
The useful span is up to half the PRF, but a larger span can be set.
The spectrum will display the PRF lines, but in case there is no video filtering, the remaining part of the PRF is not a trouble.

NOTE: Video Filters:

Video filters specifications:

- Filter-type: Low-pass, 4 or 6 poles.
- Load impedance: 200 Ohms.
- Cut frequency: ½ PRF (pulse repetition frequency).

Video filters are used to reduce the PRF spurs during the spectral analysis of the pulsed phase noise. A 40dB attenuation of the PRF is needed, only not to saturate the low noise amplifier. The valid span analysis is half the PRF.
For example: if PRF= 100KHz, use the video Filter 100KHz in the "DESIGN/PULSE" menu. Then the valid span analysis is 50KHz.

Pulse Added Noise Measurements

Units:

"N" for nanosecond.
"U" for microsecond.
"M" for millisecond.

Introduction:

In order to measure a pulse modulated signal, the PN9000 system will have to cope with the following problems:

1) <u>Loss of power</u>:

The average or rms power decreases in accordance with the duty cycle of the pulse signal. The exact loss of power is given by the formula 20 log (duty cycle). Thus, for 10 % duty cycle the rms power of the modulated signal is 20 dB lower than in CW, and for 1% duty cycle it is 40 dB lower (100 times as low!). As a result, the detected phase noise will also be lower at the same ratio. To display the real noise of the modulated signal and to control the measurement process (such as the lock control) the software will have to compensate it by computing an offset which corresponds to the duty cycle. That is the reason why the software menu needs the value of the duty cycle.

As a consequence, the residual noise of the system will increase in the same proportions. Generally there is no problem because pulsed sources are mostly in the MW range and their phase noise is higher than the one of RF sources. However one must pay attention to it.
The system has also to compensate the loss of the phase lock loop sensitivity due to the duty cycle.

With a lower input power, it could be tricky to calibrate the phase detector. So the PN9000 software includes a gain adjustment to prevent from this (used for calibration only).

2) <u>Bessel response for spurs</u>:

The power of a pulsed signal is split around the carrier on the fundamental and harmonics of the pulse signal. It can easily be seen with the use of a spectrum analyzer. These "spurs" are very powerful and can saturate the LNA used to bring the phase noise, which is low by nature, to the operating input level of the A/D converter. A filter (called video or PRF filter), will be plugged between the phase detector output and the LNA input. The optimized cut value for this filter is half the PRF because this is the useful frequency range of a pulsed signal without aliasing problem. With a lower input power, it could be tricky to calibrate the phase detector. So the PN9000 software includes a gain adjustment to prevent from this (used for calibration only).

Advice for measurements:

In addition to the above phenomena, the jitter (or phase noise) of the pulse generator can contribute to increase the noise of the pulse modulated signal, although this is difficult to quantify.

The PN9815 option is a single slot module that has been designed to prevent from this problem. It includes two functions: a pulse generator and a microwave pulser.

The pulse generator is driven from of a crystal oscillator and digital circuits to adjust PRF and duty cycle from the PN9000 software. The use of the PN9815 is strongly advised to generate a low noise pulse waveform.

The microwave pulser, driven by the pulse generator, can be used for two purposes:

- To generate a pulsed signal from a CW signal.
- To generate a pulse window allowing measurement at a specific place in the initial DUT pulse.

For example: If the noise contribution of the rising and falling edge has to be removed, the PN9815 can be programmed with a smaller pulse width in order to remove this part of the initial pulse.

The PN9813 option is a single slot module which provides 5 video filter values. They are selected from the software. These values must be specified by the customer when the purchase order is placed. Additional values can be provided in a second module, upon request. There is no time limit.

The PN9341 phase detector option must be used because it includes the SMA connectors to connect the video filter. They are located on the front panel.

One must take care of the increase of the residual noise due to power reduction.

For example: If the MW phase detector is used, the residual noise of the base system will be -165 dBc/Hz at 10 kHz offset with +6 dBm CW RF and LO inputs. With a 10 % duty cycle pulsed signal, the residual noise of the base system will increase by 20 dB, i.e. -145 dBc/Hz, which still allows to measure very clean radar sources. With 1 % duty cycle it will be reduced to -125 dBc/Hz.

Added Noise Measurement Methods

1) Block Diagram:

➡ See the appendix of the WPN9000 manual to get a picture of the diagram.

Measurement process

1) Connections & Input levels:

To make easy measurements, a good level of the RF input (output of the DUT) is 0 to +6 dBm.
-Connect the reference source to the microwave pulser PN9815 and the added noise module PN9841.
Take care: PN9841 input Level is 0dBm (If the PN9100 is used, put a 10dB pad).
-Connect the DUT between the PN9841 and the microwave phase detector.

⚠Care:
1] The average output power of the PN9841 is +15dBm, adapt this level to the DUT input.
2] The RF input power of the phase detector is between 0 / +6dBm.

-Connect "External input" of the PN9341 phase detector to the "Video Input" of the PN9813 video filter and the PN9813 output to the "2nd LO input" of the PN9341 phase detector.

2) Configuration Settings:

Use the following menus to set up the measurement configuration:

- Select the Wizard "Pulse".
- Select "Added Noise".
- Select the calibration method: Phase shifter or external LO substitution.
- Select the frequency range , RF or Microwave.
- Select the Menu "Manual".

3) Pulse Configuration:

This selection has two purposes:

- Program the PN9815 and the PN9813 modules

- Define the pulse configuration for the pulse compensation software.

Select in the top box: "Pulse config" / "Pulse" , to open the pulse setting menu.
Select the pulse width and the repetition rate (units: N for nanosecond, U for microsecond, M for millisecond).
The system computes the corresponding duty cycle and PRF.
Select the video filter (≤1/2 PRF).
PRESS: "SEND TRIG" and press "OK" to quit the menu.

4) Carrier frequency:

In the "Manual" menu, select:

- An external source can be used instead of the PN9100.

5) Calibration:

Select the menu "Manual": measure Kphi
According the selected method of calibration: Phase shifter or LO substitution, there are two different menus. On the top left of the screen, the calibration procedure is described.

6) Measurement:

Run the spectral analysis.
The useful span is up to half the PRF, but a larger span can be set.
The spectrum will display the PRF lines, but according there is a video filtering, the remaining part of the PRF is not a trouble.

NOTE: Video Filters:

Video filters specifications:
Filter-type: Low-pass, 4 or 6 poles
Load impedance: 200 Ohms
Cut frequency: ½ PRF (pulse repetition frequency)
Video filters are used to reduce the PRF spurs during the spectral analysis of the pulsed phase noise.
A 40dB attenuation of the PRF is needed, only not to saturate the low noise amplifier. The valid span analysis is half the PRF.

For example: If PRF= 100 KHz, use the video Filter 100 KHz in the "DESIGN/PULSE" menu. Then the valid span analysis is 50 KHz.

Setling Time Measurement (Option PN3000)

The target is to measure the switching time of a frequency source when switching from F1 to F2.
The measurement is done on phase acquisition; the frequency acquisition can be computed on the final phase acquisition slope.
In other words, how long does it take to be at N degrees from the phase stabilization (or at N Hz) of the final frequency F2 .
The PN3000 option includes the software function and the PN9811 hardware module.

Principle of Operation
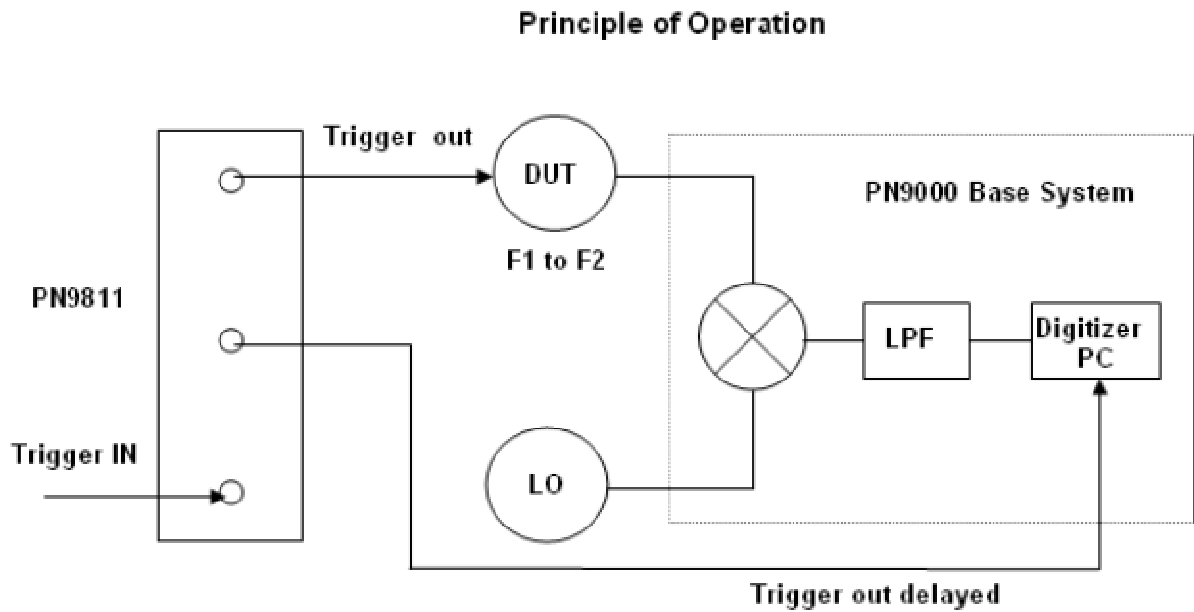
The principle of the measurement is to record the phase transient generated on a DUT which switches frequency from F1 to F2. The Test Set acts as a phase receiver at the final frequency F2, the frequency acquisition, which is the frequency offset ΔF from F2, is computed from the final phase transient slope. The phase acquisition is measured within ± 90° of the final phase, the corresponding frequency acquisition is computed with $\Delta F = \Delta \Phi / (360 \, T)$, this process is perfectly adapted to small frequency offset ΔF over short time T.

PN9811 Trigger Module

A trigger is needed to control the measurement process: switching the source and providing T_0 (reference time) for the resulting phase acquisition plot . When there is no external trigger coming from the DUT , the PN9811 will give one when pressing the key "Measure".
The trigger sent to the processor board can also be delayed in order to display the result with an appropriate scale of time by removing a known delay from T_0.

PN3000 Specifications

- Frequency range: Same as PN9000 Phase detector module and PN9100 reference source.
- Scale time: 20ms to 50ms per division, or 200ms to 500ms (full scale) progression 1/2/5.
- Delay on "Trigger Acq": 100ns to 1s in 4 ranges.
- 100ns to 6.5535ms (step 100ns)
- 6.5535ms to 65.535ms (step 1ms)
- 65.535ms to 655.35ms (step 10ms)
- 655.35ms to 1s (step 20ms)

- Display : Frequency and phase

- A / Phase :

- Scale from −90° to + 90°.

- Accuracy < 0.15° up to 70°.

- B / Frequency : Computed from phase transient slope DF= DF / (360 T)

    Example : If DF < 10° over T = 1msec DF < 28Hz from F2

Measurement Process

Connect the DUT signal on the RF input port of the PN9000 phase detector module and the reference signal (PN9100) set at the final frequency F2 on the LO input port.
Connect the second cable from digitizing board (on the back of the PC) to the port : "Trigger Acq" of the PN9811 module .
To make a measurement :

- 1) Select "Setling Time" in the method.

- 2) Select Phase Acquisition in the Config button.
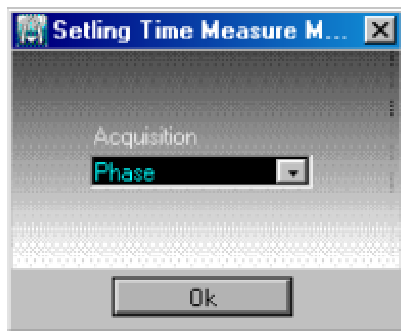
- 3) Select range Frequency.
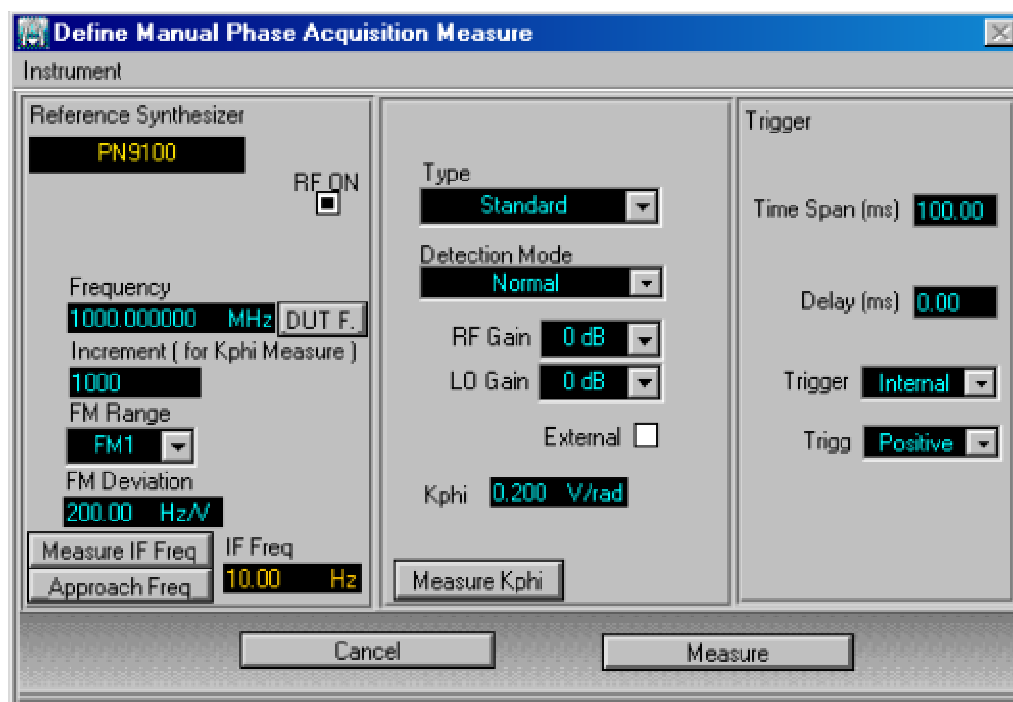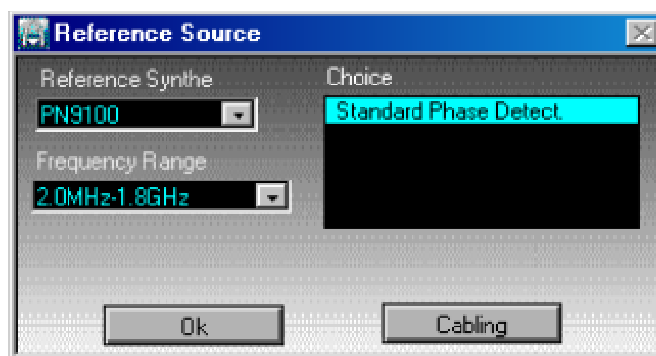
🔴 4.1) Approach Frequency.

Set the DUT at the final F2 frequency. Set the Reference source at F2 , in CW mode If the two sources RF and LO are not locked to the same time base (10MHz for the PN9100 , available on the front panel) this generates a low beat frequency at the output of the phase detector , the "phase acquisition" display will show this beat signal instead of stable phase . There is two solutions : either approach as close as possible the two sources (Press button "Approach Frequency") , or locked the two sources on the same time base.

🔴 4.2) Calibration.

The frequency beat used to measure the kphi is defined by the parameter 'Increment' in Hz. Press button "Measure kphi".

🔴 4.3) Select Trigger Mode.

If the trigger mode is set on "external", the start of the acquisition will wait until an external trigger signal is set on the input port "Trigger in" of the PN9811 module. If the trigger mode is set on "internal", the PN9811 module generates a trigger pulse (output port "Trigger out") and the acquisition starts immediately after pressing the button "Measure" from "Phase acquisition window".

🔴 7) Press the button "Measure" to get the "Phase acquisition" display windows.
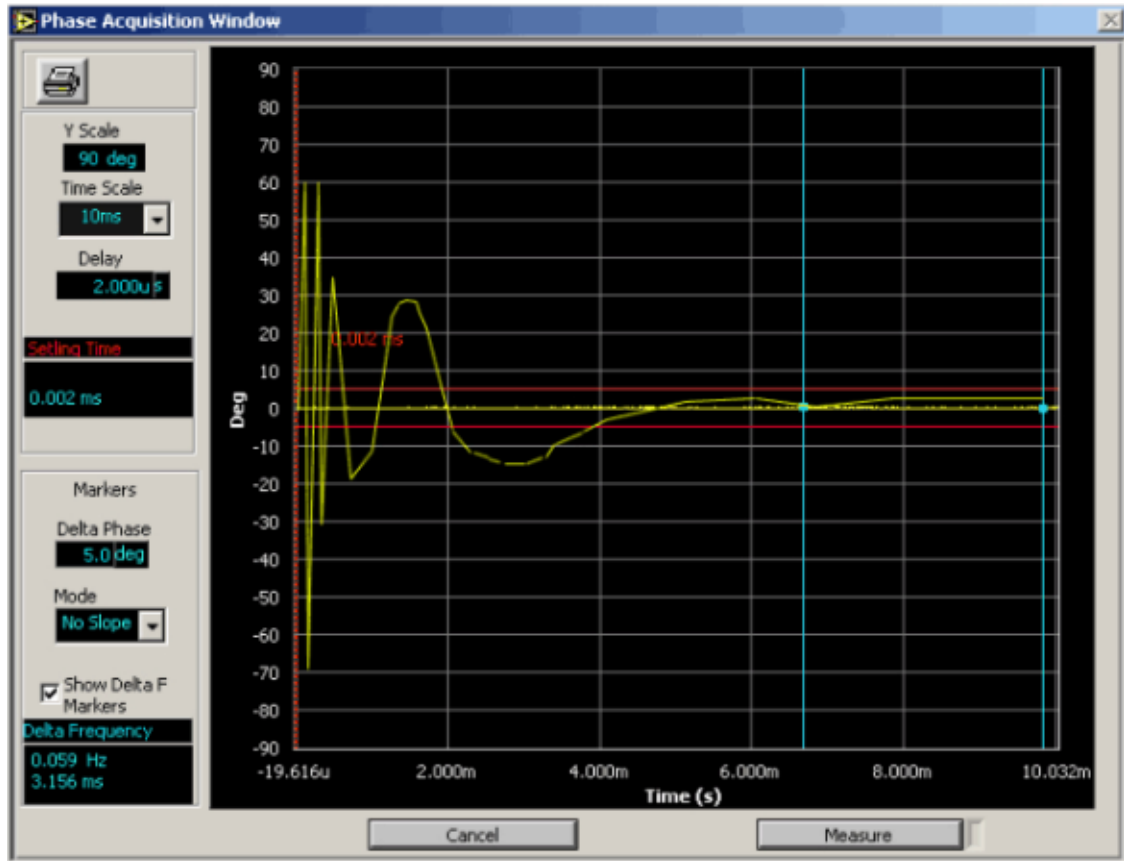
Y Scale: This parameter is used to adjust the Y axis representing the phase (± 90° maximum).

Time Scale: This parameter is used to adjust X axis representing the time domain .

To choose the scale time: select from 200µs to 500ms full scale.

Delay parameter: By selecting a delay value, it is possible to introduce a delay between the trigger start command and the start of the acquisition (delay between output port "Trigger out" and output port "Trigger ACQ"), this allows expending the time scale only during the significant transient time and letting the first part of the transition. Delay from 100ns to 1s with 4 ranges.

Markers menu: Delta Phase: Set two red lines marker offset by the value "Delta Phase".

Mode: No slope: The two lines markers are two horizontal lines.

Extended modes will be available

Show Delta F : Display the frequency offset computed on the phase acquisition curve , according the relation : delta F = delta F / (360 T) The two vertical blue lines define the range T of the computation and the position on the phase acquisition .

Measurement: Set the DUT to the start frequency (F1) and Press button "Measure".

Frequency Stability Measurement (Option PN3100*)

(*)PN3100: Option for long term frequency stability measurement.
The PN9000 has the capability to measure short term, 0.01msec to 10sec, and long term, 0.1sec to 10 000sec, frequency stability of very stable sources.

<u>Short Term Stability</u> is measured in processing the data of a phase noise measurement.

The short term Stability, in the range of 0.01msec to 10sec, is computed from the phase noise spectrum measured in the frequency domain.

To perform such analysis, use the menu ¦x / VARIANCE.
This feature is included in the standard PN9000 software, and need not any hardware option.

<u>Long Term Stability</u> requires the PN3100 option, it is measured with the built-in PN9000 frequency counter.

PRINCIPLE OF OPERATION
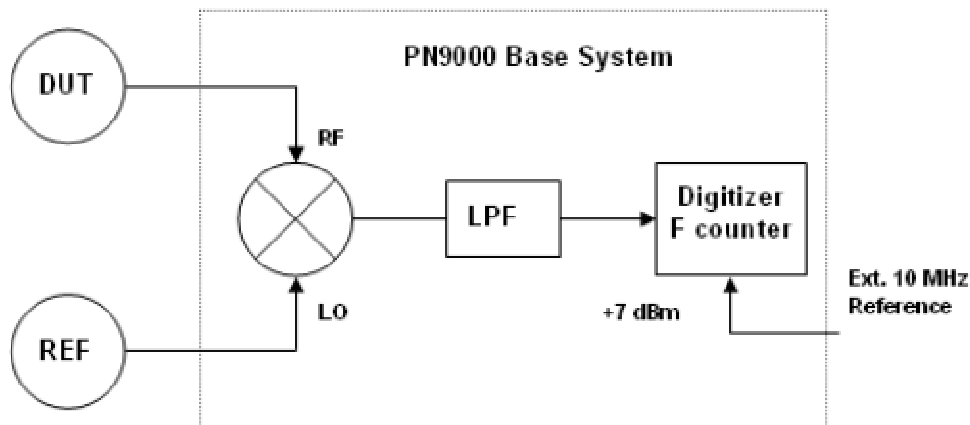
The DUT signal is connected to the RF input of the phase noise detector module and the reference source connected to the LO input. Since there is no phase locking, the phase detector operates as a mixer. DUT or Reference source will be tuned in order to obtain a low frequency beat at the out put of the mixer. This beat will be shown on the bar graph and measured with the PN9000 counter.
The stability of the reference source should be better than the DUT stability to be measured. A specific high stability source can be provided on request, the standard 10MHz time base of the PN9000 is not a long term high stability reference so the operator has to select an external reference source such as a Rubidium or Cesium clock .

<u>Frequency resolution</u> :

- 🟡 1/ Suppose a 10MHz DUT frequency.

- 🟡 2/ The frequency counter has a resolution of 1.10^{-7} for 1sec measurement (1.10^{-8} for 10sec .....) , a 1Hz IF can be measured with 1.10^{-7} Hz on 1sec

- 🟡 3/ Considering this IF is obtained by direct transposition of the DUT , the 1.10^{-7} Hz resolution on the IF corresponds to 1.10^{-14} resolution on the 10MHz DUT (1.10^{-15} resolution for 10sec ...)

Actually there are several factors which will limit the measurement accuracy to lower values. The first one comes from the reference source. It is easy to understand that the limit will be the stability of the reference. The second will be the stability of the frequency counter. The standard reference for the built-in counter is not ovenized, the "Digitizer board' , plug into the computer , provides an input connector for an

external 10 MHz (Module options are available for 10MHz ovenized xtal oscillators), the stability of this reference is not as critical as the input Reference Source used to transpose the DUT .The frequency counter needs only to be at 1.10^{-7} for 1sec measurement (see above) it is the reason any standard 10MHz ovenized xtal oscillator can be used .

IF Frequency :

🟡 1/ The minimum measurement time is related to the IF , with an IF = 1Hz the minimum measurement time will be 1sec , with an IF = 10Hz the minimum time will be 0,1sec .

🟡 2/ The IF has to be set exactly to a rounded value between 1Hz and 10Hz (1Hz , 2Hz 3Hz .... 10Hz , setting compare to a rounded value < 10%) .This IF is used to define the measurement time (one second measurement time is obtained by one clock with 1Hz IF and two clocks with 2Hz IF .....)

Before to start a measurement:

🟡 1/ Does the reference source has the long term stability compatible with the expected DUT performance.

🟡 2/ Is it possible to offset the Reference source and the DUT source by 1Hz / 10Hz.

🟡 3/ Does the Digitizing board is driven by an external 10MHz ovenized xtal oscillator

PN3100 Specifications

RESOLUTION:
The frequency counter resolution is 10^{-7} for 1Hz signal measured on 1sec.
The resolution depends on the downconvertion ratio and Time of sample measurement.

Resolution = $(10^{-7}$ beatF) / (Fo T).
Fo = DUT frequency.
T = time of sample measurement.
BeatF = downconverted signal frequency.
Example : for a DUT signal = 10MHz , Time of sample measurement = 1sec
and beat frequency = 10Hz , Resolution = $(10^{-7}$ 10Hz) / (10MHz 1sec) = 10^{-13} .

Resolution table, for 10MHz DUT

	Beat = 1Hz	Beat = 10Hz
Time = 0.1s	NA	10^{-12}
Time = 1s	10^{-14}	10^{-13}
Time = 10s	10^{-15}	10^{-14}
Time = 100s	10^{-16}	10^{-15}
Time = 1000s	10^{-17}	10^{-16}

RESIDUAL
A true measurement is limited by the resolution and the residual stability of the system. To measure this residual a synthesizer is used as reference on LO port and compare with its own time base on the RF port. See typical values in the next two tables for 1Hz and 10Hz beat frequency:

Residual test performed with a PN9100 RF synthesizer

Beat = 1Hz	Resolution	PN9100 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 PN9100 RF synthesizer

Beat = 10Hz	Resolution	PN9100 10MHz
Time = 0.1s	NA	10^{-12}
Time = 1s	10^{-14}	10^{-13}
Time = 10s	10^{-15}	10^{-14}
Time = 100s	10^{-16}	10^{-15}
Time = 1000s	10^{-17}	10^{-16}

Measurement Process

Hardware   configuration:
Connect the DUT on the RF port of the "RF phase detector" module .
Connect the Reference on the LO port.
Set a beat frequency between the sources, according the expected resolution.
Connect a 10MHz reference on the "Acquisition board', inserted in the back of the computer (BNC connector) .

To run a measurement:

- 🟠 1) Select the menu "Manual" .

- 🟠 2) Select "Curve" measurement or "One Point" measurement.

- 🟠 3) "One Point" menu :
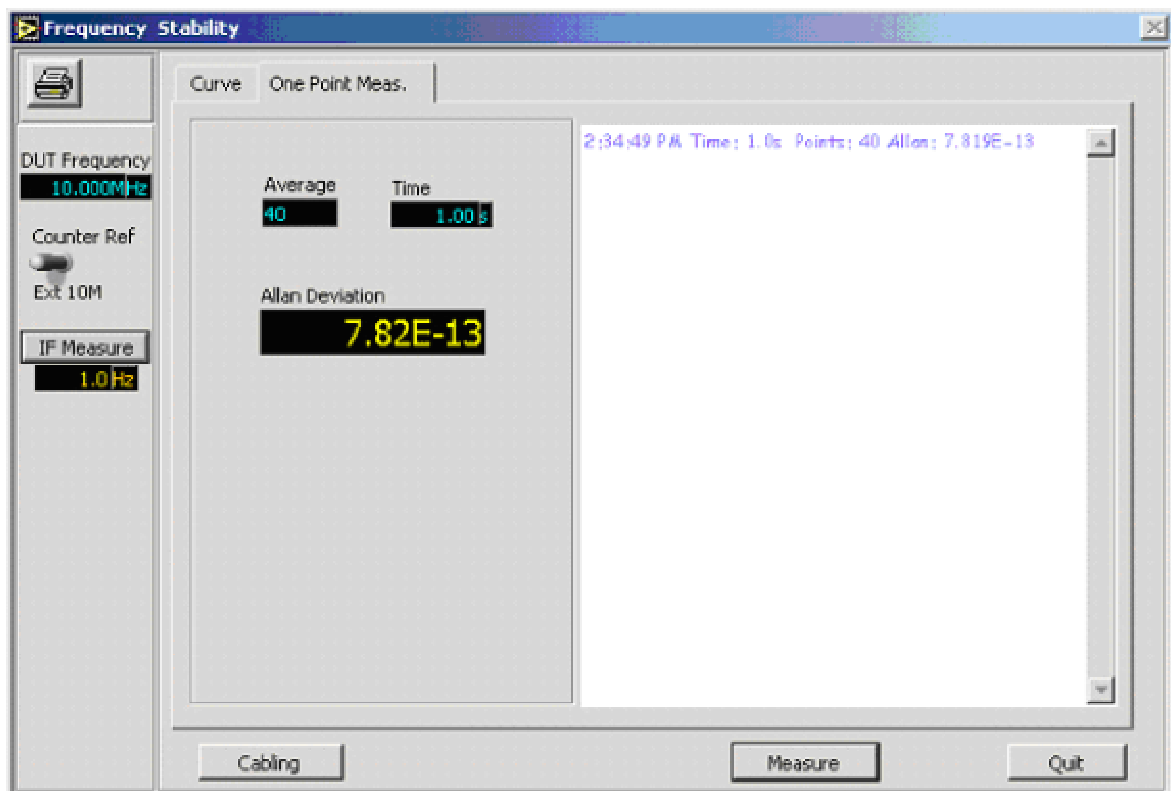
- ▪ 3 1) Select the DUT frequency (example : 10MHz)
- ▪ 3.2) Select the counter reference frequency , recommended : external (use the 10MHz time base)
- ▪ 3.3) The IF has to be set exactly to a rounded value between 1Hz and 10Hz (1Hz , 2Hz 3Hz .... 10Hz , setting < 10%) .
  This IF is used to define the measurement time (one second measurement time is obtained by one clock with 1Hz IF and two clocks with 2Hz IF .....)
- ▪ 3.4) Select : the number of averages , the time T (from 100msec to 10000sec)

▪ 3.5) Run : "Measure" , the result is displayed in the box : "Allan deviation" .

🔵 4) "Curve" menu :
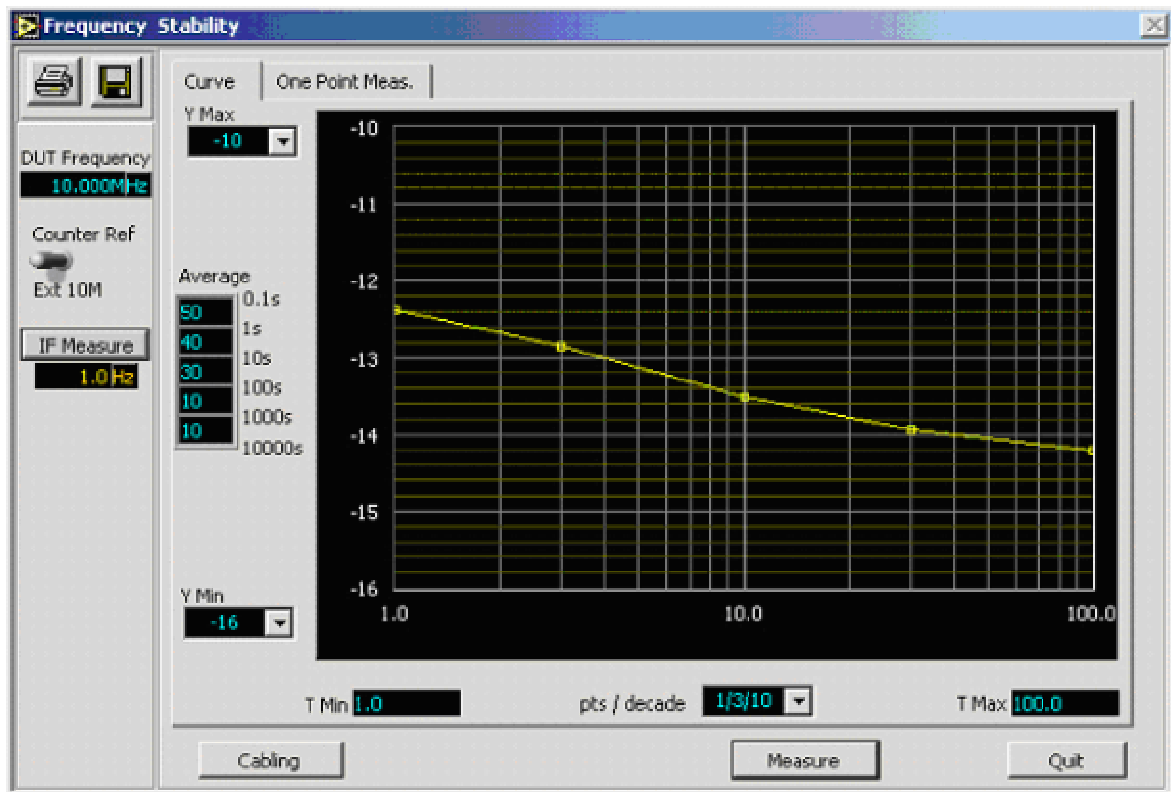
▪ 4.1) Select the DUT frequency (example : 10MHz)
▪ 4.2) Select the counter reference frequency , recommended : external (use the 10MHz time base)
▪ 4.3) The IF has to be set exactly to a rounded value between 1Hz and 10Hz (1Hz , 2Hz 3Hz ……. 10Hz , setting < 10%) .This IF is used to define the measurement time (one second measurement time is obtained by one clock with 1Hz IF and two clocks with 2Hz IF …..)
▪ 4.4) Select : the number of averages (defined for each decade of time) , the time scale (from 100msec to 10000sec) , the Y scale and the number of points per decade .
▪ 4.5) Run : "Measure" .

4

TOP BAR MENU

1. File Menu List

What follows is a list of recent additions to our web. Whenever we publish a paper, write a specification, submit a status report, or add anything else to our web, we'll put a notice here. Every month we'll remove the oldest items. The most recent changes are listed first, and each item is linked to the page with the updated content.

- Open Plot
- Save Plot
- Page Setup
- Print
- Dos Import
- BMP Export
- JPG Export
- PNG Export
- Text Export
- Reset
- Quit

Open Plot/Recall Data

Curves can be recalled from any directory and stored into WPN9000 memories: A B C....
First select the file to be recalled and saved into the memory A B C....
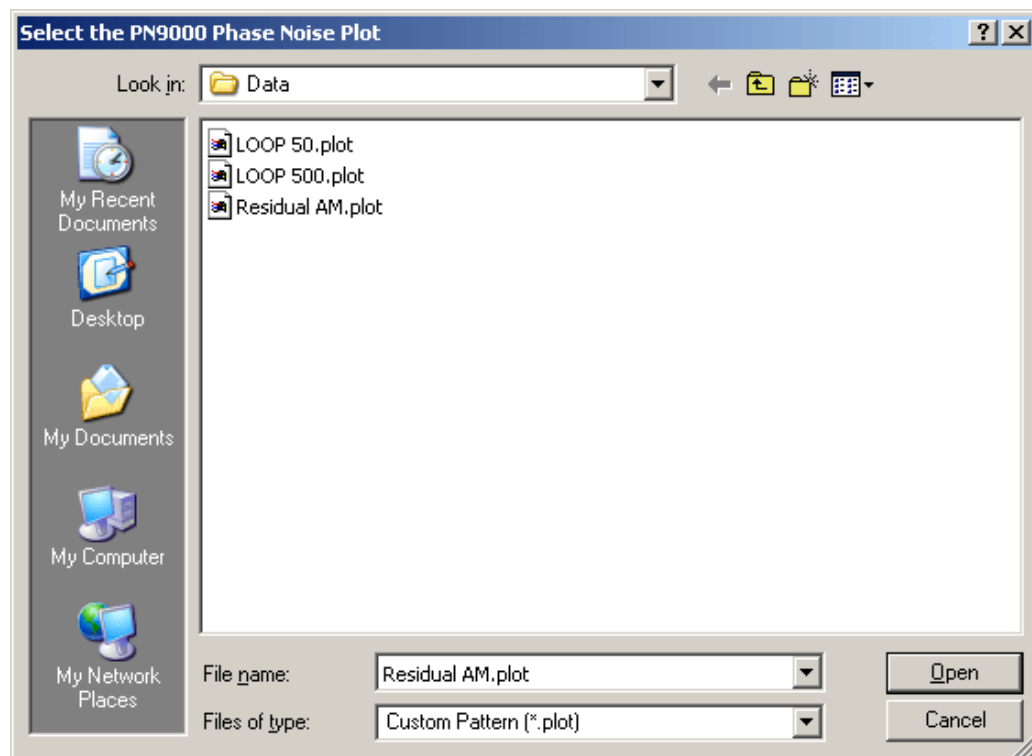
When the file is selected, the software displays the corresponding curve. Then this curve can be stored into any current memory A ; B ; C....
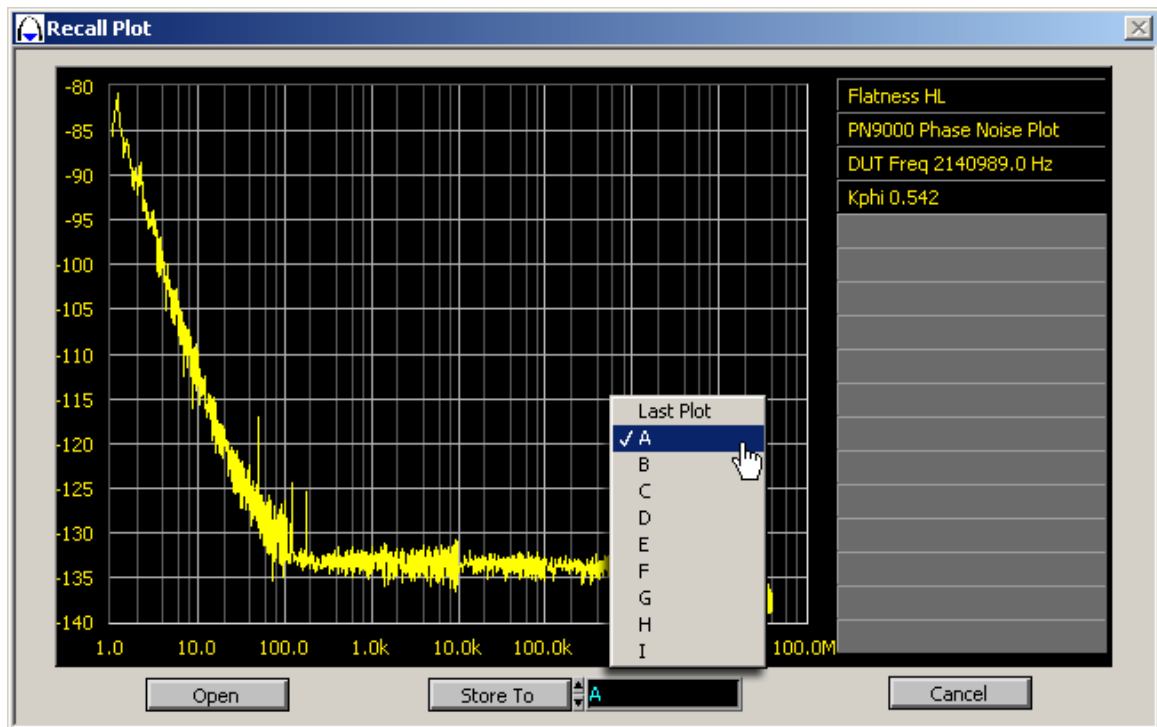
Save Plot / Save Data

Select on WPN9000 bar menu "File / Save Plot"
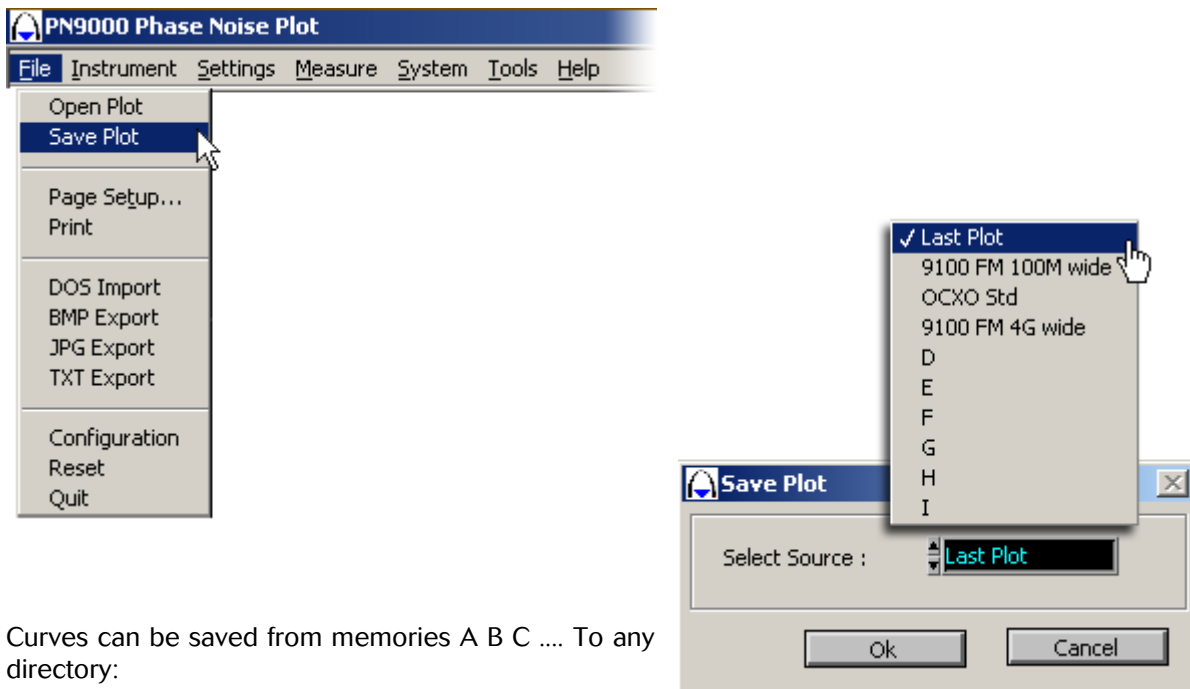
Curves can be saved from memories A B C .... To any directory:
Select first the memory A B C ... to be saved.

Then, select a directory and a name file:
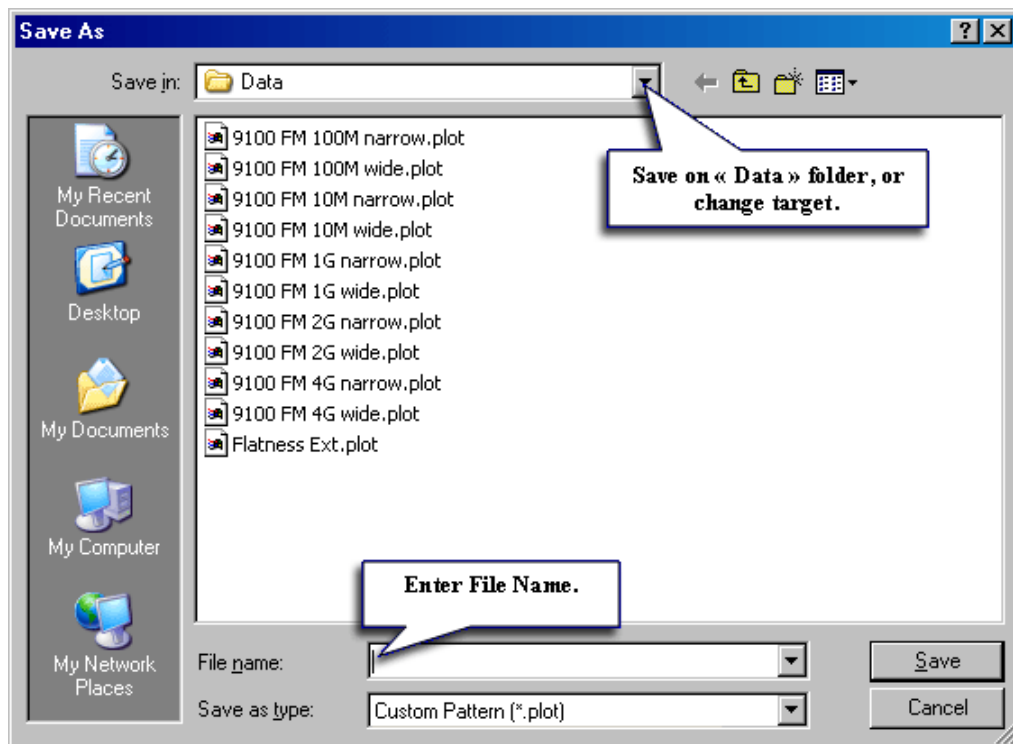
Page Setup and Print Driver:

Select on WPN9000 bar menu "File / Page Setup..."
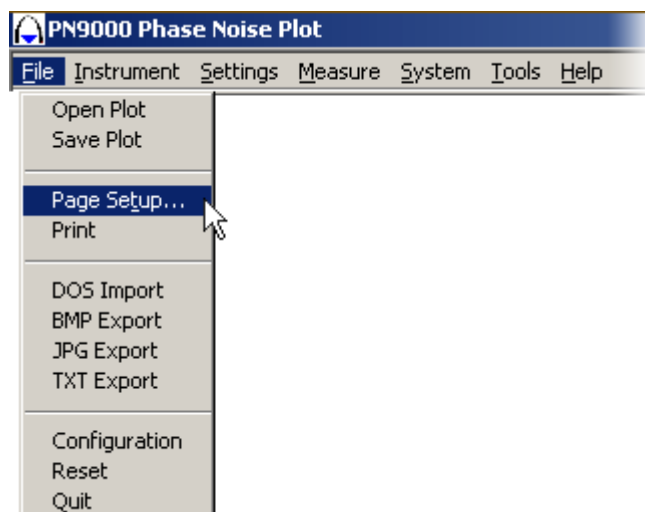
Print Header (name/Date/Page#): Informations on printing page.

Use default margins from preferences: Use default Printer margins.

Custom margins: Define your margins parameters on your printer page.

CANCEL: Abord print Configuration.

OK: Valid Configuration.

Printer Setup ...: Select Printer and change configuration parameters on Microsoft Windows Printer driver.
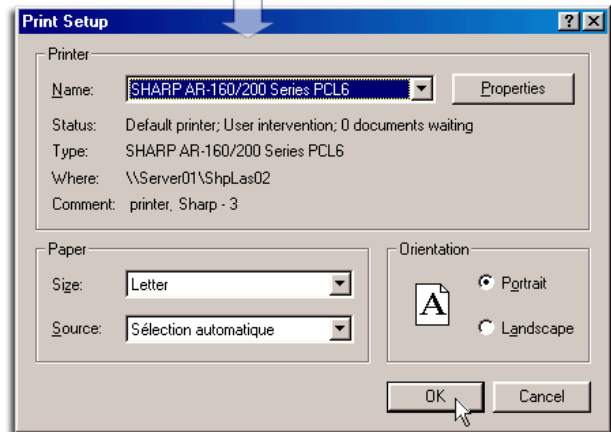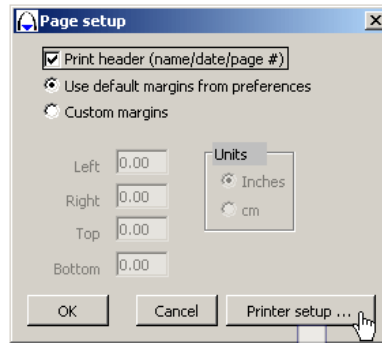
Print Curve

Select on WPN9000 bar menu "File / Print"
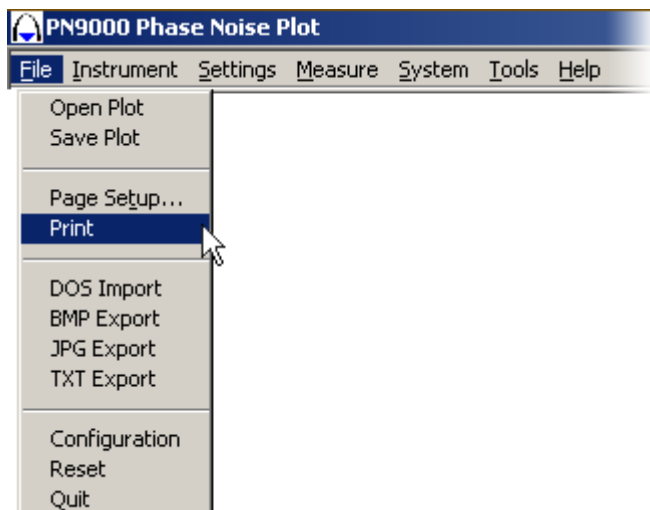
To print: First select the memory. Then after pressing OK, the software changes the video to get a black and white standard print.
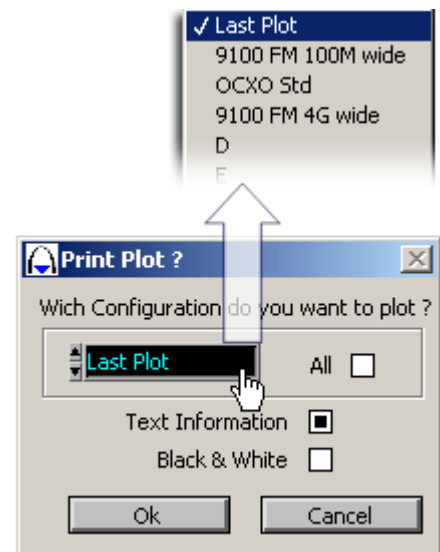
CANCEL: Abord print edition.

PRINT: Print curve on default windows printer.

.JPG: Export curve to file JPG format. (See: JPG Export)

.BMP: Export curve to file BMP format. (See: BMP Export)
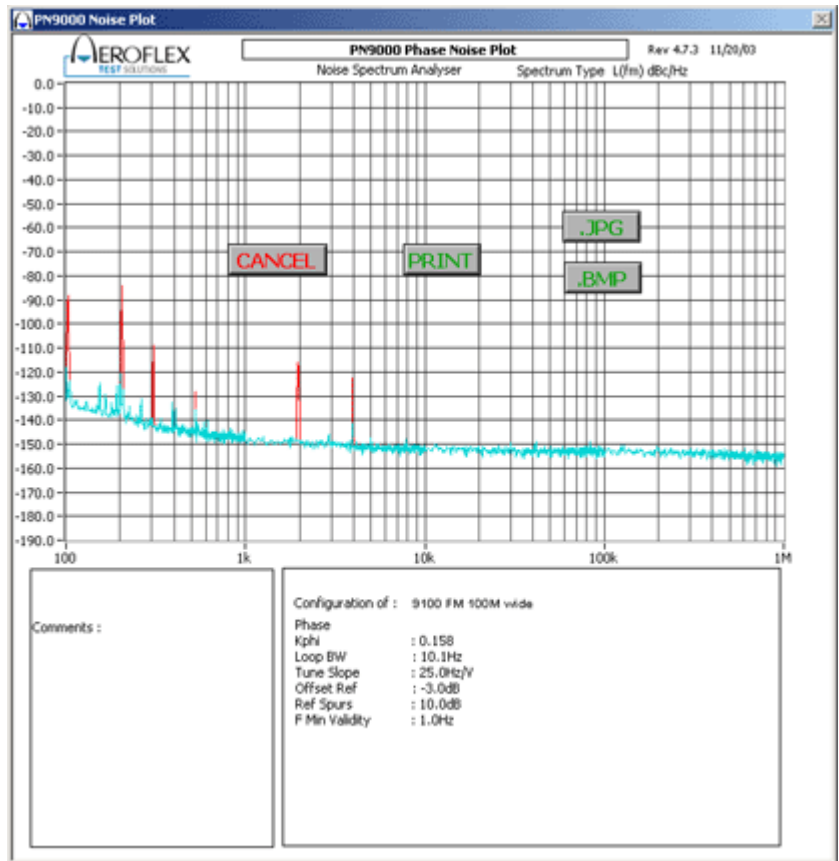
PN9000 MS-DOS Curves Import:

Select on WPN9000 bar menu "File / DOS Import"
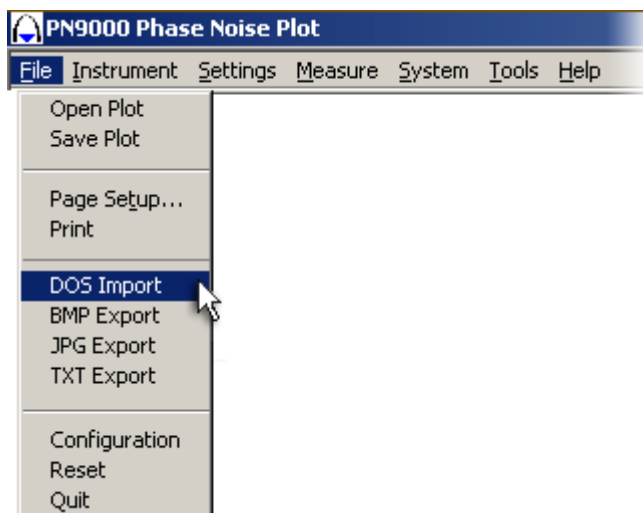
With the Windows software it is possible to retrieve curves under DOS PN9000. In this window, select the DOS file which is immediately displayed and belongs to the list file. Store this DOS file into a memory.
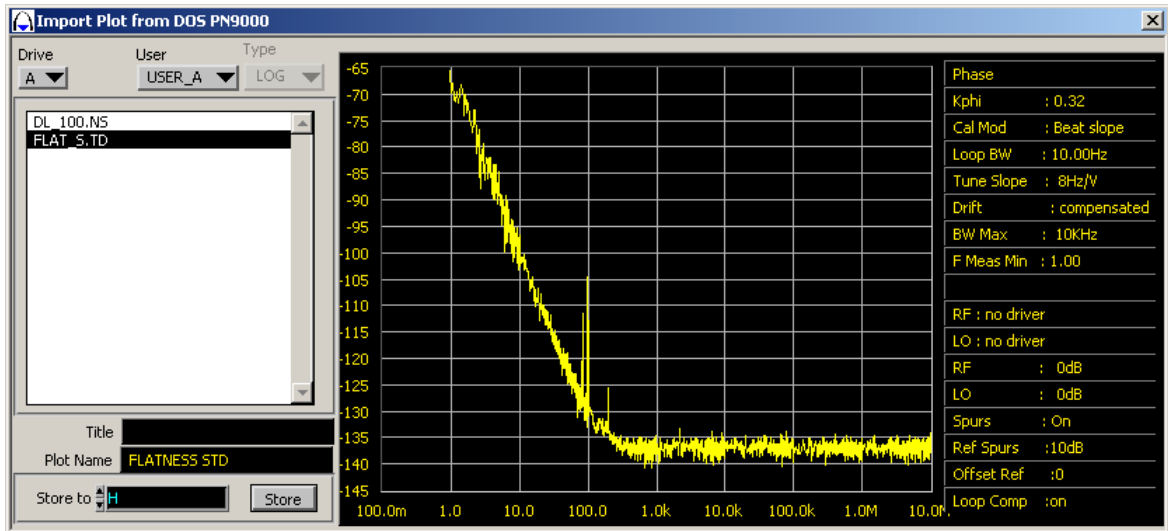
BMP Picture Format Export

Select on WPN9000 bar menu "File / BMP Export"
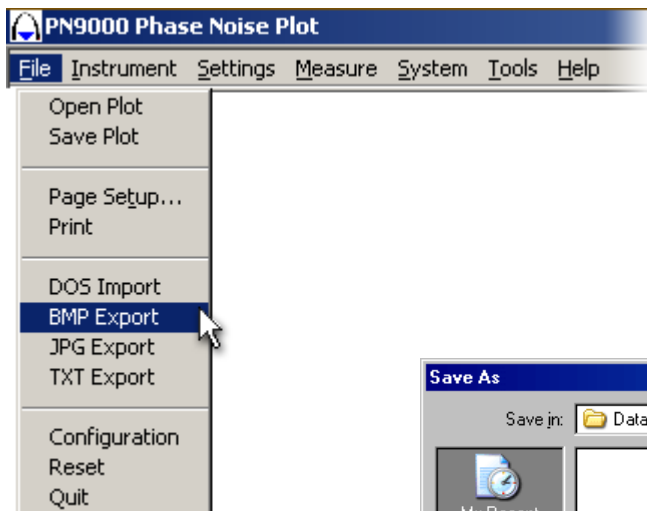
Save displayed curve on Bitmap File (.bmp), possible to export image file on Microsoft Word or similar software.
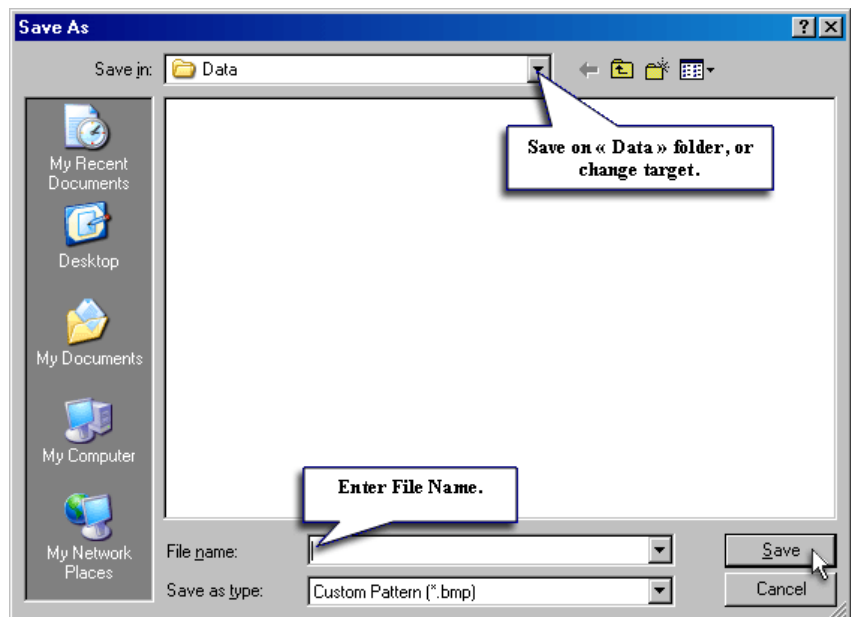
JPG Picture Format Export

Select on WPN9000 bar menu "File / JPG Export"
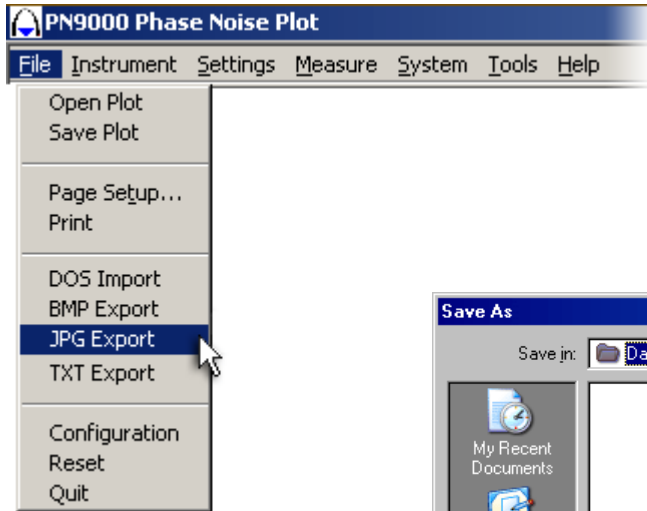
Save displayed curve on Joint "Photographic Experts Group" File (.JPG), possible to export image file on Microsoft Word or similar software.
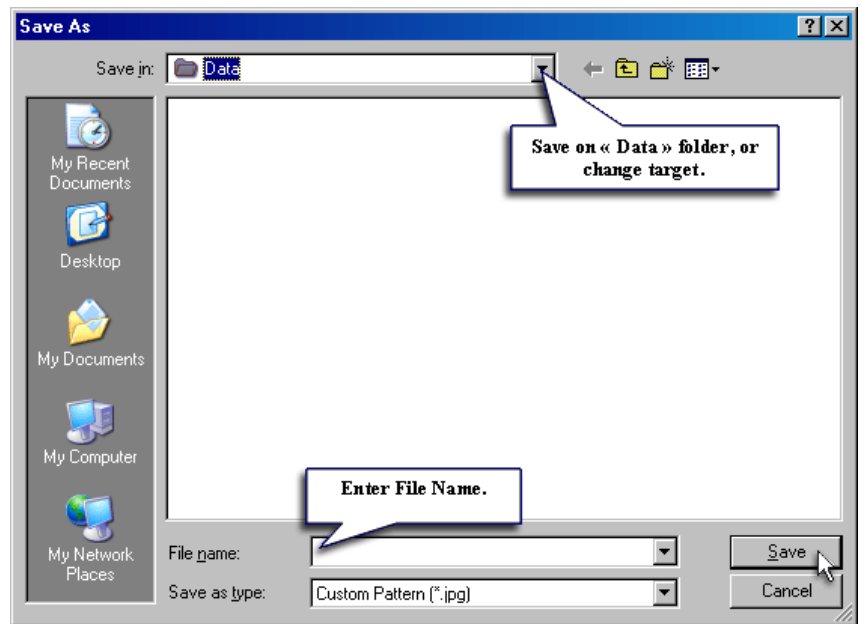
PNG Picture Format Export

Select on WPN9000 bar menu "File / PNG Export"
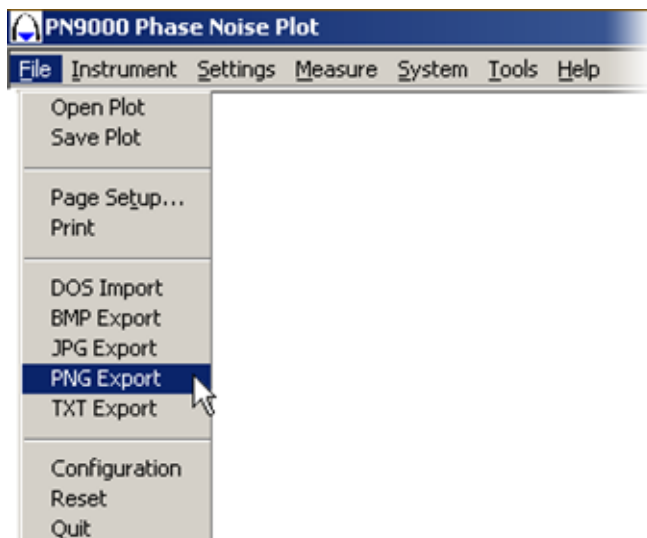
Save displayed curve on « Portable Network Graphics" File (.PNG), possible to export image file on Microsoft Word or similar software.

TXT Plot Format Export

Select on WPN9000 bar menu "File / TXT Export"

Select Curve to export.
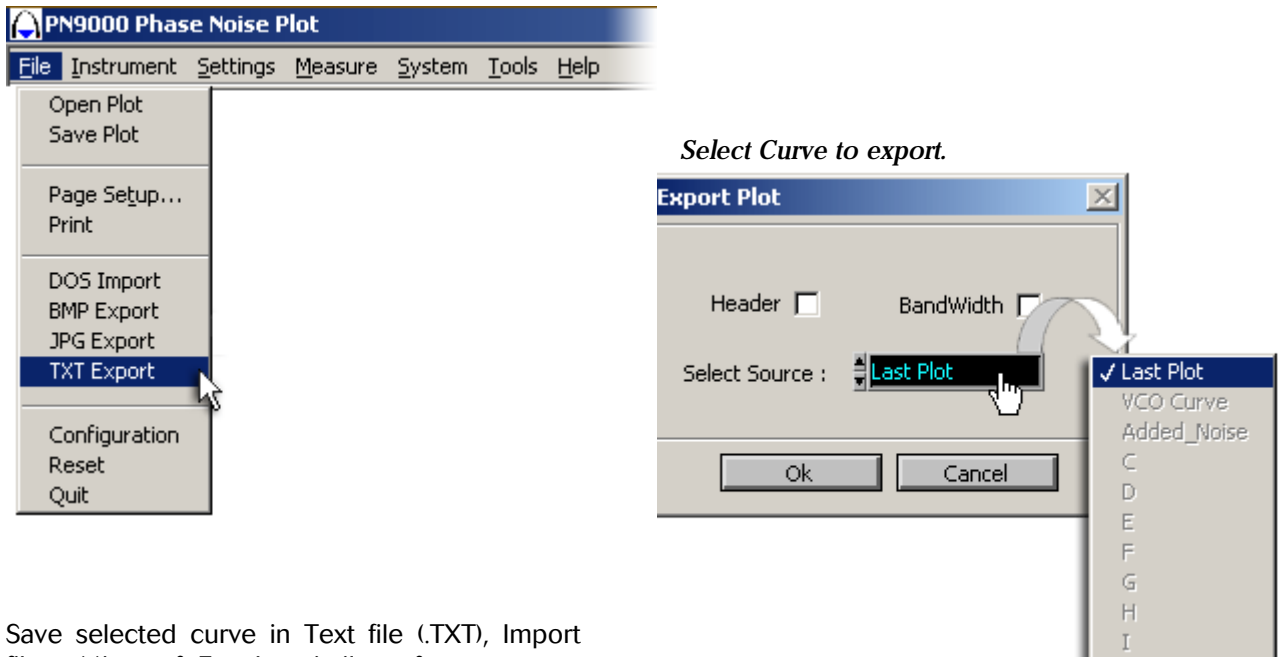
Save selected curve in Text file (.TXT), Import file to Microsoft Excel or similar software.
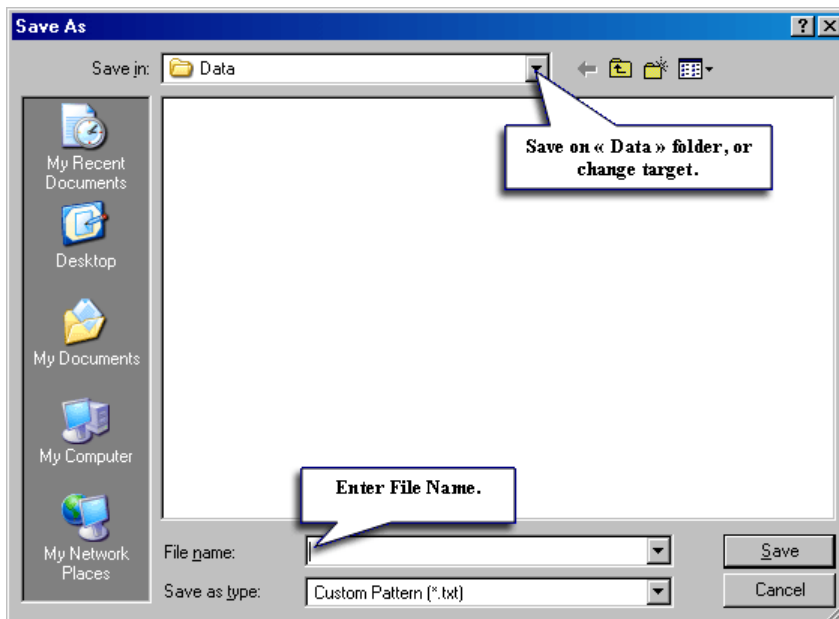
Configuration Menu

Configuration Menu is a backup folder for save configurations environment. The folder content Windows location, parameters measurements, and others global values.
User recall backup in the list for restore all parameters environment and run measure without enter values again.
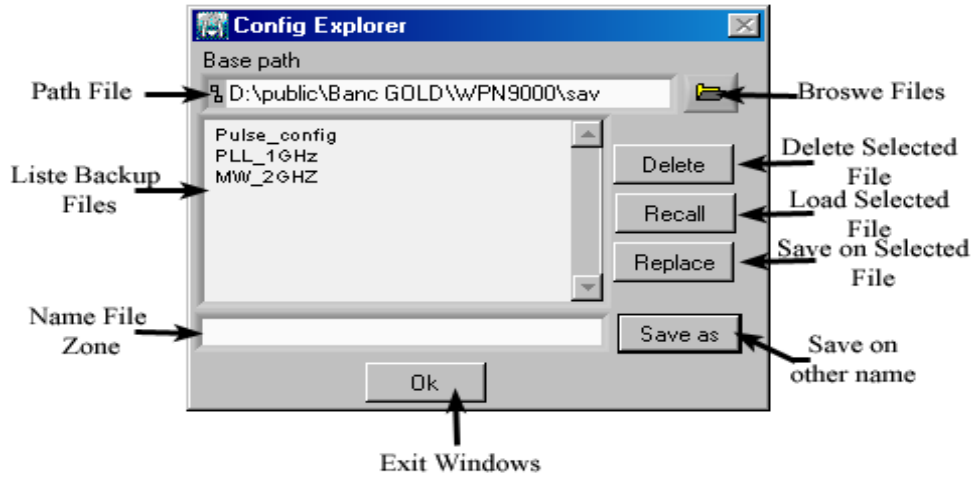
Quit Menu

Select on WPN9000 bar menu "File / Quit"
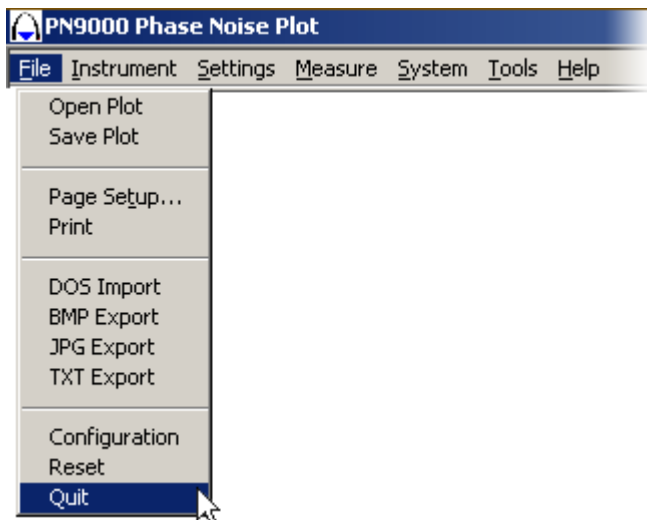
This Operation Close WPN9000 application.
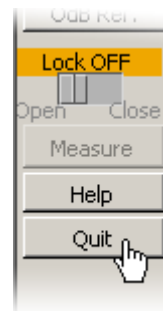
Reset Menu

Select on WPN9000 bar menu "File / Reset"
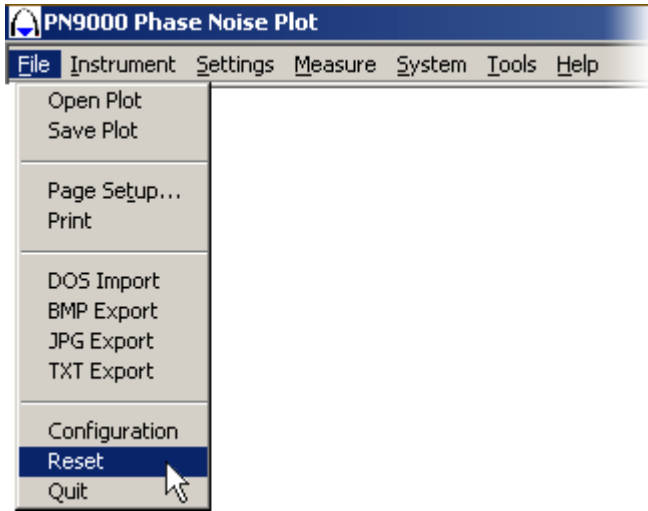
This Operation initializes WPN9000 application.
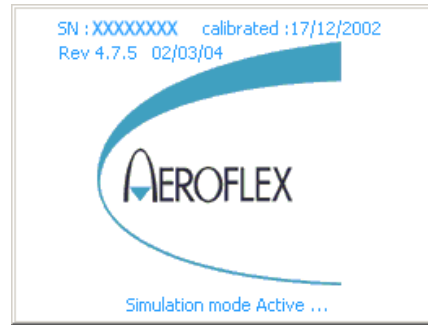
2. Instrument Menu List

- 🟠 [Frequency Counter](#)
- 🟠 [Power meter](#)
- 🟠 [Synthesizer](#)
- 🟠 [VCXO](#)
- 🟠 [Tune Voltage](#)
- 🟠 [Power supply](#)
- 🟠 [AM Calibration](#)
- 🟠 [Ext LO Driver](#)

Frequency Counter

Select on WPN9000 bar menu "Instrument / Frequency Counter"
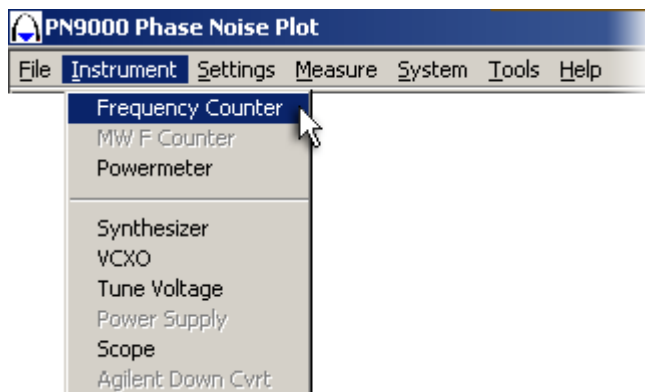
From the Tools window, the user can access the internal frequency counter. The measuring method can be changed such as the resolution, by increasing the "digits". The operator can select the RF or LO frequency or the beat Frequency between the RF and LO.
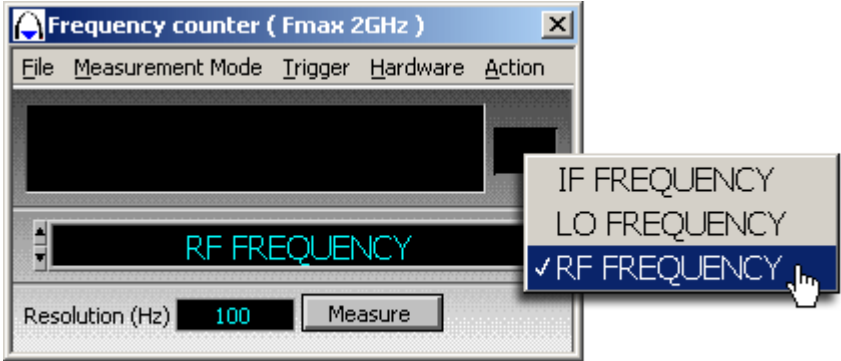
Microwave Frequency Counter (With Options PN9151, PN9152)

Select on WPN9000 bar menu "Instrument / MW F Counter"
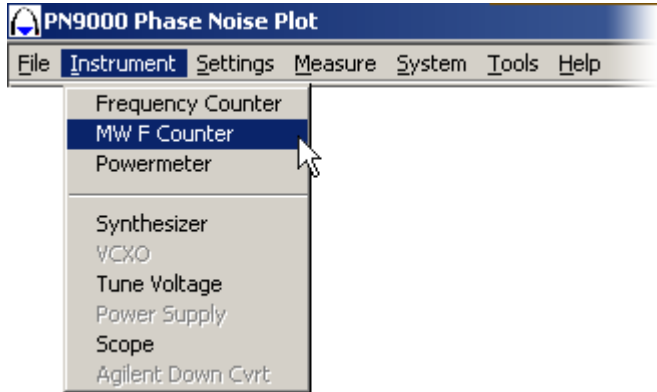
The goal of this method is to make frequency measurements above 2GHz. This method requires the use of a PN9100 RF Frequency Synthesizer to translate the microwave range down to the frequency counter basic range.
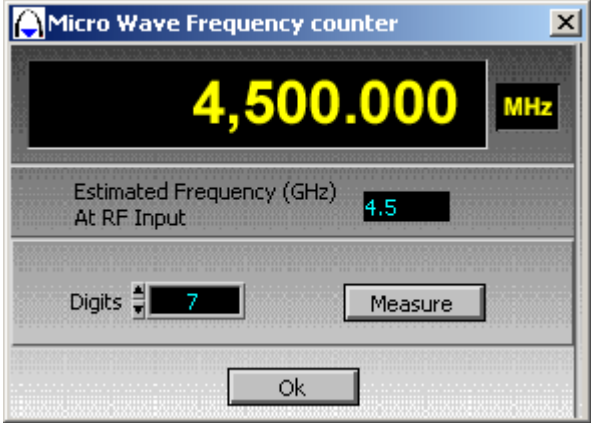
The range of measurement is from 2GHz to 4.5GHz. The user can increase the range up to 18GHz with the microwave doublers options:

- PN9151 Microwave Doubler: 4.5 - 9GHz
- PN9152 Microwave Doubler: 9 - 18GHz

Power Meter

Select on WPN9000 bar menu "Instrument / Powermeter"
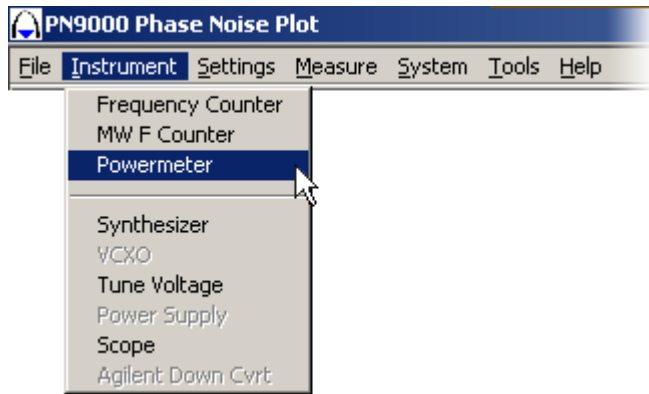
The user can check quickly the power which is on the RF port if the AM Detector option has been installed. This mode is not an accurate Power Meter mode; it is only used for an estimate of the power, ± 2dB. The Power range is from +19dBm to -5dBm.
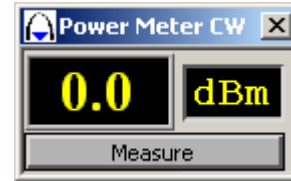
Synthesizer Control

Select on WPN9000 bar menu "Instrument / Synthesizer"
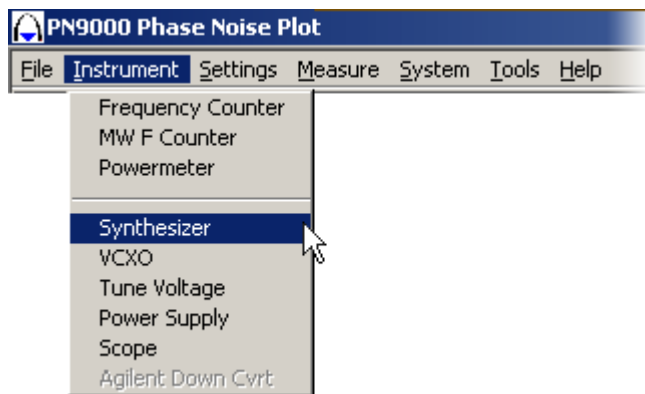
The basic parameters to be selected are: frequency, Level (dBm).

🔵 External Synthesizer:
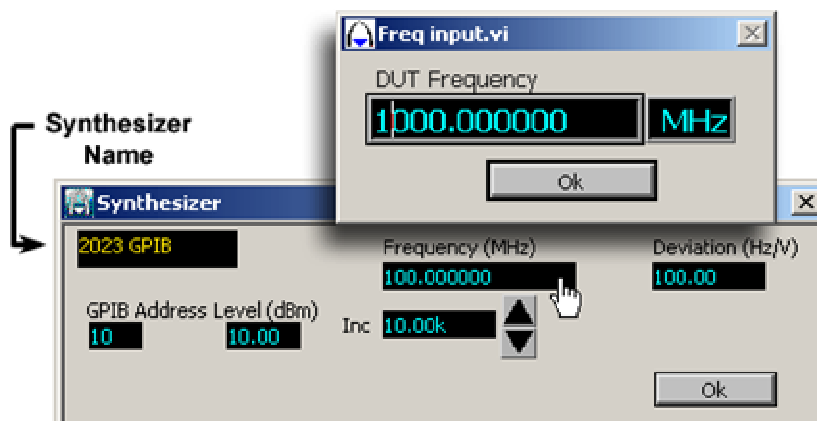
GPIB Address: Set GPIB Address external synthesizer.
Level: Set Output signal level (dBm).
Frequency (MHz): Set the frequency.
Deviation (Hz/V): Display the deviation.
Frequency: Set the DUT frequency.
Inc.: Set the increment frequency.
OK: Set Configuration.

🔵 With PN9100 Synthesizer:

PN9100 is DC/FM Frequency synthesizer 2 MHz to 4.5/18 GHz. (18Ghz with optional doublers extend the base frequency range to 9 and 18 GHz.)
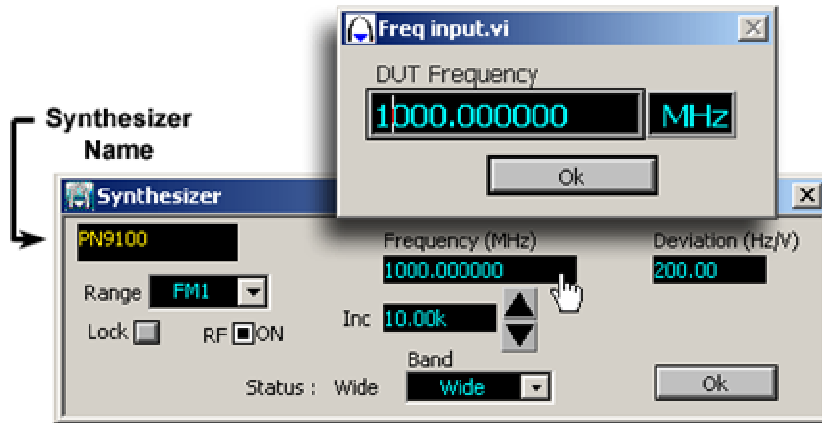
Range: Set the FM deviation (With PN9100 see table).
Lock: To force the lock PN9100 synthesizer.
Frequency (MHz): Set the frequency
Deviation (Hz/V): Display the FM deviation.
Frequency: Set the DUT frequency.
Inc.: Set the increment frequency.
Band: Set the loop Bandwidth of PN91000.
OK: Set Configuration.

CW and DC FM Range 1

Frequency Range, MHz	Slope Hz/V	FM Max
17360 - 18000	3200	FM1
8680 - 17360	3200	FM1
4340 - 8680	1600	FM1
2048 - 4340	800	FM2
1024 - 2048	400	FM2
512 - 1024	200	FM2
256 - 512	100	FM3
128 - 256	50	FM3
64 - 128	25	FM3
32 - 64	12.5	FM3
16 - 32	6.25	FM4
8 - 16	3.12	FM4
4 - 8	1.56	FM4
2 - 4	0.78	FM4

The DC/FM ranges FM2/3/4 are not always available. It depends on carrier frequency.

VCXO On/Off Control:

Select on WPN9000 bar menu "File / Print"
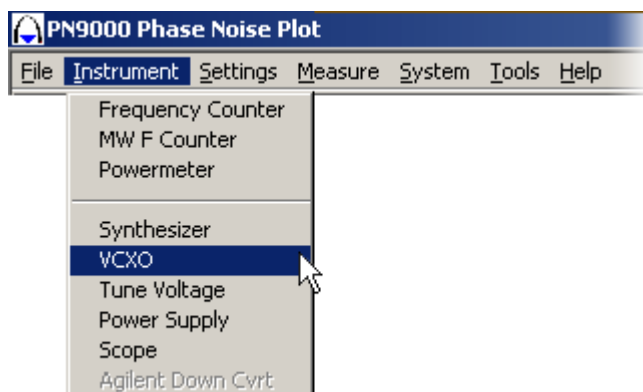
Select OCXO Frequency Output for activate Module.
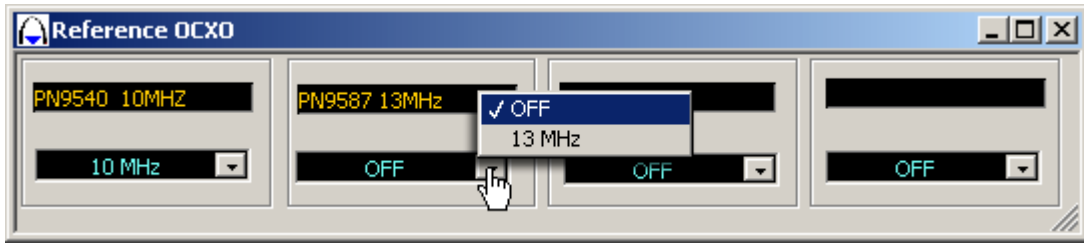
Tune Voltage Control

Select on WPN9000 bar menu "Settings /Tune Voltage"
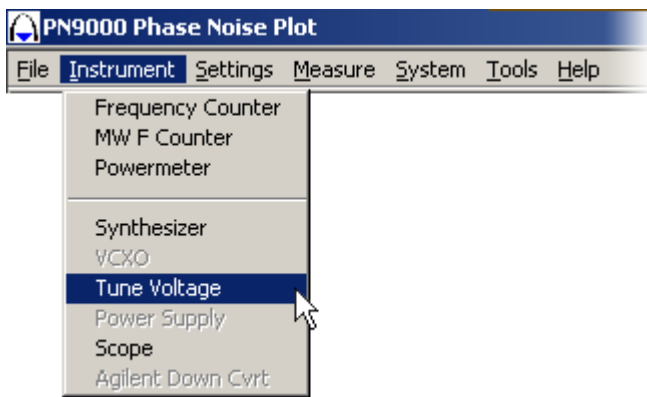
The operator can change the DC voltage presents on the Lock module output.
The minimum value is -10 Volts and the maximum is +10 Volts (+/-20V with option).
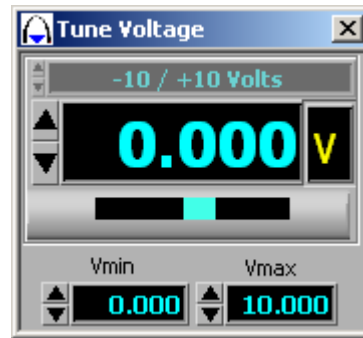
The bottom blue box indicates the selected digit to be modified.

Power Supply Control:

Select on WPN9000 bar menu "Instrument / Power Supply"
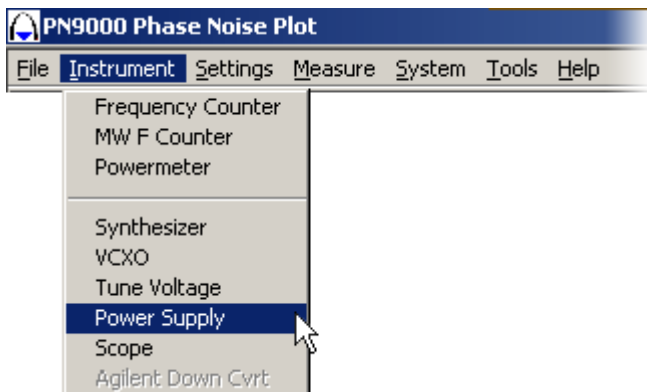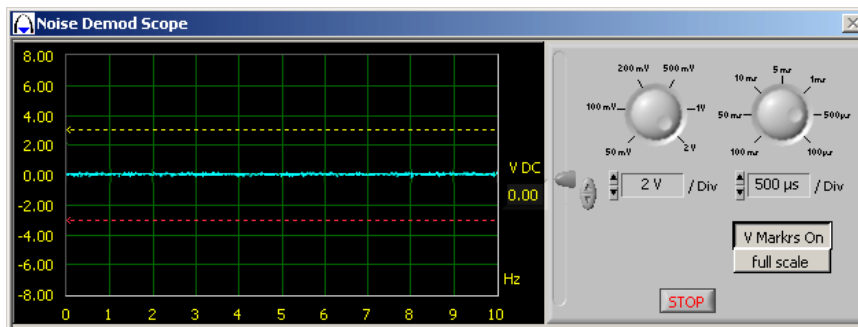

This module is used for VCO or OCXO power.
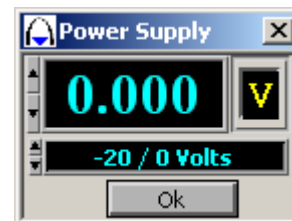
Scope Measurement:

Select on WPN9000 bar menu "Instrument / Scope"
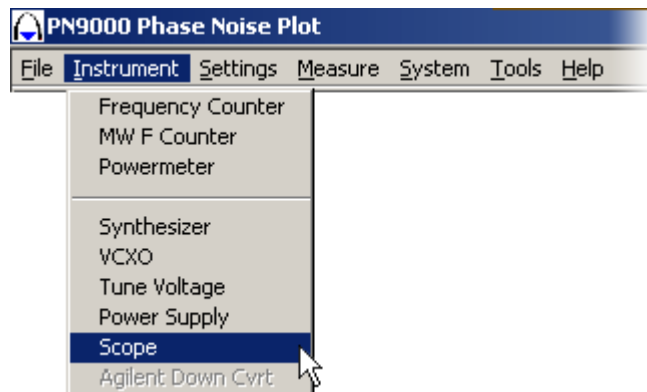
This virtual instrument acts as a scope put on the output noise voltage:

Change Time Base division, and Voltage division with rounds buttons.

V Markrs On: Display Marker on scope screen.

Full Scale: Reset parameters in full scale.

Stop: Close Virtual Scope.

V DC (cursor): Change Zero reference.

Setting Menu List

- Display
- Markers
- Title
- Specline
- Advanced
- Gain
- AM Calibration
- Ext LO Driver

Display Setting Menu

Select on WPN9000 bar menu "Settings / Display"
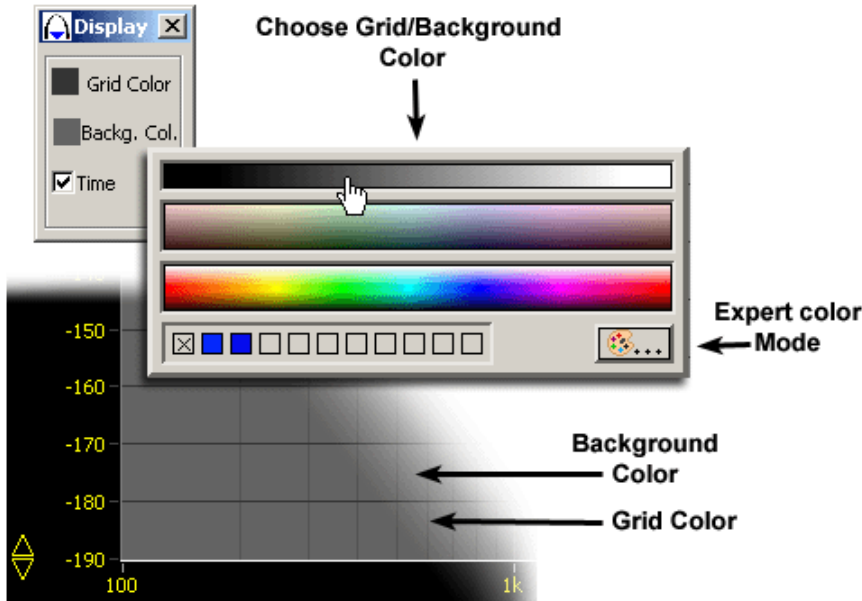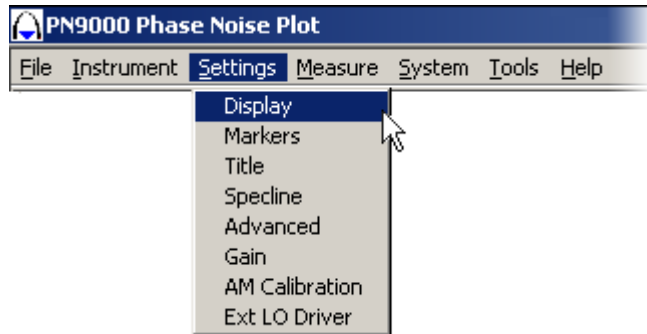
Grid Color: Select Grid Color.

Backg. Col.: To change the background color.

Time: To display the date.

Marker Menu
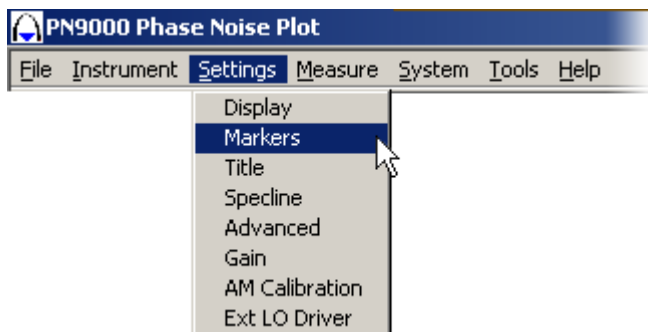
Select on WPN9000 bar menu "Settings / Markers"

Select the curve for Markers from 1 to 10.
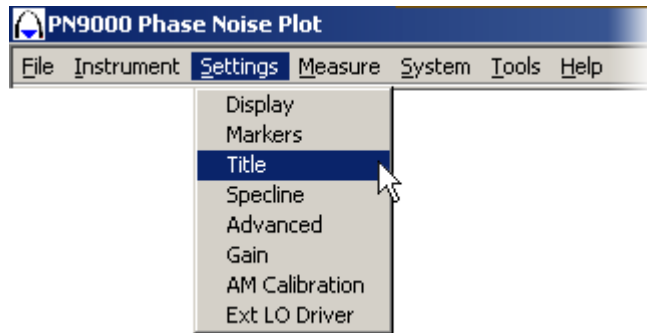Then move the cursor with the mouse.
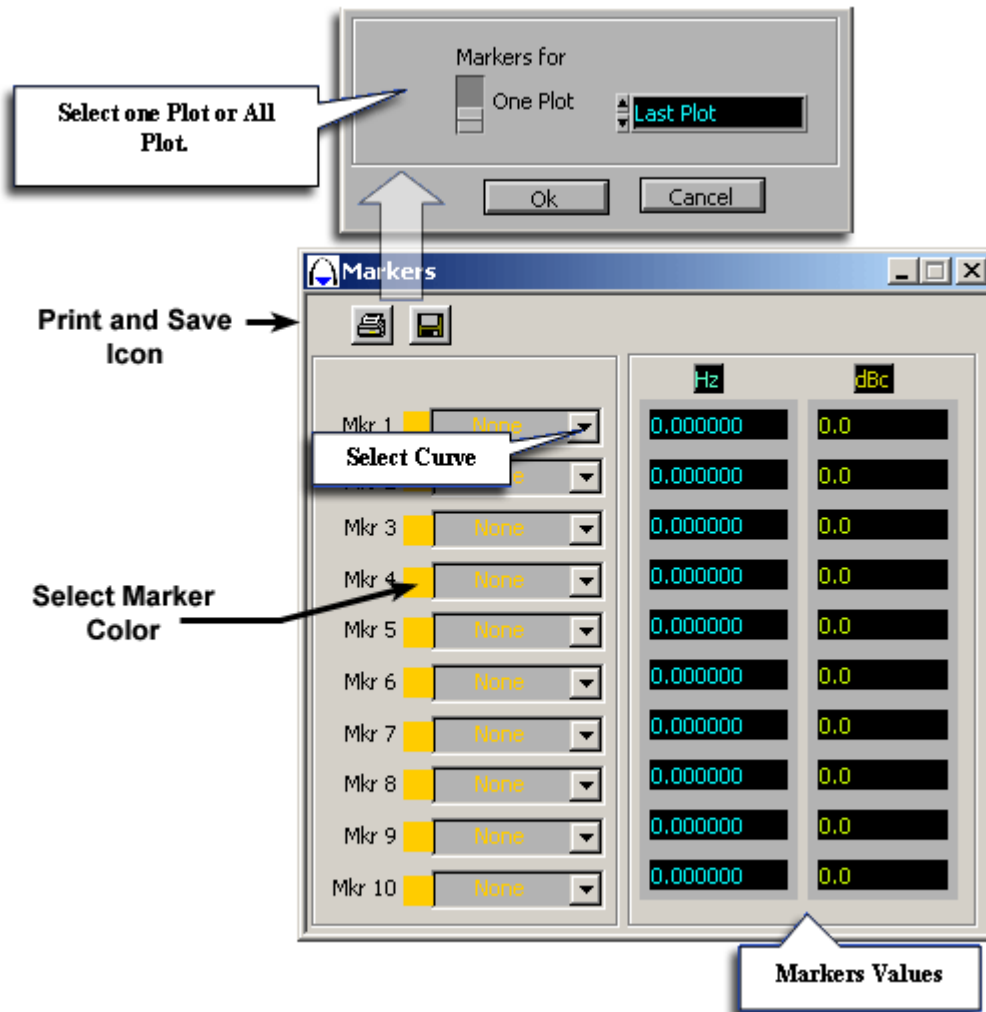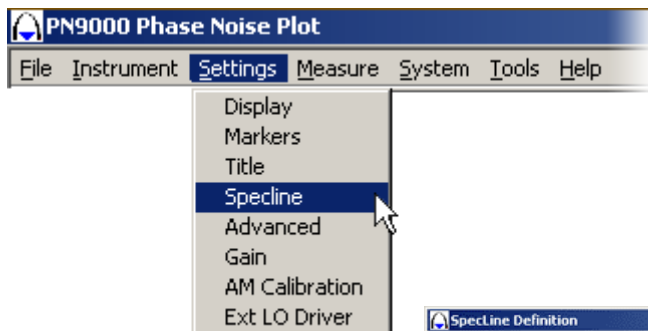
Print Markers List:
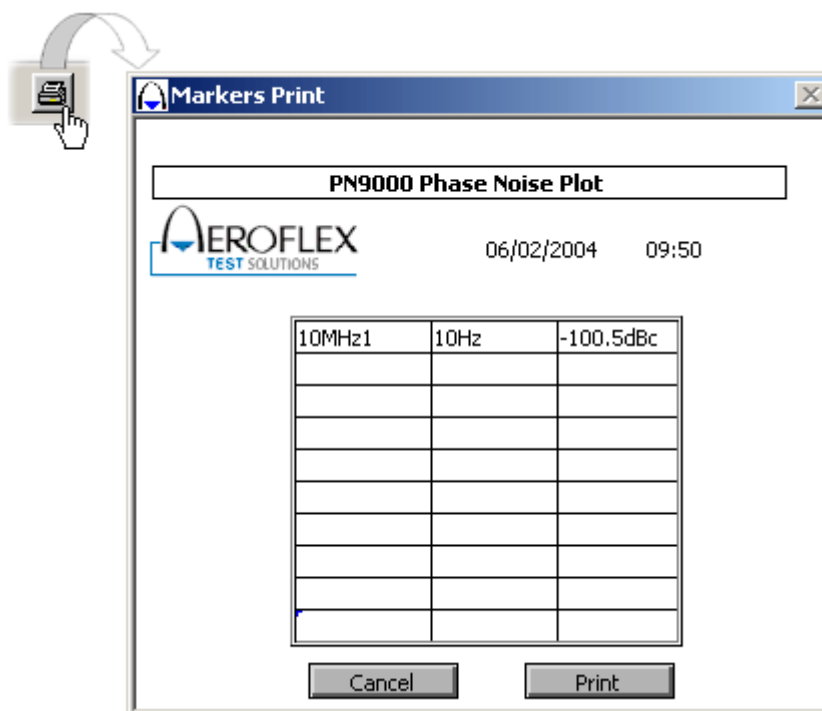
Title Menu

Select on WPN9000 bar menu "Settings / Title"

This function enables to entitle the measure the user is making. Click "OK" to write a new title.

Specline Menu

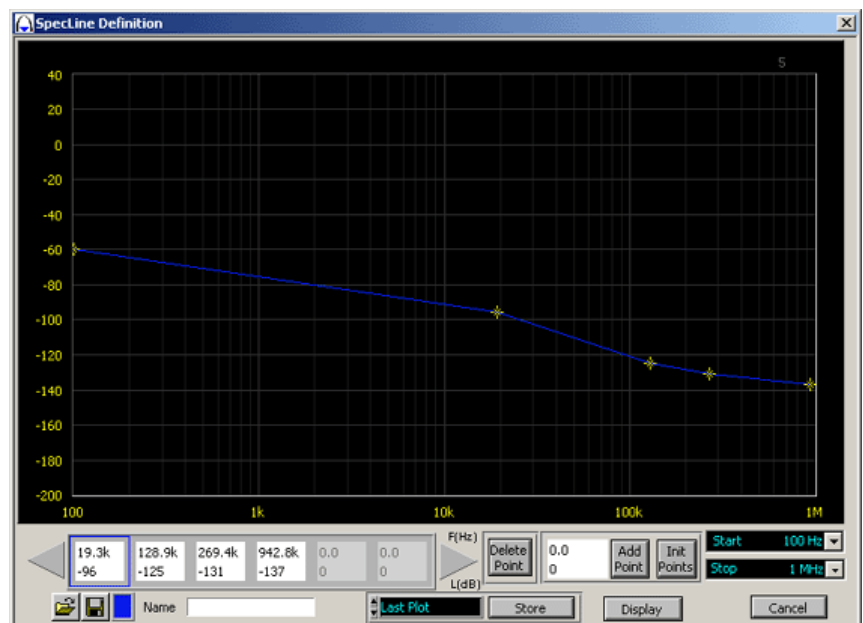Select on WPN9000 bar menu "Settings / Specline"

-The specline curve can be entered by selecting each cross bar with the mouse or by entering values in the bottom bar (enter frequency and level).

-The display scale can be changed with the "start" and "stop" boxes.

-To enter intermediate values, for example 5KHz, between 1,1K and 10K: use "Add point" and first enter the frequency and the level.

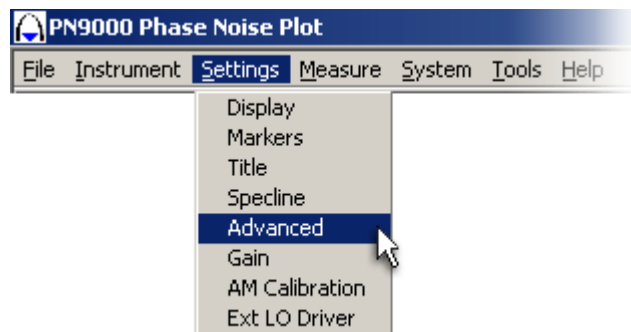-The specline can be stored into any memory (from A to I), and then displayed later.

-The specline can be directly displayed from the "Specline menu Display".
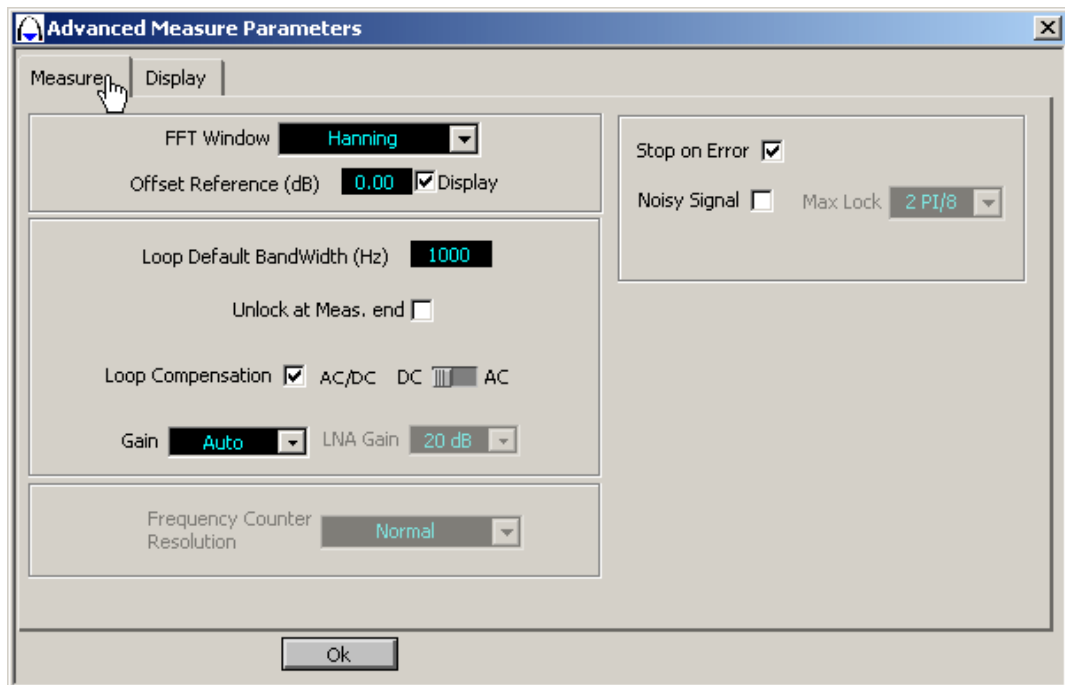
Cancel: Exit the window.

Advanced Measure Parameters Menu:

Select on WPN9000 bar menu "Settings / Advanced"

A) <u>Measure</u>:

FFT Window: Different standard signal processing windows are available, but in the general case use only the Hanning.

Offset Reference (dB) : Value applied to the measurement.
Example: Compensation of a multiplication factor (20 Log N) or 3 dB compensation fot two identical source measurement.

Display (On/Off):

- On: The offset is reported on the graph.

- Off: The offset not reported on the graph.

Loop Default Bandwidth (Hz): In the phase lock loop menu, for the PLL method, the user can select this default value for the Loop bandwidth. The user can change this default value.

Unlock at Meas. end (On/Off):

- ● On : The lock control is open at the end of the spectral analysis
- ● Off: The lock control is closed.

Loop Compensation: For a calibrated measurement, tick off the "Loop compensation" box. With the PLL method, the demodulated phase noise inside the Loop Bandwidth of the reference is modified because the Loop effect. The signal processing software compensates this effect to normalize the plot.
For example: If the Loop Bandwidth = 500 Hz, the phase noise at any offset below 500Hz is modified, the software computes this effect and compensates the data.
For specific purposes, the user can switch this compensation off, but the plot is no more normalized inside the Loop bandwidth.

DC/AC: Used only for debug purpose.

Gain: Auto, Replay, Manual.
-Auto: the system will define decade per decade the maximum video gain amplifying the noise to obtain the maximum dynamic.

Stop on error (On/Off):

- ● On: The measurement process Stop in case of error.
- ● Off: The measurement process continuous even in case of error.

Noisy Signal (On/Off): on: In case of very noisy signal, this selection allows the system to increase the "Lock" detection range, this range can be selected by "Max Lock".

To save time, it is possible to select :

-Replay: the system uses the same values as the last measurement.
-Manual: the system uses the value defined in the box: "LNA= xx dB".

B) Display:
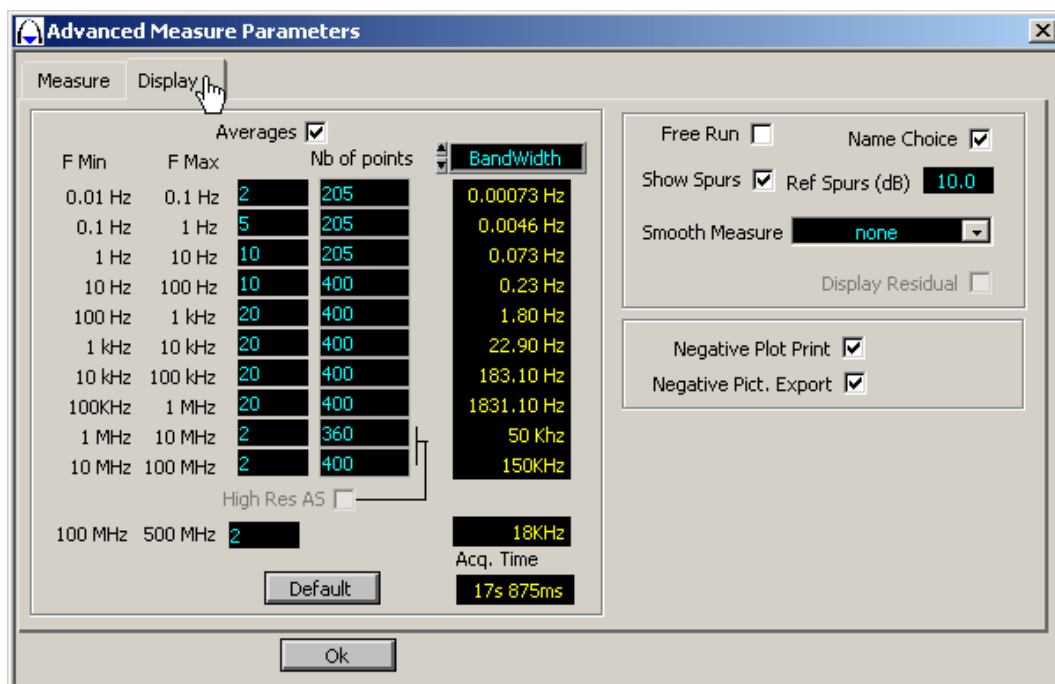
In accordance with the number of plots, the user can see the sampling frequency.

The user can select specific values to configure his own measurements.

Averages: Number of averages per decade. The dispersion of the video noise of the plot depends on the number of averages. A standard value is 20. Instead of using a too large value, yone had better use the smooth process. It is much more efficient in time. Select the top box to validate the average.

Nb of points: The number of point into one decade define the frequency resolution. An approximation: resolution = (2 x max decade frequency) / Nb of points.

For example: Decade !K 10K, N=400 resolution = 2x10K/400=50Hz.

Bandwidth = The FFT corresponding Bandwidth is displayed according the decade end the number of points.

Free Run: The system launches a new measurement until the user presses the "space bar" or "esc" key.

Name Choice: Before each measurement the system may require a name for the current curve.

Show Spur: If selected the spurs will be displayed in dBc/Hz, if not selected the spurs will be suppressed from the plot.

Ref Spur: The signal processing detecting the spurs from the noise uses a reference level between the noise and the spur to decide if the data is a spur or is a noise. The amplitude of the noise is variable, it depends of the average number, the user has the capability to set a specific value. The standard is 10dB, which means that a data is detected as a spur if there are 10dB between the top of the spur and the closing noise. Use a minimum value of 3dB when the measurement is done with a large number of averages.

Smooth Measure: A special signal processing can smooth the results in order to reject the video noise due to a limited number of averages.
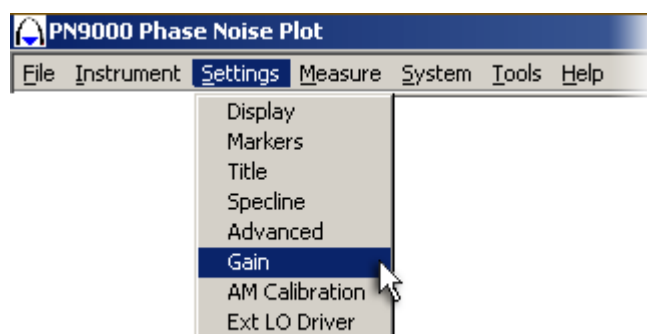
Negative Plot Print: Opposite colors of the curves, for an impression on white Background.

Negative Pict. Export: Opposite colors of the curves, for see pictures on white Background.

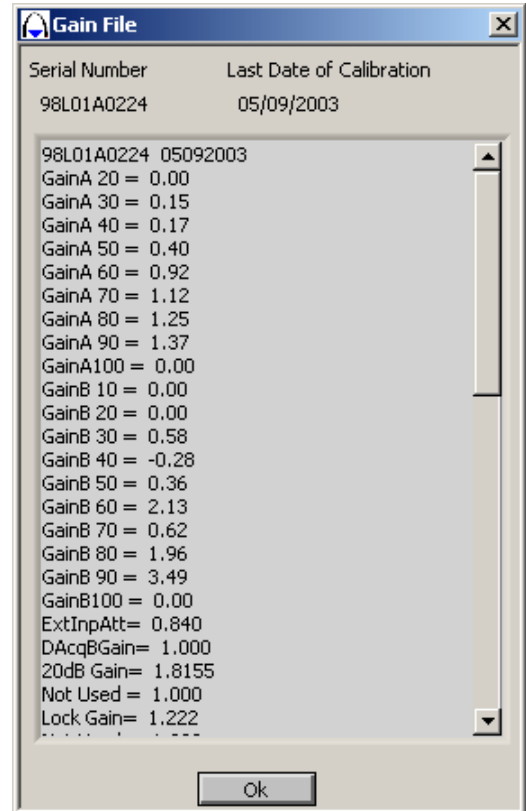## Displays the current PN9000 correction factors
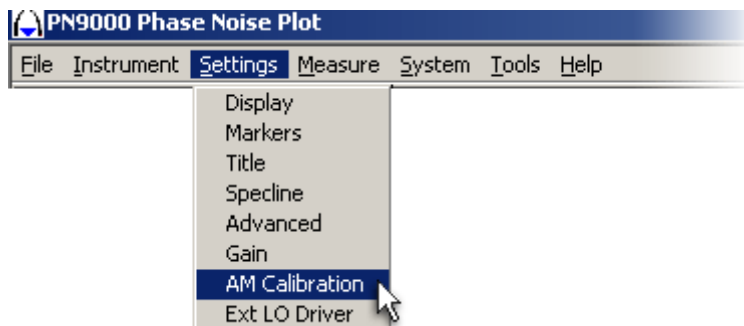
Select on WPN9000 bar menu "Settings / Gain"

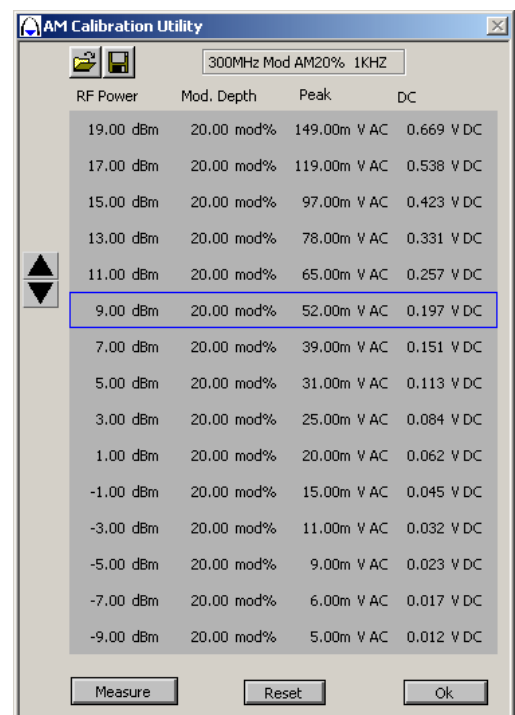The first line shows the PN9000 serial number and the latest date of calibration.

The other lines correspond to all correction factors apply during a measurement to insure the accuracy.

Gain File

Serial Number   Last Date of Calibration
98L01A0224   05/09/2003

```
98L01A0224 05092003
GainA 20 =  0.00
GainA 30 =  0.15
GainA 40 =  0.17
GainA 50 =  0.40
GainA 60 =  0.92
GainA 70 =  1.12
GainA 80 =  1.25
GainA 90 =  1.37
GainA100 =  0.00
GainB 10 =  0.00
GainB 20 =  0.00
GainB 30 =  0.58
GainB 40 = -0.28
GainB 50 =  0.36
GainB 60 =  2.13
GainB 70 =  0.62
GainB 80 =  1.96
GainB 90 =  3.49
GainB100 =  0.00
ExtInpAtt=  0.840
DAcqBGain=  1.000
20dB Gain=  1.8155
Not Used =  1.000
Lock Gain=  1.222
```

Ok

AM Calibration Menu:

Select on WPN9000 bar menu "Settings / AM Calibration"

AM Calibration Utility

300MHz Mod AM20% 1KHZ

RF Power	Mod. Depth	Peak	DC
19.00 dBm	20.00 mod%	149.00m V AC	0.669 V DC
17.00 dBm	20.00 mod%	119.00m V AC	0.538 V DC
15.00 dBm	20.00 mod%	97.00m V AC	0.423 V DC
13.00 dBm	20.00 mod%	78.00m V AC	0.331 V DC
11.00 dBm	20.00 mod%	65.00m V AC	0.257 V DC
9.00 dBm	20.00 mod%	52.00m V AC	0.197 V DC
7.00 dBm	20.00 mod%	39.00m V AC	0.151 V DC
5.00 dBm	20.00 mod%	31.00m V AC	0.113 V DC
3.00 dBm	20.00 mod%	25.00m V AC	0.084 V DC
1.00 dBm	20.00 mod%	20.00m V AC	0.062 V DC
-1.00 dBm	20.00 mod%	15.00m V AC	0.045 V DC
-3.00 dBm	20.00 mod%	11.00m V AC	0.032 V DC
-5.00 dBm	20.00 mod%	9.00m V AC	0.023 V DC
-7.00 dBm	20.00 mod%	6.00m V AC	0.017 V DC
-9.00 dBm	20.00 mod%	5.00m V AC	0.012 V DC

Measure   Reset   Ok

The calibration of the AM option is performed at the factory. If it is needful the operator can run a new calibration process; he will have to make sure he will not damage the current calibration files. Define the input power on the AM detector (from +19dBm maximum, down to -10dBm minimum).

- Set a calibrated 20% AM on the source under test. This value should be very accurate because it used as reference.
- Select a line and press "Measure". All the defined lines should be measured. The typical frequency source is 300MHz, but this value can be changed in the total frequency range of the AM detector.
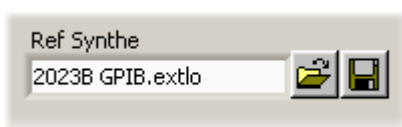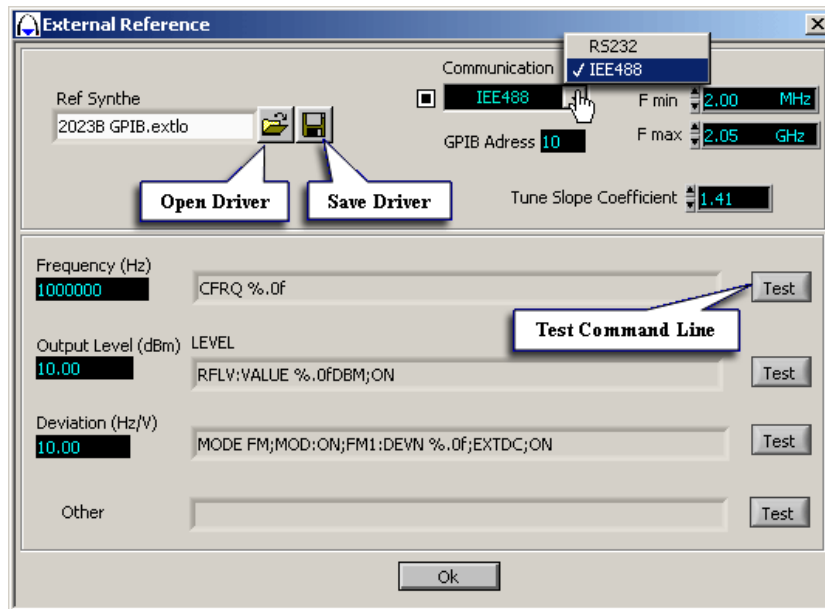
GPIB or RS232 External Synthesizer Driver

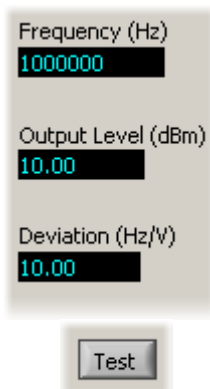Select on WPN9000 bar menu "Settings / Ext LO Driver"
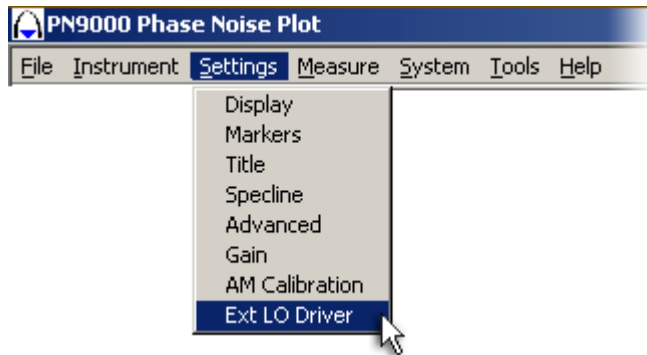
This menu aims at creating or testing an IEEE or RS232 Driver for an external reference source.

 "Open" or "Save" a specific driver. For example, 2023B synthesizer.

The Driver can be controlled with either RS232 or GPIB.

 Enter the exact and complete syntax for other command lines.

 Command lines, frequency, level, FM modulation, can be tested with the corresponding values (they can be changed).

4. Measure Menu List

- Tune Slope
- Jitter

Tune Slope

This Menu allows measuring the frequency tune slope of the source controlled by the phase-lock loop ("FM DC" input).
This menu can operate in two modes:

- Main Mode: The tune slope is measured at on specific point. (This capability allows measuring the slope at the current locking point. Only if VMax = VMin)

- Subsidiary Mode: The tune slope is measured in a voltage range. (Measuring the slope in a voltage range allows obtaining a complete curve from Vmin to Vman. This funtion is particulary useful when measuring crystal oscillator which have substantially variable slope figures Vmin/Vmax range.)
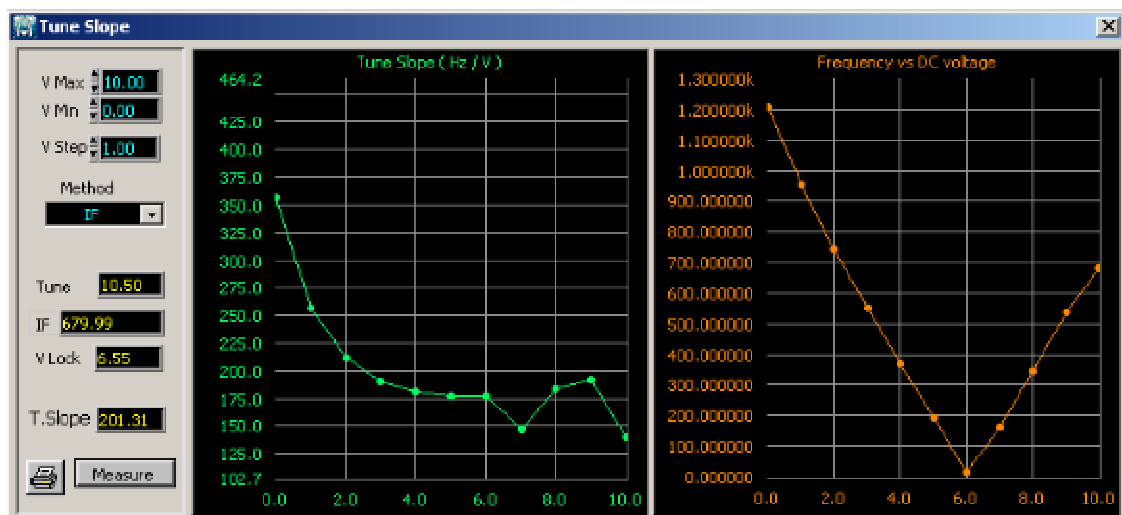
V Max: V Max = "Max" value of the control voltage. When the case is selected, the "Vcontrol" value is carried forward into Vmin and Vmax. In this case, if Vmin and Vmax are not modified, the slope measurement will be made at one point only, define by "Vcontrol".

V Min: V Min = "Min" value of the control voltage.When the case is selected, the "Vcontrol" value is carried forward into Vmin and Vmax. In this case, if Vmin and Vmax are not modified, the slope measurement will be made at one point only, define by "Vcontrol".

V Step: Voltage range for which the slope is measured.

Method: Select either direct beat frequency IF or RF/LO.
        IF: High resolution (0.1Hz/v) for high tune slope.
        LO/RF: Low resolution (200Hz/v) for low tune slope.

IF (LO or RF): Display Real frequency.

Tune: Display Tune Voltage on measurement.

V Lock: After measurement display Lock Voltage value.

Mean T.Slope: Display means tune slope values.

Print: Print tune slope curve.

Measure: Launch process.

Jitter

1) Definition:

A signal with phase noise can be represented as: $s(t) = A \sin [2\pi F_o t + F(t)]$

Another view of the noise contribution is the time domain:

$s(t) = A \sin [2\pi F_o (t + F(t)/ 2\pi F_o)] = A \sin [2\pi F_o (t + DT (t))]$

With $DT (t) = F(t)/ 2\pi F_o$ (time domain fluctuation or Jitter).

This Jitter has a spectral density: $S_{DT} (f) = (1/(2\pi F_o))^2 \ S_F (f)$

$S_F (f)$ = phase noise spectral density.

The PN9000 Phase Noise Test Set measures the spectral density $S_F (f)$, so $S_{DT} (f)$ can be obtained by computation.

The Jitter is a noise fluctuation in the time domain, having a spectral density $= S_{DT} (f)$ and in the majority of cases with a gaussian distribution with a standard deviation $sqrt(s^2)$:

Jitter rms = $sqrt(s^2)$ = sqrt $[\int S_{DT} (f) d(f)]$

With $\int$ integral from F_{offset} min to F_{offset} max from the carrier.

The Jitter rms is the time fluctuation within a Bandwidth: Fmin / Fmax.

This Jitter can be called the absolute Jitter (by opposition of the differential Jitter).

The unities are generally expressed in picoseconds rms (10^{-12}).

According the relation: $DT (t) = F(t)/ 2\pi F_o$, the carrier frequency need to be entered in the computation.

As any noise fluctuation the Jitter can be expressed as rms value or peak to peak value. The coefficient to get peak to peak from RMS is obtained by the gaussian distribution properties: with a coefficient = 6 the peak to peak noise represents 99% of the noise.

Standard relation: Jitter peak to peak = 6 Jitter RMS .

A more precise value can be taken considering the expecting BER related to the amount of noise to take into account (=99% if the coefficient =6).

(detailed computation not yet included in the software)

Note: In a real measurement the spurious coming with the carrier generate a coherent Jitter (at the opposite of the random Jitter coming from noise). The system detects the spurs from the noise and computes separately the RMS / peak to peak coefficient for sinusoidal signal and for noise. The result can displayed as: noise only, spur only or noise + spur.

---

2) Absolute Jitter:

The following menu "JITTER BW" addresses the computation of the Jitter from the spectral density: $S_F (f)$. Before the computation a phase noise measurement has to be done and store into a memory.
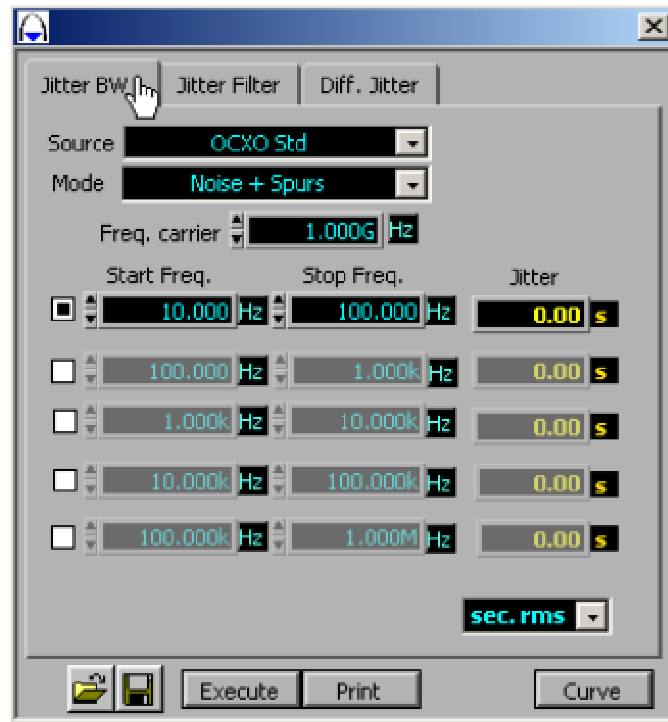
Source: Memory selected to do the computation.
Mode: The computation can be done on the noise only, the spurs only or the noise + spurs.
Freq.carrier: Enter the carrier frequency.
Unites: The result can be expressed in RMS or peak peak (with a ratio of 6).
Start Freq / Stop Freq: Define the integration bandwidth.
Execute: Run the computation.
Print/Plot: Print or plot the result.

3) Absolute Jitter within a filter:
In some standards for Wireless telecommunication the integration of the noise is not into a simple form:
from F_{offset} min to F_{offset} max but a filtering shape is defined for each standard, with the following menu the
operator has the capability to define this filtering.
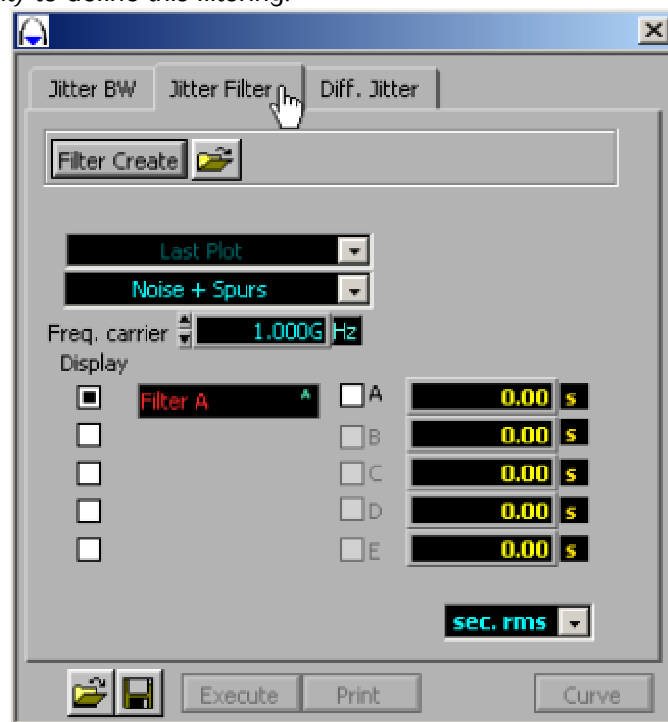
Create a filter with the "Specline" tool, press "Filter Create".
As for Jitter BW, select the curve and the mode (noise, spurs).
Five different filters can be stored into the memories A,B,C,D,E.
Five simultaneous computation can be performed (Solution with the A,B,C,D box).

Filter can be stored or recalled from back-up directories, only one filter can be displayed with the curve (Displayed Box).

   4) Jitter differential:
The previous definition of the Jitter takes into account all the noise close to the carrier and express the result as a noisy carrier compare to an ideal stable carrier. It is an absolute Jitter.
For some applications only the relative effect of the noise on two particular rising edges is of interest.
If the two edges are separated by the clock value, the Jitter is called: Clock to Clock stability.
If the two edges are separated by a significant amount of clock values, the Jitter is called the differential Jitter over a time **t**.
This process corresponds to a specific filtering of phase noise (and spurs):
Jitter differential = **sqrt [(1/(2pF$_o$))** ^{2} **ò S$_F$ (f) H^2(f) df]**
With **H (f) = sin(p t f$_{offset}$)** , with **t** = time separating the two edges.
H(f) acts into two ranges of f$_{offset}$:

   🟡 High value of F$_{offset}$: H(f) acts as a filter removing the spectral content every f$_{offset}$ = 1 / **t** . The value F$_{offset}$ is high compared to a standard phase noise measurement plot.

   🟡 Low value of F$_{offset}$: H(f) acts as a high pass filter removing the low frequency content of the noise : from 0Hz (or the carrier) to (1 / **pt**) for a first approximation the sin(**p** t f$_{offset}$) = a high pass filter (sin 0 = 0)

The use of the Jitter differential is complex because the two effects of the corresponding filtering.

Clock to Clock stability is not addressed by a Phase noise system because the f$_{offset}$ will be generally too large (for 10GHz carrier , **t** = 100 psec for two adjacent clocks).
In this case the very wide band noise is to be taken into account.

Differential Jitter for larger **t** (ex : 1µsec , 1 / **pt** = 318KHz) is achievable to a phase noise system . In this case the differential Jitter can be also directly related to the frequency stability called: Allan variance (this relation will not developed in this chapter).

This differential Jitter is a more common representation with a "sampling scope".
In fact the scope is triggered at each sweep, so the display represents the differential Jitter between the rising edge at the trigger start and the measured edge.

(The way a "sampling scope" is measuring Jitter is not developed in this chapter)
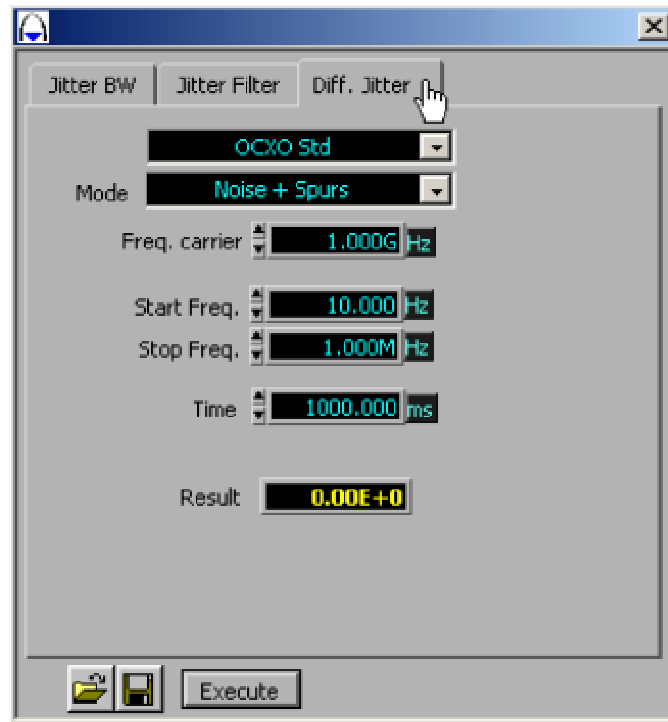
Start Freq / Stop Freq: Added to the clock to clock filtering and additional.
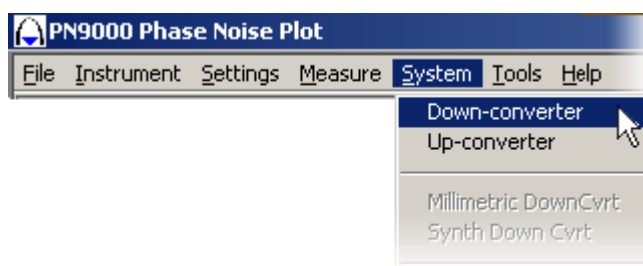Time: Clock to clock Time offset (entered with "ms" unites).

System Menu List

Control of hardware options

- Down Converters
- Isolator Amplifier
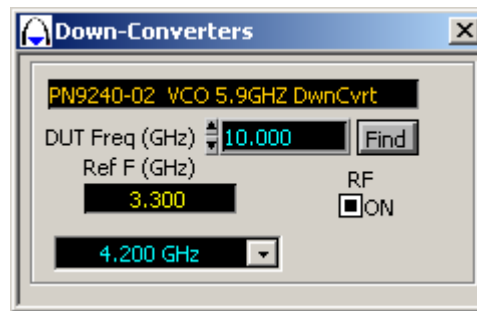- Time Base
- Up Converters
- Pulse
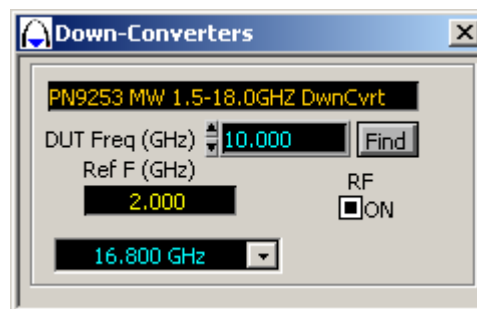- Setling Time

Down-Converter Menu (PN9240-02/PN9253-00)

Select on WPN9000 bar menu "System / Down-Converter"

Select Down-Converter type and parameters:
     Down-Converter VCO:

     Down-Converter PLL:

The Down Converter menu is automatically called in the "Manual" and "Auto" windows of the corresponding method. This menu presents an access to the Down Converter configuration, independently of the measurement process. For example the operator can select a specific reference frequency configuration and use it while operating in Manual mode (only with the Manual mode; the Automatic mode forces its own configuration). In order to use the configuration selected in this menu, don't enter the DUT carrier frequency in the manual mode. This entry will change the configuration in accordance with the Manual mode software routine.

Manual Selection:
Select the bottom line: "4.000 GHz" for the PN9240 or "11.4GHz" for the PN9253.
Select the right frequency range.

Automatic Selection:
Enter the DUT frequency in GHz: "DUT Freq (GHz)".
Press the "Find" switch.
The system displays the selected Ref frequency "Ref F (GHz)".

Notice for the VCO down Converter: According to the DUT frequency, a strong intermodulation can occur with the internal DRO reference sources (for the PN9240-00: 3GHz and 4GHz; for the PN9240-02: 3.3Ghz; 3.9GHz and 4.2GHz). This intermodulation affects the 1MHz to 40MHz span analysis; it creates large discontinuities in the spectrum. The frequency of the intermodulation should be higher than 80MHz in order not to affect the measurement. In case of problems in the span from 1MHz to 40 MHz, move the DUT frequency to reject the spur above 80MHz.
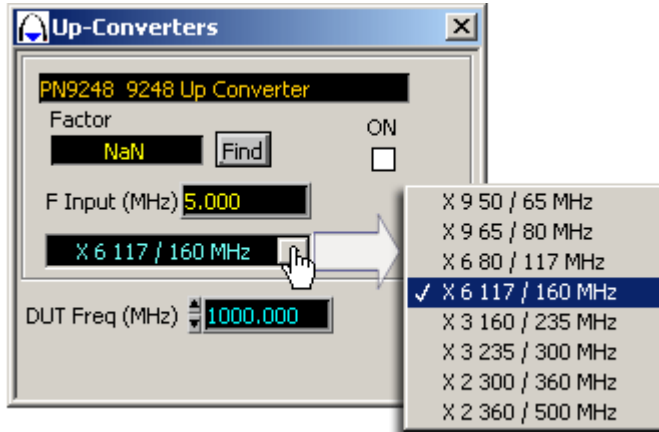
The button "ON" should be selected, as displayed.

UP-Converters Menu (PN9248)

Select on WPN9000 bar menu "System / UP-Converter"
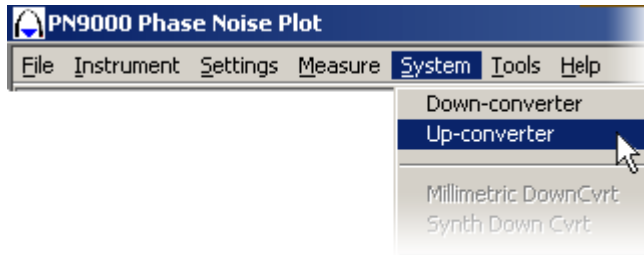
Define Up-Converter parameters.

The Up Converter menu is automatically called in the "Manual" and "Auto" windows of the Delay Line method. This menu shows an access to the Up Converter configuration, independently of the measurement process. For example the operator can select a specific frequency range and use it when operating in Manual mode (only with the Manual mode). The Automatic mode forces its own configuration). In order to use the configuration selected in this menu, don't enter the DUT carrier frequency in the manual mode; this entry will change the configuration in accordance with the Manual mode software routine.

Manual Selection:
Select the line "x 6 80/117MHz".
Select the right frequency range. In this example the frequency range is from 80 MHz to 117MHz. The first number indicates the multiplier ratio: 6.

Automatic Selection:
Enter the DUT frequency (in MHz): " DUT Freq (MHz)". Press the "Find" switch.
The system displays:
The multiplier factor (6).
The Delay Line input frequency (600 MHz).
The frequency range (x6 80/117MHz).

Notice: The "ON" switch should be selected, as displayed. The multiplier factor is taken into account during the measurement.

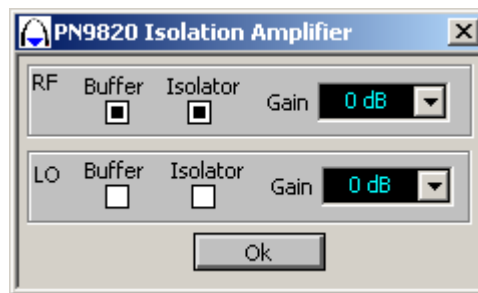## Isolator Amplifier Menu (PN9820)

Select on WPN9000 bar menu "System / Isolator Amplifier"
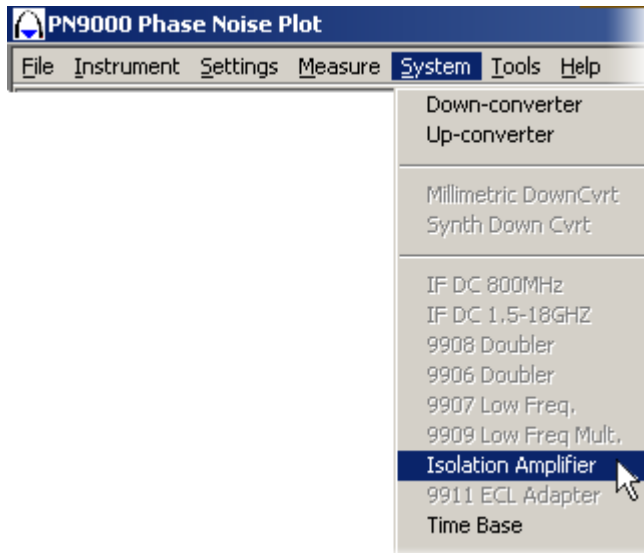
This option presents three functions:
 - Buffer with a high input impedance and 0dB gain.
 - Isolator with 30dB isolation and 0dB gain.
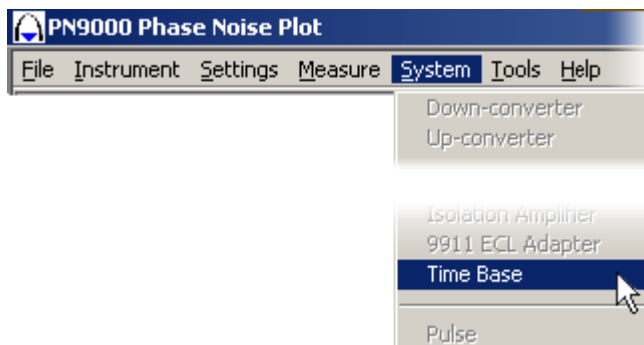 - Variable gain.

Buffer is 500 Ohms input impedance at 10MHz.
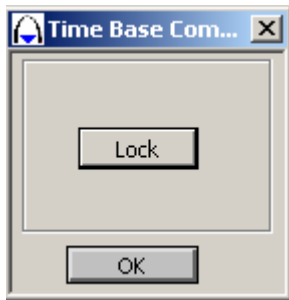For a higher frequency the input capacitance (1 Picof) reduces the impedance.
The isolator combines an attenuator and an amplifier. Isolation is about 30dB.

Time Base Menu

Select on WPN9000 bar menu "System / Time Base"

Control of the "time base" hardware module:

The time base combines a 10MHz oscillator with a 100MHz one and a 1GHz very low noise VCXO (1GHz: only with the microwave down converter).

All these oscillators are locked together. The lock process is only set during the initialization of the software. In a problem should occur (the green led on the front panel is lighted off), run a new "lock" process.

Pulse Menu

The software provides pulse measurements = 10%.

Units: N: nanosecond
         U: microsecond
         M: millisecond

NB. *The DOS software enables measurements below 10%.*
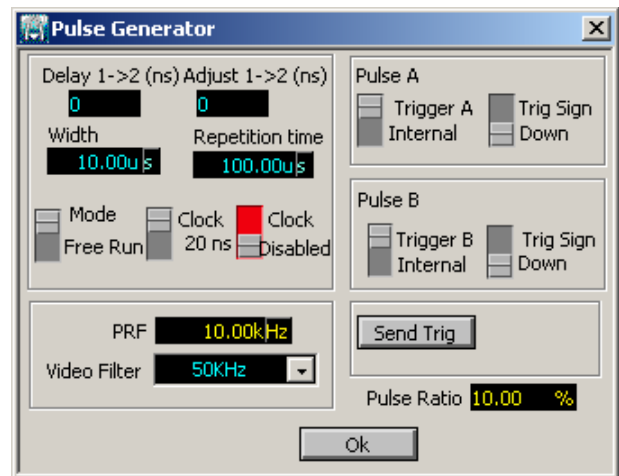
Tools Menu

- Maths
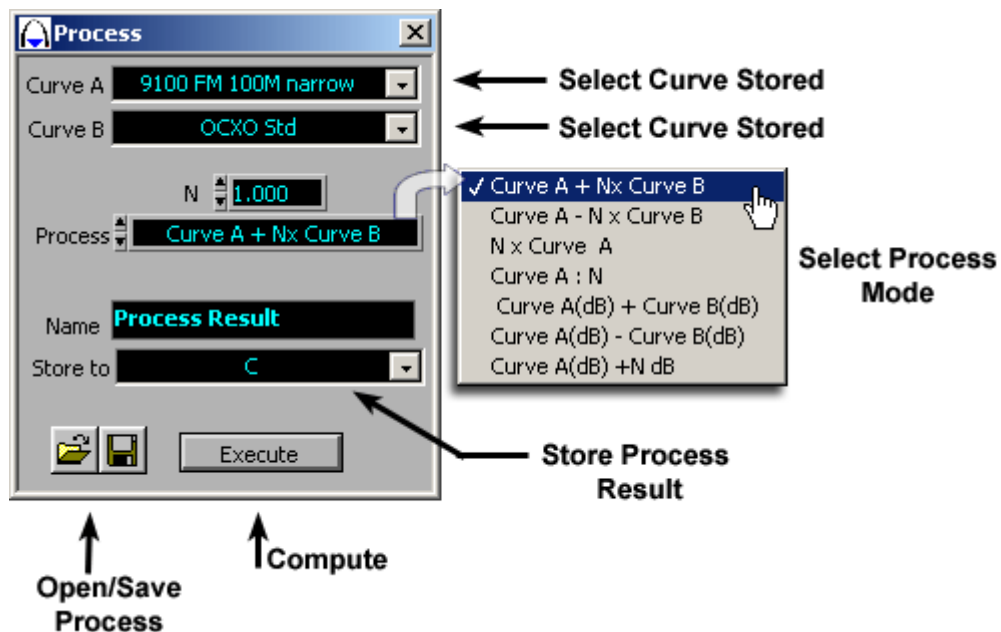- User
- Windows

Maths Menus :

Select on WPN9000 bar menu "Tools / Maths"
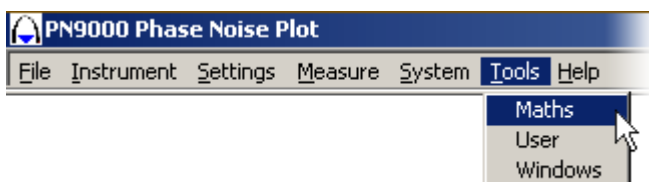
Access to graphic process and formula computation.

1) Process:

Select first the curves to apply the process (one or two curves , depending on the process).
Enter a value for N, if the process requires N.
Select the process:
Store the result into the standard memory A to I.

Process:

Curve A x N, add 20 Log (N) to the curve A, used to multiply the spectrum according the frequency carrier multiplication N.
Curve A / N, subtract -20 Log (N) to the curve A , used to divide the spectrum according the frequency carrier division N.
Curve A (dB) + Curve B (dB), Curve A (dB) - Curve (dB), add/subtract the two curves directly in dB.
Example: curve A = -100 dB, curve B = -20, result = -120 dB.
Generally this process is used to add a filtering expressed in dB to a curve. The curve B can be defined with the specline menu.
Curve A (dB) + N (dB), add directly N dB to the curve A.
Example, curve A = -100, N = 3, result = -97 dB.

Curve A + N Curve B,Curve A - N Curve B, add/subtract the two curves, multiplying the curve B by N. The software transfers first the data in linear, then computes the formula and takes the Log .Example, curve A = -100 , N=1, curve B = -100, result for addition = -97 dB.

2) Spurs:
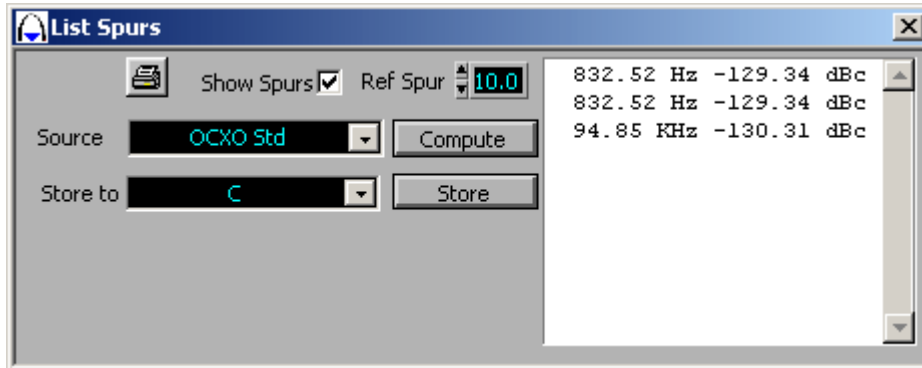
Display of the spurs list according the curve selection.

The spurs are detected according the reference "Ref spur".
To detect the spurs from the noise, the signal processing uses a reference level between the noise and the spur to decide if the data is a spur or is a noise. The amplitude of the noise is variable; it depends on the number of averages. If the criteria is to small, the software will pick up every noise spike as a spur. A standard value is 10dB, meaning a data is detected as a spur if there 10dB between the top of the spur and the closing noise.
Use a minimum value of 3dB when the measurement is done with a large number of averages.
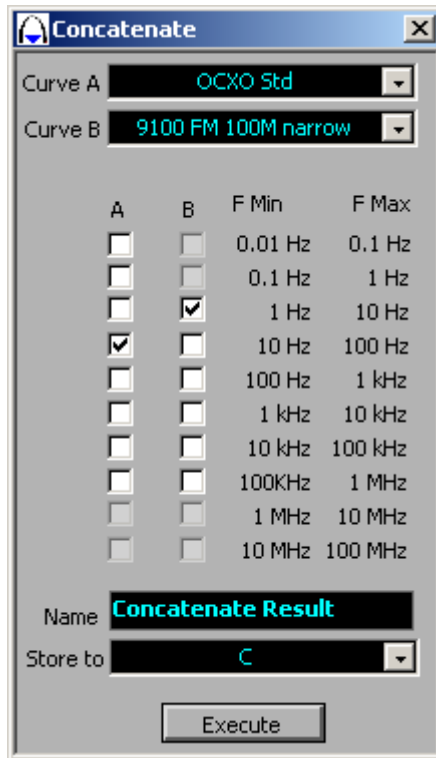
3) Smooth:
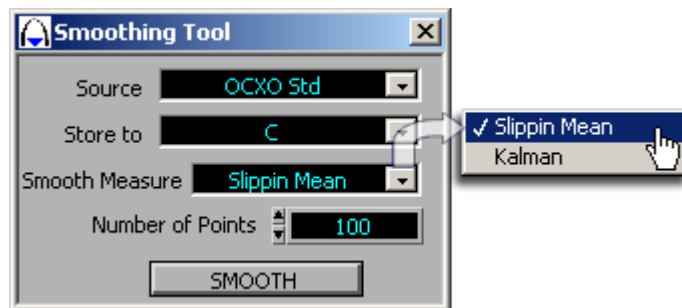
Select the curve to be smoothed.
Select the memory to store the result curve.
Select the type of smoothing (Slipping mean , Kalman). Test on a curve, to choose the right process.
Select the length of the smooth sequence, longer is the sequence more efficient is the smooth but this reduce the curve variation.
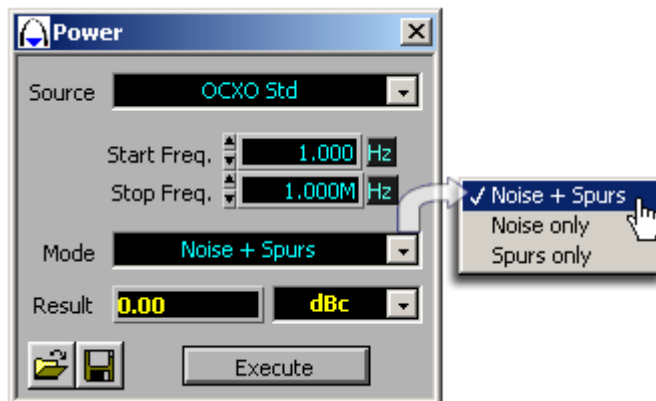"SMOOTH": Run the smooth process.

4) Concatenate:

This process construct one curve from part of two curves:

- Select the two curves A/B.
- Select decade per decade from which curve the data should be taken.
- Give a one name and the memory to store the new curve.
- "Execute" the process.

5) Power:

Computation of the noise integration into defined bandwidth.

Select the curve.
Define the integration bandwidth.
Select integration of the noise only, the spur only or the noise and the spur.
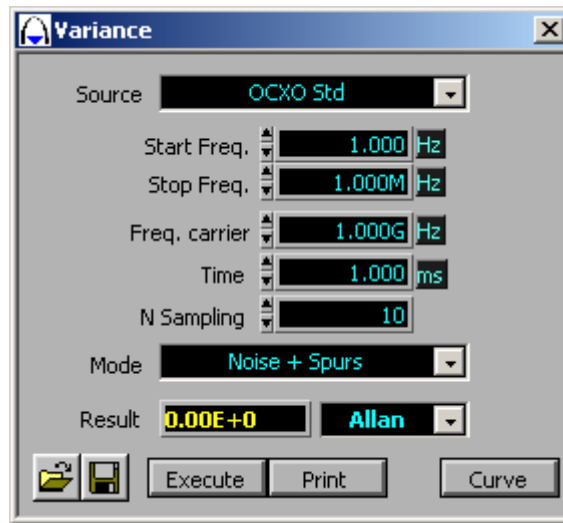Result: The result can be expressed in dBc/Hz , radian/degree/Hertz square and root mean square.
Execute: Run the computation.

6) Jitter:

See more information on "Measure Menu > Jitter" in Documentation

---

7) <u>Variance</u>:

Computation of the noise integration into defined bandwidth and expressed in VARIANVE unity.
The variance is the ratio of the frequency fluctuations with the carrier frequency, all values measured during a time T.
Select the curve.
Define the integration bandwidth.
Enter the carrier frequency.
Enter the integration Time.
Some variance depend on a sampling factor N.
Select integration of the noise only , the spur only or the noise and the spur.
Result: the result is a ration it is expressed in 10-x.
Execute: run the computation.
Print: Print Curve with variance information.

8) <u>3 Osc. A B C (Optional)</u>:
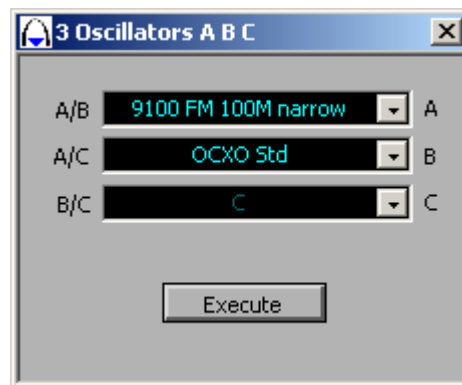
From three sommes measurement, the system can extract the individual phase noise spectrum.
Measurement somme A with somme B → somme A with somme C → somme B with somme C.
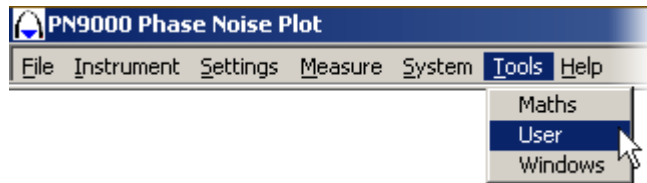After, "Execute" results are stored:

Somme A → A.
Somme B → B.
Somme C → C.

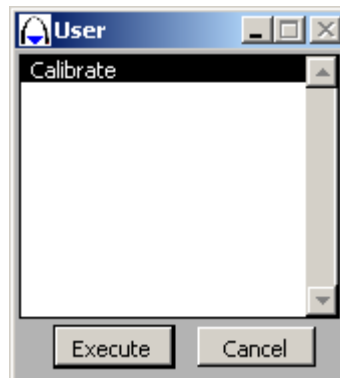Curve previous measurement (A/B, A/C, B/C) are erased.

User Menu :

Select on WPN9000 bar menu "Tools / User"

This Windows list WPN9000 Plug-ins, depends on the options installed in the PN9000 Test Set.

Should you need more information, feel free to contact us at: info-test@aeroflex.com
Or visit our Web Site: http://www.aeroflex.com